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1996 Annual Fish and Shellfish Report

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EXECUTIVE SUMMARY

In 1996, the Massachusetts Water Resources Authority (MWRA) conducted a biomonitoring program for fish and shellfish. The 1996 activities represent the latest year in a continuing biomonitoring program which supports evaluation of the future MWRA effluent outfall 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 1996 fish and shellfish monitoring program was to further define the baseline condition of three indicator species: winter flounder (*Pleuronectes americanus*), Northern lobster (*Homarus americanus*), and blue mussel (*Mytilus edulis*). Specimens were collected from sites in Boston Harbor (Deer Island Flats (DIF), off *Discovery* at the New England Aquarium), Massachusetts Bay (Future Outfall Site (FOS), Nantasket Beach (NB), Broad Sound (BS)), and Eastern Cape Cod Bay (ECCB). Baseline conditions 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 various tissues. These tissues included: for the winter flounder - liver and filet; for the northern lobster - hepatopancreas and tail meat; and for the blue mussel - soft tissue. The monitored parameters were examined for spatial trends between stations in 1996 and interannual variations from previous monitoring data. In addition, body burdens of certain pesticides (DDT, aldrin/dieldrin, chlordane, heptachlor, etc.), PCBs, lead, and mercury were compared to FDA Action limits and monitoring program warning limits to evaluate potential risk or trends. Body burdens of DDT, PAHs, and PCBs were normalized for lipids to determine the baseline level for the harbor. Finally, the results were evaluated for their ability to answer the underlying monitoring hypotheses.

Flounder

Winter flounder were collected at five sites (DIF, NB, BS, FOS, ECCB) for the 1996 monitoring program. The mean age of fish collected at both DIF and FOS was significantly higher than for BS, and significantly higher at FOS than at ECCB. In general, the mean flounder age at DIF and BS has declined since 1989, but has shown little change at other stations.

The external condition of the collected fish indicated few abnormalities. Fin erosion varied between stations (range = 0.1 to 0.5), with the DIF and NB fish significantly higher than the FOS. The amount of fin erosion observed throughout was considered at the low end of the range and well below that observed in the late 1980s.

The flounder liver histology results indicated that DIF and BS fish exhibited the greatest prevalence of lesion hydropic vacuolation (focal, tubular, centrotubular). Interannual comparison of the lesion prevalence at DIF indicated a statistically significant decrease over the period 1987 to 1996. Neoplasia was absent from fish collected in 1996 except in one specimen from DIF. Neoplasm prevalence in DIF winter flounder has fallen from elevated levels in the 1980s to near undetectable levels during the 1992-1996 period.

Fifteen winter flounder were collected at five sites (DIF, FOS, ECCB, NB, BS) for analysis of tissue concentration of organic and inorganic contaminants in filet and liver. The spatial patterns of tissue contaminant levels in winter flounder were examined. Mean 1996 concentrations of organic compounds in filets and liver tissue were generally highest at DIF and lowest at ECCB. Mercury was highest at FOS and lowest at BS; other metals (Ag, Cr, Cu, Ni, Pb, Zn) detected in liver tissue showed station-to-station variation.

Interannual comparisons of tissue organic contaminant levels for the period 1992-1996 displayed some station-to-station variability, but two general trends observed were for elevated concentrations of DDT and PCBs and reduced chlordane levels in 1996 fish relative to earlier years. For metals, the observed tissue levels were comparable to or somewhat lower than 1994 and earlier years.

The relationship between contaminant levels and liver histopathology was explored. Plotting the prevalence of centrotubular hydropic vacuolation (CHV) against winter flounder tissue levels from fish collected across the monitoring area during 1992-1996 indicated relationships for selected organic compounds and mercury in filet, and chlordanes in liver, but for other organic compounds or metals, no relationship exists. These relationships will be further examined during future monitoring years.

Comparison was made between flounder edible tissue contaminant levels and FDA regulatory action limits. The 1996 levels, like those detected in previous monitoring years (1992-1995), were well below the federal legal limits. Lipid-normalized concentrations of organic contaminant were determined as part of the establishment of baseline pre-discharge reference levels for the FOS location.

Lobster

Fifteen northern lobster were collected at three sites (DIF, FOS, ECCB) for the 1996 monitoring program. Twenty-four legal size lobsters were collected by direct trapping, 21 others were obtained from commercial traps located at or within 2 km of 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, weight, or sex ratios was observed between stations with the exception of a preponderance of male lobsters at FOS. With the exception of one incidence of shell erosion at FOS and one at ECCB, no deleterious external conditions were noted.

The spatial patterns of tissue contaminant levels in northern lobster were examined. Mean 1996 concentrations of organic compounds in edible tail meat tissue were generally highest at DIF and lowest at ECCB. In the hepatopancreas, the organic compounds were generally highest at FOS and lowest at ECCB. Mean mercury concentrations in both tail meat and hepatopancreas were highest at FOS and lowest at DIF. The highest concentrations of other metals in hepatopancreas were at DIF (Ag, Cr, Cu, Pb), FOS (Zn), or ECCB (Ni). Comparison of 1996 data with previous years (1992-1995) indicates that most tissue contaminant levels were comparable to the range previously observed.

Comparison was made between lobster edible tissue contaminant levels and FDA regulatory action limits for pesticides, PCBs, and mercury. The 1996 levels, like other monitoring years (1992-1995), were well below the federal legal limits and indicate no risk for human consumption. Body burdens of total DDT, total PAH, and total PCB in lobster hepatopancreas were normalized for lipids to determine baseline pre-discharge reference levels for the FOS location.

Blue Mussel

Mussels were collected at two reference sites (Gloucester, Sandwich) and deployed for 60 days in arrays at three sites (DIF, FOS, and off *Discovery* in Boston Harbor). Sandwich mussels were used as reference material to better assess the potential bioaccumulation of mercury and lead. Arrays were successfully retrieved at all three sites. Mussel survival within the deployed arrays was high ($\geq$83%). Sex determination of the mussels indicated a higher proportion of males than females, and a higher proportion of mature males than immature males.

Although the 1996 PAH results were slightly confounded by differences in analytical technique, the spatial and temporal trends observed were consistent with those observed in 1992-1995. The LMW-PAHs were highest in the DIF mussels, while HMW-PAHs were highest in *Discovery* site mussels. NOAA total PAH body burdens for all sites were comparable to 1991-1995 levels. Pesticide (DDT, chlordane, dieldrin) levels were also comparable to earlier data.

Lead tissue concentrations were statistically greater in the *Discovery* and FOS site mussels. Mercury was not significantly different among the three deployment locations and reference site and mussel tissue concentrations were uniformly low. These low concentrations, specifically in DIF mussels, contrasted with other studies, and further evaluation of mercury body burdens may be necessary to fully evaluate the bioavailability of mercury to deployed mussels at the three locations.

Comparison was made between mussel tissue contaminant levels and FDA regulatory action limits for mercury and lead. The 1996 levels were well below the federal legal limits and indicate no risk for human consumption. Body burdens of total DDT, total PAH, and total PCB in mussel tissue were normalized for lipids to determine baseline pre-discharge reference levels for the FOS location.

Evaluation of Monitoring Hypotheses

An integral part of the MWRA fish and shellfish monitoring is a periodic re-evaluation of the adequacy of the current program to fulfill the overall goals of the monitoring program. In particular, this means a re-examination of the adequacy and effectiveness of the underlying monitoring hypotheses to answer questions regarding the potential effects of the relocated MWRA effluent.

Of the five monitoring hypotheses, three are associated with the potential for edible tissue (flounder, lobster, mussel) to exceed warning levels for mercury, lead, or PCBs. These hypotheses appear to be sufficient. Current tissue concentrations are generally an order of magnitude or more below warning and FDA regulatory levels. Calculation of significant increase values indicate that tissue levels approaching the warning or action levels should be readily detectable in the program.

Detection of bioaccumulative lipophilic contaminants, was further evaluated due to greater-than-anticipated levels of some organic contaminants (pesticides, PCBs) in flounder liver and lobster hepatopancreas. A review of the magnitude of interlaboratory analytical performance was conducted and concluded that differences in analytical data between laboratories are negligible. Calculation of significant increase values based on the current baseline indicates that the monitoring should be able to detect significant changes in the tissue levels below warning threshold levels (i.e. twice baseline concentrations). Similarly, the monitoring hypothesis evaluating 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.

1.0 INTRODUCTION

In 1996, the Massachusetts Water Resources Authority (MWRA) conducted a biomonitoring program for fish and shellfish as one part of a multi-faceted environmental monitoring program (MWRA, 1991). This program is the latest year in a continuing biomonitoring program (MWRA, 1991) which supports evaluation of the future MWRA effluent outfall, located approximately 9½ miles offshore of Deer Island in Massachusetts Bay (as shown in Figure 1-1). The goal of Phase I 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 fish and shellfish monitoring is to define the baseline condition of three indicator species [i.e., winter flounder (*Pleuronectes americanus*), Northern lobster (*Homarus americanus*), blue mussel (*Mytilus edulis*)] in terms of biological parameters (length, weight, biological condition), the presence of disease (both internal and external), and the concentrations of organic and inorganic compounds in various tissues, including the liver (winter flounder), hepatopancreas (lobster), and edible tissues (winter flounder filet, blue mussel soft tissue, and lobster tail). This baseline characterization of the health of winter flounder, lobster, and mussel in Boston Harbor, Massachusetts Bay, and Eastern Cape Cod Bay (i.e., Boston Harbor and the Bays) forms the basis for assessing potential changes resulting from the relocation of the outfall discharge.

One survey per indicator species was conducted in 1996 in Boston Harbor and the Bays to determine the body burden of toxic compounds of these three species, and to assess the physiological status of flounder and lobster, following the procedures and protocols described in greater detail in Section 2. Section 3 presents the results of the 1996 surveys, and discusses the recent data, as well as comparisons with historical data. Section 4 presents the conclusions drawn from these 1996 survey results and historical trends. Section 5 includes recommendations for the biomonitoring program, while Section 6 lists the references cited in this document.

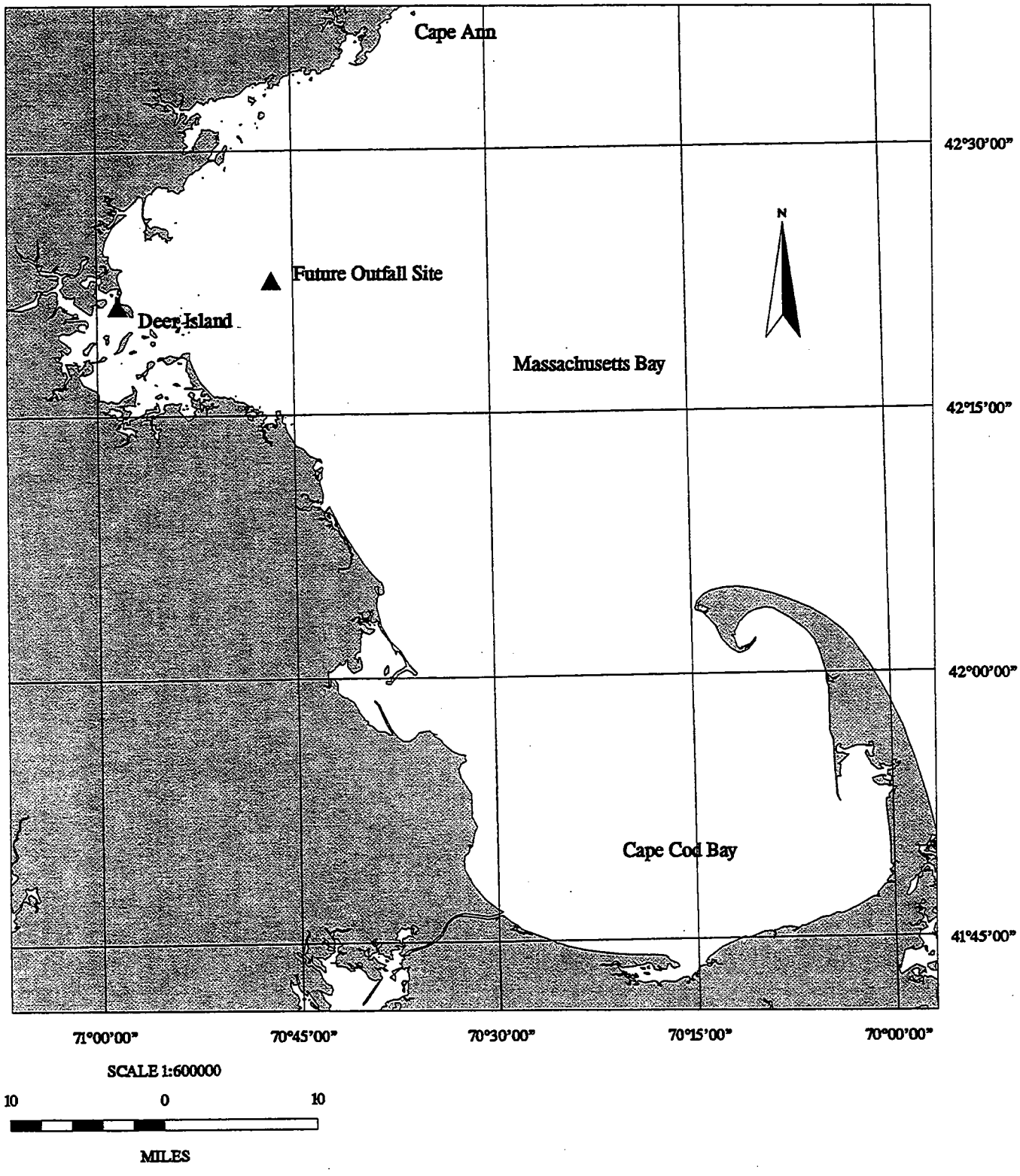


FIGURE 1-1
1996 Biomonitoring Program Study Area

2.0 METHODS

This section provides an overview of the methods and protocols used in the three surveys. The definitive descriptions of the methods are contained in: *Combined Work/Quality Assurance Project Plan (CW/QAPP) for the Fish and Shellfish Monitoring: 1995-97 (Fish and Shellfish Monitoring CW/QAPP)* (Mitchell *et al.*, 1995).

2.1 Winter Flounder Monitoring

Winter flounder (*P. americanus*) were obtained from five locations in Boston Harbor and the Bays for gross examination, histology, aging, and chemical analyses of liver and fillet tissue. Figure 2-1 depicts the five sampling locations for winter flounder monitoring during 1996.

2.1.1 Stations and Sampling

Fish were collected at Deer Island Flats (Station 1, located in Boston Harbor), off Nantasket Beach (Station 2), Broad Sound (Station 3), the Future Outfall Site (Station 4, in Massachusetts Bay), and Eastern Cape Cod Bay (Station 5) in sampling conducted between April 14 and April 29, 1996 (Figure 2-1, Stations 1-5). The F/V *Odessa*, captained by William Crossen, was used to conduct otter trawls at each of the five sites. Table 2-1 presents the trawl data for the flounder surveys including stations, positions, etc. Tows were conducted until 50 sexually mature (4- to 5-year old) winter flounder of 30 cm or more in length were obtained. Only 30 fish were obtained at Deer Island Flats, and only 49 were obtained at the Future Outfall Site for a survey total of 229 fish.

Fifteen of the 50 sexually mature fish collected at each station were selected randomly, identified with a fin clip, and held in static, aerated, ambient seawater prior to dissection for chemical and histopathological analysis at a clean lab. Fish from Stations 1, 2, 3 and 4 were processed at the Northeastern University Marine Station at Nahant, while those from Station 5 were processed in Woods Hole. The remaining 35 fish were killed on board by cervical section and used for histological processing (see Section 2.1.4).

All 50 specimens from each site were visually examined and external conditions such as for fin rot and other abnormalities (e.g., lymphocystis) were noted. Each fish was weighed and measured for total and standard lengths.

Fish were also assessed for sexual maturity. After each fish was killed by cervical section, an oval incision was made in the ventral body wall overlying the liver and anterior ventral gonad. The gonads were examined, and their color and sex recorded. Sexual maturity was determined on the basis of the following criteria: gonads are blue-gray in immature fish; pink and elongated in mature females; and

white and triangular in mature males. This examination was conducted in the clean lab for the 15 fish held in the live tank, and in the field for the remaining 35 fish.

2.1.2 Age Determination

Scale samples were collected from each fish for age determination. Mucus, debris, and epidermis was removed from the dorsum of the caudal peduncle prior to obtaining scale samples. Scales were collected by wiping in the direction of the tail with a blunt-edged knife by applying quick, firm, scraping motions in the direction of the head. Scales were scraped into envelopes labelled for each individual fish. Age was determined by enumerating the annuli on a scale sample taken from each fish.

2.1.3 Dissection of Fish

The fifteen fish held on board in the live tank at each station were delivered to the clean lab established for the project at the Northeastern University Marine Station at Nahant for dissection (fish from Stations 1,2,3 and 4 were processed here, while those from Station 5 were processed at Woods Hole). Each fish was assigned a sample identification number indicating the date and site of collection. All fish were killed by cervical section. Fish were dissected in a laminar flow hood, using a precleaned titanium knife (precleaning consisted of rinsing with 10% HCl, Milli-Q water, acetone, dichloromethane, and hexane). The fillets (muscle tissue) were removed from the flounder, and the skin removed from the fillet.

2.1.4 Histological Processing

Livers were removed from the 50 fish collected at each site. Each liver was examined for color and gross abnormalities. Three equidistant slices were placed in a separate clearly labeled cassette and preserved in 10% buffered formalin for histological processing.

Liver slices were embedded in paraffin. Two 5 μm sections were cut from each of these three sections, and stained with hematoxylin and eosin according to standard methods (Hillman *et al.*, 1994). The remaining liver tissue from the 15 flounder designated for chemical analysis was retained.

2.1.5 Histological Analysis

The 229 liver samples set aside for histological analysis were initially examined for the prevalence and severity of the following lesions, which were described in Moore, 1991 and Hillman *et al.*, 1994:

- Vacuolation (including centrotubular, tubular hydropic, and focal hydropic);
- Macrophage aggregation;
- Biliary duct proliferation; and
- Neoplasia.

Slides were prepared for each fish, including three liver sections per slide. Each slide was examined under bright-field illumination at 25x, 100x, and 200x. The severity of each lesion was rated on a scale from 0 to 4, as follows:

- 0 = absent
- 1 = minor
- 2 = moderate
- 3 = severe
- 4 = extreme.

For each lesion and each fish, a histopathological index was calculated as the mean of scores from three liver slices on one slide. A lesion index was also calculated for each site, based on the mean scores for each particular lesion at each site.

2.1.6 Tissue Processing

Chemical analyses were performed on composite samples of flounder fillet and liver tissues obtained from the 15 fish set aside in the live well at each of the 5 sites: Deer Island Flats, the Future Outfall Site, Eastern Cape Cod Bay, off Nantasket Beach, and Broad Sound. Fillet tissues from individual fish were homogenized separately; the liquid from each sample was stored with the homogenate. Fillet composites contained equal portions of dorsal and caudal tissue. Equal amounts of liver (or fillet) were used from each of the five fish. Liver tissue samples were pooled at the time of sampling (i.e., first 5 liver samples = Pool #1, etc). Wet weights were recorded for each liver and fillet sample. After compositing, the tissues were re-homogenized prior to shipment for chemical analysis. Remaining liver and fillet tissues were placed in labeled containers, frozen, and archived.

2.1.7 Chemical Analyses

Chemistry analyses performed on composited flounder tissues are listed in Table 2-2. Flounder fillets were analyzed for mercury, polychlorinated biphenyls (PCBs), chlorinated pesticides, and lipids. Flounder livers were analyzed for trace metals, PCBs, polycyclic aromatic hydrocarbons (PAHs), chlorinated pesticides, and lipids. The composited samples were split for organic and metals analyses at separate laboratories.

2.1.7.1 Organic Compound Analyses

Tissue samples were serially extracted for PAH, chlorinated pesticides, and PCBs. An aliquot of homogenized tissue was extracted with dichloromethane (DCM) and sodium sulfate using a Tekmar tissuemizer. An aliquot of the original sample was retained for dry weight determination. The sample was weighed in a Teflon extraction jar, spiked with the appropriate surrogate internal standards. Sodium

sulfate and solvent were added, the samples were macerated for 2 minutes, and centrifuged. The solvent extract was decanted into an Erlenmeyer flask. After each extraction (two homogenizations and a third shake by hand), the centrifuged solvent was combined in the flask. A 10-ml aliquot of the combined extracts was removed for lipid weight determination, and sodium sulfate was added to the extract remaining in the flask. After approximately 30 minutes, the contents of the flask was processed through an alumina column. The elutriate from the column was concentrated to 900 µl (via a Kuderna-Danish apparatus and nitrogen evaporation techniques). The concentrated extract was further cleaned using a high performance liquid chromatographic (HPLC) gel-permeation technique (which removes common contaminants that interfere with the instrument, including lipids). The post-HPLC extract was concentrated to approximately 500 µl under nitrogen gas, and the recovery internal standards were added to quantify extraction efficiency. The tissue final extract was split for analysis, with one half remaining in DCM for PAH analysis, and one half solvent-exchanged with isooctane for PCB/pesticide analysis.

As in previous years (i.e. 1992-1995), co-planar PCB congeners 77 and 126 were reported in the MWRA Fish and Shellfish Monitoring Program data for 1996. The PCB analyses on the program in 1995 and 1996 used a dual column confirmation, which minimizes but does not completely eliminate the possibility of other congeners co-eluting with congeners 77 and 126. Thus, there is greater uncertainty associated with the PCB congener 77 and 126 results due to the potential interferences from other PCB congeners.

Sample extracts were analyzed for PAH compounds in the selected-ion monitoring (SIM) mode by gas chromatography/mass spectrometry (GC/MS) using a modification of EPA Method 8270. The modifications include operating the mass spectrometer in the SIM mode, and tuning the mass spectrometer with PFTBA. Pesticides and PCB congeners were analyzed and quantified using gas chromatography/electron capture detection (GC/ECD) using EPA Method 8080, modified to include additional analytes and a second column for qualitative confirmation.

2.1.7.2 Metals Analyses

Tissues were analyzed for the metals indicated in Table 2-2. Approximately 0.75 g of wet tissue (0.3 g dry tissue) were weighed into the Teflon inserts of Parr Bombs. The sample was turned into a slurry upon the addition of 3 ml of superpure aqua-regia. The bombs were sealed and heated for three minutes. The bombs were then cooled, another 2 ml of superpure aqua-regia added, and heated for two minutes. The digestate was diluted to a final volume of 50 ml and transferred to a precleaned 125 ml polyethylene bottle. The digestate was analyzed for silver, cadmium, chromium, nickel, copper, lead, and zinc by inductively coupled plasma-mass spectrometry (ICP-MS). In order to achieve the low detection limits required for mercury analysis, the EPA method for total recoverable mercury (EPA Method 245.1) was modified. Mercury was analyzed using a flow injection cold vapor technique with atomic absorption detection following preconcentration on gold amalgam (McIntosh, 1993).

2.1.8 Data Reduction and Statistical Analyses

Data reduction was conducted as described in the Fish and Shellfish Monitoring CW/QAPP (Mitchell *et al.*, 1995). 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 results with those of previous years were made. Possible relationships between observed lesions and contaminant body burdens were also investigated.

In addition to reporting the prevalence and lesion index of hydropic vacuolation, historical data has included several other lesions, including macrophage aggregates, biliary proliferation, neoplasia, and a lesion unreported before 1993, referred to as "balloon hepatocytes".

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.

2.1.9 Deviations from CW/QAPP

At Deer Island Flats, only 30 fish were collected during the April survey due to fish availability limitations. At the Future Outfall Site, one fish died before processing for histological analysis.

The CW/QAPP states that samples are to be collected under a hood aboard the vessel, at dockside. This has proved to be impracticable in the field. Therefore, fish from all other Stations #1, 2, 3, and 4 were processed at a clean dissection bench established at the Nahant Marine Laboratory while those from Station #5 were processed at Woods Hole.

2.2 Northern Lobster Monitoring

Northern lobsters (*H. americanus*) were collected from three locations for gross examination and chemical analyses of hepatopancreas and edible (tail) tissue. Figure 2-1 presents the sampling locations for the 1996 survey.

2.2.1 Stations and Sampling

Lobsters were collected at three stations for gross examination and analysis of chemical contaminants in the tail and hepatopancreas. As with previous surveys (1992, 1994, 1995) sampling was conducted in late July- early August (note sampling in 1993 was in April). Sampled stations included Deer Island Flats (Station 1, in Boston Harbor), the Future Outfall Site (Station 4, in Massachusetts Bay), and Eastern Cape Cod Bay (Station 5), (Figure 2-1, Stations 1, 4, and 5). The F/V Tina Marie, captained by Alex Brown,

was used to set and collect 20 lobster traps at Eastern Cape Cod Bay. The F/V Windmere, captained by Peter Mahoney, was used to set and collect 60 lobster traps at the Future Outfall Site (Mr. Mahony volunteered to set the additional 40 traps) and 20 lobster traps at Deer Island Flats. Table 2-3 contains the trap data for the 1996 surveys. Traps were set for 3-4 days (FOS, DI) and 5 days (ECCB) to collect 15 legal-size non-berried individuals. The desired number of individuals was supplemented through the purchase of commercially obtained lobsters from traps set in the general area of the target location. Eleven lobsters were purchased at ECCB from Cape Tip Fisheries, and 10 were purchased at the FOS from a local lobsterman.

2.2.2 Size and Sex Determination

Immediately upon removal from the traps, lobsters were measured with a commercial lobster gauge to determine if the lobster met the legal size limit. Lobsters which did not meet the legal size limit were enumerated and immediately returned to the sea. Lobsters that met the legal size limit were assigned a unique sample identification number, according to the system established by ENSR in 1995. Lobsters were then measured for carapace length and width, and weighed on a Sartorius® balance (accuracy ± 1 gram).

In addition to length, width, and weight measurements, the sex of individual lobsters was recorded on the field data sheets. External conditions were noted, including the presence or absence of black gill disease, shell erosion, parasites, external tumors, and other external abnormalities. Upon completion of the field observations, lobsters were placed in labelled, doubled plastic bags, and preserved on dry ice. Lobsters were transported to the analytical laboratory and kept frozen until dissected and the tissue composited.

2.2.3 Dissection of Lobster

Because clean conditions could not be satisfied in the field, lobster dissection was conducted in the laboratory setting. Each lobster was assigned a unique laboratory identification number in the field. Lobsters were thawed prior to dissection. The hepatopancreas and edible meat (tail only) was removed from each lobster via ventral incisions in the carapace and tail.

2.2.4 Tissue Processing

Once the hepatopancreas and edible tissues were removed from the carapace, each was homogenized separately. Composite samples were generated by homogenizing the edible tissue of five randomly-selected lobsters, with an equal amount (±5% by weight) of tissue from each lobster. Equal volumes of hepatopancreas homogenate (±5%) from the same five lobsters were composited and rehomogenized prior to chemical analysis. Three composite samples of hepatopancreas and edible tissue were analyzed per station.

2.2.5 Chemical Analyses

The chemical analyses conducted on lobster hepatopancreas and edible tissue samples followed the same procedures used for analysis of flounder tissue described in Section 2.1.7. A list of the chemical analytes is given in Table 2-2. Lobster hepatopancreas tissues were analyzed for trace metals and organic compounds. Edible tissues were analyzed for mercury and organic compounds.

2.2.6 Data Reduction and Statistical Analyses

Data reduction was conducted as described in the Fish and Shellfish Monitoring CW/QAPP (Mitchell *et al.*, 1995). Spatial and temporal trends of contaminants in composites of edible lobster tissue and hepatopancreas tissue were evaluated through available data from 1985 through 1996. Comparisons were made to the FDA Legal Limits and other appropriate levels of regulatory concern.

2.2.7 Deviations From CW/QAPP

All positions were slightly different from those specified. In Eastern Cape Cod Bay, traps were set slightly north of the specified position. The Deer Island Flats traps were not set in the anchorage area, but rather along the base of the drop-off on the southern edge of the flats. At the Future Outfall Site, traps were set about 1.5 miles east of the specified position upon the recommendations of two local lobstermen.

Lobster traps were not set repeatedly at each sampling site until 15 lobsters were obtained. Remaining lobsters were purchased. At Eastern Cape Cod Bay, only four lobsters were caught in the set traps. The remaining 11 were purchased from Cape Tip Fisheries, a Provincetown company that buys lobsters from local lobstermen fishing along the 12-m contour between Provincetown and Wellfleet. At Deer Island Flats, only five lobsters were caught in the set traps. The remaining 10 were purchased from a local lobsterman retrieving traps from near the ship's channel south of Governors Island Flats.

Carpace length was measured as the distance from the posterior edge of the eye socket to the posterior edge of the carapace, rather than as the distance from the tip of the rostrum to the posterior edge of the median uropod. This ensured consistency with the measurements taken during the 1995 survey.

Lobsters were not killed and dissected in the field, as the requisite clean conditions could not be guaranteed. Lobsters were immediately assessed for external conditions, placed on dry ice, and delivered to the laboratory frozen, under chain-of-custody, for later thawing and analysis.

2.3 Mussel Bioaccumulation Monitoring

Mussel condition (growth and reproduction) is used to assess the current health of mussel populations in the Boston Harbor and Bay areas prior to the relocation of the existing effluent discharge and to provide a common yardstick to compare biomonitoring results to other areas covered by the National Oceanographic and Atmospheric Administration's (NOAA) National Status and Trends (NST) program. Blue mussels (*M. edulis*) were obtained from two reference stations, deployed at 3 stations, and retrieved for determination of biological contamination. The station locations used in the 1996 survey are shown in Figure 2-1. Short-term soft tissue accumulation of station-specific contaminants was monitored over a period of 60 days. Specimens were collected from reference sites and deployed during a June survey, and the mussels were collected after incubation in August, 1996.

2.3.1 Stations and Reference Areas

Mussels were deployed and retrieved at three sites, including a baseline reference site. Figure 2-1 illustrates the sampling locations in Boston Harbor and Massachusetts Bay. Table 3-12 presents the 1996 mussel survey sampling design.

Mussels were deployed on June 28, 1996 from the R/V *Profile* in replicate arrays at the sites described below:

- Approximately 75 meters east of Deer Island Light, within the zone of initial dilution (ZID) of the Deer Island effluent discharge. This site was selected for monitoring the potential bioaccumulation associated with the Deer Island effluent discharge;

- The stern of the *Discovery*, anchored at the New England Aquarium in Boston Inner Harbor. This site serves as a "dirty" control, allowing the evaluation of ambient contamination within Boston Inner Harbor; and

- The Large Navigation Buoy (LNB) located approximately one nautical mile(NM) south of the project MWRA offshore discharge installation. This site is monitored for predischarge baseline conditions. (Note that this location is referred to as the Future Outfall Site in both the flounder and lobster studies.)

2.3.2 Mussel Collection

Approximately 1070 mussels were collected from the University of Massachusetts Research Station at Hodgkins Cove, Gloucester, MA on June 27, 1996. Mussels from this location have been shown to be relatively free of organic contamination, and have been used in previous bioaccumulation studies conducted throughout the Massachusetts coastline (Camp, Dresser and McKee, 1988; MRI, 1989; Downey

and Young, 1992; Downey *et al.*, 1993; Downey, 1994a and 1994b). However, concerns have been raised relative to the concentrations of mercury and other metals in Gloucester mussels, therefore an additional number of mussels were collected at an alternate control site in Sandwich, MA. Accordingly, only tissue derived from Sandwich-harvested mussels was used for all metal analyses. All analyses of organic contaminants were performed on Gloucester-harvested mussels.

Mussels were harvested during low tide. Only mussels between 55 and 70 mm in total length were used. Total length was recorded on a subset of 200 of the 1070 mussels collected in Gloucester. Approximately 45 Gloucester mussels were randomly distributed to each of 22 plastic cages, and suspended overnight in seawater along the seawall adjacent to the UMass Research Station in Gloucester. Approximately 45 Sandwich mussels were distributed to separate cages and suspended overnight in seawater at the Sandwich collection site. In addition, a subsample of 30 Gloucester mussels and 10 Sandwich mussels were sent on ice to the Aquatec facility on June 28, 1996 for initial biological analyses, including total length, sex and sexual maturity, and tissue weights. Samples of Gloucester and Sandwich mussels were stored frozen for chemical analyses.

2.3.3 Mussel Deployment

At the Deer Island Light, four arrays were deployed on June 28, 1996. Each deployment array consisted on two replicate cages containing approximately 45 Gloucester-harvested mussels per cage (= 90 Gloucester mussels) and one cage containing 45 Sandwich-harvested mussels for a total of approximately 135 mussels per array. The cages were attached to polypropylene line with nylon cable ties. The arrays were positioned within the water column by steel mooring weights and a styrofoam subsurface buoy. The subsurface buoy for each array was located approximately 3 meters above the bottom, and the cages were fixed approximately 1 meter below the buoy (or 2 meters above the bottom). At Deer Island Light, the arrays were deployed in approximately 4 to 6 meters mean low water (MLW), approximately 75 meters east of the light. Deployment positions were confirmed with an on-board Loran-C instrument, and latitude and longitude measurements were recorded.

Two arrays were deployed at the *Discovery*, a New England Aquarium vessel, on June 28, 1996. Each deployment array consisted of two replicate cages containing approximately 45 Gloucester-harvested mussels per cage (= 90 Gloucester mussels) and one cage containing 45 Sandwich-harvested mussels for a total of approximately 135 mussels per array. The arrays were suspended on a nylon line off the stern of the vessel. The six cages were attached in 2 sets (0.2 meters between sets); each set was considered to be a deployment array. The arrays were anchored approximately 2 to 2½ meters above the bottom in approximately 7 to 9 meters of water.

Five arrays were deployed at the LNB station on June 28, 1996. Each array consisted of three cages, with a total of approximately 135 Gloucester and Sandwich mussels, as previously described. The arrays were deployed near the LNB with a mooring and suspension system similar to that deployed at the Deer Island

Light. In addition, a surface buoy was attached to the subsurface buoy, which was deployed approximately 13 meters below the surface.

2.3.4 Mussel Retrieval

On August 7, 1996, mid-deployment period retrieval activities were conducted. One array was collected from each of the study locations. The mussels from each location harvested at 40 days were checked in the field for gross abnormalities and apparent survival, frozen, and archived (they were not used during the remainder of the study).

Mussels were retrieved on August 27, 1996, for a total deployment period of 60 days. Mussels were retrieved at all three stations. At the *Discovery*, one array was recovered, containing 45 Sandwich mussels and 88 Gloucester mussels. At the Deer Island Light, two arrays were recovered, containing 140 Gloucester mussels and 90 Sandwich mussels. Two arrays, containing 180 Gloucester mussels and 90 Sandwich mussels, were retrieved from the LNB. Random subsamples of mussels from each station were set aside for biological and chemical analyses. Mussels for chemical and biological analysis were stored in separate labeled plastic bags and preserved on ice for transport. All mussels were transported on ice to Aquatec on August 27, 1996, and stored frozen (for chemical analyses) or refrigerated (for biological analyses).

2.3.5 Determination of Biological Condition

Of the mussels collected in Gloucester, the total shell lengths (in mm from umbo to distal gape) were recorded for a subsample of 200 mussels. Measurements were made in the field with Vernier calipers to 0.1 mm to obtain an average size estimate for the entire sample population of approximately 1070 mussels. Random subsamples of 30 mussels harvested at Gloucester were selected from the predeployment mussels and from the mussels retrieved at the full deployment period from Deer Island Light and the LNB. Only 17 mussels were available from the Gloucester-*Discovery* mussels at 60 days due to unexpected high mortality. Mussels from this subsample were processed for biological analyses. These included observations of viability at recovery, shell weight, shell length, total tissue weight (both wet and dry), and gonadal tissue weight (wet and dry). Each mussel was opened by slicing the adductor muscles between the valves with a microtome blade. The gill tissue was drawn back to expose the gonad. A small aliquot of macerated gonadal tissue was transferred to a slide and examined under a compound microscope for sex and sexual maturity. Sexually mature males were identified by sperm motility and immature males by lack of sperm motility. Sexually mature females were identified by the presence of eggs of a diameter greater than 60 microns, while those with egg diameters less than 60 microns were considered to be sexually immature.

Approximately 530 mussels were collected from the alternate control site in Sandwich, MA. At the time of collection, the sizes of a subsample of 60 of these mussels were measured and recorded. Ten mussels

were retained for sex determinations and measurements of gonadal and non-gonadal wet weights. These alternate control mussels were harvested at the LNB, Deer Island and from the *Discovery* after a 60-day deployment. Biological analyses were conducted as described above for the Gloucester mussels, although mussel dry weights were not measured on the alternate control mussels.

2.3.6 Tissue Processing

A random subsample of Gloucester derived mussels (50 mussels per station) were selected from pre-deployment mussels and from each of the three stations' 60-day deployment harvest. Replicate samples for chemical analysis were prepared as composites of ten mussels, for a total of 5 replicate composite samples at each of the four locations. 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 each of the 10 mussels using disposable Teflon-coated stainless steel blades rinsed with methanol and deionized water prior to use.

A random subsample of Sandwich derived mussels (25 mussels per station) were selected from pre-deployment mussels, LNB, Deer Island Light and *Discovery* full deployment mussels. These were prepared as described above for the Gloucester mussels, although composite samples consisted of 5 mussels per composite, for a total of 5 replicate composite samples at each of the four locations.

2.3.7 Chemical Analyses

Table 2-2 summarizes the chemical analyses conducted on mussel tissues. Samples assigned to each specific pool were homogenized together prior to conducting analyses. Organic and inorganic analyses were conducted according to the procedures described for flounder or lobster chemical analyses (Section 2.1.7).

2.3.8 Data Reduction and Statistical Analyses

The extent of bioaccumulation of contaminants in blue mussels was evaluated, and compared to initial contaminant levels in control mussels. Evaluation focused on spatial and temporal trends in contaminant accumulation. Data were compared to mussel body burdens of contaminants in other studies, including the NOAA Status and Trends Mussel Watch monitoring program, and other available studies. The relationship(s) between biological condition and tissue contamination was also assessed.

2.3.9 Deviations from the CW/QAPP

There was a deviation from the CW/QAPP in the preparation of composite mussel samples for chemical analysis under Task 24. The CW/QAPP calls for 20 composite samples of 10 mussels each. Due to an error, ADL inadvertently prepared one large "supercomposite" of 200 gm using > 10 mussels. This left insufficient tissue for completion of remaining samples. This deviation was discussed with MWRA and several alternatives considered.

The final decision was to make use of the available biological tissue from the 60-day retrieval and not use any from the 40-day retrieval. In some, but not all, cases sufficient backup material (i.e, mussels from replicate arrays from the same station) was available. In cases where backup material was not available, less than 5 gm/sample were used to make the composites (2-3 gm/material). Insufficient material was available from the Predeployment Gloucester mussels and the Discovery Sandwich mussels for the full 5 composites. In these cases, only 3 samples were prepared. Accordingly, a total of 18 mussel composites out of the planned 20 samples were obtained for the Gloucester mussels, and 18 out of the 20 planned for the Sandwich mussels.

2.4 General Data Treatment and Reduction

This section describes data reduction performed on 1996 Fish and Shellfish data as part of the 1996 MWRA Harbor and Outfall Monitoring Project. Samples were analyzed for trace metals, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides. Morphological data were collected for all samples and histopathology data were collected for flounder and lobster samples. Data were presented to ENSR from the analytical laboratories conducting the various analyses in both paper and electronic format.

All data were entered into the database in the required format. Laboratory replicate samples (samples that were diluted and run a second time if instrument detection levels were exceeded) were combined and treated as one sample. Duplicate samples were treated as a separate entry in the database. All analytical data entered into the database were in dry weight units.

For this document all data were retrieved from the MWRA Database for the years 1993-1996. Data from other years were obtained from reports as referenced in individual sections. Flounder and lobster data from the database were summarized into averages per station per analyte. All non-detects were treated as zero. Duplicate samples were averaged and the result treated as an individual sample. Standard error was calculated. Mussel data were summarized using the lowest detection limit value for all non-detects. Wet weight data for organics were calculated by multiplying the percentage dry weight of a sample with the analytical result for that sample. Data for inorganics were reported in both wet and dry weights, so no calculation was necessary. Lipid normalized data were calculated with the following formula for 1995-1996:

Lipid normalized concentration = mass sample toxicant/g mass sample lipid

Mussel morphology data were summarized by averaging the biological data reported for each group of mussels (i.e. data from mussels harvested from Gloucester and deployed at Deer Island were averaged together).

TABLE 2-1

Flounder Survey Collection Data

Station	Trawl Date	Start Time	End Time	Latitude (degrees)	Longitude (degrees)	Bottom Time (minutes)	Number of Fish >300 mm
Deer Island	4/15/96	3:48 PM	4:25 PM	42.348	70.97	37	8
	4/15/96	4:38 PM	5:41 PM	42.349	70.973	63	7
	4/15/96	5:51 PM	6:52 PM	42.349	70.975	61	11
	4/15/96	7:13 PM	7:36 PM	42.349	70.972	23	4
Nantasket Beach	4/15/96	2:12 PM	3:25 PM	42.292	70.86	73	56
Broad Sound	4/15/96	8:35 AM	9:40 AM	42.412	70.963	65	5
	4/15/96	10:15 AM	11:20 AM	42.437	70.89	65	15
	4/15/96	11:36 AM	12:10 PM	42.447	70.897	34	13
	4/15/96	12:30 PM	12:40 PM	42.445	70.896	10	4
	4/15/96	12:52 PM	1:36 PM	42.443	70.898	44	13
Future Outfall Site	4/18/96	8:50 AM	10:16 AM	42.393	70.828	86	22
	4/18/96	10:50 AM	12:42 PM	42.39	70.827	112	40
Cape Cod Bay	4/29/96	9:20 AM	10:25 AM	41.967	70.121	95	90

TABLE 2-2

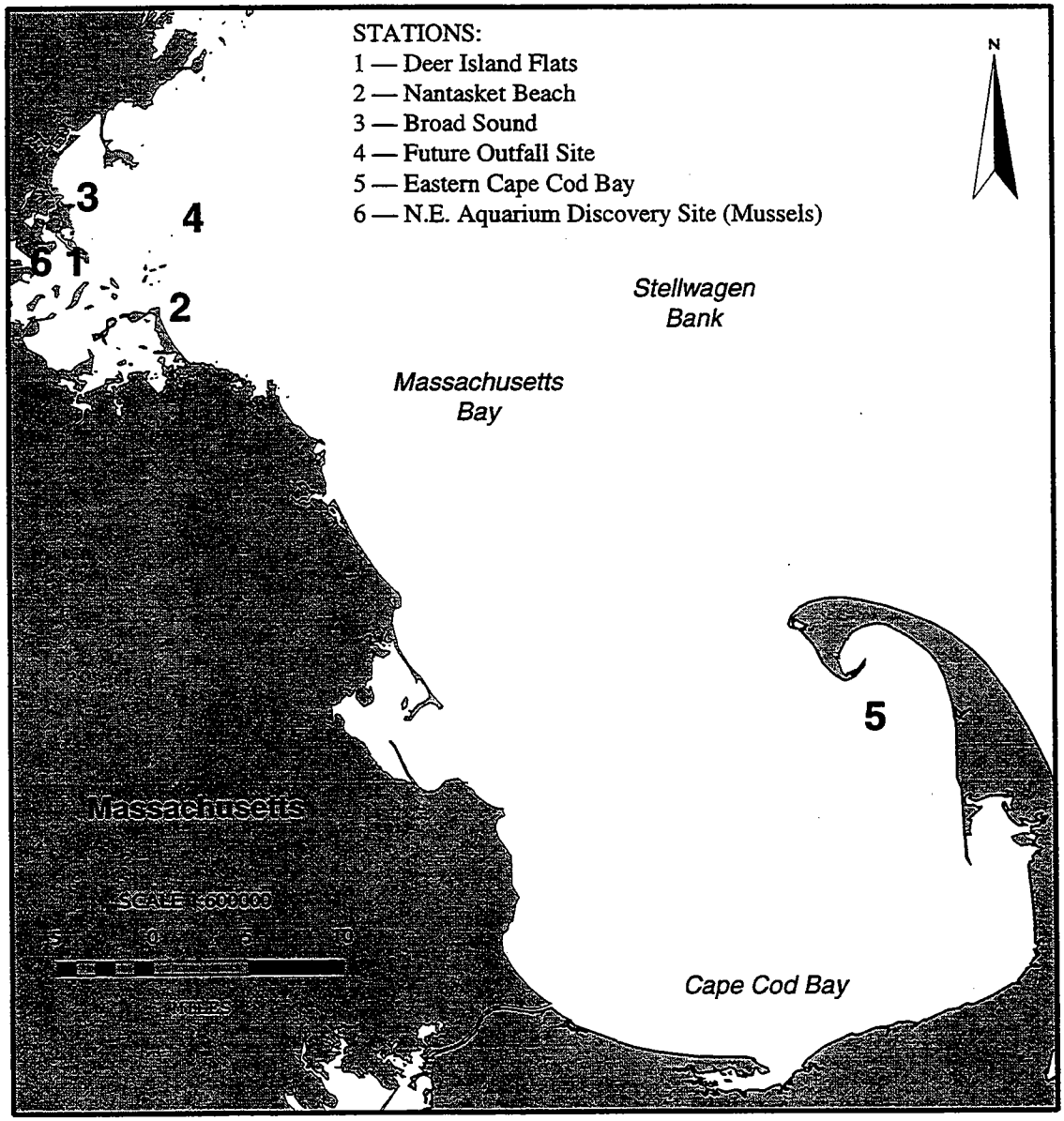
Chemistry Analyses for Fish and Shellfish Monitoring

Organism	Number/Type of Sample	Parameters
Flounder	15 / Fillet	Mercury Polychlorinated Biphenyls Chlorinated Pesticides Lipids
Flounder	15 / Liver	Trace metals Polychlorinated Biphenyls Polyaromatic Hydrocarbons Chlorinated Pesticides Lipids
Lobster	9 / Meat	Mercury Polychlorinated Biphenyls Chlorinated Pesticides Lipids
Lobster	9 / Hepatopancreas	Trace metals Polychlorinated Biphenyls Polyaromatic Hydrocarbons Chlorinated Pesticides Lipids
Mussel	18 / Soft tissue	Mercury Lead Polychlorinated Biphenyls Polyaromatic Hydrocarbons Chlorinated Pesticides Lipids

TABLE 2-3

Lobster Survey Collection Data

Station	Date	Start Time	End Time	Latitude	Longitude
Deer Island	8/26/96	8:25 AM	10:30 AM	42.34	70.98
Future Outfall Site	8/26/96	11:30 AM	12:20 PM	42.39	70.79
Cape Cod Bay	8/6/96	10:10 AM	2:15 PM	42.05	70.17



M960345

FIGURE 2-1
Winter Flounder, Lobster and Mussel Sampling Locations

3.0 RESULTS AND DISCUSSIONS

The results of the three 1996 biomonitoring surveys are reported in this section. The results of the Flounder Survey are given in Section 3.1; the results of the Lobster Survey are given in Section 3.2; and the results of the Mussel Bioaccumulation Survey are presented in Section 3.3.

3.1 Winter Flounder

3.1.1 Fish Collected

Winter flounder, each a minimum 30 cm in length, were collected between April 14 and 29, 1996 at five stations in the study area. Fifty fish were collected at Nantasket Beach, Broad Sound, and Cape Cod Bay. Thirty were collected at Deer Island, and 49 were collected at the Future Outfall. The catch per unit effort (CPU), defined as the number of fish obtained per minute of bottom trawling time, was highest at Eastern Cape Cod Bay in 1996 (Table 3-1). The lowest CPU of 1996 was observed at Deer Island Flats, as is true for many of the years of the fish biomonitoring study. The CPU is determined in order to make a relative comparison of catch efficiency within the study between years.

3.1.2 Age/Length Parameters

The physical characteristics (i.e., mean age, length, weight) of the winter founder collected in 1996 are given in Table 3-2, and the interannual trends at the five stations are depicted in Figures 3-1a through 3-1e. The total length and weights were comparable for all stations in 1996; there was less than 10% difference between average station values for length, and less than 25% difference between average station values for weight. The average age at Broad Sound (3.9 years) was significantly lower than at Deer Island Flats (4.3 years) or at the FOS (4.5 years). The average age at the Future Outfall Site (4.5 years) was significantly higher than the average age at Eastern Cape Cod Bay (4.0 years). As shown in Figures 3-1a and 3-1d, the mean ages of Deer Island Flats and Future Outfall Site flounder increased slightly in 1996 as compared to previous years. At Nantasket Beach and Broad Sound, the age declined slightly in 1996 (Figures 3-1b, 3-1c). In general, the mean age has been decreasing at Deer Island and Broad Sound since 1989. At the other stations, little change in the mean age has been observed throughout the study. Mean fish length varied little between years at most stations and reflects the minimum size requirement (i.e., minimum 30 cm required for the study).

3.1.3 External Condition

The physical characteristics and external conditions (i.e., fin erosion, gross abnormalities) of winter flounder collected in 1996 are presented as averages per station in Table 3-2. As described in Section 2.1.1, 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 varied between station (0.1 to 0.5), with Deer Island Flats and Nantasket Beach being significantly higher than the Future Outfall Site. This amount of fin erosion would be considered in the low end of the range (Murchelano, 1975) and, with regard to the DIF station, apparently well below the fin erosion observed (but not quantified) in the later 1980's (pers. obs. M. Moore).

3.1.4 Interstation Comparison of Lesion Prevalence

The prevalence of histological changes in winter flounder liver from the 1996 survey is shown in Table 3-3. Neoplasia was absent from all flounder with the exception of one individual from Deer Island. Fish from Deer Island Flats and Broad Sound showed the greatest prevalence of the chemically-associated lesion hydropic vacuolation (i.e., focal, tubular, and centrotubular hydropic vacuolation). Other lesions that were recorded include macrophage aggregation, and biliary, hepatocytic and pancreatic lesions. These lesions did not show a trend that related to the apparent gradient of chemical contamination. They may be part of an undescribed series of pathological process or processes in these fish. The balloon cells appeared much as described previously (Hillman *et al.*, 1994; Hillman and Peven, 1995). They are probably apoptotic cells (i.e., cells that are dying from any of a number of causes). It is worth noting that balloon hepatocytes were substantially less at most sites than at 1993-1994.

3.1.5 Temporal Comparison of Lesion Prevalence

The prevalence of toxic chemical-associated liver lesions in winter flounder from Deer Island Flats was noted by Murchelano and Wolke (1985) in a 1984 study. Annual monitoring of the lesions in winter flounder from the Harbor has been ongoing since 1987 (Moore, 1991; Moore *et al.*, 1992; Moore and Stegeman, 1993; Hillman *et al.*, 1994). Four additional locations in Massachusetts and Eastern Cape Cod Bays were added in 1991 (Moore *et al.*, 1992). These studies have provided an internally consistent baseline data set on winter flounder liver pathology for the Deer Island Flats and Future Outfall sites, in addition to other sites in the region. This has been critical because of the existing Deer Island outfall's apparent biological effects, such as the hepatocellular hydropic vacuolation and other toxicopathic lesions, and the need to understand and document the change in biological impact on this ecosystem of recent and projected changes in sewage management by the MWRA. These changes include cessation of ocean dumping of sludge in December 1991, initiation of primary and planned secondary treatment, and the relocation of the effluent outfall to the future site, now scheduled to occur in 1998.

The rationale and necessary background information on the biology and toxicology of winter flounder have been reported previously (Moore *et al.*, 1992; Moore and Stegeman, 1993; Hillman *et al.*, 1994, Moore *et al.*, 1996). In these previous studies, hydropic vacuolation in the liver of winter flounder was detectable at all stations sampled, but was substantially more prevalent at the contaminated near-urban sites. Moore (1991) has shown a close association between hydropic vacuolation and liver neoplasms in winter

flounder, and Johnson *et al.* (1992) and Moore *et al.* (1996) have demonstrated that hydropic vacuolation was closely correlated with a suite of chemical contaminants, particularly chlorinated hydrocarbons. Hydropic vacuolation can be regarded as a harbinger of neoplastic risk, given adequate duration and level of exposure to carcinogens. Hydropic vacuolation appears to be an irreversible change. This is in distinct contrast to hydropic degeneration. The irreversibility of the former was shown convincingly when flounder from Deer Island Flats were maintained for 5 months on clean water and clean food, with no reduction in vacuolation prevalence over that time (Moore *et al.*, 1996). Therefore, given age-specific analysis and between-year consistency in histopathological interpretation, observation of the prevalence of hydropic vacuolation is an appropriate long-term monitoring parameter for the effects of benthic contaminants on winter flounder in the Boston Harbor/Massachusetts Bay area. Thus, hydropic vacuolation is one of the principal lesions emphasized in this report.

As in previous years, lesion prevalence is associated with age, length, and years of analysis. Previous Spearman Rank analyses have shown a significant decrease in lesion prevalence within recent years at DIF (MWRA, 1997).

Neoplasm prevalence in winter flounder from Deer Island Flats has fallen from a persistently elevated level in the 1980's to zero or near-zero levels in the last five years of this study. This trend has been accompanied by a reduction in the prevalence of the three stages of hydropic vacuolation. These temporal trends are summarized in Figures 3-1a through 3-1e.

3.1.6 Relationships Between Age, Length and Lesion Prevalence

As in previous years, age and length is also associated with lesion prevalence, but the age/length distribution is adequately comparable between stations to make spatial comparisons valid. Figure 3-2 illustrates the relationship with age at the Deer Island Flats study area, in fish spawned from 1980 through 1992. The lines in the figure represent the prevalence of lesions in successive years for a specific age class year. As can be seen, there is a general tendency for increase over years. This tendency was previously discussed in the 1995 Annual Fish and Shellfish Report (Mitchell *et al.*, 1997). One of the potential confounding factors for this type of analysis is the widely-varying number of samples collected between years.

3.1.7 Spatial Comparison of Tissue Contaminant Levels

The patterns of tissue contaminant levels (i.e., body burdens) were examined for winter flounder collected in the 1996 survey. The mean tissue contaminant levels for winter flounder are given in Table 3-4 as unit of mass contaminant per mass dry weight. The two tissue types of concern were edible tissue (fillets) and liver tissue. Results for fillets are presented in Figure 3-3, while those for flounder liver are shown in Figures 3-4 and 3-5. The associated lines on the bar graphs represent one standard error.

3.1.7.1 Edible Tissue

The levels of target analytes (total DDT, dieldrin, total chlordane, total PCBs, and mercury) in winter flounder fillets from the five 1996 survey sites (Deer Island Flats, Future Outfall Site, Eastern Cape Cod Bay, Nantasket Beach, and Broad Sound) are shown in Figure 3-3. Comparisons of the 1996 mean concentrations of organic compounds in fillets across the study area indicate that chlordane, total DDT, and PCBs were lowest in Eastern Cape Cod Bay flounder, while dieldrin was lowest at Broad Sound. Deer Island Flats flounder fillets consistently contained the highest concentrations of these four organics. Total PCB concentrations were approximately 32% higher at Deer Island Flats than at the Future Outfall Site. In 1996, mercury was highest in Future Outfall Site fillets, while mean tissue concentrations of mercury were lowest at Broad Sound. The mean tissue concentration of mercury at Broad Sound was slightly below the Eastern Cape Cod Bay value, which was the highest of record for that station.

3.1.7.2 Liver

The levels of organic target analytes (total DDT, dieldrin, total chlordane, total PCBs, total PAHs) in winter flounder liver from the 1996 survey are shown in Figure 3-4. As with the edible tissues, an interstation comparison of concentrations of organic compounds in flounder livers indicates that the highest mean tissue concentrations were consistently found at Deer Island Flats, while the lowest typically occurred in Eastern Cape Cod Bay flounder. The only exceptions were PAHs, where the highest concentrations occurred at the Future Outfall Site, and the lowest at Deer Island (although values at all sites were similar), and dieldrin, where tissue concentrations were below the method detection limit in all three liver composite samples from Broad Sound.

The levels of inorganic target analytes (Ag, Cr, Cu, Hg, Ni, Pb, Zn) in winter flounder liver from the 1996 survey are shown in Figure 3-4 and Figure 3-5. An interstation comparison of inorganics indicates that the distribution of metals did not follow the gradient of tissue burdens established by the organic contaminants. For example, cadmium (not shown), copper, lead, nickel, and silver were highest at the Future Outfall Site in 1996. Zinc was highest at the Eastern Cape Cod Bay station, while chromium and mercury were highest at Nantasket Beach.

3.1.8 Temporal Comparison of Contaminant Levels

The temporal or interannual variation of tissue contaminant levels was examined. The pattern of temporal variation can be seen for flounder fillet in Figure 3-3, while that for flounder liver is given in Figures 3-4 and 3-5. Each of these figures show data from 1992 to 1996 surveys, grouped according to sampling station. The associated line represents one standard error.

3.1.8.1 Edible Tissue

Annual tissue concentrations of organic compounds from 1992 to 1996 were analyzed in winter flounder of Deer Island Flats, the Future Outfall Site, Eastern Cape Cod Bay, Nantasket Beach, and Broad Sound (Figure 3-3). At Deer Island Flats, concentrations of total PCBs were within the range of previously recorded values (1992 through 1995 studies); while total chlordane, total DDT, and dieldrin were lowest in 1996 for the five-year period. At the Future Outfall Site, total chlordane, total DDT, and total PCBs in 1996 were the lowest of record, while tissue concentrations of dieldrin fell within the 1992 to 1995 range. At Eastern Cape Cod Bay, levels of total chlordane and total DDT were the lowest of the record period, and total PCBs and dieldrin were within the 1992 to 1995 range. Total chlordane, total DDT, dieldin, and total PCBs were all within the range measured in 1992 and 1994 at Nantasket Beach. At Broad Sound, concentrations of these four organics were the lowest of the record period.

Mercury was assessed in flounder fillets collected in 1996 from these five stations. Although tissue concentrations at Deer Island Flats, the Future Outfall Site, and Nantasket Beach were within the range of previously observed values, the concentration of mercury at Eastern Cape Cod Bay in 1996 was the highest of the record period, with an increase over 1995 values of 300%. The mean tissue concentration of flounder from Broad Sound decreased from the 1994 value by 21%, resulting in the lowest concentration of the record period.

3.1.8.2 Liver

Annual tissue concentrations of organic compounds in flounder livers from 1992 to 1996 were measured for Deer Island Flats, the Future Outfall Site, Eastern Cape Cod Bay, Nantasket Beach, and Broad Sound winter flounder (Figures 3-4, 3-5). Mean concentrations of total chlordane, total DDT, dieldrin, total PAHs, and total PCBs were in 1996 in flounder sampled throughout the study area were generally within the range of the previous years (1992 through 1995). [Note: the 1992 flounder liver PAH values are considered suspect due to potential contamination introduced at the time of dissection and were deleted from consideration. The 1993 PAHs were also anomolously high, but sufficient uncertainty remains as to the cause. To be conservative, these data were retained in the analyses.] At Deer Island Flats, concentrations of all five of the above mentioned organics were within the range previously measured. Future Outfall Site concentrations of total DDT, dieldrin,total PCBs, and total PAHs were within the range previously measured. The concentration of total chlordane was slightly below the range previously measured. At Eastern Cape Cod Bay, all five organics were within the range previously measured. Concentrations of all organics except total PAHs at Nantasket Beach were within the range previously measured. PAHs at this site were the highest of the record period, increasing over the 1994 value by 44%. At Broad Sound, concentrations of total chlordane, total DDT, dieldrin, and total PCBs all decreased (dieldrin was not detected; total chlordane decreased by 51%). Total PAHs at this site increased over the 1994 value by 54%.

Tissue concentrations of inorganic metals in livers were also measured at these five stations in 1996. At Deer Island Flats, mean flounder liver concentrations of copper, nickel, and chromium followed a continuing trend of decreasing annual levels. Zinc concentrations were slightly lower than in 1995, but within the previously observed range. Mercury, lead, and silver concentrations were elevated in comparison to 1995 mean values. The increase ranged from 31% (silver) to 152.3% (lead). At the Future Outfall Site, nickel levels in 1996 were the lowest of record. Silver and copper concentrations were the highest of the record period (copper increased slightly, silver by 127%); chromium, zinc, and mercury were within the range previously measured. At Eastern Cape Cod Bay, flounder liver mean concentrations increased slightly over the 1995 mean value for nickel, and mercury. The liver tissue means of silver, chromium, copper, lead and zinc were within the previously observed range. The mean concentrations of zinc and nickel at Nantasket Beach decreased from the 1994 values, resulting in the lowest values of the record period (nickel has been decreasing steadily since 1992). Concentrations of silver and chromium were the highest of the record period, and have been increasing steadily since 1992. Lead, copper, and mercury were within the range previously measured. At Broad Sound, concentrations of lead, nickel, chromium, and zinc were the lowest of the record period. Silver, copper, and mercury were within the range previously measured.

3.1.9 Relationship of Contaminant Levels to Histopathology

The relationship between tissue contaminants and indices of histopathological effects was investigated. This relationship provides the linkage between changes in chemical bioavailability and human seafood consumption risk, as indicated by fish body burdens, and potential ecotoxicological impacts, as indicated by fish histopathology. It also tests how one set of measures might predict the other. The prevalence of hydropic vacuolation was compared with chemical contaminant concentrations in fish collected from monitoring stations. Comparable analyses for samples analyzed in 1992, for instance, have shown significant correlations with halogenated organic compounds such as the DDT and chlordane groups (Moore *et al.*, 1996). Organic contaminant and histology data were compared between all stations for the years 1992-1996 (Moore *et al.*, 1992; Shea, 1993; Hillman *et al.*, 1994; Hillman and Peven, 1995).

These relationships are illustrated in Figures 3-6a to 3-6e for fillet tissue concentrations of selected organic compounds and mercury; and in Figures 3-7a through 3-7c for liver tissue concentrations of selected organic compounds. Each data point in each figure compares a specific chemical or group of chemicals in either the liver or fillet, with the prevalence of hydropic vacuolation at the same station in the same year. Examination of these plots reveals a persistent relationship for total PCBs, chlordanes and DDTs, which support the notion that histopathological data is a reasonable predictor for tissue burden of these compound classes.

3.1.10 Relationship of Contaminant Levels to FDA Legal Limits

Comparison was made between tissue contaminant levels and regulatory action limits. The U.S. Food and Drug Administration (FDA) has set legal limits for the maximum tissue concentrations of specific organic compounds and pesticides in the edible portions of fish and fishery products. For the MWRA biomonitoring program, Caution Levels are set at 50% of FDA Limits, and Warning Levels are set at 80% of FDA Limits (MWRA 1997). Caution and Warning Levels apply to the Future Outfall Site 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 1996 mean concentrations of target analytes per station were compared to the FDA's Legal Limits. These are presented below in Table 3-5.

The available historical data as well as data gathered during this program (1992-1996), were compared to the FDA Legal Limits for mercury and PCBs in Figure 3-8. Note that the concentrations in this figure are expressed as mass contaminants per mass wet weight. As both Table 3-7 and Figure 3-8 indicate, the tissue concentrations in winter flounder edible tissues are well below the federal legal limit for fish and shellfish.

3.1.11 Lipid Normalized Concentrations

Lipid normalized concentrations indicate how much of a chemical has accumulated in the lipids, or fatty tissues, of an organism. This parameter is significant because many chemicals accumulate at a higher rate in the lipids of fish than into other tissue components. Therefore, lipid-normalized contaminant concentrations are often much higher than whole-tissue concentrations. The percentage of lipids in a fish is also important because the bioconcentration of certain organics depends on the content of lipids in an organism. A fish with a higher lipid content will bioaccumulate more of these organics than a fish with a smaller lipid content. The lipid normalized concentrations for flounder are presented in Table 3-6 and graphically displayed in Figure 3-9a-b.

Lipid normalized concentrations for flounder fillet are presented in Figure 3-9a. In 1996, lipid normalized concentrations of total DDT and PCBs were highest at Deer Island and lowest at Eastern Cape Cod Bay. A similar trend is exhibited by concentrations in flounder liver (Figure 3-9b). The concentrations in 1996 were lower than those in 1995 for Deer Island, the Future Outfall Site, and Eastern Cape Cod Bay by as much as 68% (ECCB PCBs). Nantasket Beach and Broad sound were not analyzed for chemisty in 1995. Total PAH lipid normalized concentrations were highest in 1996 at Nantasket Beach and lowest at the Future Outfall Site. The lipid normalized concentrations of PAHs at Deer Island, the Future Outfall Site, and Eastern Cape Cod Bay were higher in 1996 than in 1995. At the Future Outfall Site, the concentration rose by 437%. The caution level for lipid normalized toxics in the MWRA Outfall Monitoring Program is two times the baseline concentration. The mean of the 1992 through 1996 data (Table 3-6) is currently considered the baseline concentration; 1997 and 1998 data will be incorporated when available.

3.2 Northern Lobster

3.2.1 Lobster Collected

The 1996 lobster survey was conducted according to the CW/QAPP (Mitchell *et al.*, 1995). At the Future Outfall Site (FOS), all 15 legal-sized nonberried lobsters were obtained. Four legal-sized nonberried lobsters were obtained at the Eastern Cape Cod Bay (ECCB), and five were obtained at Deer Island Flats (DIF). The remaining 11 lobsters for ECCB were purchased from Cape Tip Fisheries, and the remaining 10 lobsters from DIF were purchased from a local lobsterman. All purchased lobsters were from traps set in the general area of the stations.

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 1996 survey. The mean length and weight of lobsters collected in 1996 are presented in Table 3-7.

As shown in Table 3-8, little difference in lobster length or weight was observed between the three sampling sites, although there was a slight trend of increasing length and weight proceeding from the Deer Island Flats to Eastern Cape Cod Bay. Although the ratio of males to females was about equal at Deer Island Flats, four times more males than females were trapped at the Future Outfall Site, and two times more males than females were trapped at Eastern Cape Cod Bay.

Table 3-8 presents the average values for general external observations made for the 15 lobsters collected at each station in the 1996 survey. With the exception of two observations of shell erosion (FOS, ECCB) no deleterious external conditions were noted.

3.2.3 Spatial Comparison of Tissue Contaminant Levels

A summary of the lobster mean tissue contaminant levels by station is presented in Table 3-9. The spatial pattern of tissue contaminant levels in lobsters collected during the 1996 survey was examined. Figure 3-10 presents a graphic picture of the spatial and temporal trends in lobster edible tissue concentrations of selected organic compounds and mercury on a station-by-station basis. Figure 3-11 shows annual concentrations of target organic analytes and mercury in lobster hepatopancreas tissues, and Figure 3-12 portrays changes in hepatopancreas metals concentrations. Each of the figures show data from 1992 to 1996 surveys, grouped according to sampling station. The associated line represents one standard error. If no line is shown, then sample size was insufficient (i.e., <3) to calculate the standard error.

3.2.3.1 Edible Tissue

The spatial pattern of tissue contaminant levels of organic compounds in edible tissue was generally uniform for lobsters collected during the 1996 survey (Figure 3-10, Table 3-9). In general, the 1996 tissue concentrations of organics were higher than those observed in 1995, but consistent with levels found in 1994. Concentrations of organic compounds were generally lowest in lobsters collected in Eastern Cape Cod Bay and highest in lobsters collected at Deer Island Flats. Several pesticides, however, exhibited a different trend. The highest concentrations of dieldrin, hexachlorobenzene (not shown), and mirex (not shown) were found at the Future Outfall Site, the lowest again being found at Eastern Cape Cod Bay.

Mean mercury concentrations were similar in Deer Island Flats and Eastern Cape Cod Bay lobsters in 1996, and somewhat elevated at the Future Outfall Site. A similar trend in mean mercury concentrations was also seen in 1993 to 1995 lobster edible tissues.

3.2.3.2 Hepatopancreas

The spatial pattern of tissue contaminant levels of organic compounds in lobster hepatopancreas was similiar to that found in the edible tissues (Tables 3-11, 3-12). The 1996 hepatopancreas concentrations were generally lowest in lobsters collected in Eastern Cape Cod Bay and highest in lobsters collected at Deer Island Flats. As seen in the edible tissues, concentrations of dieldrin, hexachlorobenzene, and mirex in lobster hepatopancreas were highest at the Future Outfall Site and lowest in Eastern Cape Cod Bay.

The highest concentrations of metals in study area lobster hepatopancreas were seen at Deer Island Flats for silver, chromium, and copper, the Future Outfall Site for lead, mercury, and zinc, and Eastern Cape Cod Bay for cadmium and nickel. The lowest concentrations of metals in lobster hepatopancreas tissues were usually seen at Eastern Cape Cod Bay (copper, lead, silver, zinc) or Deer Island Flats (cadmium, mercury, nickel).

3.2.4 Temporal Comparison of Tissue Contaminant Levels

The temporal trends of tissue contaminants in lobster edible tissue and hepatopancreas are shown in Figures 3-10 through 3-12. Figure 3-13 summarizes both historical and recent lobster edible tissue data for PCBs and mercury and compares them to FDA Legal Limits.

3.2.4.1 Edible Tissues

In 1996, concentrations of organic compounds in lobster edible tissues at Deer Island Flats and the Future Outfall Site were consistently higher than concentrations measured in 1995. Concentrations in Eastern Cape Cod Bay lobster edible tissues were higher in 1996 than 1995 for total chlordane, but slightly lower for total DDT, dieldrin and total PCBs.

Total DDT, total chlordane, dieldrin, and total PCBs increased by approximately 31% (dieldrin) to 1344% (chlordane) from concentrations observed in the edible tissues of lobster of Deer Island Flats in 1995. While these increases over 1995 concentrations are large, it should be noted that for chlordane, the 1995 value was the lowest of the record period. Comparing 1994 with 1996 values, dieldrin decreased by 26% and chlordane increased only 8%. The concentration of total PCBs at DIF was above the 1992-1995 range. At the Future Outfall Site, concentrations of these organics increased from 1995 to 1996 by approximately 29% (total DDT) to 548% (chlordane). The 548% increase in chlordane is a reflection of the fact that the 1995 meausured concentration (0.59 ppb) was the lowest of the record period. Comparing 1994 with 1996 concentrations results in a 25% decrease in chlordane. Concentrations of these organics in Eastern Cape Cod Bay lobsters collected in 1996 were generally within the range of observations made from 1992 to 1995.

Concentrations of mercury increased from 1995 to 1996 by 41% in the edible tissues of lobsters collected at Deer Island Flats. The mean concentration of mercury in lobsters of the Future Outfall Site was within the range of those observed from 1992 to 1996. The mean concentration of mercury in lobsters at Eastern Cape Cod Bay increased over the 1995 value by 76%.

3.2.4.2 Hepatopancreas

Concentrations of organic compounds in lobster throughout the study area were generally observed to be outside the range of values observed from 1992 to 1995. At Deer Island Flats, lobster concentrations of chlordane, total DDT, dieldrin, and total PCBs were the highest of the record period. Concentrations were above 1995 mean values by 61% (PCBs) to 415% (chlordane). It should be noted, however, that many of the 1995 values were unusually low. For instance, the 1996 mean concentration of chlordane was 71% higher than the 1994 value, a much smaller increase than the 415% change between 1995 and 1996. At the Future Outfall Site, the mean concentrations of total chlordane, total DDT, dieldrin and total PCBs were the highest of the record period. However, the increase over 1995 concentrations for dieldrin (34%), total DDT (10%), and PCBs (7%) were slight. Chlordane increased by 113%, while total PAHs decreased slightly by 0.3% from 1995 mean concentrations. Mean concentrations of chlordane, total DDT, and total PCBs at Eastern Cape Cod Bay were generally within the range of values observed from 1992 to 1995. The mean concentration of dieldrin increased by 68% from 1995 to 1996, while the concentration of total PAH decreased from the 1995 value by 43%.

Mean concentrations of inorganics in lobster hepatopancreas tissues were generally within the range of values observed from 1992 to 1996. At Deer Island Flats, the mean tissue concentrations of copper, lead, silver, and zinc increased over the 1995 values. Chromium, mercury, and nickel mean concentrations were lower than 1995 values and the lowest of record. At the Future Outfall Site, mean concentrations of copper, lead, mercury, nickel, and zinc were all within the range of the 1992 to 1995 values. Concentrations of chromium and nickel were the lowest of the record period. At the Eastern Cape Cod Bay station, concentrations of copper, lead, mercury, nickel, and zinc were within the range of values

observed between 1992 and 1995. The mean concentration of silver was the highest of the record period, increasing over the 1995 value by 88%. The measured chromium concentration was the lowest of the record period, with a 15% decrease from the 1995 value.

3.2.5 Relationship of Contaminant Levels to FDA Legal Limits

The U.S. Food and Drug Administration has set legal limits for maximum concentrations of numerous organic compounds and mercury in the edible portions of fish and fishery products (U.S. EPA, 1989). These organic compounds include: total PCBs (2.0 ppm); aldrin/dieldrin (0.3 ppm); chlordane (0.3 ppm); DDT (5.0 ppm); DDE (5.0 ppm); DDD (5.0 ppm); DDI (5.0 ppm); endrin (0.3 ppm); heptachlor/ heptachlor-epoxide (0.3 ppm); kepone (0.3-0.4 ppm); mirex (0.1 ppm); and toxaphene (5.0 ppm). For the MWRA biomonitoring program, Caution Levels are set at 50% of FDA Limits, and Warning Levels are set at 80% of FDA Limits (MWRA 1997). Caution and Warning Levels apply to the Future Outfall Site only. These three levels provide reference benchmarks for detecting adverse changes (and their potential human health risks) once the new outfall is on line.

Table 3-10 compares the mean wet weight concentrations of these organic compounds and mercury in lobster edible tissues collected throughout the study area in 1996 to the applicable FDA Legal Limits. As the table indicates, all organic tissue contaminant levels were far below all applicable benchmarks, normally by 2 or more orders of magnitude. Mercury levels in lobster were also well below the three benchmark levels. The annual trends in the tissue concentrations are shown in Figure 3-13. This figure indicates that, while edible meat concentrations of PCBs and mercury are below concern, hepatopancreas PCBs concentration exceeded FDS legal limits. This potential concern is consistent with the current MA State Advisory regarding consumption of lobster tomalley (i.e., hepatopancreas) for lobsters caught in Massachusetts waters.

3.2.6 Lipid Normalized Concentrations

Lipid normalized concentrations for lobster meat and hepatopancreas tissues are presented as wet weights in Table 3-11 and Figure 3-14a-b. Lipid normalized concentrations of total DDT and total PCBs in lobster meat were greatest at Deer Island and lowest at Eastern Cape Cod Bay (Figure 3-14a). The 1996 values were greater than 1995 at all stations. The values at the Future Outfall Site were the greatest of the record period for both DDT and PCBs.

Similarly, lipid normalized concentrations of total DDT, total PAHs, and total PCBs for lobster hepatopancreas in 1995 and 1996 were consistently highest at Deer Island and lowest at Eastern Cape Cod Bay (Figure 3-14b). The concentrations of these organics in the hepatopancreas of lobsters at Deer Island and the Future Outfall Site increased from 1995 to 1996. The most dramatic increase was that of total PAHs in Deer Island (111%). The concentrations of total DDT and total PCBs remained about the same in Eastern Cape Cod Bay; however, total PAHs decreased by 40%.

The Caution Level for lipid normalized toxics in the MWRA Outfall Monitoring Program is two times baseline. Ultimately, the 1992 through 1997 data will be considered as baseline.

3.3 Blue Mussel

3.3.1 Mussels Collected

The final mussel retrieval for 1996 was conducted on August 27, 1996 (60 days after deployment). Mussels were retrieved from Deer Island (Station 1, in Boston Harbor), the Large Navigation Buoy (Station 4, the approximate site of the Future Outfall Site, and hereafter referred to it by that name), and the *Discovery* (Station 6, a vessel at the New England Aquarium). Further details on mussel retrieval and cage condition are given in Section 2.3.4. The mussels/arrays deployed and recovered at each sampling location are quantified in Table 3-12.

3.3.2 Biological Condition Indices

As part of the 1996 Mussel Bioaccumulation Survey, data were collected on the survival, sexual maturity, size, and weights for pre-deployment and recovered mussels. The results of survival and sexual maturity analyses of the mussels retrieved at each station are summarized in Table 3-13.

3.3.2.1 Survival

As shown in Table 3-13, the percent survival observed in the cages was high (i.e., ≥83%) for both the forty- and sixty day harvested mussels. Survival at the forty-day harvest of the mussels was 87 to 99 percent for the Gloucester mussels, and 93 to 100 percent for the Sandwich mussels. Comparable survival was observed at 60 days, including 97 to 100 percent for the Sandwich mussels at all stations and 91 to 92 percent for Gloucester mussels at Deer Island and and Future Outfall Site, respectively. The poorest survival rate (83 percent) was for Gloucester mussels at the *Discovery*.

3.3.2.2 Sexual Maturity

A representative sample of randomly selected mussels was examined from five locations (Gloucester pre-deployment, Sandwich pre-deployment, Deer Island, the Future Outfall Site, and the *Discovery*) to determine the sex ratio and stage of gametogenesis of mussels (Table 3-13). Sex was determined visually with the female gonads generally appearing orange, while the males were more yellow in color following methods described by Downey *et al.* (1995).

Of the 30 pre-deployment mussels from Gloucester which were examined in June, ten of twelve females collected were immature and 2 were mature. Fourteen of the 18 males collected were mature and four were immature. The proportion of mature females in the Gloucester pre-deployment mussels is consistent

with observations made earlier in this study (i.e., 1991-95 surveys). After 60 days of deployment, 30 mussels were examined from Deer Island and the Future Outfall Site, and 17 mussels were examinied from the *Discovery*. At Deer Island 18 mussels were female (nine mature and nine immature) and 12 were male (six mature and six immature). Future Outfall Site mussels were predominantly male (21, of which nine were mature and 12 were immature). Of the nine female mussels, four were mature and five were immature. At the Discovery, ten mussels were female (six mature and four immature) and seven were male (three mature and four immature).

Ten pre-deployment mussels from Sandwich, MA were also examined. All 10 were mature males. After 60 days of deployment, five mussels were examined from each of the three sites. At Deer Island, there were three mature females and two mature males. At the Future Outfall Site, there was one mature female, three mature males, and one immature male. At the *Discovery*, two mature females and three mature males were found.

3.3.2.3 Growth and Condition

The size and growth of the mussels at the various stations were statistically analyzed using a two sample t-test assuming equal variances, using Microsoft Excel® (Table 3-14). Due to unequal sample sizes before and after deployment, the planned paired t-test was inappropriate for 1996 data. Mean shell length in Gloucester pre-deployment mussels was 56.93 mm. Mean shell length increased in these mussels deployed at Deer Island (62.6 mm), at the *Discovery* (62.9 mm), and at the Future Outfall Site (63.16 mm); these observed changes were statistically significant ($P<0.05$). The mean shell length of Deer Island, *Discovery*, and Future Outfall Site mussels were not significantly different from each other ($P>0.05$). The mean shell wet weight of Deer Island mussels (15.72 g) was significantly higher ($P<0.05$) than pre-deployment mussels (11.28 g). The mean shell wet weights of *Discovery* mussels (16.36 g) and Future Outfall Site mussels (16.53 g) were also significantly different from Gloucester pre-deployment mussels.

The mean shell length of Sandwich mussels before deployment was 63.12 mm. This value increased significantly ($P<0.05$) in Sandwich mussels deployed at Deer Island (66.88 mm), the Large Naviation Buoy (67.16), and the *Discovery* (67.20 mm). Mean shell weights at these sites also increased significantly ($P<0.05$) from Sandwich predeployed mussels (13.16 g). At Deer Island, shell weight increased to 16.1 g, at the Future Outfall Site to 17.06 g, and at the *Discovery* to 17.23 g.

The mean non-gonadal soft tissue wet weights of Deer Island, Future Outfall Site, and *Discovery* mussels were significantly different ($P<0.05$) from the Gloucester pre-deployment mussels ($P<0.05$). The gonadal mean wet weights for Deer Island, Future Outfall Site, and *Discovery* mussels were also significantly larger ($P<0.05$) than the Gloucester pre-deployment mussels. Deer Island mussels were not significantly ($P>0.05$) different from *Discovery* mussels for these parameters. Deer Island mussels were also not significantly ($P>0.05$) different from Future Outfall Site mussels for nongonadal and gonadal weights.

However, *Discovery* mussels were significantly smaller (P<0.05) than Future Outfall Site mussels and Deer Island and Future Outfall Site mussels for these parameters.

The mean non-gonadal wet weights of Sandwich mussels deployed at Deer Island, the Future Outfall Site, and the *Discovery* were not significantly different from Sandwich pre-deployment non-gonadal weights (P>0.05). The difference between pre-deployment mussels and those deployed at the three stations were statistically significant for mean non-gonadal wet weights.

3.3.3 Spatial Comparison of tissue Contaminant Levels

The differences in mussel tissue contaminant levels were examined across the various sampling and deployment locations. For purposes of comparison with historical data (Downey *et al.*, 1992; 1993; Downey, 1994a; 1994b; Downey *et al.*, 1995) detection limits were treated as measured values for those compounds reported as not detected.

3.3.3.1 PAH compounds

The compound list of Low Molecular Weight PAHs (LMW-PAH) (defined as those target 2 and 3 ringed compounds) and High Molecular Weight PAHs (HMW-PAH) (defined as 4, 5 and 6 ringed target compounds) analyzed in 1995 and 1996 differed slightly as compared to previous years (Table 3-15). In order to examine trends in body burdens of mussels harvested with previous studies, the total PAHs (t-PAH), LMW-PAHs, and the HMW-PAHs, were calculated two ways. The sums of LMW-PAHs and HMW-PAHs were calculated by adding all of the LMW- or HMW-PAHs listed in Table 3-16, respectively.

The target analyte list of polynuclear aromatic hydrocarbons (PAH's) included both an expanded group of analytes and the target compounds used in the Mussel Watch program by NOAA. The results of these analyses by A.D. Little were tabulated and summarized by ENSR personnel (Table 3-16). For comparability purposes with historical data, a "NOAA" list of compounds (Table 3-15) was used to discern any apparent spatial and/or temporal trends at the stations.

Average body burdens of NOAA Low Molecular Weight (LMW) PAHs were the highest in mussels deployed at Deer Island (431 ug/kg dry) (Table 3-17). Discovery deployed mussels also had higher average body burdens (268 ug/kg dry) than Gloucester pre-deployment (195 ug/kg dry), while mussels from the Future Outfall Site averaged the lowest (72 ug/kg dry).

Several individual LMW-PAHs were in detectable concentrations in the Gloucester pre-deployment mussels. Average concentrations of 1-methylnaphthalene, 2,6-dimethylnaphthalene, 2,3,5 trimethylnaphthalene and naphthalene were statistically equal in Deer Island mussels compared to

Gloucester mussels. Phenanthrene, 1-methylphenanthrene, anthracene, and fluorene were all found in the highest concentrations in Deer Island mussels ($P<0.05$).

Average body burdens of NOAA High Molecular Weight (HMW) PAHs were significantly higher in both Deer Island (799 ug/kg dry) and Discovery (2233 ug/kg dry) deployed mussels when compared to the average body burdens of Gloucester pre-deployment mussels (207 ug/kg dry) ($P<0.05$) (Table 3-17). As noted with the LMW-PAHs, several individual HMW-PAHs were found in detectable concentrations (i.e., chrysene, fluoranthene, and pyrene). Individual HMW-PAHs were routinely found at significantly higher concentrations in Discovery deployed mussels compared to Gloucester pre-deployed and Deer Island mussels ($P<0.05$). The FOS deployed mussels displayed both LMW-PAH and HMW-PAH tissue concentrations that were substantially lower than mussels harvested from Deer Island, Discovery and the Gloucester pre-deployment mussels ($P<0.05$).

Total PAHs (t-PAH) were highest in the Discovery mussel tissues (2500 ug/kg dry) and lowest in the FOS mussels (142 ug/kg dry) ($P<0.05$). Deer Island mussel t-PAH burdens averaged 1230 ug/kg dry which was significantly higher than Gloucester Predeployment tPAH body burdend of 402 ug/kg dry.

3.3.3.2 Pesticides

Five pesticides (aldrin, endrin, heptachlor epoxide, lindane gamma-BHC, and 2,4' DDE) were found at or near detection levels at all stations in 1996 (Tables 3-18 and 3-19). Six compounds (dieldrin, alpha-chlordane, trans-nonachlor, heptachlor, 4,4-DDE, and 2,4-DDT) were found at significantly higher levels in Deer Island and Discovery mussels, after 60 days of exposure, as compared to the pre-deployment mussels ($P<0.05$). Heptachlor, mirex and 4,4-DDT concentrations were significantly higher in Deer Island mussels as compared to Discovery mussels, however, hexachlorobenzene, 2,4-DDD and 4,4-DDD concentrations were significantly higher in Discovery mussels. The tissue concentrations for 2,4-DDT, alpha-chlordane and trans-nonachlor were numerically higher in Deer Island mussels as compared to Discovery mussels, while dieldrin concentrations were numerically higher in Discovery mussels. Tissue concentrations of 2,4-DDD in Discovery mussels were significantly higher as compared to pre-deployment mussels, however, pre-deployment mussels had significantly higher Mirex concentrations.

The tissue concentrations of 2,4-DDD, 4,4-DDD, and 4,4-DDE were significantly higher in pre-deployment mussels as compared to FOS mussels ($P<0.05$). The pesticide 2,4-DDT was not detected in pre-deployment mussels, but was detected in FOS mussels.

3.3.3.3 Polychlorinated Biphenyls

Mussel tissues were analyzed for twenty-one polychlorinated biphenyl (PCB) congeners (Tables 3-20 and 3-21). Eleven of the twenty-one PCB congeners (BZ #'s 8, 28, 101, 105, 118, 128, 138, 153, 180, 187, and 195) were found in significantly higher tissue concentrations in Deer Island deployed mussels when compared to the Gloucester pre-deployment mussels ($P<0.05$). Discovery mussels had significantly higher tissue concentrations for thirteen (BZ #'s 28, 44, 52, 66, 101, 105, 118, 128, 153, 170, 180, 187, and 138) of the twenty-one PCB congeners examined as compared to pre-deployment mussels. Tissue concentrations for an additional 5 of the twenty-one PCB congeners examined were numerically equal or higher in Discovery mussels as compared to pre-deployment mussels (but were not significantly higher). Eleven of the twenty PCB congeners (BZ #'s 28, 44, 52, 66, 101, 105, 118, 128, 153, 180, and 187) were significantly higher in the Discovery mussels as compared to Deer Island mussels ($P<0.05$).

Two congeners (BZ #'s 77 and 126) were not routinely detected in mussel body burdens from all three stations. One congener (BZ # 18) was not detected in pre-deployment, Deer Island or Discovery mussels, but was detected in FOS mussels. Nine PCB congeners (BZ #'s 28, 44, 52, 101, 105, 118, 153, 180, and 187) were found in significantly higher tissue concentrations in pre-deployment mussels as compared to the FOS mussels ($P<0.05$).

3.3.3.4 Mercury and Lead

Mercury tissue concentrations from mussels harvested during Sandwich pre-deployment, the Discovery, Deer Island and FOS deployments (0.13 mg/kg, 0.13 mg/kg, 0.15 mg/kg and 0.15 mg/kg, respectively) were similar in mussels from all four locations (Table 3-22) ($P>0.05$). Average lead tissue concentrations in Discovery deployed mussels (9.4 mg/kg) was significantly higher than the Sandwich pre-deployment concentrations (2.9 mg/kg) ($P<0.05$). The Deer Island mussel body burdens of 6.3 mg/kg were not statistically different from the Discovery deployed mussels ($P>0.05$). The lead tissue body burdens for FOS mussels (1.6 mg/kg) was not significantly different from Sandwich pre-deployment mussels (2.9 mg/kg), however, Deer Island and Discovery lead mussel body burdens (6.3 and 9.4 mg/kg, respectively) were significantly higher than FOS mussels.

3.3.4 Temporal Trends in Tissue Contaminants

The differences in mussel tissue contaminant levels were also examined across the various study years. These comparisons are discussed below for each of the analytical groups. Please note that in the figures accompanying this section, the apparent "zero" FOS concentrations in 1995 is due to the loss of these arrays and biological samples and not due to non-detectable levels.

3.3.4.1 PAH Compounds

Reported Gloucester pre-deployment NOAA LMW-PAH body burdens of 195 ug/kg dry was nearly two times greater than average pre-deployment body burdens (1991-1995 burdens ranged from 66 to 113 ug/kg dry) (Figure 13-15a). LMW-PAH body burdens in Discovery deployed was approximately 268 ug/kg dry which was numerically higher than previously reported Discovery body burdens which ranged from 79 to 239 ug/kg during the 1991-1995 studies (Figure 13-15b).

Deer Island LMW-PAH body burdens of 431 ug/kg dry were intermediate in 1996 with LMW-PAH body burdens ranging from a high of 516 ug/kg dry in 1991 to a low of 169 ug/kg dry in 1993. The temporal pattern of average LMW-PAHs in Deer Island deployed mussels display a decreasing trend from 1987 to the lowest concentrations in 1993. During the last 4 years (1993 through 1996) there appears to be a trend of increasing LMW-PAH body burdens in Deer Island deployed mussels (Figure 13-15d).

Although overall NOAA LMW-PAH body burden trends were consistent with results reported for previous years, analyses of 1996 individual LMW-PAH analytes were less consistent with previous years for Deer Island and Gloucester stations. During previous studies (Downey and Young 1992; Downey *et al.* 1993; Downey 1994; Downey *et al.* 1995; and Downey and Moffat 1996) the methylnaphthalenes (1-methylnaphthalene, 2-methylnaphthalene, 2,6-dimethylnaphthalene, and 2,3,5-trimethylnaphthalene) and phenanthrenes (phenanthrene and 1-methylphenanthrene) were routinely found in higher concentrations in Deer Island deployed mussels compared to mussels deployed at the other three stations. However, in 1996, none of the Deer Island methylnaphthalene average body burdens were significantly higher than pre-deployment burdens, suggesting minimal to no bioaccumulation. Phenanthrene was significantly higher ($P<0.05$) in Deer Island deployed mussels than pre-deployment mussels but not significantly higher than Discovery deployed mussels.

Examination of the 1996 individual methylnapthalene and phenanthrene Gloucester pre-deployment mussel data with 1994 and 1995 pre-deployment data revealed several interesting relationships. With the exception of 2,3,5 trimethylnaphthalene which was similar between 1994 and 1996 results, the remaining reported methylnaphthalene compounds were typically 1.5 to 2 times higher in Gloucester pre-deployment mussel tissue concentrations in 1996. Comparison of the pre-deployment tissue concentrations between 1995 and 1996 although confounded by differences in the parameter list and detection levels still suggest much higher concentrations in 1996. For example, the C1-methylnaphalenes (which includes both 1-methylnaphthalene and 2-methylnapthalene) pre-deployment body burdens reported in 1995 averaged 10.7 ug/kg dry while the 1996 pre-deployment body burdens for the two compounds were 13.6 and 24.7 ug/kg dry for a total of approximately 38 ug/kg dry for the two compounds (i.e., C1-Methyl naphthalene).

Deer Island deployed mussels also displayed different methylnaphthalene patterns in 1996 than either 1994 and 1995 Deer Island deployed mussels. The 1996 Deer Island deployed mussel tissue concentrations were comparable for both the 1-methylnaphthalene (12 ug/kg and 12 ug/kg in 1994), 2-methylnaphthalene

(19.2 ug/kg to 21 ug/kg in 1994) and 1-methylphenanthrene (25 ug/kg to 26 ug/kg in 1994) to 1994 mussel concentrations. However, 2,6 dimethylnaphthalene (14.8 ug/kg to 33 ug/kg in 1994), and 2,3,5-trimethylnaphthalene (11.5 ug/kg to 45 ug/kg in 1994) mussel were reportedly lower in 1996 while phenanthrene (63 ug/kg to 35 ug/kg in 1994) was higher in 1996 (63 ug/kg) Deer Island deployed mussels ($P<0.05$).

As noted earlier, differences in target compound list in 1995 and 1996 may confound historical comparisons. However, in both 1995 and 1996 the C1-C4 methylnaphthalenes and C1-C4 methylphenanthrenes were part of the analyte list (although this grouped compound list was not analyzed prior to 1995). The respective comparisons of 1995 and 1996 C1-methylnaphthalenes (18.2 to 22.2 ug/kg), C2-methylnaphthalenes (59.3 to 48.4 ug/kg), C3-methylnaphthalenes (114.5 to 95.8 ug/kg), and the C4-methylnaphthalenes (160.8 to 154 ug/kg) did not reveal large differences between the two years for any group of methylnaphthalenes. The respective comparisons of 1995 and 1996 C1-phenanthrene/anthracene (58.2 to 118 ug/kg), C2-phenanthrenes/anthracene (158.3 to 240 ug/kg), C3-phenanthrene/ anthracene (153.3 to 230 ug/kg), and C4-phenanthrene/anthracene (106 to 162 ug/kg) suggest that the phenanthrenes/anthracenes were about 50 percent higher in 1996. Anthracene was also about two times higher in 1996 (23 ug/kg) compared to 1995 (13.5 ug/kg).

The Gloucester pre-deployment mussel HMW-PAH body burdens were substantially higher in 1996 compared to 1991-1995. Three compounds, fluoranthene, pyrene, and chrysene, accounted for nearly two thirds of the NOAA HMW-PAHs. These compounds were nearly three times higher than pre-deployment mussel tissue concentrations reported for 1994 and 1995 harvested mussels.

The average NOAA HMW-PAHs burden for 1996 Deer Island deployed mussels (799 ug/kg) was comparable to those burdens reported for 1991-1995 Deer Island deployed mussels. The HMW-PAH average burdens ranged from a high of 1507 ug/kg in 1992 to a low of 421 ug/kg in 1995. Fluoranthene, pyrene and chrysene were approximately 1.5 to 2 times higher in Deer Island deployed mussels in 1996 compared to 1994 and 1995 reported results.

The NOAA HMW-PAHs for 1996 Discovery deployed mussels (2233 ug/kg) was also comparable to historical values for 1991-1995. The HMW-PAH average burdens at this station ranged from a high of 3347 ug/kg in 1992 to a low of 1210 ug/kg in 1993. Individual tissue concentrations for 1996 HMW-PAHs, particularly fluoranthene, pyrene, chrysene and benz(a)anthracene, were comparable to 1994 concentrations. The 1995 HMW-PAH mussel body burdens were among the lowest recorded for all stations.

3.3.4.2 Pesticides

The 1996 t-DDT tissue concentrations at all stations increased over 1995 levels (Figure 3-16a-d). The 1996 Deer Island t-DDT levels were at the highest levels since the study began in 1991 (Figure 3-16d). The significant increase in 1996 t-DDT levels in Deer Island mussels can be largely attributed to significant increases in 2,4-DDT, 4,4-DDE, and 4,4-DDT as compared to 1995 concentrations (2,4-DDD and 4,4-DDD concentrations were numerically higher in 1996 as compared to 1995). The 1996 t-DDT concentrations in Discovery mussels were higher as compared to 1995 concentrations, however the 1996 levels were slightly lower than the peak levels observed in 1993 (Figure 3-16c). The 1996 t-DDT concentrations in pre-deployment mussels were also higher as compared to 1991-1992 and 1994-1995 concentrations. The 1996 t-DDT concentrations at the FOS were similar to the peak concentrations observed in 1993 (Figure 3-16b). These data suggests that the t-DDT concentrations in pre-deployment, Deer Island and FOS mussels are generally increasing. However, analytical variability has made the identification of subtle trends difficult. Yearly variations in the observed t-DDT concentrations may be partly attributable to analytical variations resulting from the use of a different capillary column configuration in 1993 and 1994 as compared to 1991-1992 (see Downey 1994 for discussion).

Hexachlorobenzene (HCB) tissue concentrations were numerically higher in mussels from all stations in 1996 as compared to 1995 mussels. HCB concentrations at all stations were lower than the HCB concentrations reported in 1993. The 1993 results may have been unreliable due to possible blank contamination with HCB during sample processing and analysis.

The mussel body burdens of total chlordane (trans-nonachlor, alpha-chlordane, heptachlor epoxide, and lindane) at the Deer Island and Discovery stations have varied numerically yearly since 1991, but tissue concentrations have remained generally at the same level through 1995 (Figure 3-16a-d). The 1996 total chlordane levels in Deer Island mussels were markedly higher as compared to all previous years studied. The total-chlordane levels at Deer Island and Discovery were numerically lower during 1995 as compared to 1994; however, the shortened exposure period in 1995 may have resulted in artificially lower tissue concentrations. The total chlordane concentrations were slightly higher than the 1995 levels for pre-deployment and Discovery mussels but were well within the range of natural annual variability. Total chlordane concentrations at the FOS in 1996 were numerically lower than those observed in 1994 and total chlordane levels also appear to be relatively stable at the FOS site. ($P<0.05$)

Dieldrin/aldrin concentrations in Deer Island mussels were about twice as high in 1996 (6.9 ug/kg) compared to 1995 levels (3.3 ug/kg) but were comparable to those levels reported in 1991-1994. The dieldrin/aldrin tissue concentrations for all stations, including the FOS, were similar to the values reported in 1991-1995. These data suggest that the dieldrin/aldrin tissue concentrations are relatively stable at all deployment sites.

3.3.4.3 Polychlorinated Biphenyls

The average tissue concentrations of two PCB congeners (BZ #'s 18 and 138) in pre-deployment, Deer Island and Discovery mussels decreased significantly between 1995 and 1996 (BZ # 18 was not detected in pre-deployment, Deer Island or Discovery mussels in 1996). One PCB congener (BZ # 180) was not detected in 1995 in pre-deployment, Deer Island or Discovery mussels but was detected in mussels from all three stations in 1996.

Although the Deer Island t-PCB tissue concentrations increased numerically from 1995 to 1996, t-PCB burdens have been relatively stable from 1991-1996 (Figure 13-17). Deer Island and PCB body burdens during 1991-1995 have been consistently lower than 1987 burdens suggesting a decrease in t-PCB exposure since 1987. The t-PCB tissue concentrations for Discovery deployed mussels increased in 1996 as compared to 1995 levels, however, the 1996 t-PCB levels were below those reported in 1992 and 1993. The pattern of t-PCBs in Discovery mussel burdens since 1991 suggest that t-PCB concentrations for mussels deployed at this station are relatively stable with slight fluctuations annually. Body burdens of t-PCBs in pre-deployment Gloucester mussels have been consistently higher than the 1991-1992 concentrations. The t-PCB concentrations at the FOS, although consistently higher than the 1992 t-PCB levels, appear to be relatively stable.

3.3.4.4 Mercury and Lead

Metal body burdens in indigenous mussels harvested throughout North America have been well described in the Mussel Watch program. Average concentrations and one standard deviation above the average (on a log normal scale) referred to as "high" values, are available for numerous sites throughout the U.S. (O'Conner 1992, O'Conner and Beliaeff 1995). There are several sites where indigenous mussels in Boston Harbor (one at Deer Island) and Cape Ann which are routinely analyzed and burdens reported which are grossly comparable to this study's stations. If the concentrations are above the "high" value, the site is generally considered to have elevated contaminant levels.

The 1996 lead body burdens for mussels deployed at the Discovery and Deer Island stations were consistent with 1993-1995 results. The 1996 lead body burdens for mussels deployed at the FOS were 2 to 3 times lower than those observed in FOS mussels in 1993-1994, possibly a result of using Sandwich mussels rather than Gloucester mussels for deployment. Discovery and Deer Island-deployed mussels were comparable statistically, suggesting that there may be other sources of available lead to Boston Inner Harbor in addition to the Deer Island POTW effluent discharge. Lead tissue concentrations from mussels harvested from Deer Island and the Discovery, exceeded the NOAA "high" lead concentration of 4.3 mg/kg, reported by O'Connor 1992.

The 1996 mercury concentrations ranged from 0.13 to 0.15 mg/kg and were not statistically different among mussels harvested from any of the study locations. The 1996 Deer Island and Discovery mussel

mercury body burdens were higher than comparable body burdens reported in 1995, but, were comparable to previous years, which ranged from 0.18 to 0.21 mg/kg for Deer Island mussels and 0.16 mg/kg for 1994 Discovery-deployed mussels (Downey *et al.* 1995).

Lower mercury body burdens in deployed mussels were anticipated in surveys after 1994 due to the use of mussels obtained from the Sandwich control site (prior deployments utilized Gloucester mussels, which were later found to exhibit mercury contamination). The pre-deployment mussel mercury average concentration of Sandwich mussels was 0.13 mg/kg which was higher than the 1995 pre-deployment Sandwich mussel body burdens of 0.065 mg/kg.

The 1996 tissue concentrations suggest that there were no statistically significant differences in bioaccumulation of mercury by the Discovery and Deer Island deployed mussels. These data could be interpreted that there are no high concentrations of bioavailable mercury present in Boston's Inner Harbor. However, these results are contrary to trends reported by the NOAA for the National Status and Trends Program Mussel Watch Project (O'Connor and Beliaeff 1995). Since 1990, three out of four annual samplings of indigenous mussels from the Deer Island location contained average body burdens which exceeded the Mussel Watch "high" concentration of 0.24 mg/kg.

There are several possible explanations for the apparent differences between the mussel tissue concentrations observed in the Mussel Watch Project and this study. The mussels collected and used in the mussel watch project are exposed year round to the waters near Deer Island while the deployed mussels were exposed for 60 days. It may be that the 60 day exposure was inadequate for steady state tissue concentrations to be reached by the deployed mussels. Analytical differences in methodologies between the Mussel Watch Project and this study also may have contributed to these apparent differences. At this time, there is no definitive answer to explain the apparent differences.

3.3.4.5 Summary

The overall trends of 1996 PAHs were generally similar to those reported in previous studies. Total NOAA PAHs and HMW-PAHs were highest in the Discovery deployed mussels. The NOAA LMW-PAHs were found in the highest concentrations in Deer Island deployed mussels.

Individual LMW-PAH analyte body burdens in Deer Island deployed mussels was different in 1996. Characteristic significant increases; as compared to pre-deployment mussels, in methyl-, dimethyl- and trimethyl- compounds in Deer Island body burdens was not observed in 1996. The reasons for the lack of discernable significant increases in Deer Island LMW-PAH body burdens as observed in previous years is unclear. There may have been a significant reduction in effluent concentrations of methylnaphthalenes which contributed to reduced bioaccumulation rates. Although this may have been possible, it is likely that other factors may have been larger contributor to the observed 1996 spatial patterns in methylnaphthalene body burdens.

Detectable and higher than average tissue concentrations of 1-methylnaphthalene and 2-methylnaphthalene in the predeployment mussels may have contributed to the lack of discernable tissue increases in Deer Island mussels in 1996. The Deer Island mussel body burdens in 1996 were comparable to previous years, but no significant increases in concentrations were found due to high variability in Gloucester mussels.

The 1996 Deer Island mussel 2,6 dimethylnaphlene and 2,3,5 trimethylnaphthalenes concentrations were also not statistically different as compared to pre-deployment mussels, but were found at concentrations that were 1.5 to 13 times lower as compared to previous years (1991-1994). The tissue concentrations of C2- and C3-methylnaphthalenes in Deer Island deployed mussels was comparable in 1995 and 1996. It may be possible that the methodology for quantifying these compounds differ between 1996 and historical approachs.

Phenanthrenes (phenanthrene and 1-methylphenanthrene) were signficantly higher in Deer Island deployed mussels in 1996 which was consistent with historical trends observed for these compounds. The C1-C4 phenanthrenes in 1996 where found to be substantially higher than the comparable 1995 C1-C4 phenanthrene Deer Island body burdens, providing additional data suggesting that phenanthrene exposure may have been higher for 1996 Deer Island deployed mussels compared to 1995.

In 1996, individual LMW-PAHs and HMW-PAHs were reported in pre-deployment tissue concentrations that were higher than historical levels. Although there may have been activities and/or fundamental changes in the use or pollutant loads to Hodgkins Cove, there were no specific activities or gross habitat changes observed during the 1996 harvest of mussels. It is possible that there have been fundamental changes in the characteristics of the Cove which will be borne out in future years' harvest of mussels and analyses of tissues.

There is also some evidence that analytical variablility may have contributed to the higher than previously reported tissue concentrations for selected individual LMW-PAH analytes. Examples of this inherent analytical variability can be seen in the individual replicate data for the Gloucester predeployment mussels. The individual analyses on the 3 replicate samples for 1-methylnaphthalene (7.8 ug/kg low to 18 ug/kg high), 2-methylnaphthalene (14 ug/kg low to 30 ug/kg high), and 2,6-dimethylnapthalene (8.8 ug/kg low to 19 ug/kg high) displayed a factor of two in tissue concentrations from low to high for these tissue analyte concentrations.

Overall the 1996 study on mussel bioaccumulation of PAHs in Boston Harbor displayed general bioaccumulation trends noted in earlier studies. The differences observed in 1996 for individual analytes, particularly the LMW-PAHs may have been related to changes in the environment, analytical differences and/or analytical variability. Only additional annual data on spatial and temporal trends in the Harbor will be able to shed light on the potential contributions of any of these (or other) factors contributing to annual variability in deployed mussel bioaccumulation variability.

3.3.5 Relationship of Contaminants to FDA Legal Limits

The U.S. Food and Drug Administration has set legal limits for maximum concentrations of mercury in the edible portions of fish and fishery products (U.S. EPA, 1989). The action level for lead is based on an EPA risk assessment of lead in drinking water (MWRA, 1997). For the MWRA biomonitoring program, Caution Levels are set at 50% of FDA Limits, and Warning Levels are set at 80% of FDA Limits (MWRA 1997). Caution and Warning Levels apply to the Future Outfall Site 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 following table (Table 3-23) compares the mean wet weight concentrations of mercury and lead in mussel tissues collected throughout the study area in 1996 to the applicable action levels. As the table indicates, mercury and lead levels in mussels were below the benchmark levels.

3.3.6 Lipid Normalized Concentrations

Lipid normalized concentrations for mussel tissue are presented in Table 3-24 and Figure 3-18. Total PAH for mussel tissue represents the 24 NOAA PAH analytes listed in the third column of Table 3-15. Lipid normalized concentrations of total DDT, total PCBs, and total PAHs are consistently highest in Discovery deployed mussels and lowest in Future Outfall Site mussels. All values observed in 1996 were within the historic range observed at individual stations, however.

The Caution Level for lipid normalized toxics in the MWRA Outfall Monitoring Program is two times baseline. The mean of the 1992 through 1996 data (Table 3-24) is considered as the baseline concentration (but will eventually include 1991-1998 data).

Table 3-1
Catch per unit effort (number of fish per minute of bottom time)
for winter flounder trawled in April 1991-1996

Site	1991	1992	1993	1994	1995	1996
Deer Island Flats	0.38	0.23	0.15	0.39	0.1	0.16
Nantasket Beach	0.48	1.29	1.52	0.76	0.88	0.77
Broad Sound	--	2.8	0.49	0.42	0.29	0.23
Future Outfall Site	0.13	0.48	0.62	0.24	0.6	0.31
Eastern Cape Cod Bay	0.67	0.49	0.77	0.42	0.21	1.38

Notes:
The same vessel and net was used at all times.

Table 3-2
Summary of physical characteristics of winter flounder sampled in 1996
from Massachusetts and Cape Cod Bays

Parameter		Deer Island Flats Station 1	Nantasket Beach Station 2	Broad Sound Station 3	Future Outfall Site Station 4	Eastern Cape Cod Bay Station 5
Number Caught	N	30	50	50	49	50
Total length	Mean	352	338	329	344	342
	S.D.	32	26	27	32	24
	Anova	2,3	--	4,5	--	--
Weight	Mean	469	423	390	477	455
	S.D.	117	119	102	139	96
	Anova	3	4	4,5	--	--
Age	Mean	4.3	4.2	3.9	4.5	4.0
	S.D.	0.9	1	0.7	0.8	0.9
	Anova	3	--	4	3,5	
Fin erosion	Mean	0.5	0.5	0.3	0.1	0.3
	S.D.	0.7	0.7	0.6	0.4	0.8
	Anova	4	4	--	--	--
Gross score	Mean	0.4	0.02	0.02	0.04	0
	S.D.	1.7	0.14	0.14	0.2	0
	Anova	2,3,4,5	--	--	--	--

Notes:
S.D. - Standard Deviation
Differences by ANOVA given as the station(s) that differed significantly from the station in that column.

Table 3-3
Prevalence (%) of histological changes in winter flounder liver from 5 stations in Massachusetts and Cape Cod Bays - 1996.

Parameter	Deer Island Flats Station 1 (30 fish)	Nantasket Beach Station 2 (50 fish)	Broad Sound Station 3 (50 fish)	Future Outfall Site Station 4 (49 fish)	Eastern Cape Cod Bay Station 5 (50 fish)
Neoplasm	3	0	0	0	0
Focal HV	3	0	2	2	0
Tubular HV	33	8	32	16	0
Centrotubular HV	43	14	44	22	2
Balloons	33	18	12	10	6
Macrophage aggregation	83	56	64	53	22
Biliary proliferation	40	14	6	8	4
Necrosis	43	8	14	16	2
Pancreatic hyperplasia	7	0	2	0	0
Pancreatic necrosis	7	0	0	0	0
Eosinophilic focus	3	0	0	0	0
Basophilic focus	3	0	0	4	0
Hepatocyte regeneration	37	4	16	18	2

Notes:
HV - Hydropic Vacuolation

TABLE 3-4 (Page 1 of 3)
Summary of Mean Flounder Tissue Contaminant Levels
1996 MWRA Flounder Survey
ng/g dry weight

PARAMETER	Deer Island		Nantasket Beach		Broad Sound		Future Outfall		Cape Cod Bay	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
DDDs - Filet										
2,4-DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-DDT	0.63	0.63	ND	ND	ND	ND	0.37	0.37	ND	ND
4,4-DDD	3.33	0.39	0.47	0.47	1.05	0.21	1.25	0.30	0.28	0.28
4,4-DDE	26.67	2.67	19.00	0.58	16.33	2.33	17.67	4.41	9.53	1.73
4,4-DDT	1.43	0.72	0.43	0.43	ND	ND	ND	ND	ND	ND
TOTAL	32.07	2.53	19.90	0.49	17.39	2.55	19.28	4.62	9.81	2.01
DDDs - Liver										
2,4-DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-DDT	10.33	10.33	ND	ND	ND	ND	ND	ND	ND	ND
4,4-DDD	42.33	26.12	10.33	5.24	13.57	1.95	16.67	9.02	5.33	5.33
4,4-DDE	350.00	66.58	170.00	25.17	162.67	43.90	243.33	78.39	98.67	5.70
4,4-DDT	17.33	9.82	12.33	1.33	ND	ND	14.33	8.09	ND	ND
TOTAL	420.00	88.49	192.67	29.69	176.23	45.70	274.33	93.20	104.00	11.02
Pesticides - Filet										
ALDRIN	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DIELDRIN	2.00	0.62	1.23	0.12	0.59	0.30	1.07	0.29	1.03	0.04
ENDRIN	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
HEXACHLOROBENZENE	0.70	0.09	0.72	0.02	1.01	0.19	0.69	0.16	0.76	0.04
LINDANE	0.05	0.05	ND	ND	ND	ND	0.04	0.04	ND	ND
MIREX	0.12	0.12	ND	ND	ND	ND	0.11	0.11	ND	ND
TOTAL	2.87	0.70	1.96	0.10	1.60	0.49	1.91	0.50	1.79	0.06
Pesticides - Liver										
ALDRIN	0.40	0.40	ND	ND	ND	ND	ND	ND	ND	ND
DIELDRIN	30.00	13.58	9.00	4.51	ND	ND	8.33	4.41	9.80	1.72
ENDRIN	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
HEXACHLOROBENZENE	5.93	3.20	ND	ND	ND	ND	3.13	3.13	ND	ND
LINDANE	0.87	0.87	ND	ND	ND	ND	ND	ND	ND	ND
MIREX	1.80	1.80	ND	ND	ND	ND	ND	ND	ND	ND
TOTAL	39.00	19.11	9.00	4.51	ND	ND	11.47	7.08	9.80	1.72
Chlordanes - Filet										
ALPHA-CHLORDANE	3.60	0.26	1.60	0.82	1.73	0.18	0.43	0.43	0.28	0.28
HEPTACHLOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
HEPTACHLOR EPOXIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRANS NONACHLOR	7.70	0.47	5.27	0.41	3.67	0.13	3.23	0.30	0.80	0.42
TOTAL	11.30	0.31	6.87	1.13	5.40	0.31	3.67	0.47	1.08	0.55
Chlordanes - Liver										
ALPHA-CHLORDANE	53.00	13.01	24.33	3.48	15.90	3.87	28.00	5.20	5.90	2.99
HEPTACHLOR	1.53	1.53	ND	ND	ND	ND	ND	ND	ND	ND
HEPTACHLOR EPOXIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRANS NONACHLOR	115.33	22.33	45.00	6.08	44.00	15.04	58.33	5.81	14.33	0.88
TOTAL	169.87	36.87	69.33	8.41	59.90	18.86	86.33	10.99	20.23	3.40
PCBs - Filet										

ND - Not Detected (considered 0 in calculations).

TABLE 3-4 (Page 2 of 3)
Summary of Mean Flounder Tissue Contaminant Levels
1996 MWRA Flounder Survey
ng/g dry weight

PARAMETER	Deer Island		Nantasket Beach		Broad Sound		Future Outfall		Cape Cod Bay	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
105	13.00	0.58	9.20	0.65	5.43	0.47	7.30	1.47	2.17	0.26
126	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
138	30.00	3.79	23.00	2.65	12.33	0.88	25.00	6.11	6.13	1.68
170	12.00	1.00	8.67	0.78	4.70	0.30	9.03	2.06	1.83	0.47
180	61.67	6.33	50.00	4.16	31.67	2.33	39.33	8.25	13.33	1.86
195	2.23	0.20	2.00	0.21	1.10	0.00	2.47	0.57	0.71	0.14
2,2',3,3',4,4'-HEXACHLOROBIPHENYL (128)	7.80	1.67	6.13	0.72	3.93	0.28	4.10	0.32	0.90	0.45
2,2',3,4,5,5',6-Cl7	15.33	0.88	14.33	1.45	9.17	1.01	12.63	2.68	5.50	1.05
2,2',3,5'-TETRACHLOROBIPHENYL (44)	0.17	0.17	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-HEXACHLOROBIPHENYL (153)	70.33	11.67	57.33	3.84	39.00	2.52	49.00	10.82	18.00	3.00
2,2',4,5,5'-PENTACHLOROBIPHENYL	15.00	1.00	11.33	0.88	7.13	1.00	9.40	2.80	4.57	0.71
2,2',5,5'-TETRACHLOROBIPHENYL (52)	2.87	0.33	1.87	0.27	0.68	0.38	1.02	0.09	0.54	0.28
2,2',5-TRICHLOROBIPHENYL (18)	0.07	0.07	ND	ND	ND	ND	0.04	0.04	ND	ND
2,3',4,4',5-PENTACHLOROBIPHENYL (118)	40.00	3.79	30.67	2.85	19.00	1.53	24.00	5.51	8.03	0.99
2,3',4,4'-TETRACHLOROBIPHENYL (66)	8.73	0.33	7.17	0.65	3.87	0.03	5.03	1.67	2.03	0.29
2,4'-DICHLOROBIPHENYL (8)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,4'-TRICHLOROBIPHENYL (28)	2.93	0.30	2.30	0.42	1.00	0.53	1.25	0.22	ND	ND
206	2.30	0.29	2.17	0.18	1.47	0.09	3.13	0.64	0.95	0.25
44 DD OLEPHIN (DDMU)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
77	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DECACHLOROBIPHENYL (209)	1.32	0.29	1.67	0.12	1.27	0.03	1.93	0.44	0.99	0.31
TOTAL	285.76	29.69	227.83	15.67	141.75	8.90	194.68	42.59	65.69	10.86
PCBs - Liver										
105	179.33	61.54	68.00	2.65	61.00	17.62	89.67	17.05	21.67	1.67
126	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
138	436.67	91.35	223.33	8.82	154.67	45.70	313.33	58.97	80.00	9.07
170	154.00	34.20	83.00	3.21	67.00	18.52	122.33	34.48	22.67	2.73
180	786.67	166.97	453.33	17.64	370.00	92.92	533.33	89.50	160.00	5.77
195	27.67	3.84	21.00	1.53	15.80	4.36	34.67	4.63	7.87	0.47
2,2',3,3',4,4'-HEXACHLOROBIPHENYL (128)	81.33	10.48	43.67	1.20	46.00	18.73	59.00	5.29	27.33	2.40
2,2',3,4,5,5',6-Cl7	193.33	18.56	136.67	13.33	113.33	26.03	183.33	37.56	69.00	4.04
2,2',3,5'-TETRACHLOROBIPHENYL (44)	6.37	3.19	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-HEXACHLOROBIPHENYL (153)	900.00	160.73	596.67	33.83	476.67	127.19	683.33	105.88	216.67	12.02
2,2',4,5,5'-PENTACHLOROBIPHENYL	186.67	12.02	93.00	3.79	83.67	20.00	121.33	19.88	44.67	3.93
2,2',5,5'-TETRACHLOROBIPHENYL (52)	37.33	7.84	14.57	3.56	ND	ND	8.57	5.21	ND	ND
2,2',5-TRICHLOROBIPHENYL (18)	3.67	3.67	ND	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5-PENTACHLOROBIPHENYL (118)	493.33	93.87	276.67	3.33	223.33	55.48	316.67	66.92	87.67	0.88
2,3',4,4'-TETRACHLOROBIPHENYL (66)	100.67	10.48	63.33	2.40	45.00	9.64	63.00	13.65	19.67	2.33
2,4'-DICHLOROBIPHENYL (8)	8.97	6.67	ND	ND	ND	ND	ND	ND	ND	ND
2,4,4'-TRICHLOROBIPHENYL (28)	38.67	9.74	18.33	0.88	4.33	4.33	17.67	9.06	2.97	2.97
206	27.67	4.26	22.67	1.33	17.27	4.69	40.00	3.51	11.13	1.99
44 DD OLEPHIN (DDMU)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
77	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DECACHLOROBIPHENYL (209)	9.93	1.53	8.87	0.50	11.97	4.10	14.33	1.20	6.80	0.62
TOTAL	3672.27	687.72	2123.10	78.39	1690.03	440.70	2600.57	463.19	778.10	33.60
PAHs - Liver										
ACENAPHTHENE	5.43	2.72	9.50	0.15	8.73	0.70	4.47	2.25	5.27	2.74
ACENAPHTHYLENE	ND	ND	ND	ND	ND	ND	2.43	1.22	ND	ND
ANTHRACENE	4.20	0.72	3.70	0.46	2.90	0.20	3.97	0.30	3.20	1.02
BENZ(A)ANTHRACENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BENZO(A)PYRENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BENZO(B)FLUORANTHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BENZO(E)PYRENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BENZO(G,H,I)PERYLENE	2.47	2.47	5.00	5.00	2.13	2.13	12.33	6.94	ND	ND
BENZO(K)FLUORANTHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND - Not Detected (considered 0 in calculations).

TABLE 3-4 (Page 3 of 3)
Summary of Mean Flounder Tissue Contaminant Levels
1996 MWRA Flounder Survey
ng/g dry weight

PARAMETER	Deer Island		Nantasket Beach		Broad Sound		Future Outfall		Cape Cod Bay	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
BIPHENYL	15.00	1.53	12.67	0.33	10.20	0.42	12.23	2.38	9.43	1.11
C1-CHRYSENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C1-DIBENZOTHIOPHENES	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C1-FLUORANTHENES/PYRENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C1-FLUORENES	ND	ND	3.67	3.67	ND	ND	ND	ND	ND	ND
C1-NAPTHALENE	46.67	4.06	41.00	2.52	37.67	6.33	45.00	10.21	36.67	6.17
C1-PHENANTHRENES/ANTHRACENE	9.33	5.21	15.67	2.03	16.33	3.33	17.97	5.32	17.33	3.53
C2-CHRYSENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C2-DIBENZOTHIOPHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C2-FLUORENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C2-NAPTHALENE	24.00	12.49	41.00	2.31	39.00	6.11	49.00	13.89	37.33	7.36
C2-PHENANTHRENE/ANTHRACENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C2F/P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C3-CHRYSENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C3-DIBENZOTHIOPHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C3-FLUORENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C3-NAPTHALENE	ND	ND	4.67	4.67	ND	ND	ND	ND	ND	ND
C3-PHENANTHRENE/ANTHRACENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C3F/P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C4-CHRYSENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C4-NAPTHALENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C4-PHENANTHRENE/ANTHRACENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHRYSENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DIBENZO(A,H)ANTHRACENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DIBENZOFURAN	11.00	0.58	14.67	0.67	14.67	2.19	13.57	2.80	14.00	1.15
DIBENZOTHIOPHENE	1.07	1.07	ND	ND	2.60	1.50	1.83	1.01	1.23	1.23
FLUORANTHENE	7.33	1.32	9.97	1.32	11.67	3.17	7.57	1.58	11.67	1.86
FLUORENE	4.00	4.00	6.43	3.22	12.20	2.14	11.43	2.89	10.83	1.09
INDENO(1,2,3-CD)PYRENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NAPHTHALENE	106.33	18.89	126.67	13.33	105.67	7.22	121.00	35.37	96.33	13.67
PERYLENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PHENANTHRENE	26.00	4.04	34.33	4.10	33.00	8.02	30.00	7.77	33.33	5.81
PYRENE	5.80	0.97	6.63	0.80	7.97	1.71	6.43	1.78	8.07	1.03
TOTAL	268.63	37.22	334.97	15.40	304.73	41.13	339.23	81.93	284.70	38.27
BENZOTHIAZOLE	24.67	2.33	36.00	4.58	37.67	7.62	39.33	14.11	33.00	4.73
Metals - Liver										
Cadmium	0.90	0.30	1.65	0.36	1.15	0.20	3.33	0.79	1.09	0.20
Chromium	0.08	0.004	0.16	0.03	0.05	0.01	0.12	0.03	0.04	0.01
Copper	42.28	19.58	74.78	4.45	68.31	13.34	125.51	34.36	65.55	7.73
Lead	2.12	0.19	2.12	0.31	3.84	1.01	4.24	0.87	2.58	1.57
Nickel	ND	ND	0.11	0.11	ND	ND	0.17	0.10	ND	ND
Silver	4.47	1.53	7.21	0.52	6.28	1.48	22.40	6.42	4.16	0.22
Zinc	87.07	24.87	120.15	0.46	124.26	8.61	120.99	5.77	126.28	2.45
Mercury	0.53	0.09	0.75	0.01	0.73	0.23	0.55	0.03	0.44	0.04
Metals - Filet										
Mercury	0.46	0.07	0.50	0.07	0.38	0.07	0.55	0.15	0.40	0.03

ND - Not Detected (considered 0 in calculations).

TABLE 3-5

Comparison of FDA Legal Limits to Mean Concentrations (wet weight) of Select Compounds In Winter Flounder Edible Tissues - 1996

Compound/Analyte	Deer Island		Future Outfall Site		Cape Cod Bay		Nantasket Beach		Broad Sound		FDA Legal Limit [1]	Caution Level [3]	Warning Level [4]
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.			
Total DDT (ppb)	5.81	0.23	3.57	0.64	1.76	0.28	3.57	0.04	3.17	0.47	5,000 [2]	NA	NA
Total Chlordanes (ppb)	2.06	0.14	0.69	0.06	0.20	0.11	1.23	0.20	0.99	0.05	300	NA	NA
Dieldrin (ppb)	0.38	0.14	0.20	0.05	0.19	0.01	0.22	0.02	0.11	0.05	300	NA	NA
Total PCBs (ppb)	51.49	1.86	36.28	5.72	11.83	1.44	40.80	2.18	25.87	1.50	2,000	1,000	1,600
Mercury (ppm)	0.09	0.01	0.10	0.03	0.07	0.01	0.10	0.01	0.07	0.01	1	0.5	0.8

Notes:

[1] U.S. EPA 1989. Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish. EPA-503/8-89-002. Office of Marine and Estuarine Protection (WH-556F) and the Office of Water Regulations and Standards (WH-552), Washington, D.C.

[2] The value represents the FDA Legal Limits for DDT (5 ppm), DDE (5 ppm), and DDD (5 ppm), which comprise the mean total DDT tissue concentration. A total DDT tissue concentration below 5 ppm assumes that all DDT derivations are not exceeded.

[3] Massachusetts Water Resources Authority (MWRA) 1997. Contingency Plan. Caution Level is 50% the FDA Legal Limit, and applies to the outfall site only.

[4] Massachusetts Water Resources Authority (MWRA) 1997. Contingency Plan. Warning Level is 80% of the FDA Legal Limit, and applies to the outfall site only.

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Table 3-6
Concentrations of Selected Organic Compounds Normalized for Lipids [1]
Flounder Fillet and Liver, 1992 - 1996
ng/g lipid

Parameter	Year	Deer Island		Future Outfall Site		Eastern Cape Cod Bay		Nantasket Beach		Broad Sound	
		Average	S.E.	Average	S.E.	Average	S.E.	Average	S.E.	Average	S.E.
Flounder Fillet											
Total DDT	1992	953.40	233.24	342.96	132.30	375.28	122.55	837.99	291.81	580.45	159.97
	1993	1193.15	239.74	1096.35	149.81	503.77	76.95	NA	NA	NA	NA
	1994	903.20	34.36	455.14	119.61	276.35	63.67	394.65	64.26	525.14	142.22
	1995	2312.97	519.38	1116.26	248.10	1116.73	152.47	NA	NA	NA	NA
	1996	1529.47	219.21	1015.92	205.73	435.72	93.81	943.33	187.30	925.67	21.64
	Baseline Mean	**1378.44**	**258.55**	**805.33**	**167.65**	**541.57**	**148.57**	**725.32**	**130.22**	**677.09**	**97.07**
Total PCBs	1992	8264.31	3301.67	2765.73	1052.34	1628.51	481.83	8087.49	2904.56	4829.15	1322.63
	1993	7260.70	1070.08	8142.03	1188.41	2214.05	316.74	NA	NA	NA	NA
	1994	10763.66	957.52	5147.91	1713.56	1183.83	229.21	3089.63	183.01	4109.50	1178.71
	1995	33414.02	4950.62	11105.20	1150.12	4346.00	424.96	NA	NA	NA	NA
	1996	13530.82	1895.52	10187.61	1600.64	2920.39	525.55	10951.31	2482.27	7758.11	724.12
	Baseline Mean	**14646.70**	**4815.72**	**7469.70**	**1558.43**	**2458.56**	**554.50**	**7376.14**	**1779.38**	**5565.59**	**864.27**
Flounder Liver											
Total DDT	1992	875.11	168.01	781.25	129.97	253.88	35.57	764.70	251.63	1247.14	200.30
	1993	766.15	NC	1104.29	NC	359.05	NC	NA	NA	NA	NA
	1994	472.49	12.24	751.95	113.37	273.58	92.43	439.12	20.06	494.30	81.22
	1995	2742.72	413.92	1951.70	385.24	1149.18	150.98	NA	NA	NA	NA
	1996	1732.62	186.13	1093.77	297.90	433.01	95.70	983.33	64.45	797.57	158.24
	Baseline Mean	**1317.82**	**413.36**	**1136.59**	**216.97**	**493.74**	**166.95**	**729.05**	**122.47**	**846.34**	**169.40**
Total PAHs	1993	3908.26	NC	3855.00	NC	4274.35	NC	NA	NA	NA	NA
	1994	253.37	28.29	682.40	183.38	649.92	380.62	627.08	253.44	276.18	68.75
	1995	731.10	11.62	273.12	68.91	337.62	28.08	NA	NA	NA	NA
	1996	1179.56	243.31	1460.18	440.18	1133.26	88.26	1778.24	284.29	1401.10	83.10
	Baseline Mean	**1518.08**	**818.86**	**1567.67**	**801.20**	**1598.79**	**906.75**	**1202.66**	**407.00**	**838.64**	**397.72**
Total PCBs	1992	11003.29	3238.01	8661.64	1561.96	1834.25	378.69	8055.86	3418.85	11233.89	1861.99
	1993	5330.68	NC	7727.96	NC	1754.25	NC	NA	NA	NA	NA
	1994	4152.55	352.87	6740.30	1413.42	1278.23	442.10	2893.37	220.73	3443.58	684.88
	1995	30442.79	7071.70	26082.16	6944.19	9909.95	5278.49	NA	NA	NA	NA
	1996	15215.93	1320.77	10633.39	1319.94	3142.16	242.23	11228.01	1607.24	7659.93	1601.21
	Baseline Mean	**13229.05**	**4743.32**	**11969.09**	**3586.29**	**3583.77**	**1611.51**	**7392.41**	**1881.31**	**7445.80**	**1743.94**

Notes:
NA - Not Applicable. (Broad sound and Nantasket beach flounder are only analyzed for chemicals in even years.)
[1] Formula: concentration/percent lipid.
S.E. - Standard Error.

TABLE 3-7

Mean Length, Weight, and Sex of Lobsters Collected in 1996 1

Station	Carapace Length (mm) Mean	S.E.	Weight (g) Mean	S.E.	Sex Ratio M/F
Deer Island Flats	86	0.82	495	15.94	8 / 7
Future Outfall Site	87	0.88	511	19.02	12 / 3
Cape Cod Bay	90	1.16	521	24.83	5 / 10

Notes:
1 Each mean is based on a sample size of 15 lobsters.
S.E. - Standard Error

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TABLE 3-8
Mean External Conditions of Lobsters Collected in 1996 1

Station	Black Gill	Shell Erosion	Parasites	External Tumors
Deer Island Flats	0	0	0	0
Future Outfall Site	0	0.07 (0.07)	0	0
Cape Cod Bay	0	0.07 (0.07)	0	0

Notes:
1 Each mean is based on a sample size of 15 lobsters. Value in parenthesis represents the standard error. Observed values were based on visual examination of lobsters. lobsters. The values range from 0 (absent) to 4 (extreme).

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TABLE 3-9 (Page 1 of 3)
Summary of Mean Lobster Tissue Contaminant Levels
1996 MWRA Lobster Survey
ng/g dry weight

Parameter	Deer Island		Future Outfall		Cape Cod Bay	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
DDDs - Meat						
2,4-DDD	0.21	0.21	ND	ND	0.11	0.11
2,4-DDE	1.37	0.91	1.93	1.93	ND	ND
2,4-DDT	ND	ND	ND	ND	ND	ND
4,4-DDD	2.87	0.35	1.27	0.09	0.90	0.15
4,4-DDE	21.67	4.18	15.33	0.88	12.00	1.00
4,4-DDT	0.20	0.20	ND	ND	ND	ND
TOTAL	26.31	3.67	18.53	2.81	13.01	1.21
DDDs - Hepatopancreas						
4,4-DDT	36.00	4.51	24.00	4.00	18.67	10.17
4,4-DDD	116.00	9.45	126.67	6.67	68.00	16.07
4,4-DDE	1016.67	91.71	776.67	52.07	600.00	91.65
2,4-DDT	3.27	2.22	ND	ND	1.57	0.23
2,4-DDD	34.33	3.93	15.00	8.14	13.93	2.70
2,4-DDE	44.73	24.22	83.47	59.27	ND	ND
TOTAL	1251.00	68.59	1025.80	30.50	702.17	117.10
Pesticides - Meat						
ALDRIN	ND	ND	ND	ND	ND	ND
DIELDRIN	8.53	0.74	9.50	1.83	3.77	0.32
ENDRIN	ND	ND	ND	ND	ND	ND
HEXACHLOROBENZENE	0.59	0.05	1.00	0.10	0.52	0.08
LINDANE	2.00	2.00	0.73	0.73	ND	ND
MIREX	0.27	0.05	0.36	0.06	0.23	0.03
TOTAL	11.39	1.87	11.59	1.86	4.51	0.37
Pesticides - Hepatopancreas						
ALDRIN	5.53	0.90	2.37	1.19	1.00	0.50
DIELDRIN	126.67	14.53	143.33	43.33	50.33	6.01
ENDRIN	ND	ND	ND	ND	ND	ND
HEXACHLOROBENZENE	17.00	1.00	17.33	0.33	13.67	1.20
LINDANE	7.10	3.63	6.13	0.69	ND	ND
MIREX	7.90	0.20	10.37	0.63	8.03	0.69
TOTAL	164.20	11.89	179.53	42.04	73.03	7.88
Chlordanes - Meat						
ALPHA-CHLORDANE	1.90	0.12	2.03	0.15	0.47	0.25
HEPTACHLOR	1.16	0.93	ND	ND	ND	ND
HEPTACHLOR EPOXIDE	ND	ND	ND	ND	ND	ND
TRANS NONACHLOR	2.57	0.38	1.77	0.19	1.05	0.19
TOTAL	5.63	0.70	3.80	0.32	1.52	0.06
Chlordanes - Hepatopancreas						
ALPHA-CHLORDANE	69.67	5.49	58.67	10.37	19.67	4.06
HEPTACHLOR	4.00	4.00	ND	ND	ND	ND
HEPTACHLOR EPOXIDE	ND	ND	ND	ND	1.20	1.20
TRANS NONACHLOR	125.33	22.70	98.00	18.48	60.33	15.92
TOTAL	199.00	16.26	156.67	22.88	81.20	19.00

ND - Not Detected (considered 0 for calculations).

TABLE 3-9 (Page 2 of 3)
Summary of Mean Lobster Tissue Contaminant Levels
1996 MWRA Lobster Survey
ng/g dry weight

Parameter	Deer Island		Future Outfall		Cape Cod Bay	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
PCBs - Meat						
105	15.67	3.18	9.03	0.82	3.73	0.38
126	ND	ND	ND	ND	ND	ND
138	18.67	2.96	15.33	3.38	4.63	0.32
170	4.77	1.02	4.60	0.35	1.80	0.12
180	58.33	13.38	26.00	2.08	13.00	0.58
195	0.87	0.18	1.92	1.12	0.28	0.01
2,2',3,3',4,4'-HEXACHLOROBIPHENYL (128)	6.33	1.21	4.87	0.50	2.30	0.12
2,2',3,4,5,5',6-Cl7	10.50	1.61	12.33	1.86	5.07	0.38
2,2',3,5'-TETRACHLOROBIPHENYL (44)	0.41	0.22	ND	ND	ND	ND
2,2',4,4',5,5'-HEXACHLOROBIPHENYL (153)	33.00	5.69	27.33	1.20	16.00	1.15
2,2',4,5,5'-PENTACHLOROBIPHENYL	6.50	0.06	4.53	0.58	2.27	0.39
2,2',5,5'-TETRACHLOROBIPHENYL (52)	3.87	0.54	3.00	1.01	0.82	0.49
2,2',5-TRICHLOROBIPHENYL (18)	ND	ND	ND	ND	ND	ND
2,3',4,4',5-PENTACHLOROBIPHENYL (118)	37.67	8.01	25.67	2.03	13.33	1.33
2,3',4,4'-TETRACHLOROBIPHENYL (66)	11.47	1.77	5.97	0.44	2.60	0.25
2,4'-DICHLOROBIPHENYL (8)	5.57	0.93	1.23	0.65	1.40	0.91
2,4,4'-TRICHLOROBIPHENYL (28)	4.90	0.60	2.83	0.18	0.79	0.10
206	1.38	0.46	2.73	1.24	0.54	0.02
44 DD OLEPHIN (DDMU)	ND	ND	ND	ND	ND	ND
77	ND	ND	ND	ND	ND	ND
DECACHLOROBIPHENYL (209)	0.51	0.03	0.71	0.09	0.31	0.06
TOTAL	220.41	27.17	148.09	2.00	68.88	5.82
PCBs - Hepatopancreas						
105	486.67	67.66	326.67	20.28	130.00	15.28
126	ND	ND	ND	ND	ND	ND
138	860.00	171.56	690.00	210.79	216.67	32.83
170	210.00	25.17	203.33	34.80	84.33	8.41
180	1366.67	145.30	1033.33	33.33	500.00	58.59
195	64.33	27.87	82.33	38.83	17.33	5.24
2,2',3,3',4,4'-HEXACHLOROBIPHENYL (128)	230.00	30.55	173.33	6.67	90.33	5.04
2,2',3,4,5,5',6-Cl7	480.00	80.83	513.33	129.91	203.33	18.56
2,2',3,5'-TETRACHLOROBIPHENYL (44)	14.43	3.10	1.87	1.07	2.39	0.94
2,2',4,4',5,5'-HEXACHLOROBIPHENYL (153)	1366.67	145.30	1093.33	63.60	620.00	73.71
2,2',4,5,5'-PENTACHLOROBIPHENYL	263.33	12.02	163.33	20.28	91.33	20.54
2,2',5,5'-TETRACHLOROBIPHENYL (52)	62.33	6.44	28.00	6.66	12.67	6.44
2,2',5-TRICHLOROBIPHENYL (18)	11.67	5.84	9.03	2.50	ND	ND
2,3',4,4',5-PENTACHLOROBIPHENYL (118)	1140.00	140.00	790.00	46.19	353.33	43.33
2,3',4,4'-TETRACHLOROBIPHENYL (66)	400.00	25.17	230.00	5.77	84.67	12.78
2,4'-DICHLOROBIPHENYL (8)	5.73	3.47	ND	ND	ND	ND
2,4,4'-TRICHLOROBIPHENYL (28)	166.67	8.82	104.33	5.67	25.00	3.61
206	81.67	44.19	119.00	60.56	25.33	4.67
44 DD OLEPHIN (DDMU)	47.33	27.14	27.67	14.68	8.00	8.00
77	ND	ND	ND	ND	ND	ND
DECACHLOROBIPHENYL (209)	15.00	1.53	21.33	2.96	8.47	1.34
TOTAL	7272.50	675.58	5610.23	565.00	2473.19	306.86

ND - Not Detected (considered 0 for calculations).

TABLE 3-9 (Page 3 of 3)
Summary of Mean Lobster Tissue Contaminant Levels
1996 MWRA Lobster Survey
ng/g dry weight

Parameter	Deer Island		Future Outfall		Cape Cod Bay	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
PAHs - Hepatopancreas						
ACENAPHTHENE	24.00	1.73	4.83	2.42	64.00	31.24
ACENAPHTHYLENE	7.33	3.67	13.17	4.60	8.93	2.17
ANTHRACENE	57.00	13.75	43.00	14.05	26.13	11.05
BENZ(A)ANTHRACENE	236.67	76.67	191.33	88.52	26.00	7.09
BENZO(A)PYRENE	296.67	121.70	255.00	91.79	26.67	6.33
BENZO(B)FLUORANTHENE	476.67	154.96	330.00	121.24	60.33	7.97
BENZO(E)PYRENE	430.00	115.04	333.33	40.96	46.33	8.82
BENZO(G,H,I)PERYLENE	213.33	58.40	203.33	6.67	33.67	4.81
BENZO(K)FLUORANTHENE	223.33	68.88	184.00	57.24	27.33	2.85
BIPHENYL	7.50	0.46	4.73	0.34	11.57	4.14
C1-CHRYSENE	263.33	44.85	147.67	39.73	18.33	9.28
C1-DIBENZOTHIOPHENES	100.33	9.67	44.00	8.74	20.33	5.36
C1-FLUORANTHENES/PYRENE	890.00	207.44	423.33	144.49	89.00	20.52
C1-FLUORENES	77.67	6.89	36.00	5.86	37.67	9.28
C1-NAPTHALENE	46.67	4.26	18.33	1.45	123.00	55.16
C1-PHENANTHRENES/ANTHRACENE	336.67	44.10	200.00	45.83	93.33	28.34
C2-CHRYSENE	213.33	31.80	102.00	19.14	22.33	1.20
C2-DIBENZOTHIOPHENE	336.67	27.28	107.67	36.26	38.00	7.21
C2-FLUORENE	350.00	10.00	106.67	21.86	65.67	16.19
C2-NAPTHALENE	101.00	4.93	39.33	5.24	98.00	42.59
C2-PHENANTHRENE/ANTHRACENE	736.67	64.89	293.33	68.88	91.00	25.24
C2F/P	483.33	65.66	213.33	60.09	44.67	9.17
C3-CHRYSENE	126.67	23.33	67.67	8.29	17.00	0.58
C3-DIBENZOTHIOPHENE	350.00	32.15	98.33	35.93	27.33	3.71
C3-FLUORENE	516.67	46.67	134.67	42.81	66.00	14.74
C3-NAPTHALENE	236.67	27.28	72.67	11.26	101.00	44.71
C3-PHENANTHRENE/ANTHRACENE	603.33	49.10	233.33	58.40	78.00	24.54
C3F/P	260.00	36.06	104.67	27.67	22.00	2.00
C4-CHRYSENE	74.33	15.56	30.33	5.70	ND	ND
C4-NAPTHALENE	340.00	17.32	86.00	17.62	48.67	18.70
C4-PHENANTHRENE/ANTHRACENE	506.67	57.83	206.67	61.73	61.00	12.42
CHRYSENE	623.33	121.15	306.67	78.60	71.33	8.41
DIBENZO(A,H)ANTHRACENE	37.67	16.33	34.33	4.41	5.20	1.01
DIBENZOFURAN	29.33	1.45	16.67	2.73	51.00	18.58
DIBENZOTHIOPHENE	14.33	0.88	9.03	2.48	12.10	5.10
FLUORANTHENE	1473.33	476.14	623.33	178.92	276.67	86.86
FLUORENE	26.00	1.15	15.33	2.73	60.67	26.77
INDENO(1,2,3-CD)PYRENE	193.33	73.56	166.67	35.28	19.87	10.15
NAPHTHALENE	27.67	3.71	18.00	2.00	79.00	28.18
PERYLENE	82.33	34.37	80.00	12.86	14.90	4.10
PHENANTHRENE	113.00	9.07	118.00	32.52	131.33	50.42
PYRENE	1273.33	435.94	526.67	199.11	157.00	61.55
TOTAL	12816.17	2478.38	6243.43	1642.45	2372.37	701.95
BENZOTHIAZOLE	23.33	0.67	19.00	4.04	26.33	11.39
Metals - Meat						
Mercury	0.86	0.07	1.07	0.22	0.94	0.10
Metals - Hepatopancreas						
Cadmium	3.32	0.33	9.30	1.20	14.44	0.47
Chromium	0.15	0.03	0.12	0.01	0.08	0.01
Copper	485.11	98.85	371.03	70.86	166.57	43.40
Lead	0.35	0.08	0.41	0.12	0.07	0.02
Mercury	0.20	0.03	0.26	0.03	0.24	0.02
Nickel	0.13	0.02	0.39	0.02	0.68	0.04
Silver	32.89	9.31	21.28	3.63	15.25	4.06
Zinc	53.82	9.46	73.86	11.34	50.33	5.12

ND - Not Detected (considered 0 for calculations).

TABLE 3-10

Comparison of FDA Legal Limits to Mean Concentrations (wet weight) of Select Compounds In Lobster Edible Tissues - 1996

Compound/Analyte	Deer Island Mean	Deer Island S.E.	Future Outfall Site Mean	Future Outfall Site S.E.	Cape Cod Bay Mean	Cape Cod Bay S.E.	FDA Legal Limit [1]	Caution Level [3]	Warning Level [4]
Total DDT (ppb)	4.04	0.60	2.77	0.36	2.50	0.15	5,000 [2]	NA	NA
Total Chlordanes (ppb)	0.86	0.11	0.57	0.04	0.30	0.03	300	NA	NA
Dieldrin (ppb)	1.31	0.13	1.42	0.24	0.73	0.09	300	NA	NA
Total PCBs (ppb)	33.74	4.25	22.26	0.46	13.25	0.43	2,000	1,000	1,600
Mercury (ppm)	0.16	0.01	0.18	0.04	0.21	0.03	1	0.5	0.8

Notes:

[1] U.S. EPA 1989. Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish. EPA-503/8-89-002. Office of Marine and Estuarine Protection (WH-556F) and the Office of Water Regulations and Standards (WH-552), Washington, D.C.

[2] The value represents the FDA Legal Limits for DDT (5 ppm), DDE (5 ppm), and DDD (5 ppm), which comprise the mean total DDT tissue concentration. A total DDT tissue concentration below 5 ppm assumes that all DDT derivations are not exceeded.

[3] Massachusetts Water Resources Authority (MWRA) 1997. Contingency Plan. Caution Level is 50% the FDA Legal Limit, and applies to the outfall site only.

[4] Massachusetts Water Resources Authority (MWRA) 1997. Contingency Plan. Warning Level is 80% of the FDA Legal Limit, and applies to the outfall site only.

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Table 3-11
Concentrations of Selected Organic Compounds Normalized for Lipids [1]
Lobster Meat and Hepatopancreas, 1992 - 1996
ng/g Lipid

Parameter	Year	Deer Island		Future Outfall Site		Eastern Cape Cod Bay	
		Average	S.E.	Average	S.E.	Average	S.E.
Lobster Meat							
Total DDT	1992	81.83	0.72	73.45	9.85	174.04	81.93
	1993	1125.78	293.65	251.90	NC	566.03	275.14
	1994	287.26	65.50	191.59	4.59	209.61	25.58
	1995	275.19	45.85	351.51	61.81	280.05	41.12
	1996	694.94	105.32	556.28	87.76	409.09	39.06
	Baseline Mean	**493.00**	**187.09**	**284.95**	**81.42**	**327.77**	**71.85**
Total PCBs	1992	521.18	5.61	455.05	95.77	824.96	439.72
	1993	5984.82	1409.89	1802.41	NC	3083.60	1402.08
	1994	1669.58	427.68	1504.61	319.95	1356.43	305.27
	1995	2484.96	458.20	2937.21	620.13	1613.98	184.26
	1996	5875.59	974.60	4439.00	96.97	2160.57	150.09
	Baseline Mean	**3307.23**	**1115.48**	**2227.66**	**679.68**	**1807.91**	**384.67**
Lobster Hepatopancreas							
Total DDT	1992	884.52	285.12	830.00	309.74	646.00	141.67
	1993	1601.21	197.45	563.50	NC	598.56	74.71
	1994	578.05	83.62	529.14	193.25	243.56	34.97
	1995	1096.48	331.40	1448.02	39.02	1111.54	106.83
	1996	2253.02	272.40	2005.51	92.98	1143.30	199.44
	Baseline Mean	**1282.65**	**294.34**	**1075.24**	**285.01**	**748.59**	**169.65**
Total PAHs	1992	43408.68	7511.37	6911.65	1022.48	14983.88	6833.23
	1993	33395.75	16592.23	11216.54	NC	7065.35	2500.70
	1994	23725.57	4717.22	7971.38	670.81	1141.18	112.87
	1995	8651.85	1684.69	10355.55	1450.59	6440.68	1241.28
	1996	22729.95	3920.18	12109.68	2923.68	3868.67	1177.48
	Baseline Mean	**26382.36**	**5804.54**	**9712.96**	**982.30**	**6699.95**	**2320.99**
Total PCBs	1992	4739.48	739.05	3650.39	1137.97	3817.41	1586.46
	1993	7197.26	1346.41	4354.72	NC	4127.62	925.07
	1994	3537.34	493.79	4179.81	2542.39	959.81	126.52
	1995	7540.79	2718.39	8163.87	636.82	4165.74	474.45
	1996	13083.99	1775.71	10893.80	729.30	4025.39	530.35
	Baseline Mean	**7219.77**	**1646.28**	**6248.52**	**1411.80**	**3419.19**	**617.81**

Notes:
[1] Formula: concentration/percent lipid.
S.E. - Standard Error.

Table 3-12
Mussel harvest and analysis design summary for 1996

Station	Initial Deployment		Analysis			Forty-day Harvest			Sixty-day Harvest	
	Mussels	Arrays	Biology [1]	Arrays	Cages	Mussels	Arrays	Cages	Mussels	Biology [1]
Gloucester	80	NA	30	NA	NA	NA	NA	NA	NA	NA
Sandwich	35	NA	10	NA	NA	NA	NA	NA	NA	NA
Future Outfall Site										
Gloucester harvested	450	5	NA	5	10	90	1	2	180	30
Sandwich harvested	225	5	NA	5	5	45	1	1	90	5
Deer Island										
Gloucester harvested	360	4	NA	4	8	88	1	2	140	30
Sandwich harvested	180	4	NA	4	4	45	1	1	90	5
Discovery										
Gloucester harvested	180	1	NA	1	4	92	1	2	88	17
Sandwich harvested	91	1	NA	1	2	46	1	1	45	5
Total										
Gloucester harvested	1070	10	30	10	22	270	3	6	408	77
Sandwich harvested	531	10	10	10	11	136	3	3	225	15

Notes:
1 Biological analyses included sex, sexual maturity, wet/dry weight of gonad-mantle and non-gonadal soft tissue, and total shell length determinations.

Table 3-13
Survival and stage of gametogenesis of mussels following predeployment, forty-day, and sixty-day collections at specific stations

Station	Number	Percent Survival	Sample Size	Females		Males	
				Mature	Immature	Mature	Immature
Predeployment							
Gloucester	NA	NA	30	2	10	14	4
Sandwich	NA	NA	10	0	0	10	0
Forty-day harvest							
Future Outfall Site							
Gloucester harvested	90	99	NA	NA	NA	NA	NA
Sandwich harvested	45	98	NA	NA	NA	NA	NA
Deer Island							
Gloucester harvested	88	99	NA	NA	NA	NA	NA
Sandwich harvested	45	93	NA	NA	NA	NA	NA
Discovery							
Gloucester harvested	92	87	NA	NA	NA	NA	NA
Sandwich harvested	46	100	NA	NA	NA	NA	NA
Sixty-day harvest							
Future Ouffall Site							
Gloucester harvested	180	97	30	4	5	9	12
Sandwich harvested	90	100	5	1	0	3	1
Deer Island							
Gloucester harvested	140	91	30	9	9	6	6
Sandwich harvested	90	97	5	3	0	2	0
Discovery							
Gloucester harvested	88	83	17	6	4	3	4
Sandwich harvested	45	98	5	2	0	3	0

Notes:
NA - Not Applicable.

TABLE 3-14

Mean Shell Length and Mussel Weight of Mussels Collected in 1996

Station	Mean Shell Length (mm)	Mean Wet Weight (g)			
		Total Organism	Gonad-Mantle	Non-gonadal Soft Tissue	Shell
Predeployment					
Gloucester	56.9	22.1	2.9	4.1	11.3
Sandwich	63.1	30.4	5.1	6.3	13.2
60 Day Retrieval					
Deer Island (Gloucester derived)	62.6	34.1	4.0	7.4	15.7
Deer Island (Sandwich derived)	66.9	38.3	4.8	9.1	16.1
Future Outfall Site (Gloucester derived)	63.2	32.8	4.7	7.9	16.5
Future Outfall Site (Sandwich derived)	67.2	38.6	6.1	10.3	17.1
Discovery (Gloucester derived)	62.8	33.9	3.6	6.5	16.4
Discovery (Sandwich derived)	67.2	37.6	5.4	9.0	17.3

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TABLE 3-15

Summary of Low Molecular Weight (LMW) and High Molecular Weight (HMW) Examined in 1996 and the Comparable Analytes from Previous Studies (1991-1995)

1996 PAH Analytes	1996 NOAA PAH Analytes	Comparable NOAA PAHs Analyzed Prior to 1996
	Low Molecular Weight PAHs	
ACENAPHTHENE	ACENAPHTHENE	ACENAPHTHENE
ACENAPHTHYLENE	ACENAPHTHYLENE	ACENAPHTHYLENE
ANTHRACENE	ANTHRACENE	ANTHRACENE
BENZOTHIAZOLE		
BIPHENYL	BIPHENYL	1,1 BIPHENYL
DIBENZOFURAN		
DIBENZOTHIOPHENE		
C1-DIBENZOTHIOPHENES		
C2-DIBENZOTHIOPHENE		
C3-DIBENZOTHIOPHENE		
2,6-DIMETHYLNAPHTHALENE		2,6-DIMETHYLNAPHTHALENE
FLUORENE	FLUORENE	FLUORENE
C1-FLUORENE		
C2-FLUORENE		
C3-FLUORENE		
1-METHYLNAPHTHALENE		1-METHYLNAPHTHALENE
2-METHYLNAPHTHALENE		2-METHYLNAPHTHALENE
1-METHYLPHENANTHRENE		1-METHYLPHENANTHRENE
NAPHTHALENE	NAPHTHALENE	NAPHTHALENE
C1-NAPTHALENE	C1-NAPTHALENE	
C2-NAPTHALENE	C2-NAPTHALENE	
C3-NAPTHALENE	C3-NAPTHALENE	
C4-NAPTHALENE		
PHENANTHRENE	PHENANTHRENE	PHENANTHRENE
C1-PHENANTHRENES/ANTHRACENE	C1-PHENANTHRENES/ANTHRACENE	
C2-PHENANTHRENE/ANTHRACENE		
C3-PHENANTHRENE/ANTHRACENE		
C4-PHENANTHRENE/ANTHRACENE		
2,3,5-TRIMETHYNAPHTHALENE		2,3,5-TRIMETHYNAPHTHALENE
	High Molecular Weight PAHs	
BENZ(A)ANTHRACENE	BENZ(A)ANTHRACENE	BENZ(A)ANTHRACENE
BENZO(A)PYRENE	BENZO(A)PYRENE	BENZO(A)PYRENE
BENZO(B)FLUORANTHENE	BENZO(B)FLUORANTHENE	BENZO(B)FLUORANTHENE
BENZO(E)PYRENE	BENZO(E)PYRENE	BENZO(E)PYRENE
BENZO(G,H,I)PERYLENE	BENZO(G,H,I)PERYLENE	BENZO(G,H,I)PERYLENE
BENZO(K)FLUORANTHENE	BENZO(K)FLUORANTHENE	BENZO(K)FLUORANTHENE
CHRYSENE	CHRYSENE	CHRYSENE
C1-CHRYSENE		
C2-CHRYSENE		
C3-CHRYSENE		
C4-CHRYSENE		
DIBENZO(A,H)ANTHRACENE	DIBENZO(A,H)ANTHRACENE	DIBENZO(A,H)ANTHRACENE
FLUORANTHENE	FLUORANTHENE	FLUORANTHENE
C1-FLUORANTHENES/PYRENE		
C2-FLUORANTHENES/PYRENE		
C3-FLUORANTHENES/PYRENE		
INDENO(1,2,3-CD)PYRENE	INDENO(1,2,3-CD)PYRENE	INDENO(1,2,3-CD)PYRENE
PERYLENE	PERYLENE	PERYLENE
PYRENE	PYRENE	PYRENE

TABLE 3-16 (Page 1 of 3)
PAH Concentration in 1996 Mussels
(ng/g dry weight)

Parameter	Gloucester Predeployment			Deer Island, August 1996				
	M9611H7TC1	M9611H7TC2	M9611H7TC3	M9611D1H7TC1	M9611D1H7TC2	M9611D1H7TC3	M9611D1H7TC4	M9611D1H7TC5
Low Molecular Weight PAHs								
1-METHYLNAPHTHALENE	7.8	15	18	8	11	11	13	17
1-METHYLPHENANTHRENE	13	9.2	9.4	18	22	24	22	38
2,3,5-TRIMETHYNAPHTHALENE	3.2	10	10	8	10	12	9.6	18
2,6-DIMETHYLNAPHTHALENE	8.8	19	15	14	10	14	20	16
2-METHYLNAPHTHALENE	14	30	30	14	19	17	20	26
ACENAPHTHENE	2.7	2.7	2.7	2.7	2.7	2.7	2.7	19
ACENAPHTHYLENE	4.9	7.4	8.8	7.7	10	7.2	10	11
ANTHRACENE	8.9	10	8.6	14	20	16	20	44
BENZOTHIAZOLE	15	34	36	16	24	17	20	22
BIPHENYL	3.7	7	7.4	5.9	8	6.6	6.4	12
C1-DIBENZOTHIOPHENES	14	2.2	2.2	26	44	36	42	54
C1-FLUORENES	4	4	4	29	46	34	50	62
C1-NAPTHALENE	14	34	34	15	20	22	24	30
C1-PHENANTHRENES/ANTHRACENE	58	32	36	78	100	110	120	180
C2-DIBENZOTHIOPHENE	24	2.2	2.2	99	140	130	170	200
C2-FLUORENE	4	4	4	78	110	90	110	150
C2-NAPTHALENE	22	34	32	38	44	44	48	68
C2-PHENANTHRENE/ANTHRACENE	58	46	44	160	220	220	280	320
C3-DIBENZOTHIOPHENE	23	2.2	2.2	140	190	190	220	220
C3-FLUORENE	4	4	4	93	240	200	280	300
C3-NAPTHALENE	30	7	7	67	86	80	96	150
C3-PHENANTHRENE/ANTHRACENE	33	26	26	150	240	200	280	280
C4-NAPTHALENE	7	7	7	100	140	140	190	240
C4-PHENANTHRENE/ANTHRACENE	26	2.1	2.1	99	160	150	170	190
DIBENZOFURAN	3.2	5.2	5.2	6	9.4	8.8	9	14
DIBENZOTHIOPHENE	2.1	2.2	2.2	6.4	8.6	9.6	8.4	17
FLUORENE	4	4	4	7.6	12	8.6	9.8	22
NAPHTHALENE	14	34	42	17	30	24	24	34
PHENANTHRENE	25	20	22	39	50	48	48	130
Total LMW PAHs	451.3	416.4	428	1356.3	2026.7	1872.5	2322.9	2884
Total NOAA LMW PAHs	187.2	192.1	204.5	291.9	382.7	369.1	408.9	700
Total Historic NOAA LMW PAHs	110	168.3	177.9	155.9	204.7	191.1	205.5	387
High Molecular Weight PAHs								
BENZ(A)ANTHRACENE	4.7	4.7	4.7	36	42	42	48	92
BENZO(A)PYRENE	5.2	4.2	6.4	21	24	20	20	58
BENZO(B)FLUORANTHENE	16	15	20	57	64	64	60	110
BENZO(E)PYRENE	12	16	18	52	68	62	66	100
BENZO(G,H,I)PERYLENE	6.7	8.2	7.6	21	28	24	22	46
BENZO(K)FLUORANTHENE	4	5.2	7	19	24	20	20	40
C1-CHRYSENE	13	15	16	34	44	46	48	76
C1-FLUORANTHENES/PYRENE	50	40	40	99	150	140	150	220
C2-CHRYSENE	8.6	6.6	6.6	22	24	24	26	36
C2F/P	28	6.6	6.6	71	90	98	110	140
C3-CHRYSENE	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
C3F/P	6.6	6.6	6.6	44	60	52	60	70
C4-CHRYSENE	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
CHRYSENE	28	28	34	72	100	94	110	170
DIBENZO(A,H)ANTHRACENE	11	11	4.6	4.3	4.8	4	4.4	10
FLUORANTHENE	75	50	48	140	190	170	190	340
INDENO(1,2,3-CD)PYRENE	3.8	5.6	9.2	16	20	17	15	40
PERYLENE	2.3	2.2	2.2	7.3	8	6.6	7.4	16
PYRENE	77	30	34	120	160	150	160	280
Total HMW PAHs	365.1	268.1	284.7	848.8	1114	1046.8	1130	1857.2
Total NOAA HMW PAHs	245.7	180.1	195.7	565.6	732.8	673.6	722.8	1302
Total Historic NOAA PAHs	245.7	180.1	195.7	565.6	732.8	673.6	722.8	1302
Total PAHs	816.4	684.5	712.7	2205.1	3140.7	2919.3	3452.9	4741.2
Total NOAA PAHs	432.9	372.2	400.2	857.5	1115.5	1042.7	1131.7	2002
Total Historic NOAA PAHs	355.7	348.4	373.6	721.5	937.5	864.7	928.3	1689

Shaded values indicated concentration of ND was reported (Not Detected). The MDL (Method Detection Limit) is used as an estimated concentration.
The value for 2,3,5 - Trimethylnaphthalene is the Minumum Reporting Limit. (No MDL available.)

TABLE 3-16 (Page 2 of 3)
PAH Concentration in 1996 Mussels
(ng/g dry weight)

Parameter	Future Outfall Site, August 1996				
	M9611D4H7TC1	M9611D4H7TC2	M9611D4H7TC3	M9611D4H7TC4	M9611D4H7TC5
Low Molecular Weight PAHs					
1-METHYLNAPHTHALENE	3.3	9.2	6.6	18	17
1-METHYLPHENANTHRENE	2.9	1.8	2.2	1.8	2.4
2,3,5-TRIMETHYNAPHTHALENE	10	10	10	10	10
2,6-DIMETHYLNAPHTHALENE	7	7	7	7	7
2-METHYLNAPHTHALENE	3.7	5.1	5.9	6.2	6.5
ACENAPHTHENE	2.7	2.7	2.7	2.7	2.7
ACENAPHTHYLENE	2.2	2.6	3.1	2.7	2
ANTHRACENE	3.2	2.9	3.8	3.4	2.9
BENZOTHIAZOLE	8.9	6	7	10	7.8
BIPHENYL	1.7	3.8	1.7	2	1.7
C1-DIBENZOTHIOPHENES	2.2	2.2	2.2	2.2	2.2
C1-FLUORENES	4	4	4	4	4
C1-NAPTHALENE	5.3	14	11	22	30
C1-PHENANTHRENES/ANTHRACENE	9.4	9.2	14	8.9	12
C2-DIBENZOTHIOPHENE	2.2	2.2	2.2	2.2	2.2
C2-FLUORENE	4	4	4	4	4
C2-NAPTHALENE	7	7	7	7	7
C2-PHENANTHRENE/ANTHRACENE	8.6	9.8	9	9.3	7.6
C3-DIBENZOTHIOPHENE	2.2	2.2	2.2	2.2	2.2
C3-FLUORENE	4	4	4	4	4
C3-NAPTHALENE	7	7	7	7	7
C3-PHENANTHRENE/ANTHRACENE	16	17	17	15	14
C4-NAPTHALENE	7	7	7	7	7
C4-PHENANTHRENE/ANTHRACENE	2.1	2.1	2.1	2.1	2.1
DIBENZOFURAN	2.9	3	4	2.5	2.6
DIBENZOTHIOPHENE	2.2	2.2	2.2	2.2	2.2
FLUORENE	4	4	4	4	4
NAPHTHALENE	6.6	8.6	9.5	11	11
PHENANTHRENE	6.3	5.9	7.6	5.6	6.4
Total LMW PAHs	148.6	166.5	170	186	191.5
Total NOAA LMW PAHs	55.4	67.7	71.4	76.3	86.7
Total Historic NOAA LMW PAHs	53.6	63.6	64.1	74.4	73.6
High Molecular Weight PAHs					
BENZ(A)ANTHRACENE	4.7	4.7	4.7	4.7	4.7
BENZO(A)PYRENE	1.4	1.9	1.5	1.5	1.7
BENZO(B)FLUORANTHENE	2.7	2.8	3.3	3.1	3.4
BENZO(E)PYRENE	3.1	4	5.2	4.1	4.1
BENZO(G,H,I)PERYLENE	3.5	2.2	2.1	1.7	1.9
BENZO(K)FLUORANTHENE	0.9	1.1	1.2	0.87	1.2
C1-CHRYSENE	6.6	6.6	6.6	6.6	6.6
C1-FLUORANTHENES/PYRENE	8.3	9.2	11	7.5	9.8
C2-CHRYSENE	6.6	6.6	6.6	6.6	6.6
C2F/P	6.6	6.6	6.6	6.6	6.6
C3-CHRYSENE	6.6	6.6	6.6	6.6	6.6
C3F/P	6.6	6.6	6.6	6.6	6.6
C4-CHRYSENE	6.6	6.6	6.6	6.6	6.6
CHRYSENE	5.4	6.6	7.4	4.8	5.6
DIBENZO(A,H)ANTHRACENE	11	11	11	11	11
FLUORANTHENE	9.4	10	13	9.2	9.9
INDENO(1,2,3-CD)PYRENE	12	12	12	12	12
PERYLENE	0.88	6.5	6.5	6.5	6.5
PYRENE	7.4	8.3	9.4	8.3	9.6
Total HMW PAHs	110.28	119.9	127.9	114.87	121
Total NOAA HMW PAHs	62.38	71.1	77.3	67.77	71.6
Total Historic NOAA PAHs	62.38	71.1	77.3	67.77	71.6
Total PAHs	258.88	286.4	297.9	300.87	312.5
Total NOAA PAHs	117.78	138.8	148.7	144.07	158.3
Total Historic NOAA PAHs	115.98	134.7	141.4	142.17	145.2

Shaded values indicated concentration of ND was reported (Not Detected). The MDL (Method Detection Limit) is used as an estimated concentration.
The value for 2,3,5 - Trimethylnaphthalene is the Minumum Reporting Limit. (No MDL available.)

TABLE 3-16 (Page 3 of 3)
PAH Concentration in 1996 Mussels
(ng/g dry weight)

Parameter	Discovery, August 1996				
	M9611D6H7TC1	M9611D6H7TC2	M9611D6H7TC3	M9611D6H7TC4	M9611D6H7TC5
Low Molecular Weight PAHs					
1-METHYLNAPHTHALENE	7.5	7	9.2	8.4	9.4
1-METHYLPHENANTHRENE	17	24	18	13	14
2,3,5-TRIMETHYNAPHTHALENE	10	5	10	3.6	6.6
2,6-DIMETHYLNAPHTHALENE	7	6	8	5.2	8
2-METHYLNAPHTHALENE	10	11	14	14	15
ACENAPHTHENE	11	10	2.7	9	8.2
ACENAPHTHYLENE	30	32	28	26	20
ANTHRACENE	55	58	44	48	40
BENZOTHIAZOLE	14	10	14	8.6	17
BIPHENYL	1.7	3.8	5	5	6.8
C1-DIBENZOTHIOPHENES	22	28	28	28	22
C1-FLUORENES	20	24	22	22	19
C1-NAPTHALENE	13	13	16	15	17
C1-PHENANTHRENES/ANTHRACENE	89	76	74	70	62
C2-DIBENZOTHIOPHENE	210	190	160	140	130
C2-FLUORENE	120	120	110	88	68
C2-NAPTHALENE	7	15	24	15	19
C2-PHENANTHRENE/ANTHRACENE	300	300	220	200	180
C3-DIBENZOTHIOPHENE	480	480	340	360	280
C3-FLUORENE	410	400	220	280	240
C3-NAPTHALENE	7	28	7	24	28
C3-PHENANTHRENE/ANTHRACENE	550	540	400	400	320
C4-NAPTHALENE	7	90	7	78	60
C4-PHENANTHRENE/ANTHRACENE	520	500	400	360	380
DIBENZOFURAN	8.6	8.6	8	7.4	7.6
DIBENZOTHIOPHENE	7.8	4.8	4.6	4	5
FLUORENE	6.8	8	7.2	5.6	7.8
NAPHTHALENE	16	24	28	24	26
PHENANTHRENE	21	24	28	22	26
Total LMW PAHs	2978.4	3040.2	2256.7	2283.8	2042.4
Total NOAA LMW PAHs	257.5	291.8	263.9	263.6	260.8
Total Historic NOAA LMW PAHs	193	212.8	202.1	183.8	187.8
High Molecular Weight PAHs					
BENZ(A)ANTHRACENE	170	190	140	140	150
BENZO(A)PYRENE	71	78	70	62	72
BENZO(B)FLUORANTHENE	280	320	280	260	240
BENZO(E)PYRENE	320	340	280	280	260
BENZO(G,H,I)PERYLENE	56	66	66	58	60
BENZO(K)FLUORANTHENE	80	76	80	70	70
C1-CHRYSENE	200	200	180	170	170
C1-FLUORANTHENES/PYRENE	530	520	420	400	360
C2-CHRYSENE	120	110	100	96	110
C2F/P	380	400	320	300	280
C3-CHRYSENE	6.6	6.6	6.6	6.6	6.6
C3F/P	210	240	190	200	190
C4-CHRYSENE	6.6	6.6	6.6	6.6	6.6
CHRYSENE	370	380	360	320	300
DIBENZO(A,H)ANTHRACENE	10	11	12	11	12
FLUORANTHENE	470	500	400	360	320
INDENO(1,2,3-CD)PYRENE	29	36	36	32	32
PERYLENE	24	24	20	20	20
PYRENE	550	580	460	400	380
Total HMW PAHs	3883.2	4084.2	3427.2	3192.2	3039.2
Total NOAA HMW PAHs	2430	2601	2204	2013	1916
Total Historic NOAA PAHs	2430	2601	2204	2013	1916
Total PAHs	6861.6	7124.4	5683.9	5476	5081.6
Total NOAA PAHs	2687.5	2892.8	2467.9	2276.6	2176.8
Total Historic NOAA PAHs	2623	2813.8	2406.1	2196.8	2103.8

Shaded values indicated concentration of ND was reported (Not Detected). The MDL (Method Detection Limit) is used as an estimated concentration.
The value for 2,3,5 - Trimethylnaphthalene is the Minumum Reporting Limit. (No MDL available.)

TABLE 3-17 (Page 1 of 2)
Summary PAH Concentration in 1996 Mussels
(ng/g dry weight)

	Gloucester Predeployment - June 1996 (Sample size = 3)					Deer Island - August 1996 (Sample size = 5)					Future Outfall Site, August 1996 (Sample size = 5)					Discovery, August 1996 (Sample size = 5)				
Parameter	**Average**	**SD**	**SE**	**Range**		**Average**	**SD**	**SE**	**Range**		**Average**	**SD**	**SE**	**Range**		**Average**	**SD**	**SE**	**Range**	
Low Molecular Weight PAHs																				
1-METHYLNAPHTHALENE	13.60	5.24	3.03	7.80	18.00	12.00	3.32	1.48	8.00	17.00	10.82	6.46	2.89	3.30	18.00	8.30	1.04	0.47	7.00	9.40
1-METHYLPHENANTHRENE	10.53	2.14	1.23	9.20	13.00	24.80	7.69	3.44	18.00	38.00	2.22	0.46	0.21	1.80	2.90	17.20	4.32	1.93	13.00	24.00
2,3,5-TRIMETHYNAPHTHALENE	7.73	3.93	2.27	3.20	10.00	11.52	3.89	1.74	8.00	18.00	10.00	0.00	0.00	10.00	10.00	7.04	2.90	1.30	3.60	10.00
2,6-DIMETHYLNAPHTHALENE	14.27	5.14	2.97	8.80	19.00	14.80	3.63	1.62	10.00	20.00	7.00	0.00	0.00	7.00	7.00	6.84	1.24	0.55	5.20	8.00
2-METHYLNAPHTHALENE	24.67	9.24	5.33	14.00	30.00	19.20	4.44	1.98	14.00	26.00	5.48	1.12	0.50	3.70	6.50	12.80	2.17	0.97	10.00	15.00
ACENAPHTHENE	2.70	0.00	0.00	2.70	2.70	5.96	7.29	3.26	2.70	19.00	2.70	0.00	0.00	2.70	2.70	8.18	3.24	1.45	2.70	11.00
ACENAPHTHYLENE	7.03	1.98	1.14	4.90	8.80	9.18	1.64	0.73	7.20	11.00	2.52	0.43	0.19	2.00	3.10	27.20	4.60	2.06	20.00	32.00
ANTHRACENE	9.17	0.74	0.43	8.60	10.00	22.80	12.13	5.43	14.00	44.00	3.24	0.38	0.17	2.90	3.80	49.00	7.48	3.35	40.00	58.00
BENZOTHIAZOLE	28.33	11.59	6.69	15.00	36.00	19.80	3.35	1.50	16.00	24.00	7.94	1.57	0.70	6.00	10.00	12.72	3.39	1.52	8.60	17.00
BIPHENYL	6.03	2.03	1.17	3.70	7.40	7.78	2.48	1.11	5.90	12.00	2.18	0.91	0.41	1.70	3.80	4.46	1.88	0.84	1.70	6.80
C1-DIBENZOTHIOPHENES	6.13	6.81	3.93	2.20	14.00	40.40	10.33	4.62	26.00	54.00	2.20	0.00	0.00	2.20	2.20	25.60	3.29	1.47	22.00	28.00
C1-FLUORENES	4.00	0.00	0.00	4.00	4.00	44.20	13.12	5.87	29.00	62.00	4.00	0.00	0.00	4.00	4.00	21.40	1.95	0.87	19.00	24.00
C1-NAPTHALENE	27.33	11.55	6.67	14.00	34.00	22.20	5.50	2.46	15.00	30.00	16.46	9.68	4.33	5.30	30.00	14.80	1.79	0.80	13.00	17.00
C1-PHENANTHRENES/ANTHRACENE	42.00	14.00	8.08	32.00	58.00	117.60	38.19	17.08	78.00	180.00	10.70	2.22	0.99	8.90	14.00	74.20	9.86	4.41	62.00	89.00
C2-DIBENZOTHIOPHENE	9.47	12.59	7.27	2.20	24.00	147.80	38.65	17.29	99.00	200.00	2.20	0.00	0.00	2.20	2.20	166.00	33.62	15.03	130.00	210.00
C2-FLUORENE	4.00	0.00	0.00	4.00	4.00	107.60	27.36	12.24	78.00	150.00	4.00	0.00	0.00	4.00	4.00	101.20	22.70	10.15	68.00	120.00
C2-NAPTHALENE	29.33	6.43	3.71	22.00	34.00	48.40	11.52	5.15	38.00	68.00	7.00	0.00	0.00	7.00	7.00	16.00	6.24	2.79	7.00	24.00
C2-PHENANTHRENE/ANTHRACENE	49.33	7.57	4.37	44.00	58.00	240.00	61.64	27.57	160.00	320.00	8.86	0.83	0.37	7.60	9.80	240.00	56.57	25.30	180.00	300.00
C3-DIBENZOTHIOPHENE	9.13	12.01	6.93	2.20	23.00	192.00	32.71	14.63	140.00	220.00	2.20	0.00	0.00	2.20	2.20	388.00	88.99	39.80	280.00	480.00
C3-FLUORENE	4.00	0.00	0.00	4.00	4.00	222.60	82.00	36.67	93.00	300.00	4.00	0.00	0.00	4.00	4.00	310.00	89.44	40.00	220.00	410.00
C3-NAPTHALENE	14.67	13.28	7.67	7.00	30.00	95.80	32.07	14.34	67.00	150.00	7.00	0.00	0.00	7.00	7.00	18.80	10.89	4.87	7.00	28.00
C3-PHENANTHRENE/ANTHRACENE	28.33	4.04	2.33	26.00	33.00	230.00	55.68	24.90	150.00	280.00	15.80	1.30	0.58	14.00	17.00	442.00	99.60	44.54	320.00	550.00
C4-NAPTHALENE	7.00	0.00	0.00	7.00	7.00	162.00	54.04	24.17	100.00	240.00	7.00	0.00	0.00	7.00	7.00	48.40	39.27	17.56	7.00	90.00
C4-PHENANTHRENE/ANTHRACENE	10.07	13.80	7.97	2.10	26.00	153.80	34.02	15.21	99.00	190.00	2.10	0.00	0.00	2.10	2.10	432.00	72.94	32.62	360.00	520.00
DIBENZOFURAN	4.53	1.15	0.67	3.20	5.20	9.44	2.88	1.29	6.00	14.00	3.00	0.60	0.27	2.50	4.00	8.04	0.55	0.25	7.40	8.60
DIBENZOTHIOPHENE	2.17	0.06	0.03	2.10	2.20	10.00	4.08	1.83	6.40	17.00	2.20	0.00	0.00	2.20	2.20	5.24	1.48	0.66	4.00	7.80
FLUORENE	4.00	0.00	0.00	4.00	4.00	12.00	5.83	2.61	7.60	22.00	4.00	0.00	0.00	4.00	4.00	7.08	0.95	0.43	5.60	8.00
NAPHTHALENE	30.00	14.42	8.33	14.00	42.00	25.80	6.50	2.91	17.00	34.00	9.34	1.84	0.82	6.60	11.00	23.60	4.56	2.04	16.00	28.00
PHENANTHRENE	22.33	2.52	1.45	20.00	25.00	63.00	37.70	16.86	39.00	130.00	6.36	0.76	0.34	5.60	7.60	24.20	2.86	1.28	21.00	28.00
Total LMW PAHs	431.90	17.77	10.26	416.40	451.30	2092.48	564.42	252.42	1356.30	2884.00	172.52	17.01	7.60	148.60	191.50	2520.30	456.61	204.20	2042.40	3040.20
Total NOAA LMW PAHs	194.60	8.92	5.15	187.20	204.50	430.52	156.81	70.13	291.90	700.00	71.50	11.49	5.14	55.40	86.70	267.52	13.82	6.18	257.50	291.80
Total Historic NOAA LMW PAHs	152.07	36.75	21.22	110.00	177.90	228.84	90.67	40.55	155.90	387.00	65.86	8.53	3.82	53.60	74.40	195.90	11.67	5.22	183.80	212.80
High Molecular Weight PAHs																				
BENZ(A)ANTHRACENE	4.70	0.00	0.00	4.70	4.70	52.00	22.76	10.18	36.00	92.00	4.70	0.00	0.00	4.70	4.70	158.00	21.68	9.70	140.00	190.00
BENZO(A)PYRENE	5.27	1.10	0.64	4.20	6.40	28.60	16.52	7.39	20.00	58.00	1.60	0.20	0.09	1.40	1.90	70.60	5.73	2.56	62.00	78.00
BENZO(B)FLUORANTHENE	17.00	2.65	1.53	15.00	20.00	71.00	22.00	9.84	57.00	110.00	3.06	0.30	0.14	2.70	3.40	276.00	29.66	13.27	240.00	320.00
BENZO(E)PYRENE	15.33	3.06	1.76	12.00	18.00	69.60	18.08	8.08	52.00	100.00	4.10	0.74	0.33	3.10	5.20	296.00	32.86	14.70	260.00	340.00
BENZO(G,H,I)PERYLENE	7.50	0.75	0.44	6.70	8.20	28.20	10.31	4.61	21.00	46.00	2.28	0.71	0.32	1.70	3.50	61.20	4.60	2.06	56.00	66.00
BENZO(K)FLUORANTHENE	5.40	1.51	0.87	4.00	7.00	24.60	8.82	3.94	19.00	40.00	1.05	0.16	0.07	0.87	1.20	75.20	5.02	2.24	70.00	80.00
C1-CHRYSENE	14.67	1.53	0.88	13.00	16.00	49.60	15.71	7.03	34.00	76.00	6.60	0.00	0.00	6.60	6.60	184.00	15.17	6.78	170.00	200.00
C1-FLUORANTHENES/PYRENE	43.33	5.77	3.33	40.00	50.00	151.80	43.55	19.47	99.00	220.00	9.16	1.35	0.60	7.50	11.00	446.00	75.37	33.70	360.00	530.00
C2-CHRYSENE	7.27	1.15	0.67	6.60	8.60	26.40	5.55	2.48	22.00	36.00	6.60	0.00	0.00	6.60	6.60	107.20	9.44	4.22	96.00	120.00
C2F/P	13.73	12.36	7.13	6.60	28.00	101.80	25.64	11.46	71.00	140.00	6.60	0.00	0.00	6.60	6.60	336.00	51.77	23.15	280.00	400.00
C3-CHRYSENE	6.60	0.00	0.00	6.60	6.60	6.60	0.00	0.00	6.60	6.60	6.60	0.00	0.00	6.60	6.60	6.60	0.00	0.00	6.60	6.60
C3F/P	6.60	0.00	0.00	6.60	6.60	57.20	9.76	4.36	44.00	70.00	6.60	0.00	0.00	6.60	6.60	206.00	20.74	9.27	190.00	240.00
C4-CHRYSENE	6.60	0.00	0.00	6.60	6.60	6.60	0.00	0.00	6.60	6.60	6.60	0.00	0.00	6.60	6.60	6.60	0.00	0.00	6.60	6.60
CHRYSENE	30.00	3.46	2.00	28.00	34.00	109.20	36.73	16.43	72.00	170.00	5.96	1.03	0.46	4.80	7.40	346.00	34.35	15.36	300.00	380.00
DIBENZO(A,H)ANTHRACENE	8.87	3.70	2.13	4.60	11.00	5.50	2.53	1.13	4.00	10.00	11.00	0.00	0.00	11.00	11.00	11.20	0.84	0.37	10.00	12.00
FLUORANTHENE	57.67	15.04	8.69	48.00	75.00	206.00	77.65	34.73	140.00	340.00	10.30	1.55	0.69	9.20	13.00	410.00	74.83	33.47	320.00	500.00
INDENO(1,2,3-CD)PYRENE	6.20	2.75	1.59	3.80	9.20	21.60	10.45	4.68	15.00	40.00	12.00	0.00	0.00	12.00	12.00	33.00	3.00	1.34	29.00	36.00

TABLE 3-17 (Page 2 of 2)
Summary PAH Concentration in 1996 Mussels
(ng/g dry weight)

	Gloucester Predeployment - June 1996 (Sample size = 3)					Deer Island - August 1996 (Sample size = 5)					Future Outfall Site, August 1996 (Sample size = 5)					Discovery, August 1996 (Sample size = 5)				
Parameter	**Average**	**SD**	**SE**	**Range**		**Average**	**SD**	**SE**	**Range**		**Average**	**SD**	**SE**	**Range**		**Average**	**SD**	**SE**	**Range**	
PERYLENE	2.23	0.06	0.03	2.20	2.30	9.06	3.91	1.75	6.60	16.00	5.38	2.51	1.12	0.88	6.50	21.60	2.19	0.98	20.00	24.00
PYRENE	47.00	26.06	15.04	30.00	77.00	174.00	61.48	27.50	120.00	280.00	8.60	0.90	0.40	7.40	9.60	474.00	88.77	39.70	380.00	580.00
Total HMW PAHs	305.97	51.88	29.95	268.10	365.10	1199.36	384.39	171.90	848.80	1857.20	118.79	6.65	2.97	110.28	127.90	3525.20	446.47	199.67	3039.20	4084.20
Total NOAA HMW PAHs	207.17	34.27	19.79	180.10	245.70	799.36	288.70	129.11	565.60	1302.00	70.03	5.48	2.45	62.38	77.30	2232.80	284.59	127.27	1916.00	2601.00
Total Historic NOAA HMW PAHs	207.17	34.27	19.79	180.10	245.70	799.36	288.70	129.11	565.60	1302.00	70.03	5.48	2.45	62.38	77.30	2232.80	284.59	127.27	1916.00	2601.00
Total PAHs	737.87	69.46	40.10	684.50	816.40	3291.84	931.29	416.49	2205.10	4741.20	291.31	20.37	9.11	258.88	312.50	6045.50	896.41	400.89	5081.60	7124.40
Total NOAA PAHs	401.77	30.38	17.54	372.20	432.90	1229.88	445.14	199.07	857.50	2002.00	141.53	15.09	6.75	117.78	158.30	2500.32	293.62	131.31	2176.80	2892.80
Total Historic NOAA PAHs	359.23	12.97	7.49	348.40	373.60	1028.20	379.36	169.66	721.50	1689.00	135.89	11.77	5.26	115.98	145.20	2428.70	294.07	131.51	2103.80	2813.80

TABLE 3-18 (Page 1 of 2)
Pesticide Concentrations in 1996 Mussels
(ng/g dry weigt)

Parameter	Gloucester Predeployment			Deer Island, August 1996				
	M9611H7TC1	M9611H7TC2	M9611H7TC3	M9611D1H7TC1	M9611D1H7TC2	M9611D1H7TC3	M9611D1H7TC4	M9611D1H7TC5
ALDRIN	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
DIELDRIN	0.48	0.48	0.48	4	5.8	4.7	6	7.5
ENDRIN	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
TOTAL	2.05	2.05	2.05	5.57	7.37	6.27	7.57	9.07
ALPHA-CHLORDANE	3.7	5.8	4.9	14	22	18	22	24
HEPTACHLOR	0.24	0.24	0.24	3	4.3	3.3	4.2	5
HEPTACHLOREPOXIDE	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
HEXACHLOROBENZENE	1.1	1.4	0.45	0.93	0.8	1	0.76	1.1
LINDANE	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
MIREX	0.64	0.85	0.86	0.51	0.68	0.51	0.79	0.73
TRANS_NONACHLOR	4.3	5.4	5.2	13	19	15	18	20
TOTAL	10.73	14.44	12.4	32.19	47.53	38.56	46.5	51.58
2,4-DDD	6.6	8.3	8	6.1	11	8.1	11	11
2,4-DDE	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
2,4-DDT	0.46	0.46	0.46	5	6.7	5.4	6.7	7
4,4-DDD	16	27	27	14	22	18	22	25
4,4-DDE	17	22	21	23	37	28	33	36
4,4-DDT	4.8	6.4	6.2	13	19	14	19	21
TOTAL	45.59	64.89	63.39	61.83	96.43	74.23	92.43	100.73
TOTAL PESTICIDES	58.37	81.38	77.84	99.59	151.33	119.06	146.5	161.38

Shaded values indicate that a concentration of ND (Not Detected) was reported. The MDL (Method Detection Limit) is used as an estimated concentration.

TABLE 3-18 (Page 2 of 2)
Pesticide Concentrations in 1996 Mussels
(ng/g dry weight)

Parameter	Future Outfall Site, August 1996					Discovery, August 1996				
	M9611D4H7TC1	M9611D4H7TC2	M9611D4H7TC3	M9611D4H7TC4	M9611D4H7TC5	M9611D6H7TC1	M9611D6H7TC2	M9611D6H7TC3	M9611D6H7TC4	M9611D6H7TC5
ALDRIN	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
DIELDRIN	0.48	3.6	0.48	0.48	3.2	12	11	8.3	8.3	6.8
ENDRIN	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
TOTAL	2.05	5.17	2.05	2.05	4.77	13.57	12.57	9.87	9.87	8.37
ALPHA-CHLORDANE	2.5	3.8	3	2.9	2.9	20	18	14	15	12
HEPTACHLOR	0.24	0.24	0.56	0.24	0.8	2	1.7	1.4	1.5	1.2
HEPTACHLOREPOXIDE	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.3
HEXACHLOROBENZENE	0.56	0.58	0.79	0.72	0.58	1.4	1.5	1.3	1.3	1.9
LINDANE	0.3	0.3	0.3	0.3	1.8	0.3	0.3	0.3	0.3	0.3
MIREX	0.8	0.98	1	0.86	0.84	0.18	0.27	0.28	0.27	0.3
TRANS_NONACHLOR	3.4	4.4	4.5	3.7	3.8	16	15	12	14	12
TOTAL	8.25	10.75	10.6	9.17	11.17	40.33	37.22	29.73	32.82	28
2,4-DDD	3	3.5	3.5	2.6	3	20	18	14	15	13
2,4-DDE	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
2,4-DDT	1.5	1.9	2	1.8	1.7	6.7	4.7	4.6	5.5	5.1
4,4-DDD	5.3	6.8	7	5.8	6	62	60	43	47	39
4,4-DDE	11	13	13	11	12	55	36	44	33	44
4,4-DDT	5.6	5.8	6.9	5.7	5.7	6.2	5.3	2.9	4.6	3.9
TOTAL	27.13	31.73	33.13	27.63	29.13	150.63	124.73	109.23	105.83	105.73
TOTAL PESTICIDES	37.43	47.65	45.78	38.85	45.07	204.53	174.52	148.83	148.52	142.1

Shaded values indicate that a concentration of ND (Not Detected) was reported. The MDL (Method Detection Limit) is used as an estimated concentration.

TABLE 3-19
Summary Pesticide Concentration in 1996 Mussels
(ng/g dry weight)

Parameter	Gloucester Predeployment - June 1996 (Sample size = 3)					Deer Island - August 1996 (Sample size = 5)					Future Outfall Site, August 1996 (Sample size = 5)					Discovery, August 1996 (Sample size = 5)				
	Average	SD	SE	Range		Average	SD	SE	Range		Average	SD	SE	Range		Average	SD	SE	Range	
ALDRIN	1.30	0.00	0.00	1.30	1.30	1.30	0.00	0.00	1.30	1.30	1.30	0.00	0.00	1.30	1.30	1.30	0.00	0.00	1.30	1.30
DIELDRIN	0.48	0.00	0.00	0.48	0.48	5.60	1.34	0.60	4.00	7.50	1.65	1.61	0.72	0.48	3.60	9.28	2.15	0.96	6.80	12.00
ENDRIN	0.27	0.00	0.00	0.27	0.27	0.27	0.00	0.00	0.27	0.27	0.27	0.00	0.00	0.27	0.27	0.27	0.00	0.00	0.27	0.27
TOTAL	2.05	0.00	0.00	2.05	2.05	7.17	1.34	0.60	5.57	9.07	3.22	1.61	0.72	2.05	5.17	10.85	2.15	0.96	8.37	13.57
ALPHA-CHLORDANE	4.80	1.05	0.61	3.70	5.80	20.00	4.00	1.79	14.00	24.00	3.02	0.48	0.21	2.50	3.80	15.80	3.19	1.43	12.00	20.00
HEPTACHLOR	0.24	0.00	0.00	0.24	0.24	3.96	0.81	0.36	3.00	5.00	0.42	0.26	0.11	0.24	0.80	1.56	0.30	0.14	1.20	2.00
HEPTACHLOREPOXIDE	0.45	0.00	0.00	0.45	0.45	0.45	0.00	0.00	0.45	0.45	0.45	0.00	0.00	0.45	0.45	0.42	0.07	0.03	0.30	0.45
HEXACHLOROBENZENE	0.98	0.49	0.28	0.45	1.40	0.92	0.14	0.06	0.76	1.10	0.65	0.10	0.05	0.56	0.79	1.48	0.25	0.11	1.30	1.90
LINDANE	0.30	0.00	0.00	0.30	0.30	0.30	0.00	0.00	0.30	0.30	0.60	0.67	0.30	0.30	1.80	0.30	0.00	0.00	0.30	0.30
MIREX	0.78	0.12	0.07	0.64	0.86	0.64	0.13	0.06	0.51	0.79	0.90	0.09	0.04	0.80	1.00	0.26	0.05	0.02	0.18	0.30
TRANS_NONACHLOR	4.97	0.59	0.34	4.30	5.40	17.00	2.92	1.30	13.00	20.00	3.96	0.47	0.21	3.40	4.50	13.80	1.79	0.80	12.00	16.00
TOTAL	12.52	1.86	1.07	10.73	14.44	43.27	7.79	3.48	32.19	51.58	9.99	1.23	0.55	8.25	11.17	33.62	5.13	2.30	28.00	40.33
2,4-DDD	7.63	0.91	0.52	6.60	8.30	9.44	2.25	1.01	6.10	11.00	3.12	0.38	0.17	2.60	3.50	16.00	2.92	1.30	13.00	20.00
2,4-DDE	0.73	0.00	0.00	0.73	0.73	0.73	0.00	0.00	0.73	0.73	0.73	0.00	0.00	0.73	0.73	0.73	0.00	0.00	0.73	0.73
2,4-DDT	0.46	0.00	0.00	0.46	0.46	6.16	0.90	0.40	5.00	7.00	1.78	0.19	0.09	1.50	2.00	5.32	0.85	0.38	4.60	6.70
4,4-DDD	23.33	6.35	3.67	16.00	27.00	20.20	4.27	1.91	14.00	25.00	6.18	0.71	0.32	5.30	7.00	50.20	10.28	4.60	39.00	62.00
4,4-DDE	20.00	2.65	1.53	17.00	22.00	31.40	5.86	2.62	23.00	37.00	12.00	1.00	0.45	11.00	13.00	42.40	8.56	3.83	33.00	55.00
4,4-DDT	5.80	0.87	0.50	4.80	6.40	17.20	3.49	1.56	13.00	21.00	5.94	0.54	0.24	5.60	6.90	4.58	1.27	0.57	2.90	6.20
TOTAL	57.96	10.74	6.20	45.59	64.89	85.13	16.48	7.37	61.83	100.73	29.75	2.60	1.16	27.13	33.13	119.23	19.22	8.60	105.73	150.63
TOTAL PESTICIDES	72.53	12.39	7.15	58.37	81.38	135.57	25.50	11.40	99.59	161.38	42.96	4.52	2.02	37.43	47.65	163.70	25.99	11.62	142.10	204.53

TABLE 3-20 (Page 1 of 2)
PCB Concentration in 1996 Mussels
(ng/g dry weight)

Parameter	Gloucester Predeployment			Deer Island, August 1996				
	M9611H7TC1	M9611H7TC2	M9611H7TC3	M9611D1H7TC1	M9611D1H7TC2	M9611D1H7TC3	M9611D1H7TC4	M9611D1H7TC5
105	6	8.4	8.6	11	18	14	17	17
126	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
138	3.4	4.8	3.5	9.7	13	10	8.2	11
170	0.74	0.92	2.4	3.4	2.8	3.9	2.1	3.4
180	22	27	28	38	53	40	47	49
195	0.032	0.081	0.14	0.7	0.48	0.25	0.28	0.35
2,2',3,3',4,4'-HEXACHLOROBIPHENYL (128)	2.7	3.4	4.7	6	8.8	6.8	7.8	8.4
2,2',3,4,5,5',6-Cl7 (187)	8.4	12	12	13	16	14	15	15
2,2',3,5'-TETRACHLOROBIPHENYL (44)	6.2	12	10	8.2	10	8.3	11	14
2,2',4,4',5,5'-HEXACHLOROBIPHENYL (153)	26	34	34	48	59	45	55	55
2,2',4,5,5'-PENTACHLOROBIPHENYL (101)	17	22	21	28	36	28	35	37
2,2',5,5'-TETRACHLOROBIPHENYL (52)	8.6	13	9.5	12	16	12	16	18
2,2',5-TRICHLOROBIPHENYL (18)	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
2,3',4,4',5-PENTACHLOROBIPHENYL (118)	17	22	22	30	40	31	39	42
2,3',4,4'-TETRACHLOROBIPHENYL (66)	11	0.57	14	12	16	11	16	18
2,4'-DICHLOROBIPHENYL (8)	1.1	0.32	0.32	1.5	2	2.2	1.9	4.6
2,4,4'-TRICHLOROBIPHENYL (28)	2.7	3.6	3.2	6.8	8.2	6.4	8.6	9.6
206	0.26	0.22	0.58	0.58	0.34	0.05	0.19	0.58
44 DD OLEPHIN (DDMU)	4.5	1	1	1	1	1	3.5	4.9
77	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
DECACHLOROBIPHENYL (209)	0.32	0.18	0.32	0.32	0.22	0.15	0.13	0.38
TOTAL PCBs	139.742	167.281	177.05	231.99	302.63	235.84	285.49	310

Shaded values indicate that a concentration of ND was reported (Not Detected. The MDL (Method Detection Limit) is used as an etimated concentration.
The value for DDMU is the Minimum reporting limit (no MDL available.)

TABLE 3-20 (Page 2 of 2)
PCB Concentration in 1996 Mussels
(ng/g dry weight)

Parameter	Future Outfall Site, August 1996					Discovery, August 1996				
	M9611D4H7TC1	M9611D4H7TC2	M9611D4H7TC3	M9611D4H7TC4	M9611D4H7TC5	M9611D6H7TC1	M9611D6H7TC2	M9611D6H7TC3	M9611D6H7TC4	M9611D6H7TC5
105	4.2	5	5.5	4.4	4.3	41	34	32	34	32
126	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
138	2.2	2.9	3.6	2.2	2.8	10	14	13	19	19
170	0.69	0.78	0.97	0.76	0.91	5.4	4.3	3.7	4.8	7.6
180	15	16	18	16	15	93	73	94	61	88
195	0.066	0.047	0.05	0.37	0.082	0.7	0.7	0.7	0.7	0.7
2,2',3,3',4,4'-HEXACHLOROBIPHENYL (128)	2	2.8	3	2.7	2.6	17	15	15	16	15
2,2',3,4,5,5',6-CI7 (187)	6.1	6.7	7	7.6	6.1	23	20	22	24	23
2,2',3,5'-TETRACHLOROBIPHENYL (44)	3.4	4.1	6	5.2	4.1	28	22	20	20	17
2,2',4,4',5,5'-HEXACHLOROBIPHENYL (153)	19	22	23	21	19	110	100	130	85	120
2,2',4,5,5'-PENTACHLOROBIPHENYL (101)	9.4	12	13	10	10	87	77	68	61	88
2,2',5,5'-TETRACHLOROBIPHENYL (52)	3.9	4.1	5.3	3.8	4	47	35	32	32	29
2,2',5-TRICHLOROBIPHENYL (18)	0.42	0.42	0.42	0.42	8.4	0.42	0.42	0.42	0.42	0.42
2,3',4,4',5-PENTACHLOROBIPHENYL (118)	11	13	14	12	12	87	68	70	54	76
2,3',4,4'-TETRACHLOROBIPHENYL (66)	4	4.2	3.7	3.8	3.6	34	29	29	27	26
2,4'-DICHLOROBIPHENYL (8)	4	2.9	2.8	4.8	9	2	2	1.2	1.4	0.73
2,4,4'-TRICHLOROBIPHENYL (28)	1	2.4	1.2	1.7	1.9	21	14	13	14	12
206	0.19	0.22	0.58	0.58	0.17	0.33	0.58	0.58	0.24	0.58
44 DD OLEPHIN (DDMU)	1	1	1	1	1	1	1	1	1	7.6
77	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
DECACHLOROBIPHENYL (209)	0.27	0.28	0.28	0.16	0.19	0.12	0.32	0.32	0.32	0.32
TOTAL PCBs	89.206	102.217	110.77	99.86	106.522	609.34	511.69	547.29	457.25	564.32

Shaded values indicate that a concentration of ND was reported (Not Detected. The MDL (Method Detection Limit) is used as an etimated concentration.
The value for DDMU is the Minimum reporting limit (no MDL available.)

TABLE 3-21
Summary PCB Concentration in 1996 Mussels
(ng/g)

Parameter	Gloucester Predeployment - June 1996 (Sample size = 3)					Deer Island - August 1996 (Sample size = 5)					Future Outfall Site, August 1996 (Sample size = 5)					Discovery, August 1996 (Sample size = 5)				
	Average	SD	SE	Range		Average	SD	SE	Range		Average	SD	SE	Range		Average	SD	SE	Range	
105	7.67	1.45	0.84	6.00	8.60	15.40	2.88	1.29	11.00	18.00	4.68	0.55	0.25	4.20	5.50	34.60	3.71	1.66	32.00	41.00
126	0.62	0.00	0.00	0.62	0.62	0.62	0.00	0.00	0.62	0.62	0.62	0.00	0.00	0.62	0.62	0.62	0.00	0.00	0.62	0.62
138	3.90	0.78	0.45	3.40	4.80	10.38	1.78	0.79	8.20	13.00	2.74	0.58	0.26	2.20	3.60	15.00	3.94	1.76	10.00	19.00
170	1.35	0.91	0.53	0.74	2.40	3.12	0.69	0.31	2.10	3.90	0.82	0.11	0.05	0.69	0.97	5.16	1.50	0.67	3.70	7.60
180	25.67	3.21	1.86	22.00	28.00	45.40	6.27	2.80	38.00	53.00	16.00	1.22	0.55	15.00	18.00	81.80	14.34	6.41	61.00	94.00
195	0.08	0.05	0.03	0.03	0.14	0.41	0.18	0.08	0.25	0.70	0.12	0.14	0.06	0.05	0.37	0.70	0.00	0.00	0.70	0.70
2,2',3,3',4,4'-HEXACHLOROBIPHENYL	3.60	1.01	0.59	2.70	4.70	7.56	1.15	0.52	6.00	8.80	2.62	0.38	0.17	2.00	3.00	15.60	0.89	0.40	15.00	17.00
2,2',3,4,5,5',6-Cl7	10.80	2.08	1.20	8.40	12.00	14.60	1.14	0.51	13.00	16.00	6.70	0.64	0.28	6.10	7.60	22.40	1.52	0.68	20.00	24.00
2,2',3,5'-TETRACHLOROBIPHENYL	9.40	2.95	1.70	6.20	12.00	10.30	2.38	1.06	8.20	14.00	4.56	1.03	0.46	3.40	6.00	21.40	4.10	1.83	17.00	28.00
2,2',4,4',5,5'-HEXACHLOROBIPHENYL	31.33	4.62	2.67	26.00	34.00	52.40	5.73	2.56	45.00	59.00	20.80	1.79	0.80	19.00	23.00	109.00	17.46	7.81	85.00	130.00
2,2',4,5,5'-PENTACHLOROBIPHENYL	20.00	2.65	1.53	17.00	22.00	32.80	4.44	1.98	28.00	37.00	10.88	1.54	0.69	9.40	13.00	76.20	11.78	5.27	61.00	88.00
2,2',5,5'-TETRACHLOROBIPHENYL	10.37	2.32	1.34	8.60	13.00	14.80	2.68	1.20	12.00	18.00	4.22	0.61	0.27	3.80	5.30	35.00	7.04	3.15	29.00	47.00
2,2',5-TRICHLOROBIPHENYL	0.42	0.00	0.00	0.42	0.42	0.42	0.00	0.00	0.42	0.42	2.02	3.57	1.60	0.42	8.40	0.42	0.00	0.00	0.42	0.42
2,3',4,4',5-PENTACHLOROBIPHENYL	20.33	2.89	1.67	17.00	22.00	36.40	5.50	2.46	30.00	42.00	12.40	1.14	0.51	11.00	14.00	71.00	12.04	5.39	54.00	87.00
2,3',4,4'-TETRACHLOROBIPHENYL	8.52	7.05	4.07	0.57	14.00	14.60	2.97	1.33	11.00	18.00	3.86	0.24	0.11	3.60	4.20	29.00	3.08	1.38	26.00	34.00
2,4'-DICHLOROBIPHENYL	0.58	0.45	0.26	0.32	1.10	2.44	1.23	0.55	1.50	4.60	4.70	2.54	1.14	2.80	9.00	1.47	0.54	0.24	0.73	2.00
2,4,4'-TRICHLOROBIPHENYL	3.17	0.45	0.26	2.70	3.60	7.92	1.32	0.59	6.40	9.60	1.64	0.56	0.25	1.00	2.40	14.80	3.56	1.59	12.00	21.00
206	0.35	0.20	0.11	0.22	0.58	0.35	0.24	0.11	0.05	0.58	0.35	0.21	0.10	0.17	0.58	0.46	0.16	0.07	0.24	0.58
44 DD OLEPHIN (DDMU)	2.17	2.02	1.17	1.00	4.50	2.28	1.82	0.81	1.00	4.90	1.00	0.00	0.00	1.00	1.00	2.32	2.95	1.32	1.00	7.60
77	0.75	0.00	0.00	0.75	0.75	0.75	0.00	0.00	0.75	0.75	0.75	0.00	0.00	0.75	0.75	0.75	0.00	0.00	0.75	0.75
DECACHLOROBIPHENYL	0.27	0.08	0.05	0.18	0.32	0.24	0.11	0.05	0.13	0.38	0.24	0.06	0.03	0.16	0.28	0.28	0.09	0.04	0.12	0.32
TOTAL PCBs	161.36	19.35	11.17	139.74	177.05	273.19	36.96	16.53	231.99	310.00	101.72	8.14	3.64	89.21	110.77	537.98	57.19	25.57	457.25	609.34

TABLE 3-22
Mercury and Lead Concentrations in 1996 Mussels
(µg/g dry weight)

Sandwich Predeployment			**Outfall site**		
Sample	Lead	Mercury	Sample	Lead	Mercury
M9611H8TC1	2.13	0.07	M9611D4H8TC1	2.09	0.27
M9611H8TC2	3.24	0.06	M9611D4H8TC2	1.30	0.08
M9611H8TC3	5.54	0.06	M9611D4H8TC3	1.45	0.21
M9611H8TC4	1.88	0.11	M9611D4H8TC4	1.60	0.07
M9611H8TC5	1.49	0.35	M9611D4H8TC5	1.40	0.09
Mean	2.86	0.13	Mean	1.57	0.15
Standard Deviation	1.64	0.12	Standard Deviation	0.31	0.09
Standard Error	0.73	0.06	Standard Error	0.14	0.04
Minimum Concentration	1.49	0.06	Minimum Concentration	1.30	0.07
Maximum Concentration	5.54	0.35	Maximum Concentration	2.09	0.27
Deer Island			**Discovery**		
Sample	Lead	Mercury	Sample	Lead	Mercury
M9611D1H8TC1	6.35	0.19	M9611D6H8TC1	8.14	0.14
M9611D1H8TC2	8.42	0.21	M9611D6H8TC2	11.29	0.10
M9611D1H8TC3	6.10	0.14	M9611D6H8TC3	8.65	0.14
M9611D1H8TC4	5.18	0.13			
M9611D1H8TC5	5.31	0.11			
Mean	6.27	0.15	Mean	9.36	0.13
Standard Deviation	1.30	0.04	Standard Deviation	1.69	0.02
Standard Error	0.58	0.02	Standard Error	0.98	0.01
Minimum Concentration	5.18	0.11	Minimum Concentration	8.14	0.10
Maximum Concentration	8.42	0.21	Maximum Concentration	11.29	0.14

TABLE 3-23

Comparison of FDA Legal Limits to Mean Concentrations (wet weight) of Select Compounds In Blue Mussel Tissues - 1996

Compound/Analyte	Deer Island Mean	Deer Island S.E.	Future Outfall Site Mean	Future Outfall Site S.E.	Discovery Mean	Discovery S.E.	Sandwich (predeployment) Mean	Sandwich (predeployment) S.E.	Comparison Values
Lead (ppm)	0.89	0.09	0.30	0.01	1.53	0.43	0.51	0.13	2 [1]
Mercury (ppm)	0.02	0.002	0.03	0.01	0.02	0.003	0.02	0.01	1, 0.8, 0.05 [2]

Notes:

[1] Massachusetts Water Resources Authority (MWRA) 1997. Contingency Plan. The value listed is a Caution Level based on an EPA risk assessement of lead in drinking water.

[2] U.S. EPA 1989. Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish. EPA-503/8-89-002. Office of Marine and Estuarine Protection (WH-556F) and the Office of Water Regulations and Standards (WH-552), Washington, D.C. Values listed are the US FDA Legal Limit, Warning Level (80% of FDA Limit) and Caution Level (50% of FDA Limit), respectively. The Caution and Warning Levels apply to the outfall site.

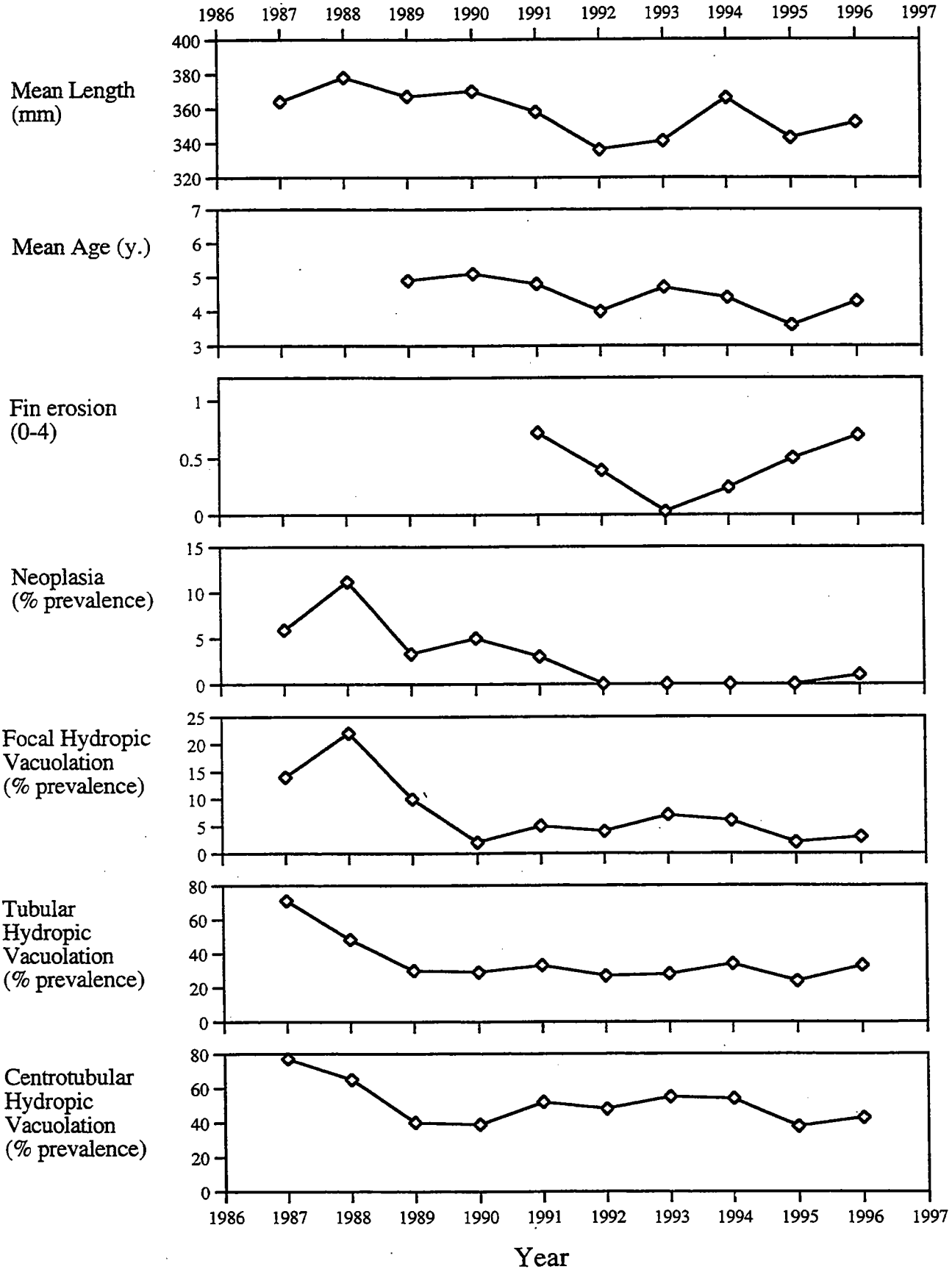
April 9, 1998

Table 3-24
Concentrations of Selected Organic Compounds Normalized for Lipids [1]
Mussel Tissue, 1992 - 1996
ng/g Lipid

Parameter	Year	Gloucester		Deer Island		Future Outfall Site		Discovery	
		Average	S.E.	Average	S.E.	Average	S.E.	Average	S.E.
Total DDT	1992	314.58	18.15	492.16	45.98	278.18	15.44	2019.61	377.62
	1993	1023.50	213.06	966.15	145.01	421.13	32.38	2450.94	504.18
	1994	631.47	31.87	999.40	49.14	334.54	26.86	1571.54	82.35
	1995	327.78	8.56	399.74	7.94	NA	NA	925.15	28.23
	1996	737.61	151.00	616.91	21.58	276.01	8.78	1206.73	141.43
	Baseline Mean	**606.99**	**133.15**	**694.87**	**122.60**	**327.46**	**34.03**	**1634.79**	**274.32**
Total PAHs [2]	1992	4493.75	487.62	37921.57	3332.02	6547.62	3467.49	69529.41	8290.85
	1993	2350.00	288.22	10230.77	1144.49	2338.03	156.16	24924.53	1409.23
	1994	6614.48	1230.90	16960.00	1487.15	2190.75	83.56	41443.24	5513.68
	1995	1371.67	93.38	4203.07	149.19	NA	NA	13876.94	384.48
	1996	4433.67	917.28	7407.71	758.81	745.69	27.19	24502.29	2010.84
	Baseline Mean	**3852.71**	**916.23**	**15344.62**	**6023.32**	**2955.52**	**1250.09**	**34855.28**	**9725.20**
Total PCBs	1992	1358.33	94.58	2607.84	167.24	1057.02	65.94	12784.31	1744.37
	1993	2982.75	512.63	4944.31	663.15	1556.20	44.16	11239.06	981.68
	1994	2555.38	77.93	3214.00	119.33	1596.92	114.84	9196.72	1313.07
	1995	1018.04	27.70	1469.84	33.23	NA	NA	4530.34	134.95
	1996	2079.33	430.21	2005.64	137.51	938.59	17.04	5385.90	404.87
	Baseline Mean	**1998.77**	**364.45**	**2848.33**	**599.79**	**1287.18**	**169.01**	**8627.27**	**1608.07**

Notes:
[1] Formula: concentration/percent lipid.
[2] For mussels, total PAH represents the 24 NOAA PAH analytes listed in the third column of Table 3-15.
NA - Not Available (The 1995 LNB array was lost).

DEER ISLAND (STATION 1)



Liver slices examined per fish: 1 for 1987 to 1990, 3 thereafter

FIGURE 3-1a

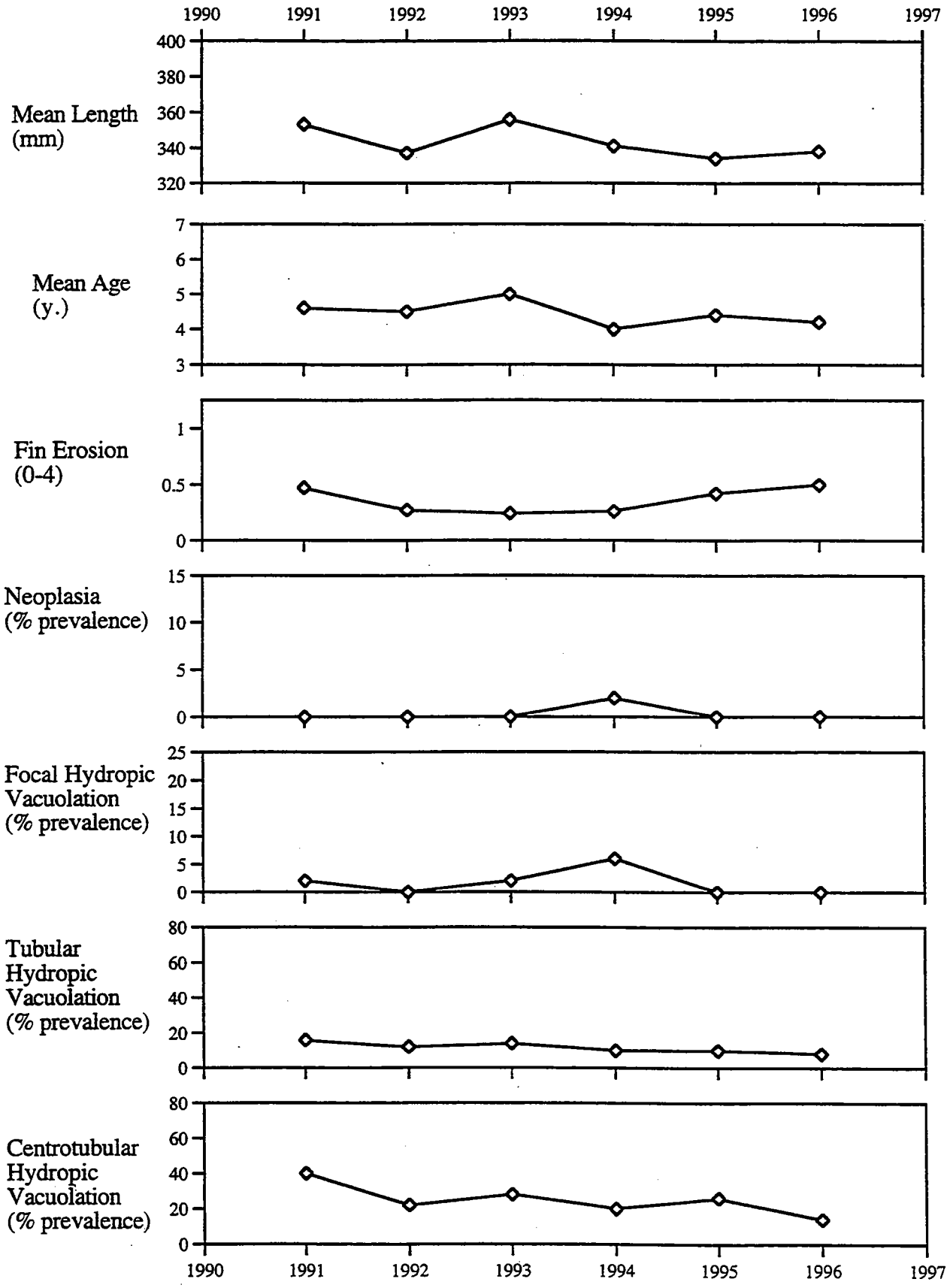

NANTASKET BEACH (STATION 2)
1990
1991
1992
1993
1994
1995
1996
1997
Mean Length (mm)
400
380
360
340
320
Mean Age (y.)
7
6
5
4
3
Fin Erosion (0-4)
1
0.5
0
Neoplasia (% prevalence)
15
10
5
0
Focal Hydropic Vacuolation (% prevalence)
25
20
15
10
5
0
Tubular Hydropic Vacuolation (% prevalence)
80
60
40
20
0
Centrotubular Hydropic Vacuolation (% prevalence)
80
60
40
20
0
Year

FIGURE 3-1b

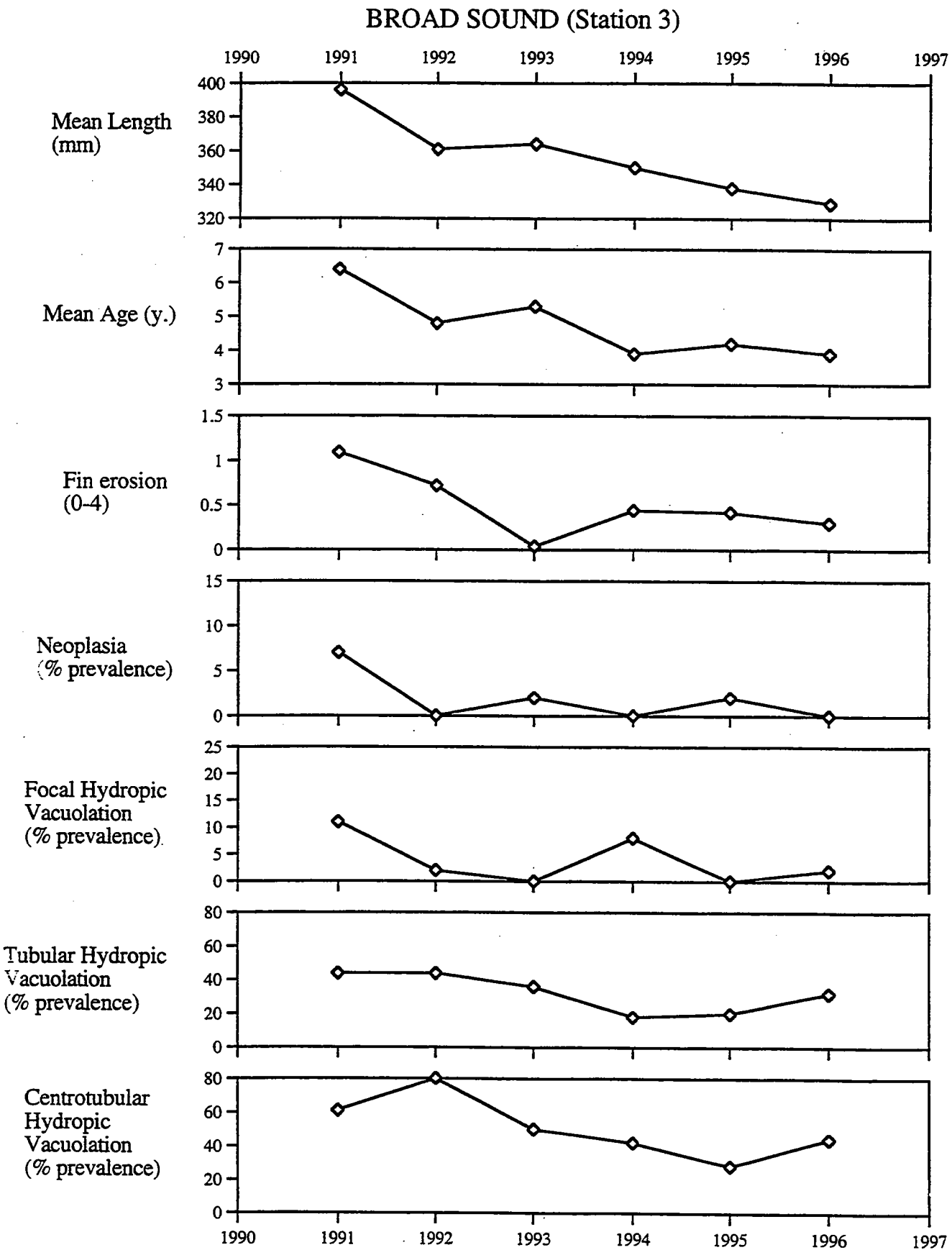

BROAD SOUND (Station 3)
1990
1991
1992
1993
1994
1995
1996
1997
Mean Length (mm)
400
380
360
340
320
Mean Age (y.)
7
6
5
4
3
Fin erosion (0-4)
1.5
1
0.5
0
Neoplasia (% prevalence)
15
10
5
0
Focal Hydropic Vacuolation (% prevalence)
25
20
15
10
5
0
Tubular Hydropic Vacuolation (% prevalence)
80
60
40
20
0
Centrotubular Hydropic Vacuolation (% prevalence)
80
60
40
20
0
Year

FIGURE 3-1c

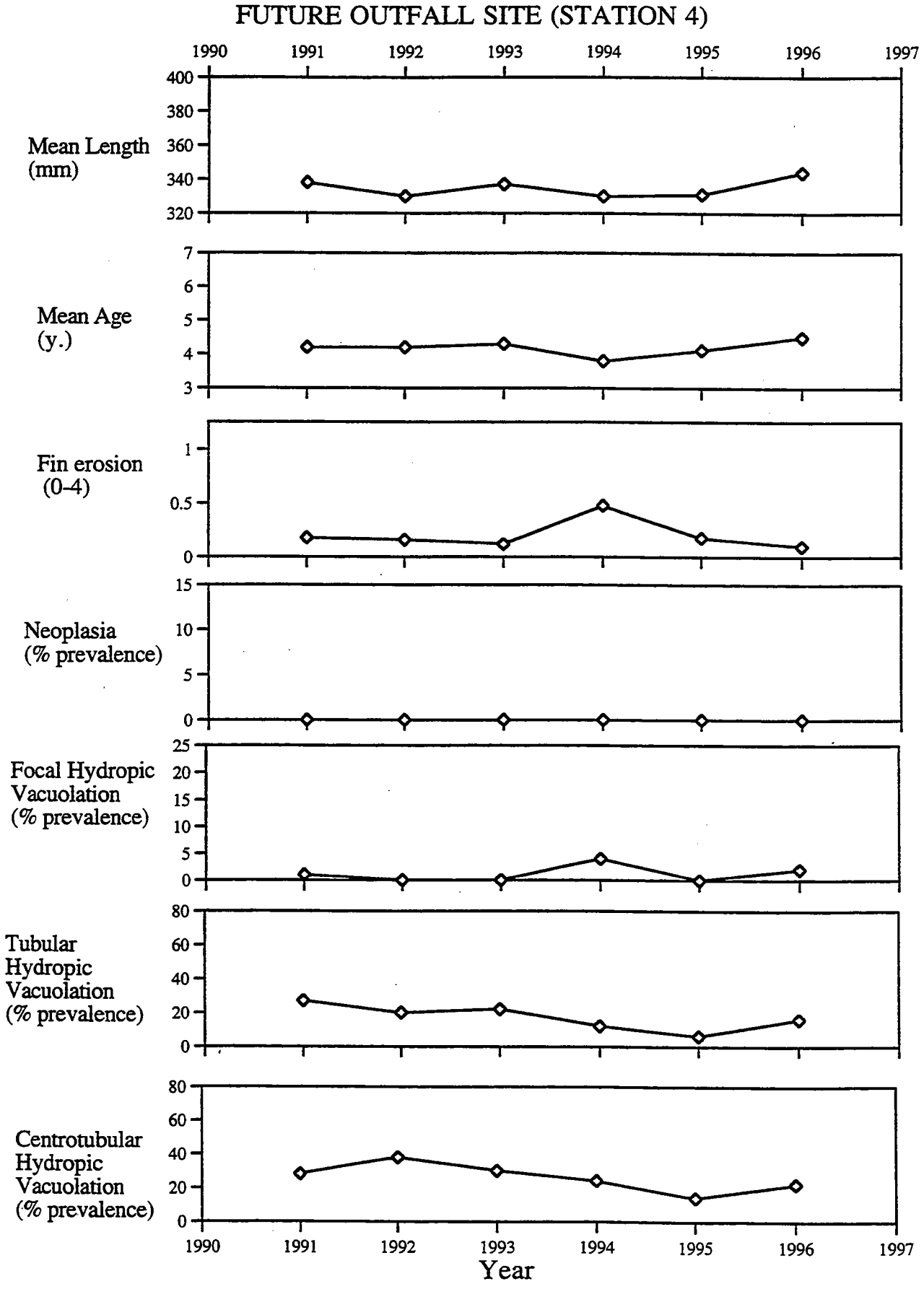
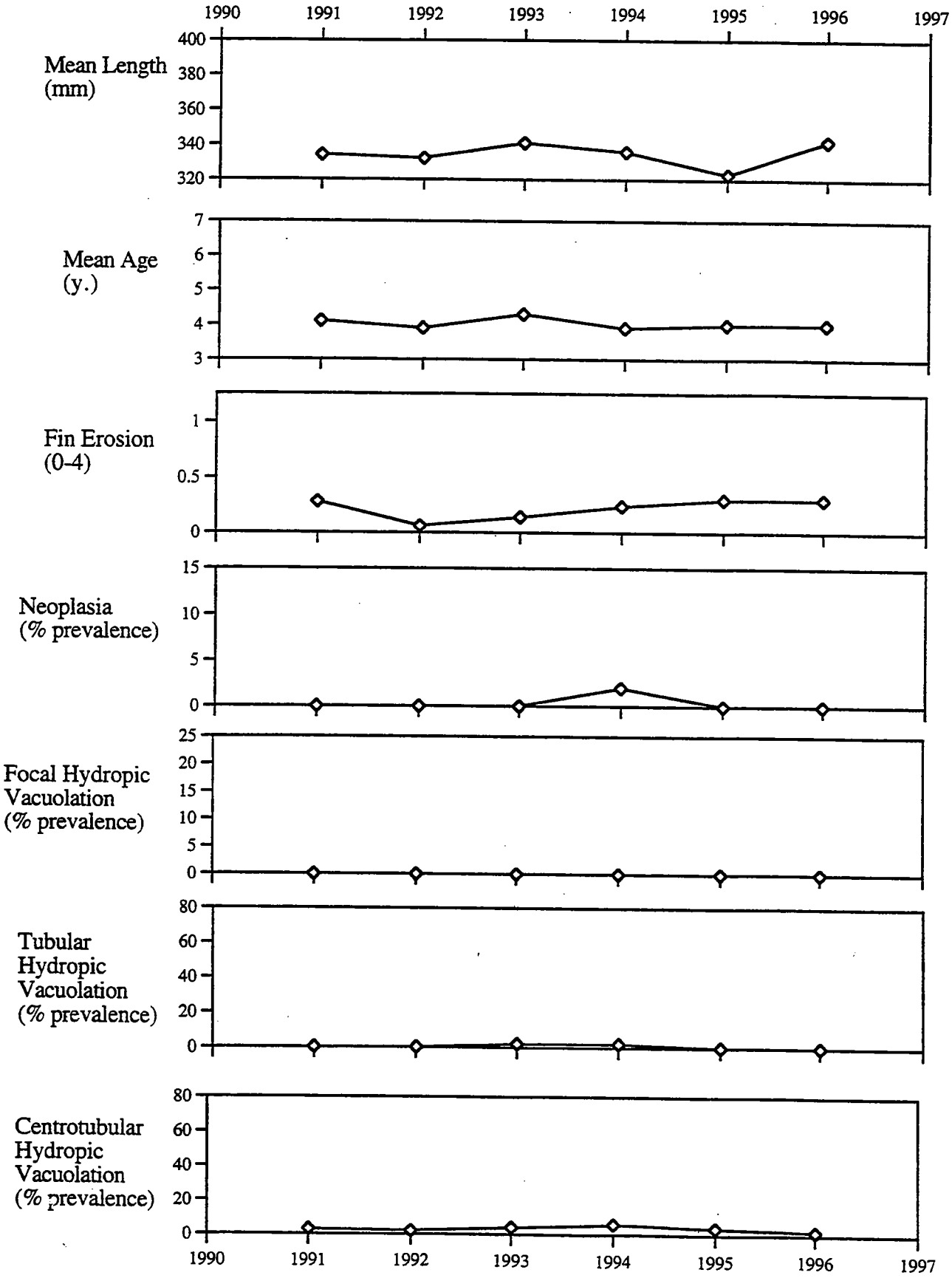

FUTURE OUTFALL SITE (STATION 4)
1990
1991
1992
1993
1994
1995
1996
1997
Mean Length (mm)
400
380
360
340
320
Mean Age (y.)
7
6
5
4
3
Fin erosion (0-4)
1
0.5
0
Neoplasia (% prevalence)
15
10
5
0
Focal Hydropic Vacuolation (% prevalence)
25
20
15
10
5
0
Tubular Hydropic Vacuolation (% prevalence)
80
60
40
20
0
Centrotubular Hydropic Vacuolation (% prevalence)
80
60
40
20
0
1990
1991
1992
1993
1994
1995
1996
1997
Year

FIGURE 3-1d

EASTERN CAPE COD BAY (STATION 5)



Year

FIGURE 3-1e

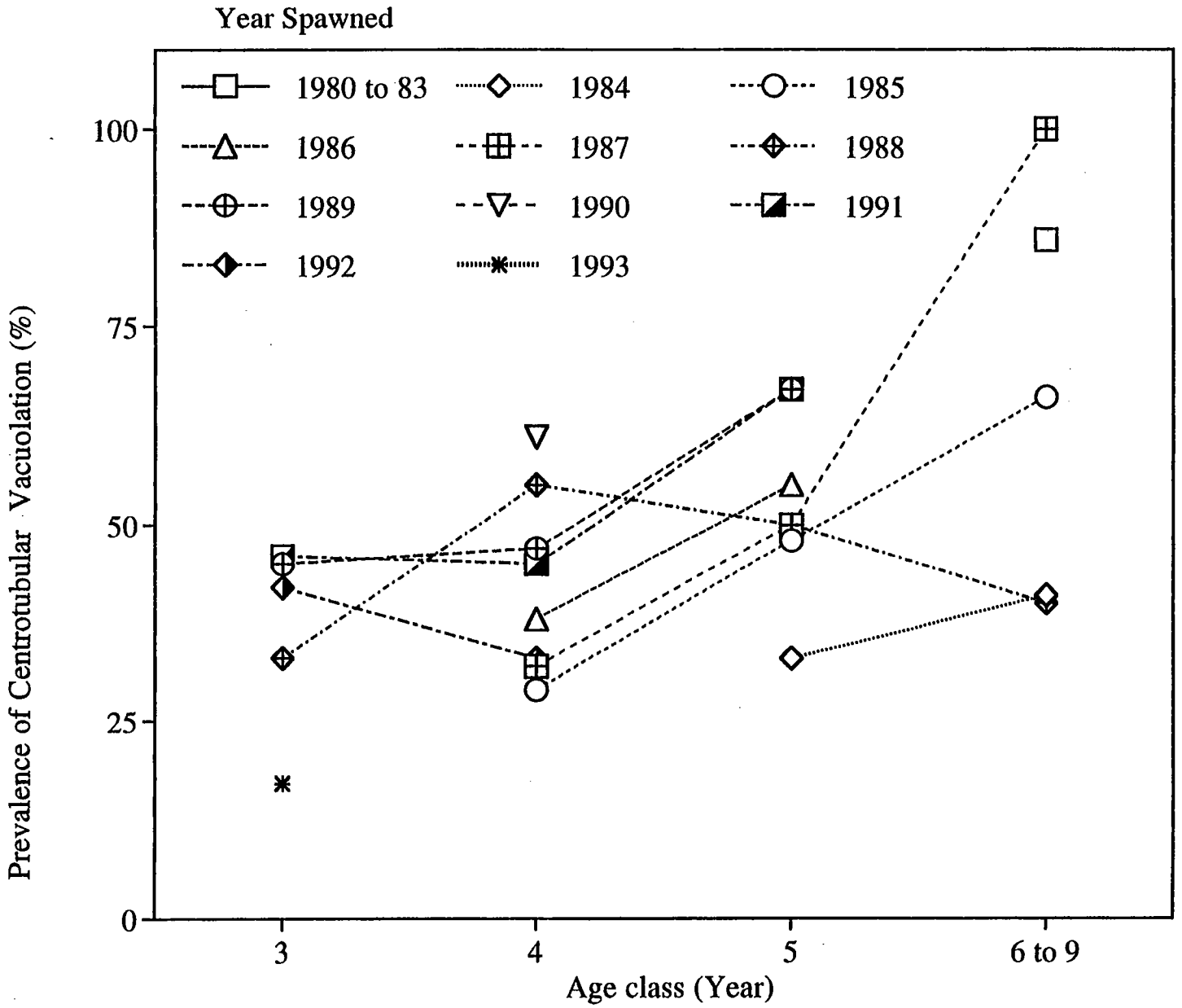


FIGURE 3-2 Progression of hydropic vacuolation through sucessive cohorts of winter flounder. Data points with N<5 omitted.

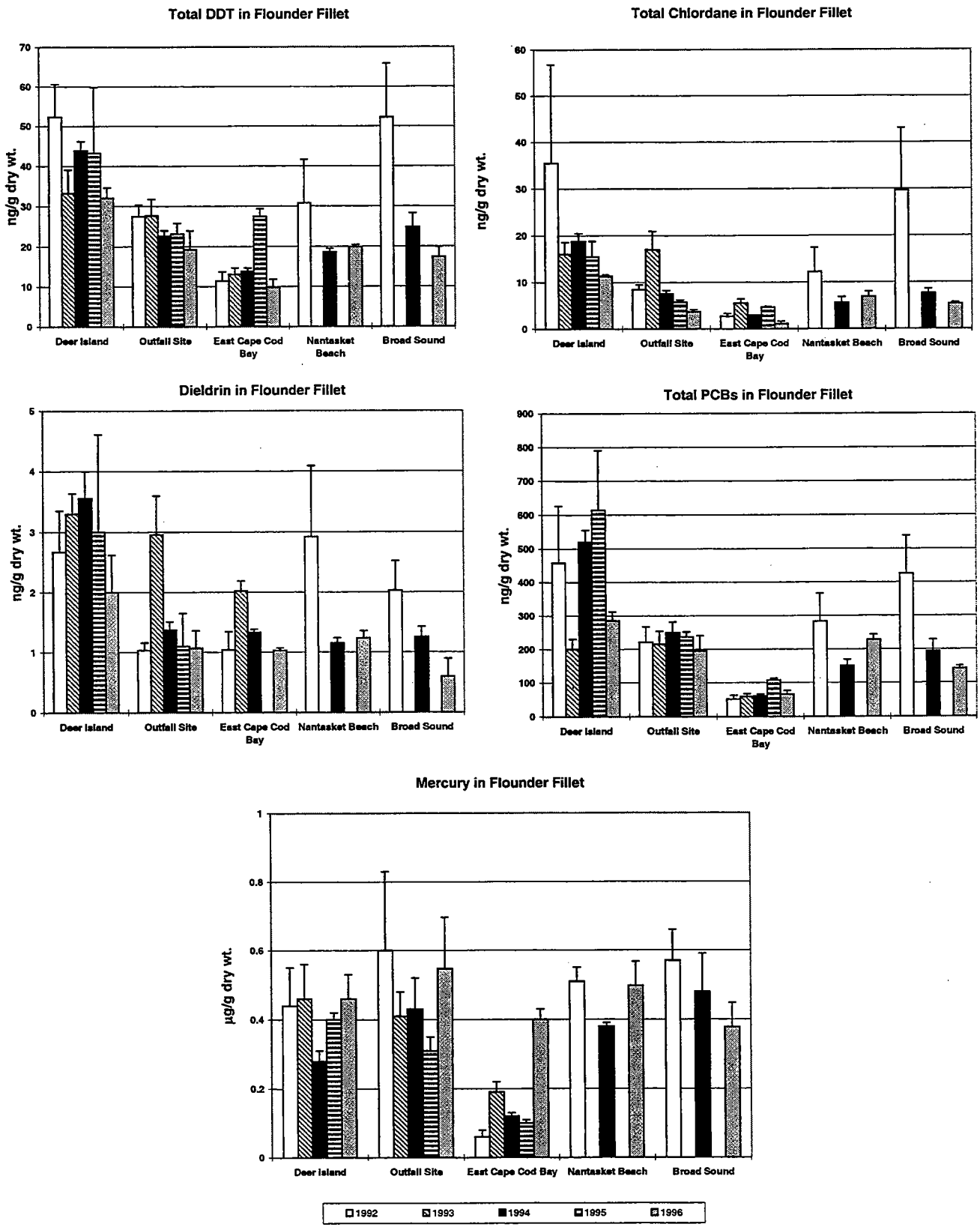


Figure 3-3
Comparison of Target Analytes in Flounder Filet, 1992-1996

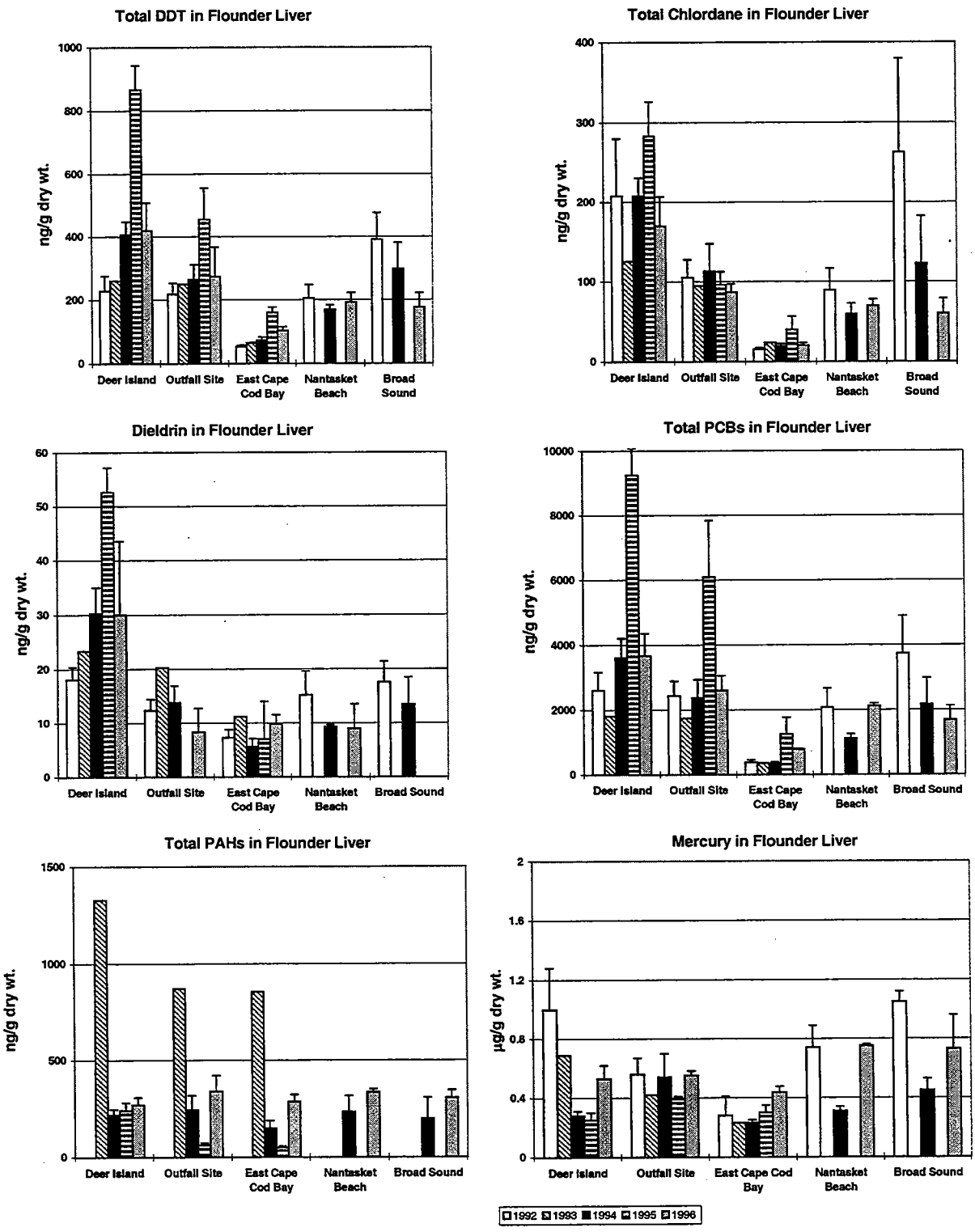


Figure 3-4
Comparison of Target Analytes in Flounder Liver, 1992-1996

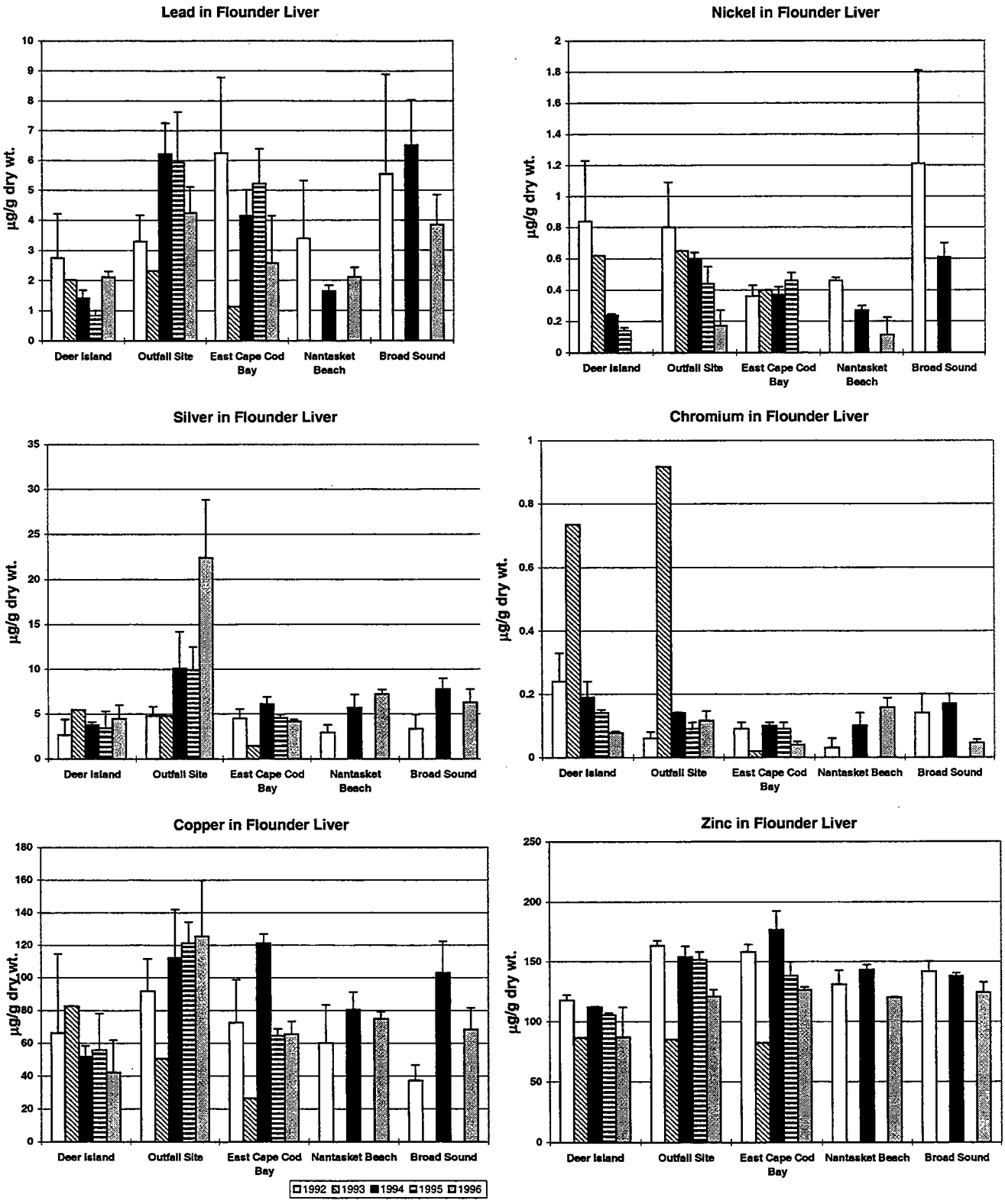


Figure 3-5
Comparison of Trace Metals in Flounder Liver, 1992-1996

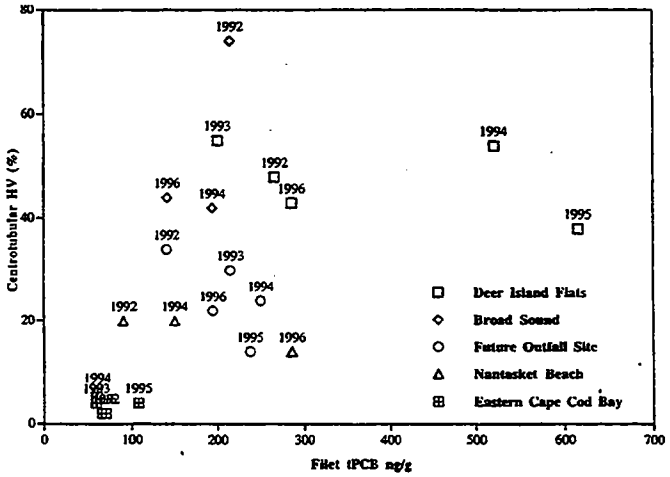


FIGURE 3-6a

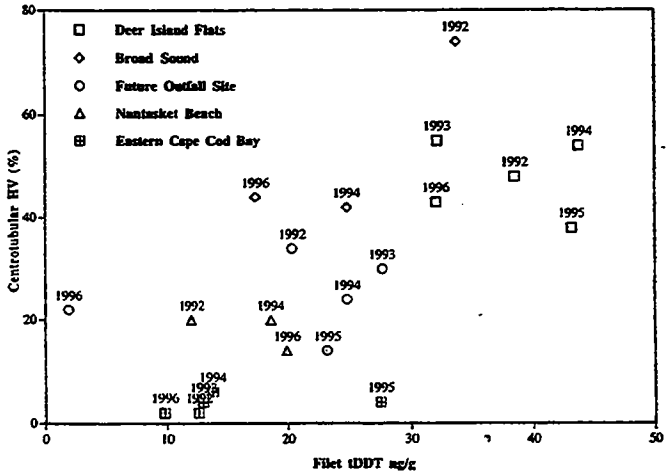


FIGURE 3-6b

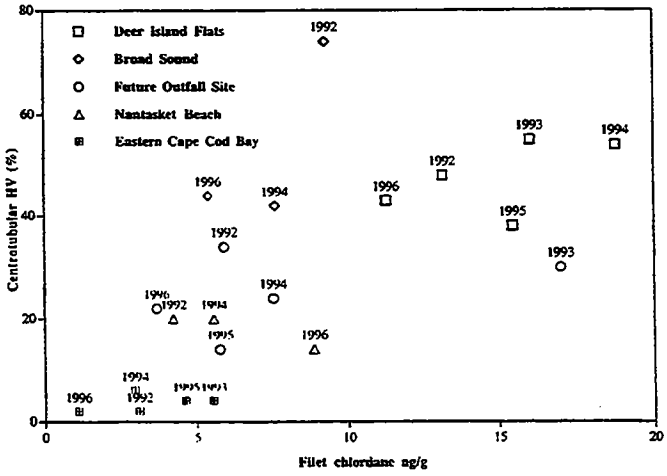


FIGURE 3-6c

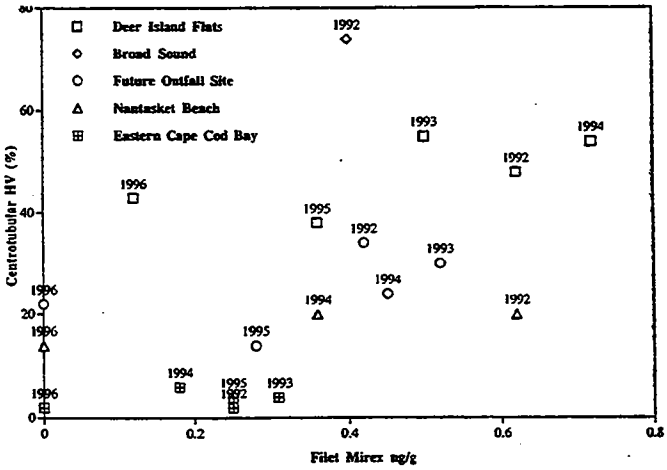


FIGURE 3-6d

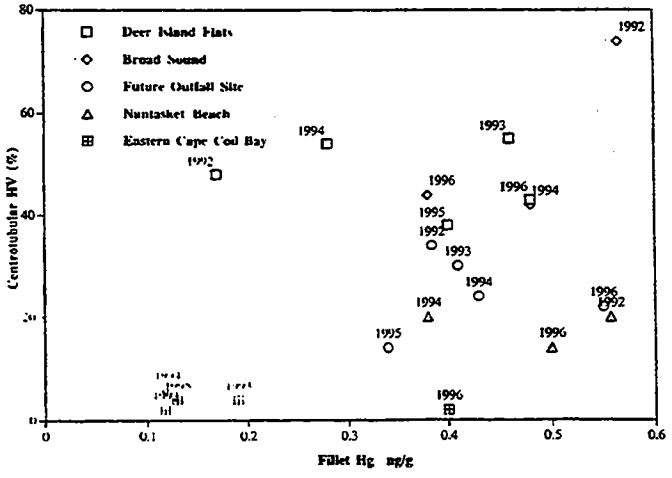


FIGURE 3-6e

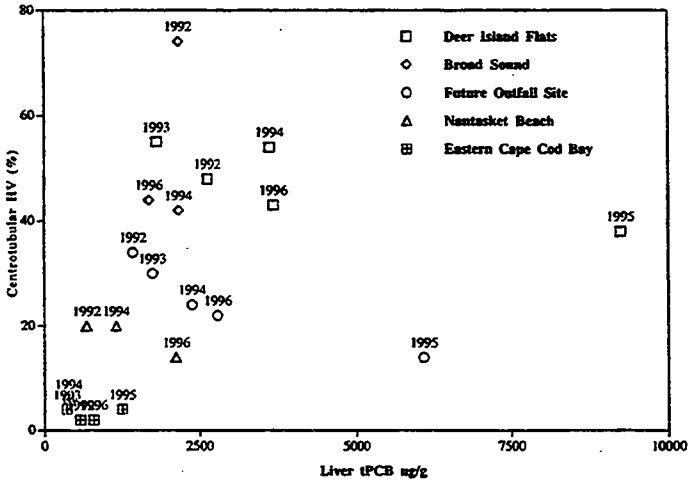


FIGURE 3-7a

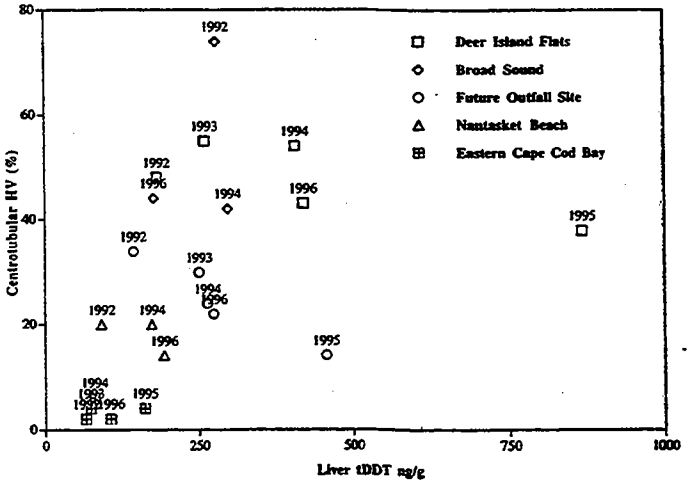


FIGURE 3-7b

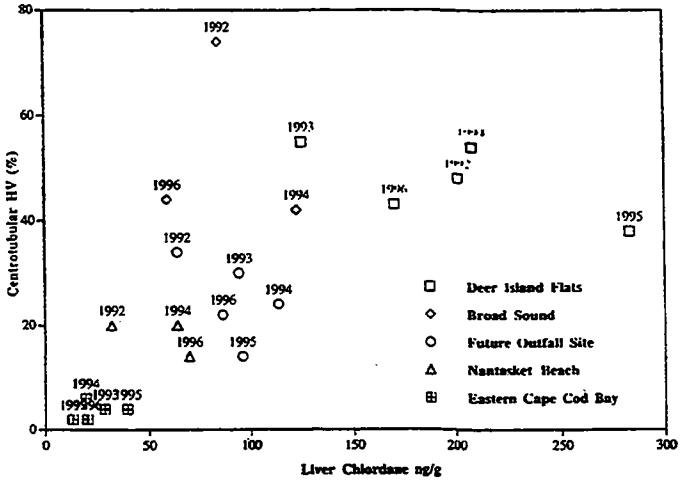
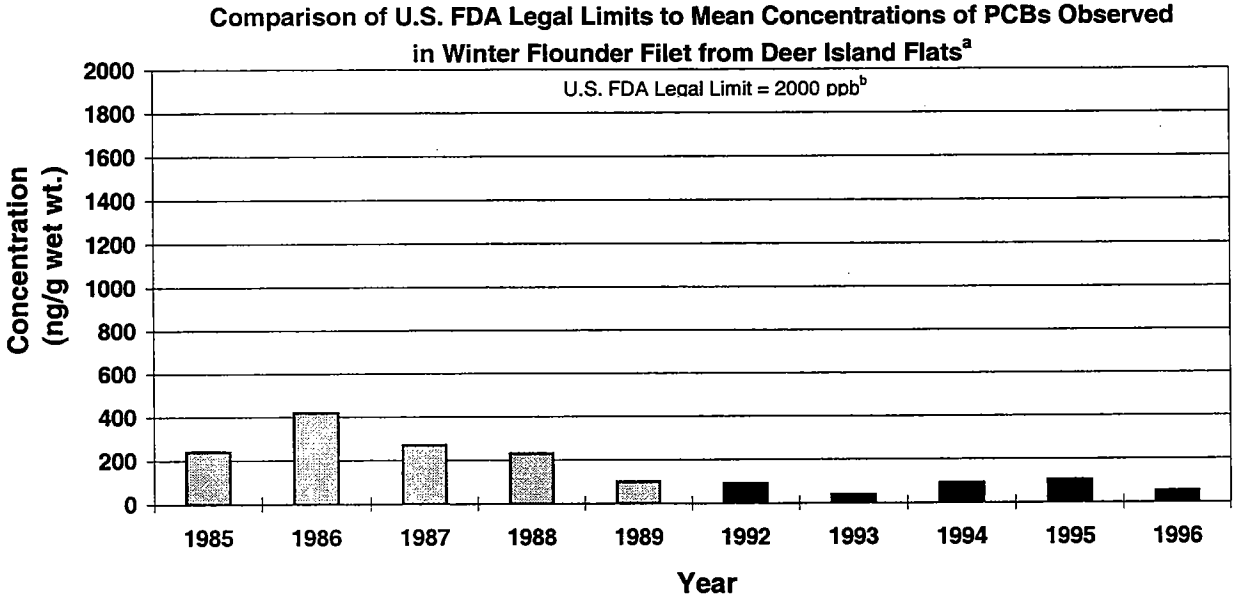
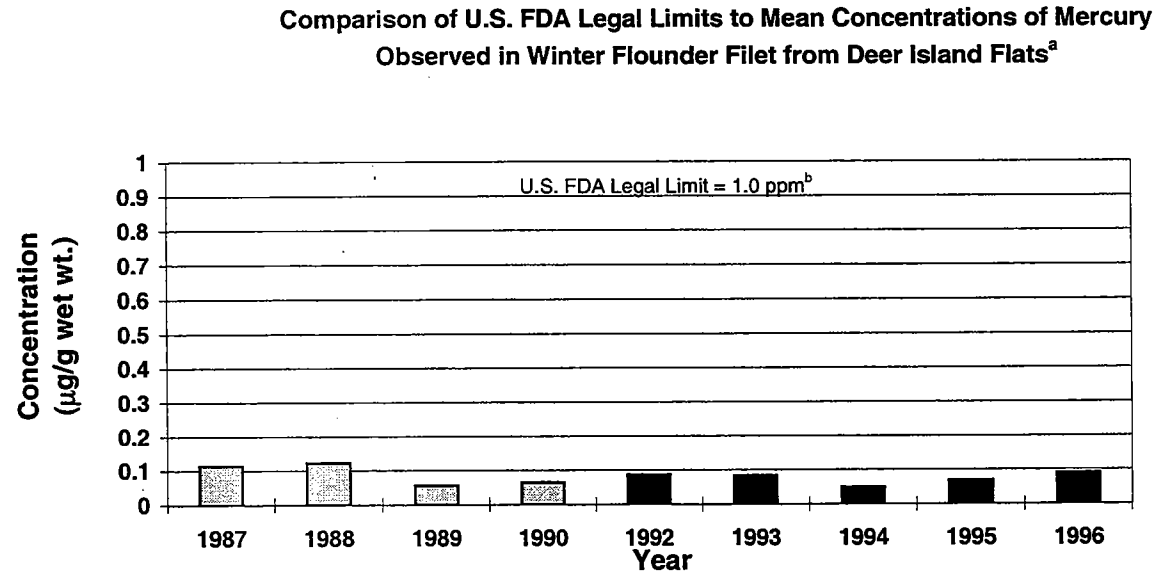


FIGURE 3-7c

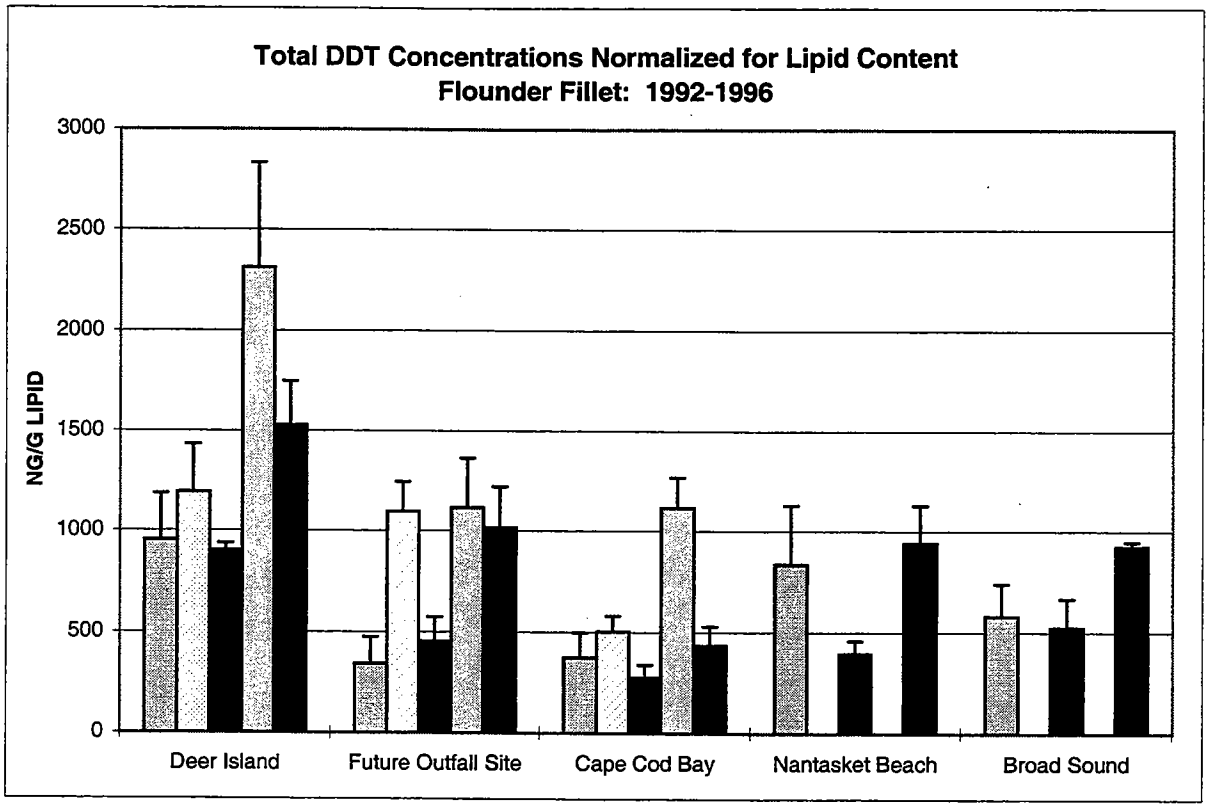




[a] 1985-1991 data is from Schwartz et al., *PCBs in Winter Flounder, American Lobster, and Bivalve Molluscs from Boston Harbor, Salem Harbor and Coastal Massachusetts:1984-1989* or *Metal Concentrations in Winter Flounder, American Lobster, and Bivalve Molluscs from Boston Harbor, Salem Harbor and Coastal Massachusetts.*, 1991. 1992-1994 data are from Hillman and Peven, *1994 Annual Fish and Shellfish Report*, 1995. 1995 data are from Mitchell, *1995 Annual Fish and Shellfish Report.* *1996 data are presented in this report.*

[b] U.S.EPA, *Assessing Human Health Risks From Chemically Contaminated Fish and Shellfish*, 1989.

Figure 3-8
Comparison of Winter Flounder Tissue Concentrations of PCBs and Mercury to U.S. FDA Legal Limits


Total DDT Concentrations Normalized for Lipid Content
Flounder Fillet: 1992-1996
NG/G LIPID
3000
2500
2000
1500
1000
500
0
Deer Island
Future Outfall Site
Cape Cod Bay
Nantasket Beach
Broad Sound

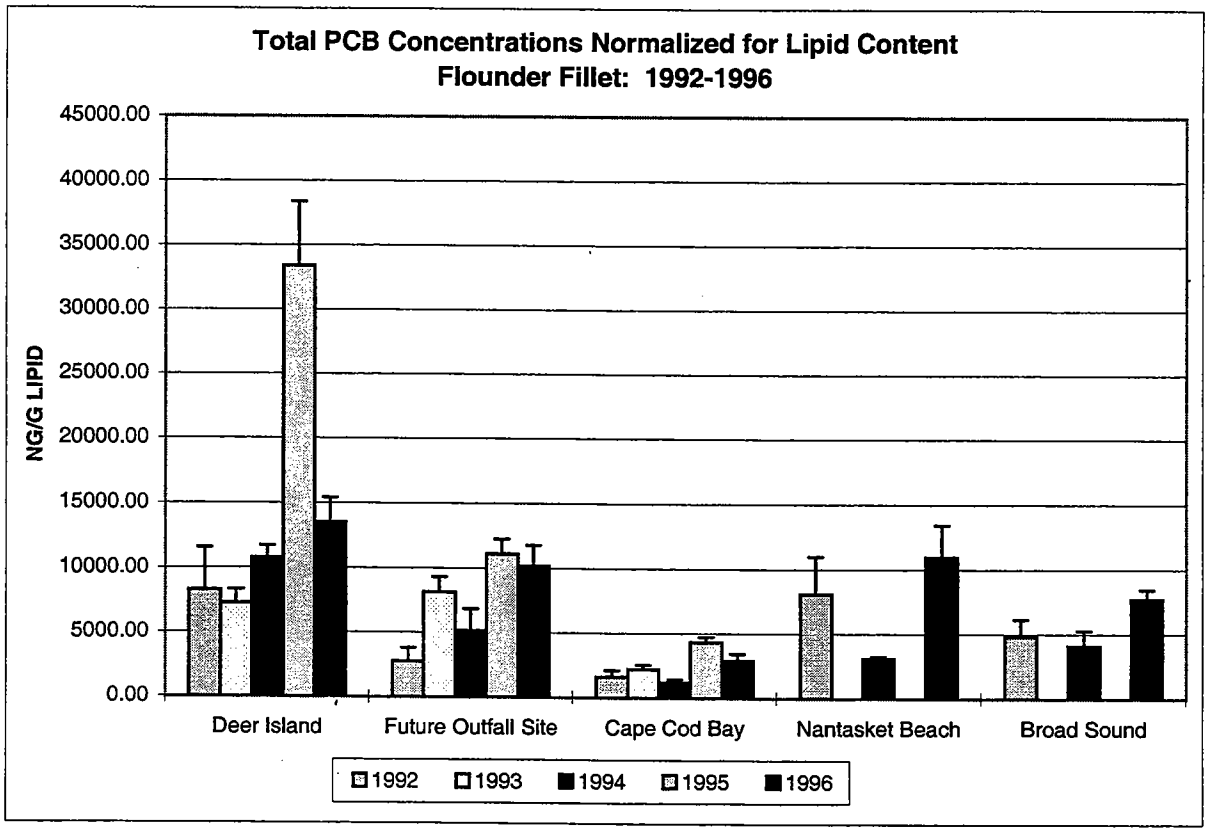
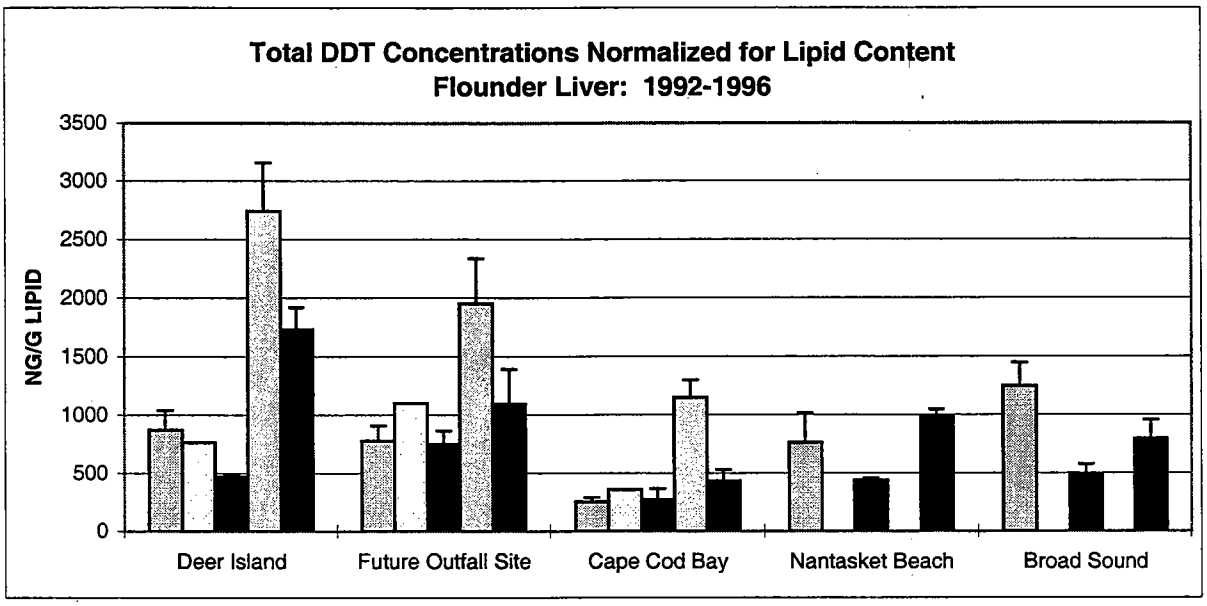
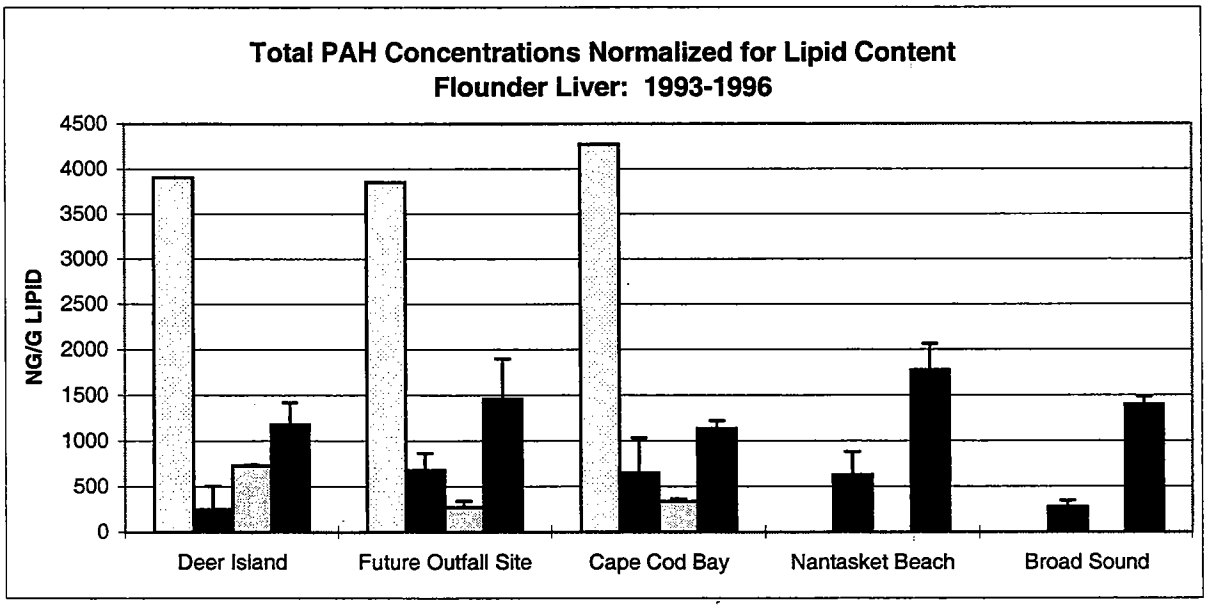

Total PCB Concentrations Normalized for Lipid Content
Flounder Fillet: 1992-1996
NG/G LIPID
45000.00
40000.00
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
Deer Island
Future Outfall Site
Cape Cod Bay
Nantasket Beach
Broad Sound
1992
1993
1994
1995
1996

Figure 3- 9a


Total DDT Concentrations Normalized for Lipid Content
Flounder Liver: 1992-1996
NG/G LIPID
3500
3000
2500
2000
1500
1000
500
0
Deer Island
Future Outfall Site
Cape Cod Bay
Nantasket Beach
Broad Sound


Total PAH Concentrations Normalized for Lipid Content
Flounder Liver: 1993-1996
NG/G LIPID
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Deer Island
Future Outfall Site
Cape Cod Bay
Nantasket Beach
Broad Sound

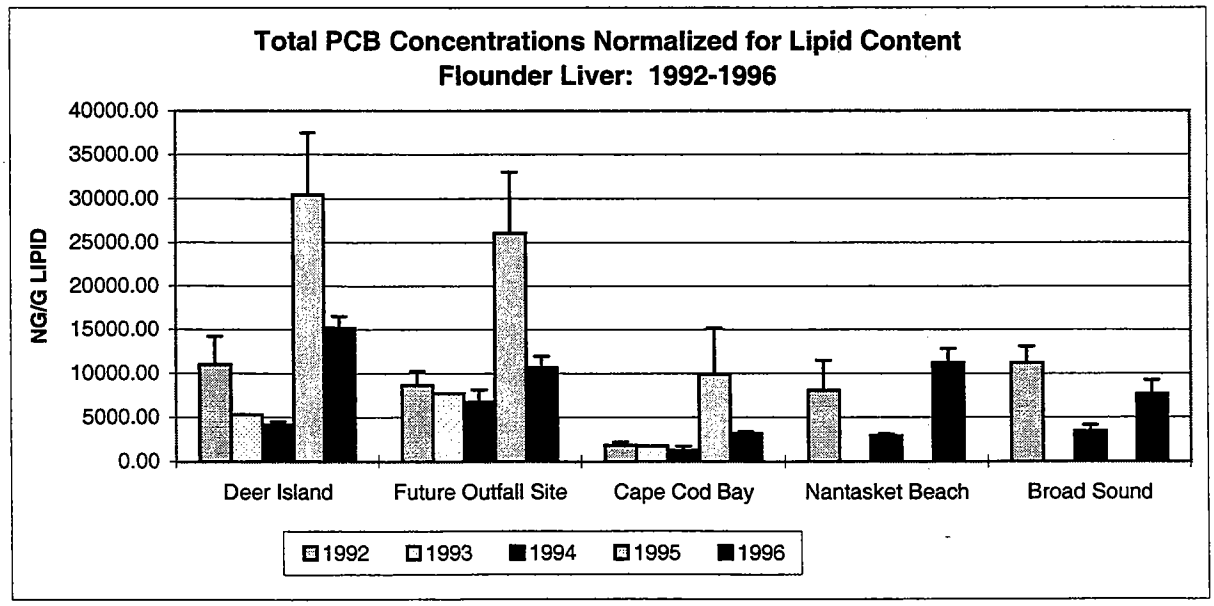

Total PCB Concentrations Normalized for Lipid Content
Flounder Liver: 1992-1996
NG/G LIPID
40000.00
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
Deer Island
Future Outfall Site
Cape Cod Bay
Nantasket Beach
Broad Sound
1992
1993
1994
1995
1996

Figure 3- 9b

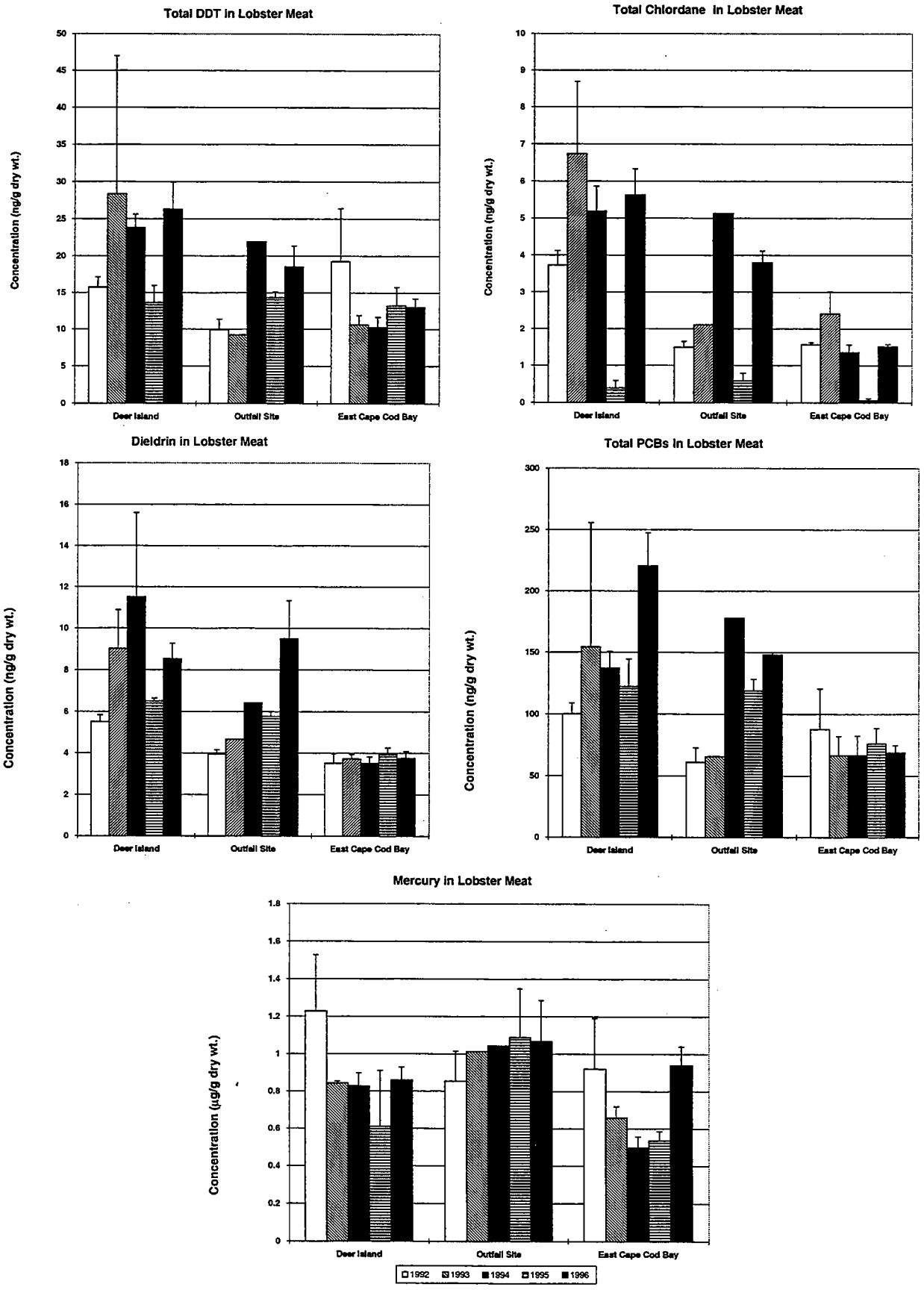


Figure 3-10
Comparison of Target Analytes in Lobster Meat 1992-1996

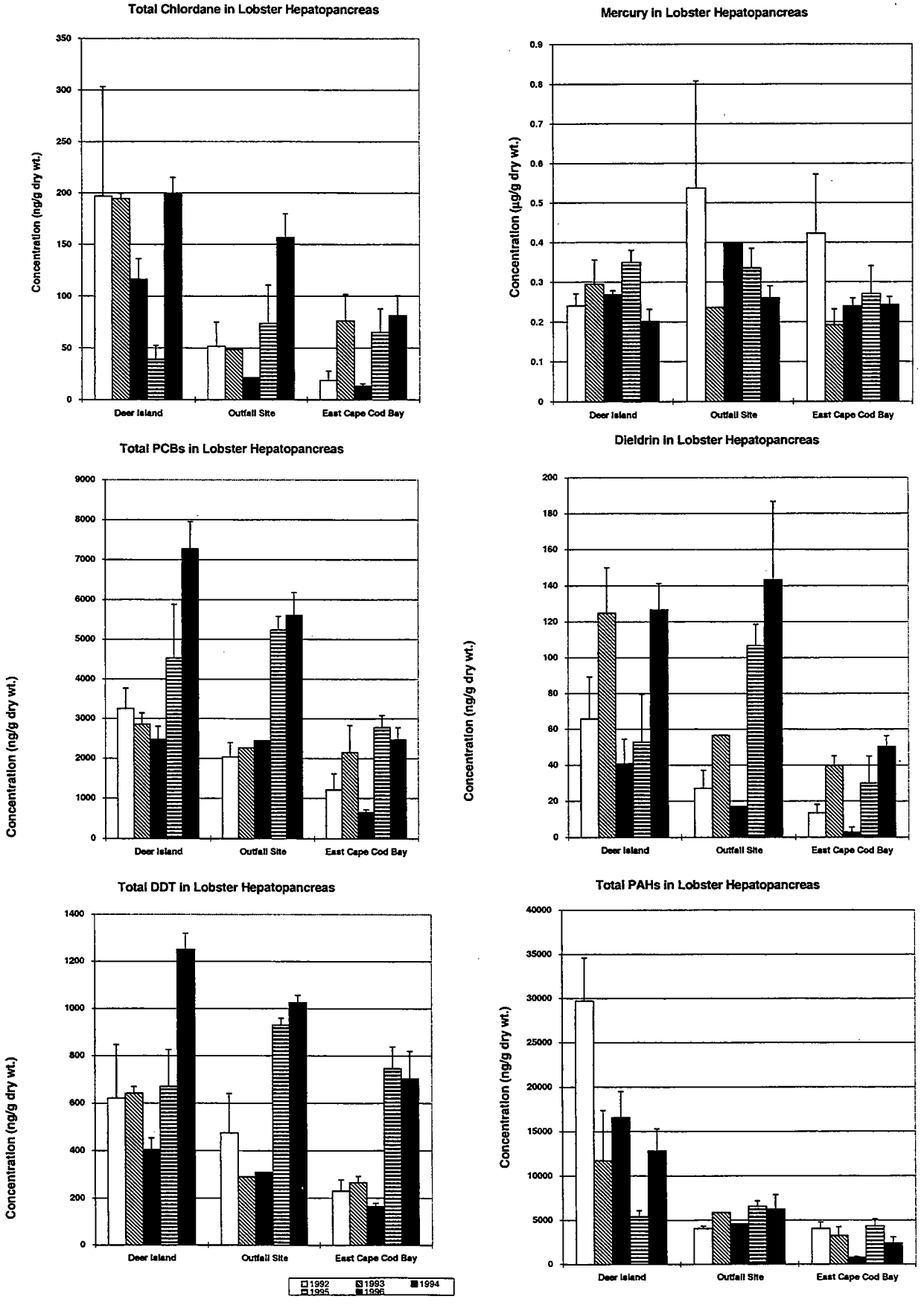


Figure 3-11
Comparison of Target Analytes in Lobster Hepatopancreas, 1992-1996

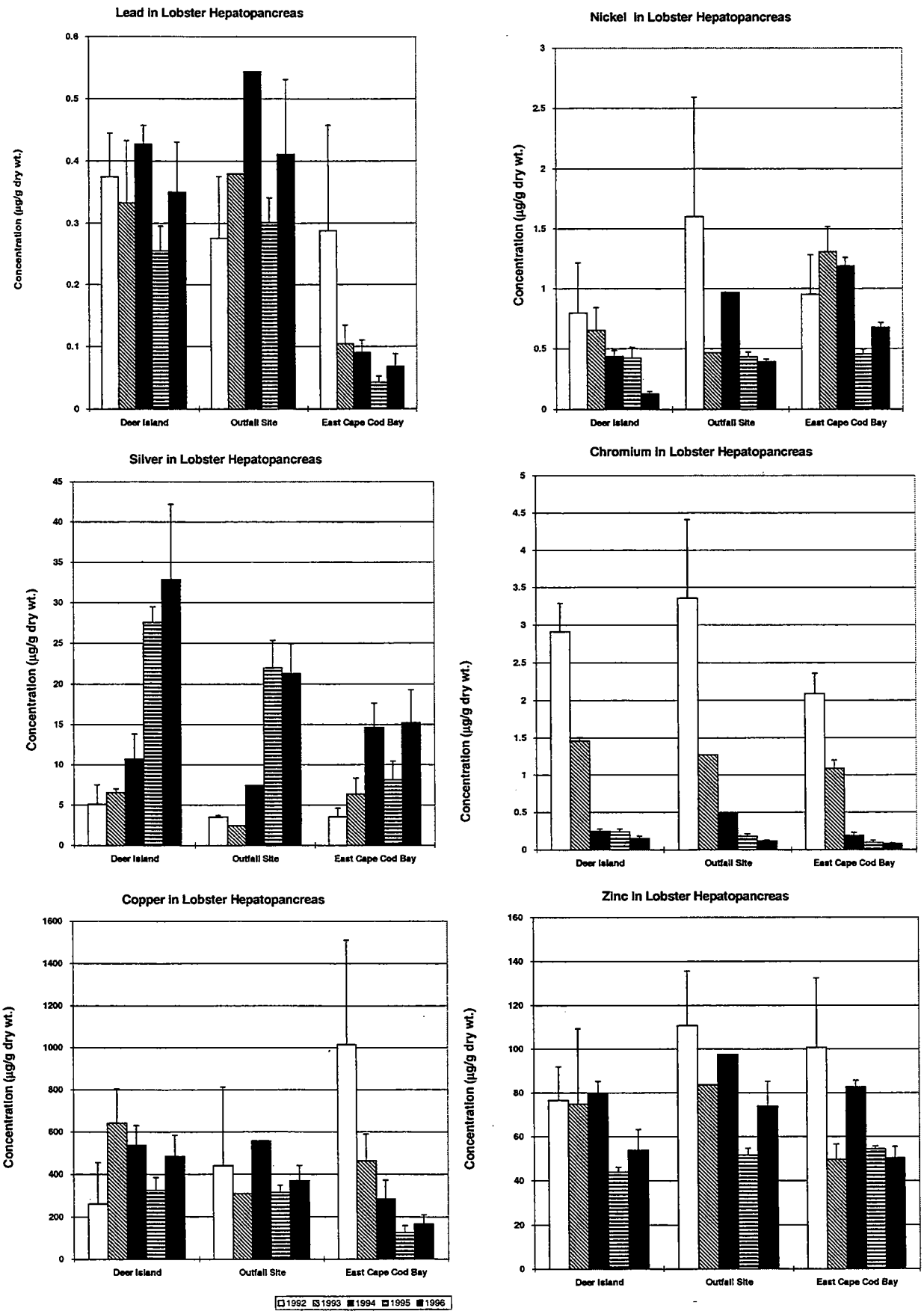
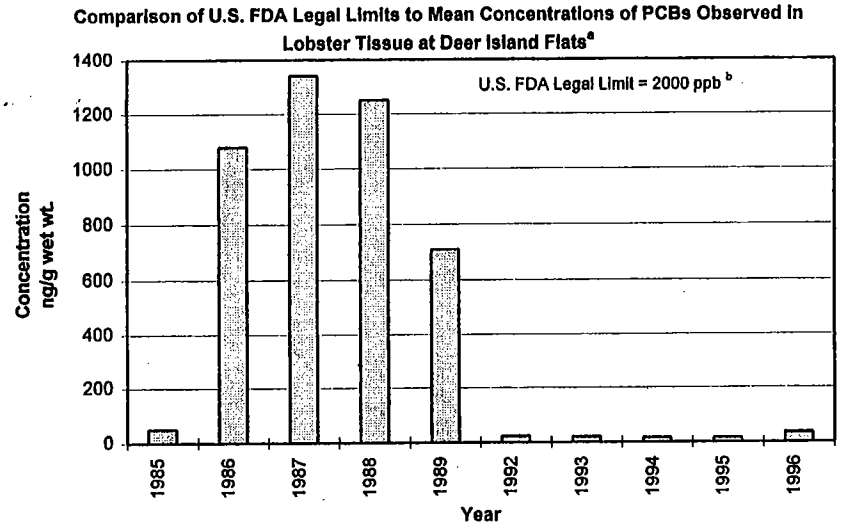
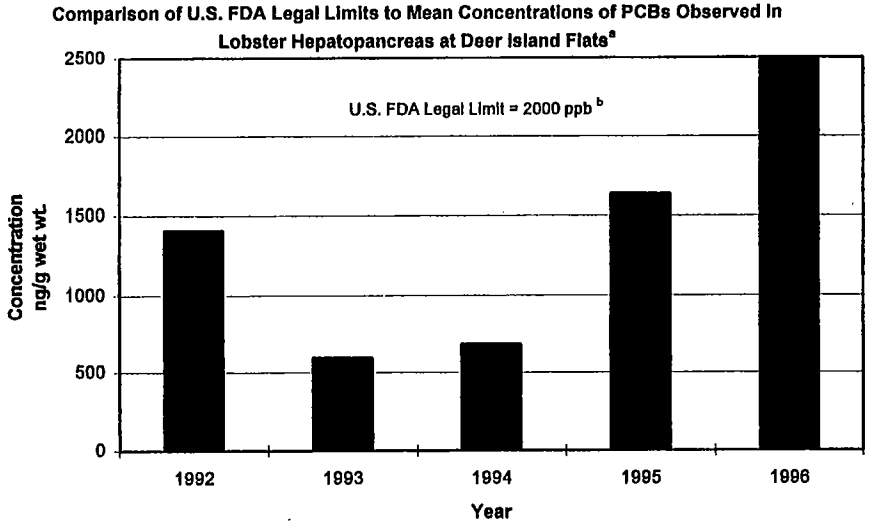
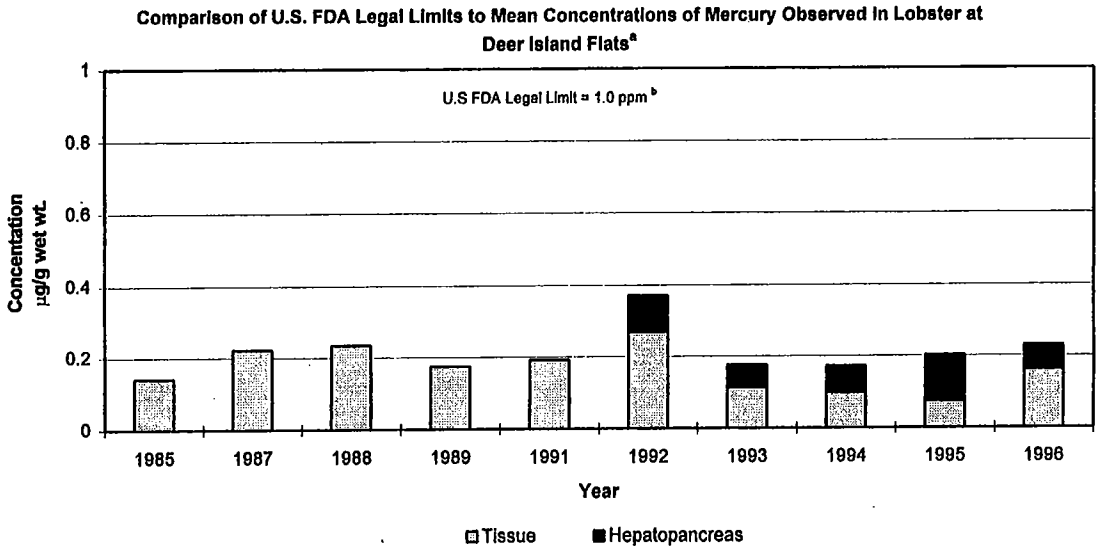


Figure 3-12
Comparison of Trace Metals in Lobster Hepatopancreas, 1992-1996



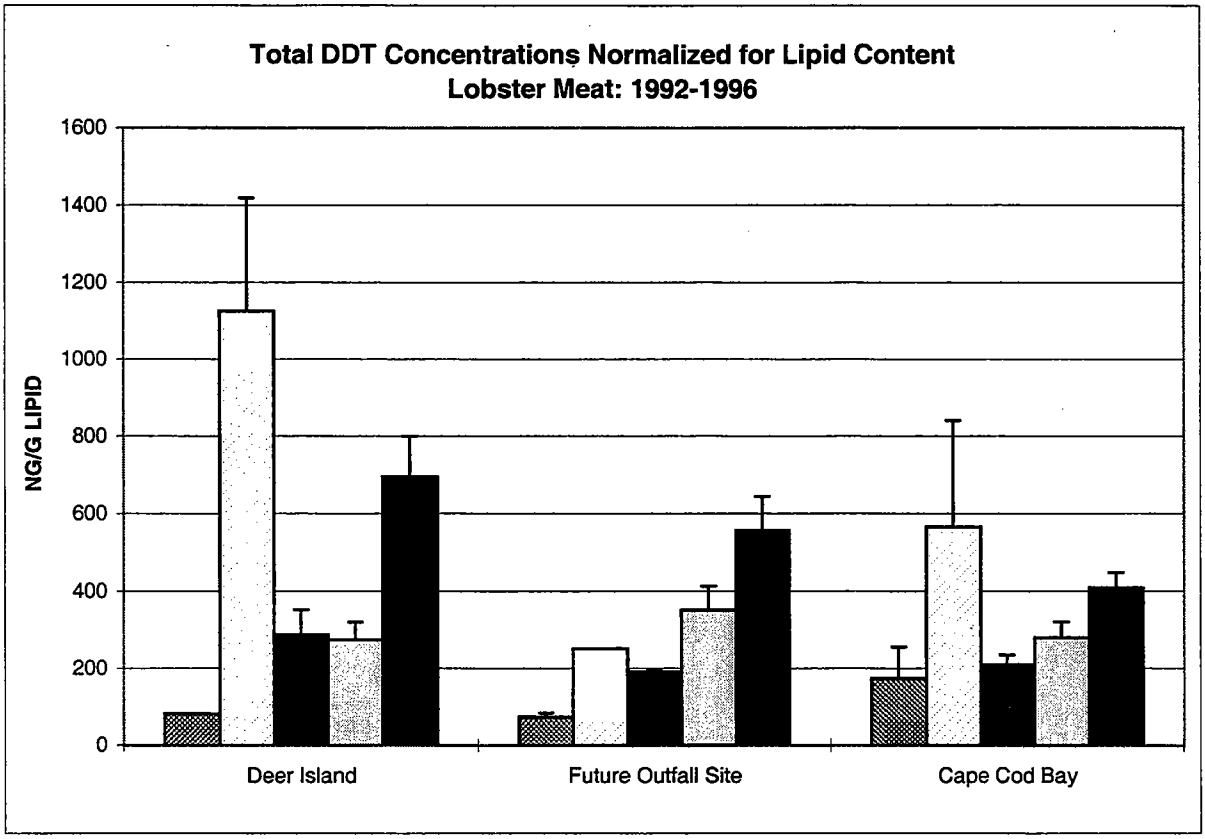




[a] 1985 data (Wallace et al., *Analysis of Contaminants in Marine Resources*, 1988) include analyses for lobster claws and tail. 1987 to 1991 data (Schwartz et al., *Metal Concentrations in Winter Flounder, American Lobster, and Bivalve Molluscs from Boston Harbor, Salem Harbor and Coastal Massachusetts:1984-1989*. 1991). Include tails, claws, hepatopancreas and gonads. 1992-1994 data (Hillman and Peven, 1994 Annual Fish and Shellfish Report, 1995) as well as 1995 and 1996 data, include tail meat only. 1995 data are from Mitchell, 1995 Annual Fish and Shellfish Report. 1996 data are presented in this report.

[b] U.S.EPA, *Assessing Human Health Risks From Chemically Contaminated Fish and Shellfish*, 1989.

Figure 3-13
Comparison of Available Data to U.S. FDA Legal Limits for PCBs and Mercury


Total DDT Concentrations Normalized for Lipid Content
Lobster Meat: 1992-1996
NG/G LIPID
1600
1400
1200
1000
800
600
400
200
0
Deer Island
Future Outfall Site
Cape Cod Bay

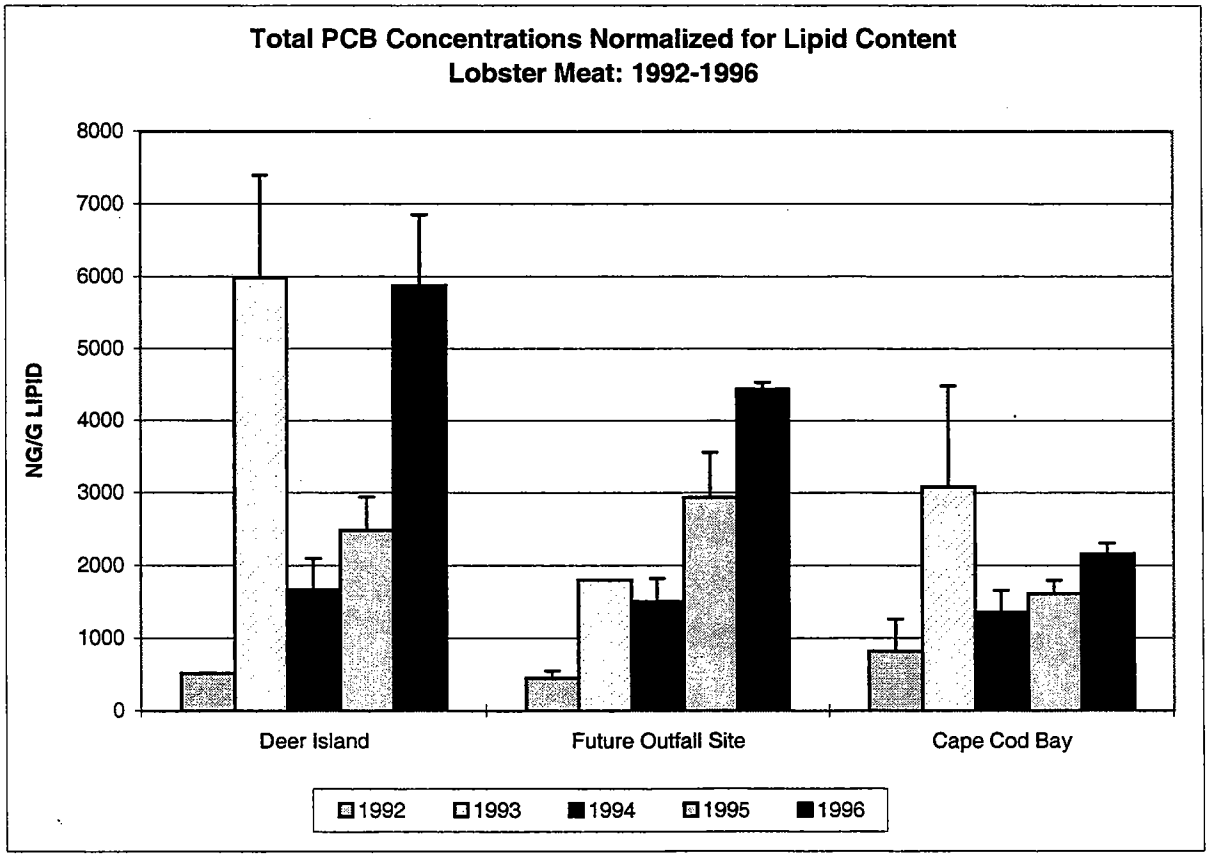
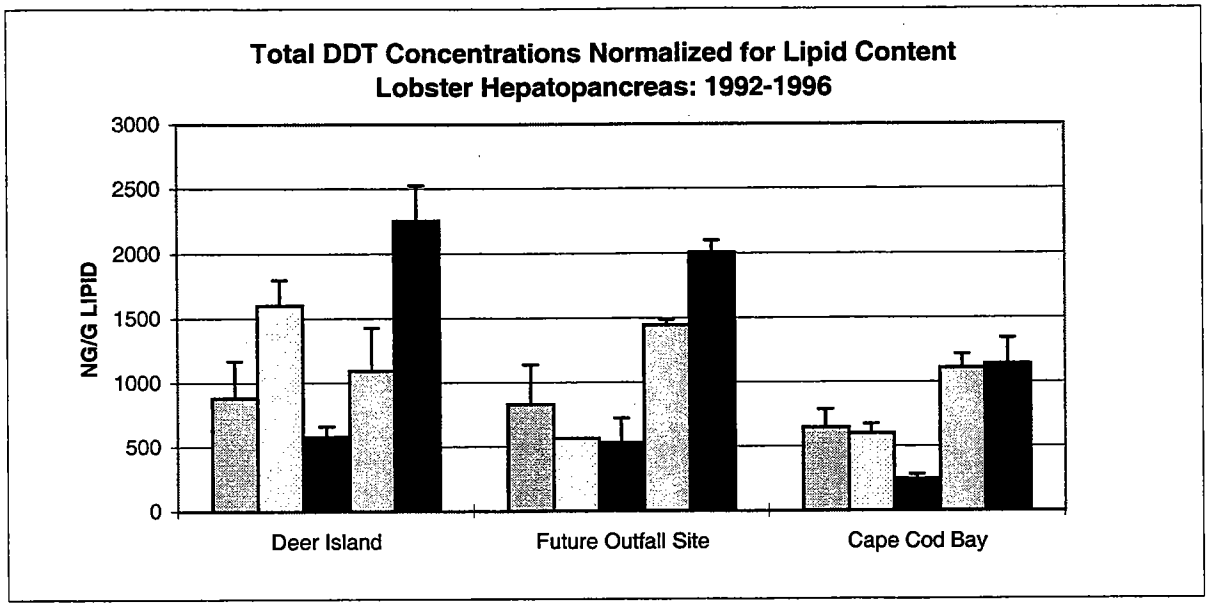
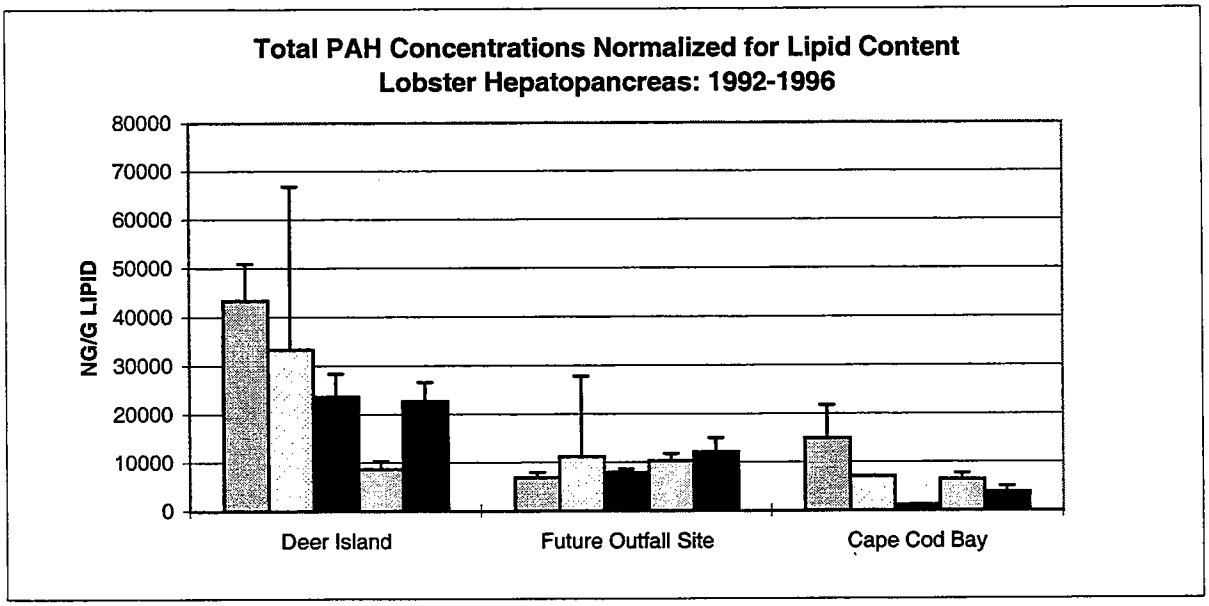

Total PCB Concentrations Normalized for Lipid Content
Lobster Meat: 1992-1996
NG/G LIPID
8000
7000
6000
5000
4000
3000
2000
1000
0
Deer Island
Future Outfall Site
Cape Cod Bay
1992
1993
1994
1995
1996

Figure 3- 14a


Total DDT Concentrations Normalized for Lipid Content
Lobster Hepatopancreas: 1992-1996
NG/G LIPID
3000
2500
2000
1500
1000
500
0
Deer Island
Future Outfall Site
Cape Cod Bay


Total PAH Concentrations Normalized for Lipid Content
Lobster Hepatopancreas: 1992-1996
NG/G LIPID
80000
70000
60000
50000
40000
30000
20000
10000
0
Deer Island
Future Outfall Site
Cape Cod Bay

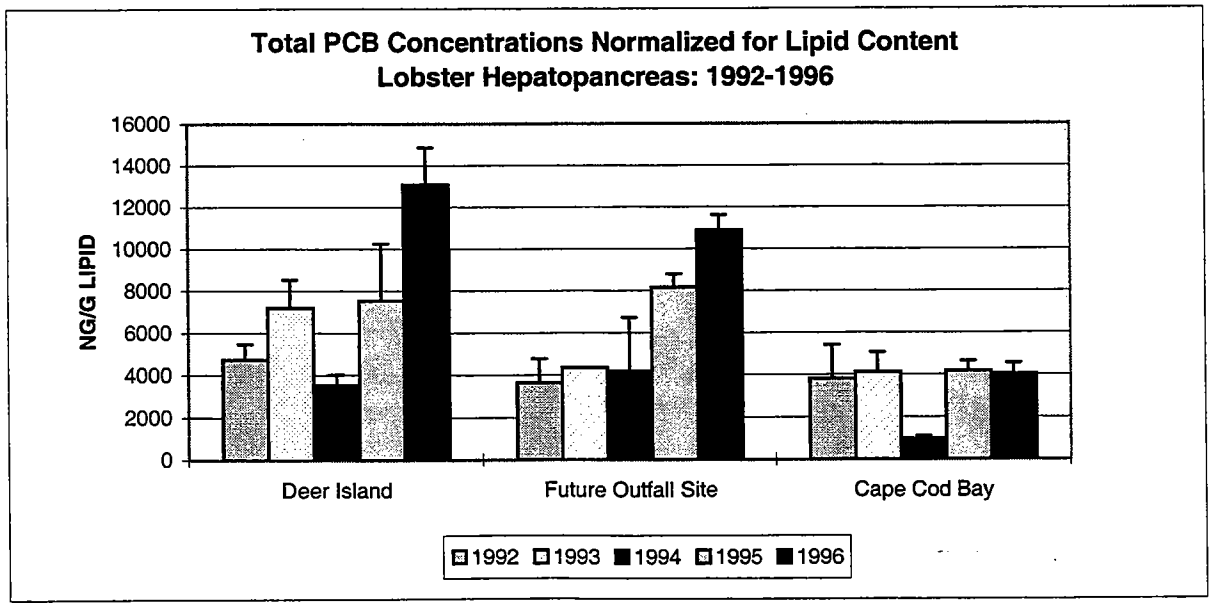

Total PCB Concentrations Normalized for Lipid Content
Lobster Hepatopancreas: 1992-1996
NG/G LIPID
16000
14000
12000
10000
8000
6000
4000
2000
0
Deer Island
Future Outfall Site
Cape Cod Bay
1992 1993 1994 1995 1996

Figure 3- 14b

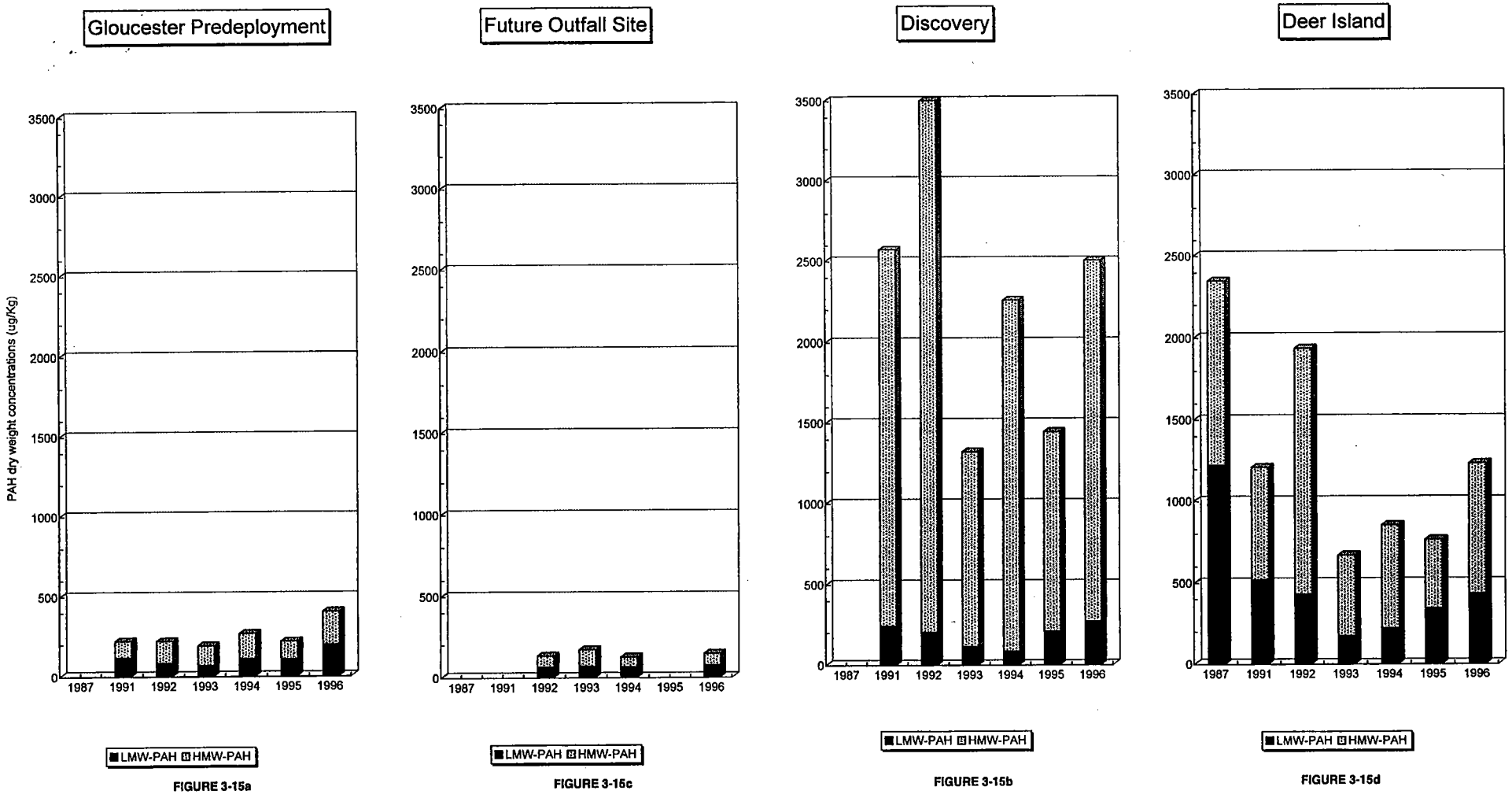


FIGURE 3-15a

FIGURE 3-15c

FIGURE 3-15b

FIGURE 3-15d

Figure 3-15a-d. Annual average PAH body burdens for 1996 deployed mussels.

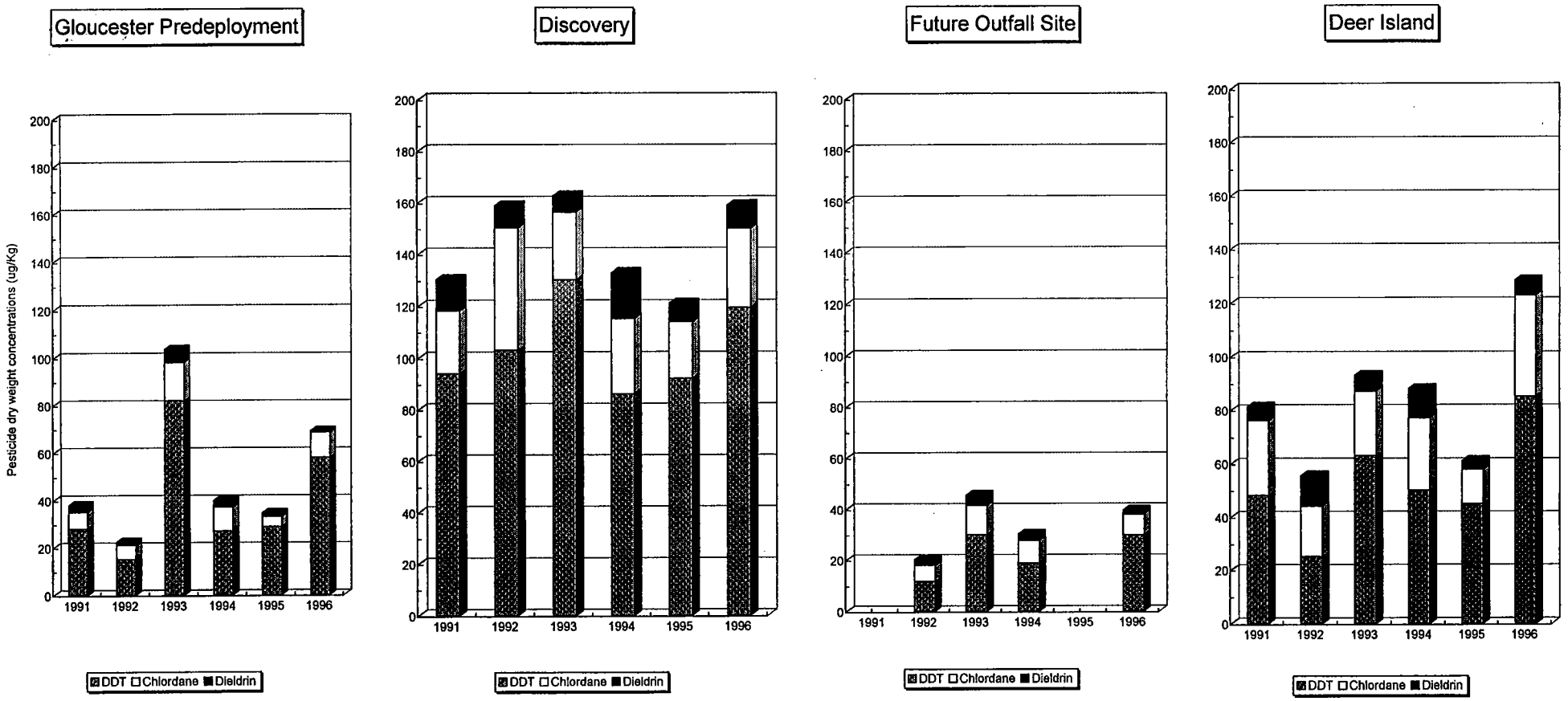


FIGURE 3-16a

FIGURE 3-16c

FIGURE 3-16b

FIGURE 3-16d

Figure 3-16a-d. Annual average pesticide body burdens for 1996 deployed mussels.

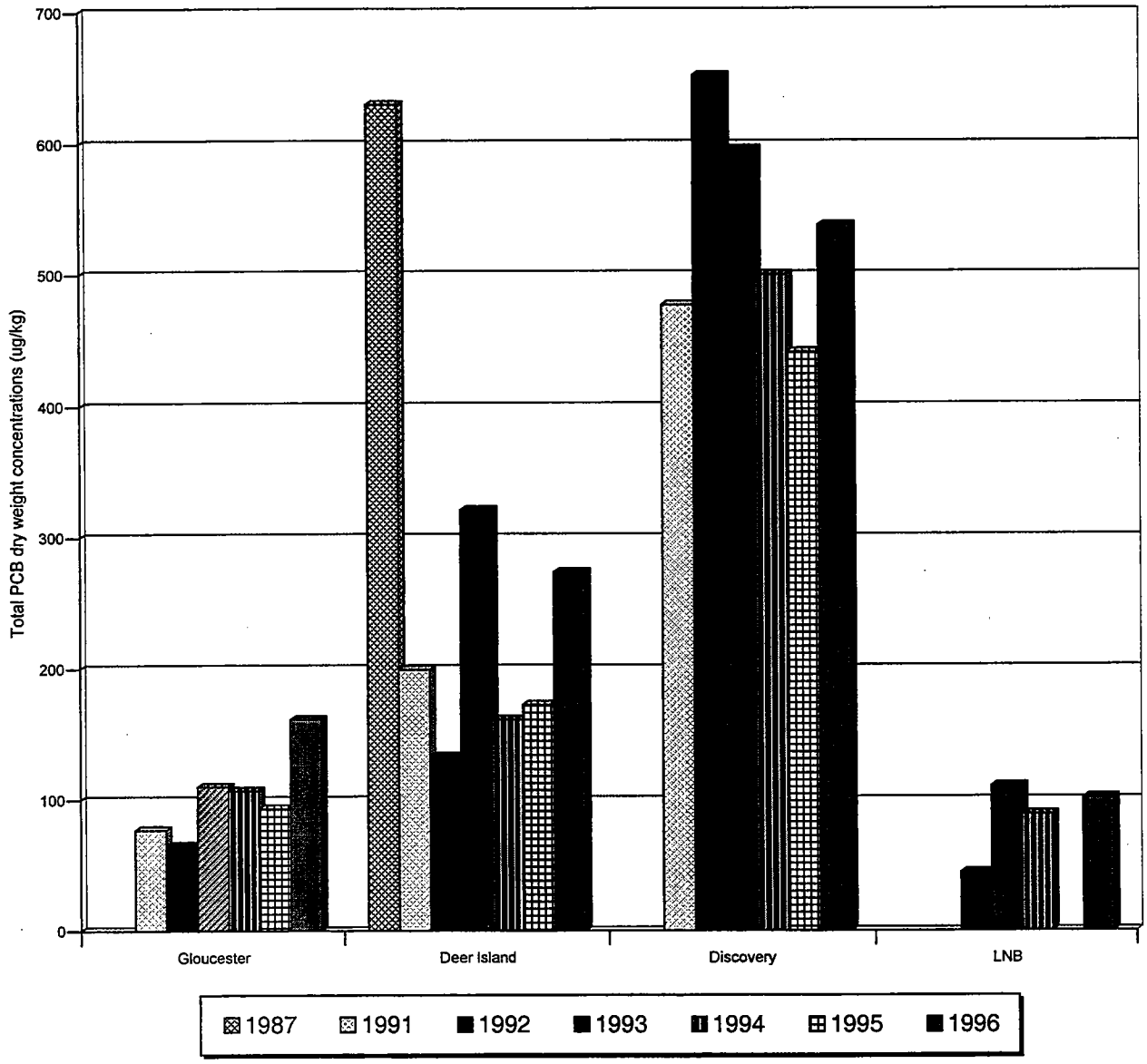
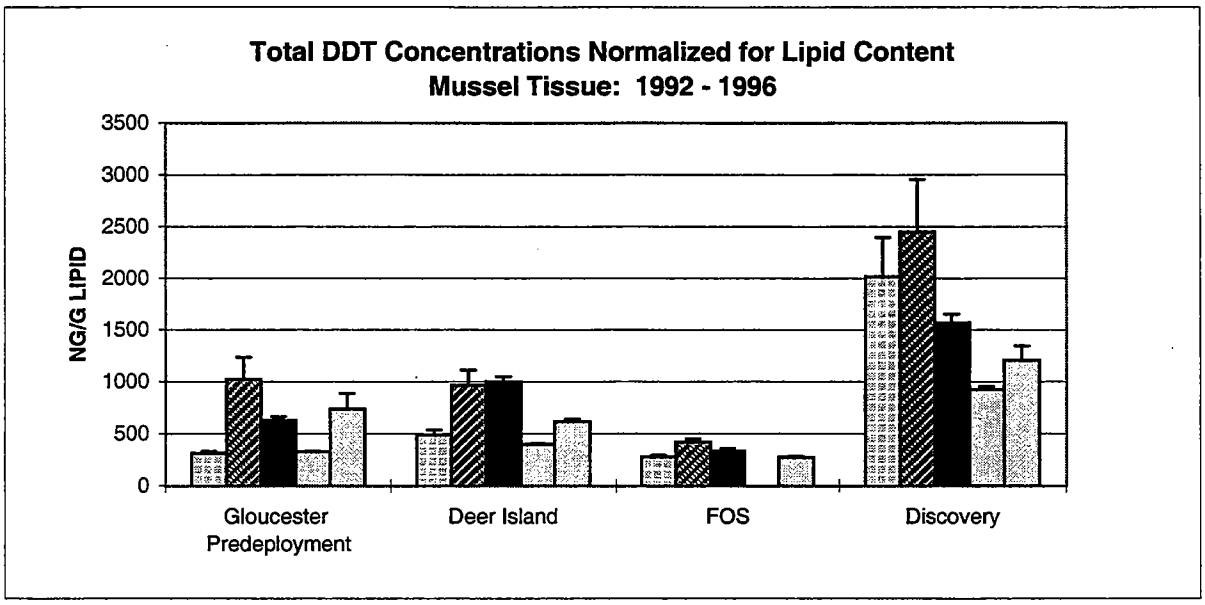
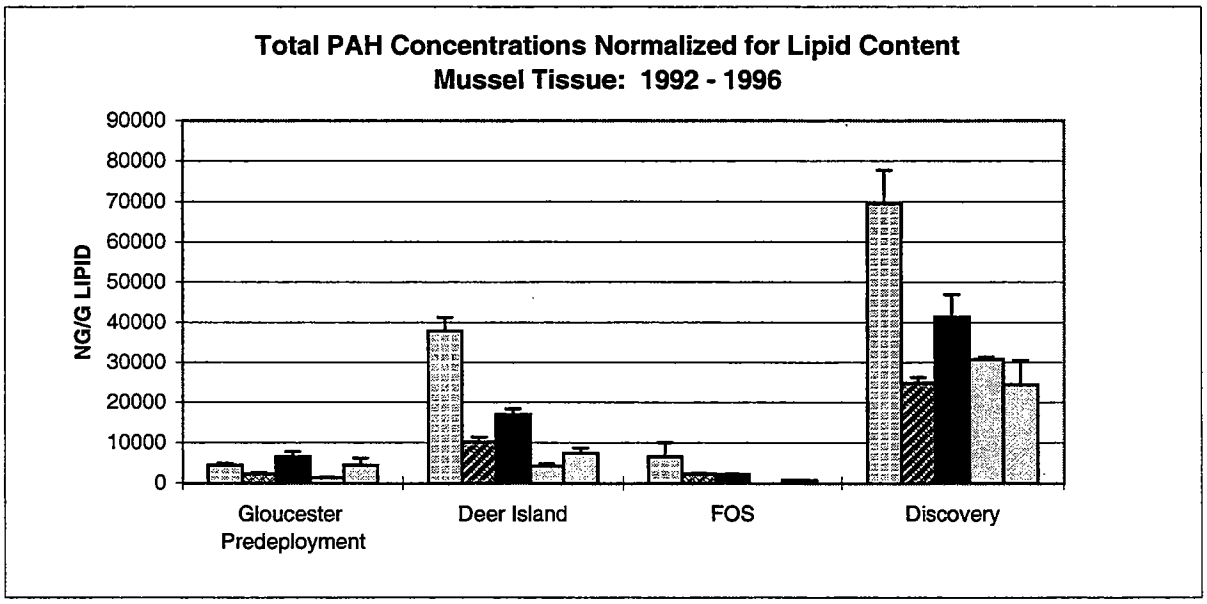


Figure 3-17. Annual average PCB body burdens for 1996 deployed mussels.


Total DDT Concentrations Normalized for Lipid Content
Mussel Tissue: 1992 - 1996
NG/G LIPID
3500
3000
2500
2000
1500
1000
500
0
Gloucester Predeployment
Deer Island
FOS
Discovery


Total PAH Concentrations Normalized for Lipid Content
Mussel Tissue: 1992 - 1996
NG/G LIPID
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Gloucester Predeployment
Deer Island
FOS
Discovery

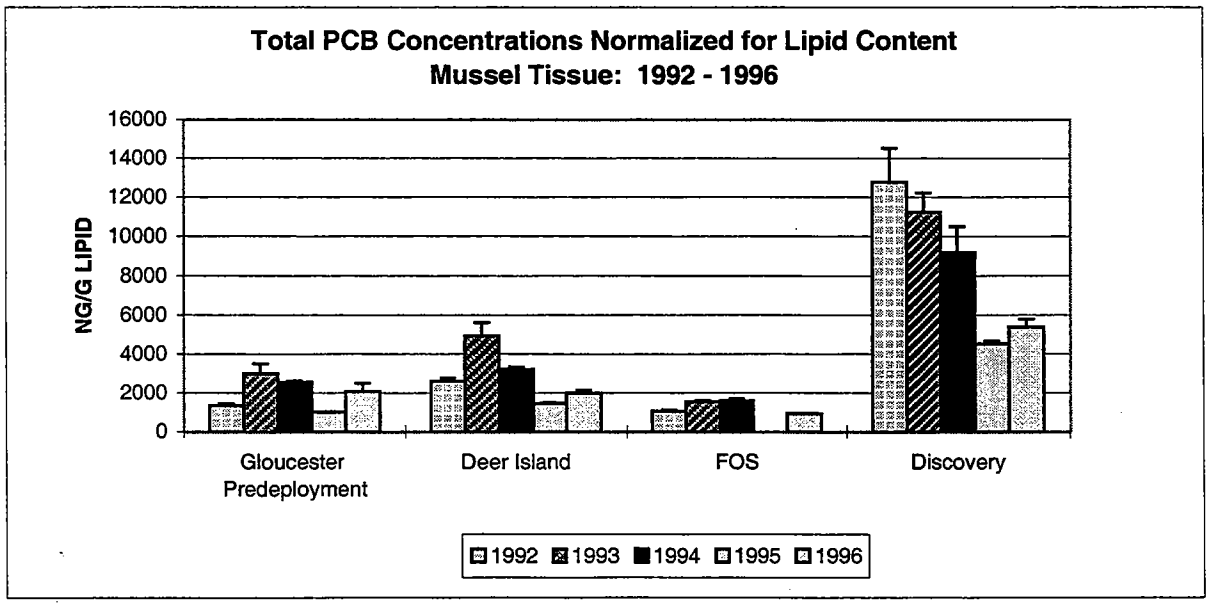

Total PCB Concentrations Normalized for Lipid Content
Mussel Tissue: 1992 - 1996
NG/G LIPID
16000
14000
12000
10000
8000
6000
4000
2000
0
Gloucester Predeployment
Deer Island
FOS
Discovery
1992
1993
1994
1995
1996

Figure 3- 18

4.0 CONCLUSIONS

The 1996 Fish and Shellfish Monitoring program was successful in providing another year's worth of data, further documenting and expanding the existing, pre-effluent diversion baseline conditions and evaluating the monitoring hypotheses. Compared to previous years, most parameters were measured within the range of past efforts. There were some exceptions to this trend, including pesticides and PCBs in flounder liver and lobster hepatopancreas, that warranted further investigation of analytical variation. More importantly, the tissue contaminant levels in edible portions of flounder and lobster were detected at levels well below the FDA legal limits nor did they exceed the warning or action levels. Further comments on the surveys are given below.

4.1 Winter Flounder

The 1996 Flounder Survey was conducted in a manner consistent with previous years' surveys. The frequency of lesion occurrence appears to be slowly declining in the nearshore area. A statistically significant decreasing relationship between prevalence of neoplasm and survey year was noted in the years 1987-1996 for Deer Island Flats. Whether this trend is linked to improvement in environmental conditions is an important monitoring issue.

The levels of most tissue contaminant concentrations were comparable to the previous four years of data, with the already noted exceptions of pesticides and PCBs. Fillet tissue contaminant concentrations were below the FDA legal limits for pesticides, PCBs and mercury (as well as action and warning limits), thus indicating no risk for human consumption.

Analyses of the last five years of data (1992-1996) histology and tissue chemistry indicate a series of statistically significant relationships between centrotubular hydropic vacuolation and tissue contaminant levels for selected analytes. These suspected causal relationships between contaminant exposure (body burdens) and detectable precursors of neoplasm should be further evaluated in following years to check any corresponding changes in prevalence and body burden following effluent diversion at FOS.

4.2 Northern Lobster

The 1996 Lobster Survey collected specimens from the three sampling locations through a combination of trapping and direct shipboard collection from lobstermen. Analyses of the lobster tissue contaminant levels found that body burdens were generally greatest at Deer Island Flat and lowest at the Eastern Cape Cod reference station. Comparison of 1996 data with previous years (1992-1995) indicates that most tissue levels of organic contaminants were increased compared to 1995 values, while concentrations of inorganics remained within the range previously observed. Lobster edible tissue contaminant

concentrations were below the FDA legal limits and action and warning limits for pesticides, PCBs and mercury, thus indicating no risk for human consumption.

4.3 Blue Mussel

The 1996 Mussel Bioaccumulation study provided data on the Discovery, Deer Island site and the Future Outfall Site. The spatial and temporal trends observed for PAHs were consistent with previous 1990's studies. The LMW-PAHs were highest in the Deer Island mussels while HMW-PAHs were highest in *Discovery* mussels. NOAA total PAH body burden for all sites were comparable to 1991-1995 levels. Pesticide (DDT, chlordane, dieldrin) levels were also comparable to earlier data.

Lead tissue concentrations were statistically greater in the *Discovery* mussels. Mercury was not significantly different among the three locations and mussel tissue concentrations were uniformly low. These low concentrations, specifically in Deer Island mussels, contrasted with other studies, particularly the NOAA Mussel Watch Project for indigenous Deer Island mussels. Further evaluation of mercury body burdens may be necessary to fully evaluate the bioavailability of mercury to deployed mussels at the three locations.

4.4 Evaluation of Monitoring Hypotheses

An integral part of the MWRA fish and shellfish monitoring is a periodic re-evaluation of the adequacy of the current program to fulfill the overall goals of the monitoring program (MWRA 1995; 1997). In particular, this means a re-examination of the adequacy and effectiveness of the underlying monitoring hypotheses to answer questions regarding the potential effects of the relocated MWRA effluent.

Of the five monitoring hypotheses (MWRA, 1995), three are associated with the potential for edible tissue (flounder, lobster, mussel) to exceed warning levels for mercury, lead, or PCBs at the Future Outfall Site. These hypotheses appear to be sufficient. Current tissue concentrations are generally an order of magnitude or more below warning and FDA regulatory levels (Table 4-1). Values approaching the caution or warning or levels are detectable at concentrations below the thresholds in the program. 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.

The remaining monitoring hypothesis, detection of trends in elevated bioaccumulative lipophilic contaminants relative to baseline concentration, was further evaluated due to greater-than-anticipated levels of some organic contaminants (pesticides, PCBs) in flounder liver, lobster hepatopancreas, and mussel tissue. A review of the magnitude of interlaboratory analytical performance was conducted and concluded that differences in analytical data between laboratories are negligible (see Appendix A of 1995 Annual Fish and Shellfish Report (Mitchell *et al.* 1997)). Since interlaboratory variation does not appear

responsible for the observed increases in some organic compounds, this monitoring hypothesis will require further study and evaluation but for the present is considered sufficient.

Table 4-1 presents baseline mean, standard error, and significant increase values for parameters of concern. This table also includes the relevent caution and warning levels for trigger parameters (MWRA, 1997). The baseline mean represents the arithmetic averages of annual means (of composite samples) for organisms collected or deployed at the Future Outfall Site during the period 1992-1996; with the exception of mussels which do not include 1995 data (due to loss of arrays at the FOS site) and the flounder liver lesion prevalence which includes date from 1991-1996. The significant increase value is the 95th percentile upper confidence limit of the arithmetic mean. It can be seen that in all cases, the significant increase value is less than twice the baseline mean for organics (i.e., PAHs, PCBs, DDT), as well as below caution levels for inorganic contaminants (i.e., Hg, Pb) and flounder liver lesion prevalence. It should be noted that eventually 1992-1998 data will be included to the baseline data prior to the initiation of the outfall relocation.

Overall, it appears that the five monitoring hypotheses associated with the fish and shellfish monitoring program are sufficient and do not require replacement. However, these hypotheses should be revisited on a annual basis as data becomes available to check their effectiveness (e.g., if additional data indicate large amounts of interannual variability ascribed to natural variation).

TABLE 4-1
Comparison of Baseline Mean Concentrations, Significantly Increased Levels, and Thresholds at the Future Outfall Site

Parameter	Baseline Mean [1]	Baseline Standard Error	Significant Increase [2]	Threshold	
				Caution Level	Warning Level
Mercury (ppm wet)					
Flounder	0.08	0.01	0.11	0.5	0.8
Lobster	0.14	0.02	0.18	0.5	0.8
Mussels	0.022	0.002	0.028	0.5	0.8
Lead (ppm wet)					
Mussels	0.59	0.15	1.04	2	3
PCBs (ppb wet)					
Flounder	40.38	1.46	43.49	1000	1600
Lobster	17.50	3.35	24.63	1000	1600
Lipid normalized PAH [5] (ppb lipid)					
Mussel	2955.52	1250.09	5,896.98	2X Baseline	--
Lipid normalized PCB (ppb lipid)					
Flounder	7469.70	1558.43	10,792.27	2X Baseline	--
Lobster	2227.66	679.68	3,676.73	2X Baseline	--
Mussel	1287.18	338.03	1,684.87	2X Baseline	--
Lipid normalized DDT (ppb lipid)					
Flounder	805.33	167.65	1,162.76	2X Baseline	--
Lobster	284.95	81.42	458.54	2X Baseline	--
Mussel	327.46	68.07	407.54	2X Baseline	--
Liver disease incidence					
(flounder only)	25.50	2.90	31.33	>harbor prevalence	--
				(1991-1996)	

Notes:
[1] Mean concentration, 1992-1996 (Flounder and Lobster). Mean concentration, 1992-1994, 1996 (Mussels; 1995 array was lost).
[2] Level at which change from the mean is considered significant from baseline mean at 5% level.
[3] Massachusetts Water Resources Authority (MWRA) 1997. Contingency Plan. Caution Level is 50% the FDA Legal Limit.
[4] Massachusetts Water Resources Authority (MWRA) 1997. Contingency Plan. Warning Level is 80% of the FDA Legal Limit.
[5] For mussels, total PAH represents the 24 NOAA PAH analytes listed in the third column of Table 3-15.

5.0 RECOMMENDATIONS

Evaluation of the 1996 Fish and Shellfish tasks indicates that the program is achieving its monitoring goals. However, refinements to the program may be warranted. Based on the 1996 results, several recommendations for future effort are suggested:

- To distinguish between natural variability and potential inter-laboratory variability in measurement of organic compounds, comparison between past and current laboratories using standardized reference material or archived tissues (Note: this issue has been addressed through comparisons described in Appendix A of 1995 Annual Fish and Shellfish Report (Mitchell *et al.* 1997). Further work may be warranted.);

- Continuation of the use of mussels collected from the Sandwich reference site to evaluate the bioaccumulation of mercury and lead;

- Since the baseline flounder histopathological database for the Harbor is well established, future collection of flounder for histopathological assays should be evaluated in light of the severely depleted local populations of this species;

- Collection of lobster should be revisited to evaluate effectiveness of trapping vs. other means of collecting geographically-documented specimens; and

- All monitoring tasks should be reviewed annually to evaluate whether their scope and effort are commensurate with the HOM goals and ability to address monitoring hypotheses.

These recommendations will be reviewed for inclusion in the 1997 Fish and Shellfish Monitoring Program.

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