# 2018 and 2021 Fish and Shellfish Tissue Chemistry Report

Massachusetts Water Resources Authority
Environmental Quality Department
Report 2023-03

**Citation:**

Madray ME, Nestler EC. 2023. **2018 and 2021 Fish and Shellfish Tissue Chemistry Report**. Boston: Massachusetts Water Resources Authority. Report 2023-03. 51 p. plus Appendices.

# 2018 and 2021
# Fish and Shellfish Tissue Chemistry Report

**Submitted to**

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November 2023

Environmental Quality Report No. 2023-03

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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 Acadia Aqua Farms, in Maine (2018) and Salem State University's Northeastern Massachusetts Aquaculture Center (NEMAC), in Massachusetts (2021) 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 2018 and 2021, 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 to Contingency Plan (MWRA 2001a) threshold values to evaluate potential risk.

**Flounder**

Winter flounder for tissue chemistry were collected at the four historical monitoring locations (DIF, NB, OS, and ECCB) in 2018, and at two monitoring locations (DIF and OS) in 2021. The 2010 Ambient Monitoring Plan was amended in 2021 to discontinue fish collections at the two external reference stations (NB and ECCB) after years of consistent evidence indicating that the outfall did not result in neoplasias or centrotubular hydropic vacuolation (CHV) (MWRA 2010 and 2021). Sizes, ages, and gender ratios observed in 2018 and 2021 were similar to recent years. Fish from OS averaged about a half year older than those from DIF in 2018 and 2021. The mean standard fish length was greatest at DIF for both years. Blind side ulcers were not present at any stations except at OS in 2018 (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.

As with 2015, no liver neoplasms were reported in 2018 or 2021, 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 CHV prevalence remains highest in fish collected off Deer Island (31% in 2018; 9% in 2021) but remains low in the vicinity of the Massachusetts Bay Outfall Site (6% in 2018; 4% in 2021).

Fifteen winter flounder were collected at each location and edible meat and liver were analyzed for chemical contaminants. All flounder edible tissue contaminant levels remain well below the federal action limits, below the MWRA Threshold Levels, and indicate no risk for human consumption. In general, mean concentrations of organic compounds in fillets were highest at Deer Island and lowest at Eastern Cape Cod Bay (lowest values were observed at the Outfall Site in 2021 when collections were not taken at ECCB), a pattern observed throughout this program. Body burdens of chlordane continued to decline from 2015 in 2018 and 2021, and although DDT contaminants slightly increased in 2018, they decreased again in 2021 to values like those reported in 2015. Metal tissue burdens were less predictable although were typically higher at OS than other stations as has been observed throughout the study.

**Lobster**

Twenty-one lobsters were collected at each of the three core monitoring stations (DIF, OS, and ECCB) for both the 2018 and 2021 surveys. The average size as determined by carapace length was similar at all stations. The percentage of females was highest at OS for both years (67% in 2018; 57% in 2021) as compared to DIF (29% in 2018 and 24% in 2021) and at ECCB (38% in 2018; 19% in 2021). In 2018 and 2021 there were two lobsters at ECCB and two lobsters at OS for a total of eight lobsters collected across both survey years that had indications of shell erosion. No other deleterious external conditions were noted.

Lobster edible tissue concentrations were well below MWRA Caution and Warning Thresholds and FDA Action Limits for human consumption. Similar to historical results organic contaminants tended to be highest in lobster collected in Boston Harbor and lowest in those from Cape Cod Bay. Chlordane increased slightly in 2018, but then decreased again in 2021 to values similar to those seen in 2015. DDTs continue to show downward trends throughout the region. Total PCBs and mercury were generally low in lobster meat at all sites despite a small spike of mercury seen in 2018. The concentration of nickel decreased at all sites in 2018 from 2015, but marginally increased in 2021 from 2018.

**Mussels**

Mussels were obtained from Acadia Aquaculture Farms off Old Point in Eastern Bay, Lamoine, ME in 2018, and from Northeastern Massachusetts Aquaculture Center (NEMAC) at Salem State University's Cat Cove Marine Laboratory in Massachusetts in 2021. These mussels were deployed in arrays at Deer Island (DIL), Boston Inner Harbor (IH), Outfall Site (OSM), and "B" Buoy (LNB). In 2018 mussel survival was high at all stations (63%-96%), and in 2021 mussel survival was exceptionally high at all stations (95%-100%).

There were no MWRA Caution and Warning Thresholds and FDA Action Limit exceedances in 2018 or 2021 for mussel tissue. The 2018 and 2021 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. With only one exception (total DDT bioaccumulation), mussels from Maine (pre-deployed 'OP' mussels) had the lowest concentrations. The prior trend in decreasing bioaccumulation of lead at station DIL continued through 2018 and 2021. Body burdens of HMW PAHs and LMW PAHs jumped to record highs post baseline period in 2021 at all stations. Concentrations of total chlordane increased in 2018 from 2015 and then again in 2021 at all stations but remained similar to or lower than baseline period concentrations. Total PCB increased sharply in 2018, but then decreased slightly in 2021 across all stations. Total DDT trends were similar to total PCB trends. Total DDT increased slightly at all stations in 2018, then decreased at OSM and LNB in 2021.

# 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 Ambient Monitoring Plan (MWRA 1997, 2004, 2010, 2021).

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 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 2018 and 2021 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 2018 and 2021, as well as selected data from previous studies. Section 4 provides a brief conclusion, summarizing findings for the 2018 and 2021 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 2018 and 2021 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: 2017-2019* (Rutecki *et al.* 2017), *Quality Assurance Project Plan (QAPP) for Fish and Shellfish Monitoring: 2020-2022 (*Rutecki *et al.* 2020*)* 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 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 Flounder Stations and Sampling

The 2018 flounder survey was conducted between April 23rd and May 7th, 2018; the 2021 flounder survey was conducted between April 27th and 28th, 2021. The following four sites were sampled during the 2018 survey; only DIF and OS were sampled in 2021 per the approved changes in the monitoring plan (MWRA 2021):

- 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 2018 and 2021 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.

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

**a. 2018**

| Station ID | Sampling Site | Number of Tows | Planned Locations | | Actual Locations[1] | |
|---|---|---|---|---|---|---|
| | | | N Latitude | W Longitude | N Latitude | W Longitude |
| DIF | Deer Island Flats | 5 | 42º20.4’ | 70º58.4’ | 42º21.0’ | 70º58.1’ |
| NB | Off Nantasket Beach | 3 | 42º17.6’ | 70º52.2’ | 42º17.4’ | 70º51.9’ |
| OS | Outfall Site | 2 | 42º23.1’ | 70º49.3’ | 42º23.0’ | 70º49.8’ |
| ECCB | East Cape Cod Bay | 1 | 41º56.2’ | 70º06.6’ | 41º55.1’ | 70º07.7’ |

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

**b. 2021**

| Station ID | Sampling Site[1] | Number of Tows | Planned Locations | | Actual Locations[2] | |
|---|---|---|---|---|---|---|
| | | | N Latitude | W Longitude | N Latitude | W Longitude |
| DIF | Deer Island Flats | 6 | 42º20.4’ | 70º58.4’ | 42º20.9’ | 70º58.0’ |
| OS | Outfall Site | 2 | 42º23.1’ | 70º49.3’ | 42º23.6’ | 70º50.2’ |
| ECCB | East Cape Cod Bay | 1 | 41º56.2’ | 70º06.6’ | 41º54.4’ | 70º08.7’ |

[1]Due to program reductions that were in effect for the 2021 sampling year there were no samples collected at NB, nor were composite samples analyzed for chemical contaminants at ECCB.

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


**Figure 2-1. 2018 and 2021 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. These results can be found in the 2018 and 2021 flounder reports (Moore *et al.* 2018 and 2021).

The remaining 15 flounder 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 Enthalpy, Inc. (formerly EnviroSystems, Inc.) 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. In 2021, the monitoring program was reduced to no longer include “Off Nantasket Beach (NB)” and to only conduct chemical analyses at two of the three stations (Deer Island Flats (DIF) and the Outfall Site (OS)). This resulted in a reduced number of samples for 2021 (12) as compared to 2018 (24).

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. Following the removal of three individual slices of liver for histology analysis (livers from the 35 fish not used for chemical analyses were removed shipboard to also be processed for histology), the remaining liver tissue from each fish was homogenized by finely chopping with the titanium knife. The liver tissue from the selected 15 fish comprised three separate composites per station.

Fillets will be removed from the same 15 flounder, and the skin will be removed from the fillets using a pre-cleaned titanium knife. Approximately equal masses of top and bottom tissue will be used from each flounder with the total amount of tissue from each individual fish making up each composite will be about the same. The same randomly grouped five fish that were homogenized into each edible tissue composite will correspond to the same five fish in the composites made for the fillets (*i.e.,* the livers of the same five specimens used for each edible tissue composite were combined for each liver composite). 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 2018 (12 pooled fillets and 12 pooled livers) and 12 pooled samples for analyses in 2021 (6 pooled fillets and 6 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 Flounder Tissue Processing and Chemical Analyses

Chemical analyses were performed by the MWRA Central Laboratory on composite samples of flounder from all stations. Two tissue types (fillet and liver) were analyzed. Both flounder fillet and livers were analyzed for PCBs/Pesticides, lipids, and mercury. Flounder livers were also 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 Lobster Stations and Sampling

Lobsters were collected on July 16 and 17, 2018, and on July 12 and 14, 2021. The animals were captured in traps deployed at each location by local lobstermen. Mr. Fred Penney collected lobsters at DIF and OS; Mr. Carl Howard collected lobsters at 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.

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

**a. 2018**

| Station ID | Sampling Site | Planned Location | | Actual Location | |
|---|---|---|---|---|---|
| | | N Latitude | W Longitude | N Latitude | W Longitude |
| DIF | Deer Island Flats | 42º20.4’ | 70º58.4’ | 42º20.2’ | 70º58.0’ |
| OS | Outfall Site | 42º23.1’ | 70º49.3’ | 42º23.2’ | 70º49.3’ |
| ECCB | East Cape Cod Bay | 41º56.2’ | 70º06.6’ | 41º48.6’ | 70º12.4’ |

**b. 2021**

| Station ID | Sampling Site | Planned Location | | Actual Location | |
|---|---|---|---|---|---|
| | | N Latitude | W Longitude | N Latitude | W Longitude |
| DIF | Deer Island Flats | 42º20.4’ | 70º58.4’ | 42º20.3’ | 70º57.6’ |
| OS | Outfall Site | 42º23.1’ | 70º49.3’ | 42º23.1’ | 70º47.6’ |
| ECCB | East Cape Cod Bay | 41º56.2’ | 70º06.6’ | 41º48.3’ | 70º13.0’ |


**Figure 2-2. 2018 and 2021 Lobster Monitoring Locations.**

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. While at sea, lobsters were kept alive in a cooler of sea water, and then placed on ice for delivery to the lab for processing. Processing of the hepatopancreas and the edible tail and claw meat tissue samples was conducted in the laboratory (Enthalpy, Inc.).

### 2.2.2 Lobster 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 to comprise six composites for each station (three edible meat composites and three hepatopancreas composites). Homogenization of edible 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 2018 and 2021 (nine edible meat samples and nine hepatopancreas samples).

### 2.2.4 Lobster 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. Additionally, 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 farm (Acadia Aqua Farms) in Lamoine, Maine for the 2018 survey and from Salem State University's Northeastern Massachusetts Aquaculture Center (NEMAC), Cat Cove Marine Laboratory in Massachusetts for the 2021 survey. These mussels were 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 Mussel Stations and Reference Area

The 2018 Acadia Aqua Farms (OP) and the 2021 NEMAC, Cat Cove Marine Laboratory (CA) pre-deployment mussels 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. Planned and actual sampling locations for mussel survey.**

**a. 2018**

| Station ID | Sampling Site | Planned Location | | Actual Location | |
|---|---|---|---|---|---|
| | | N Latitude | W Longitude | N Latitude | W Longitude |
| DIL | Deer Island Light | 42º20.40' | 70º57.20' | 42º20.39' | 70º57.20' |
| OS-M2 | Outfall Site – Mussel Array 2 | 42° 23.22' | 70° 47.18' | 42º23.22' | 70°47.18' |
| OS-M3 | Outfall Site - Mussel Array 3 | 42º23.17' | 70º47.47' | 42º23.17' | 70º47.47' |
| LNB | LNB "B" Buoy | 42º22.67' | 70º47.13' | 42º22.67' | 70º47.12' |
| IH | Boston Inner Harbor | 42º21.50' | 71º02.90' | 42º21.53' | 71°02.92' |
| OP | Acadia Aqua Farms - Lamoine, ME | 44º27.00' | 68º19.80' | 44º27.0' | 68º19.80' |

**b. 2021**

| Station ID | Sampling Site | Planned Location | | Actual Location | |
|---|---|---|---|---|---|
| | | N Latitude | W Longitude | N Latitude | W Longitude |
| DIL | Deer Island Light | 42º20.40' | 70º57.20' | 42º20.40' | 70º57.20' |
| OS-M2 | Outfall Site – Mussel Array 2 | 42° 23.22' | 70° 47.18' | 42º23.22' | 70°47.19' |
| OS-M3 | Outfall Site - Mussel Array 3 | 42º23.17' | 70º47.47' | 42º23.17' | 70º47.47' |
| LNB | LNB "B" Buoy | 42º22.67' | 70º47.13' | 42º22.67' | 70º47.13' |
| IH | Boston Inner Harbor | 42º21.50' | 71º02.90' | 42º21.53' | 71°02.92' |
| CA | NEMAC Cat Cove Marine Lab - Salem, MA | 42º41.00' | 70º27.00' | 42º41.00' | 70º27.00' |

### 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 mussel survey planning effort was conducted by Normandeau in 2017 in consultation with the Maine Department of Marine Resources (DMR). When no appropriate intertidal locations could be identified, MWRA agreed to use purchased farmed mussels of appropriate size as an alternative. However, due to red tides around Salem State University's Northeastern Aquaculture Center (NEMAC) , Acadia Aqua Farms' mussels were utilized for the 2018 mussel survey, which were harvested by the grower on June 25, 2018 from aquaculture sites off Old Point in Eastern Bay, Lamoine, ME. Mussels were held under refrigeration until picked up by Normandeau staff on June 26, 2018. Mussels for the 2021 survey were from Salem State University's NEMAC offshore mussel farm. Mussels were collected from the offshore mussel farm by NEMAC on May 17, 2021, and then held at the Cat Cove facility's holding tanks, or on their grow lines at Smith Pool (in Salem, MA) until being picked up by Normandeau on June 29, 2021.For both the 2018 and 2021 surveys, 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 numbers to provide the necessary biological material. For the 2018 survey mussels were deployed on June 27, 2018, in replicate arrays at the four sites, and in 2021 deployment was on June 30, 2021, in replicate arrays at each of the four sites (Figures 2-3 and 2-4). A backup array was deployed in 2021 at the Inner Harbor station due to elevated mortality in past surveys to ensure enough mussels would be present at the 60-day retrieval. 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).

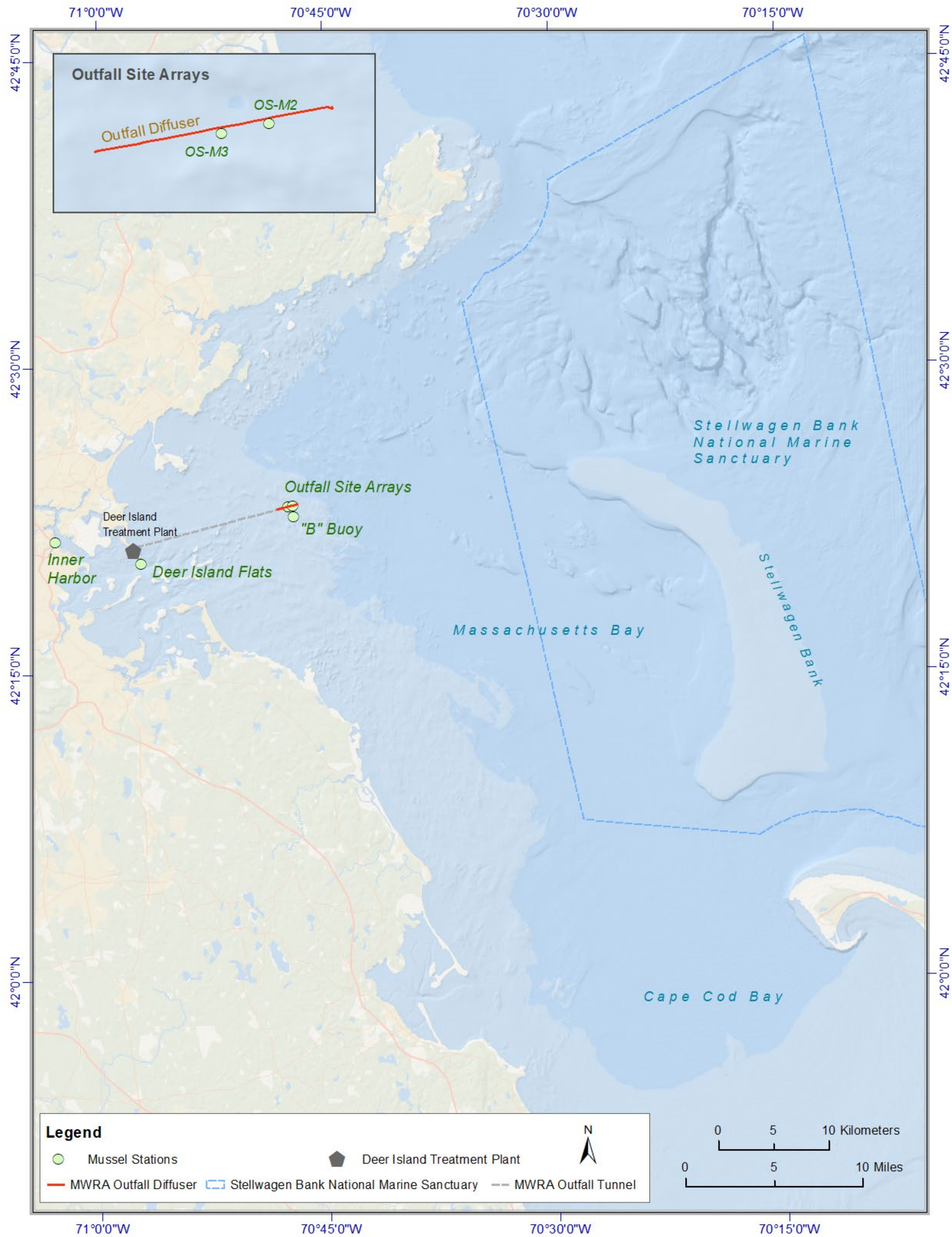



**Figure 2-3. 2018 and 2021 Mussel Deployment Locations.**

**Table 2-4. Summary of mussel deployment scheme for 2018 and 2021.**

| Site | Description/ Location | Water Depth[a] | Cage Height Above Bottom[b] | # Arrays | # Cages/Array | # Mussels/ Cage |
|---|---|---|---|---|---|---|
| DIL | Deer Island Light | 2-5 m | <1-1.5m | 2 (3 in 2018) | 2 | 60 |
| OS | Outfall Site | 33m | 12m | 5 | 2 | 60 |
| LNB | "B" Buoy | 33m | 12 m | 2 | 2 | 60 |
| IH | Boston Inner Harbor | 8-11m | 1.5-4.5m[b] | 2 | 2 | 60[c] |

[a] Based on historical data.

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

[c] In 2018 at Site IH the 40-day array had 57 and 58 mussels/cage; the 60-day array had 93 and 94 mussels/cage.

At OSM, three arrays were deployed at two locations (OS-M2 and OS-M3) 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.

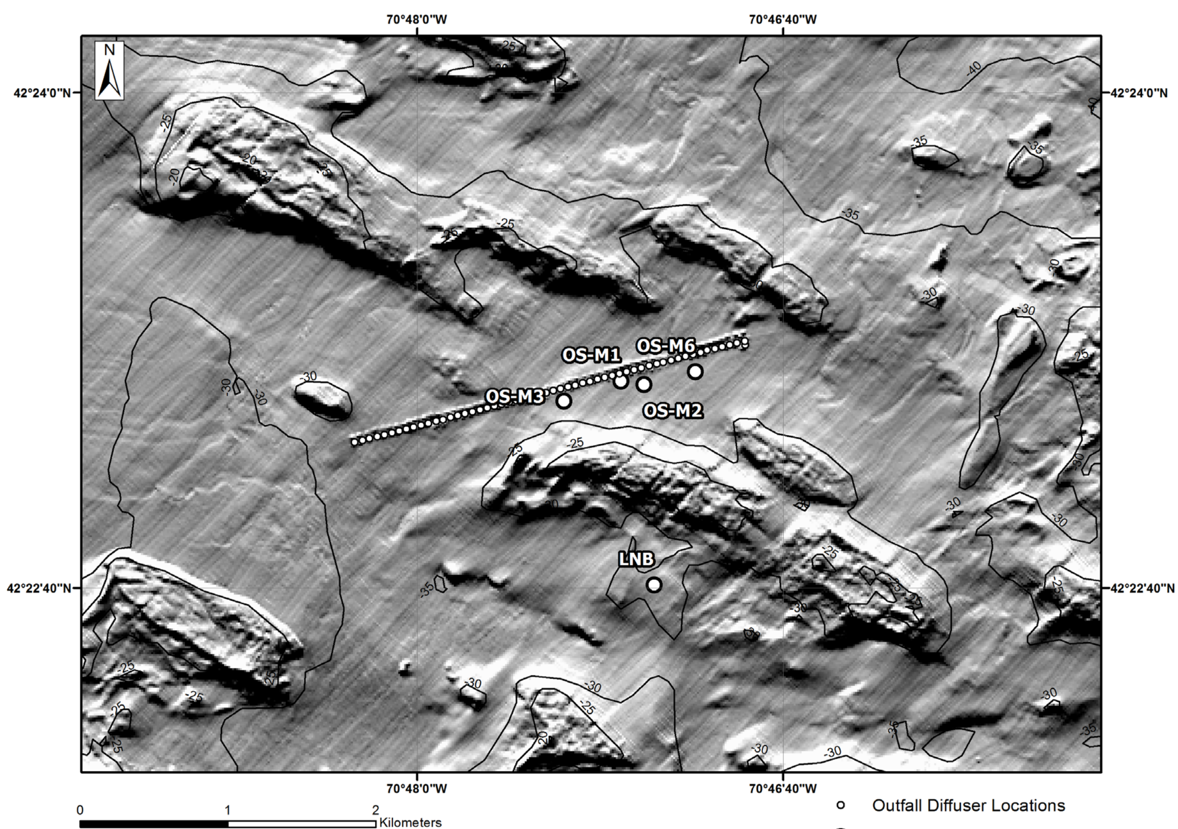



**Figure 2-4. Mussel Deployment Locations at OS in 2018 and 2021.**

### 2.3.4 Mussel Retrieval

Mussel retrieval for both the 2018 and 2021 surveys were 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 2018 40-day retrieval occurred on August 8 (43 days after deployment) and the 60-day retrieval occurred on August 27 (62 days after deployment) The 2021 40-day retrieval occurred on August 9 (40 days after deployment) and the 60-day retrieval occurred on August 30 (60 days after deployment). Mortality from the 40 and 60-day retrievals was generally low apart from arrays at the Inner Harbor location. Mortalities ranged from 4% (LNB) to 37% (Inner Harbor) in 2018 and from 0% (at several stations) to 5% (Inner Harbor). There was no apparent increase in mortality between the 43/40-day and 62/60-day collections for either year. See Table 3-5 for complete mussel mortality information.

### 2.3.5 Mussel 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 the three non-outfall stations (DIL, IH, and LNB) and eight composites from the outfall cages. MWRA's Deer Island Laboratory determined the minimum wet weight of mussel tissue required for analysis (75 g) for organic and inorganic parameters and Enthalpy, Inc. prepared as many replicates as possible using the available individuals. The number of replicates prepared was:

- Pre-eployment – 5 replicates of 25 mussels each
- IH – 4 replicates of 60 mussels
- LNB – 4 replicates of 60 mussels each
- DIL – 4 replicates of 60 mussels each (an additional 2 replicates deployed as backup in 2018)
- OS-M2 – 4 replicates of 60 mussels each
- OS-M3 – 4 replicates of 60 mussels each
- OS-M6 – 2 replicates of 60 mussels each (backup array)

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.

## *2.4 Chemical Analyses of Tissue Samples*

Flounder, lobster, and mussel tissue samples were processed by Enthalpy, Inc. (formerly EnviroSystems, Inc.) and delivered to the MWRA Central Lab for analysis. 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.

**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 (2018); 6 (2021) | NR | * | NR | * | NR | * | * |
| Flounder Liver | 12 (2018); 6 (2021) | * | * | * | * | * | * | * |
| 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** | |

### 2.4.1 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.

### 2.4.2 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). Digestates are analyzed by ICP (Inductively Coupled Plasma) according to MWRA Central Lab SOP #1008.3 (MWRA, 2008a). Elements that are undetected by ICP may be analyzed by GFA (DLS SOP #1150.3 (MWRA, 2008b) for lower reporting limits. Results are reported as μg/g dry-weight.

Samples for mercury analysis are digested and analyzed according to MWRA Central Lab SOP #1236.0 (MWRA, 2006a) using cold-vapor atomic absorption spectroscopy (CVAA). A 200 mg lyophilized aliquot is cold-digested with 15 mL dilute $HNO_3$ and $H_2SO_4$ overnight. Samples are heated in a 58ºC water bath for 1 hour, and then heated again at 80ºC 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. 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).

### 2.4.3 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.

## 2.5 Data Treatment, Reduction, and Statistical Analyses

This section describes the data reduction performed on 2018 and 2021 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 (Rutecki *et al.* 2020). Chemical constituents were presented graphically and compared among stations and over time.

Specifics of data handling are as follows:

- All 2018 and 2021 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, and OS-M6) were averaged for 2018, 2021, and time-series plots.
- All fish and shellfish data (2018, 2021, 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.

# 3.0 RESULTS

## *3.1 Winter Flounder*

### 3.1.1 Lounder FSummary of Survey Results

Winter flounder collections in 2018 and 2021, along with physical characteristics, external condition, and liver histopathology are described in detail in the annual flounder monitoring report (Moore *et al.* 2018 and 2021). In summary, sizes, ages, and gender ratios observed in 2018 and 2021 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 (Table 3-3).

**Table 3-1. Summary of physical characteristics of flounder collected in 2018 and 2021.**

**a. 2018**

| Parameter | DIF | | | ECCB | | | NB | | | OS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | STDDEV | N | Mean | STDDEV | N | Mean | STDDEV | N | Mean | STDDEV | N |
| Age (years) | 4.23 | 0.87 | 39 | 4.24 | 0.74 | 50 | 4.02 | 0.74 | 50 | 3.82 | 0.72 | 50 |
| Standard Length (mm) | 285.38 | 27.18 | 39 | 280.18 | 18.78 | 50 | 276.64 | 19.13 | 50 | 269.98 | 18.75 | 50 |
| Total Length (mm) | 349.46 | 32.7 | 39 | 339.26 | 21.91 | 50 | 336.76 | 23.2 | 50 | 329.16 | 22.89 | 50 |
| Weight (g) | 516.41 | 160.24 | 39 | 451.4 | 134.48 | 50 | 442.1 | 100.81 | 50 | 411.4 | 110.99 | 50 |

Std. Dev. = Standard Deviation

**b. 2021**

| Parameter | DIF | | | OS | | |
|---|---|---|---|---|---|---|
| | Mean | STDDEV | N | Mean | STDDEV | N |
| Age (years) | 4.78 | 0.94 | 32 | 5.14 | 1.06 | 49 |
| Standard Length (mm) | 283.09 | 23.63 | 33 | 273.68 | 21.53 | 50 |
| Total Length (mm) | 343.45 | 28.21 | 33 | 332.54 | 24.68 | 50 |
| Weight (g) | 490.61 | 141.29 | 33 | 441.56 | 103.39 | 50 |

Std. Dev. = Standard Deviation

**Table 3-2. Prevalence (%) of external conditions assessed for flounder collected in 2018 and 2021.**

**a. 2018**

| External Conditions | Station (Sample size) | | | |
|---|---|---|---|---|
| | DIF (39) | ECCB (50) | NB (50) | OS (50) |
| Bent Fin Ray | 18 | 2 | 10 | 2 |
| Blind Side Ulcers | 0 | 0 | 0 | 2 |
| Fin Erosion (Fin Rot) | 41 | 4 | 20 | 6 |
| Lymphocystis | 10 | 2 | 26 | 50 |

Sample size – 50 fish at each station

**b. 2021**

| External Conditions | Station (Sample size) | |
|---|---|---|
| | DIF (33) | OS (50) |
| Bent Fin Ray | 6 | 8 |
| Blind Side Ulcers | 0 | 0 |
| Fin Erosion (Fin Rot) | 6 | 18 |
| Lymphocystis | 12 | 38 |

Sample size – 50 fish at each station

**Table 3-3. Prevalence (%) of liver lesions in flounder collected in 2018 and 2021.**

**a. 2018**

| Liver Conditions | Station (Sample size) | | | |
|---|---|---|---|---|
| | DIF (39) | ECCB (50) | NB (50) | OS (50) |
| Balloons | 10 | 8 | 10 | 6 |
| Bile Duct Protozoan | 0 | 0 | 0 | 0 |
| Biliary Proliferation | 28 | 10 | 6 | 10 |
| Centrotubular Hydropic Vacuolation | 31 | 2 | 12 | 6 |
| Focal Hydropic Vacuolation | 3 | 0 | 0 | 0 |
| Liver Flukes | 0 | 0 | 0 | 0 |
| Macrophage Aggregation | 54 | 38 | 58 | 54 |
| Neoplasia | 0 | 0 | 0 | 0 |
| Tubular Hydropic Vacuolation | 13 | 0 | 2 | 4 |

**b. 2021**

| Liver Conditions | Station (Sample size) | |
|---|---|---|
| | DIF (33) | OS (50) |
| Balloons | 3 | 8 |
| Bile Duct Protozoan | 6 | 0 |
| Biliary Proliferation | 9 | 2 |
| Centrotubular Hydropic Vacuolation | 9 | 4 |
| Focal Hydropic Vacuolation | 0 | 0 |
| Liver Flukes | 0 | 0 |
| Macrophage Aggregation | 30 | 54 |
| Neoplasia | 0 | 0 |
| Tubular Hydropic Vacuolation | 6 | 2 |

### 3.1.2 Flounder Contaminant Levels

Contaminant levels were determined for both edible tissue (fillets) and liver tissue for winter flounder. 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) and East Cape Cod Bay (ECCB) where they have been measured every three years since the inception of this program. Due to revisions in the monitoring program, collections at the NB and ECCB locations were discontinued starting in 2021. 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 at Deer Island (DIF) had the highest concentrations of organic contaminants (Figures 3-1 to 3-3). During 2018, organic contaminant levels were lowest at ECCB; and in 2021, levels were lowest at the Outfall Site (OS), and comparable to recent historic values at ECCB (which was not sampled in 2021). The 2018 results for total chlordane (the sum of alpha chlordane, trans-nonachlor, heptachlor, and heptachlor epoxide) broke from the previous downward trend and increased slightly at ECCB and OS, but then decreased again at both sampled stations (DIF and OS) in 2021 (Figure 3-1). A similar trend occurred with 4-4 DDE (the predominant DDT breakdown isomer) and PCB concentrations with an increase across all stations in 2018, then a decrease in 2021 continuing with the previously seen downward trend (Figures 3-2 and 3-3). The 2021 results at DIF and OS for both 4-4 DDE and PCB were the lowest seen in the history of the program. Mercury concentrations in fillet were within historical ranges at all four stations in 2018 with a slight decrease in concentrations at all stations except at NB (Figure 3-4). In 2021, mercury concentrations increased at OS and decreased at DIF, but remained within historical ranges for each of those stations; no temporal trends were evident at any of the stations.

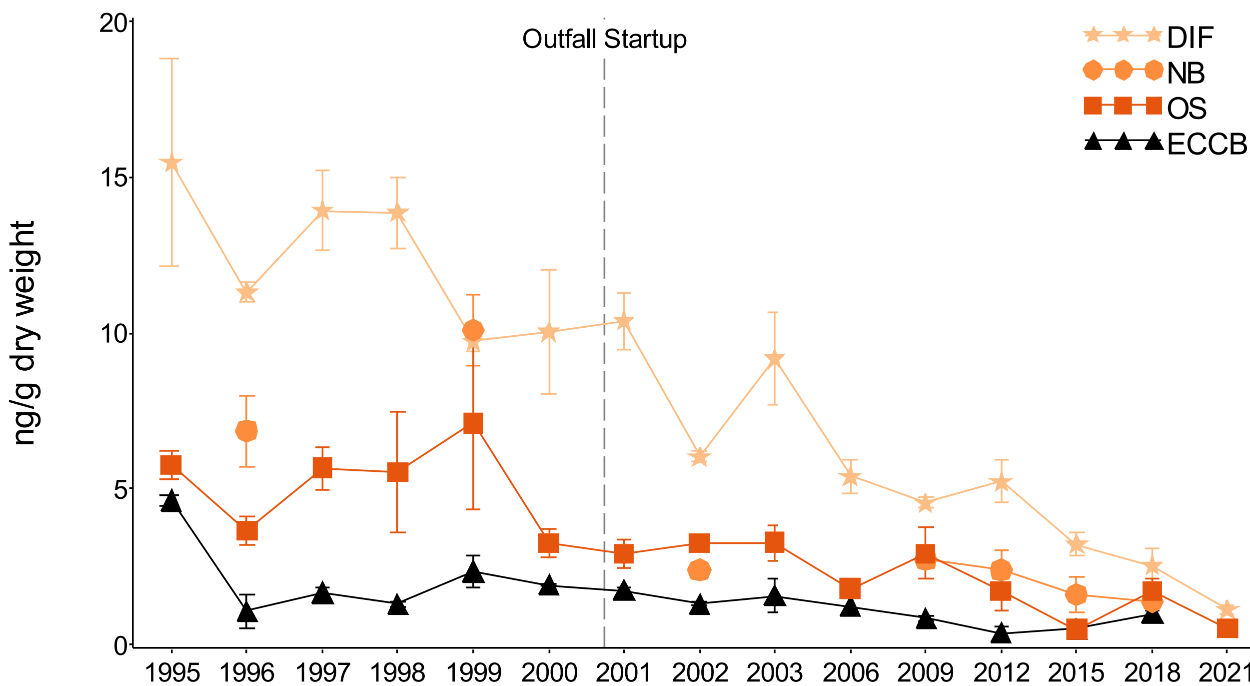



**Figure 3-1. Total chlordane in flounder fillet (1995-2021).**

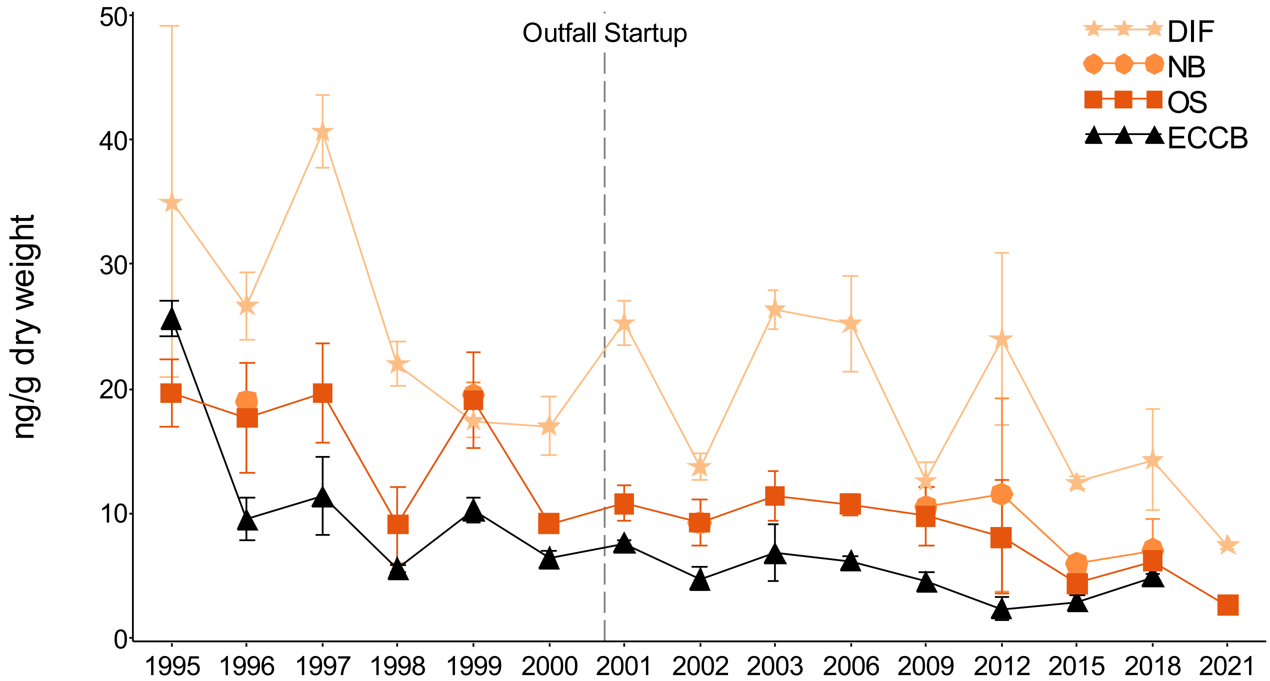



**Figure 3-2. 4-4 DDE in flounder fillet (1995-2021).**

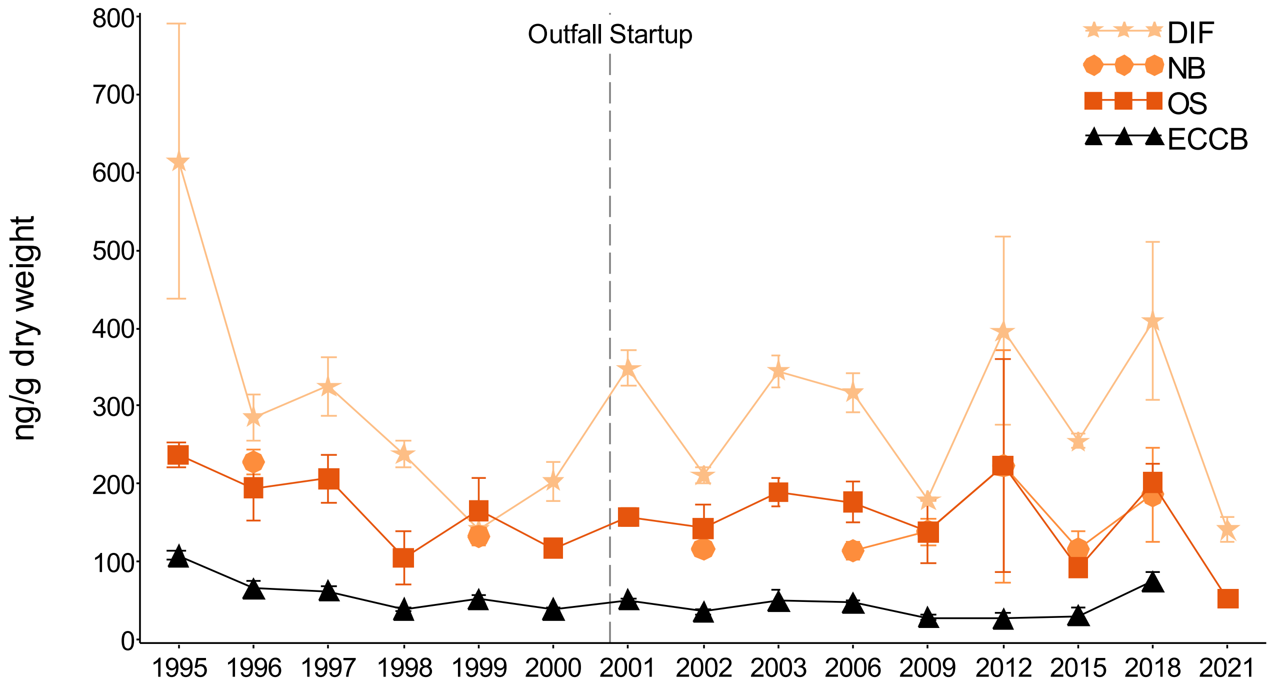



**Figure 3-3. Total PCB in flounder fillet (1995-2021).**

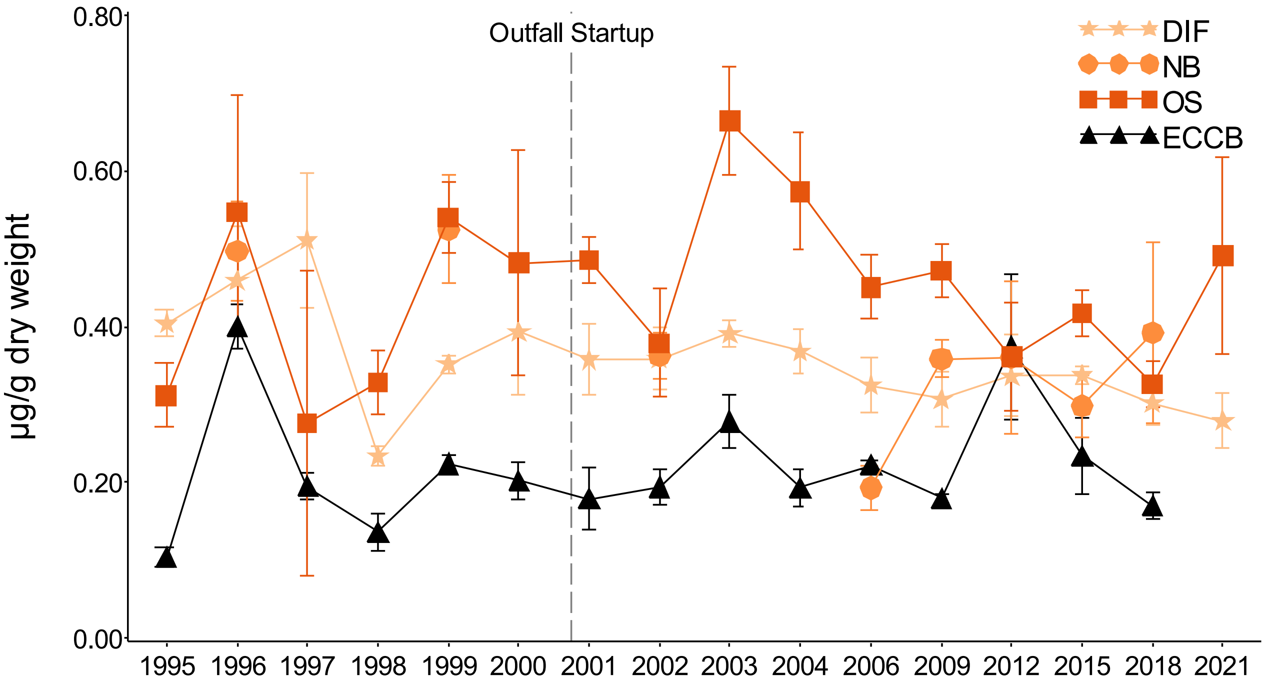



**Figure 3-4. Mercury in flounder fillet (1995-2021).**

**Liver -** Spatial and temporal patterns of organic contaminants in flounder liver were similar to those in fillets. Total chlordane in flounder liver in 2018 and 2021 was similar at all sampled stations and among the lowest concentrations reported throughout the history of the program (Figure 3-5). No chlordane results were reported for 2006 as the result values were blank denoted with an 'a' qualifier indicating the following "Usable non-detect result; not detected at or above the level of the sample-specific quantitation limit (QL). Database value input as null." (MWRA, 2006b). Concentrations of total PCBs increased slightly in 2018, then decreased again in 2021 to low concentrations akin to 2015. The highest concentrations were reported at DIF, as has been the case historically for the program (Figure 3-6). Concentrations of silver marginally increased in 2018 from 2015 at all stations except at ECCB, then decreased at both DIF and OS in 2021 to relatively low levels, similar to values reported in recent years (Figure 3-7). Nickel in flounder liver was within historic ranges at all four stations in 2018, but sharply increased at OS in 2021 to one of the highest concentrations reported in the history of the program (Figure 3-8). The variability in nickel over this time-series does not indicate any long-term trend. Lead concentrations in flounder liver were also within historical ranges at all stations in 2018 and 2021 (Figure 3-9). Similar to previous years, lead concentrations in 2018 and 2021 remained highest at OS.

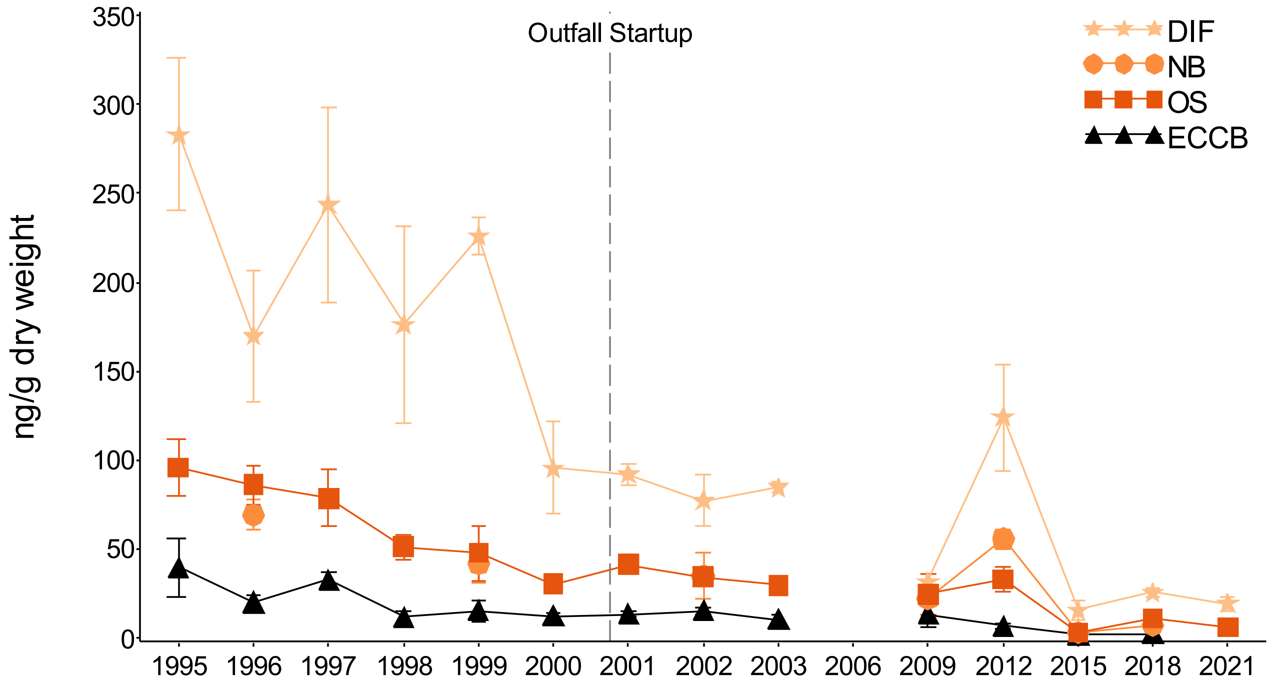



**Figure 3-5. Total Chlordane in flounder liver (1995-2021).**

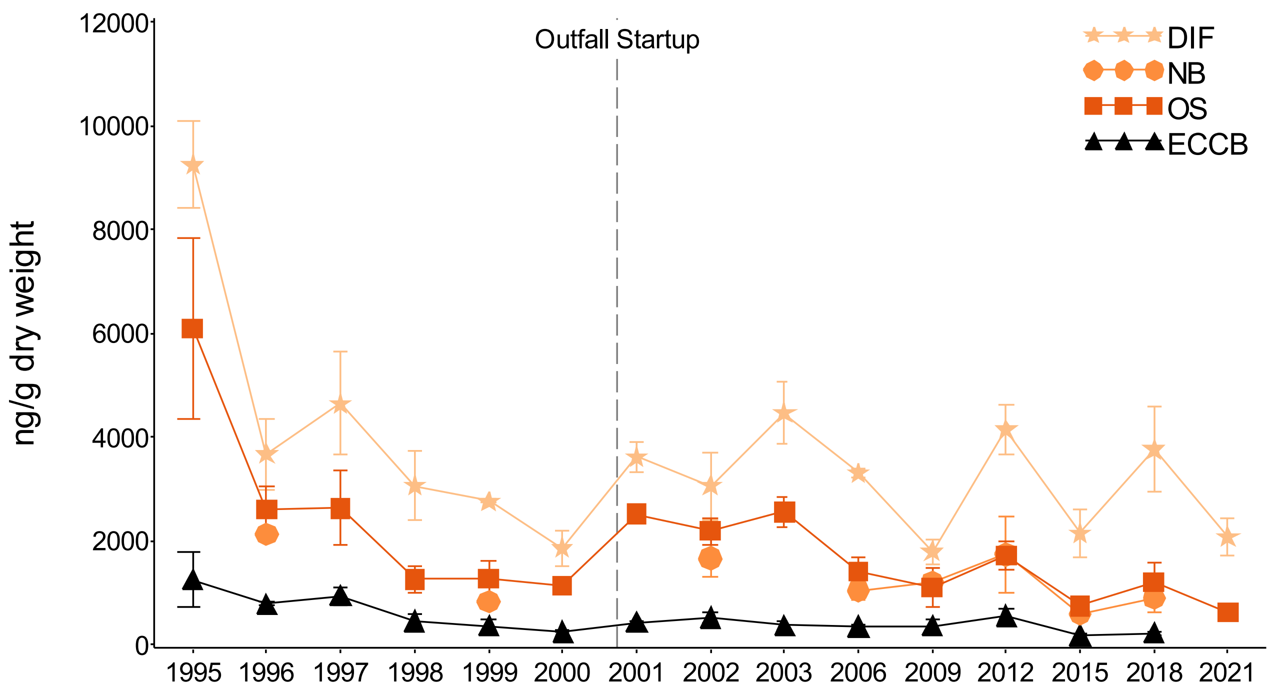



**Figure 3-6. Total PCBs in flounder liver (1995-2021).**

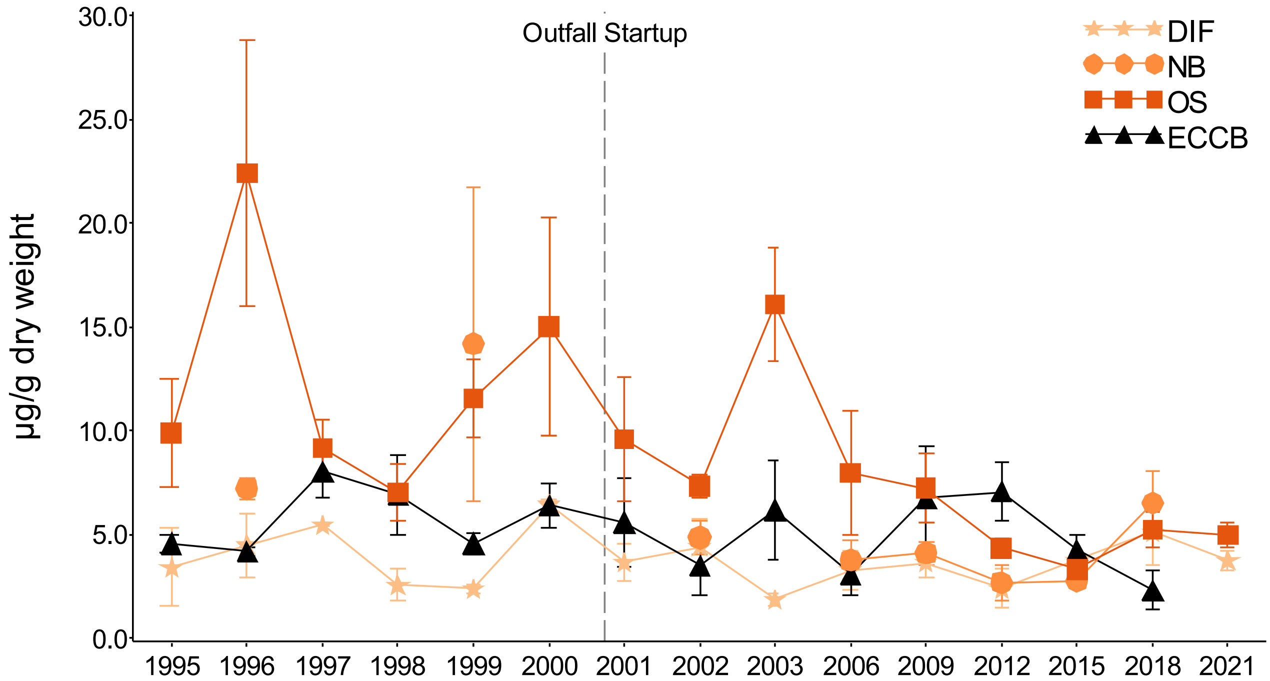



**Figure 3-7. Silver in flounder liver (1995-2021).**

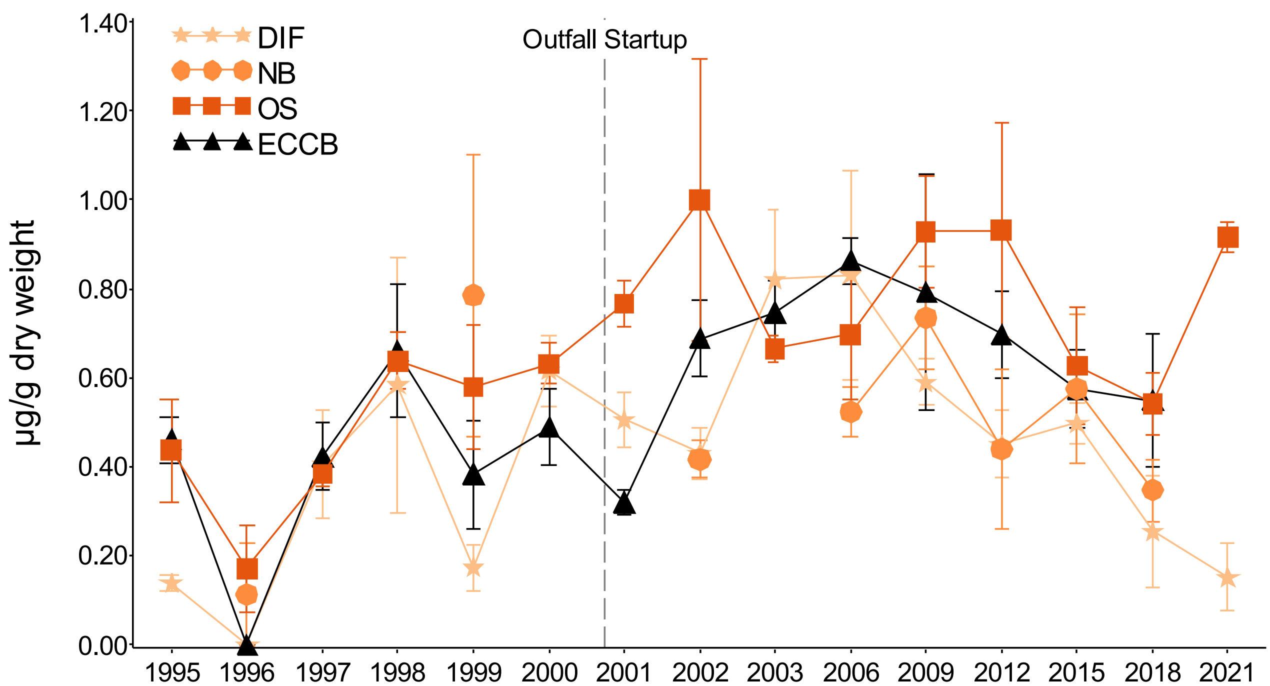



**Figure 3-8. Nickel in flounder liver (1995-2021).**

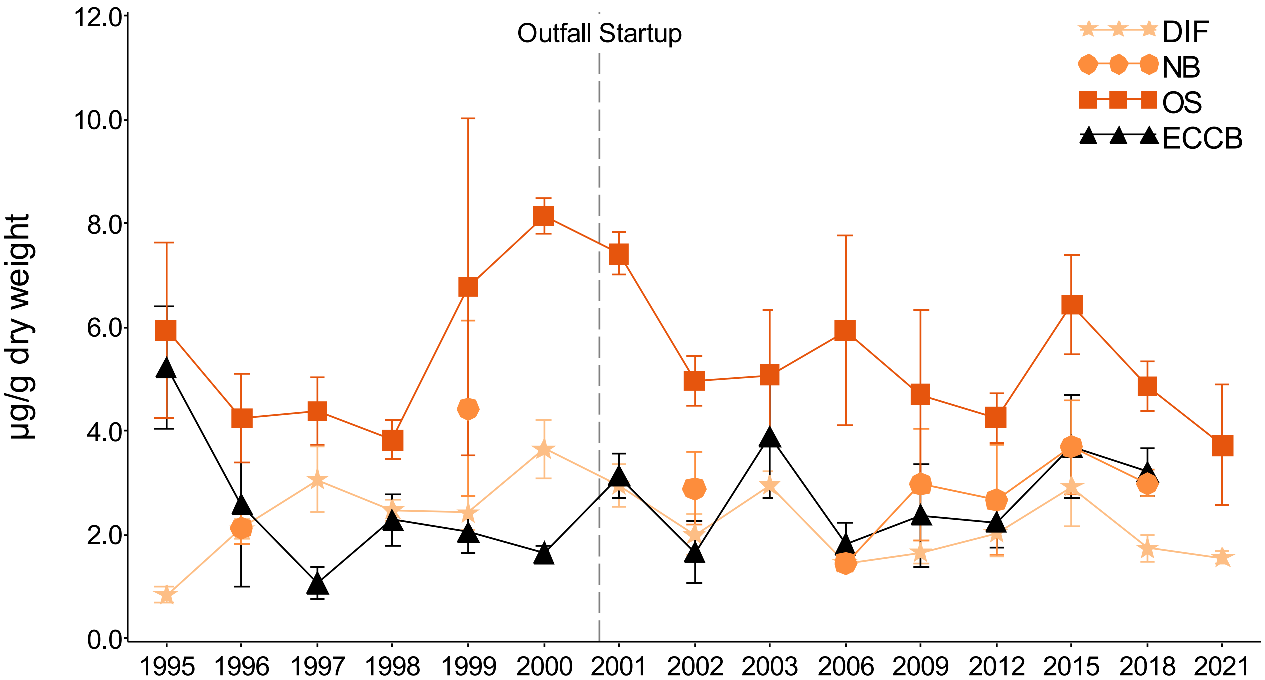



**Figure 3-9. Lead in flounder liver (1995-2021).**

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, recent data suggests a downward trend at OS, with no apparent trends at the other stations. In 2021, as with many previous years, the highest concentrations of silver were observed at OS (Figure 3-7).

## *3.2 Lobster*

### 3.2.1 Lobster Size, Sex, and External Conditions

Weight, carapace length, and sex were determined for 21 lobsters from each of the three sites in both 2018 and 2021 (Table 3-4). The average carapace lengths for both survey years were similar at all locations as has been typically found throughout the study. Weights were collected from all stations in 2018 and 2021 with the average weight in 2021 above the historical averages at both DIF (Deer Island) and Cape Cod Bay (ECCB). Similar to 2015, lobsters were predominantly male at DIF and ECCB; females predominated at the Outfall Site (OS). This was typical of historical ECCB and OS results but differed from past data from DIF where females typically predominated. In both survey years there were four lobsters (two lobsters at ECCB and two at OS) for a total of eight lobsters collected across both survey years that had indications of shell erosion. No other deleterious external conditions were reported at any location.

**Table 3-4. Mean length and weight, and % females of lobsters collected in 2018 and 2021.**

**a. 2018**

| Parameter | DIF | | | OS | | | ECCB | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **S.D.** | **N** | **Mean** | **S.D.** | **N** | **Mean** | **S.D.** | **N** |
| Carapace Length (mm) | 87 | 5 | 21 | 84 | 2 | 21 | 97 | 8 | 21 |
| Weight (g) | 488 | 103 | 5 | 677 | 211 | 21 | 483 | 61 | 21 |
| Percent female (%) | 29 | | 21 | 67 | | 21 | 38 | | 21 |

**b. 2021**

| Parameter | DIF | | | OS | | | ECCB | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **S.D.** | **N** | **Mean** | **S.D.** | **N** | **Mean** | **S.D.** | **N** |
| Carapace Length (mm) | 88 | 5 | 21 | 84 | 4 | 21 | 94 | 8 | 21 |
| Weight (g) | 553 | 95 | 21 | 494 | 95 | 21 | 663 | 189 | 21 |
| Percent female (%) | 24 | | 21 | 57 | | 21 | 19 | | 21 |

### 3.2.2 Lobster Tissue Contaminant Levels

Contaminant levels were determined for both edible meat (tail and claw meat) and hepatopancreas for lobster collected in the 2018 and 2021 surveys. In this section the body burdens of selected contaminants measured in 2018 and 2021 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. Temporal changes in body burdens in lobsters from Cape Cod Bay in 2015 to 2021 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 DIF and lowest in those from ECCB. This pattern continued in 2018 and 2021, although differences among stations were low for all contaminants. In 2018 and 2021, lobsters from DIF had the highest concentrations of total chlordane, while concentrations in those collected at ECCB and OS were marginally lower (Figure 3-10). As with total chlordane, concentrations of total DDT and total PCB were only slightly higher at DIF than at other stations in 2018 and 2021 (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.

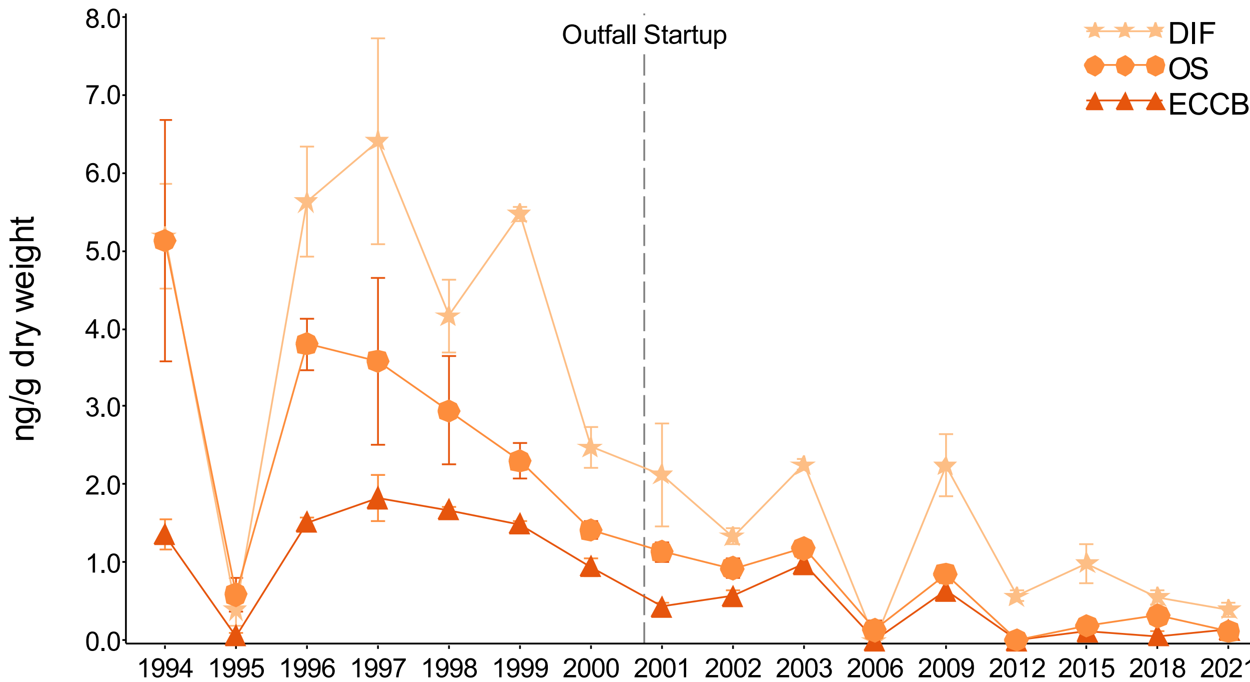



**Figure 3-10. Total Chlordane in lobster meat (1994-2021).**

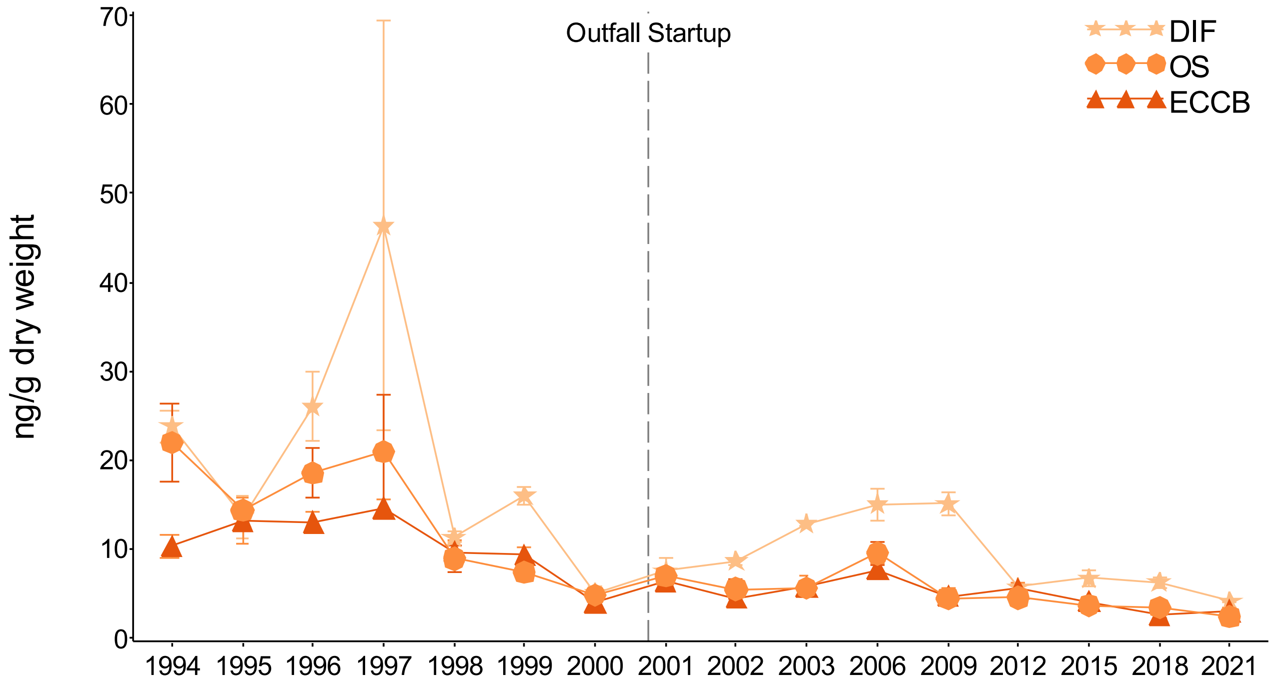



**Figure 3-11. Total DDT in lobster meat (1994-2021).**

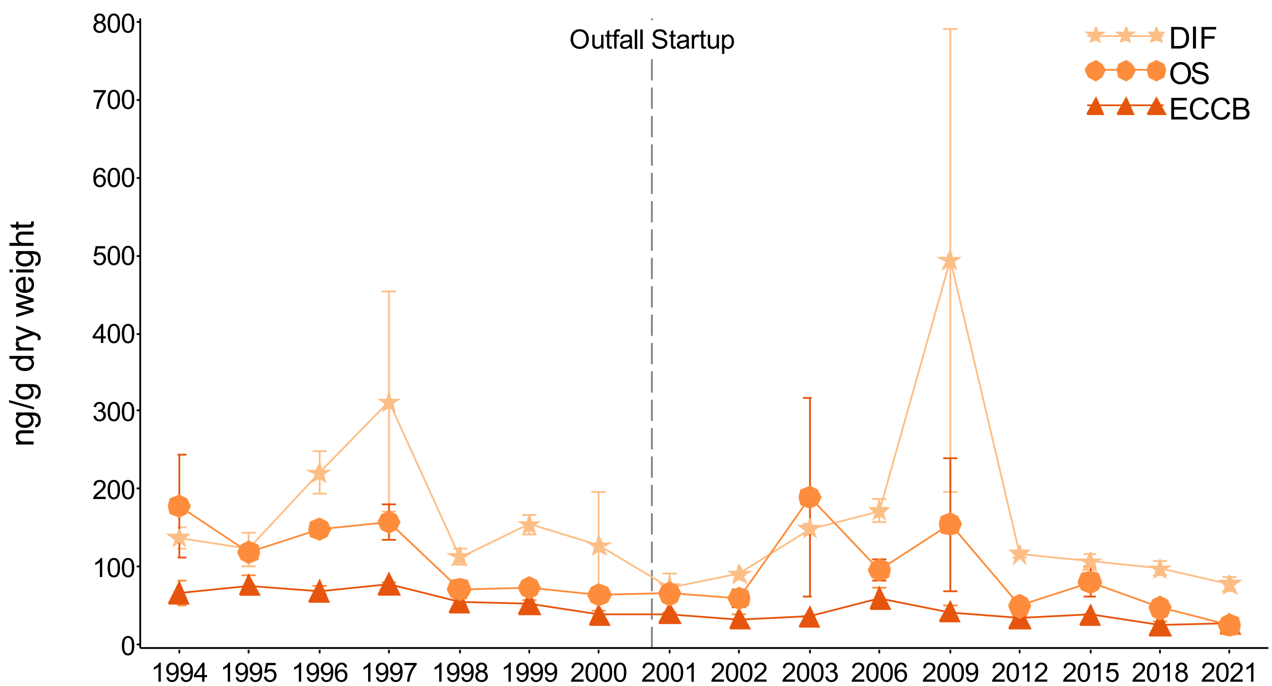



**Figure 3-12. Total PCBs in lobster meat (1994-2021).**

Mercury concentrations in lobster meat in 2018 and 2021 were highest at OS and lowest at ECCB (Figure 3-13). Although concentrations increased at all three stations in 2018, they decreased again in 2021 to values similar to those seen in 2015. Results at all three stations in were within the range of historical variation.

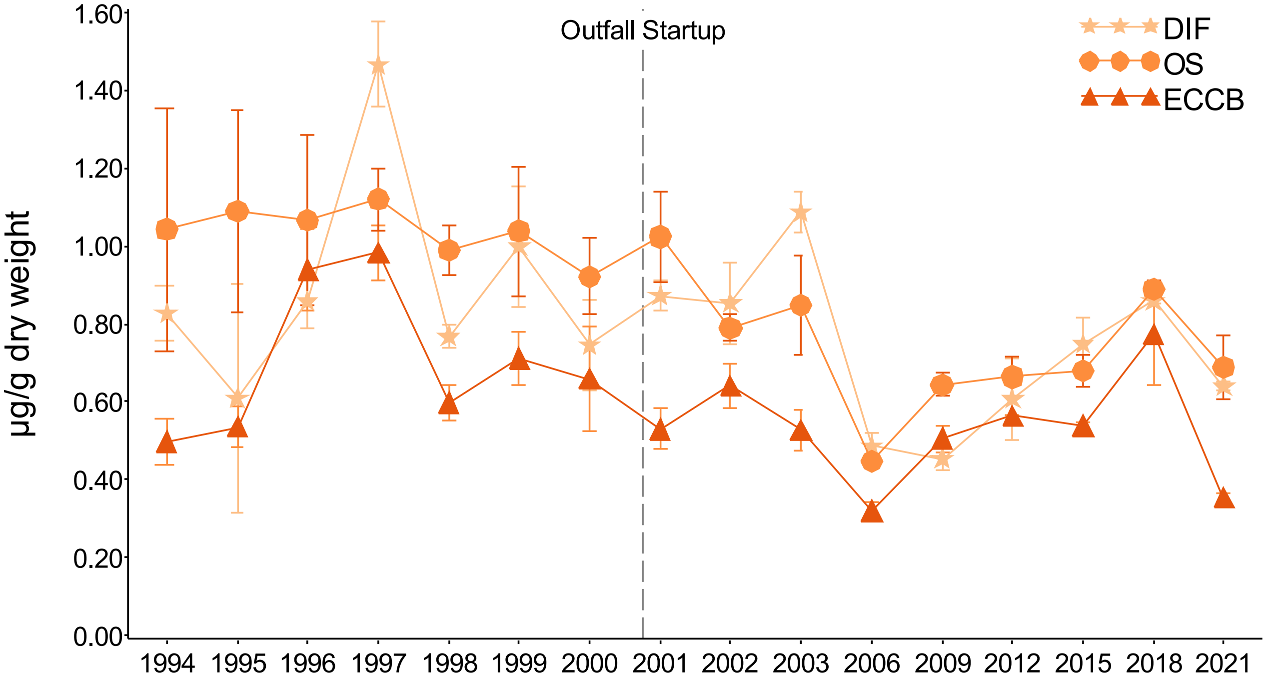



**Figure 3-13. Mercury in lobster meat (1994-2021).**

**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 2018 and 2021 (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).

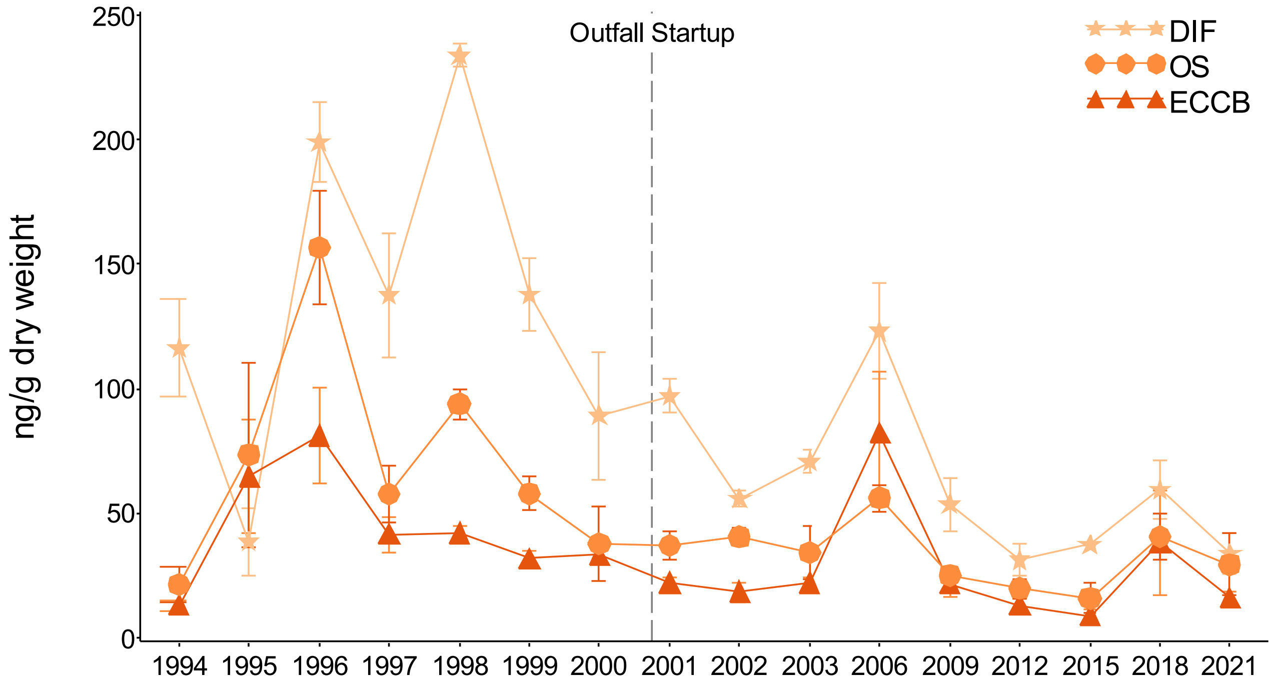



**Figure 3-14. Total chlordane in lobster hepatopancreas (1994-2021).**

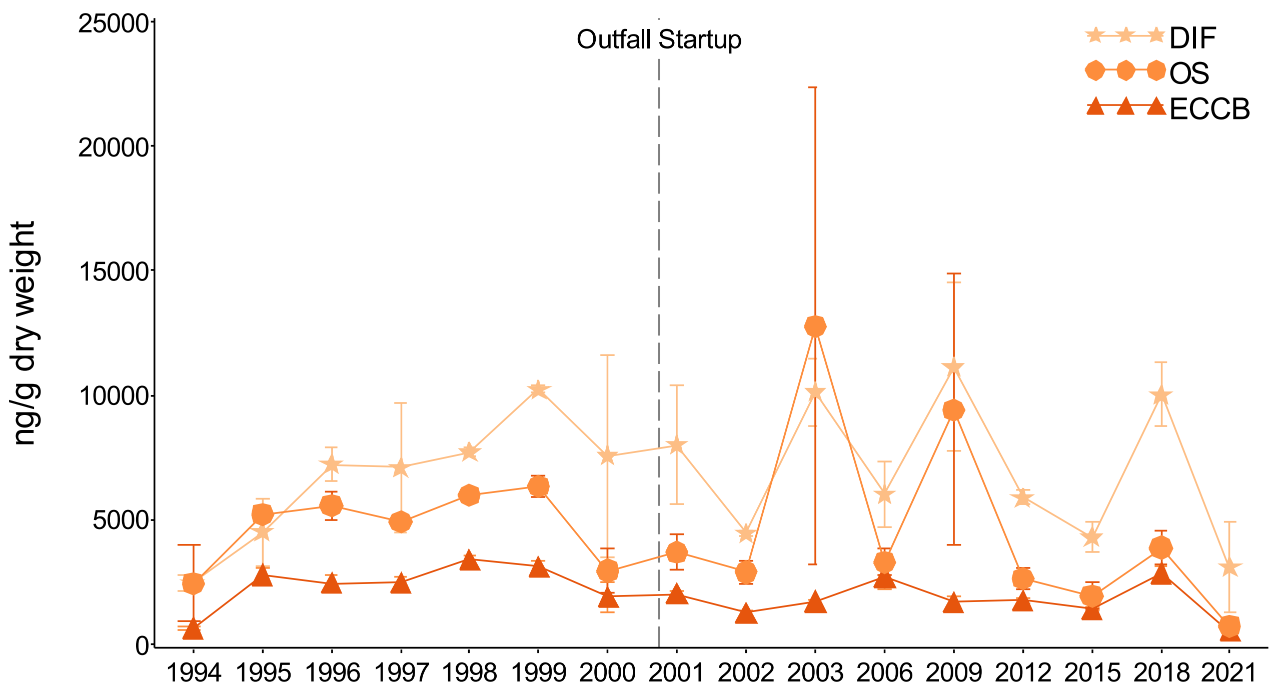



**Figure 3-15. Total PCBs in lobster hepatopancreas (1994-2021).**

Cadmium concentrations in lobster hepatopancreas in 2018 and 2021 were higher at OS and ECCB than at DIF (Figure 3-16). Copper concentrations were also relatively higher at OS, with lowest concentrations at ECCB (Figure 3-17). Nickel concentrations in 2018 decreased sharply from 2015, and then marginally increased in 2021 to values similarly high in at OS and ECCB, and lower at DIF (Figure 3-18). Lead concentrations in 2018 were highest at DIF and lowest at ECCB, then reduced to almost none at all stations in 2021 (Figure 3-19). Nickel concentrations have been relatively stable throughout the history of the program, with elevated levels recorded in 2009, 2012, and 2015 at OS and ECCB. Nickel levels in 2018 and 2021 were similar to lower historical levels seen at all three (four in 2018) sites with no visible long-term trends. In both 2018 and 2021, nickel was highest at ECCB and lowest at DIF. 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).

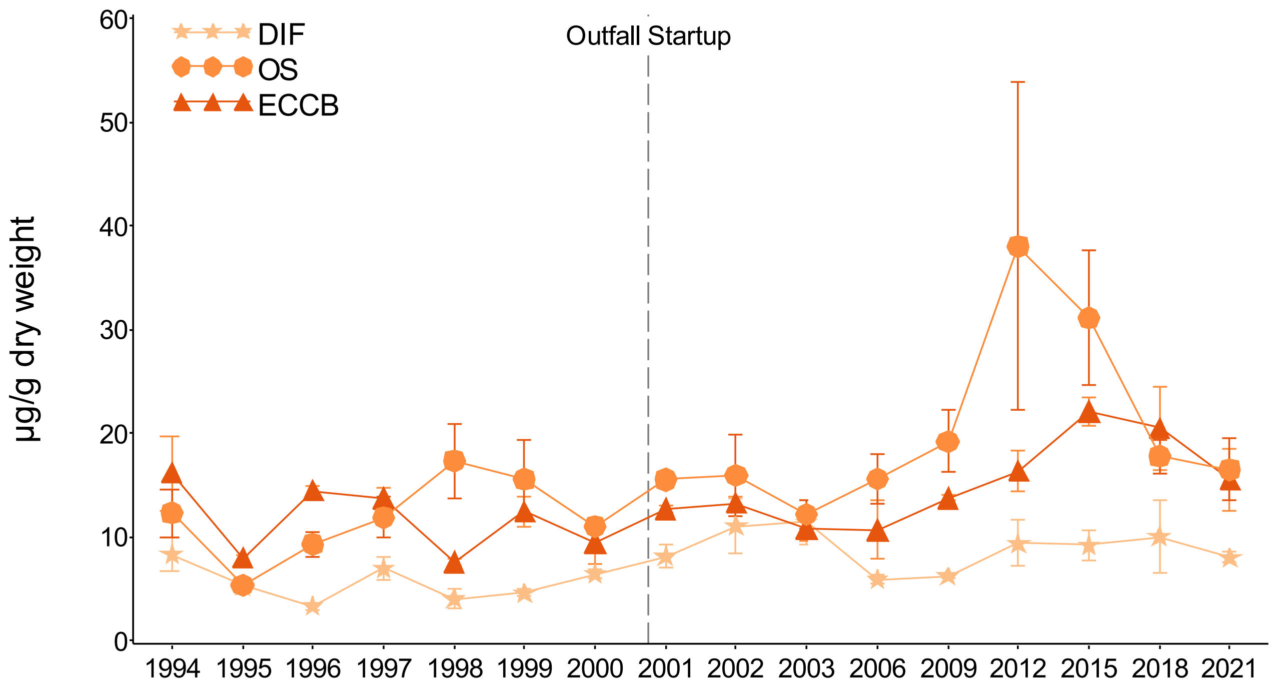



**Figure 3-16. Cadmium in lobster hepatopancreas (1994-2021).**

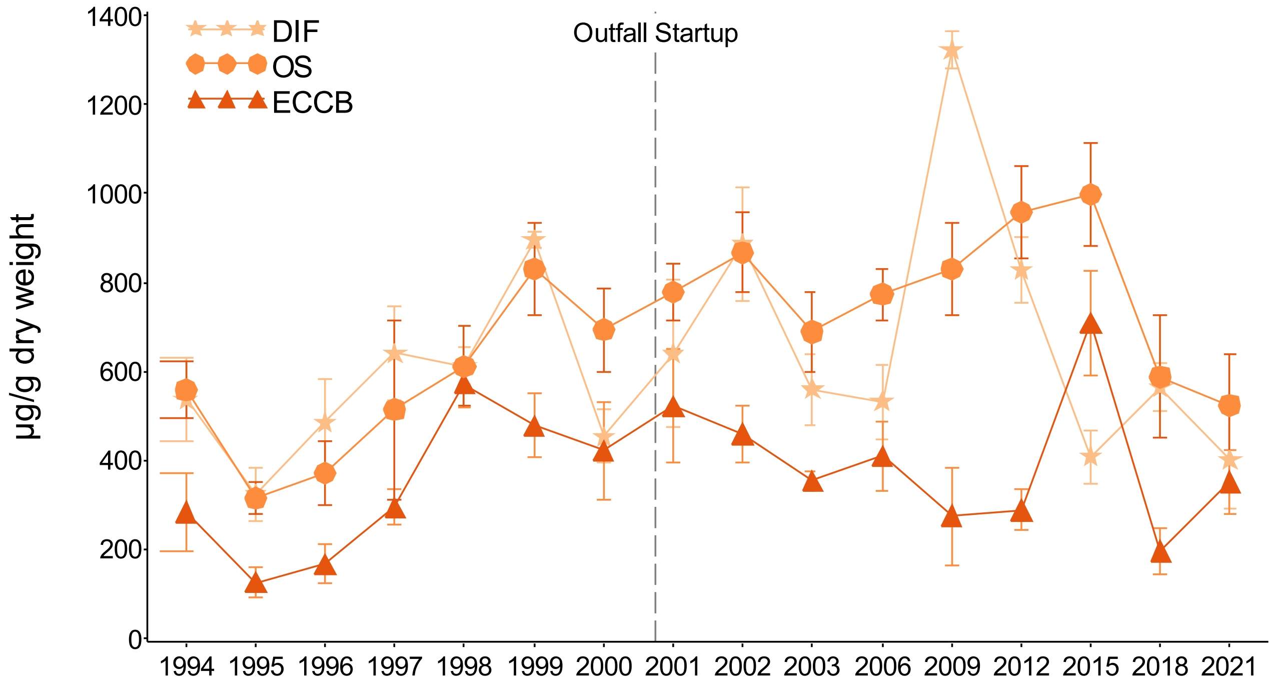



**Figure 3-17. Copper in lobster hepatopancreas (1994-2021).**

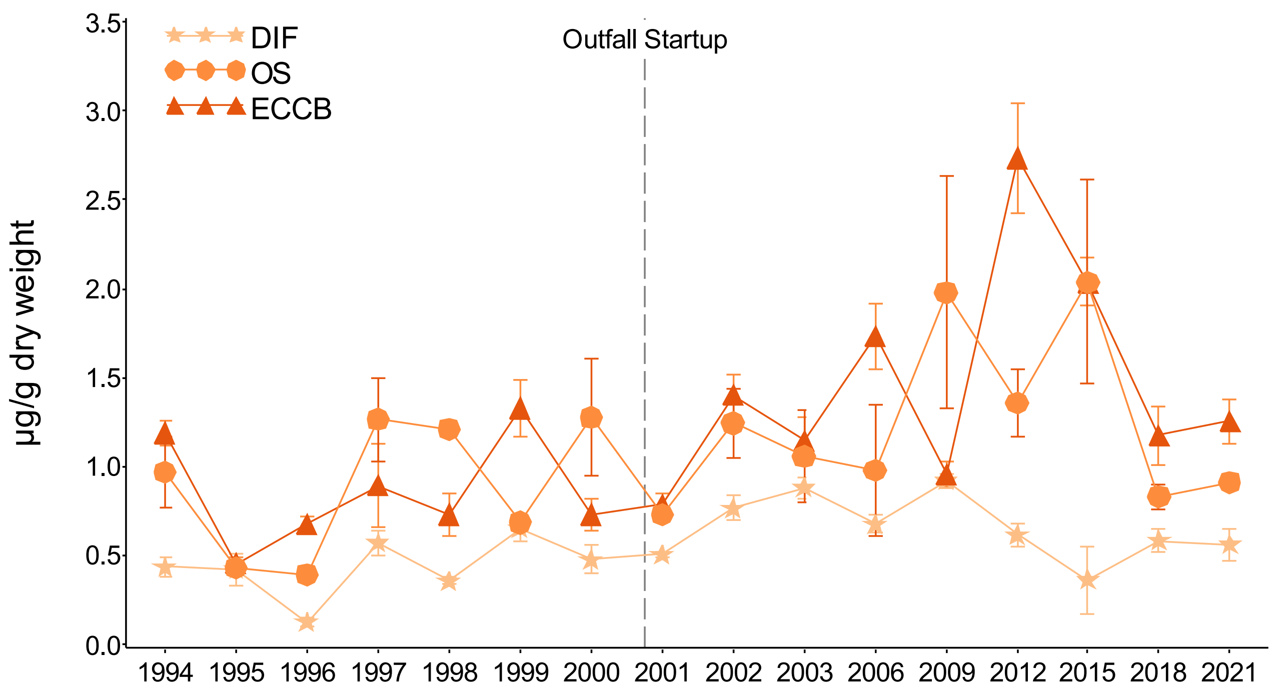



**Figure 3-18. Nickel in lobster hepatopancreas (1994-2021).**

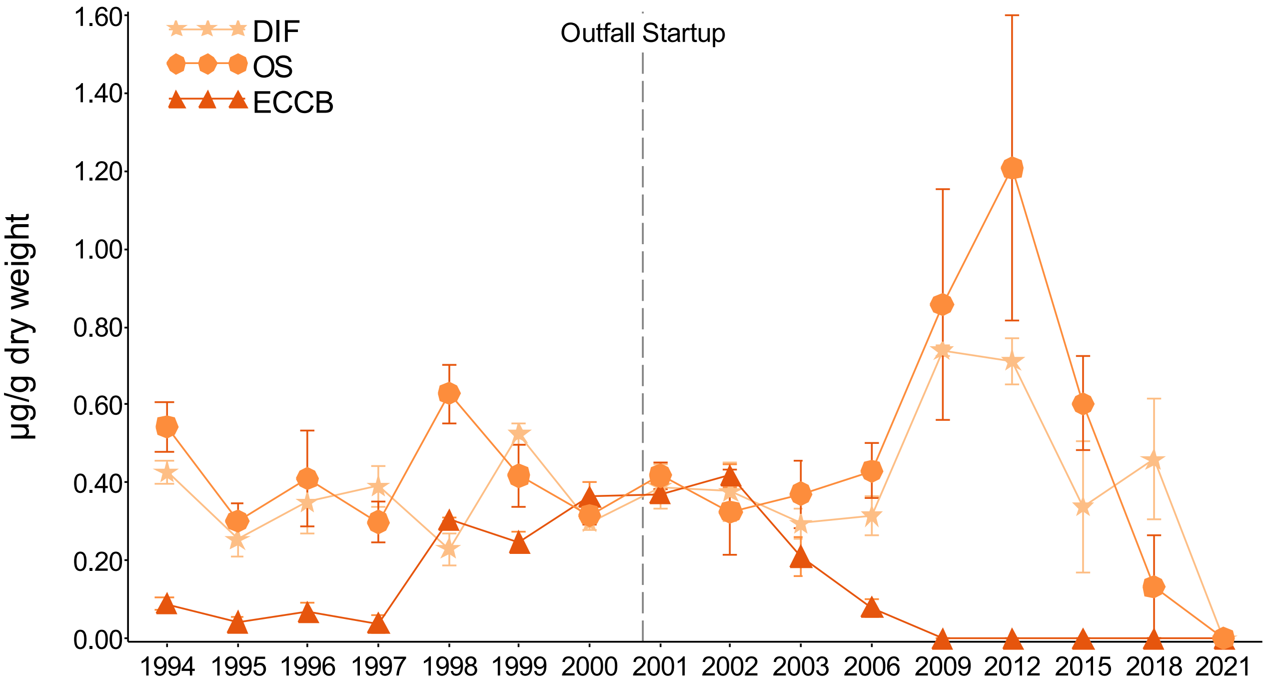



**Figure 3-19. Lead in lobster hepatopancreas (1994-2021).**

## *3.3 Blue Mussel*

### 3.3.1 Mussel Survival

The mussel survey in 2018 consisted of a 43-day retrieval (August 8) where mussels were collected and archived, and then a 62-day retrieval (August 27) at which time mussels were collected from all stations. For the 2021 survey, mussels were collected at 40 days (August 9) and archived, then again at 60 days (August 30) at all stations. 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. Table 3-5 summarizes the survival data from the 2018 and 2021 deployments.

**Table 3-5. 2018 and 2021 caged mussel survival data.**

**a. 2018**

| Collection | Site | Total Mussels | Dead Mussels | Survival Rate |
|---|---|---|---|---|
| 40-day | IH | 115 | 43 | 63% |
| | DIL | 120 | 21 | 82% |
| | OS-M2 | 120 | 10 | 92% |
| | OS-M3 | 120 | 8 | 93% |
| | LNB | 120 | 10 | 92% |
| 60-day | IH | 187 | 57 | 70% |
| | DIL | 120 | 30 | 75% |
| | OS-M2 | 120 | 8 | 93% |
| | OS-M3 | 120 | 10 | 92% |
| | LNB | 120 | 5 | 96% |

**b. 2021**

| Collection | Site | Total Mussels | Dead Mussels | Survival Rate |
|---|---|---|---|---|
| 40-day | IH | 120 | 4 | 97% |
| | DIL | 120 | 0 | 100% |
| | OS-M2 | 120 | 1 | 99% |
| | OS-M3 | 120 | 0 | 100% |
| | LNB | 120 | 0 | 100% |
| 60-day | IH | 120 | 6 | 95% |
| | DIL | 120 | 0 | 100% |
| | OS-M2 | 120 | 0 | 100% |
| | OS-M3 | 120 | 0 | 100% |
| | LNB | 120 | 0 | 100% |

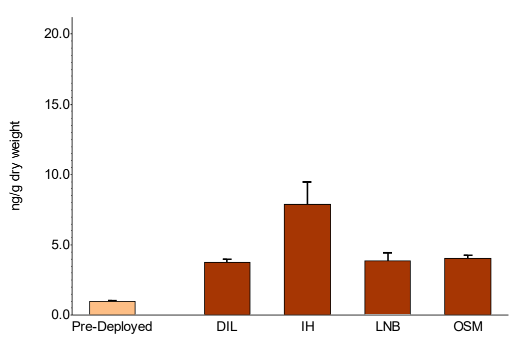
### 3.3.2 Mussel Tissue Contaminant Levels

**2018 and 2021 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 2018 and 2021 results were largely consistent with past years. Contaminant concentrations were generally highest at Boston Inner Harbor (IH) and lower at other stations, especially Outfall Site (OSM) and "B" Buoy (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 (particularly for 2021), followed by Deer Island (DIL) (Figure 3-21). Bioaccumulation of total DDTs in 2018 was similar to PCBs, with highest concentrations at IH, followed by DIL, and then LNB and

OSM. Total DDT concentrations in mussels deployed during 2021 were also highest at IH, followed by DIL, LNB, and OSM (Figure 3-22). Concentrations of Total DDT in 2021 were marginally higher in the 'Pre-Deployed' mussels than in those deployed at LNB and OSM. These findings indicated some level of depuration in mussels deployed at those locations. As in 2015, Low Molecular Weight (LMW) PAHs were also highest at IH during 2018 and 2021, and relatively similar at other locations (Figure 3-23). Similar to the DDT concentrations, LMW PAHs were higher in 'Pre-Deployed' mussels than those retrieved from DIL, LNB and OSM in 2021 (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 in 2018 were highest in mussels deployed at IH followed by DIL, but were similar at the other locations, and only slightly above levels found in the 'Pre-Deployed' mussels (Figure 3-25a). Mercury concentrations during 2021 were highest in the 'Pre-Deployed' mussels, which were comparable to those deployed at OSM (Figure 3-25b). Some level of depuration was apparent at the three other deployment locations, with the lowest mercury concentrations in 2021 at DIL. Lead bioaccumulation followed a similar pattern to mercury with the highest concentrations in mussels deployed at IH in 2018, but the highest concentration being in the pre-deployed mussels in 2021 with all the stations at similar concentration levels (Figure 3-26). In 2021, the 'Pre-Deployed' mussels had higher concentrations of several parameters (e.g., mercury and lead) than concentrations reported from some MWRA stations following deployment. This finding indicates higher contaminant concentrations in the source mussels than had been reported during previous MWRA bioaccumulation studies. It also indicates some level of depuration during the 60-day deployment in 2021.

Due to a decline in intertidal mussel populations, no suitable locations were identified to collect "clean" wild mussels for the 2021 bioaccumulation study. Therefore, the best available option was to purchase appropriately sized mussels from an aquaculture facility. The Salem State University's Northeastern Massachusetts Aquaculture Center (NEMAC) was identified as the preferred source for mussels in 2021. The mussels were harvested by NEMAC from their offshore mussel farm. Unfortunately, the direct transfer of mussels from NEMAC's offshore mussel farm to Normandeau staff could not be coordinated for the late June deployment at MWRA stations. Mussels were collected from the offshore mussel farm by NEMAC on May 17, 2021, and then held at the Cat Cove facility's holding tanks, or on their grow lines at Smith Pool (in Salem, MA) until being picked up by Normandeau on June 29, 2021.



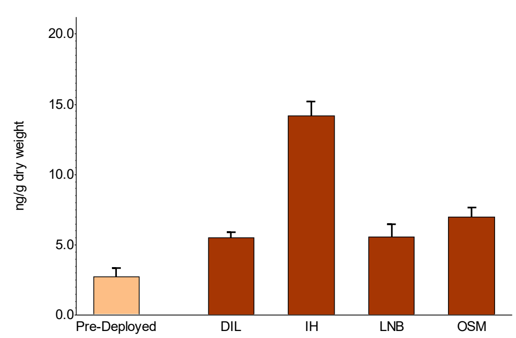




**Figure 3-20. Total chlordane bioaccumulation in mussels for 2018 (left) and 2021 (right).**

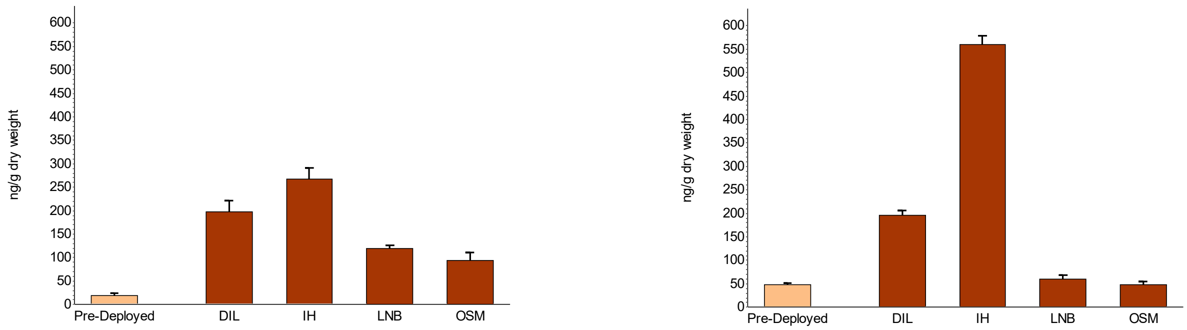



**Figure 3-21. Total PCB bioaccumulation in mussels for 2018 (left) and 2021 (right).**

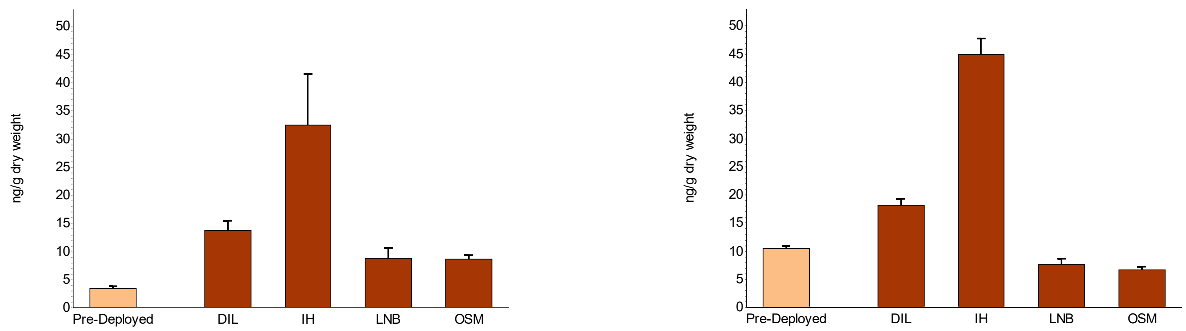



**Figure 3-22. Total DDT bioaccumulation in mussels for 2018 (left) and 2021 (right).**

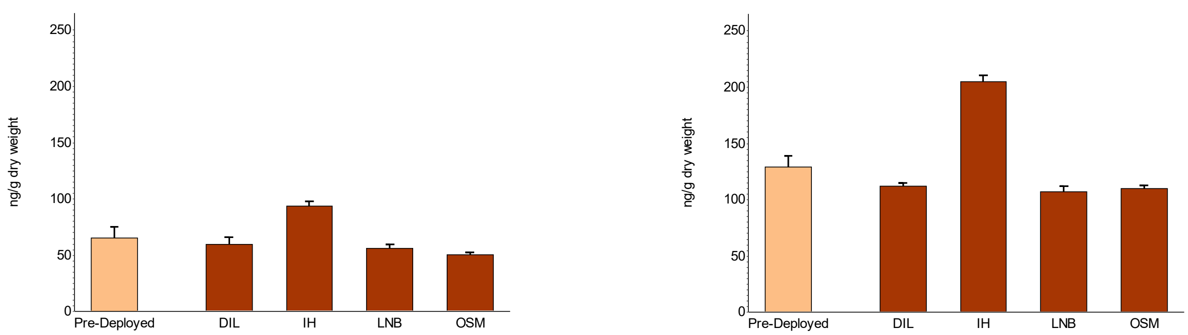



**Figure 3-23. Total NOAA LMW PAH bioaccumulation in mussels for 2018 (left) and 2021 (right).**

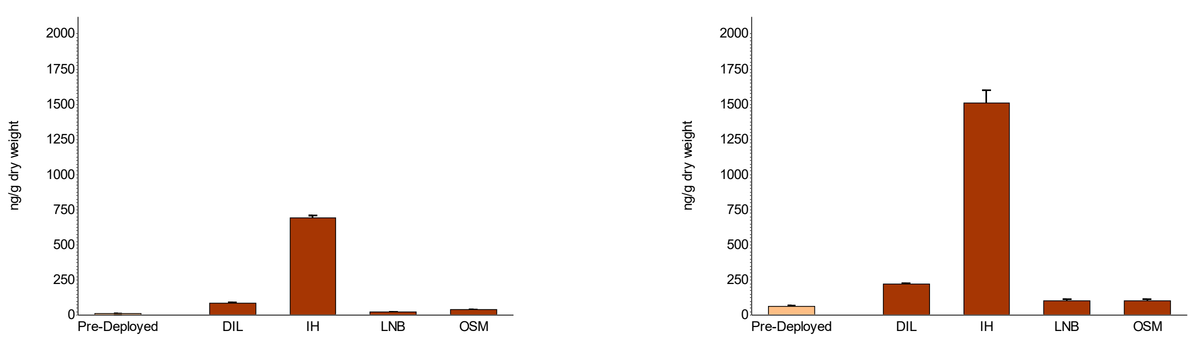



**Figure 3-24. Total NOAA HMW PAH bioaccumulation in mussels for 2018 (left) and 2021 (right).**

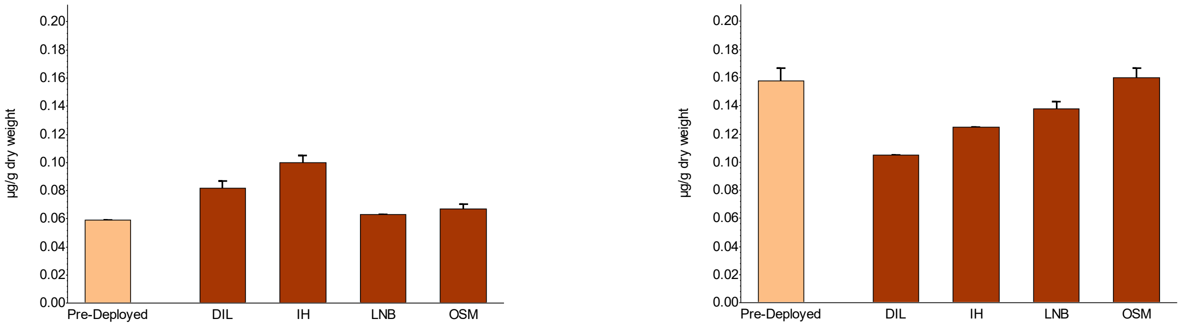



**Figure 3-25. Mercury bioaccumulation in mussels for 2018 and 2021.**

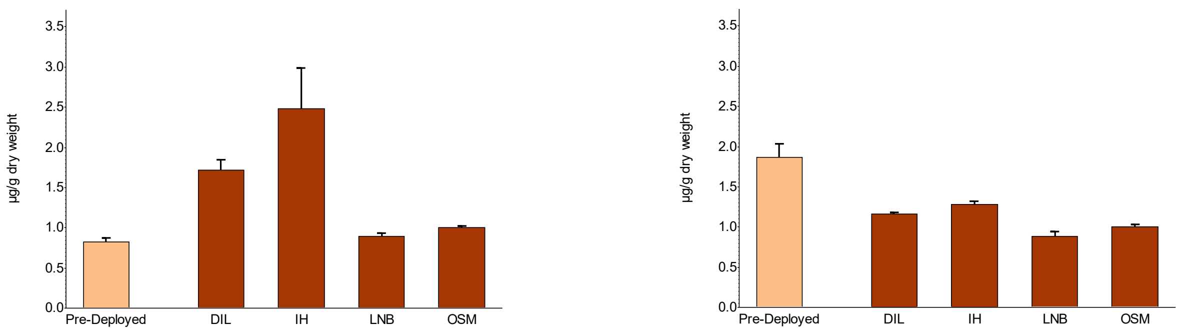



**Figure 3-26. Lead bioaccumulation in mussels for 2018 (left) and 2021 (right).**

The 2018 and 2021 mussel bioaccumulation results generally continue to 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).

**Inter-annual comparison –** This study is intended to assess whether there have been changes in water quality either at the current (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 through 2015 (Figure 3-27). Although total chlordane increased in both 2018 and 2021 at all station, concentrations remain generally lower than those observed prior to effluent diversion. Likewise, PCB and DDT concentrations have decreased at all three sites during the past decade but saw a slight increase in 2018 followed by a decrease across all stations (except DIL) in 2021 (Figures 3-28 and 3-29). LMW PAHs decreased slightly in 2018, followed by an equivalent increase in 2021 in mussels deployed at all stations (Figure 3-30). HMW PAHs concentrations followed the same pattern with a slight decrease in 2018 followed by a slight increase in 2012 at all stations (Figure 3-31). Bioaccumulation of lead at DIL has decreased over time, a trend that continued in 2018 and 2021; lead concentrations remained low at DIL, OSM and LNB in 2018 and 2021 (Figure 3-32).

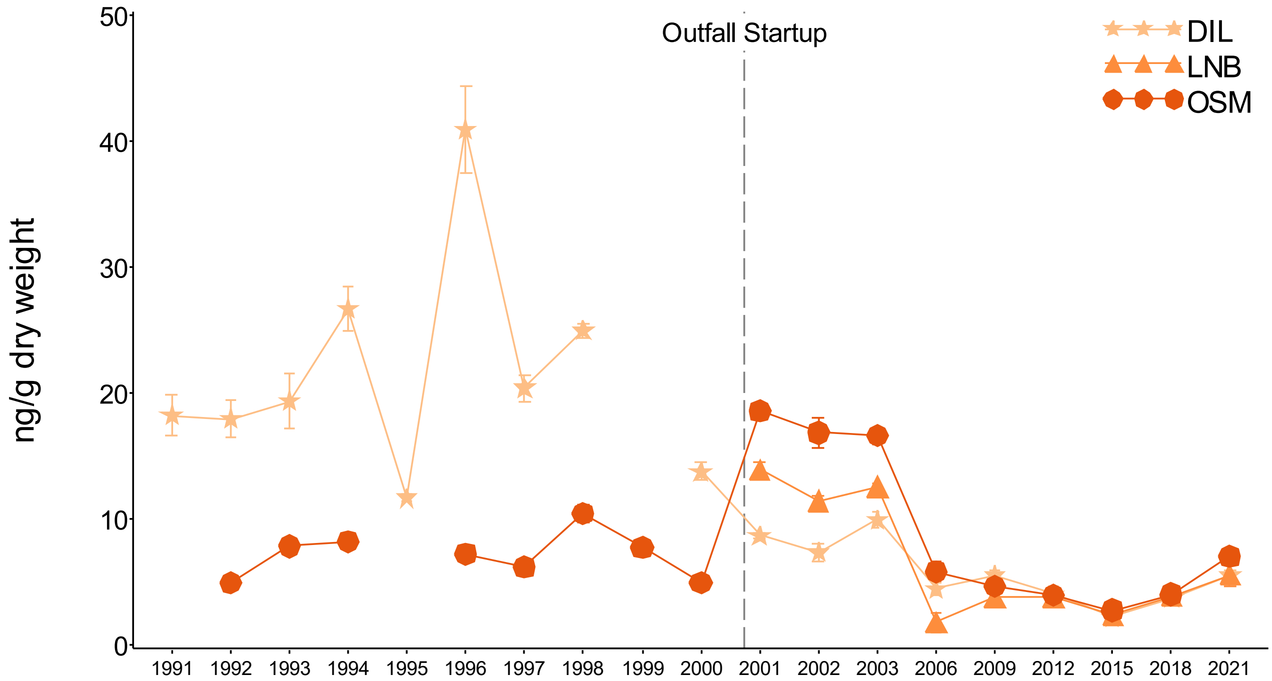



**Figure 3-27. Total chlordane trends in mussels (1991-2021).**

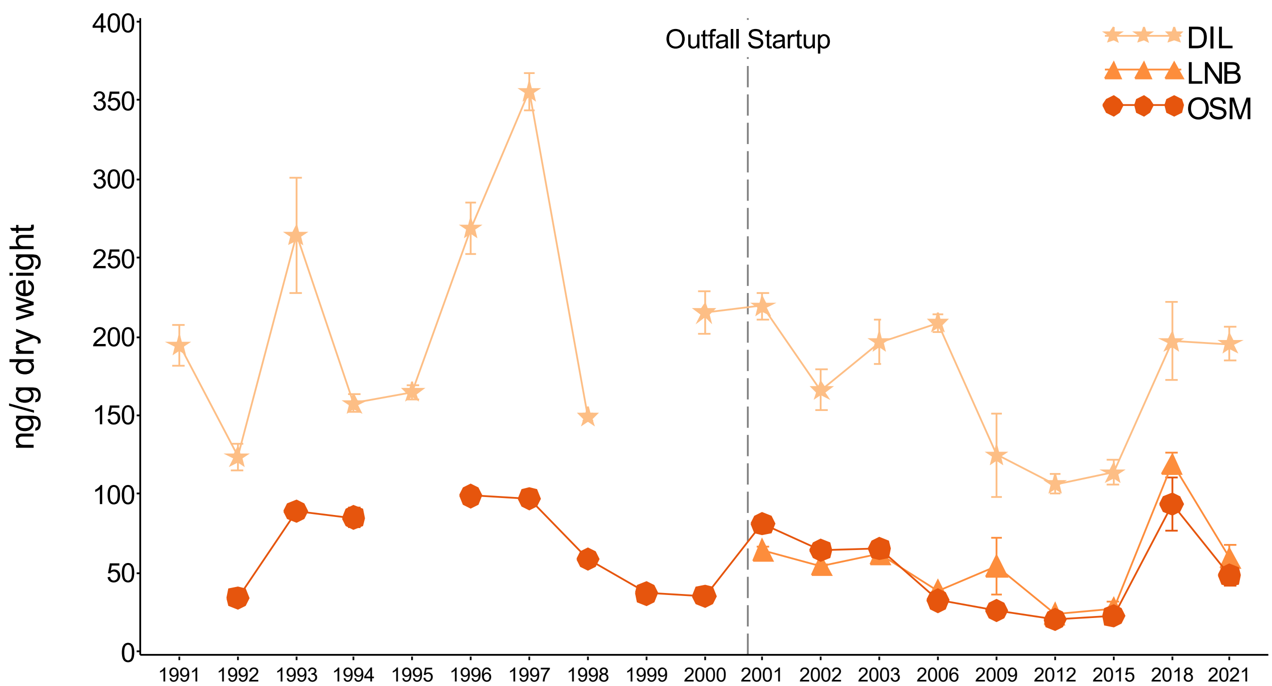



**Figure 3-28. Total PCB trends in mussels (1991-2021).**

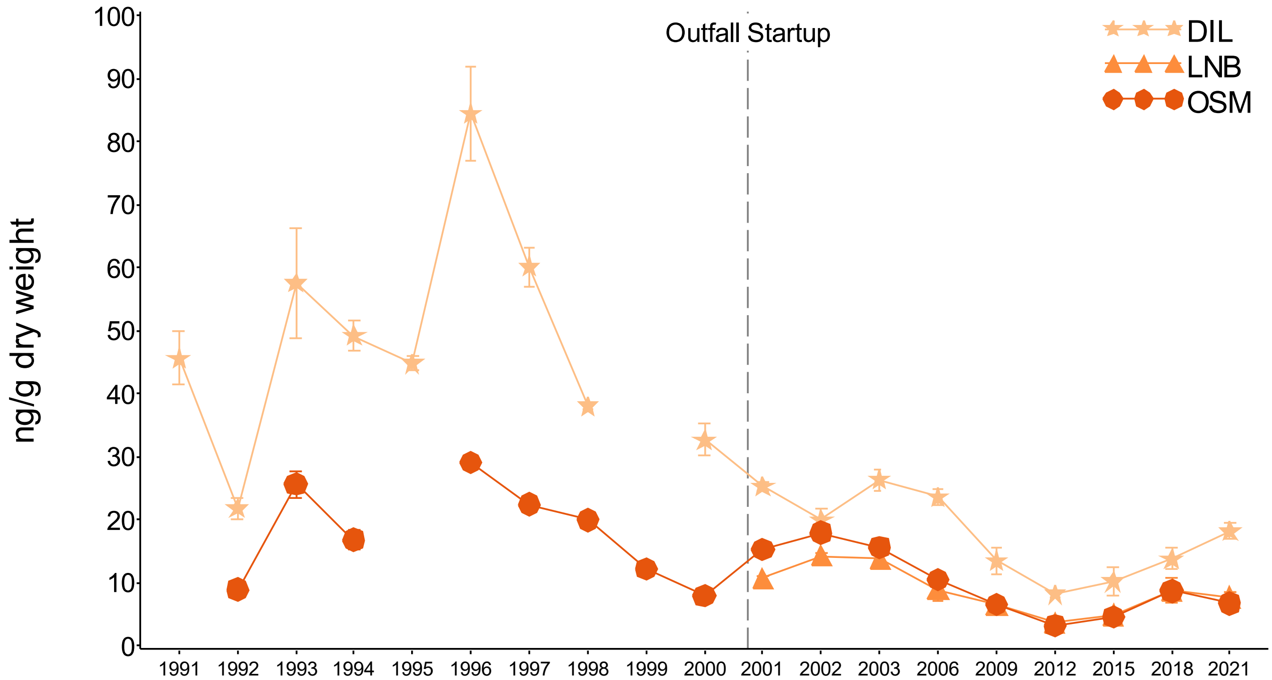



**Figure 3-29. Total DDT trends in mussels (1991-2021).**

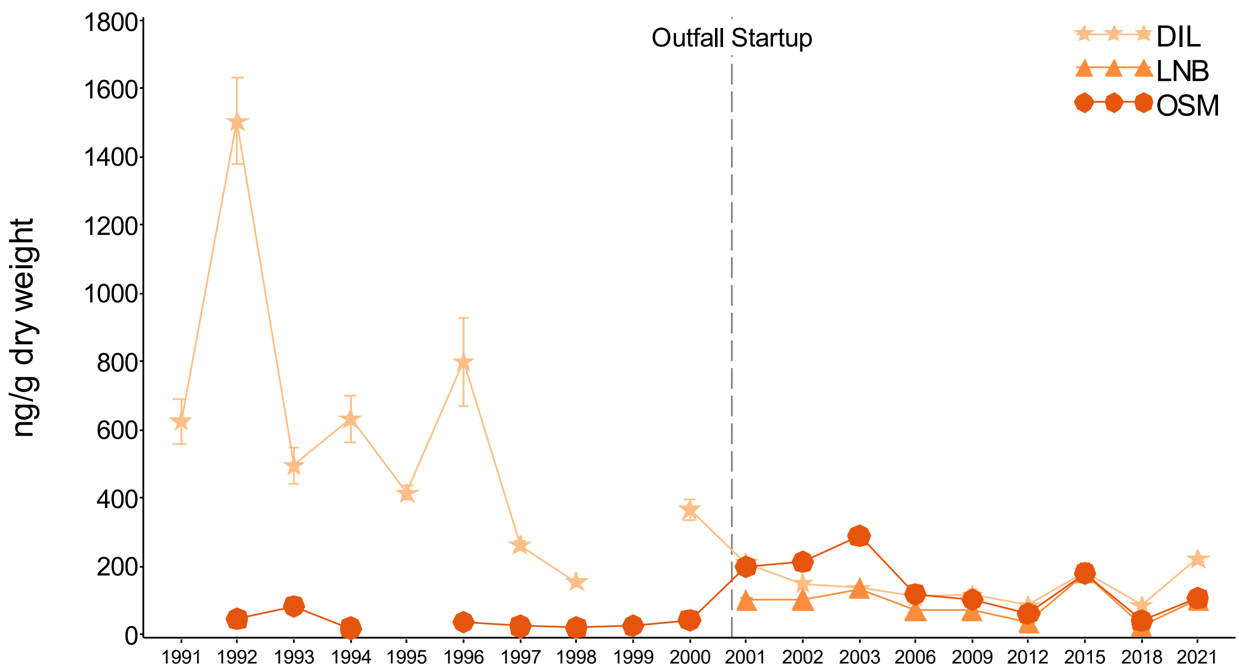



**Figure 3-30. Total NOAA LMW PAH trends in mussels (1991-2021).**

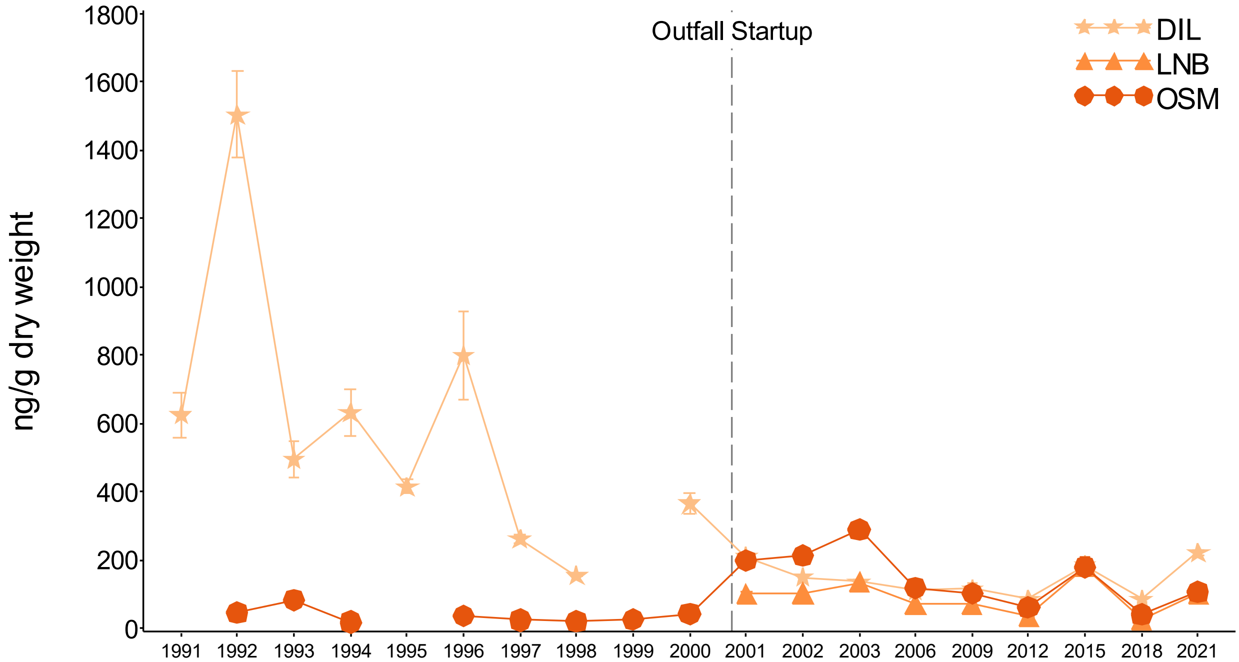



**Figure 3-31. Total NOAA HMW PAH trends in mussels (1991-2021).**

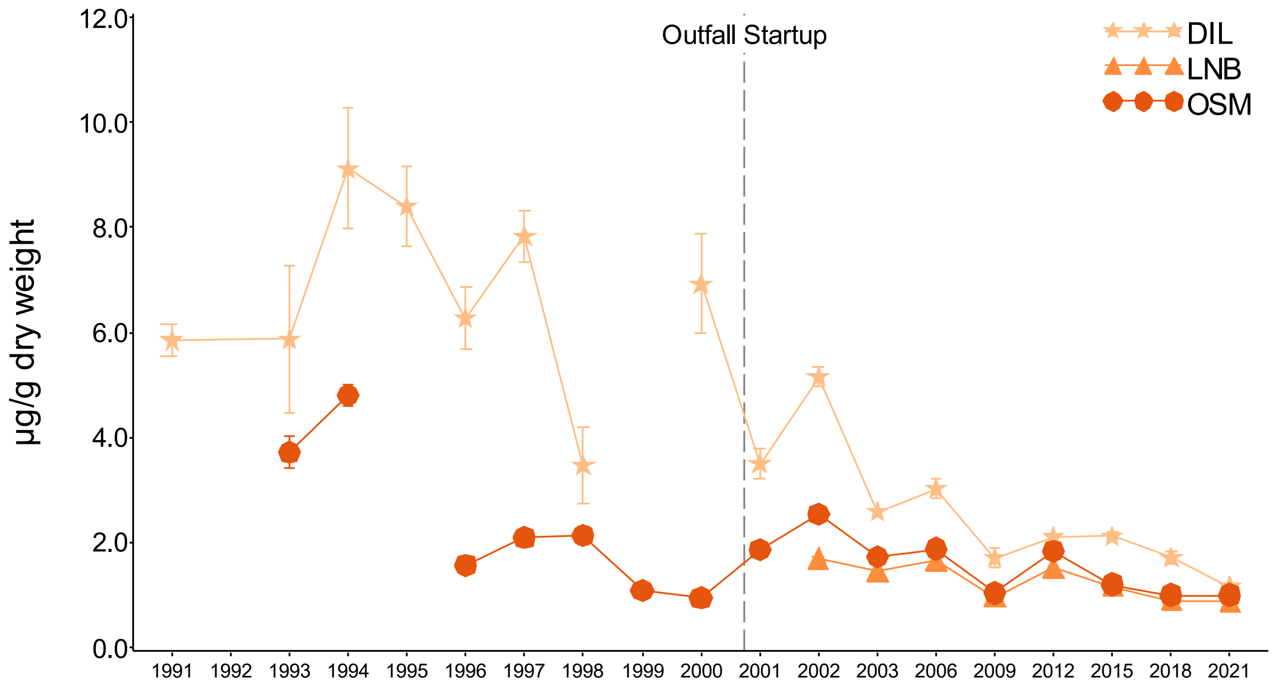



**Figure 3-32. Lead trends in mussels (1991-2021).**

### *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 2018 and 2021 all thresholds were met (Table 3-8).

**Table 3-6. Comparison of 2018 and 2021 flounder fillet results to MWRA Caution Levels.**

| Caution Threshold | | | 2018 Results | 2021 Results |
|---|---|---|---|---|
| Chlordane | 484.0 | ng/g lipid | 27.0 | 15.7 |
| DDT | 1552.0 | ng/g lipid | 107.0 | 89.7 |
| Dieldrin | 127.0 | ng/g lipid | 0.0 | 0.0 |
| PCB | 1000.0 | ng/g wet | 35.7 | 8.9 |
| Mercury | 500 | ng/g wet | 57.0 | 83.0 |
| Liver Disease | 44.9 | % | 6.0 | 4.0 |

**Table 3-7. Comparison of 2018 and 2021 lobster meat results to MWRA Caution Levels.**

| Caution Threshold | | | 2018 Results | 2021 Results |
|---|---|---|---|---|
| Chlordane | 150.0 | ng/g lipid | 2.6 | 1.8 |
| DDT | 683.0 | ng/g lipid | 28.5 | 36.8 |
| Dieldrin | 322.0 | ng/g lipid | 0.0 | 11.9 |
| PCB | 1000.0 | ng/g wet | 9.0 | 4.6 |
| Mercury | 500.0 | ng/g wet | 170.0 | 128.0 |

**Table 3-8. Comparison of 2018 and 2021 mussel results to MWRA Caution Levels.**

| Caution Threshold | | | 2018 Results | 2021 Results |
|---|---|---|---|---|
| Chlordane | 205.0 | ng/g lipid | 33.0 | 31.7 |
| DDT | 483.0 | ng/g lipid | 70.9 | 30.7 |
| Dieldrin | 50.0 | ng/g lipid | 0.0 | 0.0 |
| PAH | 2160.0 | ng/g lipid | 726.0 | 992.0 |
| PCB | 1000.0 | ng/g wet | 13.0 | 6.8 |
| Mercury | 500.0 | ng/g wet | 9.3 | 22.0 |
| Lead | 2000.0 | ng/g wet | 140.0 | 139.0 |

# 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 2018 and 2021 to recent years. 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 continued to be higher in Boston Harbor (IH) than offshore (OSM and LNB). Organics have generally declined over time with the exception of PAHs, which were highest at most stations in 2021. Similar to most organics, lead concentrations in deployed mussels have declined over time.

Despite the fact that there is evidence of anthropogenic contamination in the three indicator species, there were no exceedances of MWRA threshold levels in 2018 or 2021, 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 |
| CHLOR | | Total chlordanes | ng/gdw | 2018 | 2.533 | 0.996 | 1.4 | 1.724 | 0.93 | 0.2 | 0.93 | 0.7 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2021 | 1.127 | N.A. | N.A. | 0.52 | 0.24 | N.A. | N.A. | 0.09 | 3 | N.A. | N.A. | 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 |
| DDT | 4,4'-DDE | p,p'-DDE | ng/gdw | 2018 | 14.305 | 4.915 | 7.069 | 6.185 | 6.96 | 0.41 | 4.32 | 1.16 | 3 | 3 | 3 | 3 |
| DDT | 4,4'-DDE | p,p'-DDE | ng/gdw | 2021 | 7.448 | N.A. | N.A. | 2.65 | 0.48 | N.A. | N.A. | 0.27 | 3 | N.A. | N.A. | 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 |
| 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 |
| METAL | Hg | Mercury | ug/gdw | 2018 | 0.302 | 0.170 | 0.392 | 0.326 | 0.05 | 0.03 | 0.20 | 0.05 | 3 | 3 | 3 | 3 |
| METAL | Hg | Mercury | ug/gdw | 2021 | 0.279 | N.A. | N.A. | 0.491 | 0.06 | N.A. | N.A. | 0.22 | 3 | N.A. | N.A. | 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 |

(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 |
| 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 |
| PCB | | Total PCBs | ng/gdw | 2018 | 408.967 | 75.057 | 186.167 | 201.933 | 176.45 | 20.36 | 102.94 | 42.80 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2021 | 141.533 | N.A. | N.A. | 52.497 | 28.73 | N.A. | N.A. | 2.98 | 3 | N.A. | N.A. | 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 | 206.975 | 15.345 | 89.110 | 105.010 | 144.27 | 3.68 | 54.40 | 45.25 | 4 | 4 | 4 | 4 |
| CHLOR | | Total chlordanes | ng/gdw | 1993 | 122.700 | 26.330 | N.A. | 92.200 | 0.00 | 0.00 | N.A. | 0.00 | 1 | 1 | N.A. | 1 |
| CHLOR | | Total chlordanes | ng/gdw | 1994 | 207.933 | 19.390 | 58.943 | 113.007 | 39.07 | 4.90 | 23.22 | 59.83 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 1995 | 283.000 | 39.733 | N.A. | 96.000 | 74.28 | 28.99 | N.A. | 28.21 | 3 | 3 | N.A. | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 1996 | 169.867 | 20.233 | 69.333 | 86.333 | 63.86 | 5.89 | 14.57 | 19.04 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 1997 | 243.667 | 32.700 | N.A. | 78.667 | 94.80 | 8.03 | N.A. | 27.61 | 3 | 3 | N.A. | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 1998 | 176.133 | 11.866 | N.A. | 51.327 | 95.25 | 5.87 | N.A. | 11.81 | 3 | 3 | N.A. | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 1999 | 225.833 | 15.419 | 41.680 | 47.800 | 18.26 | 10.65 | 18.81 | 26.48 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2000 | 95.713 | 12.387 | N.A. | 30.350 | 44.34 | 2.29 | N.A. | 6.19 | 3 | 3 | N.A. | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2001 | 91.877 | 13.513 | N.A. | 41.353 | 10.61 | 2.14 | N.A. | 9.38 | 3 | 3 | N.A. | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2002 | 77.173 | 15.427 | 34.707 | 34.483 | 25.06 | 3.15 | 22.70 | 1.98 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2003 | 84.813 | 10.433 | N.A. | 29.677 | 4.45 | 4.37 | N.A. | 5.59 | 3 | 3 | N.A. | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2006 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | 0 | 0 | 0 | 0 |
| CHLOR | | Total chlordanes | ng/gdw | 2009 | 31.867 | 13.418 | 22.460 | 24.696 | 2.80 | 12.63 | 4.52 | 19.29 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2012 | 124.097 | 6.720 | 55.773 | 33.077 | 51.86 | 2.78 | 9.53 | 12.46 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2015 | 15.708 | 2.303 | 3.180 | 3.039 | 10.06 | 2.60 | 1.67 | 0.39 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2018 | 25.623 | 2.401 | 7.170 | 10.922 | 4.58 | 1.55 | 3.63 | 4.30 | 3 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2021 | 19.427 | N.A. | N.A. | 6.146 | 7.09 | N.A. | N.A. | 1.46 | 3 | N.A. | N.A. | 3 |
| METAL | Ni | Nickel | ug/gdw | 1992 | 0.840 | 0.362 | 0.464 | 0.799 | 0.78 | 0.14 | 0.03 | 0.59 | 4 | 4 | 4 | 4 |
| METAL | Ni | Nickel | ug/gdw | 1993 | 0.620 | 0.397 | N.A. | 0.648 | 0.00 | 0.00 | N.A. | 0.00 | 1 | 1 | N.A. | 1 |
| METAL | Ni | Nickel | ug/gdw | 1994 | 0.237 | 0.367 | 0.269 | 0.597 | 0.02 | 0.09 | 0.05 | 0.06 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 1995 | 0.138 | 0.461 | N.A. | 0.437 | 0.03 | 0.09 | N.A. | 0.20 | 3 | 3 | N.A. | 3 |
| METAL | Ni | Nickel | ug/gdw | 1996 | 0.000 | 0.000 | 0.113 | 0.171 | 0.00 | 0.00 | 0.20 | 0.17 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 1997 | 0.405 | 0.422 | N.A. | 0.384 | 0.21 | 0.13 | N.A. | 0.05 | 3 | 3 | N.A. | 3 |
| METAL | Ni | Nickel | ug/gdw | 1998 | 0.583 | 0.660 | N.A. | 0.637 | 0.50 | 0.26 | N.A. | 0.11 | 3 | 3 | N.A. | 3 |
| METAL | Ni | Nickel | ug/gdw | 1999 | 0.173 | 0.383 | 0.785 | 0.579 | 0.09 | 0.21 | 0.55 | 0.24 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 2000 | 0.615 | 0.489 | N.A. | 0.631 | 0.14 | 0.15 | N.A. | 0.08 | 3 | 3 | N.A. | 3 |
| METAL | Ni | Nickel | ug/gdw | 2001 | 0.505 | 0.319 | N.A. | 0.767 | 0.11 | 0.05 | N.A. | 0.09 | 3 | 3 | N.A. | 3 |
| METAL | Ni | Nickel | ug/gdw | 2002 | 0.430 | 0.688 | 0.417 | 1.000 | 0.10 | 0.15 | 0.07 | 0.55 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 2003 | 0.820 | 0.747 | N.A. | 0.665 | 0.27 | 0.12 | N.A. | 0.05 | 3 | 3 | N.A. | 3 |
| METAL | Ni | Nickel | ug/gdw | 2006 | 0.830 | 0.863 | 0.523 | 0.697 | 0.41 | 0.09 | 0.10 | 0.25 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 2009 | 0.589 | 0.792 | 0.735 | 0.928 | 0.09 | 0.46 | 0.20 | 0.22 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 2012 | 0.450 | 0.697 | 0.439 | 0.931 | 0.13 | 0.17 | 0.31 | 0.42 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 2015 | 0.498 | 0.574 | 0.575 | 0.626 | 0.08 | 0.15 | 0.29 | 0.23 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 2018 | 0.254 | 0.548 | 0.347 | 0.542 | 0.22 | 0.26 | 0.12 | 0.12 | 3 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 2021 | 0.151 | N.A. | N.A. | 0.915 | 0.13 | N.A. | N.A. | 0.06 | 3 | N.A. | N.A. | 3 |
| METAL | Ag | Silver | ug/gdw | 1992 | 2.656 | 4.465 | 2.908 | 4.768 | 3.49 | 2.15 | 1.72 | 2.13 | 4 | 4 | 4 | 4 |
| METAL | Ag | Silver | ug/gdw | 1993 | 5.460 | 1.410 | N.A. | 4.780 | 0.00 | 0.00 | N.A. | 0.00 | 1 | 1 | N.A. | 1 |
| METAL | Ag | Silver | ug/gdw | 1994 | 3.757 | 6.110 | 5.670 | 10.113 | 0.56 | 1.41 | 2.57 | 7.12 | 3 | 3 | 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 | Ag | Silver | ug/gdw | 1995 | 3.417 | 4.549 | N.A. | 9.891 | 3.26 | 0.68 | N.A. | 4.50 | 3 | 3 | N.A. | 3 |
| METAL | Ag | Silver | ug/gdw | 1996 | 4.472 | 4.160 | 7.212 | 22.403 | 2.65 | 0.38 | 0.90 | 11.11 | 3 | 3 | 3 | 3 |
| METAL | Ag | Silver | ug/gdw | 1997 | 5.470 | 8.015 | N.A. | 9.170 | 0.17 | 2.11 | N.A. | 2.36 | 3 | 3 | N.A. | 3 |
| METAL | Ag | Silver | ug/gdw | 1998 | 2.547 | 6.901 | N.A. | 7.023 | 1.34 | 3.34 | N.A. | 2.31 | 3 | 3 | N.A. | 3 |
| METAL | Ag | Silver | ug/gdw | 1999 | 2.370 | 4.533 | 14.177 | 11.567 | 0.35 | 0.93 | 13.07 | 3.26 | 3 | 3 | 3 | 3 |
| METAL | Ag | Silver | ug/gdw | 2000 | 6.437 | 6.393 | N.A. | 14.993 | 0.45 | 1.88 | N.A. | 9.11 | 3 | 3 | N.A. | 3 |
| METAL | Ag | Silver | ug/gdw | 2001 | 3.670 | 5.570 | N.A. | 9.597 | 1.57 | 3.69 | N.A. | 5.21 | 3 | 3 | N.A. | 3 |
| METAL | Ag | Silver | ug/gdw | 2002 | 4.393 | 3.487 | 4.843 | 7.343 | 2.30 | 2.44 | 1.38 | 0.99 | 3 | 3 | 3 | 3 |
| METAL | Ag | Silver | ug/gdw | 2003 | 1.857 | 6.163 | N.A. | 16.067 | 0.57 | 4.18 | N.A. | 4.72 | 3 | 3 | N.A. | 3 |
| METAL | Ag | Silver | ug/gdw | 2006 | 3.263 | 3.047 | 3.750 | 7.970 | 1.67 | 1.72 | 1.69 | 5.23 | 3 | 3 | 3 | 3 |
| METAL | Ag | Silver | ug/gdw | 2009 | 3.643 | 6.737 | 4.083 | 7.220 | 1.32 | 4.38 | 0.98 | 2.92 | 3 | 3 | 3 | 3 |
| METAL | Ag | Silver | ug/gdw | 2012 | 2.395 | 7.060 | 2.680 | 4.343 | 1.68 | 2.40 | 1.49 | 0.84 | 3 | 3 | 3 | 3 |
| METAL | Ag | Silver | ug/gdw | 2015 | 3.730 | 4.270 | 2.757 | 3.303 | 0.48 | 1.25 | 0.19 | 0.79 | 3 | 3 | 3 | 3 |
| METAL | Ag | Silver | ug/gdw | 2018 | 5.120 | 2.300 | 6.523 | 5.220 | 2.78 | 1.64 | 2.66 | 1.53 | 3 | 3 | 3 | 3 |
| METAL | Ag | Silver | ug/gdw | 2021 | 3.737 | N.A. | N.A. | 4.970 | 0.78 | N.A. | N.A. | 1.08 | 3 | N.A. | N.A. | 3 |
| PCB | | Total PCBs | ng/gdw | 1992 | 2609.250 | 372.725 | 1844.200 | 2415.000 | 1123.76 | 130.18 | 1126.33 | 943.63 | 4 | 4 | 4 | 4 |
| PCB | | Total PCBs | ng/gdw | 1993 | 1797.000 | 336.500 | N.A. | 1733.000 | 0.00 | 0.00 | N.A. | 0.00 | 1 | 1 | N.A. | 1 |
| PCB | | Total PCBs | ng/gdw | 1994 | 3615.000 | 343.700 | 1115.833 | 2381.667 | 1032.41 | 91.68 | 234.12 | 972.97 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 1995 | 9243.000 | 1249.233 | N.A. | 6090.667 | 1453.46 | 901.45 | N.A. | 3026.93 | 3 | 3 | N.A. | 3 |
| PCB | | Total PCBs | ng/gdw | 1996 | 3672.000 | 778.100 | 2123.000 | 2600.667 | 1191.18 | 58.19 | 136.04 | 802.15 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 1997 | 4638.000 | 938.367 | N.A. | 2629.333 | 1718.60 | 307.21 | N.A. | 1259.57 | 3 | 3 | N.A. | 3 |
| PCB | | Total PCBs | ng/gdw | 1998 | 3060.667 | 448.367 | N.A. | 1255.967 | 1142.14 | 221.71 | N.A. | 427.43 | 3 | 3 | N.A. | 3 |
| PCB | | Total PCBs | ng/gdw | 1999 | 2761.000 | 360.300 | 825.200 | 1271.133 | 55.65 | 192.82 | 170.10 | 565.81 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2000 | 1856.333 | 249.867 | N.A. | 1140.667 | 602.33 | 25.08 | N.A. | 96.21 | 3 | 3 | N.A. | 3 |
| PCB | | Total PCBs | ng/gdw | 2001 | 3611.333 | 424.333 | N.A. | 2513.000 | 523.47 | 47.67 | N.A. | 119.58 | 3 | 3 | N.A. | 3 |
| PCB | | Total PCBs | ng/gdw | 2002 | 3059.000 | 515.900 | 1661.333 | 2186.667 | 1116.84 | 164.33 | 647.49 | 439.24 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2003 | 4462.333 | 371.900 | N.A. | 2558.667 | 1029.32 | 136.87 | N.A. | 494.95 | 3 | 3 | N.A. | 3 |
| PCB | | Total PCBs | ng/gdw | 2006 | 3309.333 | 351.500 | 1046.400 | 1411.000 | 163.10 | 67.44 | 294.60 | 483.59 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2009 | 1789.333 | 356.967 | 1191.333 | 1101.200 | 426.31 | 216.84 | 106.04 | 665.88 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2012 | 4139.333 | 557.267 | 1731.767 | 1709.667 | 803.98 | 227.03 | 1264.51 | 453.53 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2015 | 2144.000 | 178.067 | 580.267 | 746.233 | 818.38 | 83.06 | 167.92 | 145.87 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2018 | 3762.667 | 219.133 | 896.133 | 1203.167 | 1441.38 | 57.32 | 458.54 | 653.71 | 3 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2021 | 2084.333 | N.A. | N.A. | 627.233 | 630.97 | N.A. | N.A. | 158.96 | 3 | N.A. | N.A. | 3 |
| METAL | Pb | Lead | ug/gdw | 1992 | 2.753 | 6.255 | 3.393 | 3.287 | 2.93 | 5.06 | 3.88 | 1.74 | 4 | 4 | 4 | 4 |
| METAL | Pb | Lead | ug/gdw | 1993 | 2.020 | 1.140 | N.A. | 2.320 | 0.00 | 0.00 | N.A. | 0.00 | 1 | 1 | N.A. | 1 |
| METAL | Pb | Lead | ug/gdw | 1994 | 1.417 | 4.150 | 1.650 | 6.220 | 0.45 | 1.51 | 0.32 | 1.81 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 1995 | 0.840 | 5.219 | N.A. | 5.938 | 0.28 | 2.03 | N.A. | 2.92 | 3 | 3 | N.A. | 3 |

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**(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 | Pb | Lead | ug/gdw | 1996 | 2.120 | 2.581 | 2.120 | 4.241 | 0.32 | 2.72 | 0.54 | 1.50 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 1997 | 3.059 | 1.071 | N.A. | 4.387 | 1.11 | 0.53 | N.A. | 1.11 | 3 | 3 | N.A. | 3 |
| METAL | Pb | Lead | ug/gdw | 1998 | 2.474 | 2.283 | N.A. | 3.818 | 0.35 | 0.87 | N.A. | 0.65 | 3 | 3 | N.A. | 3 |
| METAL | Pb | Lead | ug/gdw | 1999 | 2.424 | 2.044 | 4.427 | 6.768 | 0.55 | 0.67 | 2.92 | 5.63 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 2000 | 3.653 | 1.650 | N.A. | 8.140 | 0.99 | 0.23 | N.A. | 0.61 | 3 | 3 | N.A. | 3 |
| METAL | Pb | Lead | ug/gdw | 2001 | 2.950 | 3.130 | N.A. | 7.410 | 0.72 | 0.72 | N.A. | 0.72 | 3 | 3 | N.A. | 3 |
| METAL | Pb | Lead | ug/gdw | 2002 | 1.997 | 1.653 | 2.890 | 4.963 | 0.69 | 1.04 | 1.21 | 0.81 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 2003 | 2.950 | 3.890 | N.A. | 5.077 | 0.44 | 2.06 | N.A. | 2.14 | 3 | 3 | N.A. | 3 |
| METAL | Pb | Lead | ug/gdw | 2006 | 1.453 | 1.820 | 1.453 | 5.933 | 0.08 | 0.69 | 0.16 | 3.16 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 2009 | 1.660 | 2.378 | 2.969 | 4.703 | 0.40 | 1.72 | 1.88 | 2.82 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 2012 | 2.033 | 2.243 | 2.660 | 4.253 | 0.81 | 0.87 | 1.83 | 0.82 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 2015 | 2.923 | 3.693 | 3.690 | 6.427 | 1.32 | 1.72 | 1.56 | 1.66 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 2018 | 1.737 | 3.203 | 2.983 | 4.860 | 0.43 | 0.79 | 0.44 | 0.81 | 3 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 2021 | 1.557 | N.A. | N.A. | 3.723 | 0.19 | N.A. | N.A. | 2.02 | 3 | N.A. | N.A. | 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 |
| CHLOR | | Total chlordanes | ng/gdw | 2018 | 0.554 | 0.059 | 0.313 | 0.15 | 0.10 | 0.11 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2021 | 0.395 | 0.130 | 0.113 | 0.16 | 0.05 | 0.03 | 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 |
| DDT | | Total DDTs | ng/gdw | 2018 | 6.292 | 2.610 | 3.386 | 1.05 | 0.63 | 0.82 | 3 | 3 | 3 |
| DDT | | Total DDTs | ng/gdw | 2021 | 4.147 | 3.052 | 2.377 | 0.17 | 0.80 | 0.43 | 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 |

(continued)

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| 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 | 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 |
| 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 |
| METAL | Hg | Mercury | ug/gdw | 2018 | 0.860 | 0.774 | 0.890 | 0.01 | 0.23 | 0.04 | 3 | 3 | 3 |
| METAL | Hg | Mercury | ug/gdw | 2021 | 0.640 | 0.353 | 0.689 | 0.02 | 0.02 | 0.14 | 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 |
| PCB | | Total PCBs | ng/gdw | 2018 | 97.967 | 25.277 | 47.217 | 14.83 | 8.60 | 8.60 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2021 | 77.673 | 27.330 | 24.933 | 16.19 | 4.53 | 4.99 | 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 |
| CHLOR | | Total chlordanes | ng/gdw | 2018 | 59.610 | 38.227 | 40.643 | 19.90 | 36.84 | 16.05 | 3 | 3 | 3 |
| CHLOR | | Total chlordanes | ng/gdw | 2021 | 34.210 | 16.297 | 29.583 | 14.13 | 4.60 | 21.23 | 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 | Cd | Cadmium | ug/gdw | 2018 | 10.017 | 20.500 | 17.733 | 5.95 | 6.92 | 2.87 | 3 | 3 | 3 |
| METAL | Cd | Cadmium | ug/gdw | 2021 | 8.027 | 15.533 | 16.500 | 0.87 | 5.17 | 5.27 | 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 |

(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 | 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 |
| 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 | Cu | Copper | ug/gdw | 2018 | 564.333 | 196.000 | 588.000 | 92.12 | 90.42 | 238.27 | 3 | 3 | 3 |
| METAL | Cu | Copper | ug/gdw | 2021 | 402.667 | 351.333 | 524.000 | 195.21 | 123.31 | 201.50 | 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 |
| METAL | Ni | Nickel | ug/gdw | 2018 | 0.584 | 1.173 | 0.833 | 0.11 | 0.29 | 0.12 | 3 | 3 | 3 |
| METAL | Ni | Nickel | ug/gdw | 2021 | 0.560 | 1.253 | 0.913 | 0.15 | 0.21 | 0.01 | 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 |

(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 |
| 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 |
| PCB | | Total PCBs | ng/gdw | 2018 | 10042.000 | 2860.667 | 3890.667 | 2213.37 | 539.36 | 1156.25 | 3 | 3 | 3 |
| PCB | | Total PCBs | ng/gdw | 2021 | 3103.667 | 528.700 | 753.767 | 3110.54 | 47.98 | 235.44 | 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 |
| 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 |
| METAL | Pb | Lead | ug/gdw | 2018 | 0.460 | 0.000 | 0.132 | 0.27 | 0.00 | 0.23 | 3 | 3 | 3 |
| METAL | Pb | Lead | ug/gdw | 2021 | 0.000 | 0.000 | 0.000 | 0.00 | 0.00 | 0.00 | 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 |
| CHLOR | | Total chlordanes | ng/gdw | 2018 | 3.736 | 7.897 | 3.858 | 4.028 | 0.52 | 3.13 | 1.13 | 0.70 | 4 | 4 | 4 | 8 |
| CHLOR | | Total chlordanes | ng/gdw | 2021 | 5.527 | 14.205 | 5.575 | 7.012 | 0.74 | 1.98 | 1.79 | 1.85 | 4 | 4 | 4 | 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 |
| 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 |

(continued)

**(Continued)**

| 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 |
| 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 |
| DDT | | Total DDTs | ng/gdw | 2018 | 13.800 | 32.478 | 8.759 | 8.633 | 3.45 | 18.16 | 3.77 | 2.23 | 4 | 4 | 4 | 8 |
| DDT | | Total DDTs | ng/gdw | 2021 | 18.145 | 45.008 | 7.628 | 6.685 | 2.45 | 5.56 | 1.98 | 1.53 | 4 | 4 | 4 | 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 |
| 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 |
| HMW-PAH_NOAA | | Total NOAA HMW PAH | ng/gdw | 2018 | 85.180 | 692.500 | 25.870 | 39.351 | 15.27 | 35.52 | 2.23 | 5.77 | 4 | 4 | 4 | 8 |
| HMW-PAH_NOAA | | Total NOAA HMW PAH | ng/gdw | 2021 | 221.925 | 1509.250 | 100.780 | 106.075 | 11.97 | 181.92 | 29.86 | 17.49 | 4 | 4 | 4 | 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 |

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| 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 |
| 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 |
| 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 |
| LMW-PAH_NOAA | | Total NOAA LMW PAH | ng/gdw | 2018 | 59.565 | 94.028 | 56.143 | 50.288 | 12.61 | 8.50 | 6.70 | 7.12 | 4 | 4 | 4 | 8 |
| LMW-PAH_NOAA | | Total NOAA LMW PAH | ng/gdw | 2021 | 112.050 | 204.625 | 107.488 | 110.185 | 6.34 | 12.16 | 8.88 | 7.58 | 4 | 4 | 4 | 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 |
| PCB | | Total PCBs | ng/gdw | 2018 | 196.975 | 266.975 | 119.300 | 93.573 | 49.97 | 48.82 | 13.49 | 48.47 | 4 | 4 | 4 | 8 |
| PCB | | Total PCBs | ng/gdw | 2021 | 195.550 | 560.625 | 59.530 | 48.329 | 20.84 | 36.45 | 17.44 | 19.20 | 4 | 4 | 4 | 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. |
| 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 |

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| 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 |
| 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 |
| METAL | Pb | Lead | ug/gdw | 2018 | 1.715 | 2.478 | 0.900 | 1.001 | 0.26 | 1.03 | 0.07 | 0.08 | 4 | 4 | 4 | 8 |
| METAL | Pb | Lead | ug/gdw | 2021 | 1.163 | 1.283 | 0.886 | 1.001 | 0.04 | 0.08 | 0.12 | 0.09 | 4 | 4 | 4 | 8 |

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