2015
Fish and Shellfish Tissue Chemistry Report

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FISH AND SHELLFISH TISSUE CHEMISTRY REPORT

Submitted to

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EXECUTIVE SUMMARY

The objective of the MWRA Fish and Shellfish monitoring program is to define the post-discharge condition of three indicator species: winter flounder (*Pseudopleuronectes americanus*), lobster (*Homarus americanus*), and blue mussel (*Mytilus edulis*). Flounder and lobster specimens were collected from three core sites in Boston Harbor and the Bays: Deer Island Flats (DIF), the Outfall Site (OS), and East Cape Cod Bay (ECCB). Flounder were also collected at one ancillary site off Nantasket Beach (NB), to provide information on flounder in the general area of the former Deer Island outfall. Caged mussels, purchased from Tightrope Seafarms and reared in Blue Hill Bay, ME, were deployed at sites in Boston Harbor and the bays to evaluate bioaccumulation potential.

This report details chemical contaminant results from flounder edible meat and liver, lobster edible meat and hepatopancreas, and whole mussels. Flounder liver histological results are also discussed. The monitored parameters were examined for spatial distribution among stations in 2015 and inter-annual variations from previous monitoring data. In addition, body burdens of certain pesticides, PCBs, PAHs, lead, and mercury were compared to FDA Action Limits and Contingency Plan (MWRA 2001a) threshold values to evaluate potential risk.

Flounder

Winter flounder were collected at the four monitoring locations (DIF, NB, OS, and ECCB). Sizes, ages, and gender ratios observed in 2015 were similar to recent years. Fish from OS and ECCB averaged about a year older than those from DIF and NB. The largest fish were found at DIF. Blind side ulcers were found at all stations except ECCB and were more prevalent at DIF (4 fish) than NB (2) or OS (2). These ulcers were first observed in marked numbers in 2003 but have become less frequent since 2005. The fish at all stations were predominantly females.

In 2015, as in 2012 no liver neoplasms were reported and the relatively low prevalence of hydropic vacuolation suggests a steady system-wide reduction in the contaminant–associated pathology over the past two decades. While lower than in the 1990's centrotubular hydropic vacuolation (CHV) remains highest in fish collected off Deer Island but remains low in the vicinity of the Massachusetts Bay Outfall Site (OS).

Fifteen winter flounder were collected at each location and edible meat and liver were analyzed for chemical contaminants. In general mean concentrations of organic compounds in fillets were highest off Deer Island and lowest at Eastern Cape Cod Bay (ECCB), a pattern observed throughout this program. Although somewhat elevated tissue concentrations of chlordane and DDT were observed at most stations in 2012, body burdens of these contaminants declined in 2015, continuing a long term pattern throughout the region. Metal tissue burdens were less predictable although were typically higher at OS than other stations as has been observed throughout the study. Concentrations of mercury in flounder meat increased at OS in 2015 but remained at the lower end of the range seen historically. Of the metals measured in livers the only apparent trend is a possible region-wide increase in nickel. All flounder edible tissue contaminant levels remain well below the federal action limits and the MWRA Threshold Levels and indicate no risk for human consumption.

Lobster

Twenty one lobsters were collected at each of the three core monitoring stations (DIF, OS, and ECCB). The average size as determined by carapace length was similar at all stations. The percentage of females varied from 24% at DIF, to 38% at ECCB and 68% at OS. Three lobsters collected from ECCB had indications of shell erosion. No other deleterious external conditions were noted.

Similar to historical lobster results organic contaminants tended to be highest in lobster collected in Boston Harbor and lowest in those from Cape Cod Bay. Chlordane and DDTs continue to show downward trends throughout the region. Total PCBs and mercury were low in lobster meat at all sites. The highest concentrations of several metals in lobster hepatopancreas were from lobsters collected at OS. The concentration of nickel measured from ECCB lobsters declined from that observed in 2012 but could still be indicative of a possible long-term region-wide increase for that metal. Lobster edible tissue concentrations were well below MWRA Caution and Warning Thresholds and FDA Action Limits for human consumption.

Mussels

Mussels were obtained from an aquaculture facility in Blue Hill Bay, Maine and deployed in arrays at Deer Island (DIL), Boston Inner Harbor (IH), Outfall Site (OSM), and "B" Buoy (LNB). Mussel survival was unusually low at all stations (17% at IH to 70% at LNB). As a result, the number of replicates available per station differed from the plan to ensure that adequate tissue was available to perform the analyses.

The 2015 data were similar to previous years with the highest contaminant levels generally observed in mussels deployed in Boston's Inner Harbor with lower concentrations in Massachusetts Bay. Without exception, mussels from Maine had the lowest concentrations. There has been a clear trend of decreasing bioaccumulation of total chlordane, DDT, PCBs, PAHs, and lead at DIL. Body burdens of total chlordane and HMW PAHs at OS exhibited increases after the offshore diversion but have since declined. Concentrations of total PCBs, total DDT, and lead were all higher in the baseline period and have been declining at OS. However, concentrations remain well below the MWRA Caution Threshold. There were no threshold exceedances in 2015.

1.0 INTRODUCTION

The Massachusetts Water Resources Authority (MWRA) has implemented a long-term Harbor and Outfall Monitoring (HOM) Program for Massachusetts and Cape Cod Bays. The objectives of the HOM Program are to assess whether the environmental impacts of the MWRA discharge are consistent with SEIS projections and whether the impacts exceed any Contingency Plan thresholds (MWRA 2001a). A detailed description of the monitoring and its rationale is provided in the Effluent Outfall Monitoring Plan developed for the baseline period and the post-discharge monitoring plan (MWRA 1997, 2004, 2010).

One aspect of the MWRA HOM program is a long-term monitoring program for fish and shellfish (MWRA 1991). The goal of the fish and shellfish monitoring is to provide data to assess environmental impact of effluent discharge into Massachusetts Bay. These data are used to ensure that discharge from the new outfall does not result in adverse impacts to fish and shellfish by comparing values with established thresholds (MWRA 2001a and b).

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

The scope of the 2015 Fish and Shellfish Report is focused primarily on assessing changes, if any, as a result of relocation of the MWRA wastewater discharge. The report first provides a summary of the survey and laboratory methods (Section 2). Section 3 presents the results of monitoring data from surveys conducted during 2015, as well as selected data from previous studies. Section 4 provides a brief conclusion, summarizing findings for the 2015 Fish and Shellfish monitoring. References can be found in Section 5. All historical data are reported in Appendices A - E.

2.0 METHODS

The methods and protocols used in the 2015 surveys conducted to collect biological specimens are similar to and consistent with previously used methods. More detailed descriptions of the methods are contained in *Quality Assurance Project Plan (QAPP) for Fish and Shellfish Monitoring: 2014-2016. (*Geoghegan *et al.* 2014*)* and *Quality assurance project plan (QAPP) for Chemistry Analyses for fish and shellfish Monitoring* (Lao *et al*., 2012).

2.1 Winter Flounder Monitoring

Winter flounder *(Pseudopleuronectes americanus)* were collected from four locations in Boston Harbor and the Bays to obtain specimens for age, weight, and length determination, gross examination of health, histology of livers, and chemical analyses of tissues to determine contaminant exposure. Chemical data were used to determine whether contaminant tissue burdens have changed since the startup of the Massachusetts Bay outfall and whether these concentrations approach human health consumption limits.

2.1.1 Stations and Sampling

The 2015 flounder survey was conducted between April 27 and May 7, 2015. Four sites were sampled to collect winter flounder for histological and chemical analyses:

- Deer Island Flats (DIF)
- Off Nantasket Beach (NB)
- Massachusetts Bay Outfall Site (OS)
- East Cape Cod Bay (ECCB)

Table 2-1 provides the planned and actual sampling sites and locations for the 2015 flounder sampling. Adjustments in location and time were made to maximize collection efforts in an attempt to collect the required 50 flounder per site. Figure 2-1 displays the flounder monitoring locations.

At each of the four designated sampling sites, otter-trawl tows were conducted from the F/V *Harvest Moon* (captained by Mr. Mark Carroll) to collect 50 sexually mature (4-5 years old, total length ≥30 cm) winter flounder. Thirty-five fish at each station were assigned unique identification numbers to indicate date, time, and site of collection. These fish were killed at sea by cervical section and used for histological processing. They were examined externally and their external condition was noted prior to histological processing. The gonads of each flounder were examined to determine sexual maturity. All specimens were weighed, and total and standard lengths were determined. Scales and otoliths were then taken from each specimen for age determination.

Of the 50 flounder collected from each station, 15 were designated for tissue chemical analysis. Because contaminant-free conditions were not available on board the vessel, the fish used for chemical analysis were maintained alive on-board (on ice) and transported to Envirosystems Inc. (Hampton, New Hampshire) for histological and organ dissections. These fish were also examined for external condition in the laboratory.

2.1.2 Dissection of Fish

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

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

Livers from the 15 fish selected for chemical analyses were removed using a titanium knife and processed for chemical analysis, after sectioning for histopathology analysis. (Livers from the fish not used for chemical analyses were removed shipboard and processed for histology as described below). Following the removal of three individual slices of liver for histology analysis, the remaining liver tissue from each fish was homogenized by finely chopping with the titanium knife and three separate composites per station were formed to correspond to the composites made for the fillets (*i.e.*, the livers of the same five specimens used for each edible tissue composite were combined). This was done to ensure comparability between fillet and liver chemical analyses. Each composite was placed in a sample container clearly identified with the unique sample identifier. This resulted in 24 pooled samples for analysis in 2015 (12 pooled fillets and 12 pooled livers). The homogenized tissue and liver samples were frozen and stored. Any remaining tissue from each specimen was archived frozen in case additional analysis was required.

2.1.3 Tissue Processing and Chemical Analyses

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

2.2 Lobster Monitoring

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

2.2.1 Stations and Sampling

Lobsters were collected on September 2, 2015 (DIF), September 17, 2015 (ECCB), and October 13, 2015 (OS). The animals were captured in traps deployed at each location by local lobstermen (Mr. Fred Penney for DIF and OS; Mr. Dave Casoli for ECCB).

Table 2-2 provides the planned and actual sampling locations for the lobster surveys. Figure 2-2 illustrates the sampling locations in Boston Harbor and the Bays. Adjustments in location and time were made to maximize collection efforts. Sampling at the outfall was delayed because of weather conditions. Sampling in Cape Cod Bay was conducted west of the preferred location because of difficulties in identifying a lobsterman to conduct the work.

Individual lobsters retained for analyses were assigned a unique identification number to indicate date, time, and site of collection. Lobsters were measured for carapace length and weight (DIF only), and gender was determined. Lobster specimens were visually examined and the condition noted. Processing of the hepatopancreas and the edible tail and claw meat tissue samples was conducted in the laboratory (Envirosystems, Inc.).

2.2.2 Size and Sex Determination

Carapace length was determined with calipers by measuring the distance from the posterior of the eye socket to the midpoint of the posterior of the carapace. Measurements were recorded to the nearest

millimeter. Specimen weight was recorded to the nearest gram. Specimens were visually examined for the presence and severity of gross external abnormalities, such as black gill disease, shell erosion, and parasites. Data for each specimen were recorded on a lobster sample collection log.

2.2.3 Dissection of Lobster

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

The lobsters collected at each site were randomly divided into three groups of seven lobsters each. Within each of the three groups, edible meat (tail and claw) and hepatopancreas from the same seven lobsters were pooled by tissue type. Homogenization of lobster meat was performed using a stainless steel TEKMAR® tissuemizer. Hepatopancreas samples were homogenized using a titanium knife to avoid metals contamination. Each composite was placed in a sample container clearly identified with the unique sample identifier. This resulted in 18 pooled samples for analysis in 2015 (nine edible meat samples and nine hepatopancreas samples).

2.2.4 Tissue Processing and Chemical Analyses

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

2.3 Mussel Bioaccumulation Monitoring

Blue mussels *(Mytilus edulis)* were obtained from an aquaculture facility (Tightrope SeaFarms) in Blue Hill Bay, ME and deployed in suspended cages at four sites in Boston Harbor and the bays. Mussels were recovered for determination of short-term accumulation of anthropogenic contaminants in soft tissues.

2.3.1 Stations and Reference Area

2015 pre-deployment mussels were obtained from the commercial grower Tightrope SeaFarms in Blue Hill BayME and were deployed at four sites:

- Deer Island Light (DIL)
- Outfall Site (OSM)
- Outfall Site "B" Buoy – 1 km south of the outfall risers (LNB)
- Boston Inner Harbor (IH)

Table 2-3 provides the planned and actual sampling sites and locations.

2.3.2 Mussel Collection

In the past, this study has used wild mussels collected from various intertidal beds. Over the years, collections have been made progressively farther north as beds have become depleted. A reconnaissance visit to previously used mussel beds at Stovers Point (Casco Bay) and Pemaquid Harbor (Johns Bay) ME in March 2015 revealed that neither bed would support harvesting the number of individuals required for this study. Mussels were purchased from a commercial grower Tightrope SeaFarm from their rope-grown stock in Blue Hill Bay, ME. The grower harvested the mussels on June 28, 2015 and held them under refrigeration. Normandeau picked up the mussels on June 29, 2015 and kept them in coolers on wet ice

until deployment on June 30, 2015. At least 100 individual mussels were randomly checked for length to ensure that mussels between 55 and 65 mm in length were deployed. A sub-sample of 100 mussels was randomly selected and set aside for pre-deployment chemical analyses.

2.3.3 Mussel Deployment

After collection, the mussels were randomly distributed to plastic cages for deployment as an array (i.e., set of cages) in sufficient number to provide the necessary biological material. At least 10% additional mussels were included to account for potential mortality. Mussels were deployed on June 30 in replicate arrays at the four sites (Figures 2-3 and 2-4). Table 2-4 lists the minimum numbers of mussels and the number of cages and corresponding arrays that were deployed at each location. Each array was deployed on a separate mooring and each with enough mussels to provide sufficient tissue to complete the study based on historical mortality rates. The locations of the arrays were recorded using Differential Global Positioning System (DGPS).

At OSM, four arrays (OS-M1, OS-M2, OS-M3, and OS-M6) were deployed at various locations just south of the diffuser heads and one approximately 1 km away at the "B" buoy (LNB) (Figure 2-4). This deployment scheme was used to better understand the spatial variability of contaminant concentrations along the length of the outfall as well as to reduce the possibility of accidental loss of all arrays.

2.3.4 Mussel Retrieval

Mussel retrieval was planned for two occasions with a collection of up to one half of the mussels per station at 40-days to provide tissue only in the event of failure to recover cages at the planned 60-day retrievals. The 40-day retrieval occurred on August 17 (47 days after deployment) and the 60-day retrieval occurred on August 31 (62 days after deployment). Mortality was unusually high, ranging from 25 (outfall cages) -89 (Inner Harbor) %. There was no apparent increase in mortality between the 47-day and 62-day collections.

2.3.5 Tissue Processing and Chemical Analyses

Individual mussels were pooled into single composites for organic and inorganic analyses. The plan was to analyze four composites (25 mussels per composite) from each of three stations (DIL, IH, and LNB) and eight composites from the outfall cages. The high mortality of the deployed mussels resulted in adjustments to this plan. MWRA's Deer Island Laboratory determined the minimum wet weight of mussel tissue required for analysis (75 g) for organic and inorganic parameters and EnviroSystems Inc. prepared as many replicates as possible using the available individuals. The number of replicates prepared was:

- Predeployment – 5 replicates of 25 mussels each
- IH – 1 replicate of 20 mussels
- LNB – 3 replicates of 21 mussels each
- DIL – 3 replicates of 21-22 mussels each
- OS-M1 – 2 replicates of 25 mussels each
- OS-M2 – 2 replicates of 25 mussels each
- OS-M3 – 2 replicates of 25 mussels each
- OS-M6 – 2 replicates of 25 mussels each

Mussel composites were prepared from individual mussels by removing attached material and byssal threads. All soft tissue, including fluids, was placed directly into a clean glass jar. Mussel composite samples were prepared for both organic and inorganic chemical analyses by homogenization of the mussels making up a replicate using a Titanium Tekmar "tissumizer" rinsed with methanol and de-ionized water prior to use. The homogenate was separated into aliquots using a titanium or Teflon utensil and placed in a pre-cleaned 4 ounce plastic jar. All composite splits were stored frozen prior to analysis.

The tissue composites were analyzed for PCBs/Pesticides, PAHs, lipids, mercury, and lead. The individual steps involved in the tissue processing and chemical analyses of these samples are detailed in Section 2.4.

Chemical Analyses of Tissue Samples

Table 2-5 summarizes the analyses performed on each type of tissue sample. The methods, references and specific analytes are listed in Table 2-6 through 2-8. The same analytical methods were used for all tissues.

2.3.6 Organic Tissue Extraction

The MWRA Central Laboratory performed all organic fish and shellfish tissue chemistry analyses. Tissue samples are extracted for PAH, chlorinated pesticides, and PCB congeners following MWRA Central Lab SOP #1189.0 (MWRA, 2004a). This extraction method utilizes sonication, and is based on EPA Method 3550B. Between 2 and 16 g of homogenized tissue is mixed with sodium sulfate and is serially extracted with methylene chloride (DCM) using sonication techniques. The sample is weighed in an extraction vessel, mixed with the appropriate amount of sodium sulfate to achieve a free-flowing consistency, and spiked with the surrogate compounds. Methylene chloride is added and the sample is sonicated using the ultrasonic disruptor. The extract is decanted in an Erlenmeyer flask through a powder funnel containing glass wool and sodium sulfate to remove any water and solid particles. After each extraction (total of three solvent additions) the filtered solvent is combined in the flask. If a percent lipids determination is to be performed, 10 mL of the total extract is removed and transferred to an aluminum weighing dish. The solvent is allowed to evaporate overnight and the pan is weighed for the percent lipids determination. The remaining extract is measured in a graduated cylinder and then concentrated to 1 mL using the TurboVap automatic concentrator technique. This concentrated extract is then processed through a silica gel cartridge and concentrated to 1.0 mL using the N-Vap automatic concentrator technique. The post-cleanup extracts are then split 50:50 for analysis by the PAH and pesticide/congener methods.

2.3.7 Metals Tissue Digestion and Analyses

The MWRA Central Laboratory performed metals digestions and analyses for Ag, Cd, Cr, Cu, Hg, Ni, Pb, and Zn. Tissue samples are prepared by weighing, freeze drying, and then weighing again to determine the dry weight. Tissue samples for Ag, Cd, Cr, Cu, Ni, Pb, and Zn are digested using a nitric acid digestion according to MWRA Central Lab SOP #1195.0 (MWRA, 2004b). A 500 to 1000 mg aliquot of each homogeneous lyophilized sample is combined with 5 mL HNO_3 and 5 mL water in a Teflon microwave vessel. Samples are cold-digested in this acid mixture overnight. Samples are then microwave digested for approximately 30 minutes. After heating and cooling, samples are filtered through Whatman #541 filters and rinsed with Milli-Q water (final volume is 50 mL).

Samples for mercury analysis are digested according to MWRA Central Lab SOP #1236.0 (MWRA, 2006). A 200 mg lyophilized aliquot is cold-digested with 15 mL dilute HNO_3 and H_2SO_4 overnight. Samples are heated in a 58^{o}C waterbath for 1 hour, and then heated again at 80^{o}C for an additional 30 minutes. Cooled samples are further oxidized with $KMnO_4$ and $K_2S_2O_8$ overnight. Deionized water is added to bring the final sample volume to 50 mL. For analysis by ICP digestates are analyzed according to MWRA Central Lab SOP #1008.3 (MWRA, 2008a). Elements that are undetected by ICP may be analyzed by GFA for lower reporting limits according to MWRA Central Lab SOP #1150.3 (MWRA, 2008b). Results are reported as μg/g dry-weight.

Analysis of Mercury - The digested sample is mixed with a reducing agent in-line to release elemental Hg vapor. Mercury is quantified by atomic absorption at 254 nm. Results are reported as µg/g dry-weight. Samples are analyzed according to MWRA Central Lab SOP #1049.3 (MWRA, 2008c).

2.3.8 Organic Analyses

PAH Analysis - Sample extracts are analyzed for PAH compounds by gas chromatography/mass spectrometry (GC/MS) operating in the selected-ion-monitoring (SIM) mode, using a 30m Rtx-5 column (or equivalent) and an Agilent 5973 detector (or equivalent) according to MWRA Central Lab SOP #1030.3 (MWRA, 2004c). The PAH compounds are quantified using the internal standard method. Concentrations of the substituted PAH homologues are determined by summing the total area of each homologue and using the response factor of the parent PAH compound.

PCB/Pesticide Analysis – Pesticides and PCB congeners are analyzed by gas chromatography/mass spectrometry (GC/MS) operating in the selected-ion-monitoring (SIM) mode, using a 60m Rtx-5 column (or equivalent) and an Agilent 5973 detector (or equivalent) according to MWRA Central Lab SOP #1173.3 (MWRA, 2004d). Two separate analyses are performed, one to determine the pesticide compounds and one for the PCB congeners. Concentrations for all target analytes are determined using the internal standard method.

All PAH, PCB congener, and pesticide results are reported in micrograms per kilogram (µg/kg) on a dry weight basis, which is determined during metals analysis.

2.4 Data Treatment, Reduction, and Statistical Analyses

This section describes the data reduction performed on 2015 Fish and Shellfish data, as well as historical data, as part of the MWRA Harbor and Outfall Monitoring Project.

Data reduction for flounder, lobster, and mussels was conducted as described in the Fish and Shellfish Monitoring QAPP (Geoghegan *et al.* 2014). Chemical constituents were presented graphically and compared among stations and over time.

Specifics of data handling are as follows:

- All 2015 chemical data were generated by MWRA's Department of Laboratory Services and loaded directly into the HOM database.
- Mussel data for all OS 60-day deployment locations (e.g. OS-M1, OS-M2, OS-M3, OS-M6) were averaged for both 2015 and time-series plots.
- All fish and shellfish data (2015 and historical) were extracted directly from the HOM database and exported into Excel files. Graphical presentations and statistical analyses were performed using SAS software (version 9.3).
- All laboratory duplicates for pre-1998 data were averaged for reporting and calculating. No laboratory duplicate data were entered for post-1998 data.
- Error bars in all graphical presentations represent standard errors. Means, standard deviation, and sample size by station and year are reported in the Appendices.
- 1992 flounder collection consisted of three individual fish and a composite of seven fish. Results were calculated by treating the composite as seven individual fish and averaging those values with the values of the other three individual fish (i.e., [(7*val1 +val2 + val3 +

val4)/10]). MWRA decided that the appropriate standard error and *n* values for this composite are null. This manipulation was done in the script used to query the data from the database and is not reflected in the EM&MS database.

- 1993 lobster selection consisted of two animals collected in June and one in August. Results were calculated by taking the average of these three animals ($n = 3$).
- Total PCB was calculated as the sum of twenty PCB congeners (Table 2-7).
- Total DDT was calculated as the sum of six DDT-related compounds: 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT (Table 2-7).
- Total chlordane was calculated as the sum of four compounds: heptachlor, heptachlor epoxide, cis-chlordane, and trans-nonachlor (Table 2-7).
- Sums of PAHs were calculated using several groupings. The "Total PAH List" and the "Historical NOAA List" are presented in Table 2-8.
- In 1995, the individual five alkylated PAHs on the "Historical NOAA List" were not measured in mussels. Instead, the C1-, C2-, and C3-alkylated naphthalene homologue groups were quantified. To make 1995 results more comparable to the "Historical NOAA List", values for the individual alkylated naphthalene compounds were estimated using ratios of the individuals to their respective homologue groups from 1996 and 1997 data sets.
- All organic data (i.e., PAHs, PCBs, and pesticides) are surrogate recovery corrected.
- The "s" qualifier was used to indicate suspect data. Unless otherwise noted, only "s"-flagged data were excluded in calculations, tables, or graphs presented in this report.
- All non-detects used in calculations and trend analyses in this report were treated as zero.
- All data entered into the database are in dry weight units.
- Wet weight tissue concentrations were calculated from the wet/dry ratio and used in comparison to MWRA Contingency Plan Thresholds.
- Years in which composite samples were made up of only one animal were excluded from temporal plots.

Table 2-1. Planned and actual sampling locations for flounder survey

Station ID	Sampling Site	Number of Tows	Planned Locations		Actual Locations[1]	
			N Latitude	W Longitude	N Latitude	W Longitude
DIF	Deer Island Flats	7	42º20.4’	70º58.4’	42º21.0’	70º58.1’
NB	Off Nantasket Beach	3	42º17.6’	70º52.2’	42º17.3’	70º51.9’
OS	Outfall Site	1	42º23.1’	70º49.3’	42º23.3’	70º49.7’
ECCB	East Cape Cod Bay	2	41º56.2’	70º06.6’	41º55.8’	70º07.6’

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

Table 2-2. Planned and actual sampling locations for lobster survey

Station ID	Sampling Site	Planned Location		Actual Location	
		N Latitude	W Longitude	N Latitude	W Longitude
DIF	Deer Island Flats	42º20.4’	70º58.4’	42º20.1’	70º71.0’
OS	Outfall Site	42º23.1’	70º49.3’	42º83.3’	70º47.8’
ECCB	East Cape Cod Bay	41º56.2’	70º06.6’	41º47.8’	70º29.9’

Table 2-3. Planned and actual sampling locations for mussel survey

Station ID	Sampling Site	Planned Location		Actual Location	
		N Latitude	W Longitude	N Latitude	W Longitude
DIL	Deer Island Light	42º20.4’	70º57.2’	42º20.4’	70º57.2’
OS-M1	Outfall Site – Mussel Array 1	42° 23.21'	70° 47.26'	42°23.22’	70°47.26’
OS-M2	Outfall Site – Mussel Array 2	42° 23.22'	70° 47.18'	42°23.21’	70°47.18’
OS-M3	Outfall Site - Mussel Array 3	42º23.17’	70º47.47’	42°23.17’	70°47.47’
OS-M6	Outfall Site - Mussel Array 6	42º23.26’	70º46.99’	42°23.25’	70°47.00’
LNB	LNB “B” Buoy	42º22.67’	70º47.13’	42º22.7’	70º47.1’
IH	Boston Inner Harbor	42º21.5’	71º02.9’	42°21.5’	71°02.9’
TS	Blue Hill Bay, ME	44º20.7’	68º34.4’	44º20.7’	68º34.4’

Table 2-4. Summary of mussel deployment scheme

Site	Description/ Location	Water Depth[a]	Cage Height Above Bottom	# Arrays	# Cages/Array	# Mussels/ Cage
DIL	Deer Island Light	2-5 m	<1-1.5m	3	2	60
OS	Outfall Site	33m	12m	4	3	60
LNB	“B” Buoy	33m	12 m	2	2	60
IH	Boston Inner Harbor	8-11m	1.5-4.5m[b]	2	2	60

[a] Arrays rise and fall with tide, so that they are at a constant depth below the water surface.
[b] Based on historical data.

Table 2-5. Summary of chemical analyses performed

Sample Type	Number of Samples	Metals (1) (other than Hg and Pb)	Hg	Pb	PCBs	PAHs	Pesticides	Lipids
Flounder Meat	12	NR	*	NR	*	NR	*	*
Flounder Liver	12	*	*	*	*	*	*	*
Lobster Meat	9	NR	*	NR	*	NR	*	*
Lobster Hepatopancreas	9	*	*	*	*	*	*	*
Mussel Tissue	24	NR	*	*	*	*	*	*

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

Table 2-6. Summary of analytical methods.

Parameter	Unit of Measurement	Method	Reference
Organic Analyses			
Organic Extraction	NA	Tissuemize/Methylene Chloride	MWRA (2004a), SOP 1189.0
Polycyclic Aromatic Hydrocarbons (PAH)	ng/g dry wt.	GC/MS-SIM	MWRA (2004c), SOP 1030.3
Polychlorinated Biphenyls (PCB)/Pesticides	ng/g dry wt.	GC/MS-SIM	MWRA (2004d), SOP 1173.3
Metals Analyses			
Digestion: Ag, Cd, Cr, Cu, Ni, Pb, Zn	NA	Microwave digestion Nitric acid	MWRA (2004b), SOP 1195.0
Digestion: Hg	NA	Nitric acid, sulfuric acid	MWRA (2006), SOP 1236.0
Analysis: Ag, Cd, Cr, Cu, Ni, Pb, Zn	µg/g dry wt	ICP AES, GFA as needed	MWRA (2008a, b), SOP 1008.3, 1150.3
Analysis: Hg	µg/g dry wt	CVA	MWRA (2008c), SOP 1049.3
Ancillary Parameters			
Lipids	% by dry weight	Gravimetric	MWRA (2004a), SOP 1189.0
Dry Weight	% by dry weight	Freeze drying	MWRA (2004b), SOP 1195.0

Table 2-7. Specific chemical analytes

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

[a] Flounder liver; lobster hepatopancreas
[b] Flounder and lobster edible tissue
[c] Flounder edible tissue and liver; lobster edible tissue and hepatopancreas
[d] Mussel soft tissue
[e] Measured in mussel tissue in 1992–1994 and 1996–2009

Table 2-8. Summary of PAH lists of analytes

Total PAH List	"Historical" NOAA PAH List
Low Molecular Weight PAHs	**Low Molecular Weight PAHs**
1-methylnaphthalene*	1-methylnaphthalene
1-methylphenanthrene*	1-methylphenanthrene
2,3,5-trimethylnaphthalene*	2,3,5-trimethylnaphthalene
2,6-dimethylnaphthalene*	2,6-dimethylnaphthalene
2-methylnaphthalene*	2-methylnaphthalene
Acenaphthene	Acenaphthene
Acenaphthylene	Acenapthylene
Anthracene	Anthracene
Benzothiozole*	
Biphenyl	Biphenyl
C1-dibenzothiophenes	
C1-fluorenes	
C1-naphthalenes	
C1-phenanthrenes/anthracenes	
C2-dibenzothiophenes	
C2-fluorenes	
C2-naphthalenes	
C2-phenanthrenes/anthracenes	
C3-dibenzothiophenes	
C3-fluorenes	
C3-naphthalenes	
C3-phenanthrenes/anthracenes	
C4-naphthalenes	
C4-phenanthrenes/anthracenes	
Dibenzofuran	
Dbenzothiophene	
Fluorene	Fluorene
Naphthalene	Naphthalene
Phenanthrene	Phenanthrene
High Molecular Weight PAHs	**High Molecular Weight PAHs**
Benzo(a)anthracene	Benzo(a)anthracene
Benzo(a)pyrene	Benzo(a)pyrene
Benzo(b)fluoranthene	Benzo(b)fluoranthene
Benzo(e)pyrene	Benzo(e)pyrene
Benzo(g,h,i)perylene	Benzo(g,h,i)perylene
Benzo(k)fluoranthene	Benzo(k)fluoranthene
C1-chrysenes	
C1-fluoranthenes/pyrenes	
C2-chrysenes	
C2-fluoranthenes/pyrenes	
C3-chrysenes	
C3-fluoranthenes/pyrenes	
C4-chrysenes	
Chrysene	Chrysene
Dibenzo(a,h)anthracene	Dibenzo(a,h)anthracene
Fluoranthene	Fluoranthene
Indeno(1,2,3-c,d)pyrene	Indeno(1,2,3-c,d)pyrene
Perylene	Perylene
Pyrene	Pyrene
* **Not Included in Total PAH**	

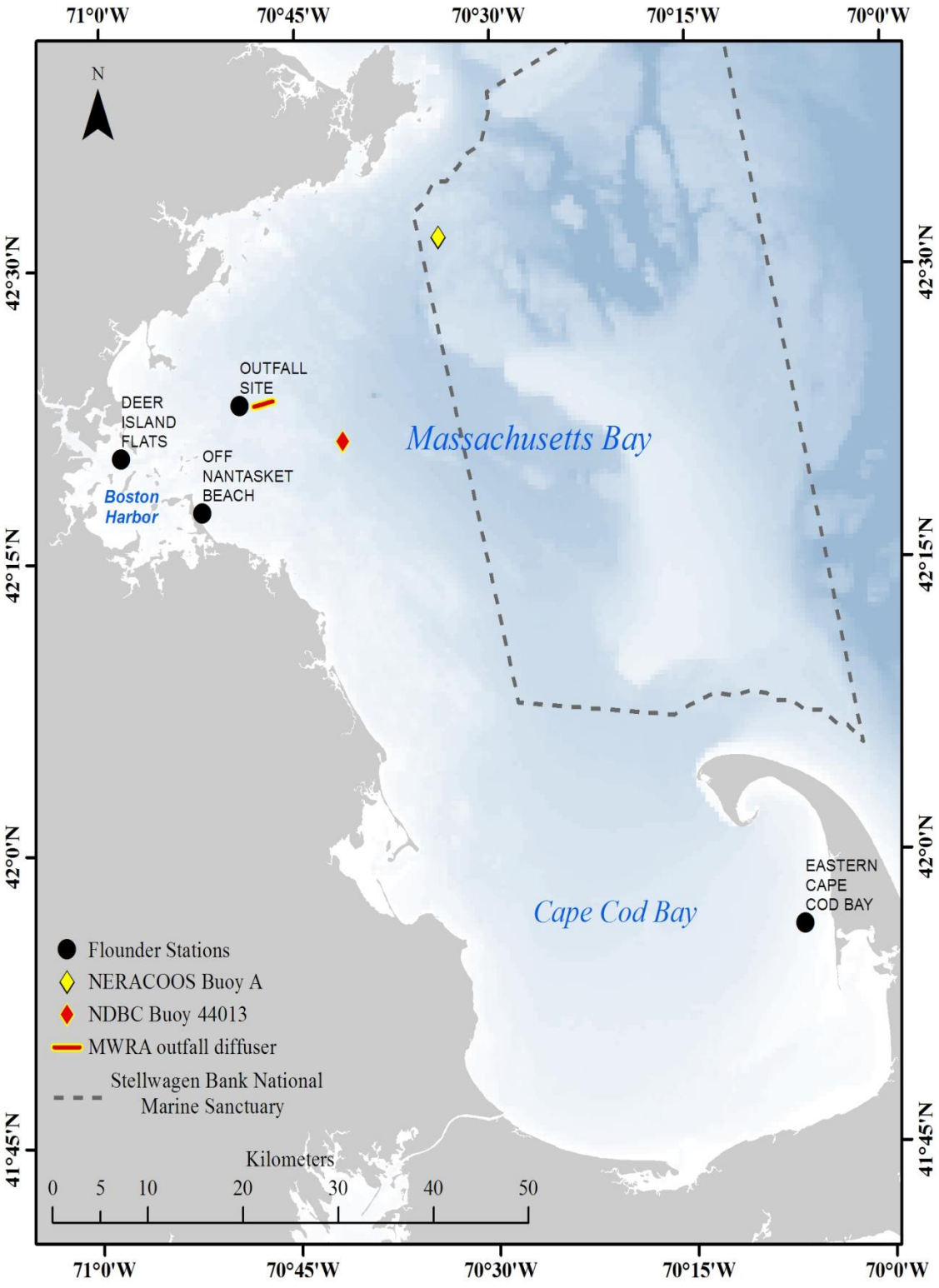

Figure 2-1. 2015 Flounder Monitoring Locations.

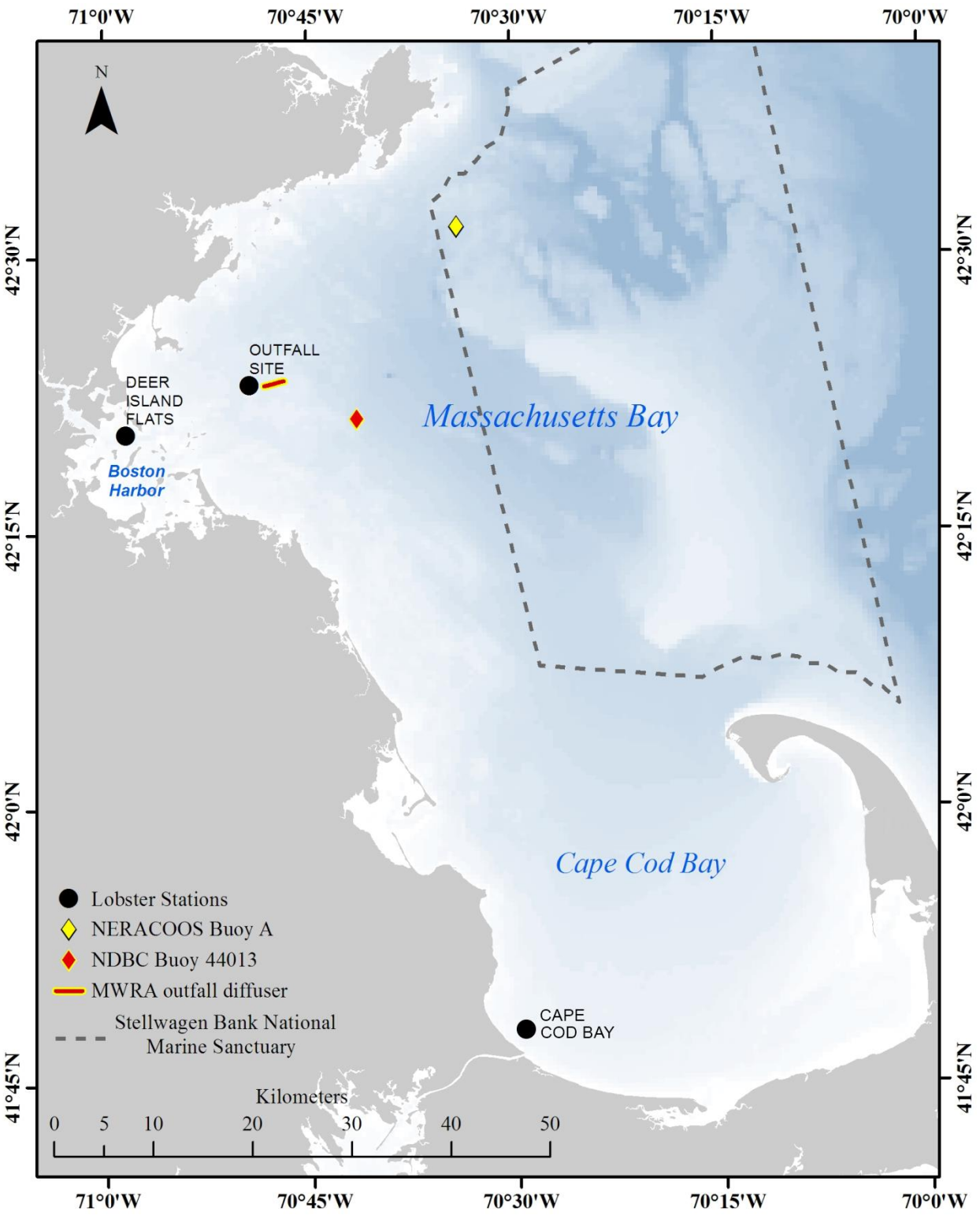

Figure 2-2. 2015 Lobster Monitoring Locations.

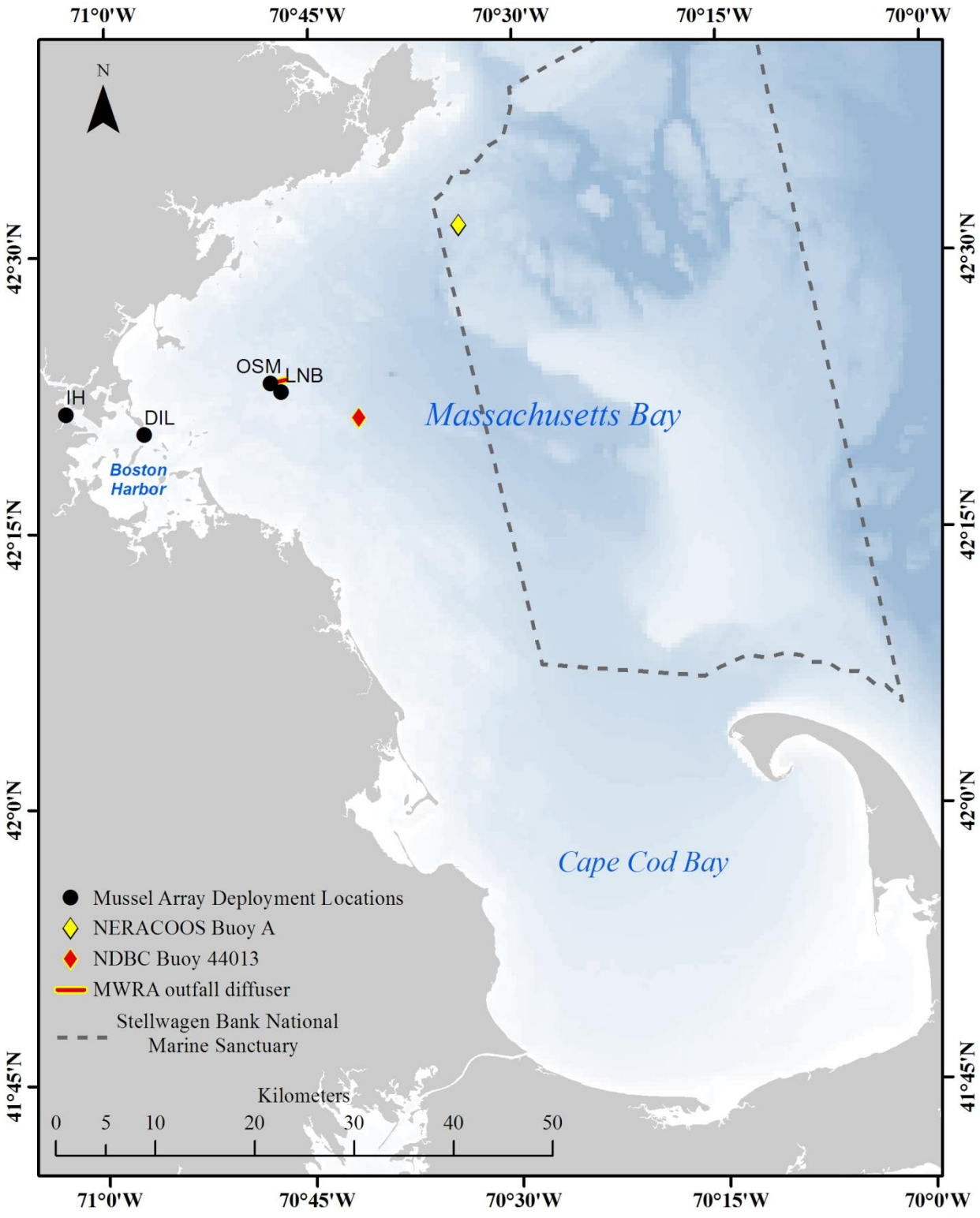

Figure 2-3. 2015 Mussel Deployment Locations.

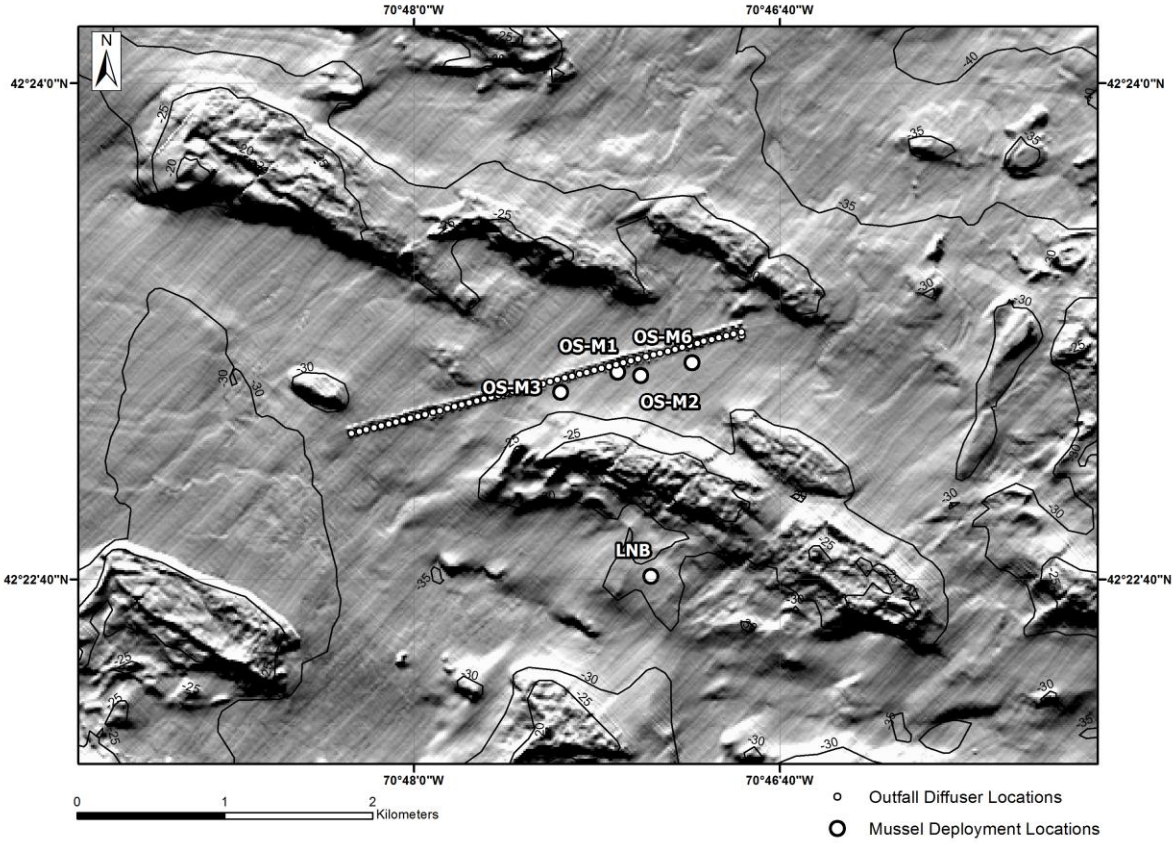

Figure 2-4. Mussel Deployment Locations at OS in 2015.

3.0 RESULTS

3.1 Winter Flounder

3.1.1 Summary of Survey Results

Winter flounder, each a minimum 30 cm in length, were collected between April 27 and May 7, 2015 at four stations in the study area (Figure 2-1**).** Flounder collections in 2015, along with physical characteristics, external condition, and liver histopathology are described in detail in the annual flounder monitoring report (Moore et al., 2016). In summary, sizes, ages, and gender ratios observed in 2015 were similar to recent years (Table 3-1). Prevalence of blindside ulcers remained low (Table 3-2). Occurrence of liver lesions was within the range observed since the start of the offshore discharge at all stations, lower than levels found at DIF during the baseline period (Table 3-3).

3.1.2 Contaminant Levels

Contaminant levels were determined for both edible tissue (fillets) and liver tissue for winter flounder collected in the 2015 survey. In this section, the body burdens of selected contaminants are presented and discussed within the context of historical trends. The trend plots begin in the year 1995 when the number of organisms per replicate increased from one to five. Beginning in 2004 contaminants have been measured every third year at all stations except Nantasket Beach (NB) where they have been measured every three years since the inception of this program. All winter flounder body burden data collected during this program are presented in Appendices A and B.

Edible fillet - As in past years, fillets from fish collected off of Deer Island had the highest concentrations of organic contaminants and those from Cape Cod Bay the lowest. The 2015 results for total chlordane (the sum of alpha chlordane, trans-nonachlor, heptachlor, and heptachlor epoxide) and 4-4 DDE (the predominant DDT breakdown isomer) continued a downward trend (Figures 3-1 and 3-2).
PCB concentrations in flounder fillet from DIF, NB, and OS were all lower in 2015 than the relatively high values reported at these stations in 2012 (Figure 3-3). Values at OS in 2015 were among the lowest observed during this program. Tissue concentrations of PCBs at ECCB remained low (Figure 3-3).
Mercury concentrations in fillet were within historical ranges at all four stations in 2015 (Figure 3-4). Concentrations remained highest at OS and lowest at ECCB; no temporal trends were evident at any of the stations.

Liver - Spatial and temporal patterns of organic contaminants in flounder liver were similar to those in fillets. Total chlordane in flounder liver was similar at all four stations in 2015, with concentrations lower than previously reported at all stations (Figure 3-5). Concentrations of total PCBs in 2015 were also among the lowest reported during the history of the program (Figure 3-6). Concentrations of both silver and nickel in flounder liver were similar at all four stations in 2015 (Figures 3-7 and 3-8). Silver concentrations at OS in 2015 were lower than previously reported at this station (Figure 3-7). Both silver and nickel in 2015 were otherwise within historical ranges at all stations. Lead concentrations in flounder liver were also within historical ranges at all stations in 2015 (Figure 3-9). Similar to previous years, lead concentrations in 2015 remained highest at OS, with no clear spatial patterns among the other three stations.

Decreases in total chlordane and 4-4 DDE in flounder tissues have occurred at all stations, and do not appear to be related to the diversion of the MWRA's effluent into Massachusetts Bay in September 2000. A Before/After Control Impact (BACI) study concluded that based upon data through 2006, changes observed in Boston Harbor and Massachusetts Bay were not statistically different from those at the control station in Eastern Cape Cod Bay (Kane-Driscoll *et al*. 2008). These region-wide decreases were

anticipated given that these compounds have been banned in the United States (DDTs since 1972 and chlordane since 1988). The similarity of the station trends may also reflect subtle differences in analytical techniques and reporting limits employed by the several laboratories used during this program. For example the PCB and pesticide analyses conducted since 2009 used a technique, MS-SIM, which eliminates interferences that may have been quantified in earlier years. Also, there is evidence from the National Marine Fisheries Service that flounder in the Gulf of Maine have been wintering in deeper, offshore waters (Nye *et al*. 2009). This suggests the possibility that the fish collected in this program may be spending more time in less contaminated environments which would result in a decrease in exposure to bio-accumulating contaminants.

In contrast to organics, temporal trends have been less apparent in flounder tissue metal concentrations. For example, there have been no apparent trends in body burdens of mercury or lead (Figures 3-4 and 3-9). Results for silver in flounder liver suggest some evidence of change over time. Although silver has historically been highest in fish from OS, the most recent data suggests a downwards trend at OS, and possibly at NB, with no apparent trends at the other two stations. In 2012 and 2015 the highest concentrations of silver were observed at ECCB.

3.2 Lobster

3.2.1 Size, Sex, and External Conditions

Weight, carapace length, and sex were determined for 21 lobsters from each of the three sites (Table 3-4). The average carapace length was similar at all locations as has been typically found throughout the study. Weights were collected only from Cape Cod Bay lobsters with the average weight in 2015 above the historical averages. Unlike 2012, lobsters were predominantly male at DIF and ECCB; females predominated at OS. This was typical of historical ECCB and OS results but differed from past data from DIF where females typically predominated. Visual inspection of the lobsters indicated three animals from ECCB had signs of shell erosion. No other deleterious external conditions were reported at any location.

3.2.2 Tissue Contaminant Levels

Contaminant levels were determined for both edible meat (tail and claw meat) and hepatopancreas for lobster collected in the 2015 survey. In this section the body burdens of selected contaminants measured in 2015 are presented and discussed within the context of historical trends. The trend plots present data beginning in 1994 when the number of organisms per replicate increased from one to five. Lobster body burden data are provided in Appendices C and D. Any temporal changes in body burdens in lobsters from Cape Cod Bay in 2015 compared to previous years should be considered in light of the fact that collections were made farther west, off Sandwich, than in in the past.

Edible Meat - Organic contaminant concentrations in lobster meat have historically been highest in animals collected off Deer Island and lowest in those from Cape Cod Bay. This pattern continued in 2015, although differences among stations were low for all contaminants. In 2015, lobsters from DIF had the highest concentrations of total chlordane, while concentrations in those collected at ECCB and OS were similarly low (Figure 3-10). Concentrations of total DDT and total PCB were only slightly higher at DIF than at other stations in 2015 (Figures 3-11 and 3-12). Decreasing concentrations over time are apparent at all stations for both total chlordane and total DDT (Figures 3-10 and 3-11). The stark decrease in 1995 total chlordane at all three stations seems likely an unresolved analytical issue and likely misrepresents actual tissue concentrations. A BACI analysis reported in Kane-Driscoll *et al.* (2008) concluded that these changes were not due to relocation of the outfall since decreases in the harbor and Massachusetts Bay were statistically no different than changes at the control station in Cape Cod Bay.

In 2015 PCB concentrations at all three stations were similar to 2012 values, among the lowest observed during this program. However, PCBs in lobster meat have shown no clear trend at any of the three stations (Figure 3-12). In 2009, lobster meat from Deer Island Flats had the highest average PCBs observed during this program. Only one of the three replicates was high, a phenomenon similar to that observed at OS in 2003. At that time analysis of tissue from each individual lobster demonstrated that the high level of PCBs in the replicate came from only one of the five lobsters in the composited replicate (Wisneski *et al.* 2004). Given that adult lobster can be highly migratory, moving inshore in the early summer and offshore in the fall, it is difficult to assess with certainty where a given lobster has been exposed to anthropogenic contaminants (see Mitchell *et al.* 1998 and Lavalli and Kropp 1999 for further discussion of lobster biology and migration).

Mercury concentrations in lobster meat in 2015 were also highest at DIF and lowest at ECCB (Figure 3-13). Results at all three stations in 2015 were similar to the previous survey and within the range of historical variation.

Hepatopancreas – Spatial patterns in the concentrations of organic contaminants in lobster hepatopancreas were similar to those reported for lobster meat. Concentrations of total chlordane and total PCBs were highest at DIF and lowest at ECCB in 2015 (Figures 3-14 and 3-15). Concentrations of total chlordane have generally decreased at all stations since the late 1990s, while results for total PCBs in hepatopancreas have changed little over time at these same stations (Figures 3-14 and 3-15).

In contrast to organics, metal concentrations in lobster hepatopancreas in 2015 were generally highest at OS and lowest at DIF. This pattern was found for cadmium and copper in 2015 (Figures 3-16 and 3-17). Nickel concentrations in 2015 were similarly high in lobster hepatopancreas from OS and ECCB, and lower at DIF (Figure 3-18). Lead concentrations in 2015 were highest at OS and lowest at ECCB (Figure 3-19). Although values at OS were lower in 2015 than in 2012 for both cadmium and lead, the current results continue to suggest a potential increasing trend in lobster hepatopancreas metal concentrations at OS. Copper and nickel are both also trending up in lobster hepatopancreas from OS. Despite these trends at OS, spatial patterns in metal concentrations suggest that the observed increases over time likely reflect a region-wide phenomenon, unrelated to the wastewater discharge, because similar trends were observed at ECCB. Concentrations of both cadmium and copper at ECCB in 2015 were higher than had been reported in any prior years (Figures 3-16 and 3-17). Nickel concentrations have increased over time at ECCB where values are typically higher than at DIF and comparable to, or higher than at OS (Figure 3-18). Many factors affect the bioavailability and bioaccumulation of metals in lobster tissues (Hunt *et al.* 2006). Increasing concentrations of certain metals in lobster hepatopancreas may reflect changes in metal bioavailability related to sediment biogeochemical and physical processes as opposed to increased metal inputs (Hunt *et al.* 2006).

3.3 Blue Mussel

3.3.1 Mussel Survival

During the 47-day retrieval, it was observed that mussel mortality was substantially higher at all locations than during past surveys (Table 3-5). As mortality did not increase appreciably by the 60-day collection and fouling was not severe for the offshore arrays, it is presumed that the hardiness of commercially rope-grown mussels may be lower than that of wild intertidal mussels exposed to tidal and wave action. Mussels were collected at 47 days (August 17) and archived. Samples were collected at all stations on August 31 (60-day retrieval) but in most cases the planned complement of 25 individuals per replicate was not available. MWRA's DLS determined the minimum wet weight of mussel tissue necessary to

perform all of the required analyses (75 g), and that information was used to determine the numbers of mussels for each composite sample.

3.3.2 Tissue Contaminant Levels

2015 Spatial Comparison – Blue mussels passively filter ambient waters and readily bio-accumulate contaminants in those waters, making them an excellent and commonly employed tool for assessing spatial patterns in water quality (O'Connor and Lauenstein 2006). For this reason the MWRA has used caged mussels as a "controlled experiment", deploying mussels from a clean environment at various locations, collecting them after a set period of time, and determining the extent of contaminant bioaccumulation.

Spatial patterns in the 2015 results were largely consistent with past years. Contaminant concentrations were generally highest at IH and lower at other stations, especially OSM and LNB. Total chlordane bio-accumulated to similar levels at all sites except IH, where concentrations were much higher than at other stations (Figure 3-20). Mussels at all stations bio-accumulated total PCBs, although the largest increases were at IH, followed by DIL (Figure 3-21). Bioaccumulation of total DDTs was similar to PCBs, with highest concentrations at IH, followed by DIL, then LNB and OSM (Figure 3-22). Low Molecular Weight (LMW) PAHs were also highest at IH followed by OSM and LNB, and lowest at DIL (Figure 3-23). High Molecular Weight (HMW) PAHs were similar at all sites except IH where they were much higher (Figure 3-24). Mercury concentrations were highest in mussels deployed at DIL, but were similar at all locations, and only slightly above levels found in the background mussels (Figure 3-25). Lead bioaccumulation followed the pattern found for most contaminants, with highest concentrations in mussels deployed at IH and lowest in mussels deployed at OSM and LNB (Figure 3-26).

The 2015 mussel bioaccumulation results generally suggest improvement in water quality along a gradient from Boston's Inner Harbor (IH), to Outer Boston Harbor (DIL), to Massachusetts Bay (OSM and LNB), to Coastal Maine (TS; where mussels were raised).

Inter-annual comparison – This study is intended to assess whether there have been changes in water quality either at the new (OSM) or old (DIL) discharge locations as a result of the diversion of wastewater discharge in September of 2000. A BACI analysis based on data through 2006 suggested that after controlling for data from a control station in Cape Cod Bay (CCB) there had been an increase of lead, PCBs, chlordane, DDE, and HMW PAHs in mussels deployed at the Outfall Site. At Deer Island only chlordane had shown a significant decrease (Kane-Driscoll *et al.* 2008).

Total chlordane has declined at DIL, LNB, and OSM since the early 2000s (Figure 3-27). While there were clear increases in chlordane in mussels deployed near the outfall in 2001-2003, concentrations are now lower than those observed prior to effluent diversion. Likewise, PCB and DDT concentrations have decreased at all three sites during the past decade (Figures 3-28 and 3-29). LMW PAHs continued a decreasing trend in mussels deployed at DIL, and remained low at OSM and LNB in 2015 (Figure 3-30). HMW PAHs were marginally higher in 2015 than in recent surveys at DIL, OSM and LNB (Figure 3-31). Bioaccumulation of lead at DIL has decreased over time, and lead concentrations remained low at DIL, OSM and LNB in 2015 (Figure 3-32).

3.4 Comparison to Thresholds

The U.S. Food and Drug Administration (FDA) has set action limits for the maximum tissue concentrations of specific contaminants in the edible portions of fish and fishery products. For the MWRA monitoring program, Caution and Warning thresholds have been set for tissue contaminant concentrations (organic and inorganic) and liver disease incidence (MWRA 2001a, MWRA 2001b). These thresholds are derived from either the FDA Action Limits, when available, or from the baseline mean of contaminant concentrations at OS. These two levels provide reference benchmarks for detecting adverse changes (and their potential human health risks) of the outfall discharge.

All thresholds for flounder fillet (Table 3-6) and lobster meat (Table 3-7) have been easily met since outfall start-up. While there have been mussel threshold exceedances in the past for total chlordane (2001) and PAH (2001, 2002, and 2003), there have been no exceedances since those times. In 2015 all thresholds were met (Table 3-8).

Table 3-1. Summary of physical characteristics of flounder collected in 2015

Parameter	DIF			ECCB			NB			OS		
	Mean	STDDEV	N	Mean	STDDEV	N	Mean	STDDEV	N	Mean	STDDEV	N
Age (years)	4.16	1.45	49	5.02	1.48	50	4.12	1.44	50	5.02	1.95	50
Standard Length (mm)	292.3	29.7	50	290.54	23.32	50	279.06	20.57	50	273.76	20.94	50
Total Length (mm)	357	36.61	50	352.28	28.77	50	340.46	24.62	50	334.52	25.35	50
Weight (g)	517.5	160.12	50	501.6	140.61	50	463.1	120.56	50	426.7	116.49	50

Std. Dev. = Standard Deviation

Table 3-2. Prevalence (%) of external conditions assessed for flounder collected in 2015.

External Conditions	Station (Sample size)			
	DIF (50)	ECCB (50)	NB (50)	OS (50)
Bent Fin Ray	20	14	2	6
Blind Side Ulcers	4	0	2	2
Fin Erosion (Fin Rot)	20	20	22	4
Lymphocystis	32	30	38	66

Sample size – 50 fish at each station

Table 3-3. Prevalence (%) of liver lesions in flounder collected in 2015.

Liver Conditions	Station (Sample size)			
	DIF (50)	ECCB (50)	NB (50)	OS (50)
Balloons	4	16	28	12
Bile Duct Protozoan	0	0	0	0
Liver Flukes	0	2	0	0
Biliary Proliferation	6	4	6	6
Macrophage Aggregation	60	42	64	62
Centrotubular Hydropic Vacuolation	32	4	10	10
Tubular Hydropic Vacuolation	24	0	0	4
Focal Hydropic Vacuolation	0	0	0	0
Neoplasia	0	0	0	0

Table 3-4. Mean length and weight, and % females of lobsters collected in 2015

Parameter	DIF			OS			ECCB		
	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
Carapace Length (mm)	88	4	21	87	3	21	91	4	21
Weight (g)	ND	ND	21	ND	ND	21	557	76	21
Percent female (%)	24		21	67		21	38		21

ND = No Data

Table 3-5. 2015 caged mussels survival data

Collection	Site	Total Mussels	Dead Mussels	Survival Rate
47-day	IH	100	79	21%
	DIL	100	65	35%
	OS-M2	100	51	49%
	OS-M3	100	41	59%
	LNB	100	30	70%
60-day	IH	100	83	17%
	DIL	100	44	56%
	OS-M1	100	44	56%
	OS-M2	100	39	61%
	OS-M3	100	43	57%
	OS-M6	100	51	49%
	LNB	100	44	56%

Table 3-6. Comparison of 2015 flounder fillet results to MWRA Caution Levels

Caution Threshold			2015 Results
Chlordane	484	ng/g lipid	19
DDT	1552	ng/g lipid	170
Dieldrin	127	ng/g lipid	0
PCB	1000	ng/g wet	15.3
Mercury	0.5	ng/g wet	0.069
Liver Disease	44.9	%	10

Table 3-7. Comparison of 2015 lobster meat results to MWRA Caution Levels

Caution Threshold			2015 Results
Chlordane	150	ng/g lipid	2.3
DDT	683	ng/g lipid	44.8
Dieldrin	322	ng/g lipid	0
PCB	1000	ng/g wet	12.1
Mercury	0.5	ng/g wet	0.102

Table 3-8. Comparison of 2015 mussel results to MWRA Caution Levels

Caution Threshold			2015 Results
Chlordane	205	ng/g lipid	16.1
DDT	483	ng/g lipid	26.3
Dieldrin	50	ng/g lipid	0
PAH	2160	ng/g lipid	1580
PCB	1000	ng/g wet	2.76
Mercury	0.5	ng/g wet	0.009
Lead	2.0	ng/g wet	0.147

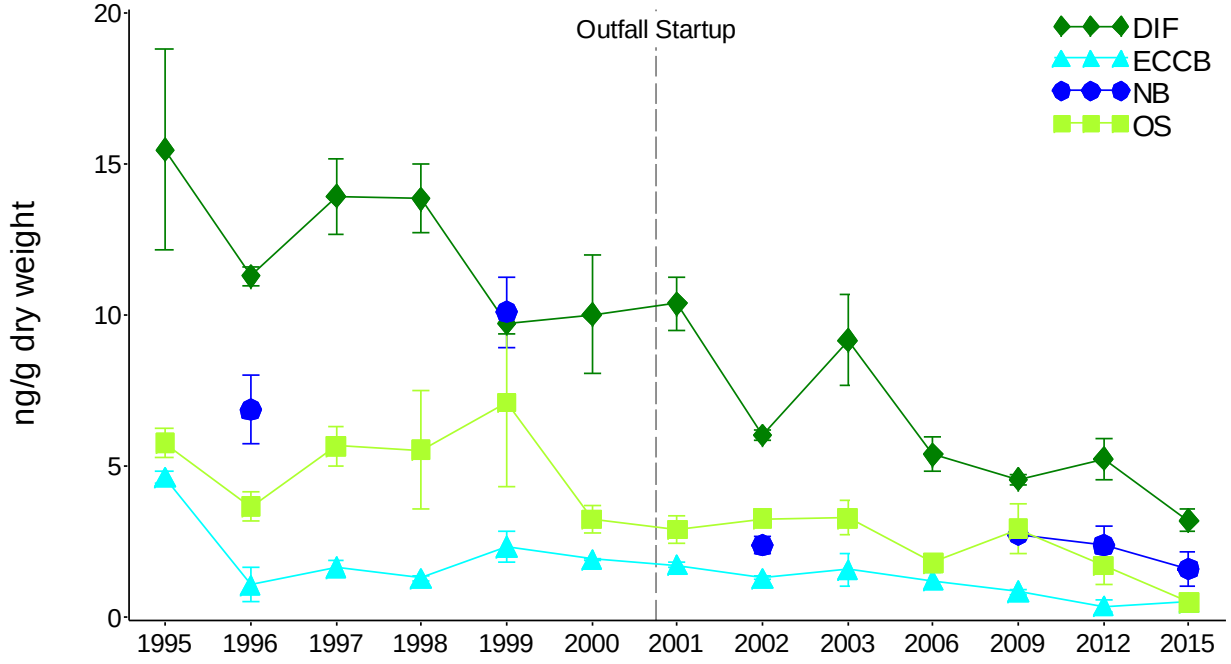

Figure 3-1. Total chlordane in flounder fillet (1995-2015)

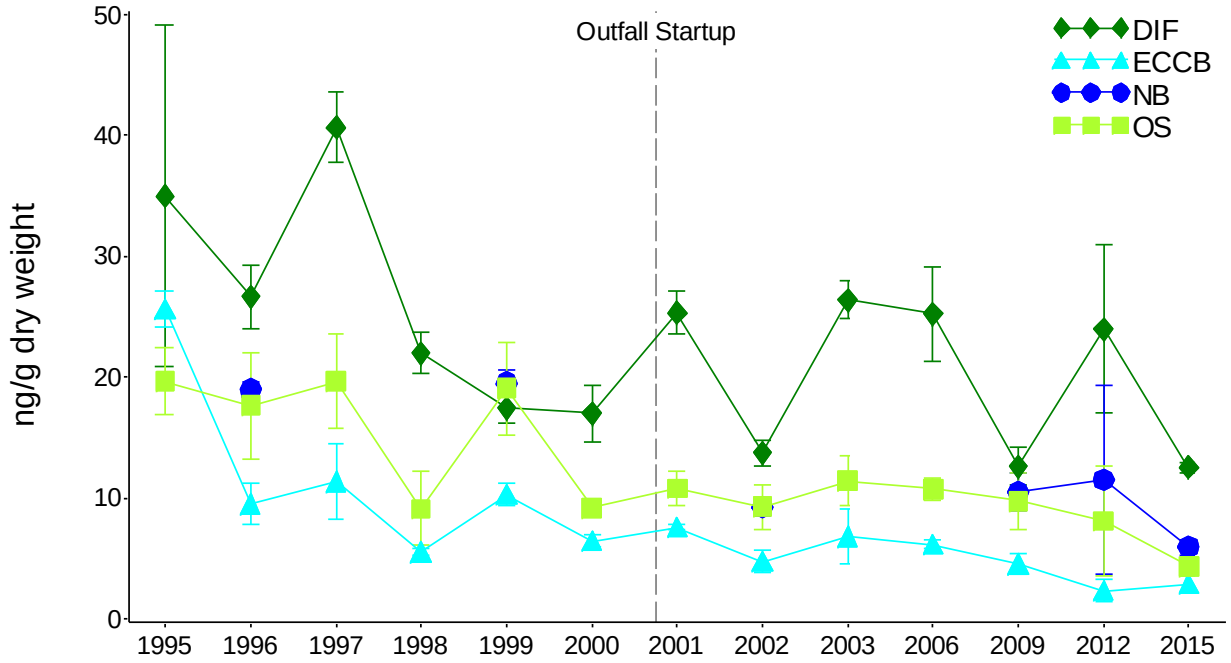

Figure 3-2. 4-4 DDE in flounder fillet (1995-2015)

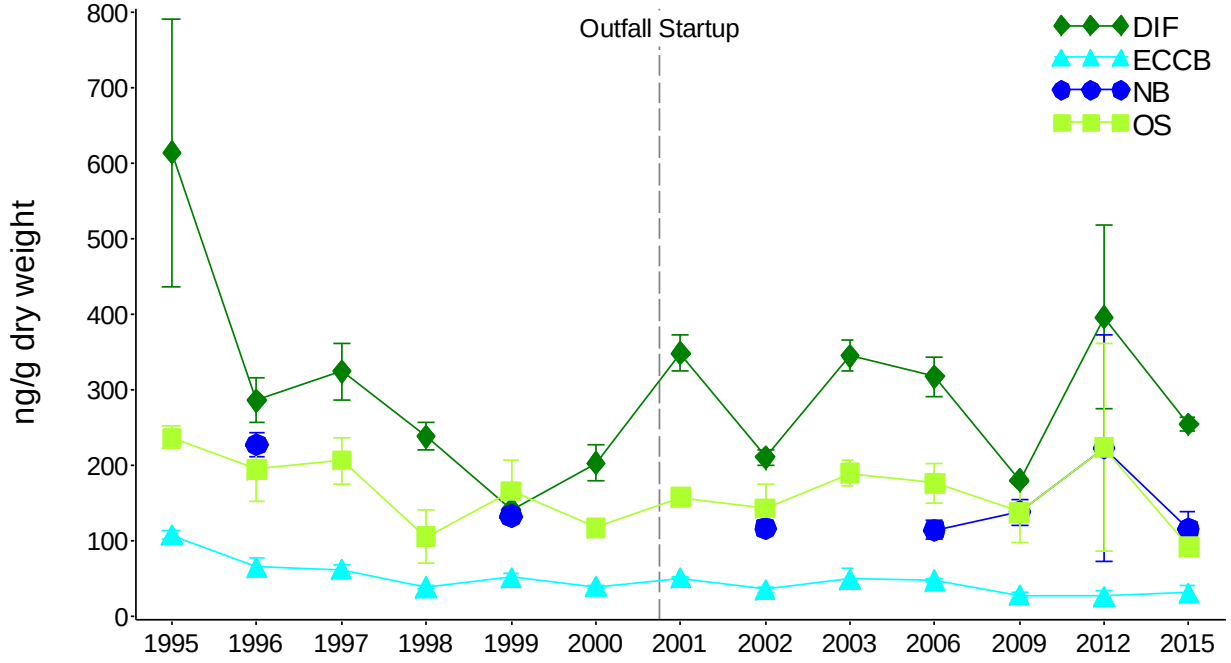

Figure 3-3. Total PCB in flounder fillet (1995-2015)

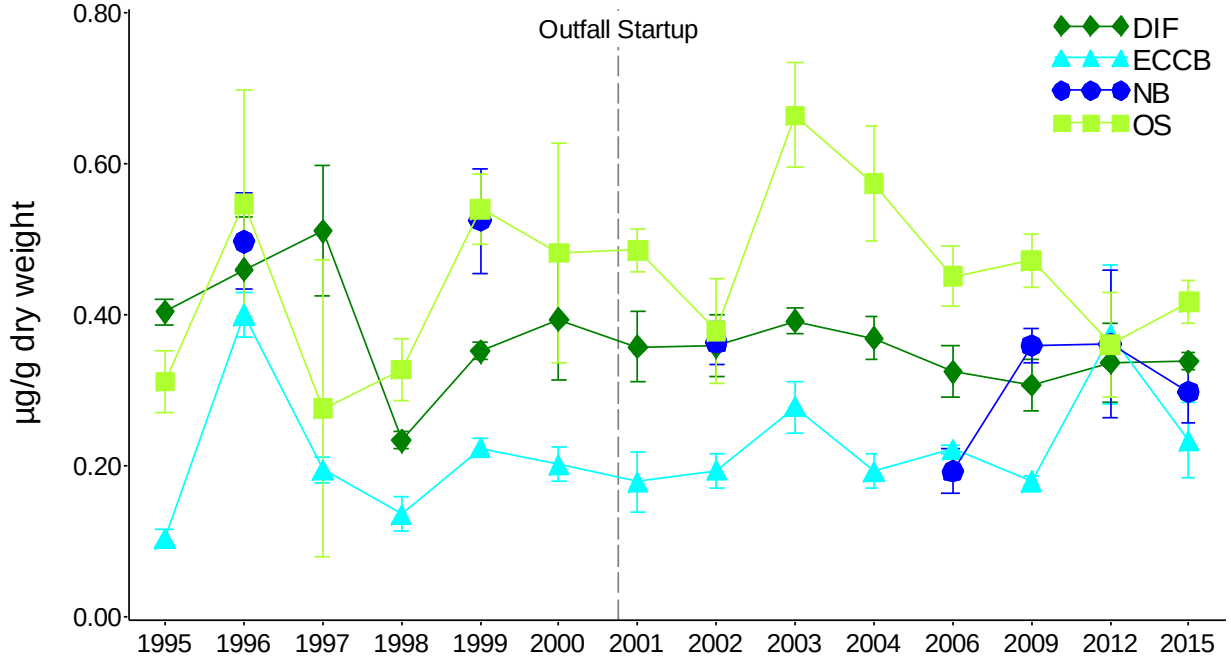

Figure 3-4. Mercury in flounder fillet (1995-2015)

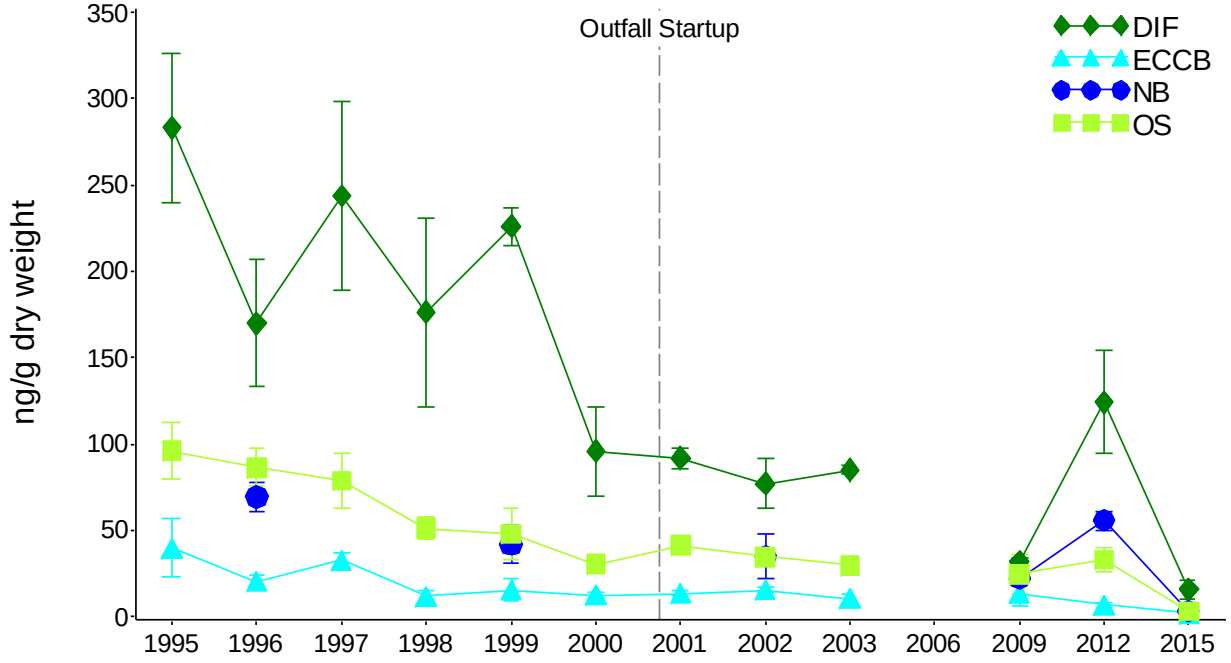

Figure 3-5. Total Chlordane in flounder liver (1995-2015)

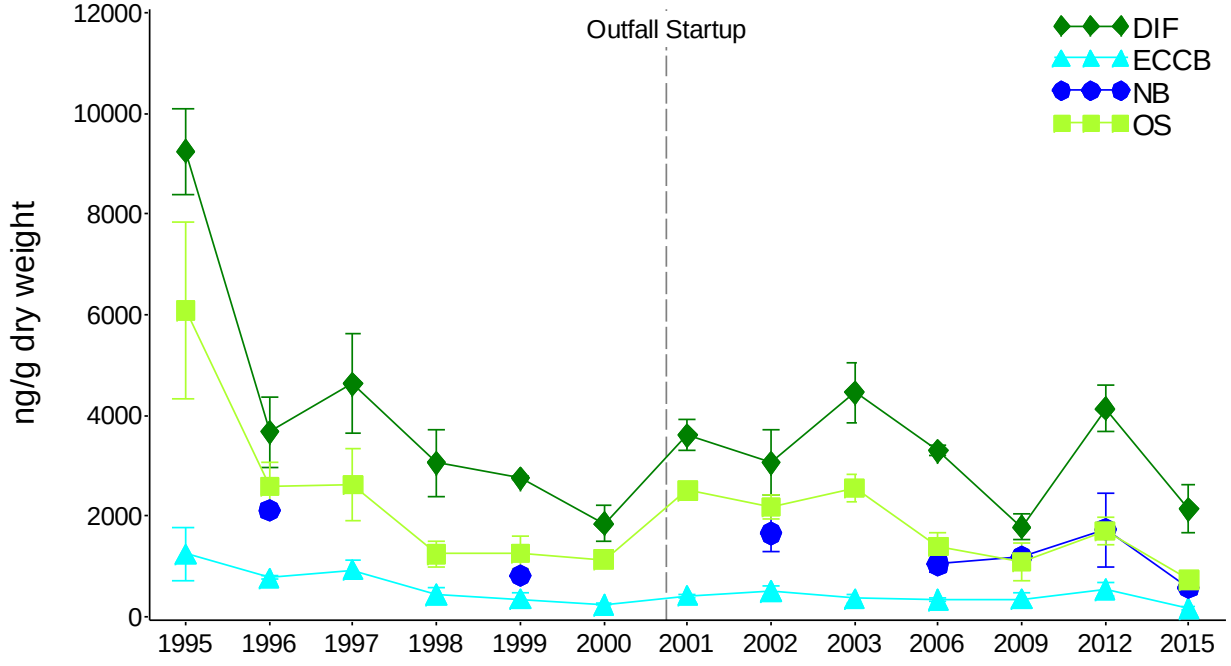

Figure 3-6. Total PCBs in flounder liver (1995-2015)

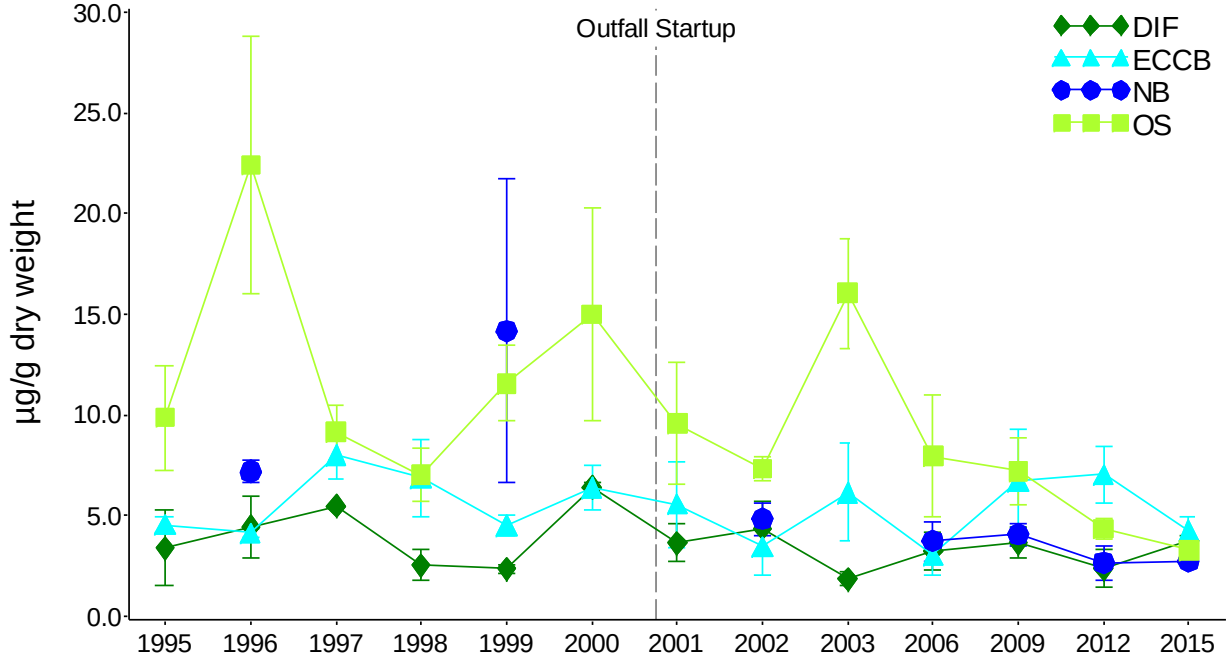

Figure 3-7. Silver in flounder liver (1995-2015)

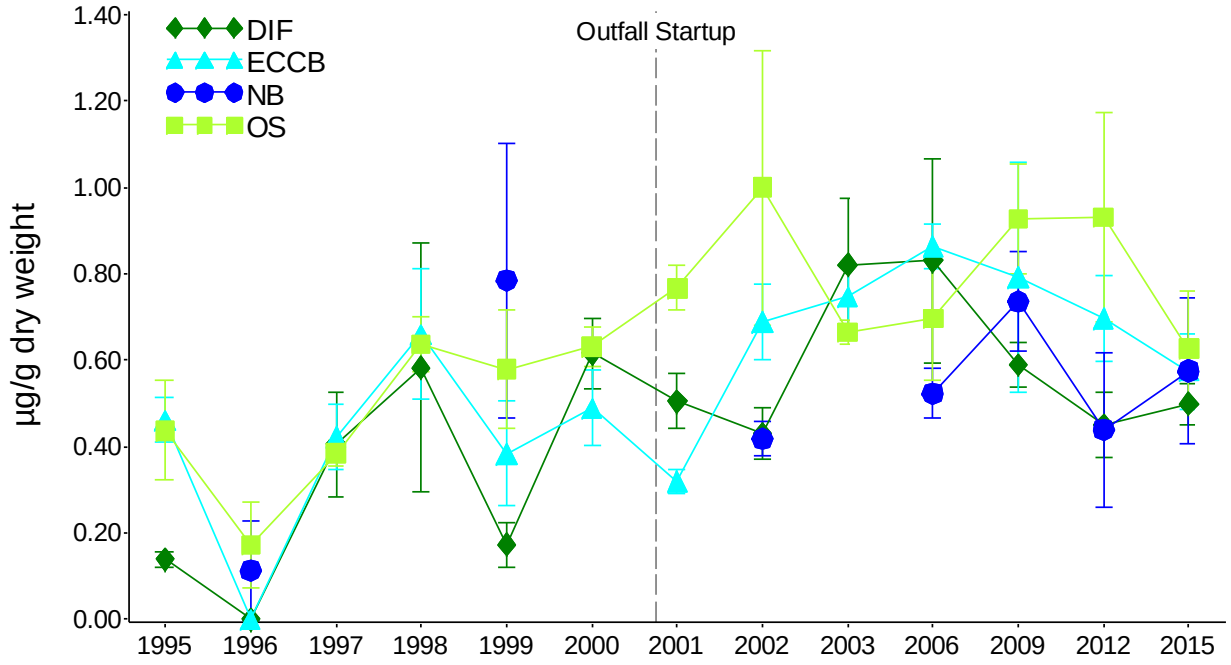

Figure 3-8. Nickel in flounder liver (1995-2015)

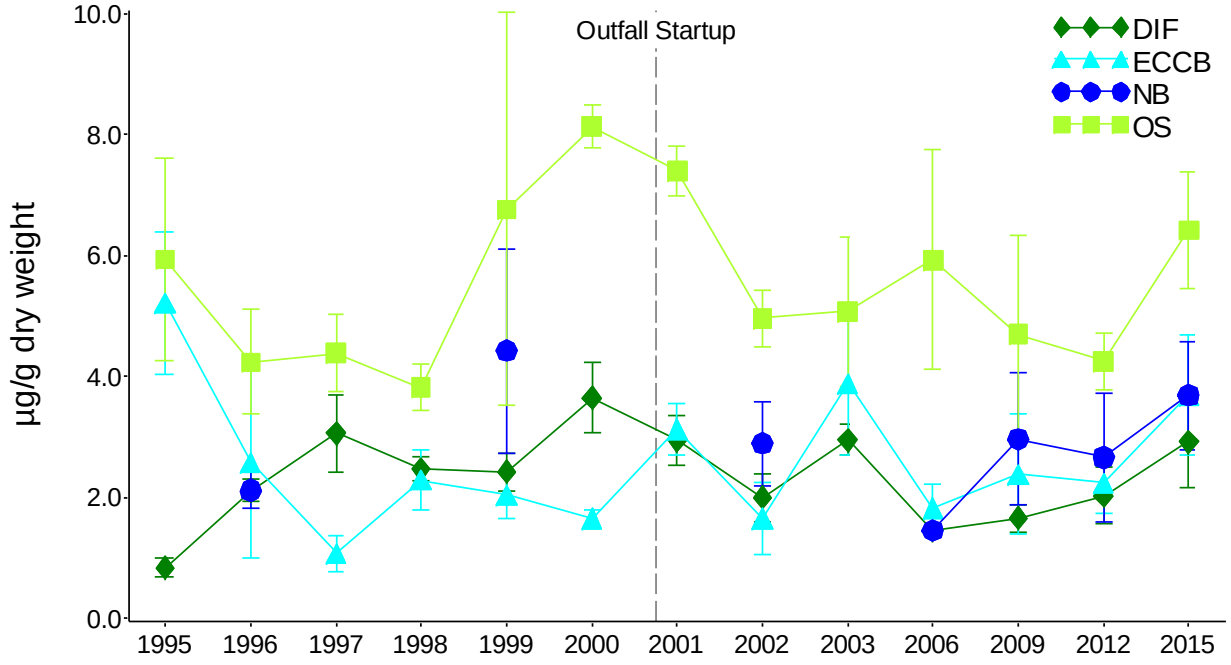

Figure 3-9. Lead in flounder liver (1995-2015)

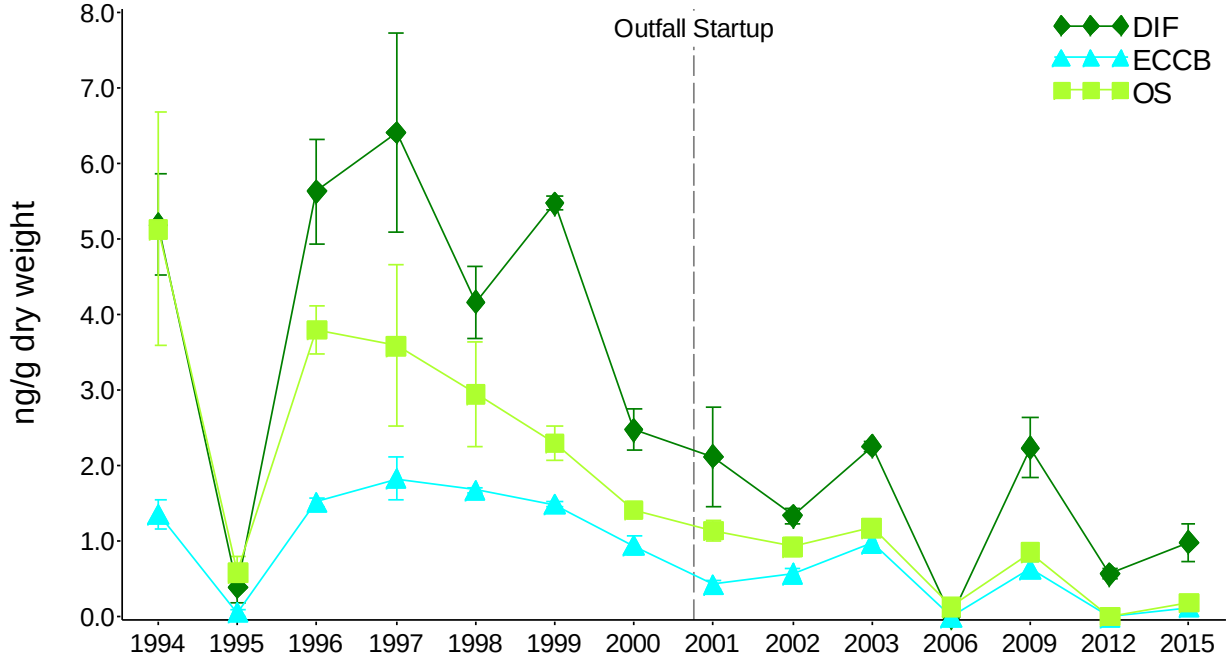

Figure 3-10. Total Chlordane in lobster meat (1994-2015)

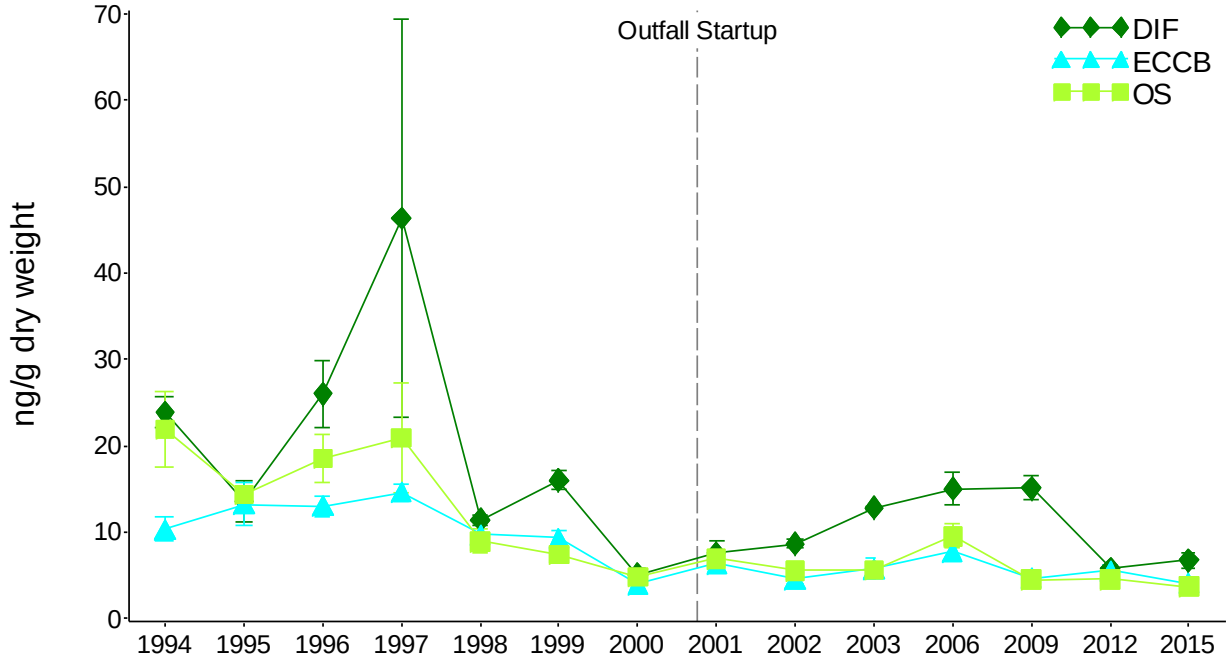

Figure 3-11. Total DDT in lobster meat (1994-2015)

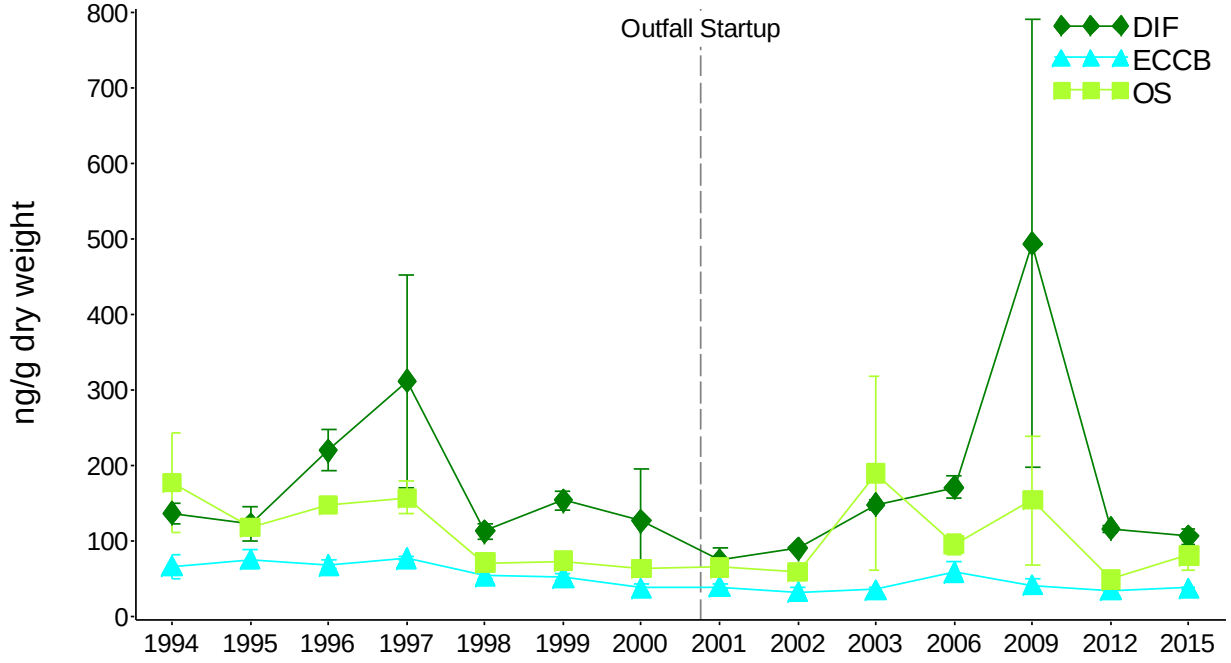

Figure 3-12. Total PCBs in lobster meat (1994-2015)

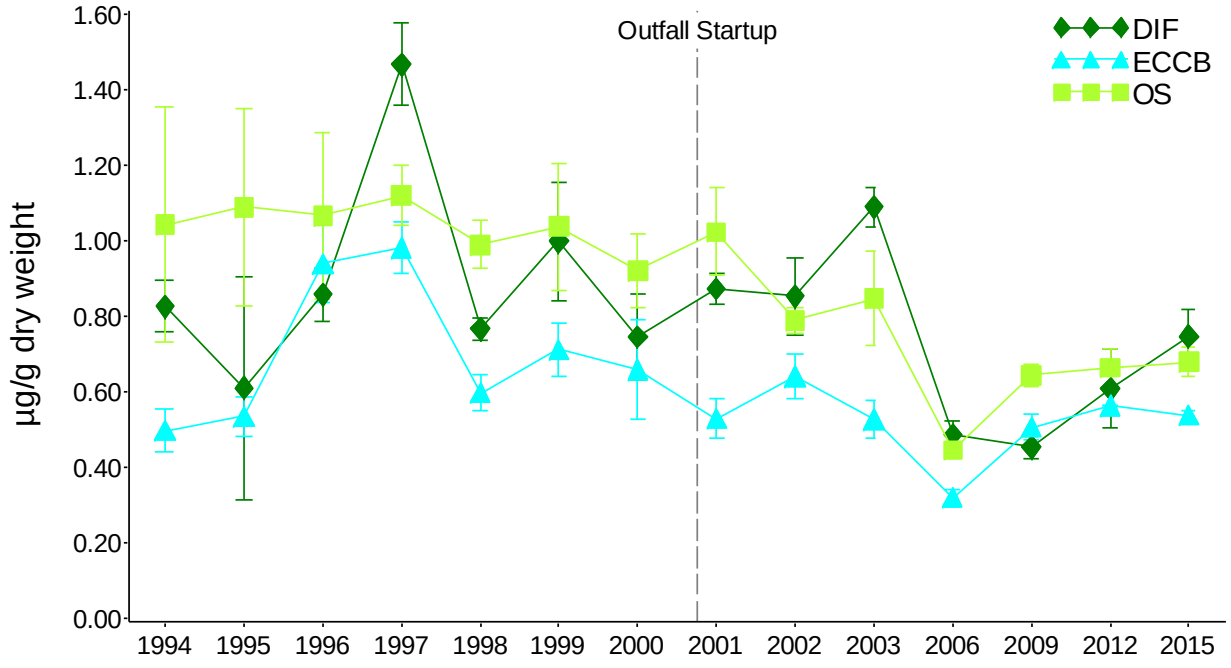

Figure 3-13. Mercury in lobster meat (1994-2015)

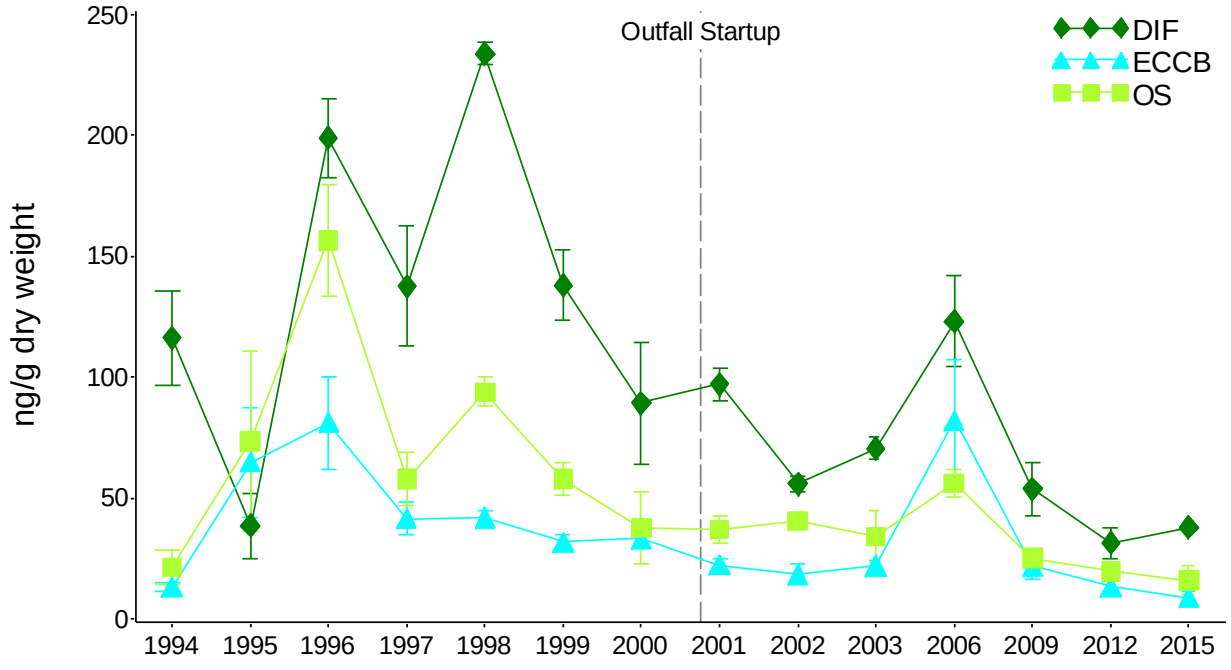

Figure 3-14. Total chlordane in lobster hepatopancreas (1994-2015)

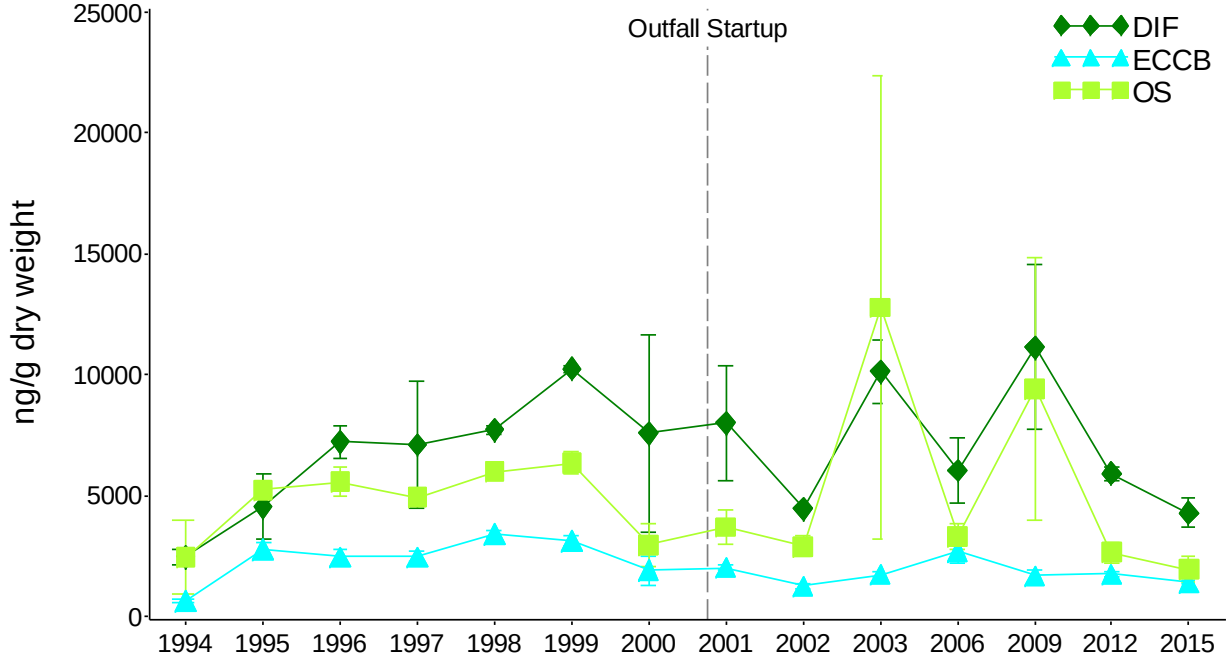

Figure 3-15. Total PCBs in lobster hepatopancreas (1994-2015)

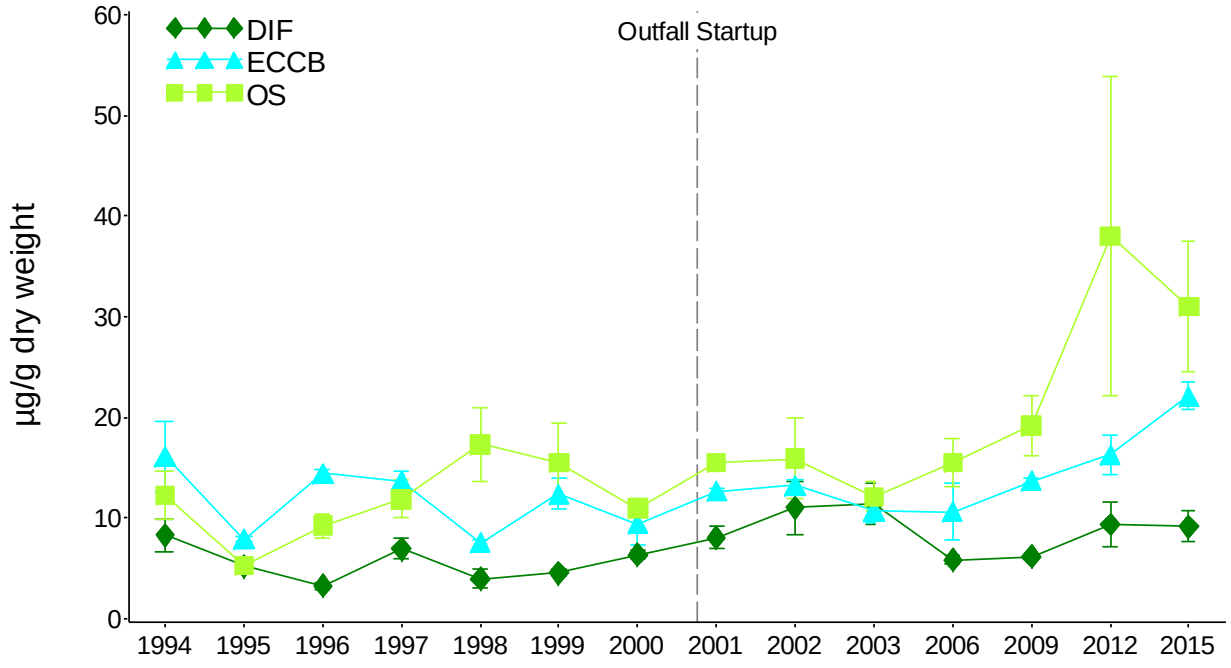

Figure 3-16. Cadmium in lobster hepatopancreas (1994-2015)

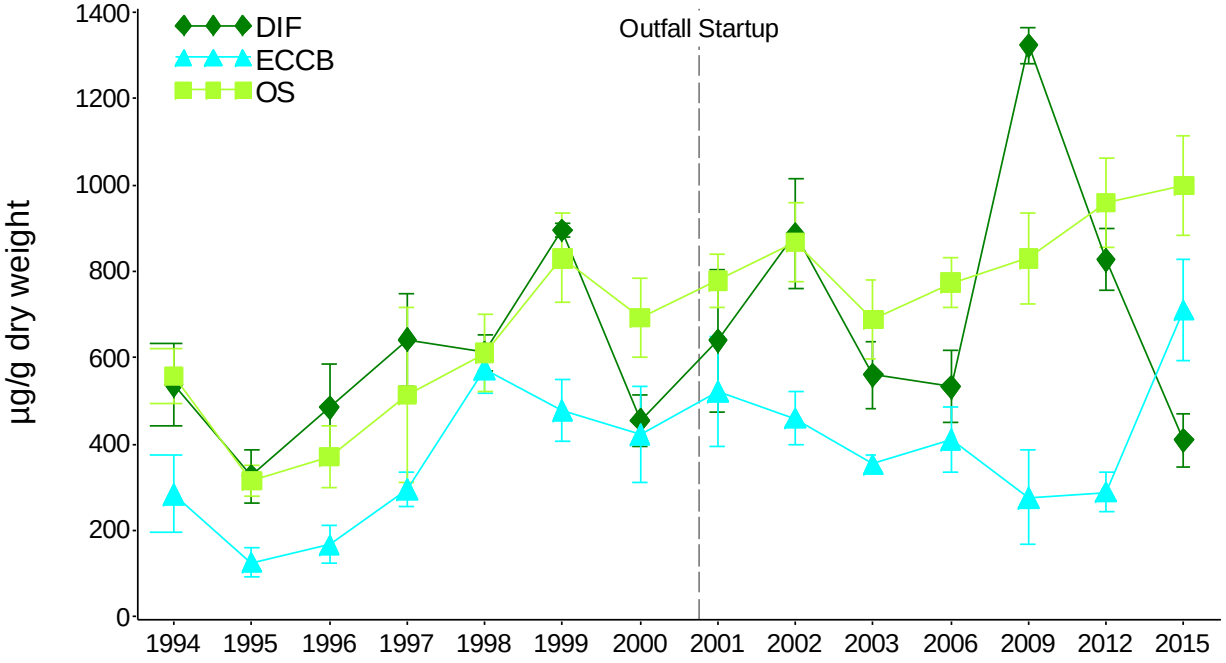

Figure 3-17. Copper in lobster hepatopancreas (1994-2015)

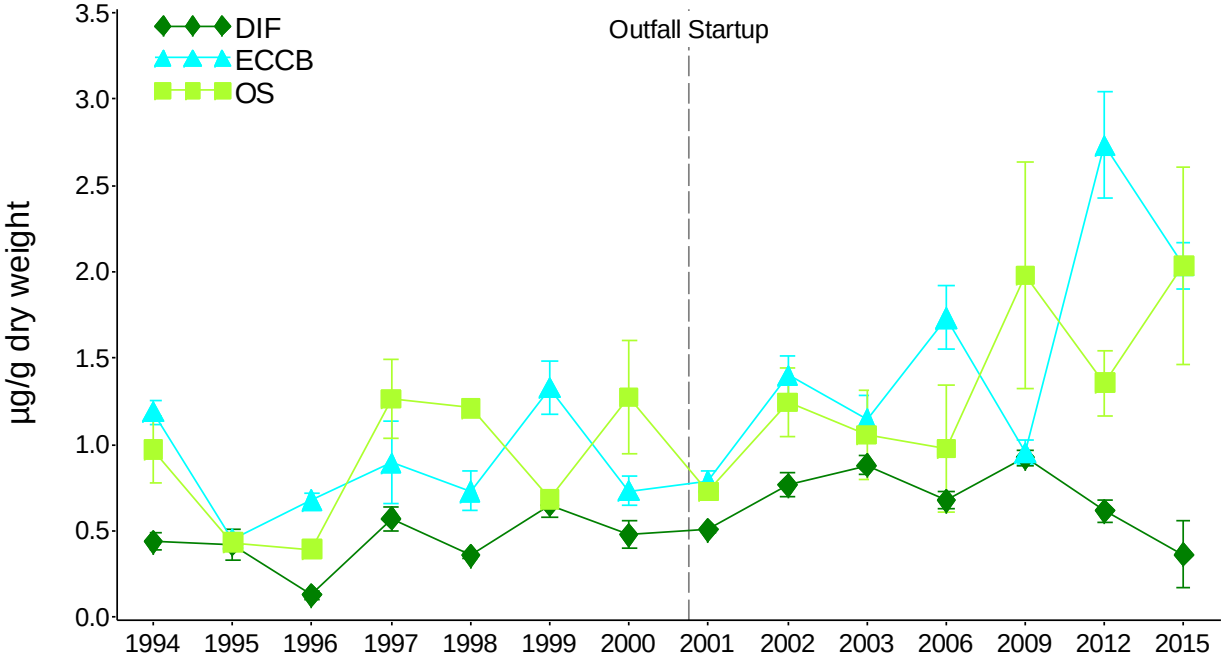

Figure 3-18. Nickel in lobster hepatopancreas (1994-2015)

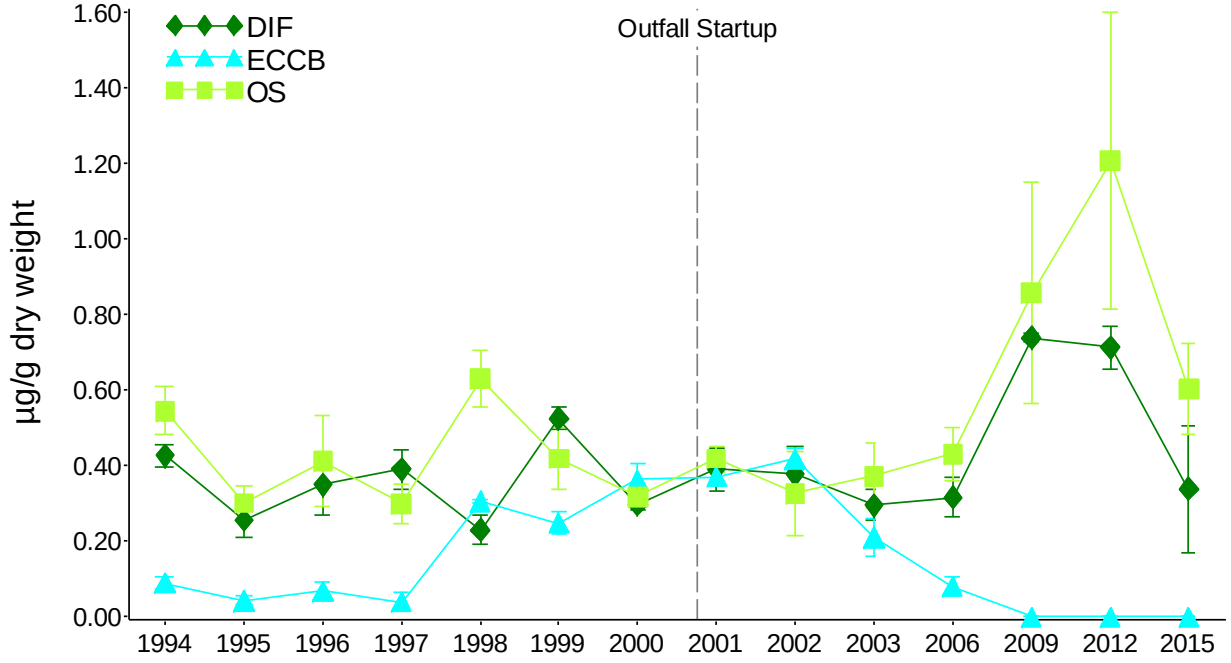

Figure 3-19. Lead in lobster hepatopancreas (1994-2015)

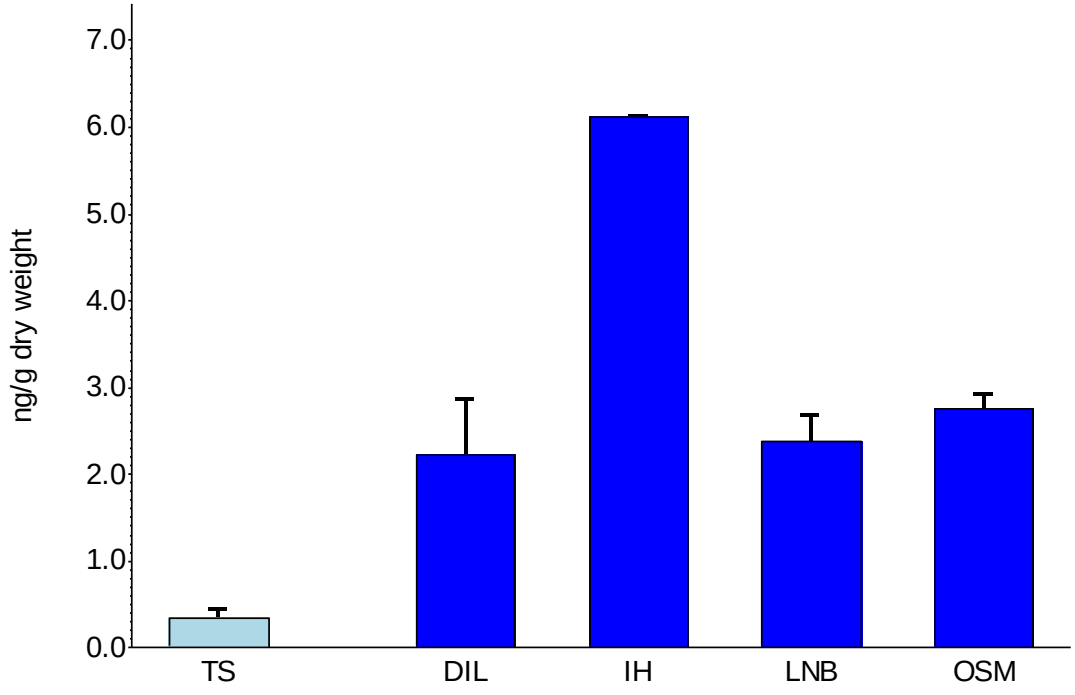

Figure 3-20. Total chlordane bioaccumulation in mussels (2015)

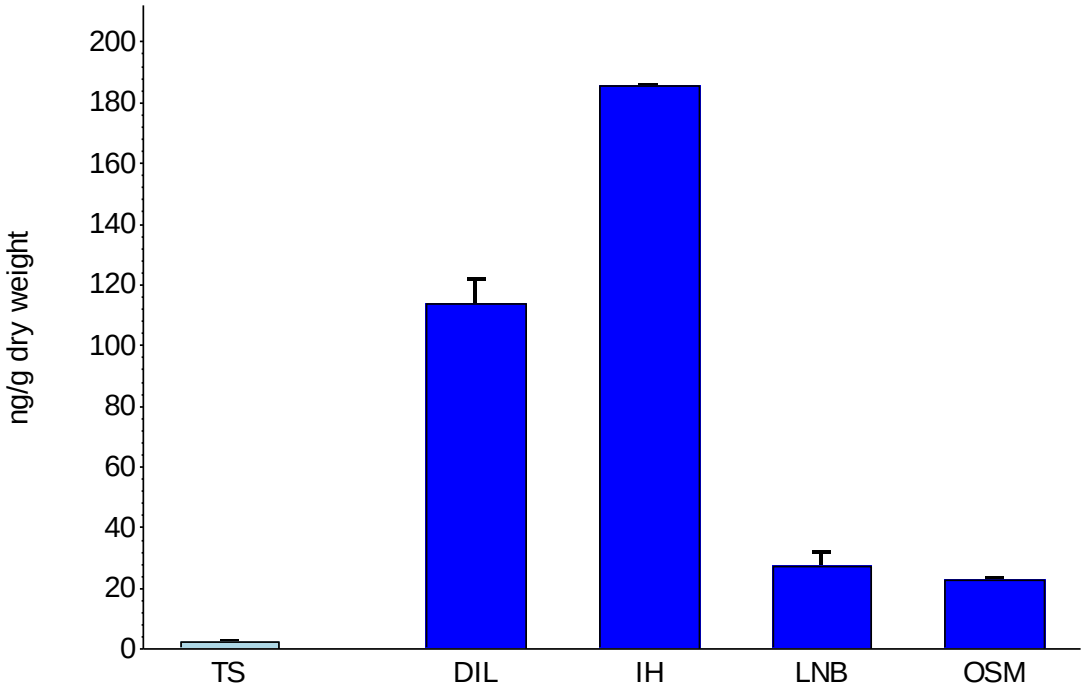

Figure 3-21. Total PCB bioaccumulation in mussels (2015)

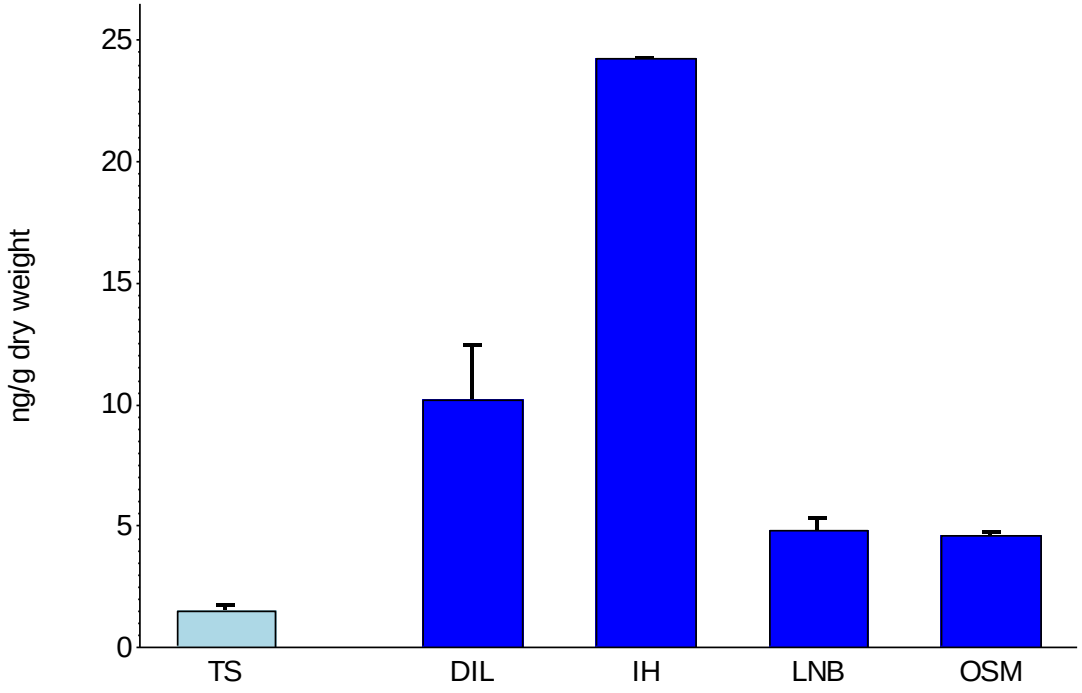

Figure 3-22. Total DDT bioaccumulation in mussels (2015)

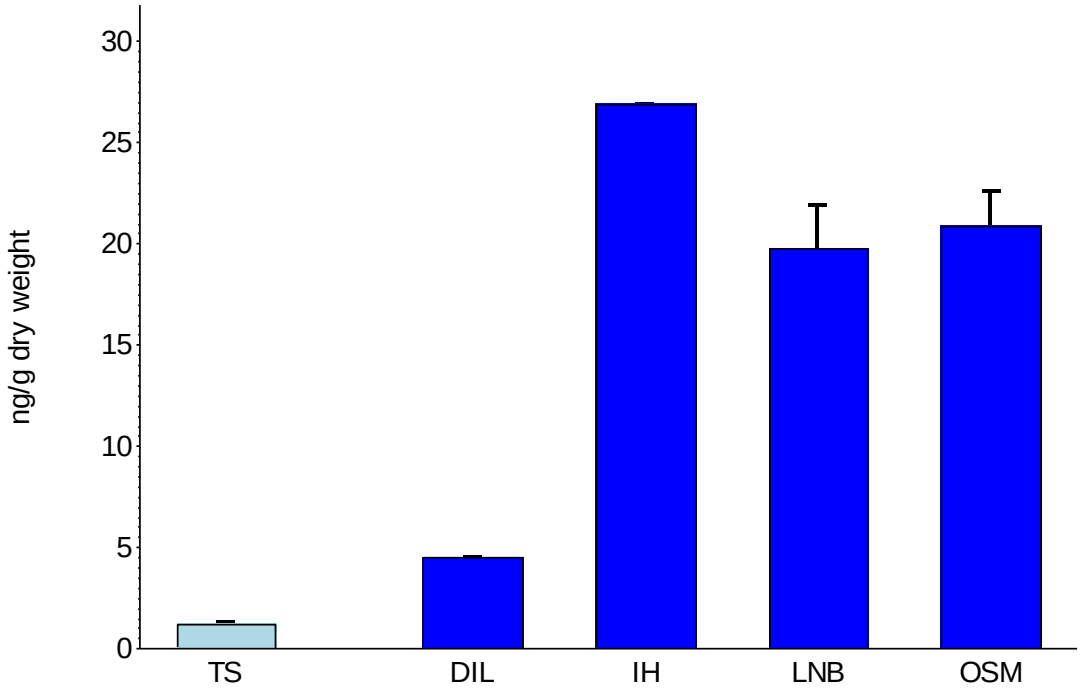

Figure 3-23. Total NOAA LMW PAH bioaccumulation in mussels (2015)

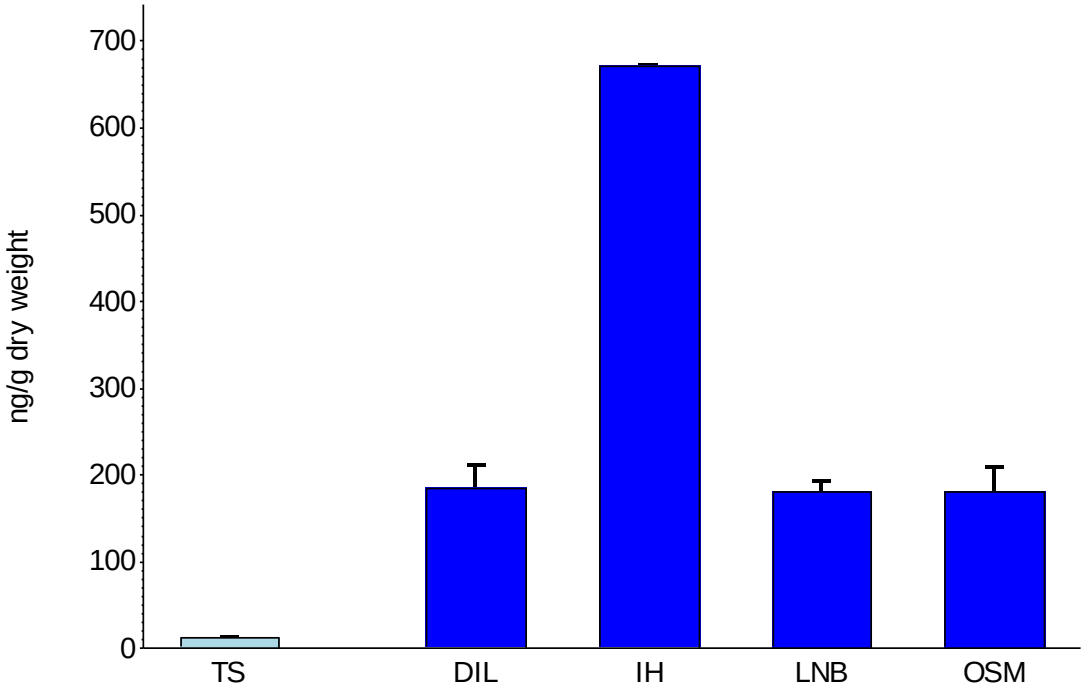

Figure 3-24. Total NOAA HMW PAH bioaccumulation in mussels (2015)

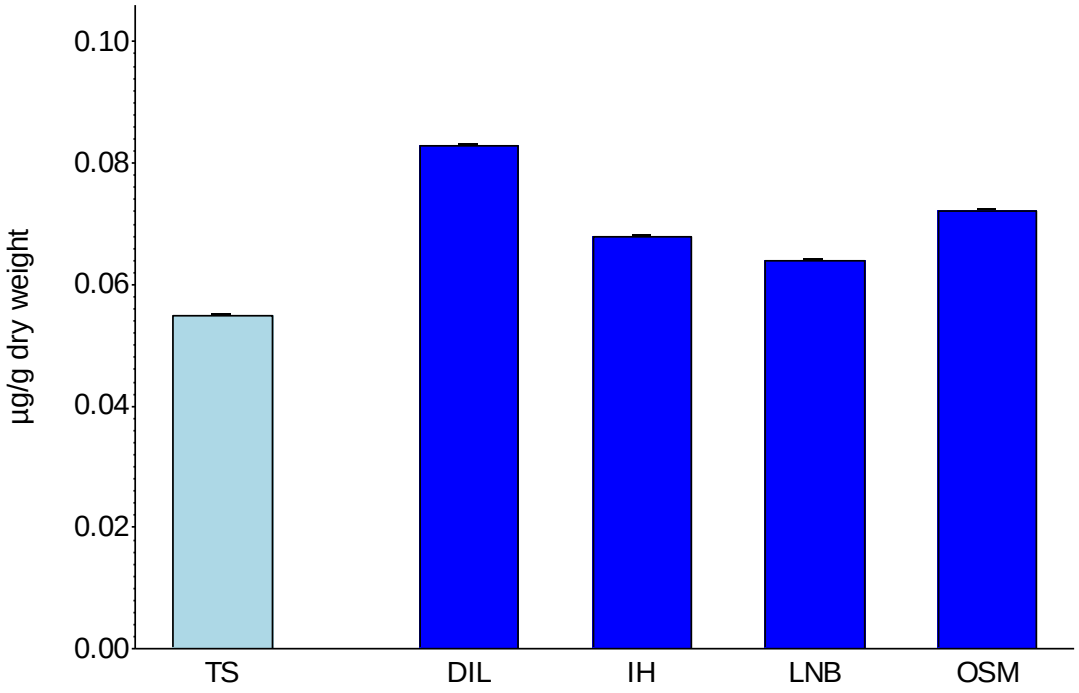

Figure 3-25. Mercury bioaccumulation in mussels (2015)

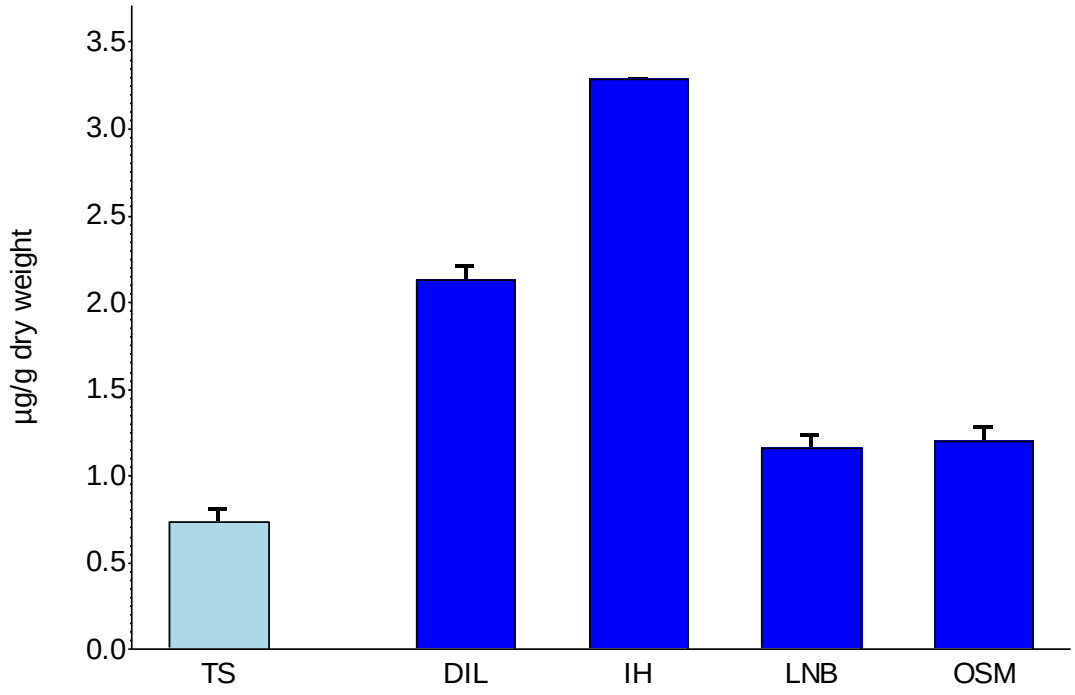

Figure 3-26. Lead bioaccumulation in mussels (2015)

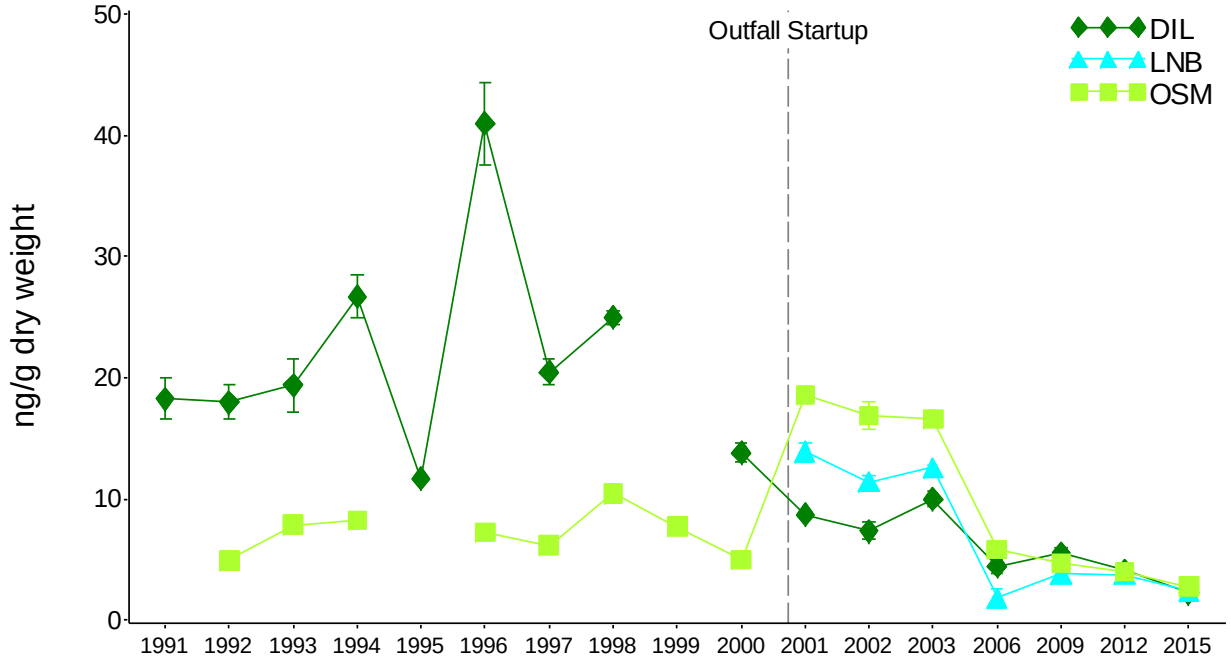

Figure 3-27. Total chlordane trends in mussels (1991-2015)

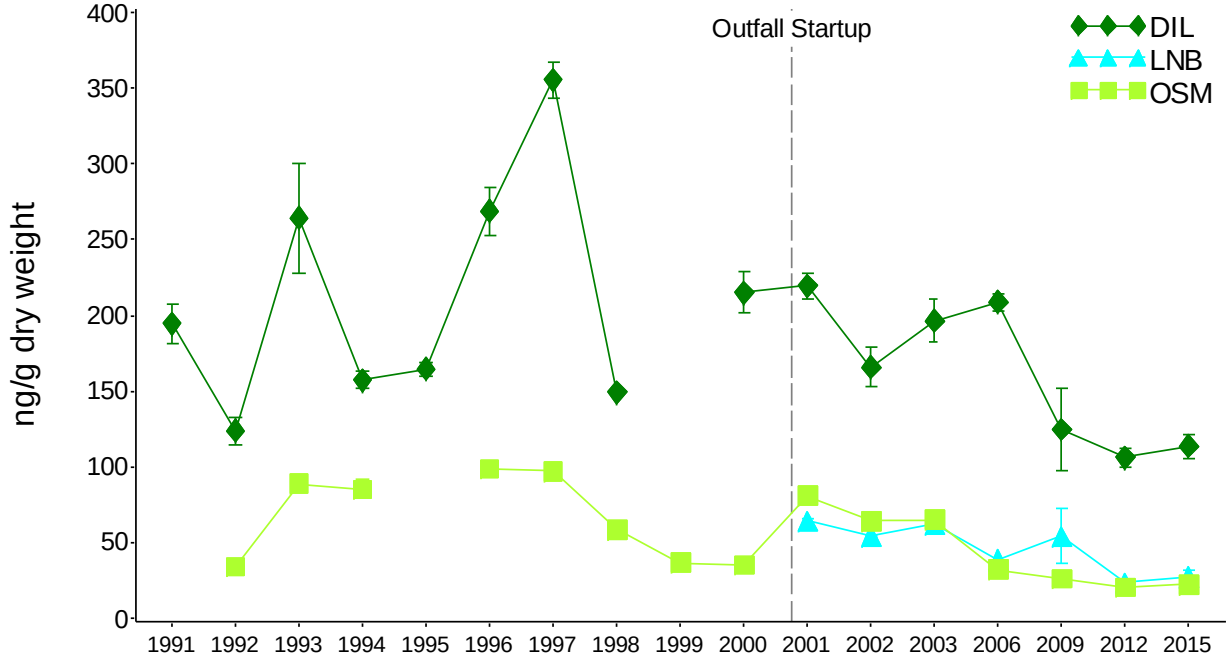

Figure 3-28. Total PCB trends in mussels (1991-2015)

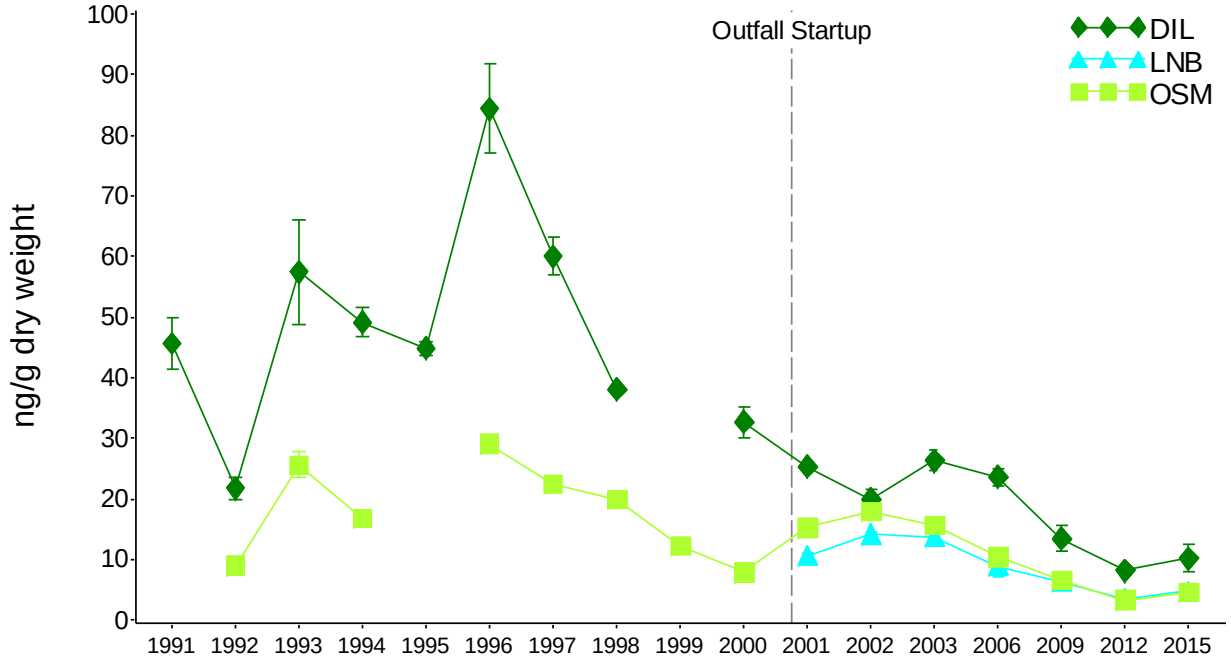

Figure 3-29. Total DDT trends in mussels (1991-2015)

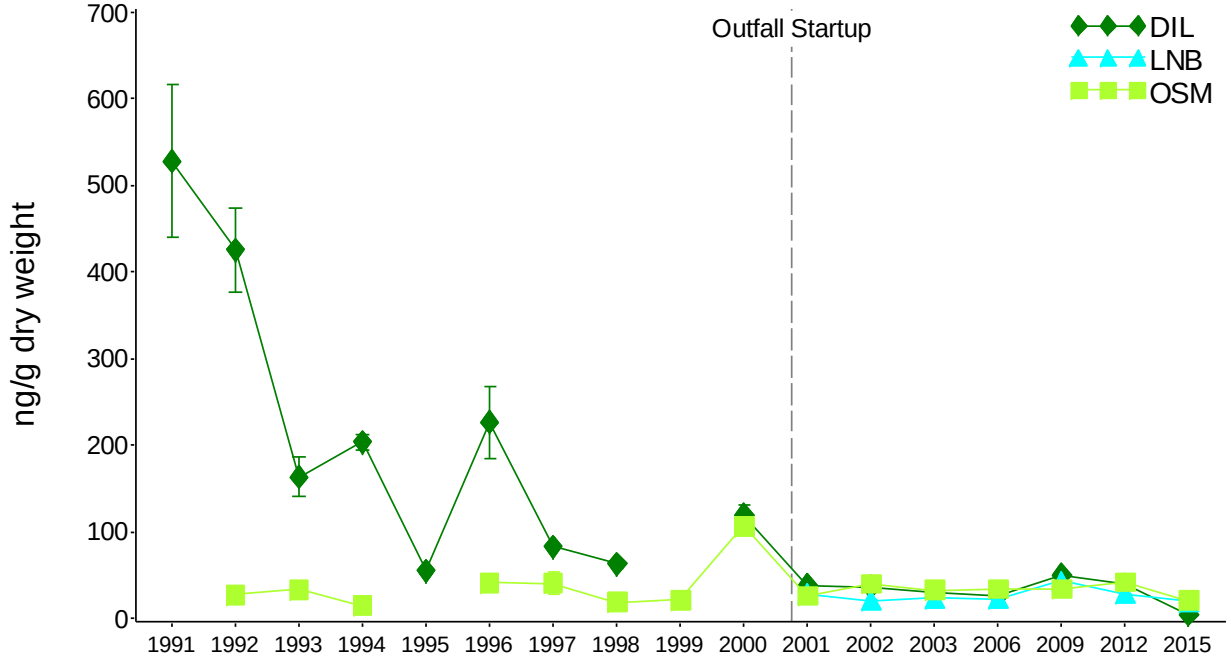

Figure 3-30. Total LMW PAH trends in mussels (1991-2015)

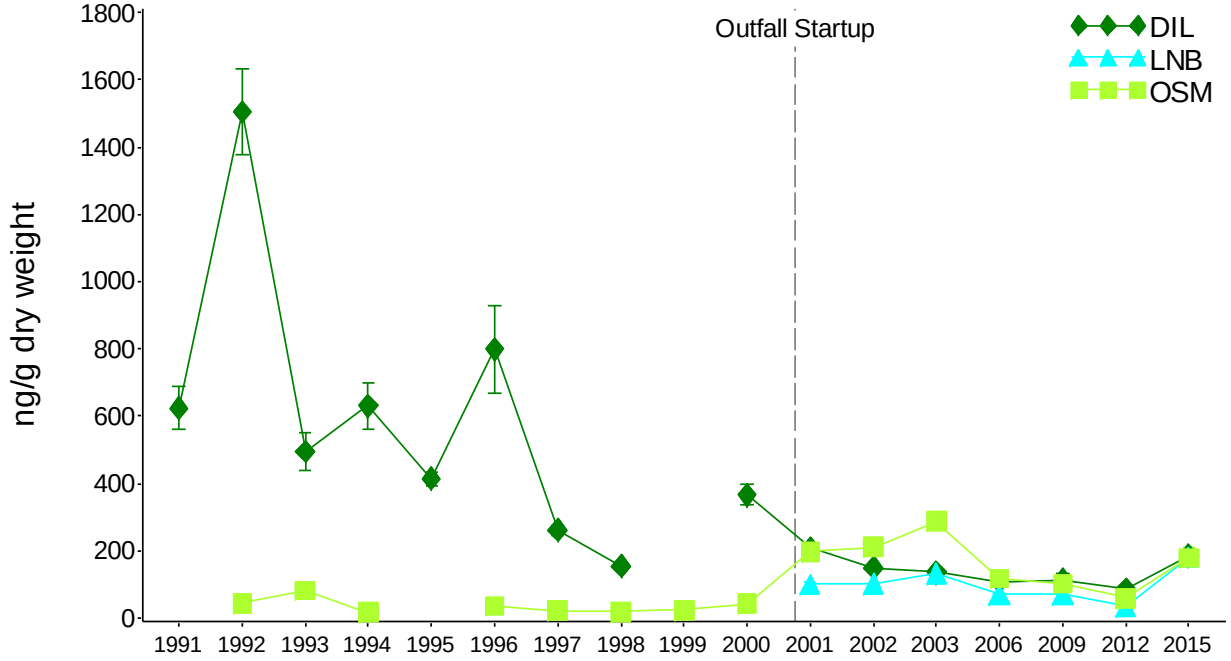

Figure 3-31. Total HMW PAH trends in mussels (1991-2015)

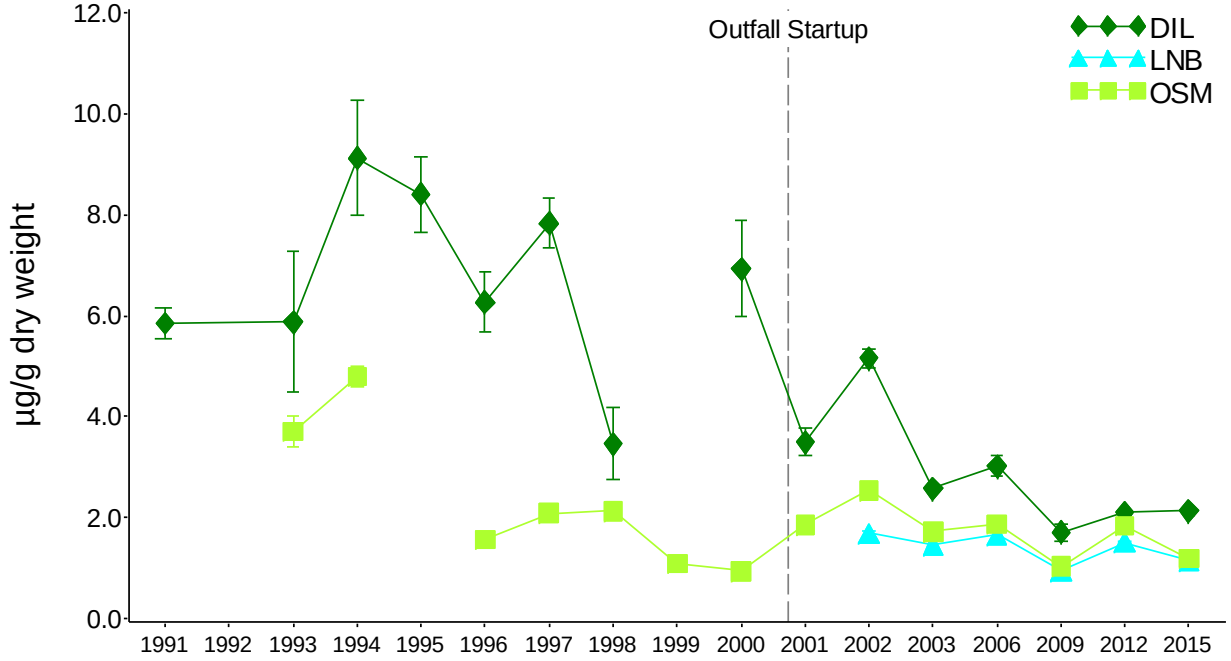

Figure 3-32. Lead trends in mussels (1991-2015)

4.0 CONCLUSIONS

Analysis of body burdens of contaminants in winter flounder, lobsters, and blue mussels potentially associated with municipal wastewater was used to evaluate potential environmental changes resulting from the diversion of MWRA's discharge from Boston Harbor to Massachusetts Bay. Winter flounder and lobsters were collected from wild populations; blue mussels were purchased from an aquaculture operation and held in cages.

In general, spatial patterns for all contaminants in all tissues were similar in 2015 to 2012. Body burdens of organics in winter flounder and lobsters have typically been higher at DIF but have generally declined over the study at all stations. Metals, on the other hand, have usually been higher at OS than other stations in these species and body burdens have not trended consistently over time.

Similarly, concentrations of organic contaminants in mussels have historically been higher in Boston Harbor (DIL) than offshore (OSM and LNB). Organics are obviously declining in the harbor but patterns offshore are less distinct. Lead has followed the same pattern both spatially and temporally.

Despite the fact that there is evidence of anthropogenic contamination in the three indicator species, there were no exceedances of MWRA threshold levels in 2015, as has been the case for all parameters since 2003.

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Appendices

Notes on Appendices:

- "N.A." indicates that no data were collected, or that results are suspect or under investigation.
- Organic contaminants were surrogate-corrected.
- Zero was used for non-detects.
- Individual component results were rounded to four significant figures before summing.

Appendix A: Summary Statistics by Chemical Parameter, Year, and Station for Flounder Fillet

Parameter and Year					Station											
					Mean				SD				N			
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	NB	OS	DIF	ECCB	NB	OS	DIF	ECCB	NB	OS
CHLOR		Total chlordanes	ng/gdw	1992	35.478	2.666	12.237	8.476	42.61	1.35	10.48	2.01	4	4	4	4
CHLOR		Total chlordanes	ng/gdw	1993	15.400	4.800	N.A.	16.198	8.25	2.77	N.A.	11.92	10	10	N.A.	9
CHLOR		Total chlordanes	ng/gdw	1994	18.783	2.930	5.570	7.550	2.97	0.05	2.20	1.28	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	1995	15.467	4.633	N.A.	5.767	5.75	0.32	N.A.	0.81	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	1996	11.300	1.077	6.867	3.667	0.53	0.96	1.97	0.81	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	1997	13.933	1.657	N.A.	5.663	2.19	0.35	N.A.	1.17	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	1998	13.857	1.293	N.A.	5.544	1.99	0.15	N.A.	3.35	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	1999	9.734	2.342	10.101	7.114	0.59	0.85	2.00	4.83	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	2000	10.032	1.915	N.A.	3.246	3.42	0.05	N.A.	0.82	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	2001	10.380	1.740	N.A.	2.917	1.55	0.15	N.A.	0.76	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	2002	6.031	1.305	2.380	3.265	0.28	0.11	0.48	0.26	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	2003	9.178	1.574	N.A.	3.279	2.58	0.97	N.A.	0.98	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	2006	5.393	1.221	N.A.	1.801	0.98	0.43	N.A.	0.45	3	3	0	3
CHLOR		Total chlordanes	ng/gdw	2009	4.559	0.853	2.725	2.927	0.31	0.16	0.13	1.43	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	2012	5.243	0.370	2.380	1.717	1.20	0.37	1.08	1.12	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	2015	3.216	0.505	1.599	0.492	0.62	0.33	0.95	0.09	3	2	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1992	30.005	8.836	21.396	15.728	8.27	3.71	15.24	2.62	4	4	4	4
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1993	17.490	9.402	N.A.	16.859	8.39	4.48	N.A.	7.54	10	10	N.A.	9
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1994	30.150	10.984	13.653	16.347	3.44	1.20	1.26	1.99	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1995	35.000	25.667	N.A.	19.667	24.43	2.52	N.A.	4.73	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1996	26.667	9.533	19.000	17.667	4.62	3.00	1.00	7.64	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1997	40.667	11.367	N.A.	19.667	5.03	5.46	N.A.	6.81	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1998	22.010	5.568	N.A.	9.134	3.02	0.55	N.A.	5.30	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1999	17.417	10.275	19.540	19.103	2.20	1.64	1.82	6.62	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2000	17.003	6.453	N.A.	9.206	4.05	0.85	N.A.	0.66	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2001	25.337	7.608	N.A.	10.806	3.07	0.42	N.A.	2.45	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2002	13.743	4.739	9.244	9.291	1.85	1.61	1.14	3.23	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2003	26.407	6.831	N.A.	11.445	2.73	3.93	N.A.	3.48	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2006	25.233	6.193	N.A.	10.747	6.73	0.72	N.A.	1.51	3	3	0	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2009	12.651	4.548	10.494	9.780	2.65	1.40	2.72	4.03	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2012	23.997	2.353	11.535	8.106	11.97	1.54	13.44	7.91	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2015	12.523	2.907	5.967	4.392	0.84	0.85	1.08	0.57	3	2	3	3

(continued)

(Continued)

Parameter and Year					Station											
					Mean				SD				N			
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	NB	OS	DIF	ECCB	NB	OS	DIF	ECCB	NB	OS
METAL	Hg	Mercury	ug/gdw	1992	0.443	0.062	0.511	0.607	0.22	0.05	0.09	0.46	4	4	4	4
METAL	Hg	Mercury	ug/gdw	1993	0.460	0.186	N.A.	0.413	0.33	0.09	N.A.	0.22	10	10	N.A.	9
METAL	Hg	Mercury	ug/gdw	1994	0.283	0.120	0.378	0.434	0.05	0.01	0.02	0.16	3	3	3	3
METAL	Hg	Mercury	ug/gdw	1995	0.404	0.104	N.A.	0.312	0.03	0.02	N.A.	0.07	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	1996	0.460	0.400	0.497	0.547	0.12	0.05	0.11	0.26	3	3	3	3
METAL	Hg	Mercury	ug/gdw	1997	0.511	0.195	N.A.	0.276	0.15	0.03	N.A.	0.34	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	1998	0.234	0.136	N.A.	0.328	0.02	0.04	N.A.	0.07	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	1999	0.352	0.224	0.525	0.540	0.02	0.02	0.12	0.08	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2000	0.394	0.202	N.A.	0.482	0.14	0.04	N.A.	0.25	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	2001	0.358	0.179	N.A.	0.486	0.08	0.07	N.A.	0.05	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	2002	0.359	0.194	0.363	0.379	0.07	0.04	0.05	0.12	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2003	0.392	0.278	N.A.	0.664	0.03	0.06	N.A.	0.12	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	2004	0.369	0.193	N.A.	0.574	0.05	0.04	N.A.	0.13	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	2006	0.325	0.222	0.193	0.451	0.06	0.01	0.05	0.07	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2009	0.307	0.180	0.359	0.472	0.06	0.01	0.04	0.06	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2012	0.337	0.374	0.361	0.361	0.09	0.16	0.17	0.12	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2015	0.338	0.234	0.298	0.417	0.02	0.07	0.07	0.05	3	2	3	3
PCB		Total PCBs	ng/gdw	1992	458.525	51.138	261.968	220.400	336.09	22.70	149.18	92.64	4	4	4	4
PCB		Total PCBs	ng/gdw	1993	197.110	55.430	N.A.	211.566	94.81	26.30	N.A.	116.63	10	10	N.A.	9
PCB		Total PCBs	ng/gdw	1994	520.033	60.233	150.567	249.900	60.60	9.97	31.49	56.38	3	3	3	3
PCB		Total PCBs	ng/gdw	1995	613.900	107.607	N.A.	237.167	305.68	9.69	N.A.	26.02	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	1996	285.767	65.690	227.833	194.700	51.42	18.81	27.14	73.76	3	3	3	3
PCB		Total PCBs	ng/gdw	1997	325.100	62.777	N.A.	206.667	64.75	11.60	N.A.	53.17	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	1998	238.433	39.413	N.A.	105.600	30.95	3.62	N.A.	60.13	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	1999	141.533	51.700	133.233	166.200	7.63	10.04	19.38	71.29	3	3	3	3
PCB		Total PCBs	ng/gdw	2000	203.300	39.460	N.A.	117.567	41.94	3.42	N.A.	15.94	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	2001	348.600	51.333	N.A.	157.733	40.71	3.57	N.A.	20.54	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	2002	211.367	36.123	116.800	143.067	17.94	6.31	8.29	54.12	3	3	3	3
PCB		Total PCBs	ng/gdw	2003	345.467	49.687	N.A.	189.600	35.53	23.19	N.A.	30.09	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	2006	317.533	47.790	114.470	176.700	43.94	3.99	20.88	46.39	3	3	3	3
PCB		Total PCBs	ng/gdw	2009	180.033	28.737	138.500	138.450	3.29	4.19	29.37	71.16	3	3	3	3
PCB		Total PCBs	ng/gdw	2012	396.267	26.827	222.897	223.917	210.10	14.13	259.61	236.71	3	3	3	3
PCB		Total PCBs	ng/gdw	2015	254.767	31.080	115.460	92.387	15.65	14.11	40.50	16.26	3	2	3	3

Appendix B: Summary Statistics by Chemical Parameter, Year, and Station for Flounder Liver

Parameter and Year					Station											
					Mean				SD				N			
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	NB	OS	DIF	ECCB	NB	OS	DIF	ECCB	NB	OS
CHLOR		Total chlordanes	ng/gdw	1992	35.478	2.666	12.237	8.476	42.61	1.35	10.48	2.01	4	4	4	4
CHLOR		Total chlordanes	ng/gdw	1993	15.400	4.800	N.A.	16.198	8.25	2.77	N.A.	11.92	10	10	N.A.	9
CHLOR		Total chlordanes	ng/gdw	1994	18.783	2.930	5.570	7.550	2.97	0.05	2.20	1.28	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	1995	15.467	4.633	N.A.	5.767	5.75	0.32	N.A.	0.81	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	1996	11.300	1.077	6.867	3.667	0.53	0.96	1.97	0.81	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	1997	13.933	1.657	N.A.	5.663	2.19	0.35	N.A.	1.17	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	1998	13.857	1.293	N.A.	5.544	1.99	0.15	N.A.	3.35	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	1999	9.734	2.342	10.101	7.114	0.59	0.85	2.00	4.83	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	2000	10.032	1.915	N.A.	3.246	3.42	0.05	N.A.	0.82	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	2001	10.380	1.740	N.A.	2.917	1.55	0.15	N.A.	0.76	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	2002	6.031	1.305	2.380	3.265	0.28	0.11	0.48	0.26	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	2003	9.178	1.574	N.A.	3.279	2.58	0.97	N.A.	0.98	3	3	N.A.	3
CHLOR		Total chlordanes	ng/gdw	2006	5.393	1.221	N.A.	1.801	0.98	0.43	N.A.	0.45	3	3	0	3
CHLOR		Total chlordanes	ng/gdw	2009	4.559	0.853	2.725	2.927	0.31	0.16	0.13	1.43	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	2012	5.243	0.370	2.380	1.717	1.20	0.37	1.08	1.12	3	3	3	3
CHLOR		Total chlordanes	ng/gdw	2015	3.216	0.505	1.599	0.492	0.62	0.33	0.95	0.09	3	2	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1992	30.005	8.836	21.396	15.728	8.27	3.71	15.24	2.62	4	4	4	4
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1993	17.490	9.402	N.A.	16.859	8.39	4.48	N.A.	7.54	10	10	N.A.	9
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1994	30.150	10.984	13.653	16.347	3.44	1.20	1.26	1.99	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1995	35.000	25.667	N.A.	19.667	24.43	2.52	N.A.	4.73	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1996	26.667	9.533	19.000	17.667	4.62	3.00	1.00	7.64	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1997	40.667	11.367	N.A.	19.667	5.03	5.46	N.A.	6.81	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1998	22.010	5.568	N.A.	9.134	3.02	0.55	N.A.	5.30	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	1999	17.417	10.275	19.540	19.103	2.20	1.64	1.82	6.62	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2000	17.003	6.453	N.A.	9.206	4.05	0.85	N.A.	0.66	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2001	25.337	7.608	N.A.	10.806	3.07	0.42	N.A.	2.45	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2002	13.743	4.739	9.244	9.291	1.85	1.61	1.14	3.23	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2003	26.407	6.831	N.A.	11.445	2.73	3.93	N.A.	3.48	3	3	N.A.	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2006	25.233	6.193	N.A.	10.747	6.73	0.72	N.A.	1.51	3	3	0	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2009	12.651	4.548	10.494	9.780	2.65	1.40	2.72	4.03	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2012	23.997	2.353	11.535	8.106	11.97	1.54	13.44	7.91	3	3	3	3
DDT	4,4'-DDE	p,p'-DDE	ng/gdw	2015	12.523	2.907	5.967	4.392	0.84	0.85	1.08	0.57	3	2	3	3
METAL	Hg	Mercury	ug/gdw	1992	0.443	0.062	0.511	0.607	0.22	0.05	0.09	0.46	4	4	4	4
METAL	Hg	Mercury	ug/gdw	1993	0.460	0.186	N.A.	0.413	0.33	0.09	N.A.	0.22	10	10	N.A.	9
METAL	Hg	Mercury	ug/gdw	1994	0.283	0.120	0.378	0.434	0.05	0.01	0.02	0.16	3	3	3	3
METAL	Hg	Mercury	ug/gdw	1995	0.404	0.104	N.A.	0.312	0.03	0.02	N.A.	0.07	3	3	N.A.	3

(continued)

(Continued)

Parameter and Year					Station											
					Mean				SD				N			
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	NB	OS	DIF	ECCB	NB	OS	DIF	ECCB	NB	OS
METAL	Hg	Mercury	ug/gdw	1996	0.460	0.400	0.497	0.547	0.12	0.05	0.11	0.26	3	3	3	3
METAL	Hg	Mercury	ug/gdw	1997	0.511	0.195	N.A.	0.276	0.15	0.03	N.A.	0.34	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	1998	0.234	0.136	N.A.	0.328	0.02	0.04	N.A.	0.07	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	1999	0.352	0.224	0.525	0.540	0.02	0.02	0.12	0.08	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2000	0.394	0.202	N.A.	0.482	0.14	0.04	N.A.	0.25	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	2001	0.358	0.179	N.A.	0.486	0.08	0.07	N.A.	0.05	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	2002	0.359	0.194	0.363	0.379	0.07	0.04	0.05	0.12	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2003	0.392	0.278	N.A.	0.664	0.03	0.06	N.A.	0.12	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	2004	0.369	0.193	N.A.	0.574	0.05	0.04	N.A.	0.13	3	3	N.A.	3
METAL	Hg	Mercury	ug/gdw	2006	0.325	0.222	0.193	0.451	0.06	0.01	0.05	0.07	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2009	0.307	0.180	0.359	0.472	0.06	0.01	0.04	0.06	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2012	0.337	0.374	0.361	0.361	0.09	0.16	0.17	0.12	3	3	3	3
METAL	Hg	Mercury	ug/gdw	2015	0.338	0.234	0.298	0.417	0.02	0.07	0.07	0.05	3	2	3	3
PCB		Total PCBs	ng/gdw	1992	458.525	51.138	261.968	220.400	336.09	22.70	149.18	92.64	4	4	4	4
PCB		Total PCBs	ng/gdw	1993	197.110	55.430	N.A.	211.566	94.81	26.30	N.A.	116.63	10	10	N.A.	9
PCB		Total PCBs	ng/gdw	1994	520.033	60.233	150.567	249.900	60.60	9.97	31.49	56.38	3	3	3	3
PCB		Total PCBs	ng/gdw	1995	613.900	107.607	N.A.	237.167	305.68	9.69	N.A.	26.02	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	1996	285.767	65.690	227.833	194.700	51.42	18.81	27.14	73.76	3	3	3	3
PCB		Total PCBs	ng/gdw	1997	325.100	62.777	N.A.	206.667	64.75	11.60	N.A.	53.17	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	1998	238.433	39.413	N.A.	105.600	30.95	3.62	N.A.	60.13	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	1999	141.533	51.700	133.233	166.200	7.63	10.04	19.38	71.29	3	3	3	3
PCB		Total PCBs	ng/gdw	2000	203.300	39.460	N.A.	117.567	41.94	3.42	N.A.	15.94	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	2001	348.600	51.333	N.A.	157.733	40.71	3.57	N.A.	20.54	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	2002	211.367	36.123	116.800	143.067	17.94	6.31	8.29	54.12	3	3	3	3
PCB		Total PCBs	ng/gdw	2003	345.467	49.687	N.A.	189.600	35.53	23.19	N.A.	30.09	3	3	N.A.	3
PCB		Total PCBs	ng/gdw	2006	317.533	47.790	114.470	176.700	43.94	3.99	20.88	46.39	3	3	3	3
PCB		Total PCBs	ng/gdw	2009	180.033	28.737	138.500	138.450	3.29	4.19	29.37	71.16	3	3	3	3
PCB		Total PCBs	ng/gdw	2012	396.267	26.827	222.897	223.917	210.10	14.13	259.61	236.71	3	3	3	3
PCB		Total PCBs	ng/gdw	2015	254.767	31.080	115.460	92.387	15.65	14.11	40.50	16.26	3	2	3	3

Appendix C: Summary Statistics by Chemical Parameter, Year, and Station for Lobster Meat

Parameter and Year					Station								
					Mean			SD			N		
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	OS	DIF	ECCB	OS	DIF	ECCB	OS
CHLOR		Total chlordanes	ng/gdw	1994	5.194	1.358	5.132	1.17	0.33	2.19	3	3	2
CHLOR		Total chlordanes	ng/gdw	1995	0.390	0.058	0.587	0.34	0.08	0.36	3	3	3
CHLOR		Total chlordanes	ng/gdw	1996	5.630	1.517	3.800	1.21	0.11	0.56	3	3	3
CHLOR		Total chlordanes	ng/gdw	1997	6.410	1.830	3.586	2.29	0.50	1.85	3	3	3
CHLOR		Total chlordanes	ng/gdw	1998	4.162	1.677	2.947	0.81	0.07	1.21	3	3	3
CHLOR		Total chlordanes	ng/gdw	1999	5.473	1.490	2.298	0.16	0.07	0.40	3	3	3
CHLOR		Total chlordanes	ng/gdw	2000	2.479	0.945	1.412	0.46	0.20	0.20	3	3	3
CHLOR		Total chlordanes	ng/gdw	2001	2.125	0.428	1.135	1.14	0.11	0.23	3	3	3
CHLOR		Total chlordanes	ng/gdw	2002	1.334	0.569	0.925	0.19	0.13	0.22	3	3	3
CHLOR		Total chlordanes	ng/gdw	2003	2.257	0.983	1.177	0.13	0.13	0.18	3	3	3
CHLOR		Total chlordanes	ng/gdw	2006	0.000	0.000	0.130	0.00	0.00	0.23	3	3	3
CHLOR		Total chlordanes	ng/gdw	2009	2.237	0.632	0.853	0.69	0.16	0.14	3	3	3
CHLOR		Total chlordanes	ng/gdw	2012	0.568	0.000	0.000	0.12	0.00	0.00	3	3	3
CHLOR		Total chlordanes	ng/gdw	2015	0.988	0.122	0.189	0.43	0.11	0.16	3	3	3
DDT		Total DDTs	ng/gdw	1994	23.827	10.300	21.935	3.10	2.39	6.16	3	3	2
DDT		Total DDTs	ng/gdw	1995	13.617	13.223	14.337	4.09	4.41	1.37	3	3	3
DDT		Total DDTs	ng/gdw	1996	25.980	13.010	18.533	6.75	2.10	4.86	3	3	3
DDT		Total DDTs	ng/gdw	1997	46.343	14.607	20.897	39.87	1.74	11.14	3	3	3
DDT		Total DDTs	ng/gdw	1998	11.377	9.686	8.915	1.07	2.41	2.46	3	3	3
DDT		Total DDTs	ng/gdw	1999	15.977	9.315	7.358	1.85	1.44	0.17	3	3	3
DDT		Total DDTs	ng/gdw	2000	5.077	3.993	4.795	1.26	1.44	1.13	3	3	3
DDT		Total DDTs	ng/gdw	2001	7.562	6.400	6.942	2.44	0.52	1.14	3	3	3
DDT		Total DDTs	ng/gdw	2002	8.632	4.511	5.502	0.81	0.92	1.77	3	3	3
DDT		Total DDTs	ng/gdw	2003	12.850	5.733	5.620	0.34	2.04	1.29	3	3	3
DDT		Total DDTs	ng/gdw	2006	15.003	7.700	9.520	3.20	1.09	2.33	3	3	3
DDT		Total DDTs	ng/gdw	2009	15.090	4.667	4.469	2.38	1.52	0.31	3	3	3
DDT		Total DDTs	ng/gdw	2012	5.725	5.563	4.525	0.72	1.04	1.24	3	3	3
DDT		Total DDTs	ng/gdw	2015	6.725	4.092	3.676	1.47	0.60	0.52	3	3	3
METAL	Hg	Mercury	ug/gdw	1994	0.827	0.498	1.043	0.12	0.10	0.44	3	3	2
METAL	Hg	Mercury	ug/gdw	1995	0.610	0.535	1.089	0.51	0.09	0.45	3	3	3
METAL	Hg	Mercury	ug/gdw	1996	0.858	0.940	1.067	0.12	0.18	0.38	3	3	3
METAL	Hg	Mercury	ug/gdw	1997	1.467	0.983	1.120	0.19	0.12	0.14	3	3	3
METAL	Hg	Mercury	ug/gdw	1998	0.767	0.598	0.990	0.05	0.08	0.11	3	3	3
METAL	Hg	Mercury	ug/gdw	1999	0.999	0.712	1.038	0.27	0.12	0.29	3	3	3
METAL	Hg	Mercury	ug/gdw	2000	0.746	0.659	0.922	0.20	0.23	0.17	3	3	3
METAL	Hg	Mercury	ug/gdw	2001	0.873	0.530	1.024	0.07	0.09	0.20	3	3	3

(continued)

(Continued)

Parameter and Year					Station								
					Mean			SD			N		
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	OS	DIF	ECCB	OS	DIF	ECCB	OS
METAL	Hg	Mercury	ug/gdw	2002	0.853	0.642	0.790	0.18	0.10	0.06	3	3	3
METAL	Hg	Mercury	ug/gdw	2003	1.089	0.528	0.848	0.09	0.09	0.22	3	3	3
METAL	Hg	Mercury	ug/gdw	2006	0.487	0.320	0.447	0.06	0.04	0.02	3	3	3
METAL	Hg	Mercury	ug/gdw	2009	0.454	0.506	0.644	0.05	0.06	0.05	3	3	3
METAL	Hg	Mercury	ug/gdw	2012	0.608	0.564	0.664	0.18	0.00	0.09	3	3	3
METAL	Hg	Mercury	ug/gdw	2015	0.748	0.538	0.680	0.12	0.02	0.07	3	3	3
PCB		Total PCBs	ng/gdw	1994	137.167	66.797	177.950	23.26	27.38	94.12	3	3	2
PCB		Total PCBs	ng/gdw	1995	122.320	76.083	118.733	38.63	21.58	16.56	3	3	3
PCB		Total PCBs	ng/gdw	1996	220.433	68.880	148.100	47.04	10.09	3.48	3	3	3
PCB		Total PCBs	ng/gdw	1997	311.833	77.553	157.633	245.28	2.55	37.90	3	3	3
PCB		Total PCBs	ng/gdw	1998	112.943	54.900	71.830	18.94	9.26	19.07	3	3	3
PCB		Total PCBs	ng/gdw	1999	154.233	52.913	73.730	22.47	7.80	5.51	3	3	3
PCB		Total PCBs	ng/gdw	2000	127.427	37.973	64.003	119.77	8.36	11.20	3	3	3
PCB		Total PCBs	ng/gdw	2001	74.257	39.897	65.513	29.40	4.34	11.88	3	3	3
PCB		Total PCBs	ng/gdw	2002	90.550	32.807	59.920	2.57	9.89	19.35	3	3	3
PCB		Total PCBs	ng/gdw	2003	148.667	35.800	189.547	11.19	3.70	221.46	3	3	3
PCB		Total PCBs	ng/gdw	2006	171.633	59.447	96.100	26.29	23.58	19.37	3	3	2
PCB		Total PCBs	ng/gdw	2009	494.400	41.920	154.490	515.07	15.09	147.63	3	3	3
PCB		Total PCBs	ng/gdw	2012	116.433	34.937	49.533	8.21	1.81	2.72	3	3	3
PCB		Total PCBs	ng/gdw	2015	106.527	38.293	81.067	17.11	2.52	33.18	3	3	3

Appendix D: Summary Statistics by Chemical Parameter, Year, and Station for Lobster Hepatopancreas

Parameter and Year					Station								
					Mean			SD			N		
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	OS	DIF	ECCB	OS	DIF	ECCB	OS
CHLOR		Total chlordanes	ng/gdw	1994	116.353	13.212	21.415	34.14	3.60	9.78	3	3	2
CHLOR		Total chlordanes	ng/gdw	1995	38.667	65.000	73.667	23.50	39.36	64.13	3	3	3
CHLOR		Total chlordanes	ng/gdw	1996	199.000	81.200	156.667	28.16	32.90	39.63	3	3	3
CHLOR		Total chlordanes	ng/gdw	1997	137.633	41.593	57.867	43.09	12.04	19.40	3	3	3
CHLOR		Total chlordanes	ng/gdw	1998	233.800	42.020	93.853	8.05	4.92	10.41	3	3	3
CHLOR		Total chlordanes	ng/gdw	1999	138.067	31.853	57.937	25.14	5.58	11.69	3	3	3
CHLOR		Total chlordanes	ng/gdw	2000	89.263	33.240	37.760	44.06	3.85	26.06	3	3	3
CHLOR		Total chlordanes	ng/gdw	2001	97.113	22.287	37.143	11.85	4.13	9.43	3	3	3
CHLOR		Total chlordanes	ng/gdw	2002	55.900	18.610	40.537	5.48	6.77	5.87	3	3	3
CHLOR		Total chlordanes	ng/gdw	2003	70.640	22.103	34.173	8.07	4.17	18.52	3	3	3
CHLOR		Total chlordanes	ng/gdw	2006	123.257	82.177	56.180	33.01	42.98	9.50	3	3	3
CHLOR		Total chlordanes	ng/gdw	2009	53.733	21.810	25.287	18.64	9.09	5.75	3	3	3
CHLOR		Total chlordanes	ng/gdw	2012	31.387	13.275	19.777	10.64	4.56	6.40	3	3	3
CHLOR		Total chlordanes	ng/gdw	2015	37.767	8.870	16.017	0.74	4.83	10.90	3	3	3
METAL	Cd	Cadmium	ug/gdw	1994	8.307	16.143	12.295	2.82	6.17	3.26	3	3	2
METAL	Cd	Cadmium	ug/gdw	1995	5.292	7.942	5.322	0.43	0.39	1.03	3	3	3
METAL	Cd	Cadmium	ug/gdw	1996	3.321	14.447	9.299	0.56	0.81	2.07	3	3	3
METAL	Cd	Cadmium	ug/gdw	1997	6.982	13.707	11.889	1.84	1.69	3.28	3	3	3
METAL	Cd	Cadmium	ug/gdw	1998	3.977	7.558	17.323	1.65	0.62	6.23	3	3	3
METAL	Cd	Cadmium	ug/gdw	1999	4.581	12.423	15.528	0.60	2.62	6.67	3	3	3
METAL	Cd	Cadmium	ug/gdw	2000	6.413	9.440	11.000	0.77	3.48	1.31	3	3	3
METAL	Cd	Cadmium	ug/gdw	2001	8.103	12.700	15.500	1.95	0.50	0.78	3	3	3
METAL	Cd	Cadmium	ug/gdw	2002	11.023	13.267	15.917	4.64	1.11	6.86	3	3	3
METAL	Cd	Cadmium	ug/gdw	2003	11.437	10.767	12.144	3.66	2.03	2.48	3	3	3
METAL	Cd	Cadmium	ug/gdw	2006	5.890	10.653	15.567	0.73	4.93	4.13	3	3	3
METAL	Cd	Cadmium	ug/gdw	2009	6.187	13.700	19.200	0.26	0.44	5.20	3	3	3
METAL	Cd	Cadmium	ug/gdw	2012	9.403	16.300	38.033	3.74	3.40	27.43	3	3	3
METAL	Cd	Cadmium	ug/gdw	2015	9.210	22.100	31.067	2.55	2.35	11.26	3	3	3
METAL	Cu	Copper	ug/gdw	1994	537.000	283.667	557.500	162.52	154.14	89.80	3	3	2
METAL	Cu	Copper	ug/gdw	1995	324.733	125.237	314.367	104.28	58.62	60.90	3	3	3
METAL	Cu	Copper	ug/gdw	1996	485.100	166.587	371.033	171.20	75.18	122.70	3	3	3
METAL	Cu	Copper	ug/gdw	1997	641.200	294.467	513.500	184.85	70.29	350.89	3	3	3
METAL	Cu	Copper	ug/gdw	1998	612.433	572.667	610.800	72.89	93.00	155.60	3	3	3
METAL	Cu	Copper	ug/gdw	1999	895.200	477.967	830.467	29.29	123.50	178.69	3	3	3
METAL	Cu	Copper	ug/gdw	2000	454.667	422.000	693.000	102.94	189.87	160.78	3	3	3
METAL	Cu	Copper	ug/gdw	2001	639.667	521.333	778.000	287.45	220.65	108.86	3	3	3

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(Continued)

Parameter and Year					Station								
					Mean			SD			N		
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	OS	DIF	ECCB	OS	DIF	ECCB	OS
METAL	Cu	Copper	ug/gdw	2002	886.667	459.667	867.167	220.49	109.56	156.22	3	3	3
METAL	Cu	Copper	ug/gdw	2003	559.600	353.533	688.500	136.07	35.57	158.28	3	3	3
METAL	Cu	Copper	ug/gdw	2006	532.667	410.333	773.000	144.61	133.84	100.50	3	3	3
METAL	Cu	Copper	ug/gdw	2009	1323.333	275.667	829.667	72.34	190.01	181.67	3	3	3
METAL	Cu	Copper	ug/gdw	2012	827.333	288.333	958.333	126.26	80.38	178.11	3	3	3
METAL	Cu	Copper	ug/gdw	2015	408.667	709.333	998.000	104.31	204.10	199.87	3	3	3
METAL	Ni	Nickel	ug/gdw	1994	0.437	1.187	0.970	0.09	0.12	0.28	3	3	2
METAL	Ni	Nickel	ug/gdw	1995	0.421	0.453	0.432	0.16	0.07	0.06	3	3	3
METAL	Ni	Nickel	ug/gdw	1996	0.126	0.676	0.393	0.04	0.07	0.03	3	3	3
METAL	Ni	Nickel	ug/gdw	1997	0.570	0.893	1.264	0.12	0.41	0.40	3	3	3
METAL	Ni	Nickel	ug/gdw	1998	0.359	0.729	1.210	0.03	0.20	0.06	3	3	3
METAL	Ni	Nickel	ug/gdw	1999	0.650	1.327	0.685	0.12	0.27	0.05	3	3	3
METAL	Ni	Nickel	ug/gdw	2000	0.478	0.730	1.274	0.14	0.15	0.57	3	3	3
METAL	Ni	Nickel	ug/gdw	2001	0.505	0.787	0.728	0.03	0.11	0.05	3	3	3
METAL	Ni	Nickel	ug/gdw	2002	0.765	1.400	1.243	0.12	0.20	0.34	3	3	3
METAL	Ni	Nickel	ug/gdw	2003	0.880	1.146	1.055	0.10	0.23	0.45	3	3	3
METAL	Ni	Nickel	ug/gdw	2006	0.677	1.733	0.977	0.09	0.32	0.64	3	3	3
METAL	Ni	Nickel	ug/gdw	2009	0.921	0.954	1.979	0.07	0.12	1.13	3	3	3
METAL	Ni	Nickel	ug/gdw	2012	0.615	2.733	1.356	0.11	0.53	0.33	3	3	3
METAL	Ni	Nickel	ug/gdw	2015	0.363	2.037	2.037	0.33	0.23	0.99	3	3	3
PCB		Total PCBs	ng/gdw	1994	2482.333	657.067	2452.550	552.30	105.33	2160.14	3	3	2
PCB		Total PCBs	ng/gdw	1995	4525.000	2779.333	5234.000	2345.59	528.82	593.26	3	3	3
PCB		Total PCBs	ng/gdw	1996	7225.333	2465.333	5582.667	1173.30	517.91	1004.18	3	3	3
PCB		Total PCBs	ng/gdw	1997	7111.333	2477.667	4935.333	4528.19	389.59	494.38	3	3	3
PCB		Total PCBs	ng/gdw	1998	7722.667	3409.667	6003.333	310.25	268.06	416.79	3	3	3
PCB		Total PCBs	ng/gdw	1999	10253.333	3132.333	6353.667	219.39	417.89	782.87	3	3	3
PCB		Total PCBs	ng/gdw	2000	7578.667	1920.667	2965.000	7028.77	1051.89	1540.41	3	3	3
PCB		Total PCBs	ng/gdw	2001	8018.000	2029.667	3696.333	4116.85	177.75	1207.57	3	3	3
PCB		Total PCBs	ng/gdw	2002	4465.000	1268.333	2897.333	142.20	155.35	756.66	3	3	3
PCB		Total PCBs	ng/gdw	2003	10135.667	1731.667	12781.333	2311.53	157.61	16594.43	3	3	3
PCB		Total PCBs	ng/gdw	2006	6045.333	2714.333	3314.000	2275.80	885.00	877.96	3	3	3
PCB		Total PCBs	ng/gdw	2009	11136.333	1691.000	9423.667	5888.08	412.11	9448.09	3	3	3
PCB		Total PCBs	ng/gdw	2012	5908.333	1762.000	2657.667	476.94	203.35	734.85	3	3	3
PCB		Total PCBs	ng/gdw	2015	4298.000	1409.000	1954.067	1073.94	120.40	893.40	3	3	3
METAL	Pb	Lead	ug/gdw	1994	0.427	0.089	0.544	0.05	0.03	0.09	3	3	2
METAL	Pb	Lead	ug/gdw	1995	0.255	0.042	0.301	0.08	0.02	0.08	3	3	3

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(Continued)

Parameter and Year					Station								
					Mean			SD			N		
Group Id	Abbrev	Descr	Unit code	Year	DIF	ECCB	OS	DIF	ECCB	OS	DIF	ECCB	OS
METAL	Pb	Lead	ug/gdw	1996	0.350	0.068	0.411	0.14	0.04	0.21	3	3	3
METAL	Pb	Lead	ug/gdw	1997	0.391	0.039	0.299	0.09	0.04	0.09	3	3	3
METAL	Pb	Lead	ug/gdw	1998	0.230	0.305	0.629	0.07	0.01	0.13	3	3	3
METAL	Pb	Lead	ug/gdw	1999	0.525	0.247	0.418	0.05	0.05	0.14	3	3	3
METAL	Pb	Lead	ug/gdw	2000	0.298	0.363	0.317	0.03	0.07	0.04	3	3	3
METAL	Pb	Lead	ug/gdw	2001	0.390	0.371	0.418	0.10	0.02	0.06	3	3	3
METAL	Pb	Lead	ug/gdw	2002	0.377	0.418	0.326	0.13	0.05	0.19	3	3	3
METAL	Pb	Lead	ug/gdw	2003	0.295	0.210	0.372	0.07	0.09	0.15	3	3	3
METAL	Pb	Lead	ug/gdw	2006	0.315	0.080	0.431	0.09	0.04	0.12	3	3	3
METAL	Pb	Lead	ug/gdw	2009	0.739	0.000	0.857	0.02	0.00	0.51	3	3	3
METAL	Pb	Lead	ug/gdw	2012	0.712	0.000	1.207	0.10	0.00	0.68	3	3	3
METAL	Pb	Lead	ug/gdw	2015	0.338	0.000	0.603	0.29	0.00	0.21	3	3	3

Appendix E: Summary Statistics by Chemical Parameter, Year, and Station for Mussel Tissue

Parameter and Year					Station											
					Mean				SD				N			
Group Id	Abbrev	Descr	Unit code	Year	DIL	IH	LNB	OSM	DIL	IH	LNB	OSM	DIL	IH	LNB	OSM
CHLOR		Total chlordanes	ng/gdw	1991	18.244	20.860	N.A.	N.A.	4.75	5.08	N.A.	N.A.	8	5	N.A.	N.A.
CHLOR		Total chlordanes	ng/gdw	1992	17.971	45.530	N.A.	4.923	3.78	13.77	N.A.	1.24	7	5	N.A.	8
CHLOR		Total chlordanes	ng/gdw	1993	19.380	22.225	N.A.	7.850	4.93	5.14	N.A.	0.72	5	4	N.A.	8
CHLOR		Total chlordanes	ng/gdw	1994	26.687	25.233	N.A.	8.221	3.14	3.33	N.A.	1.03	3	3	N.A.	7
CHLOR		Total chlordanes	ng/gdw	1995	11.700	20.780	N.A.	N.A.	0.49	2.74	N.A.	N.A.	5	5	N.A.	N.A.
CHLOR		Total chlordanes	ng/gdw	1996	40.960	31.220	N.A.	7.252	7.68	5.15	N.A.	0.98	5	5	N.A.	5
CHLOR		Total chlordanes	ng/gdw	1997	20.428	29.042	N.A.	6.176	2.38	4.98	N.A.	0.63	5	5	N.A.	5
CHLOR		Total chlordanes	ng/gdw	1998	24.968	25.766	N.A.	10.468	1.26	3.97	N.A.	2.10	5	5	N.A.	8
CHLOR		Total chlordanes	ng/gdw	1999	N.A.	22.496	N.A.	7.723	N.A.	2.34	N.A.	0.71	N.A.	5	N.A.	8
CHLOR		Total chlordanes	ng/gdw	2000	13.796	28.354	N.A.	4.956	1.66	5.91	N.A.	1.05	5	5	N.A.	8
CHLOR		Total chlordanes	ng/gdw	2001	8.688	12.250	13.921	18.551	0.52	1.18	1.78	1.89	5	5	8	8
CHLOR		Total chlordanes	ng/gdw	2002	7.364	12.600	11.408	16.851	1.64	1.17	0.90	3.21	5	5	4	8
CHLOR		Total chlordanes	ng/gdw	2003	9.992	26.558	12.563	16.614	1.45	4.63	0.49	1.74	5	5	4	8
CHLOR		Total chlordanes	ng/gdw	2006	4.461	6.766	1.828	5.828	1.23	2.59	1.53	1.49	5	5	4	4
CHLOR		Total chlordanes	ng/gdw	2009	5.522	10.940	3.790	4.666	0.89	1.41	0.30	0.58	4	4	4	8
CHLOR		Total chlordanes	ng/gdw	2012	4.079	7.828	3.760	3.987	1.31	0.91	0.89	1.01	4	4	4	8
CHLOR		Total chlordanes	ng/gdw	2015	2.221	6.117	2.383	2.763	1.10	0.00	0.52	0.44	3	1	3	8
DDT		Total DDTs	ng/gdw	1991	45.638	89.180	N.A.	N.A.	11.68	24.08	N.A.	N.A.	8	5	N.A.	N.A.
DDT		Total DDTs	ng/gdw	1992	21.727	99.488	N.A.	8.910	4.71	42.10	N.A.	1.52	7	5	N.A.	8
DDT		Total DDTs	ng/gdw	1993	57.500	127.975	N.A.	25.575	19.38	53.73	N.A.	6.00	5	4	N.A.	8
DDT		Total DDTs	ng/gdw	1994	49.173	77.723	N.A.	16.783	4.17	10.10	N.A.	3.89	3	3	N.A.	7

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(Continued)

Parameter and Year					Station											
					Mean				SD				N			
DDT		Total DDTs	ng/gdw	1995	44.800	91.480	N.A.	N.A.	2.30	12.24	N.A.	N.A.	5	5	N.A.	N.A.
DDT		Total DDTs	ng/gdw	1996	84.400	118.500	N.A.	29.020	16.48	19.22	N.A.	2.60	5	5	N.A.	5
DDT		Total DDTs	ng/gdw	1997	60.040	134.860	N.A.	22.416	6.80	21.48	N.A.	2.76	5	5	N.A.	5
DDT		Total DDTs	ng/gdw	1998	38.040	81.954	N.A.	19.914	1.40	11.44	N.A.	2.90	5	5	N.A.	8
DDT		Total DDTs	ng/gdw	1999	N.A.	85.904	N.A.	12.188	N.A.	7.03	N.A.	1.32	N.A.	5	N.A.	8
DDT		Total DDTs	ng/gdw	2000	32.682	99.968	N.A.	7.875	5.56	15.80	N.A.	1.83	5	5	N.A.	8
DDT		Total DDTs	ng/gdw	2001	25.326	47.670	10.607	15.228	1.58	4.49	1.37	1.66	5	5	8	8
DDT		Total DDTs	ng/gdw	2002	19.980	47.708	14.228	17.920	3.74	4.15	0.69	1.92	5	5	4	8
DDT		Total DDTs	ng/gdw	2003	26.334	115.120	13.730	15.626	3.74	17.12	0.33	1.90	5	5	4	8
DDT		Total DDTs	ng/gdw	2006	23.592	40.554	8.881	10.437	3.06	16.32	3.59	2.55	5	5	4	7
DDT		Total DDTs	ng/gdw	2009	13.442	29.760	6.408	6.571	4.39	3.50	0.94	1.14	4	4	4	8
DDT		Total DDTs	ng/gdw	2012	8.197	23.315	3.569	3.260	1.34	4.42	0.92	0.65	4	4	4	8
DDT		Total DDTs	ng/gdw	2015	10.173	24.270	4.795	4.588	3.90	0.00	0.89	0.52	3	1	3	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1991	624.875	2112.000	N.A.	N.A.	182.73	376.49	N.A.	N.A.	8	4	N.A.	N.A.
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1992	1504.550	3343.400	N.A.	45.100	360.22	905.41	N.A.	19.57	8	5	N.A.	7
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1993	495.167	1210.333	N.A.	83.625	133.00	179.07	N.A.	35.22	6	6	N.A.	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1994	632.667	2175.667	N.A.	18.286	119.18	399.36	N.A.	13.38	3	3	N.A.	7
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1995	415.300	1238.200	N.A.	N.A.	43.64	66.18	N.A.	N.A.	5	5	N.A.	N.A.
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1996	799.360	2232.800	N.A.	37.130	288.70	284.59	N.A.	3.69	5	5	N.A.	5
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1997	260.980	1345.400	N.A.	23.674	31.11	215.75	N.A.	3.73	5	5	N.A.	5
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1998	154.320	1865.000	N.A.	19.746	6.02	240.01	N.A.	1.86	5	5	N.A.	8

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(Continued)

Parameter and Year					Station											
					Mean				SD				N			
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	1999	N.A.	2506.200	N.A.	25.128	N.A.	239.86	N.A.	2.10	N.A.	5	N.A.	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	2000	365.525	2182.800	N.A.	43.175	61.62	314.65	N.A.	4.92	4	5	N.A.	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	2001	209.740	1281.800	100.765	197.850	14.71	143.54	23.68	12.96	5	5	8	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	2002	149.920	837.460	103.025	212.050	5.79	408.99	3.65	48.55	5	5	4	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	2003	135.880	1747.600	133.975	288.075	17.81	290.07	10.10	38.15	5	5	4	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	2006	110.360	1143.000	70.470	119.225	15.75	169.71	3.00	18.17	2	2	2	4
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	2009	115.403	656.375	70.110	102.903	35.03	95.52	22.22	9.21	4	4	4	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	2012	86.350	683.450	34.990	60.614	6.17	50.14	4.05	7.92	4	4	4	8
HMW-PAH_NOAA		Total NOAA HMW PAH	ng/gdw	2015	185.367	672.000	180.533	179.766	43.58	0.00	21.02	78.50	3	1	3	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1991	528.250	209.000	N.A.	N.A.	250.28	42.86	N.A.	N.A.	8	4	N.A.	N.A.
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1992	426.013	194.780	N.A.	27.329	136.81	98.72	N.A.	4.09	8	5	N.A.	7
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1993	163.667	92.000	N.A.	33.250	54.89	37.06	N.A.	12.36	6	6	N.A.	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1994	203.667	53.333	N.A.	14.714	14.57	7.57	N.A.	4.96	3	3	N.A.	7
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1995	55.450	125.300	N.A.	N.A.	6.04	6.77	N.A.	N.A.	5	5	N.A.	N.A.
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1996	226.680	189.620	N.A.	41.480	91.85	14.22	N.A.	9.25	5	5	N.A.	5
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1997	83.460	147.500	N.A.	40.748	4.47	27.30	N.A.	27.29	5	5	N.A.	5
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1998	63.402	181.760	N.A.	18.753	10.66	48.19	N.A.	3.15	5	5	N.A.	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	1999	N.A.	175.680	N.A.	21.464	N.A.	36.23	N.A.	1.32	N.A.	5	N.A.	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	2000	119.465	277.200	N.A.	106.416	24.56	30.30	N.A.	24.93	4	5	N.A.	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	2001	38.258	114.318	28.868	25.793	4.09	20.18	8.08	2.01	5	5	8	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	2002	36.298	80.288	20.783	39.949	4.45	15.43	1.53	15.56	5	5	4	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	2003	29.326	172.680	23.133	32.848	4.44	33.81	0.54	4.70	5	5	4	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	2006	26.320	67.270	22.515	33.615	4.60	8.64	3.34	4.77	2	2	2	4
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	2009	50.200	119.050	43.035	34.225	6.66	17.33	15.52	3.17	4	4	4	8
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	2012	38.963	108.775	28.748	41.921	6.12	11.56	0.47	19.89	4	4	4	8

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Parameter and Year					Station											
					Mean				SD				N			
LMW-PAH_NOAA		Total NOAA LMW PAH	ng/gdw	2015	4.491	26.880	19.807	20.864	0.09	0.00	3.66	4.82	3	1	3	8
PCB		Total PCBs	ng/gdw	1991	194.863	462.040	N.A.	N.A.	36.68	77.94	N.A.	N.A.	8	5	N.A.	N.A.
PCB		Total PCBs	ng/gdw	1992	123.769	639.440	N.A.	34.295	23.10	194.55	N.A.	7.69	7	5	N.A.	8
PCB		Total PCBs	ng/gdw	1993	264.340	480.000	N.A.	89.050	80.78	95.96	N.A.	7.57	5	4	N.A.	8
PCB		Total PCBs	ng/gdw	1994	157.500	484.367	N.A.	85.144	9.79	123.55	N.A.	16.45	3	3	N.A.	7
PCB		Total PCBs	ng/gdw	1995	164.760	436.020	N.A.	N.A.	9.92	32.41	N.A.	N.A.	5	5	N.A.	N.A.
PCB		Total PCBs	ng/gdw	1996	268.680	532.560	N.A.	98.788	36.10	56.61	N.A.	8.10	5	5	N.A.	5
PCB		Total PCBs	ng/gdw	1997	355.580	752.660	N.A.	97.346	26.08	99.56	N.A.	4.99	5	5	N.A.	5
PCB		Total PCBs	ng/gdw	1998	149.180	460.020	N.A.	58.806	5.01	65.34	N.A.	7.77	5	5	N.A.	8
PCB		Total PCBs	ng/gdw	1999	N.A.	491.800	N.A.	36.873	N.A.	46.82	N.A.	3.04	N.A.	5	N.A.	8
PCB		Total PCBs	ng/gdw	2000	215.260	592.320	N.A.	35.490	31.28	75.87	N.A.	4.05	5	5	N.A.	8
PCB		Total PCBs	ng/gdw	2001	219.400	398.100	64.305	81.011	19.48	23.20	5.05	7.24	5	5	8	8
PCB		Total PCBs	ng/gdw	2002	165.800	297.540	54.498	64.330	28.87	24.05	1.22	3.06	5	5	4	8
PCB		Total PCBs	ng/gdw	2003	196.520	484.300	61.935	65.186	31.17	72.04	0.65	8.16	5	5	4	8
PCB		Total PCBs	ng/gdw	2006	208.720	289.560	38.520	32.276	12.80	64.22	1.33	7.33	5	5	4	8
PCB		Total PCBs	ng/gdw	2009	124.795	284.300	54.365	26.231	53.58	35.66	35.86	2.14	4	4	4	8
PCB		Total PCBs	ng/gdw	2012	106.410	238.275	23.785	20.428	12.03	21.25	2.63	3.50	4	4	4	8
PCB		Total PCBs	ng/gdw	2015	113.833	185.400	27.500	22.484	13.55	0.00	6.97	2.96	3	1	3	8
METAL	Pb	Lead	ug/gdw	1991	5.850	6.400	N.A.	N.A.	0.85	1.85	N.A.	N.A.	8	5	N.A.	N.A.
METAL	Pb	Lead	ug/gdw	1993	5.880	N.A.	N.A.	3.713	3.13	N.A.	N.A.	0.84	5	N.A.	N.A.	8
METAL	Pb	Lead	ug/gdw	1994	9.125	6.667	N.A.	4.800	2.29	2.23	N.A.	0.61	4	3	N.A.	8
METAL	Pb	Lead	ug/gdw	1995	8.402	8.536	N.A.	N.A.	1.69	1.15	N.A.	N.A.	5	5	N.A.	N.A.

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Parameter and Year					Station											
					Mean				SD				N			
METAL	Pb	Lead	ug/gdw	1996	6.272	9.359	N.A.	1.567	1.30	1.69	N.A.	0.31	5	3	N.A.	5
METAL	Pb	Lead	ug/gdw	1997	7.831	9.893	N.A.	2.093	1.09	3.59	N.A.	0.20	5	5	N.A.	5
METAL	Pb	Lead	ug/gdw	1998	3.470	4.092	N.A.	2.135	1.62	0.49	N.A.	0.48	5	5	N.A.	8
METAL	Pb	Lead	ug/gdw	1999	N.A.	4.694	N.A.	1.089	N.A.	0.80	N.A.	0.23	N.A.	5	N.A.	8
METAL	Pb	Lead	ug/gdw	2000	6.929	13.204	N.A.	0.943	2.13	2.17	N.A.	0.17	5	5	N.A.	8
METAL	Pb	Lead	ug/gdw	2001	3.502	10.056	N.A.	1.864	0.61	2.01	N.A.	0.28	5	5	N.A.	8
METAL	Pb	Lead	ug/gdw	2002	5.156	8.036	1.690	2.540	0.41	0.71	0.08	0.16	5	5	4	8
METAL	Pb	Lead	ug/gdw	2003	2.586	9.112	1.463	1.726	0.09	1.19	0.25	0.17	5	5	4	8
METAL	Pb	Lead	ug/gdw	2006	3.026	3.624	1.655	1.879	0.44	0.62	0.14	0.34	5	5	4	8
METAL	Pb	Lead	ug/gdw	2009	1.708	1.965	0.958	1.036	0.36	0.29	0.11	0.12	4	4	4	8
METAL	Pb	Lead	ug/gdw	2012	2.105	3.318	1.515	1.840	0.10	0.31	0.06	0.14	4	4	4	8
METAL	Pb	Lead	ug/gdw	2015	2.130	3.290	1.163	1.203	0.13	0.00	0.12	0.21	3	1	3	8

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