Bioaccumulation of selected organic compounds and metals in mussels deployed near Deer Island discharge and in Massachusetts Bay, 1994

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Bioaccumulation of Selected Organic Compounds and Metals in Mussels Deployed Near Deer Island Discharge and in Massachusetts Bay, 1994

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EXECUTIVE SUMMARY

A mussel (*Mytilus edulis*) bioaccumulation study was conducted in 1994 for the Massachusetts Water Resources Authority (MWRA). This 1994 study was a continuation of previous studies (Downey and Young 1992; Downey et al. 1993; Downey et al. 1994). The objectives of the 1994 study were to determine whether selected Polynuclear Aromatic Hydrocarbons (PAHs), pesticides, Polychlorinated Biphenyls (PCBs), and metals bioaccumulate in mussels deployed near the Deer Island Publicly Owned Treatment Works (POTW) and to obtain background data on the uptake of specific target compounds by mussels deployed offshore near the projected new Deer Island outfall.

Mussels harvested from Hodgkins Cove (Gloucester) were deployed on June 25, 1994 at three locations: approximately 75 meters (m) east of the Deer Island Light; off the stern of the Discovery (New England Aquarium); and in the vicinity of the Large Navigation "B" Buoy (LNB) approximately nine miles offshore. The Discovery deployment was used as a 'dirty' control, the Deer Island was the 'test' location, and the LNB deployment was the 'background' station for assessment of contamination near the proposed new offshore outfall.

A random subsample (30 mussels) of harvested mussels was selected from each array and used to determine the average shell length, average wet weights (total, gonad/mantle, and non-gonadal), the proportion of females and males present, and sexual maturity for each station. The remaining mussels from each array were used to make composite samples, consisting of 10 mussels each, for chemical analyses.

The 60-day harvested mussels examined for the stage of gametogenesis were also examined for abnormalities in the soft tissue. No lesions or parasites were observed on any of the mussels examined.

Although average shell length increased by 2.9 - 3.9 mm for mussels deployed for 60 days at the three stations, the differences were not statistically significant.

Average percent solids and percent lipids of mussels (after 60 day deployment) were highest in LNB mussels and lowest in Deer Island mussels; the observed differences were not statistically significant.

Matrix spikes and matrix spike duplicates were run on samples 233366 (Deer Island mussels) and 233376 (LNB mussels) which reduced the tissue mass available for PCB, PAH and pesticide analyses. Due to these reductions in tissue mass, PAH and pesticide data obtained for these samples were excluded from analyses.

Average total Polynuclear Aromatic Hydrocarbons (tPAH) tissue concentrations of 2255 ug/kg dry weight in Discovery mussels were significantly higher than all other mussel deployment groups. Deer Island deployed average tPAH body burdens (848 ug/kg dry weight) were significantly greater than either Gloucester predeployment or LNB deployed mussels which averaged 264 ug/kg and 122 ug/kg, respectively. Although the LNB average tPAH body burdens were numerically lower than Gloucester predeployment body burdens, these differences were not significant.

As observed in previous years (1991-1993) the methylnaphthalenes (1-methyl-, 2-methyl-, 2,6-dimethyl-, and 2,3,5-trimethyl-) and 1-methylphenanthrene were typically found in Deer Island mussel tissue concentrations that were two to four times greater than Discovery mussels. In contrast to the low molecular weight PAHs (LMW-PAHs), all of the high molecular weight PAHs (HMW-PAHs) target compounds were found in the higher tissue concentrations in the Discovery mussels.

Average alpha-chlordane body burdens were found at similar concentrations for Discovery mussels (12.8 ug/kg dry weight) and Deer Island mussels (13.8 ug/kg dry weight). Mussels harvested from the LNB (3.6 ug/kg dry weight) and Gloucester

predeployment (3.5 ug/kg dry weight) body burdens were found at significantly lower concentrations than either Deer Island and/or Discovery deployed mussels.

Of the twenty target individual PCB congeners, ten congeners were found at or near the detection levels in mussels harvested from Deer Island after the 60-days deployment. Generally, the Discovery individual PCB congener concentrations were the highest observed (of those detected) from the four stations in 1994. Deer Island congener concentrations were routinely similar to or less than congener concentrations observed for Discovery mussels. Four of the PCB congeners (CL3-PCB(28), CL4-PCB(44), CL4-PCB(77) and CL7-PCB(170)) were detected in significantly higher concentrations in Deer Island mussels compared to Gloucester predeployment mussels. Total PCB tissue concentrations were highest in Discovery mussels as compared to Deer Island mussels. The LNB PCB body burdens were routinely lower as compared to mussels deployed at the other stations, including Gloucester predeployment mussels.

The total DDT (tDDT) tissue concentrations were numerically lower in mussels harvested from all stations in 1994 as compared to 1993 tissue concentrations. The 1994 tDDT tissue concentrations were generally similar to the 1991 and 1992 tissue concentrations observed at all stations. The (tDDT) tissue body burdens were three to five times higher in Discovery and Deer Island mussels as compared to predeployment and LNB mussels. The tDDT body burdens in Discovery mussels were nearly two times higher than Deer Island mussel tissue body burdens. Dieldrin tissue body burdens in Deer Island and Discovery deployed mussels were similar, but were five to thirteen times higher than predeployment and LNB mussels. The tissue body burdens of trans-nonachlor were nearly the same between the predeployment (4.00 ug/kg) and LNB mussels (3.77 ug/kg) and between Deer Island (11.24 ug/kg) and Discovery mussels (11.03 ug/kg). However the transnonachlor tissue body burdens were nearly three times higher in Deer Island and Discovery mussels as compared to the predeployment and LNB mussels.

The average Deer Island deployed mussel lead body burden (9125.0 ug/kg dry weight) and average Gloucester predeployment mussel lead body burden (8600.0 ug/kg dry weight) were similar. However, mussels harvested from the LNB had an average lead body burden (4800.0 ug/kg dry weight) which was significantly less than either the Deer Island or Gloucester predeployment mussels.

Gloucester predeployment mussels had an average mercury body burden (176.7 ug/kg dry weight) that was lower than the average mercury body burden of mussels deployed at Deer Island (208.3 ug/kg dry weight), but higher than the average mercury body burden for mussels deployed at the LNB (130.6 ug/kg dry weight). The observed differences in the average mercury body burdens between all three deployment locations were not statistically significant.

The 1994 relative spatial trends of mussel body burdens for the three stations were consistent with spatial trends reported for 1991 - 1993 mussels. Total LMW-PAHs, particularly the methylnaphthalenes (2-methyl-, 1-methyl-, 2,6-dimethyl-, and 2,3,5-trimethyl-) were consistently found in the highest tissue concentrations in the Deer Island tissues (1991-1994). These higher concentrations in the Deer Island mussels during all four studies suggest that the Deer Island effluent may be an important source of these contaminants for mussels deployed at Deer Island Light. In contrast, the higher HMW-PAH body burdens in Discovery mussels suggest that there are other source(s) of HMW-PAHs within the Boston Harbor which are of importance for mussel bioaccumulation.

The results of this study have qualitatively mimicked the results of previous studies (1991-1993). Generally tPAHs, LMW-PAHs, and HMW-PAHs displayed a trend of lower tissue concentrations in 1991-1994 Deer Island mussels compared to 1987 tissue concentrations. Annual variability in the total PAHs, total PCBs, and pesticides for 1991-1994 Deer Island mussels has not revealed any consistent trends during this four year period.

The 1991-1994 studies have also indicated that Deer Island effluent probably contributes LMW-PAHs for bioaccumulation in mussels in proximity to the Deer Island discharges. Cursory comparisons of the bioaccumulation patterns and Deer Island water quality analyses indicate that biomonitoring techniques provide a useful tool in monitoring Deer Island effluent water quality trends for target compounds such as PAHs, pesticides, and PCBs that may bioaccumulate in aquatic biota.

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1.0 OVERVIEW

This 1994 bioaccumulation study was conducted for the Massachusetts Water Resources Authority (MWRA) as part of Inchcape Testing Services Aquatec Laboratories (Aquatec) 1993 contract (Number S147) with MWRA. The objective of this study was to determine whether selected compounds bioaccumulate in the tissue of blue mussels (*Mytilus edulis*) deployed near the Deer Island Publicly Owned Treatment Works (POTW) sewage outfall. An additional objective of the study was to obtain background data on uptake of target compounds by mussels deployed offshore near the projected new Deer Island outfall.

Several studies examining the potential bioaccumulation of analytes in mussels have been conducted at the Deer Island POTW. The study conducted by the MWRA in 1987 (MWRA 1988) used caged mussels deployed at the sewage outfall for 30-60 days to assess mussel tissue concentrations of selected organic compounds (PAHs, PCBs, and pesticides) and selected heavy metals. In addition to the Deer Island sampling location, the projected new offshore discharge location was also sampled as part of the 1987 study.

A bioaccumulation study near the Deer Island Light in the Zone of Initial Dilution (ZID), an area that is exposed to Deer Island POTW effluent, was conducted by Aquatec, Inc. (Downey and Young 1992) from June through August 1991 with biological support provided by Marine Research Inc. (MRI, 1991). This study was designed to be generally comparable to the 1987 study conducted by MWRA. However, different analytical methodologies were used to attain lower detection limits in 1991 for organic compounds in mussel tissue.

The 1991 Aquatec study employed two 'control' locations: the stern of the vessel Discovery at the New England Aquarium; and at the Gloucester location in Hodgkins Cove on Cape Ann. The Discovery location served as the 'dirty' control with the mussel

tissue analyses characterizing mussel exposure and bioaccumulation of target compounds in Boston's Inner Harbor. The Gloucester location served as the 'clean' control providing estimates of 'background' contaminant levels in mussel tissue. Mussels exposed at the Deer Island location were compared to predeployment mussels and to mussels exposed at the two 'clean' control locations to identify apparent trends in target compound concentrations in mussel tissues.

This study was continued in 1992 and 1993 (Downey et al. 1993; Downey 1994). The predeployment at Gloucester, Deer Island and Discovery locations and analytical methodologies were consistent with the 1991 study. However, mussels were deployed at the projected new offshore discharge location while the Gloucester location was used for mussel harvest only.

The current 1994 study was designed to mimic the previous three Aquatec studies and the 1987 MWRA study. Mussels were deployed at three locations in June 1994 with the Deer Island and Discovery locations again part of the 1994 study. The Large Navigation Buoy (LNB) near the site of the projected new offshore discharge, served as the third deployment site of this bioaccumulation study. This location was also used in the 1987 MWRA study and the 1992 and 1993 Aquatec study. Tissue analyses were conducted using methods similar to those employed in 1991 - 1993.

2.0 METHODS

2.1 Mussel Collection

On June 24, 1994, approximately 940 mussels were collected for testing purposes from the University of Massachusetts' (UMASS) Research Station at Hodgkins Cove in Gloucester, Massachusetts (Table 1). This area was chosen because mussels from this location were relatively free of contaminants and had been used in previous bioaccumulation studies: for the South Essex Sewage District (Camp, Dresser, and McKee, Inc. 1988), New Bedford, Massachusetts (MRI 1989), 1991 Deer Island study (Downey and Young 1992), 1992 Deer Island Study (Downey, et al. 1993), 1993 Deer Island Study (Downey 1994), and the 1993 Lynn Municipal Discharge study (Downey, 1994).

Mussels were harvested during low tide and each mussel individually checked for approximate total length. Mussels which fell into a nominal 55-65 mm range were retained for the study; mussels outside this range were returned to the beds. Of the approximate 940 mussels retained, 200 were randomly selected for measurement of total length. The total shell length (mm from umbo to distal gape) was measured with Vernier calipers to 0.1 mm to obtain an average size estimate for the sample population (940 mussels) and to ensure that the majority of the mussels fell within the desired length range. Approximately fifty (40 for LNB) mussels (both measured and unmeasured) were randomly distributed to each of 19 plastic cages (22.5cm x 22.5cm x 22.5cm) and submerged overnight in seawater by suspending the cages from the seawall adjacent to the UMASS Research Station. A subsample of 80 mussels was transported unfrozen on ice to Aquatec on June 25, 1994, for initial biological (total length, sex and sexual maturity, and tissue weights) and chemical analyses.

2.2 Mussel Deployment

On June 25, 1994, mussels in cages were deployed from Aquatec's 25 foot Research Vessel "Profile" at the following three sites (Figure 1):

1) Deer Island Light: located approximately 75 meters east of the navigation light and within the ZID of the Deer Island POTW effluent discharge. This site was the "target" study area for detection of potential contaminant bioaccumulation attributable to the Deer Island POTW.

2) The stern of the vessel "Discovery": located at the New England Aquarium, in Boston's Inner Harbor. This site served as "dirty" control to evaluate the extent of ambient contamination within Boston's Inner Harbor.

3) Large Navigation Buoy: (LNB) located approximately one nautical mile (NM) south of the projected MWRA offshore discharge installation. This LNB site provided predischarge baseline data.

Three arrays were deployed at the Deer Island Light. Each deployment array consisted of two replicate cages containing approximately 50 mussels each for a total of about 100 mussels per array. Both cages were attached to polypropylene line with nylon cable ties. Steel mooring weights (about 100 kg) and a 25 cm diameter styrofoam subsurface buoy were used to stabilize the location of each array in the water column. A polypropylene line, approximately 75 meters in length, tethered each array anchor to the riprap surrounding the light. The arrays at Deer Island were deployed in about 4-6 meters of water, mean low water (MLW), approximately 75 meters east of Deer Island Light. The subsurface buoy for each array was located about 3 meters from the bottom and the two cages per array were fastened about 1 meter below the buoy (cage depth approximately 2 m from bottom). Deployment positions were documented using on-board Loran-C readings in latitude and longitude.

Two arrays were deployed at the Discovery Station on June 25, 1994. Each array consisted of two replicate cages containing 50 mussels per cage (approximately 100 mussels per array). The arrays were suspended on a nylon line from the stern of "Discovery", a New England Aquarium vessel. The four cages were attached in pairs

(0.2m between pairs) with each pair considered to be a deployment array. The arrays were arranged approximately 2-2.5 meters from the bottom at a depth of 7-9 meters and anchored with approximately 25 kg of weight.

The deployment array at the LNB Station consisted of three replicate cages containing 40 mussels per cage. On June 25, 1994, three arrays (3 cages per array) were deployed near the LNB using a mooring and suspension system. A 13 cm diameter Styrofoam surface (pot) buoy was tied to a subsurface 30 cm diameter buoy which was deployed about 13 meters below the surface. The pot buoy was allowed to float freely at the surface.

2.3 Mussel Retrieval

On August 3, 1994, one array was collected from each of the three locations; LNB, Discovery and Deer Island. Exposure time was 40 days for all stations. Mussels were checked in the field for survival, frozen, and stored for future analyses. These mussels were not used during the remainder of the study.

The sixty-day harvest of mussels occurred on August 24, 1994, from the three stations. Only one of the two remaining arrays, approximately 100 mussels, was recovered from Deer Island Ligh (one array, two cages, was lost). One array, approximately 89 mussels, was recovered from Discovery and two arrays, about 216 mussels, were recovered from the LNB. Random subsamples of mussels were obtained for biological and chemical analyses. Mussels for chemical and biological analyses were stored in coolers in separately labeled plastic bags and kept cold during transport. On August 24, 1994, all mussels were transported on ice to Aquatec and stored frozen (for chemical analyses) or refrigerated (for biological analyses).

2.4 Biological Analyses

For biological analyses, a random subsample of 30 mussels was selected from the predeployment mussels and from each of the three stations 60-day collection. Mussels for biological analyses were processed to obtain total shell length, total wet weight and reproductive condition.

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

Each mussel was opened by slicing the adductor muscles between the valves with a microtome blade. The gill tissue was drawn back to expose the gonad. A small aliquot of macerated gonad tissue was transferred to a slide and examined under a compound microscope for the sex and sexual maturity determinations. Sexually mature males were identified by sperm motility and immature males by lack of sperm motility. Sexually mature females were identified by presence of eggs with a diameter greater than 60 microns; otherwise the female mussel was identified as an immature.

2.5 Chemical Analyses

Random subsamples of mussels (30-80 depending on the station) were selected from the predeployment mussels and from each of the three stations 60-day mussel harvest. These subsamples were used to create composite samples to be used for chemical analyses. Composite samples were prepared by dissecting 10 mussels per composite using disposable Teflon-coated stainless steel blades that were rinsed with methanol and deionized water prior to use. Each individual mussel was rinsed with

deionized water and the shell surface was scrubbed to remove attached material. Byssal threads were removed and all soft tissue including fluids were shucked directly into an amber 250-ml I-Chem Certified clean bottle. The ten mussel composite sample was then homogenized using an Omni Mixer Homogenizer with a titanium generator. The sample was then split in two by distributing approximately 20 g of sample into a clear 125 ml I-Chem bottle for metals and solids analyses. The remaining (60 g) sample was kept in the original container for PAH, PCB and pesticide analyses.

The tissues were refrozen and held until chemical extraction was initiated. The extraction and analytical procedures for organics generally followed National Status and Trends Methodologies (Figure 2). As in the 1991 through 1993 studies, tissues were analyzed for Polynuclear Aromatic Hydrocarbons (PAH) using Gas Chromatography/Mass Spectrometry (GC/MS), while pesticides and polychlorinated biphenyls (PCBs) were analyzed using Gas Chromatography/ Electron Capture Detection (GC/ECD).

Generally, internal standards were spiked into each sample prior to extraction to achieve a more representative quantification of the PAH, PCB, and pesticide target analytes. The spiked analytes were as follows:

<u>PAH Internal Standards:</u>

Naphthalene-d8
Acenaphthene-d10
Phenanthrene-d10
Chrysene-d12
Perylene-d12

<u>Pesticide/PCB Internal Standards:</u>

Dibromooctafluorobiphenyl
CL5-PCB(121)
CL8-PCB(204)

The sample-specific experimental recoveries of the internal standards (summarized in Appendixes C and D) were used for correction of the reported results for target analytes in the mussels. The polychlorinated biphenyls were referred to by level of chlorination followed by the BZ congener number designation in parenthesis.

Blank analyses, laboratory matrix spike (MS) and matrix spike duplicates (MD) were conducted routinely. For each type of analysis, at least two MS and MD analyses were conducted for approximately 10 percent quality control sampling.

Lipid determinations were completed following the National Status and Trends Methodologies.

Tissue extraction for metals was completed following procedures depicted in Figure 3. Analyses of lead was completed using Graphite Furnace Atomic Absorption (Method 7421) while mercury was analyzed using cold vapor atomic absorption (Method 7471).

2.6 Statistical Analyses

Both parametric and nonparametric statistics were used for evaluation of the data. Biological measurements were analyzed using Analysis of Variance (ANOVA) and t-tests since sample size at each station was large (generally N=30). Confidence intervals for each biological comparison of two stations were determined using the approach outlined by Snedecor and Cochran (1973) for ANOVA with unequal sample size.

Statistical analyses of individual chemical constituents on a dry weight basis were completed using the Mann-Whitney U test, a nonparametric test which provides a powerful alternative to the parametric t-test. This test was selected since the relatively small sample size (generally 8 samples or less) suggested that the data may not meet the assumptions of the t-test. The Mann-Whitney U test is an excellent alternative to

the t-test with its power-efficiency approximating 95.5 percent as sample size increases (Siegel 1956).

Tissue analyte concentrations were reported on a dry weight basis. Average calculations (used in both tables and figures) of PAHs, PCBs, and pesticides (i.e., sum of individual sample analytes) were determined using the detection limit value for the analyte as an estimated concentration for those analytes not detected. Difficulties were encountered during the organic analyses of two samples, sample 233376 from LNB mussels and sample 233366 from Deer Island mussels, as a result they were excluded from statistical analyses of PAH, PCB, and pesticide data.

Lipid-adjusted average dry weight values for the PAHs, PCBs, and pesticides were normalized by dividing the dry weight tissue concentration by the sample-specific dry weight lipid mass. These lipid-adjusted average values were plotted for comparison among the stations.

Tissue analyte concentrations of metals were reported on a dry weight basis. Metal concentrations were also reported on a non-gonadal adjusted dry weight basis. Generally, it is believed that metal bioaccumulation in mussels occurs primarily in non-gonadal tissue and was adjusted as follows:

$$\mathbf{Me(NON) = Me\ (TST/NGT)}$$

where:

Me(NON) = non-gonadal metal concentration (ug/kg dry weight)
Me = metal concentration (ug/kg dry weight)
TST = total soft tissue mass (g) (from biological analysis)
NGT = non-gonadal tissue mass (g) (from biological analysis)

3.0 RESULTS

3.1 Biological Analyses

3.1.1 Survival

On August 3, 1994, (40 days post-deployment) one array was harvested from each of the three locations. The cages were removed from the deployment moorings and mussels examined for gross abnormalities, apparent survival and fouling of the cages. No abnormalities were observed and survival was 98 - 99% at all stations (Table 2).

Fouling varied among locations after forty days. The LNB cages were covered with a fine brown silt and a few attached barnacles. At the Discovery station, cages were moderately to extensively covered with slime with some occlusion of the spaces between the bars of the cage. Sea squirts were abundant on and within cages deployed at Discovery. The two Deer Island cages were moderately fouled with a brown silt-like material; small crabs, starfish, isopods, and polychaetes were also observed. Mussels obtained from the three locations were harvested, enumerated, and stored frozen in the laboratory. Since the August 60-Day retrieval was successful, these mussels were not used further for biological or chemical analyses.

Mussels were harvested at the end of the 60-day exposure from the three locations on August 24, 1994. Mussel survival was very high for all three locations; 94 percent for Discovery mussels, 100 percent for the LNB and Deer Island mussels (Table 2).

Cages retrieved from the LNB on August 24, 1994, were lightly covered with a brown silt; many small barnacles were attached to some of the mussels. The barnacles were easily removed by gently wiping them from the surface of the shell. Mussels were attached to each other within the cages by byssus threads. The overall health and

condition of the mussels was excellent with no abnormalities, lesions, or parasites noted.

Deer Island cages and mussels were extensively covered with hydrozoans and fine silt-like material. Barnacles present on several of the mussels (less than 10 percent) were believed to be predominantly carryover from incomplete removal during the initial harvest at Hodgkins Cove. Small crabs, seed mussels and amphipods were also observed inside the cages.

The Discovery cages exhibited extensive fouling, predominantly sea squirts, which covered the cage bars. Silt-like material was also found on surfaces not occupied by the sea squirts including the shells of the mussels. Spaces between mussels also commonly contained large amounts of this silt-like material with accumulations of several millimeters on shells. Several crabs and amphipods were also present.

3.1.2 Sexual Maturity

A representative sample of randomly selected mussels was examined from the four locations to determine the sex ratio and stage of gametogenesis of mussels (Table 2). Female gonads were generally orange in color while the males were more of a yellow color.

For the 30 predeployment mussels examined from Gloucester in June, 6 of 7 females were mature while 3 of the 23 males were mature. The proportion of mature females in the Gloucester predeployment mussels is consistent with the observations of previous years (1991,1992, and 1993); however, the high proportion of immature males is atypical. It is not clear why the proportion of immature males was dramatically higher in 1994 as compared to the previous three years. The 30 random mussels examined at

the sixty day harvest (24 August 1994) yielded 8, 13, and 10 mature females and 1, 4, and 1 mature males from the Deer Island, Discovery, and LNB stations, respectively.

The 60-day harvested mussels examined for the stage of gametogenesis were also examined for abnormalities, such as lesions or parasites in the soft tissue. No lesions or parasites were observed on any of the mussels examined.

3.1.3 Growth and Condition

Although mean shell length increased by 2.9-3.9 mm for mussels deployed at the three stations, only the Deer Island (60-day) mussels were significantly larger than the Gloucester predeployment mussels ($P \leq 0.05$) (Table 3). Differences in mean shell wet weights for the three stations (60-day) were significantly larger than Gloucester predeployment mussels ($P \leq 0.05$).

The average non-gonadal soft tissue wet weights for LNB mussels was significantly larger than the means for all other stations ($P \leq 0.05$). The Discovery and Deer Island mean non-gonadal tissue wet weights were not significantly different from the predeployment mussels ($P > 0.05$). The gonadal mean wet weights for all three stations were significantly larger than the Gloucester predeployment mussels, but were not significantly different from each other.

3.2 Tissue Concentrations

3.2.1 Lipids and Solids

Average percent lipids was not significantly different among mussels harvested from the Gloucester (predeployment), LNB, Discovery and Deer Island stations ($P > 0.05$) (Table 4).

The average percent solids of mussels harvested from Discovery (13.6 percent) was similar to the solids composition of the Gloucester predeployment mussels (13.8 percent) and to the Deer Island mussels (13.0). The percent solids of the LNB mussels (16.7 percent) was significantly higher than the percent solids of mussels from all of the other stations ($P \leq 0.05$) (Table 4).

3.2.2 Polynuclear Aromatic Hydrocarbons

Matrix spikes and matrix spike duplicates were run on samples 233366 (Deer Island mussels) and 233376 (LNB mussels) which reduced the tissue mass available for PCB, PAH and pesticide analyses. Due to these reductions in tissue mass, PAH and pesticide data obtained for samples 233366 and 233376 were excluded from analyses.

The average total Polynuclear Aromatic Hydrocarbons (tPAHs) body burdens were low in both the Gloucester predeployment (264 ug/kg dry weight) and LNB (122 ug/kg dry weight) with concentrations at or near detection level for many of the compounds (Tables 5 and 6). Deer Island average mussel tPAH tissue concentrations (848 ug/kg dry weight) were significantly higher than Gloucester predeployment and LNB mussels ($P \leq 0.05$). Average tPAH tissue concentrations in Discovery deployed mussels (2255 ug/kg dry weight) were significantly higher than all other mussel deployment groups ($P \leq 0.05$).

The Low Molecular Weight (LMW) PAHs, defined as the two and three ring groups, were significantly higher in the Deer Island mussels (217 ug/kg dry weight) as compared to the other three groups; Gloucester, LNB and Discovery ($P \leq 0.05$) (Figure 4). The average LMW-PAH tissue concentrations for Gloucester, LNB and Discovery mussels were similar, LMW-PAH concentrations averaged 106, 61 and 79 ug/kg dry weight, respectively. The methylnaphthalenes (1-methyl-, 2-methyl-, 2,6-dimethyl-, and 2,3,5-trimethyl-) and 1-methylphenanthrene were typically found in Deer Island tissue

concentrations that were two to four times greater than Discovery mussels ($P \leq 0.05$) (Table 6 and Figure 5).

The High Molecular Weight (HMW) PAHs, defined as the four through six ring compounds, were found in significantly higher concentrations in Discovery mussels (2176 ug/kg dry weight) as compared to the Deer Island mussels (631 ug/kg dry weight) (Table 6 and Figure 4). The Discovery and Deer Island mussels HMW-PAH body burdens were significantly higher than both the Gloucester predeployment (158 ug/kg dry weight) and the LNB mussels (61 ug/kg dry weight) ($P \leq 0.05$). The mean concentration of HMW-PAHs in LNB deployed mussels was significantly lower than the Gloucester predeployment mussels ($P > 0.05$).

Average body burdens for all of the HMW-PAHs examined were higher in Discovery mussels as compared to Deer Island mussels (Figure 6). Of the eleven HMW-PAHs, seven analytes were more than two times higher in Discovery mussels as compared to Deer Island mussels ($P \leq 0.05$).

The lipid-adjusted tissue concentrations were similar to the dry weight trends (Figure 6). Most of the LMW-PAH lipid-adjusted tissue concentrations were higher for Deer Island while the HMW-PAH lipid-adjusted tissue concentrations were higher in Discovery mussels.

3.2.3 Pesticides

Six pesticides; hexachlorobenzene, heptachlor, aldrin, heptachlor epoxide, 2,4' DDE, and mirex - were found at or near detection levels at all stations (Tables 7 and 8; Figure 7). Lindane tissue concentrations were lower at Deer Island (1.6 ug/kg dry weight) as compared to Discovery mussels (2.2 ug/kg dry weight); but, higher than the LNB mussel tissue concentrations (0.59 ug/kg dry weight); however, the reported concentrations for these compounds were at or near their respective detection levels.

Alpha-chlordane body burdens were found at similar tissue concentrations in the Discovery (12.8 ug/kg dry weight) and Deer Island (13.8 ug/kg dry weight) mussels ($P>0.05$). Mussel body burdens at these two stations were significantly higher than mussels harvested from the LNB (3.6 ug/kg dry weight) and Gloucester predeployment (3.5 ug/kg dry weight) body burdens ($P\leq0.05$).

The analyses of trans-nonachlor revealed the highest body burdens in Discovery mussels (11.0 ug/kg) and Deer Island mussels (11.2 ug/kg dry weight) compared to the LNB mussels (3.8 ug/kg dry weight) or the Gloucester predeployment mussels (4.0 ug/kg dry weight) ($P\leq0.05$).

The Deer Island mussel tDDT tissue concentrations (50.0 ug/kg dry weight) was significantly higher compared to LNB and Gloucester mussels, 18.6 and 26.5 ug/kg dry weight, respectively. The highest body burden of tDDT occured in the Discovery mussels (86 ug/kg dry weight); however, the Deer Island mussels were not significantly different from the Discovery mussels ($P>0.05$).

Dieldrin was found in similar concentrations at Discovery (15.6 ug/kg dry weight) and Deer Island (10.4 ug/kg dry weight) stations. The mussel dieldrin body burdens at the LNB (2.0 ug/kg dry weight) and Gloucester (1.2 ug/kg dry weight) were significantly less than the body burdens of Discovery and Deer Island mussels ($P\leq0.05$).

Lipid-adjusted pesticide concentrations in mussels collected from the four stations displayed trends similar to those observed for pesticides dry weight comparisons (Figure 8).

3.2.4 Polychlorinated Biphenyls

Mussel tissues were analyzed for twenty polychlorinated biphenyls (PCBs) congeners (Table 9). There were six PCB congeners (CL2-PCB(8), CL5-PCB(126),

CL7-PCB(170), CL8-PCB(195), CL9-PCB(206), and CL10-PCB(209)) which were generally found at or near the detection levels in mussel tissue from all stations.

The LNB and Gloucester average total PCB (tPCB) tissue concentrations (88.9 and 107.4 ug/kg dry weight, respectively) were significantly less than Deer Island and Discovery tissue concentrations (160.7 and 500.4 ug/kg dry weight, respectively). The differences in tPCB concentrations observed between Deer Island and Discovery mussel were statistically significant ($P \leq 0.05$) (Table 10 and Figure 9). The lipid-adjusted PCB tissue concentrations were similar to those trends reported for the dry weight tissue concentrations (Figure 10).

The average tissue concentrations for PCBs CL2-PCB(8), CL3-PCB(18) and CL9-PCB(206) were more than two and a half times higher in Gloucester predeployment mussels as compared to Deer Island mussels. Four PCB congeners; CL3-PCB(28), CL4-PCB(44), CL4-PCB(77), and CL7-PCB(170) were detected in tissue concentrations that were at least two and a half times higher in Deer Island mussels as compared to Gloucester predeployment mussels (Table 10 and Figure 9). Average tissue concentrations for each PCB congener examined were consistently higher in Discovery mussels as compared to Deer Island and LNB mussels.

3.2.5 Mercury and Lead

Mussels collected from Gloucester predeployment (June) and sixty day harvest (August) at LNB, Deer Island, and Discovery were analyzed for mercury and lead (Table 11). Average mercury body burdens for Gloucester, LNB, Deer Island, and Discovery mussels (176.7, 130.6, 208.3, and 163.0 ug/kg dry weight, respectively) were not statistically significant ($P>0.05$).

Although Deer Island mussels possessed the highest average lead body burden (9125 ug/kg dry weight) and the LNB mussels had the lowest lead body burden (4800

ug/kg dry weight) (Table 11); no statistically significant differences in lead body burdens were detected ($P>0.05$).

The trends of non-gonadal tissue adjustment of mercury concentration in mussels were similar to the dry weight trends; mercury was found in highest concentrations in Deer Island mussels (343 ug/kg dry weight) and in lowest concentration in LNB mussels (210 ug/kg dry weight) ($P\leq0.05$).

Numerically, non-gonadal lead concentrations were highest in Deer Island mussels (15,018 ug/kg dry weight) and lowest in the LNB mussels (7712 ug/kg dry weight). None of the non-gonadal adjusted average tissue concentrations from the four stations were significantly different ($P>0.05$).

3.3 Temporal Trends

3.3.1 Polynuclear Aromatic Hydrocarbons

The LNB mussel tPAH body burdens in 1994 compared favorably to the tPAH body burdens reported in 1992 - 1993 (Table 12). Overall the LNB PAH body burdens were at or near detection level. Total PAH body burdens in LNB mussels were consistently less than the Deer Island and Discovery mussels body burdens from 1992 to 1994.

Many of the individual LMW-PAH analyte concentrations in Deer Island and Discovery mussels were numerically lower in 1994 than in the previous three years (Figures 11 and 12). An apparent decrease in the concentrations of 2-methyl, 1-methyl-, 2,6-dimethyl- and 2,3,5-trimethyl - naphthalenes in the Deer Island mussels was observed from 1991 to 1993; however, these compounds showed a slight increase in concentration in 1994.

Although the HMW-PAHs were generally the lowest in 1993 (1994 concentrations were generally intermediate) for most of the individual analytes, the highest tissue concentrations were typically observed in the 1992 for mussels collected from both Deer Island (Figure 11) and Discovery stations (Figure 12).

3.3.2 Pesticides

Hexachlorobenzene (HCB) tissue concentrations were reported at lower levels for mussels collected in 1994 from Deer Island and Discovery stations as compared to the 1993 concentrations. The 1993 results may have been unreliable due to possible blank contamination with HCB during sample processing and analysis.

The mussel body burdens of total-chlordane (trans-nonachlor, alpha-chlordane, heptachlor epoxide, and lindane gamma-BHC) and total DDTs (2,4-DDE, 4,4-DDE, 2,4-DDD, 2,4-DDT, 4,4-DDD, 4,4-DDT) at the Deer Island and Discovery stations have varied yearly since 1991, but have remained generally at the same level (Table 12).

The alpha-chlordane concentrations of Deer Island mussels was similar among the first three years, however, the 1994 results show a slight numerical increase in alpha-chlordane concentration (Figure 13). Dieldrin concentrations in Deer Island mussels were higher in 1994 as compared to the previous three years, however, analytical variability may have contributed to the observed differences.

The alpha-chlordane levels of Discovery mussels were similar in 1991 and 1992 but were about 40 percent lower in 1993. The alpha-chlordane concentrations in 1994 Discovery mussels was only slightly higher than the 1993 alpha-chlordane level (Figure 14). Dieldrin concentrations in Discovery mussels increased sharply between 1993 and 1994. This observation was in contrast to the trend of decreasing dieldrin concentrations observed from 1991 to 1993. The 1994 results, as with previous years, should be viewed with caution since the analytical results have been highly variable.

Deer Island mussel tissue concentrations for 2,4'-DDE, 4,4'-DDE, and 2,4'-DDT were slightly higher in 1994 than in previous years. The concentrations of 2,4'-DDD, 4,4'-DDD, and 4,4-DDT were lower in 1994 as compared to 1993 Deer Island mussels. No consistent trends in tDDT concentrations have been observed in Deer Island mussels during the past four years. Yearly variations in the observed tDDT concentrations may be partly attributable to analytical variations resulting from the use of a different capillary column configuration in 1993 and 1994 as compared to 1991-1992. Although the concentrations of 2,4'-DDE, 4,4'-DDE, and 4,4'-DDD were slightly higher in 1994 Deer Island and Discovery mussels the tDDT concentrations, at both stations, were numerically lower as compared to their respective 1993 concentrations.

3.3.3 Polychlorinated Biphenyls

Relatively high body burdens were observed in the 1993 and 1994 in Deer Island mussels for one congener; CL4-PCB(66) (Figure 15). The tissue concentrations of seventeen out of twenty PCB congeners were higher in 1993 Deer Island mussels (particularly CL4-PCB(52), CL4-PCB(77), CL5-PCB(101), CL6-PCB(138), and CL7-PCB(187)), as compared to the 1991, 1992, and 1994 levels. The PCB tissue concentrations for 1991, 1992, and 1994 Deer Island mussels were generally similar.

Two PCB congeners, CL5-PCB(105) and CL5-PCB(118), were noticeably higher in 1994 Discovery mussels compared to 1993 Discovery mussels (Figure 16). Generally, the remaining individual congener concentrations for Discovery mussels were at or below the average concentrations for the previous three years.

The tPCB body burdens were generally lower in mussels collected from all stations in 1994 compared to their respective deployment stations in 1993 (Table 12). Discovery mussel tPCB body burdens in 1994 were intermediate; higher than 1991 body burdens and lower than 1992 body burdens.

3.3.4 Mercury and Lead

Mercury tissue body burdens increased slightly at the Deer Island and LNB stations from 1993 to 1994, however, these increases were not significant. The 1994 Deer Island mercury tissue body burdens were the highest reported for that station to date. Mercury levels in the 1994 Gloucester predeployment mussels were lower than those reported in 1993, but, were still slightly higher than the national average mussels as reported by the Mussel Watch Program. Mercury concentrations in Discovery mussels were slightly higher in 1994 as compared to the national average as reported by the Mussel Watch Program. As with the reported results for lead, any apparent trends should be viewed with caution since analytical variability may affect the final results.

Lead body burdens for Gloucester, LNB, and Deer Island mussels were slightly higher in 1994 as compared to the 1993 levels. Discovery lead body burdens were higher in 1994 as compared to 1991 measurements. The apparent increase in lead body burdens may indicate a trend of increased lead body burdens at all stations, however, analytical variability may contribute to the observed increases.

4.0 Discussion

The 1994 tPAH tissue concentrations in Gloucester, Deer Island, and Discovery deployed mussels increased over 1993 tissue concentrations, while tPAH tissue concentrations decreased slightly for LNB deployed mussels. The observed increase in tPAH tissue concentrations was generally equally distributed between high and low molecular weight PAH species, however, the increase in tPAHs in 1994 Discovery deployed mussels was a result of increased concentrations of HMW-PAHs (LMW-PAHs at Discovery actually decreased slightly in 1994). These increases are in contrast to the general trend of decreasing tPAH tissue concentrations observed in studies conducted from 1987-1993 (Downey and Young, 1992; Downey et al. 1993).

Although the 1994 tPAH Deer Island and Discovery tissue concentrations indicate a relative increase, as compared to 1993 levels, the 1994 concentrations were still below those observed in 1991 and 1992. The 1993 concentrations may have been artificially low due to a high degree of variability. This variability may have contributed significantly to apparent differences among studies conducted in different years; therefore, any apparent trends should be viewed with caution.

The 1994 relative spatial trends of mussel body burdens for the three stations were consistent with spatial trends reported for 1991 through 1993 mussels. The total LMW-PAHs were found in highest concentrations in Deer Island mussels with the methyl-naphthalenes (2-methyl-, 2,6-dimethyl-, and 2,3,5-trimethyl-), phenanthrene, and 1-methylphenanthrene having the highest concentrations of the LMW-PAHs. The results of the 1994 study support the previous findings with respect to LMW-PAHs; high concentrations of the methylnaphthalene compounds in the Deer Island mussels suggests the Deer Island effluent is an important source of these contaminants for mussels deployed in proximity to the Deer Island sewage outfall.

In contrast, HMW-PAHs, were generally found in higher tissue concentrations in Discovery mussels, but, were also significantly elevated in the Deer Island mussels. These observations suggest that the direct effluent exposure may not be the primary source of these contaminants for bioaccumulation. Important source(s) of these contaminants appear to be more widespread throughout Boston Harbor and seem to have a significant influence on the distribution and availability for bioaccumulation of these contaminants at both Deer Island and Discovery stations. Consistently high tissue concentrations of HMW-PAHs in only Discovery mussels suggest that this "ambient" HMW-PAH contamination is not uniform throughout Boston Harbor and may be more prevalent in the inner harbor area.

The 1994 tDDT tissue concentrations in Deer Island mussels were similar to the 1991 tDDT tissue concentrations and indicate relatively stable tDDT concentrations

from 1987 to 1994. The tDDT tissue concentrations for Discovery deployed mussels decreased from the peak levels observed in 1993 to concentrations similar to those observed in 1991 and 1992. Analytical difficulties encountered in 1993 may have obscured the annual comparisons of body burdens at the Discovery and Gloucester stations; however, the 1994 tDDT tissue concentrations for Deer Island and the LNB stations were very similar to the 1993 findings.

The Deer Island tPCB tissue concentrations decreased slightly from 1993 to 1994. This observation suggests a general trend of decreasing tPCB concentrations since 1987. The tPCB tissue concentrations for Discovery deployed mussels decreased slightly between 1993 and 1994, however, the Discovery tPCB concentrations have generally increased from 1991 to 1994. These trends should be viewed with caution since analytical variability may significantly influence these observations.

The 1994 lead body burden for predeployment, Deer Island, and LNB mussels was higher than the 1993 concentrations at the same stations. The 1994 lead tissue body burdens for all stations were 2 to 5 times higher than the national mean and 1 to 2 times higher than the national "high" average reported by the Mussel Watch Program.

Mercury concentrations in the 1994 predeployment mussels were lower as compared to 1993 predeployment mussels while 1994 Deer Island and LNB mercury tissue concentrations were slightly higher than 1993 levels. The 1994 mercury tissue body burdens for mussels at all of the study sites were 1 to 3 times higher than the national mean reported by the Mussel Watch Program; however, all mercury levels were below the national "high" average.

The 1994 study has not provided any additional insight into the existence of specific trends as described in previous studies (1991 through 1993). Generally tPAHs, LMW-PAHs, HMW-PAHs and tPCBs displayed a trend of lower tissue concentrations in

Deer Island 1991-1993 mussels compared to 1987 tissue concentrations. Annual variability in tPAH, tPCB, and total pesticides tissue concentrations for 1991-1994 Deer Island mussels has made it difficult to identify consistent trends during this four year period.

The 1991-1994 studies have also indicated the Deer Island effluent probably contributes LMW-PAHs, particularly methylnaphthalenes, for bioaccumulation in mussels in proximity to the discharges. Annual comparisons of the bioaccumulation patterns of mussels and routine analyses of Deer Island water quality indicate that these biomonitoring techniques provide a useful tool in monitoring Deer Island effluent water quality trends for target compounds such as PAHs, PCBs, pesticide, metals and presumably other compounds that are bioaccumulated by mussels.

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Table 1. Mussel harvest and analysis experimental design summary for 1994. Square brackets represent the number of cages.

		Initial Deployment		Analysis		Forty - Day Harvest		Sixty - Day Harvest Analyses		
Station	Arrays	Mussels	Body Burden[1]	Biology[2]	Arrays	Mussels	Arrays	Mussels	Body Burden[1]	Biology[2]
Gloucester	NA	80	3	30	NA	NA	NA	NA	NA	NA
LNB	3	360	NA	NA	1[3]	118	2[6]	216	8	30
Deer Island	3	300	NA	NA	1[2]	89	1[2]	100	4	30
Discovery	1	200	NA	NA	1[2]	98	1[2]	89	3	30
Total Mussels		**940**								

NA - Not applicable

1. Body burden included the chemical analyses of mussel tissue. Numbers listed represent the number of composite samples. Each composite sample consisted of ten mussels. Samples were stored frozen until analysis.

2. Biology included sex, sexual maturity, wet weight of gonad-mantle and non-gonadal soft tissue, shell weight, and total shell length determinations.

Table 2. Survival and stage of gametogenesis of mussels for following "predeployment" (Gloucester), "forty" - day and "sixty" - day collections at specific stations.

Station	Number	Percent Survival	Sample Size	Number of Females		Number of Males	
				Mature	Immature	Mature	Immature
"Predeployment"							
Gloucester	NA	NA	30	6	1	3	20
"Forty" - Day							
LNB	118	98	NA	NA	NA	NA	NA
Deer Island	89	98	NA	NA	NA	NA	NA
Discovery	98	99	NA	NA	NA	NA	NA
"Sixty" - Day							
LNB	108	100	30	10	0	1	19
Deer Island	100	100	30	8	2	1	19
Discovery	89	94	30	13	0	4	13

NA - Not applicable

Table 3. Summary of various biological measurements expressed as mean values for mussels. "Predeployment" Gloucester represents measurements on mussels at the beginning of the study and "Sixty" - day retrieval represent values at the end of the study. All values reported on a wet basis.

Station	Mean Shell Length (mm)	Total Organism	Mean Wet Weight (g)		
			Gonad - Mantle	Non - gonadal Soft Tissue	Shell
"Predeployment"					
Gloucester	59.8	NA	2.1	4.1	12.0
"Sixty" - day					
LNB	62.9	28.1	3.7	6.1	14.1
Deer Island	63.7	30.9	3.1	4.8	14.6
Discovery	62.7	28.0	3.0	4.7	13.9

NA - Not Available

Table 4. Percent lipids and solids of mussels collected from four stations, 1994.

Station	N	Percent Lipids (dry weight) Mean	SD	Range	Percent Solids (dry weight) Mean	SD	Range
"Predeployment"							
Gloucester	4	0.58	0.10	0.45 - 0.68	13.8	0.7	13.1 - 14.8
"Sixty" - Day							
LNB	8	0.93	0.26	0.58 - 1.40	16.7	0.5	16.0 - 17.6
Deer Island	4	0.65	0.04	0.58 - 0.68	13.0	0.3	12.7 - 13.3
Discovery	3	0.74	0.05	0.68 - 0.77	13.6	1.7	11.7 - 14.8

N = number of composite samples

Table 5. Polynuclear aromatic hydrocarbons (ug/kg dry weight) concentrations in mussels exposed at the four stations. The total low molecular weight PAHs and total high molecular weight PAHs summed by group (i.e. 2 & 3 ring and 4, 5 & 6 ring) were calculated using detection limit values as an estimated concentration when individual analytes were not detected.

	Gloucester Predeployment, June 1994			Large Navigation Buoy, August 1994							
Laboratory ID:	225476	225477	225478	233376	233377	233378	233379	233381	233382	233383	233384
Parameter											
Naphthalene	11	12	12	<12	5	6	6	5	5	6	<5
2-Methylnaphthalene	14	13	12	<12	<5	<5	5	5	7	6	<5
1-Methylnaphthalene	8	8	8	<12	<5	<5	<5	<5	<5	<5	<5
1,1-Biphenyl	<6	<6	<7	<12	<5	7	<5	<5	<5	<5	<5
2,6-Dimethylnaphthalene	6	6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Acenaphthylene	<6	<6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Acenaphthene	<6	<6	<7	<12	<5	<5	<5	<5	<5	<5	<5
2,3,5-Trimethylnaphthalene	11	9	7	<12	<5	<5	<5	<5	<5	<5	<5
Fluorene	<6	<6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Phenanthrene	14	12	16	<12	<5	<5	<5	5	5	5	5
Anthracene	13	12	11	13	<5	<5	<5	<5	<5	<5	<5
1-Methylphenanthrene	<6	<6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Total of 2 & 3 ring groups	107	102	108	145	60	63	61	60	62	62	60
Fluoranthene	23	18	21	20	6	6	7	7	8	7	6
Pyrene	36	10	18	17	<5	<5	5	5	5	5	<5
Benz(a)anthracene	8	6	14	<12	<5	<5	<5	<5	<5	<5	<5
Chrysene	11	9	14	<12	<5	10	<5	<5	5	<5	<5
Benzo(b) and Benzo(k)fluoranthene	14	10	20	<12	<5	<5	<5	<5	<5	<5	<5
Benzo(e)pyrene	36	6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Benzo(a)pyrene	45	<6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Perylene	23	<6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Indeno(1,2,3-cd)pyrene	25	<6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Dibenzo(a,h)anthracene	<6	<6	<7	<12	<5	31	<5	<5	<5	<5	<5
Benzo(g,h,i)perylene	30	<6	<7	<12	<5	<5	<5	<5	<5	<5	<5
Total of 4, 5 & 6 ring groups	257	89	129	145	56	87	57	57	58	57	56
Total PAH's	364	191	237	290	116	150	118	117	120	119	116

	Deer Island, August, 1994				Discovery, August 1994		
Laboratory ID:	233366	233367	233368	233369	233371	233372	233373
Parameter							
Naphthalene	21	10	12	11	7	7	6
2-Methylnaphthalene	30	20	21	23	6	5	<5
1-Methylnaphthalene	18	12	12	13	<5	<5	<5
1,1-Biphenyl	<17	<5	7	<5	<5	<5	<5
2,6-Dimethylnaphthalene	45	32	29	39	<5	<5	<5
Acenaphthylene	<17	<5	<5	<5	<5	<5	<5
Acenaphthene	<17	<5	<5	<5	6	9	6
2,3,5-Trimethylnaphthalene	59	45	40	49	5	7	<5
Fluorene	<17	7	8	8	<5	<5	<5
Phenanthrene	55	37	31	38	10	13	10
Anthracene	21	11	8	10	9	12	10
1-Methylphenanthrene	36	28	22	28	7	9	8
Total of 2 & 3 ring groups	353	217	200	234	75	87	75
Fluoranthene	245	146	108	159	325	661	493
Pyrene	200	118	87	126	324	633	482
Benz(a)anthracene	80	56	48	64	191	195	148
Chrysene	128	87	76	94	216	293	232
Benzo(b) and Benzo(k)fluoranthene	141	107	88	131	396	372	278
Benzo(e)pyrene	87	60	50	72	228	285	213
Benzo(a)pyrene	32	25	18	30	99	86	72
Perylene	<17	9	7	10	19	22	17
Indeno(1,2,3-cd)pyrene	<17	16	11	18	31	27	22
Dibenzo(a,h)anthracene	<17	5	<5	6	13	10	8
Benzo(g,h,i)perylene	41	23	12	21	48	48	40
Total of 4, 5 & 6 ring groups	1005	652	510	731	1890	2632	2005
Total PAH's	1358	869	710	965	1965	2719	2080

Table 6. Average concentrations of PAHs (ug/kg dry weight) from mussels harvested during predeployment at Gloucester and during the 60-day retrieval from the three stations. Averages were calculated using the detection limit values as an estimated concentration when individual analytes were not detected.

Parameter	June Predeployment Gloucester (SAMPLE SIZE -3)			August 60-Day Retrieval Large Navigation Buoy (SAMPLE SIZE -8)			August 60-Day Retrieval Deer Island (SAMPLE SIZE -4)			August 60-Day Retrieval Discovery (SAMPLE SIZE -3)		
	Avg	SD	Range	Avg	SD	Range	Avg	SD	Range	Avg	SD	Range
Naphthalene	12	0.7	11 - 12	5	0.5	5 - 6	11	1.0	10 - 12	7	0.6	6 - 7
2-Methylnaphthalene	14	0.7	13 - 14	5	0.8	5 - 7	21	1.5	20 - 23	5	0.6	5 - 6
1-Methylnaphthalene	8	0.0	8 - 8	5	0.0	5 - 5	12	0.6	12 - 13	5	0.0	5 - 5
1,1-Biphenyl	6	0.0	6 - 6	5	0.8	5 - 7	6	1.2	5 - 7	5	0.0	5 - 5
2,6-Dimethylnaphthalene	6	0.0	6 - 6	5	0.0	5 - 5	33	5.1	29 - 39	5	0.0	5 - 5
Acenaphthylene	6	0.0	6 - 6	5	0.0	5 - 5	5	0.0	5 - 5	5	0.0	5 - 5
Acenaphthene	6	0.0	6 - 6	5	0.0	5 - 5	5	0.0	5 - 5	7	1.7	6 - 9
2,3,5-Trimethylnaphthalene	10	1.4	9 - 11	5	0.0	5 - 5	45	4.5	40 - 49	6	1.2	5 - 7
Fluorene	6	0.0	6 - 6	5	0.0	5 - 5	8	0.6	7 - 8	5	0.0	5 - 5
Phenanthrene	13	1.4	12 - 14	5	0.0	5 - 5	35	3.8	31 - 38	11	1.7	10 - 13
Anthracene	13	0.7	12 - 13	5	0.0	5 - 5	10	1.5	8 - 11	10	1.5	9 - 12
1-Methylphenanthrene	6	0.0	6 - 6	5	0.0	5 - 5	26	3.5	22 - 28	8	1.0	7 - 9
Total of 2 & 3 ring groups	105	3.5	102 - 107	61	1.2	60 - 63	217	17.0	200 - 234	79	6.9	75 - 87
Fluoranthene	21	3.5	18 - 23	7	0.8	6 - 8	138	26.5	108 - 159	493	168.0	325 - 661
Pyrene	23	18.4	10 - 36	5	0.0	5 - 5	110	20.6	87 - 126	480	154.5	324 - 633
Benz(a)anthracene	7	1.4	6 - 8	5	0.0	5 - 5	56	8.0	48 - 64	178	26.1	148 - 195
Chrysene	10	1.4	9 - 11	6	1.9	5 - 10	86	9.1	76 - 94	247	40.6	216 - 293
Benzo(b) and Benzo(k)fluoranthene	12	2.8	10 - 14	5	0.0	5 - 5	109	21.5	88 - 131	349	62.4	278 - 396
Benzo(e)pyrene	21	21.2	6 - 36	5	0.0	5 - 5	61	11.0	50 - 72	242	38.0	213 - 285
Benzo(a)pyrene	26	27.6	6 - 45	5	0.0	5 - 5	24	6.0	18 - 30	86	13.5	72 - 99
Perylene	15	12.0	6 - 23	5	0.0	5 - 5	9	1.5	7 - 10	19	2.5	17 - 22
Indeno(1,2,3-cd)pyrene	16	13.4	6 - 25	5	0.0	5 - 5	15	3.6	11 - 18	27	4.5	22 - 31
Dibenzo(a,h)anthracene	6	0.0	6 - 6	9	9.8	5 - 31	5	0.6	5 - 6	10	2.5	8 - 13
Benzo(g,h,i)perylene	18	17.0	6 - 30	5	0.0	5 - 5	19	5.9	12 - 23	45	4.6	40 - 48
Total of 4, 5 & 6 ring groups	173	118.8	89 - 257	61	11.4	56 - 87	631	91.4	510 - 731	2176	399.4	1890 - 2632
Total PAH's	278	122.3	191 - 364	122	12.3	116 - 150	848	105.2	710 - 965	2255	406.2	1965 - 2719

Table 7. Pesticides (ug/kg dry weight) concentrations in mussels exposed at the four stations. Total pesticides were calculated using detection limit values as an estimated concentration when individual analytes were not detected.

	Gloucester Predeployment, June 1994			Large Navigation Buoy, August 1994							
Laboratory ID:	225476	225477	225478	233376	233377	233378	233379	233381	233382	233383	233384
Parameter											
Hexachlorobenzene	<0.61	2.00	0.74	<3.73	<0.57	0.68	<0.56	<0.56	<0.49	<0.92	<0.51
Lindane gamma-BHC	<0.61	<0.72	1.25	<3.73	<0.57	<0.51	<0.56	<0.56	<0.49	<0.92	<0.51
Heptachlor	<0.61	<0.72	1.68	<3.73	<0.57	<0.51	<0.56	<0.56	<0.49	<0.92	<0.51
Aldrin	<0.61	3.65	<0.62	<3.73	<0.57	0.54	<0.56	0.60	0.81	<0.92	0.72
Heptachlor Epoxide	1.61	2.12	1.64	6.05	1.16	2.08	0.88	0.84	0.66	<0.92	0.66
alpha-Chlordane	3.49	3.63	3.28	8.86	2.85	2.91	2.87	4.19	3.92	4.50	3.65
trans-Nonachlor	3.73	3.70	4.57	7.14	3.05	3.23	2.99	4.53	4.02	4.66	3.90
Dieldrin	2.18	<0.72	<0.62	<3.73	1.57	1.62	1.68	2.24	2.15	2.49	2.01
2,4-DDE	3.45	3.33	<0.62	7.45	<0.57	<0.51	<0.56	<0.56	<0.49	<0.92	<0.51
4,4-DDE	8.98	7.93	8.15	25.45	5.70	6.10	6.55	8.67	7.18	9.07	8.25
2,4-DDD	<0.61	<0.72	<0.62	<3.73	<0.57	<0.51	<0.56	<0.56	<0.49	<0.92	<0.51
2,4-DDT	<0.61	<0.72	<0.62	<3.73	<0.57	<0.51	<0.56	<0.56	<0.49	<0.92	<0.51
4,4-DDD	14.04	13.88	13.36	14.41	4.99	5.33	5.17	7.65	6.80	8.33	8.00
Mirex	1.54	1.63	2.78	<4.56	<0.55	<0.49	<0.56	<0.56	<0.54	<0.95	<0.56
4,4-DDT	<0.67	<0.76	<0.55	<4.56	<0.55	2.75	2.43	3.54	3.27	3.60	4.10
Dieldrin/Aldrin group	**2.78**	**4.37**	**1.25**	**7.45**	**2.15**	**2.16**	**2.24**	**2.83**	**2.96**	**3.41**	**2.73**
Chlordane group	**9.43**	**10.16**	**10.74**	**25.77**	**7.63**	**8.73**	**7.30**	**10.12**	**9.09**	**11.00**	**8.72**
DDD/DDE/DDT	**28.36**	**27.34**	**23.93**	**59.33**	**12.96**	**15.71**	**15.82**	**21.55**	**18.71**	**23.76**	**21.88**

	Deer Island, August, 1994				Discovery, August 1994		
Laboratory ID:	233366	233367	233368	233369	233371	233372	233373
Parameter							
Hexachlorobenzene	<4.68	<0.76	<0.67	<0.65	<1.64	<2.69	<2.11
Lindane gamma-BHC	<4.68	1.54	1.25	1.89	<1.64	<2.69	<2.11
Heptachlor	6.32	1.60	1.23	1.38	<1.64	<2.69	<2.11
Aldrin	9.36	<0.76	<0.67	<0.65	<1.64	<2.69	<2.11
Heptachlor Epoxide	6.40	0.95	<0.67	<0.65	4.30	<2.69	<2.11
alpha-Chlordane	35.52	15.15	12.46	13.84	12.76	14.63	11.10
trans-Nonachlor	30.44	12.50	10.43	10.78	9.30	13.31	10.47
Dieldrin	<4.68	11.29	9.99	9.87	34.45	10.31	<2.11
2,4-DDE	<4.68	5.06	4.49	4.61	12.74	<2.69	<2.11
4,4-DDE	36.76	19.74	16.73	16.67	33.45	33.23	34.98
2,4-DDD	<4.68	<0.76	<0.67	<0.65	<1.64	<2.69	<2.11
2,4-DDT	<4.68	4.48	3.77	4.00	<1.64	<2.69	<2.11
4,4-DDD	41.80	17.79	15.40	15.98	39.43	43.88	33.12
Mirex	<5.85	<0.69	<0.58	<0.57	<1.81	<3.02	<2.32
4,4-DDT	25.40	7.01	5.91	6.19	2.67	<3.02	<2.32
Dieldrin/Aldrin group	**14.04**	**12.05**	**10.66**	**10.52**	**36.09**	**13.00**	**4.22**
Chlordane group	**77.04**	**30.14**	**24.81**	**27.16**	**28.00**	**33.31**	**25.80**
DDD/DDE/DDT	**118.00**	**54.84**	**46.97**	**48.10**	**91.57**	**88.19**	**76.76**

Table 8. Average concentrations of pesticides (ug/kg dry weight) from mussels harvested during predeployment at Gloucester and during the 60-day retrieval from the three stations. Averages were calculated using the detection limit values as an estimated concentration when individual analytes were not detected.

Parameter	June Predeployment Gloucester (SAMPLE SIZE -3)			August 60-Day Retrieval Large Navigation Buoy (SAMPLE SIZE -7)			August 60-Day Retrieval Deer Island (SAMPLE SIZE -3)			August 60-Day Retrieval Discovery (SAMPLE SIZE -3)		
	Avg	SD	Range	Avg	SD	Range	Avg	SD	Range	Avg	SD	Range
Hexachlorobenzene	1.11	0.77	0.61 - 2.00	0.61	0.15	0.49 - 0.92	0.69	0.06	0.65 - 0.76	2.15	0.52	1.64 - 2.69
Lindane gamma-BHC	0.86	0.34	0.61 - 1.25	0.59	0.15	0.49 - 0.92	1.56	0.32	1.25 - 1.89	2.15	0.52	1.64 - 2.69
Heptachlor	1.00	0.59	0.61 - 1.68	0.59	0.15	0.49 - 0.92	1.40	0.19	1.23 - 1.60	2.15	0.52	1.64 - 2.69
Aldrin	1.63	1.75	0.61 - 3.65	0.67	0.15	0.54 - 0.92	0.69	0.06	0.65 - 0.76	2.15	0.52	1.64 - 2.69
Heptachlor Epoxide	1.79	0.28	1.61 - 2.12	1.03	0.49	0.66 - 2.08	0.76	0.17	0.65 - 0.95	3.03	1.13	2.11 - 4.30
alpha-Chlordane	3.47	0.17	3.28 - 3.63	3.56	0.68	2.85 - 4.50	13.82	1.35	12.46 - 15.15	12.83	1.76	11.10 - 14.63
trans-Nonachlor	4.00	0.49	3.70 - 4.57	3.77	0.69	2.99 - 4.66	11.24	1.11	10.43 - 12.50	11.03	2.06	9.30 - 13.31
Dieldrin	1.17	0.87	0.62 - 2.18	1.96	0.35	1.57 - 2.49	10.38	0.79	9.87 - 11.29	15.62	16.81	2.11 - 34.45
2,4-DDE	2.47	1.60	0.62 - 3.45	0.59	0.15	0.49 - 0.92	4.72	0.30	4.49 - 5.06	5.85	5.98	2.11 - 12.74
4,4-DDE	8.35	0.55	7.93 - 8.98	7.36	1.32	5.70 - 9.07	17.71	1.76	16.67 - 19.74	33.89	0.95	33.23 - 34.98
2,4-DDD	0.65	0.06	0.61 - 0.72	0.59	0.15	0.49 - 0.92	0.69	0.06	0.65 - 0.76	2.15	0.52	1.64 - 2.69
2,4-DDT	0.65	0.06	0.61 - 0.72	0.59	0.15	0.49 - 0.92	4.08	0.36	3.77 - 4.48	2.15	0.52	1.64 - 2.69
4,4-DDD	13.76	0.36	13.36 - 14.04	6.61	1.44	4.99 - 8.33	16.39	1.25	15.40 - 17.79	38.81	5.41	33.12 - 43.88
Mirex	1.99	0.69	1.54 - 2.78	0.60	0.16	0.49 - 0.95	0.61	0.07	0.57 - 0.69	2.38	0.61	1.81 - 3.02
4,4-DDT	0.66	0.10	0.55 - 0.76	2.89	1.17	0.55 - 4.10	6.37	0.57	5.91 - 7.01	2.67	0.35	2.32 - 3.02
Dieldrin/Aldrin group	2.80	1.56	1.25 - 4.37	2.64	0.48	2.15 - 3.41	11.08	0.85	10.52 - 12.05	17.77	16.46	4.22 - 36.09
Chlordane group	10.11	0.65	9.43 - 10.74	8.94	1.30	7.30 - 11.00	27.37	2.67	24.81 - 30.14	29.04	3.86	25.80 - 33.31
DDD/DDE/DDT	26.54	2.32	23.93 - 28.36	18.63	3.96	12.96 - 23.76	49.97	4.26	46.97 - 54.84	85.51	7.76	76.76 - 91.57

Table 9. Polychlorinated biphenyl (ug/kg dry weight) concentrations in mussels exposed at the four stations. Total PCBs were calculated using detection limit values as an estimated concentration when individual analytes were not detected.

Laboratory ID:	Gloucester Predeployment, June 1994			Large Navigation Buoy, August 1994							
Parameter	225476	225477	225478	233376	233377	233378	233379	233381	233382	233383	233384
CL2 - PCB (8)	4.69	8.67	4.15	<3.73	<0.57	<0.51	<0.56	<0.53	<0.49	<0.92	<0.51
CL3 - PCB (18)	2.78	3.09	2.19	5.91	1.62	1.16	1.13	1.40	1.50	1.44	1.27
CL3 - PCB (28)	3.51	4.16	3.77	4.55	1.51	1.75	1.52	2.29	2.19	2.17	1.89
CL4 - PCB (44)	<0.61	<0.72	7.08	<3.73	2.57	3.09	2.81	3.38	3.17	3.89	3.53
CL4 - PCB (52)	6.59	7.07	6.75	<3.73	<0.57	2.59	2.71	3.99	2.82	4.25	3.78
CL4 - PCB (66)	10.94	11.14	10.58	13.91	5.75	6.22	6.05	8.48	8.42	9.20	8.98
CL4 - PCB (77)	<0.61	<0.72	<0.62	26.05	9.34	12.22	11.54	13.02	13.30	14.25	16.14
CL5 - PCB (101)	15.53	17.28	16.96	17.00	7.18	7.71	7.44	11.07	9.71	12.16	10.43
CL5 - PCB (105)	4.92	6.19	5.32	6.09	3.14	3.04	3.00	4.30	4.32	5.08	4.57
CL5 - PCB (118)	11.35	11.05	10.62	15.59	7.49	7.27	7.00	10.26	10.15	12.13	9.90
CL6 - PCB (153)	12.53	13.30	14.85	19.82	11.54	11.57	10.54	16.28	14.05	17.85	15.33
CL5 - PCB (126)	<0.67	<0.76	<0.55	<4.56	<0.55	<0.49	<0.56	<0.52	<0.54	<0.95	<0.56
CL6 - PCB (128)	1.80	1.73	1.63	<4.56	1.40	1.42	1.39	2.09	1.84	2.24	2.06
CL6 - PCB (138)	12.87	12.49	10.68	20.61	8.53	8.71	8.37	12.32	12.25	13.66	13.04
CL7 - PCB (170)	<0.67	<0.76	<0.55	<4.56	<0.55	0.56	<0.56	<0.52	<0.54	<0.95	<0.56
CL7 - PCB (180)	2.48	2.68	2.95	5.22	1.70	1.68	1.81	2.20	2.23	2.56	2.27
CL7 - PCB (187)	4.35	4.37	3.28	8.61	3.24	3.30	3.11	4.80	5.46	5.34	5.12
CL8 - PCB (195)	0.72	<0.76	<0.55	<4.56	<0.55	<0.49	<0.56	<0.52	<0.54	<0.95	<0.56
CL9 - PCB (206)	3.17	5.49	2.95	<4.56	<0.55	<0.49	<0.56	<0.52	<0.54	<0.95	<0.56
CL10 - PCB (209)	1.04	<0.76	1.13	<4.56	<0.55	<0.49	<0.56	<0.52	<0.54	<0.95	<0.56
Total PCBs	101.84	113.18	107.19	181.87	68.91	74.74	71.77	99.03	94.58	111.88	101.60

Laboratory ID:	Deer Island, August, 1994				Discovery, August 1994		
Parameter	233366	233367	233368	233369	233371	233372	233373
CL2 - PCB (8)	<4.68	<0.76	0.98	1.12	<1.64	<2.69	<2.11
CL3 - PCB (18)	14.92	1.30	1.17	<0.65	2.12	7.37	5.76
CL3 - PCB (28)	26.80	10.43	8.75	9.40	14.44	19.51	15.28
CL4 - PCB (44)	27.24	8.02	7.16	7.77	20.00	29.94	<2.11
CL4 - PCB (52)	33.92	11.82	10.25	10.92	33.68	36.64	28.38
CL4 - PCB (66)	47.48	17.24	15.22	15.98	54.63	67.37	<2.11
CL4 - PCB (77)	89.48	2.80	2.43	2.49	7.66	46.09	<2.11
CL5 - PCB (101)	63.04	21.05	18.86	18.68	69.34	94.25	73.16
CL5 - PCB (105)	21.48	9.62	9.25	8.81	25.71	31.72	26.04
CL5 - PCB (118)	54.24	19.26	17.42	16.62	59.66	82.98	64.97
CL6 - PCB (153)	61.88	25.77	23.58	23.16	63.30	81.39	66.01
CL5 - PCB (126)	<5.85	<0.69	<0.58	<0.57	<1.81	<3.02	<2.32
CL6 - PCB (128)	9.65	3.46	2.96	2.99	10.05	12.55	9.84
CL6 - PCB (138)	63.50	23.39	20.12	20.37	69.34	80.41	62.54
CL7 - PCB (170)	6.70	2.29	2.58	2.24	2.97	<3.02	<2.32
CL7 - PCB (180)	15.75	5.38	5.24	4.74	8.18	9.13	7.96
CL7 - PCB (187)	19.35	7.28	6.45	6.50	17.85	20.06	16.22
CL8 - PCB (195)	<5.85	<0.69	<0.58	<0.57	<1.81	<3.02	<2.32
CL9 - PCB (206)	<5.85	<0.69	<0.58	<0.57	<1.81	<3.02	<2.32
CL10 - PCB (209)	<5.85	<0.69	<0.58	<0.57	<1.81	<3.02	<2.32
Total PCBs	583.51	172.63	154.74	154.72	467.81	637.20	396.23

Table 10. Average concentrations of PCBs (ug/kg dry weight) from mussels harvested during predeployment at Gloucester and during the 60-day retrieval from the three stations. Averages were calculated using the detection limit values as an estimated concentration when individual analytes were not detected.

Parameter	June Predeployment Gloucester (SAMPLE SIZE -3)			August 60-Day Retrieval Large Navigation Buoy (SAMPLE SIZE -7)			August 60-Day Retrieval Deer Island (SAMPLE SIZE -3)			August 60-Day Retrieval Discovery (SAMPLE SIZE -3)		
	Avg	SD	Range	Avg	SD	Range	Avg	SD	Range	Avg	SD	Range
CL2 - PCB (8)	5.84	2.47	4.15 - 8.67	0.58	0.15	0.49 - 0.92	0.95	0.18	0.76 - 1.12	2.15	0.52	1.64 - 2.69
CL3 - PCB (18)	2.69	0.46	2.19 - 3.09	1.36	0.18	1.13 - 1.62	1.04	0.34	0.65 - 1.30	5.08	2.69	2.12 - 7.37
CL3 - PCB (28)	3.82	0.33	3.51 - 4.16	1.90	0.32	1.51 - 2.29	9.53	0.85	8.75 - 10.43	16.41	2.71	14.44 - 19.51
CL4 - PCB (44)	2.80	3.70	0.61 - 7.08	3.21	0.44	2.57 - 3.89	7.65	0.44	7.16 - 8.02	17.35	14.10	2.11 - 29.94
CL4 - PCB (52)	6.80	0.24	6.59 - 7.07	2.96	1.25	0.57 - 4.25	11.00	0.79	10.25 - 11.82	32.90	4.18	28.38 - 36.64
CL4 - PCB (66)	10.89	0.28	10.58 - 11.14	7.58	1.51	5.75 - 9.20	16.15	1.02	15.22 - 17.24	41.37	34.59	2.11 - 67.37
CL4 - PCB (77)	0.65	0.06	0.61 - 0.72	12.83	2.14	9.34 - 16.14	2.57	0.20	2.43 - 2.80	18.62	23.95	2.11 - 46.09
CL5 - PCB (101)	16.59	0.93	15.53 - 17.28	9.39	1.97	7.18 - 12.16	19.53	1.32	18.68 - 21.05	78.92	13.42	69.34 - 94.25
CL5 - PCB (105)	5.48	0.65	4.92 - 6.19	3.92	0.85	3.00 - 5.08	9.23	0.41	8.81 - 9.62	27.82	3.38	25.71 - 31.72
CL5 - PCB (118)	11.01	0.37	10.62 - 11.35	9.17	1.94	7.00 - 12.13	17.77	1.35	16.62 - 19.26	69.20	12.22	59.66 - 82.98
CL6 - PCB (153)	13.56	1.18	12.53 - 14.85	13.88	2.76	10.54 - 17.85	24.17	1.40	23.16 - 25.77	70.23	9.76	63.30 - 81.39
CL5 - PCB (126)	0.66	0.10	0.55 - 0.76	0.59	0.16	0.49 - 0.95	0.61	0.07	0.57 - 0.69	2.38	0.61	1.81 - 3.02
CL6 - PCB (128)	1.72	0.09	1.63 - 1.80	1.78	0.37	1.39 - 2.24	3.14	0.28	2.96 - 3.46	10.81	1.50	9.84 - 12.55
CL6 - PCB (138)	12.01	1.17	10.68 - 12.87	10.98	2.34	8.37 - 13.66	21.29	1.82	20.12 - 23.39	70.76	9.02	62.54 - 80.41
CL7 - PCB (170)	0.66	0.10	0.55 - 0.76	0.61	0.15	0.52 - 0.95	2.37	0.18	2.24 - 2.58	2.77	0.39	2.32 - 3.02
CL7 - PCB (180)	2.70	0.24	2.48 - 2.95	2.06	0.34	1.68 - 2.56	5.12	0.34	4.74 - 5.38	8.42	0.62	7.96 - 9.13
CL7 - PCB (187)	4.00	0.62	3.28 - 4.37	4.34	1.07	3.11 - 5.46	6.74	0.47	6.45 - 7.28	18.04	1.92	16.22 - 20.06
CL8 - PCB (195)	0.67	0.11	0.55 - 0.76	0.59	0.16	0.49 - 0.95	0.61	0.07	0.57 - 0.69	2.38	0.61	1.81 - 3.02
CL9 - PCB (206)	3.87	1.41	2.95 - 5.49	0.59	0.16	0.49 - 0.95	0.61	0.07	0.57 - 0.69	2.38	0.61	1.81 - 3.02
CL10 - PCB (209)	0.98	0.20	0.76 - 1.13	0.59	0.16	0.49 - 0.95	0.61	0.07	0.57 - 0.69	2.38	0.61	1.81 - 3.02
Total PCB's	**107.40**	**14.70**	**101.84 - 113.18**	**88.93**	**16.92**	**68.91 - 111.88**	**160.70**	**10.33**	**154.72 - 172.63**	**500.41**	**123.75**	**396.23 - 637.20**

Table 11. Target metals (ug/kg dry weight) concentrations in mussels exposed at Gloucester and three stations. Total metals were calculated using the detection limit value as an estimated concentration when individual analytes were not detected. Tissue weight data were obtained from Table 3.

											Total Weight (g)		NON-GONADAL Tissue Concentration Adjusted	
	Gloucester Predeployment, June 1994										Soft	Non-		
Laboratory ID:	225475	225476	225477						AVE	STD	Tissue	Gonadal	AVE	STDS
Parameter														
Mercury	220	290	20						176.7	140.1	6.2	4.1	267.2	211.9
Lead	5700	13800	6300						8600.0	4513.3	6.2	4.1	13004.9	6825.0
	Large Navigation Buoy, August, 1994													
Laboratory ID:	233376	233377	233378	233379	233381	233382	233383	233384						
Parameter									AVE	STD				
Mercury	120	132	109	145	122	123	84	210	130.6	36.6	9.8	6.1	209.9	58.9
Lead	4700	4600	4300	4100	5200	6000	4400	5100	4800.0	614.1	9.8	6.1	7711.5	986.6
	Deer Island, August, 1994													
Laboratory ID:	233366	233367	233368	233369										
Parameter									AVE	STD				
Mercury	126	177	230	300					208.3	74.5	7.9	4.8	342.7	122.5
Lead	9200	8900	6400	12000					9125.0	2291.1	7.9	4.8	15018.2	3770.8
	Discovery, August, 1994													
Laboratory ID:	233371	233372	233373											
Parameter									AVE	STD				
Mercury	155	167	167						163.0	6.9	7.7	4.7	267.0	11.4
Lead	5800	9200	5000						6666.7	2230.1	7.7	4.7	10922.0	3653.6

Table 11. Target metals (ug/Kg dry weight) concentrations in mussels exposed at Gloucester and three stations. Total metals were calculated using the detection limit value as an estimated concentration when individual analytes were not detected. Tissue weight data were obtained from Table 3.

Table 12. Comparison of body burdens of deployed mussels for select organic compounds and metals.

Parameters	Mussel Watch National Mean Average	Mussel Watch National High (1) Average	MWRA 1987 Deer Island Average	MWRA 1991 Gloucester Average	MWRA 1991 Deer Island Average	MWRA 1991 Discovery Average	MWRA 1992 Gloucester Average	MWRA 1992 LNB Average	MWRA 1992 Deer Island Average	MWRA 1992 Discovery Average
PAH (ug/Kg dry weight)										
LMW PAH			1221	113	516	239	80	61	427	199
HMW PAH			1123	104	691	2330	136	69	1507	3347
Total PAH	260	890	2343	217	1207	2569	216	129	1934	3546
Pesticides (ug/Kg dry weight)										
Total Chlordane	14	31		7	28	24	6	6	19	47
Total DDT	37	120	63	28	48	94	15	12	25	103
Polychlorinated Biphenyls (ug/Kg dry weight)										
Total PCB	110	470	630	77	199	477	65	44	133	652
Metals (mg/Kg dry weight)										
Mercury	0.09	0.24	0.12							
Lead	1.80	4.30	7.15	6.50	6.40	5.90				

Parameters	Lynn 1993 60-DAY Gloucester Average	Lynn 1993 60-DAY Lynn Average	Predeployment Gloucester Average	MWRA 1993 (2) 60-day LNB Average	MWRA 1993 (2) 60-day Deer Island Average	MWRA 1993 (2) 60-day Discovery Average	Predeployment Gloucester Average	MWRA 1994 60-day LNB Average	MWRA 1994 60-day Deer Island Average	MWRA 1994 60-day Discovery Average
PAH (ug/Kg dry weight)										
LMW PAH	70	90	66	66	169	110	106	61	217	79
HMW PAH	113	143	122	101	496	1210	158	61	631	2176
Total PAH	183	232	188	166	665	1321	264	122	848	2255
Pesticides (ug/Kg dry weight)										
Total Chlordane	9	15	16	11	24	26	10	9	27	29
Total DDT	24	36	82	30	63	130	27	19	50	86
Polychlorinated Biphenyls (ug/Kg dry weight)										
Total PCB	86	134	239	110	321	596	107	89	161	500
Metals (mg/Kg dry weight)										
Mercury	0.56	0.17	0.39	0.10	0.18		0.18	0.13	0.21	0.16
Lead	2.80	2.40	5.12	3.71	5.88		8.60	4.80	9.13	6.67

1 "High" concentrations were reported by the Mussel Watch Program as one where the logarithmic value is more than the mean plus one standard deviation of the logarithms for all concentrations.

2 Concentrations may be biased high due to the GC/ECD methodologies for pesticides / PCB's employed in 1993 (Downey et al. 1994)

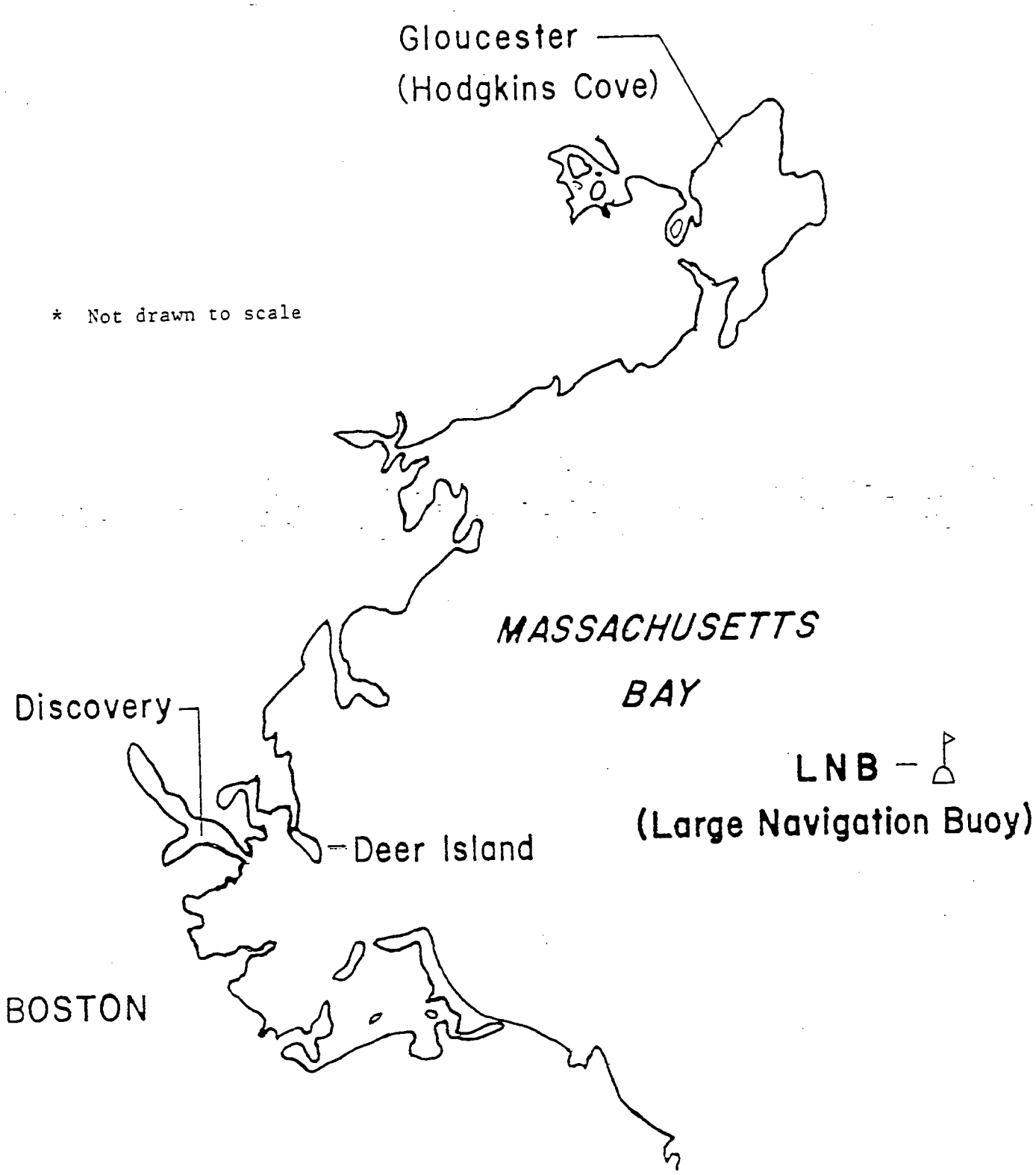

Figure 1. The mussel deployment locations for the 1994 bioaccumulation study. The Gloucester location was the source of all mussels for this study.

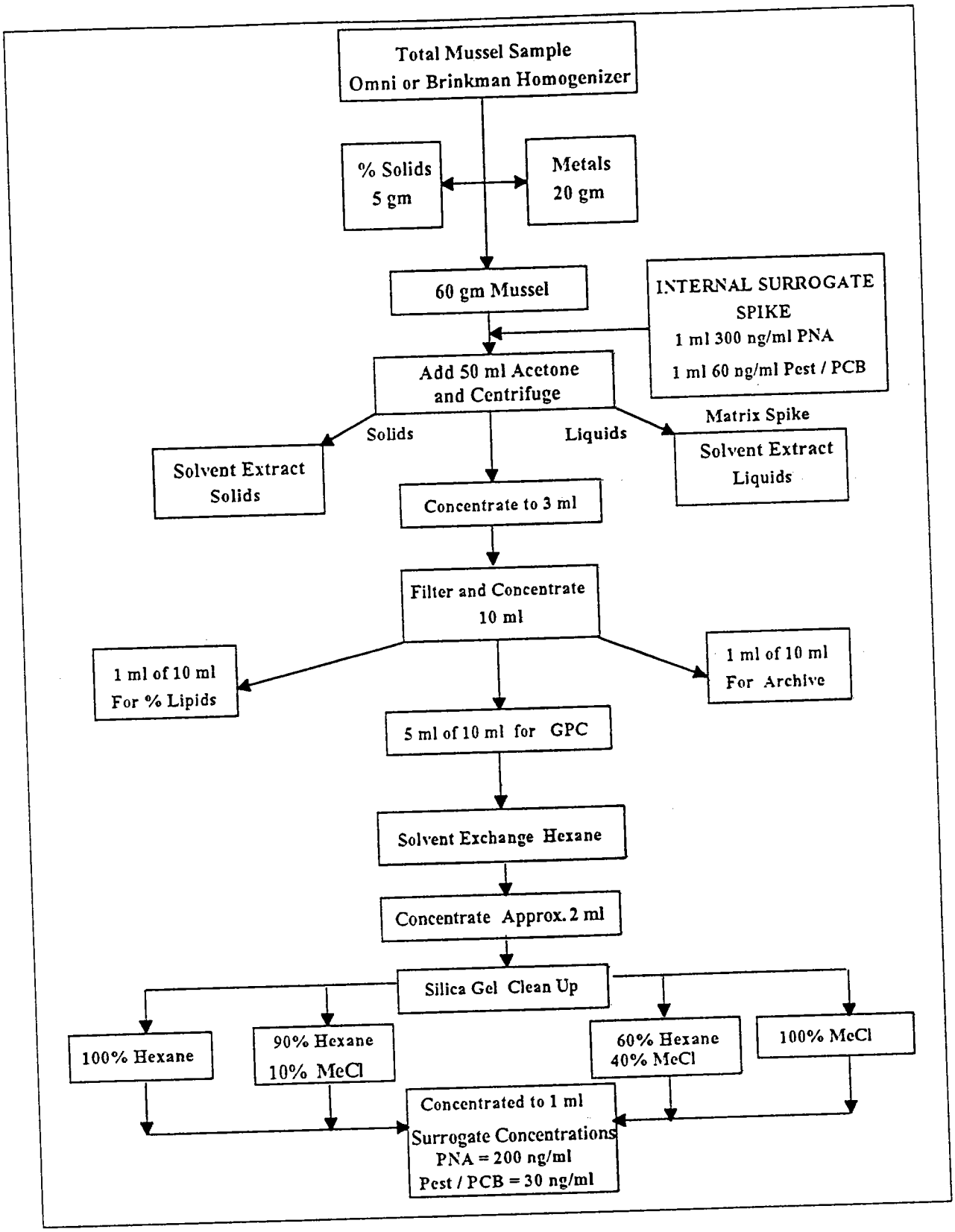

Figure 2. Extraction procedures and analytical methods for organic compounds.

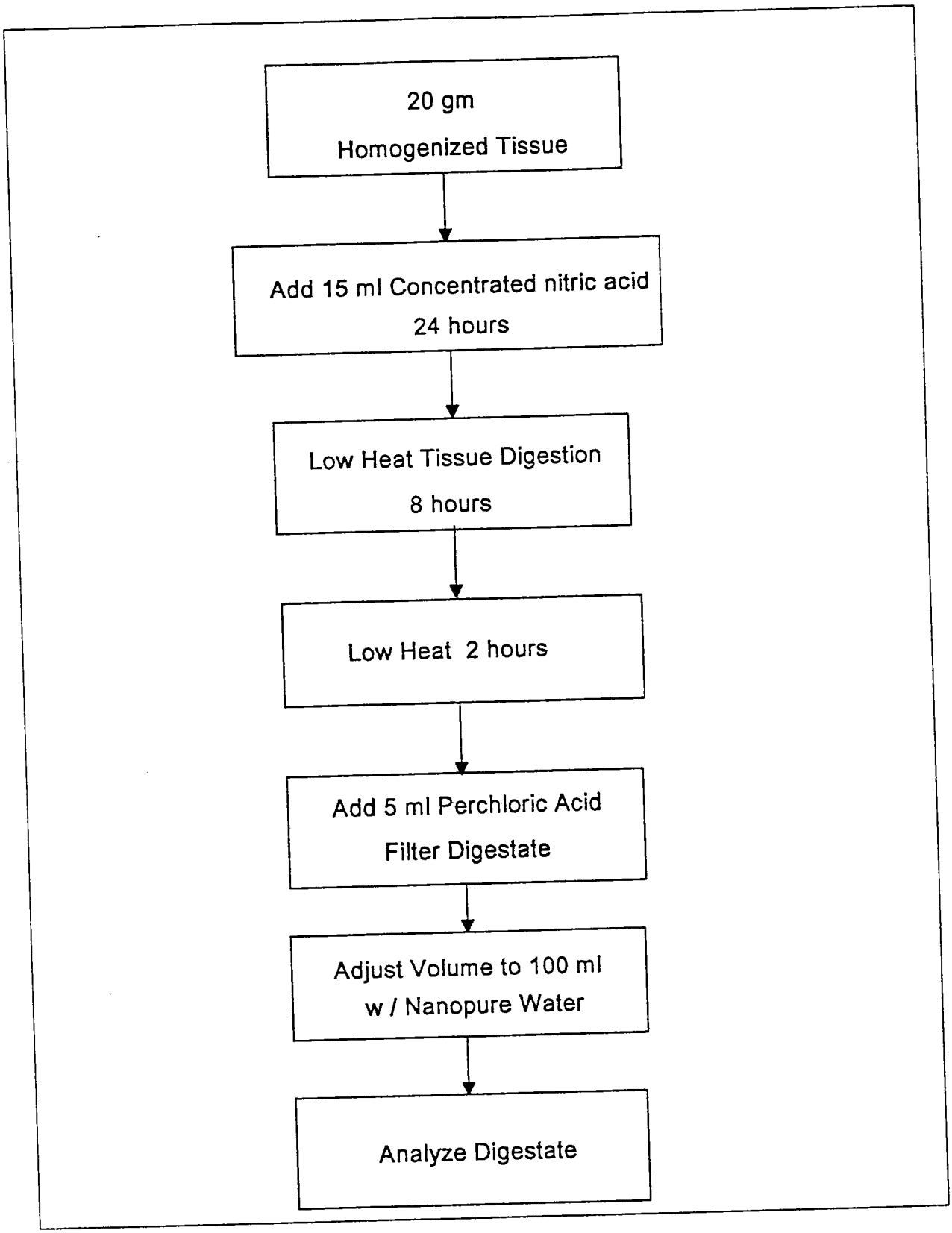

Figure 3. Methodology used for metals analysis of mussel tissues.

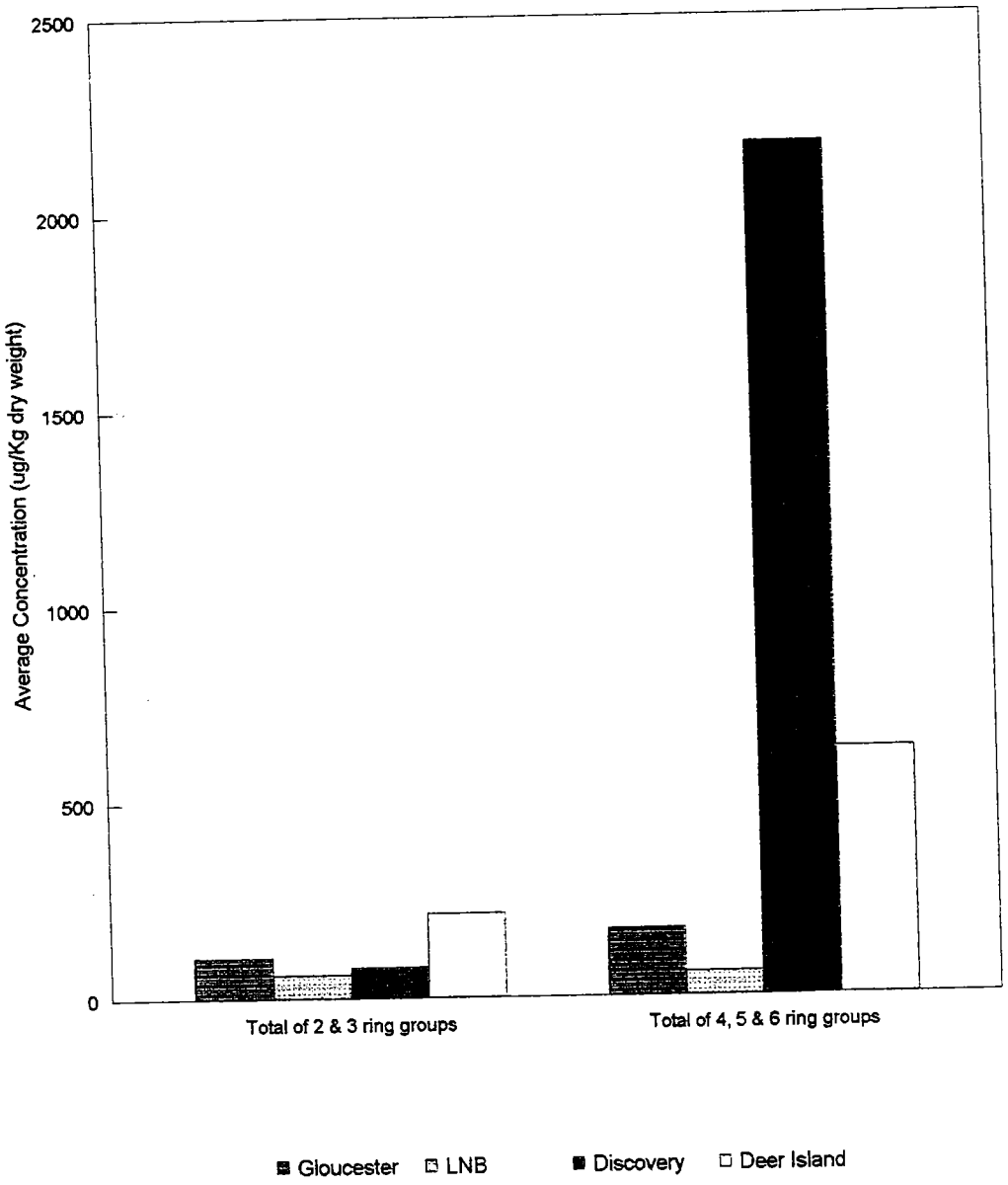

Figure 4. Average concentration of two groups (2 & 3 ring; 4, 5 & 6 ring) of polynuclear aromatic hydrocarbons in mussel tissue collected from the four stations.

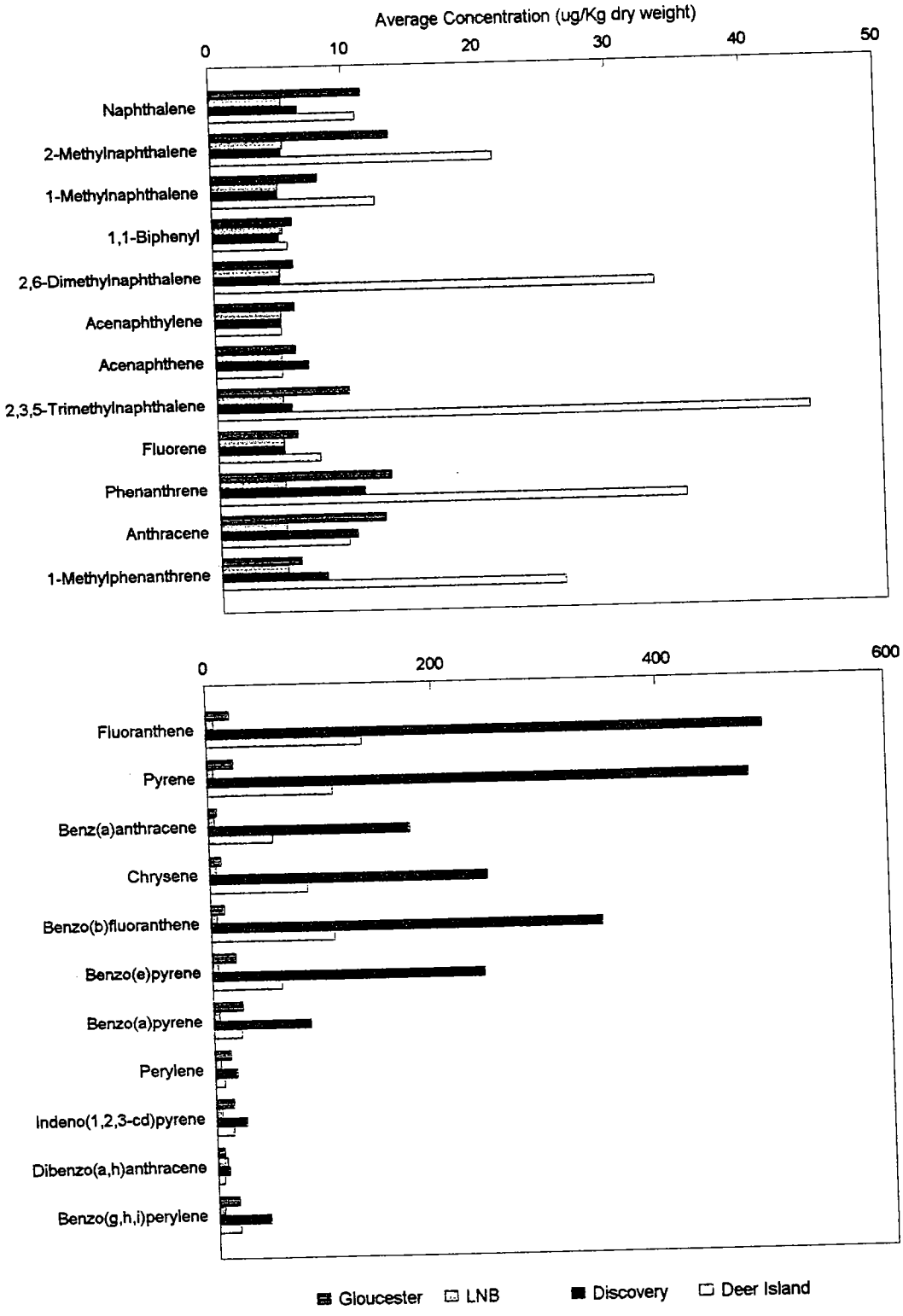

Figure 5. Average polynuclear aromatic hydrocarbons in mussel tissue collected from the four stations.

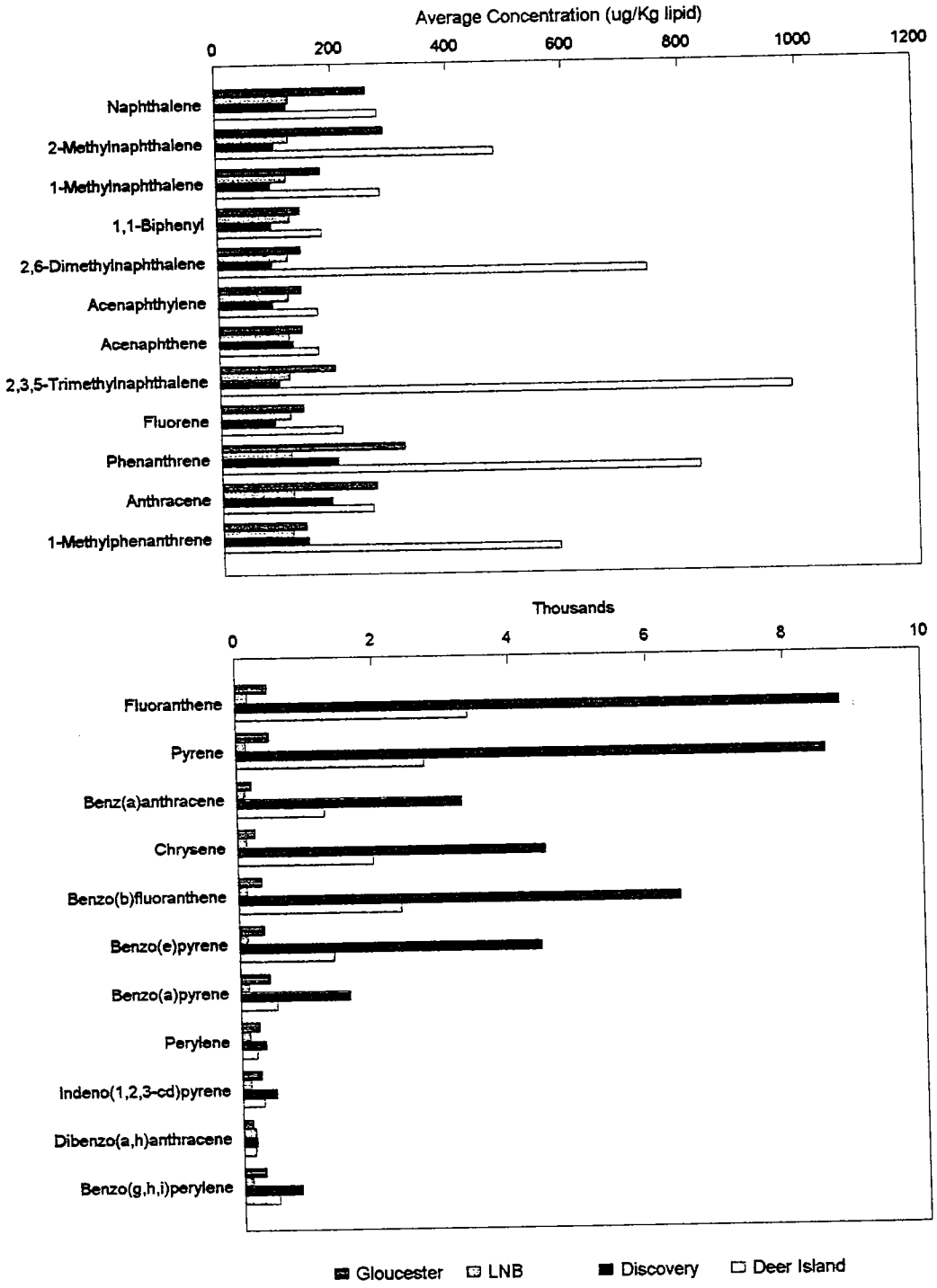

Figure 6. Lipid adjusted average polynuclear aromatic hydrocarbons in mussel tissue collected from the four stations.

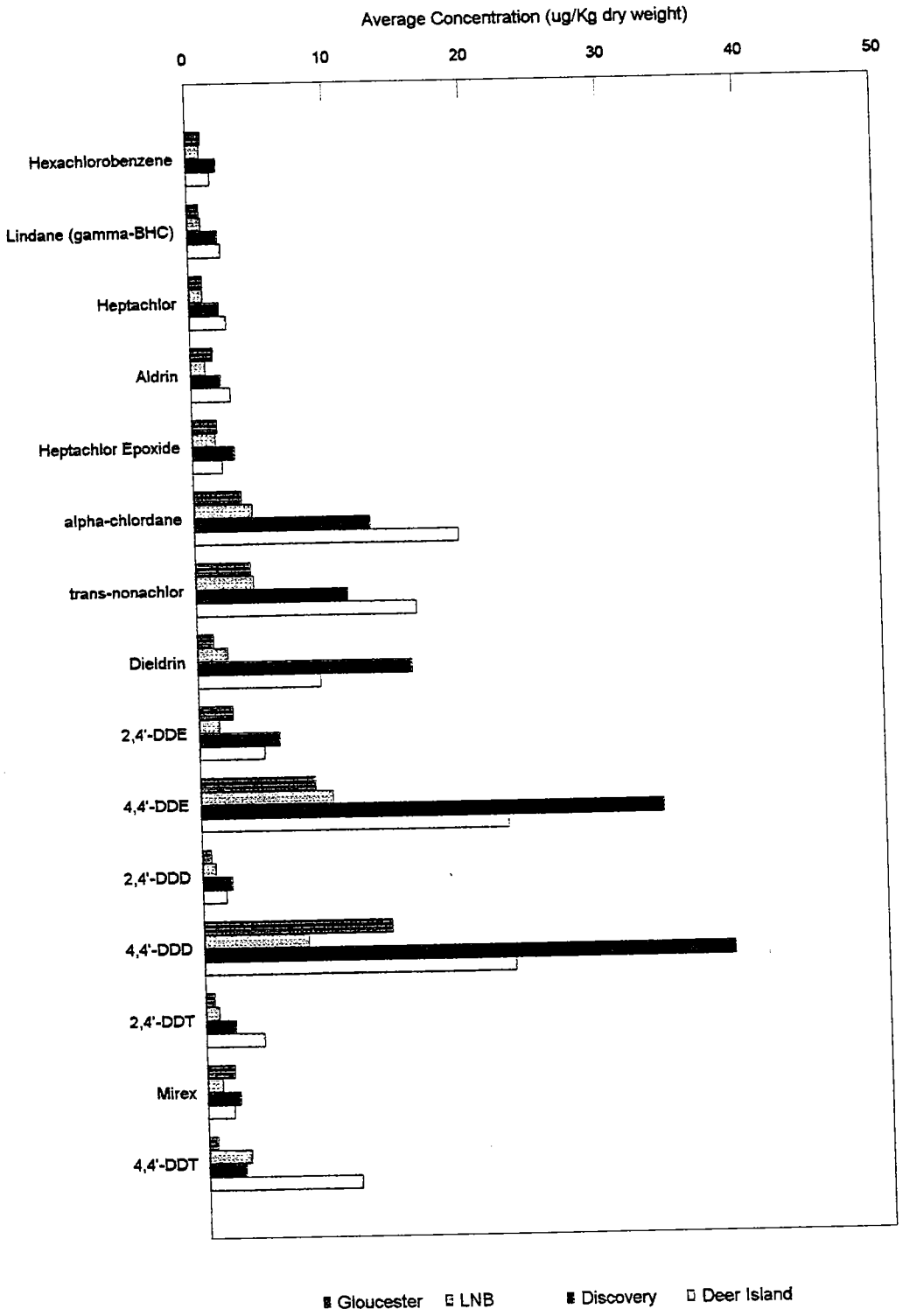

Figure 7. Average Concentration of pesticides in mussel tissue collected from the four stations.

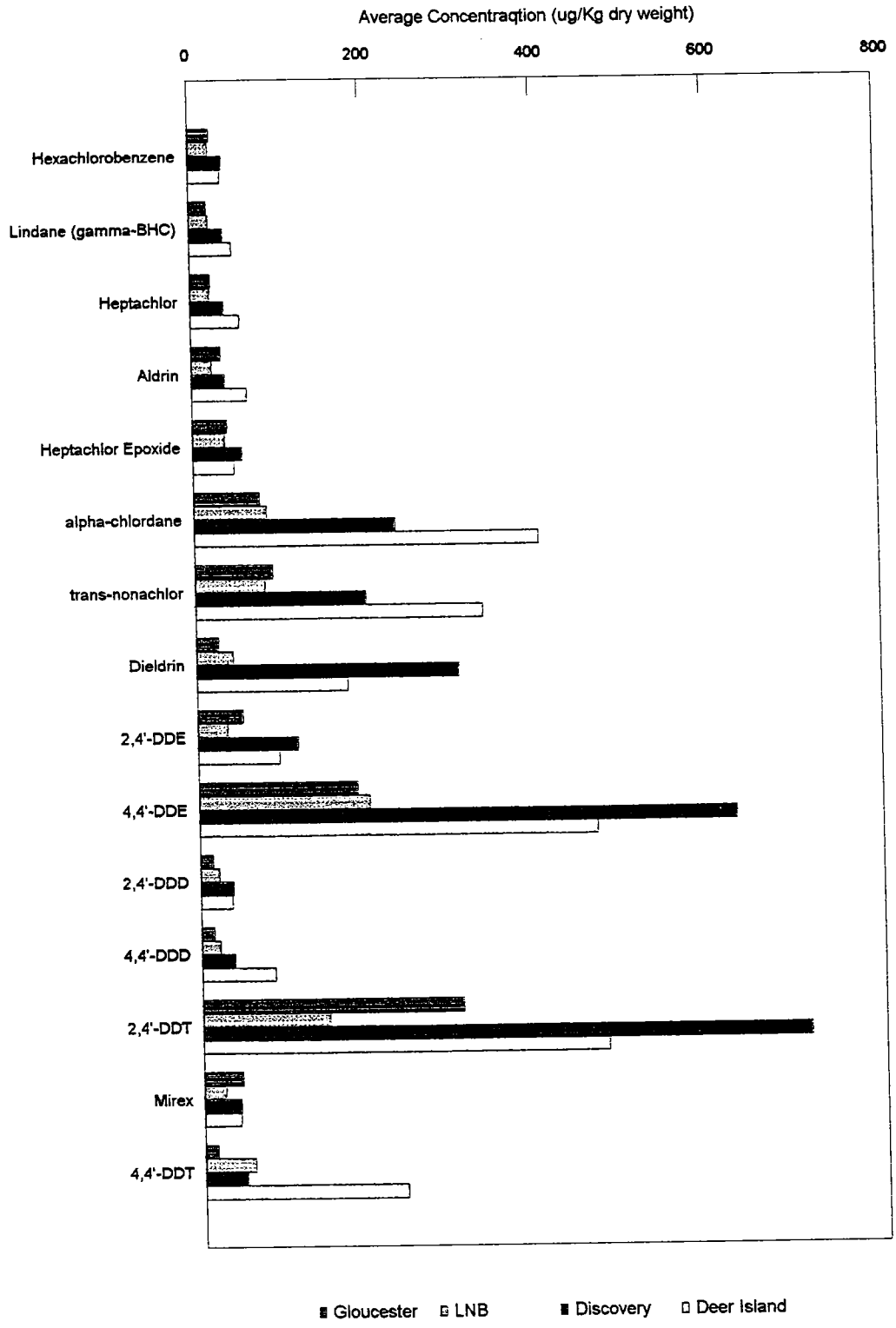

Figure 8. Lipid adjusted average pesticides in mussel tissue collected from the four stations.

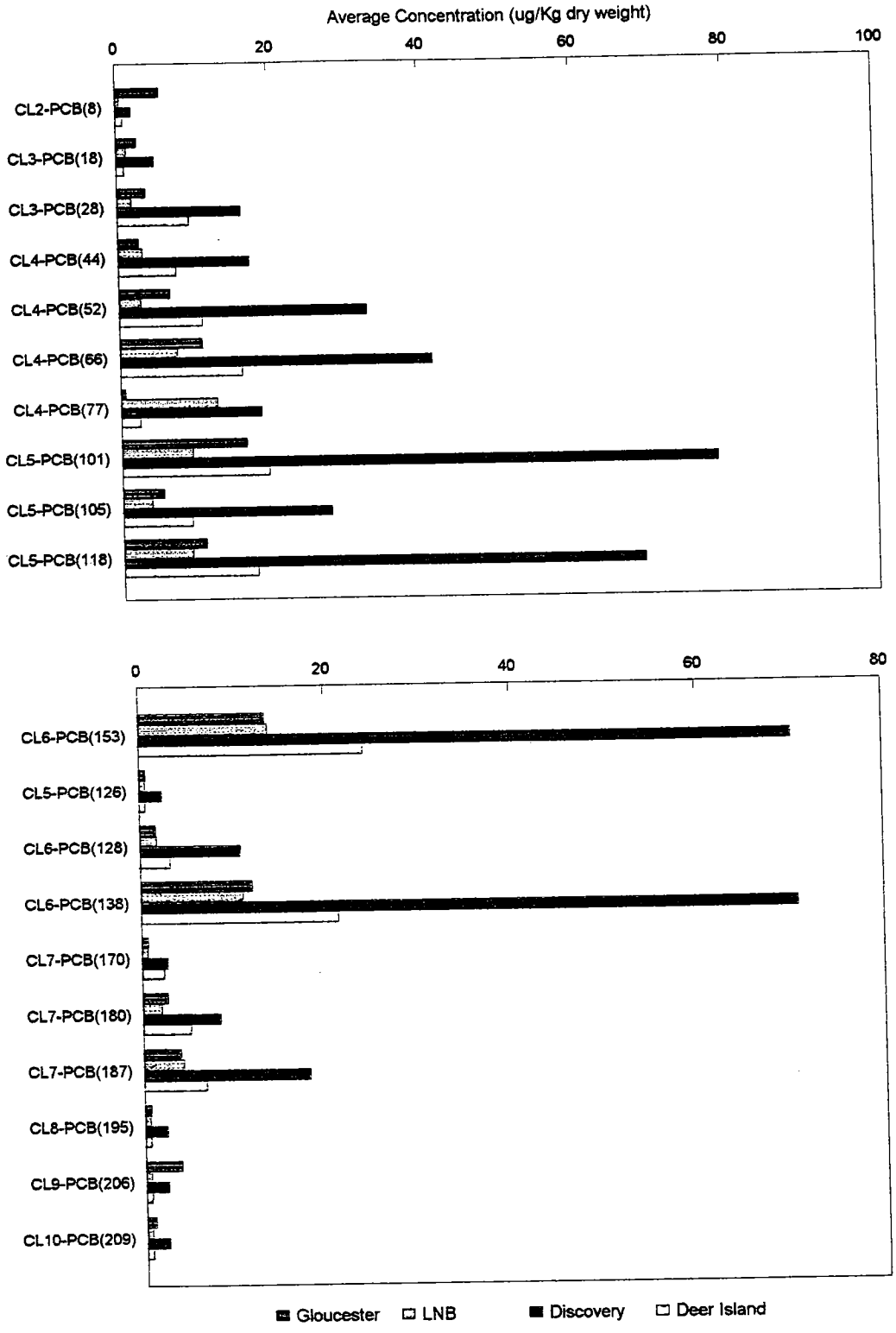

Figure 9. Average concentration of polychlorinated biphenyls in mussel tissue collected from the four stations.

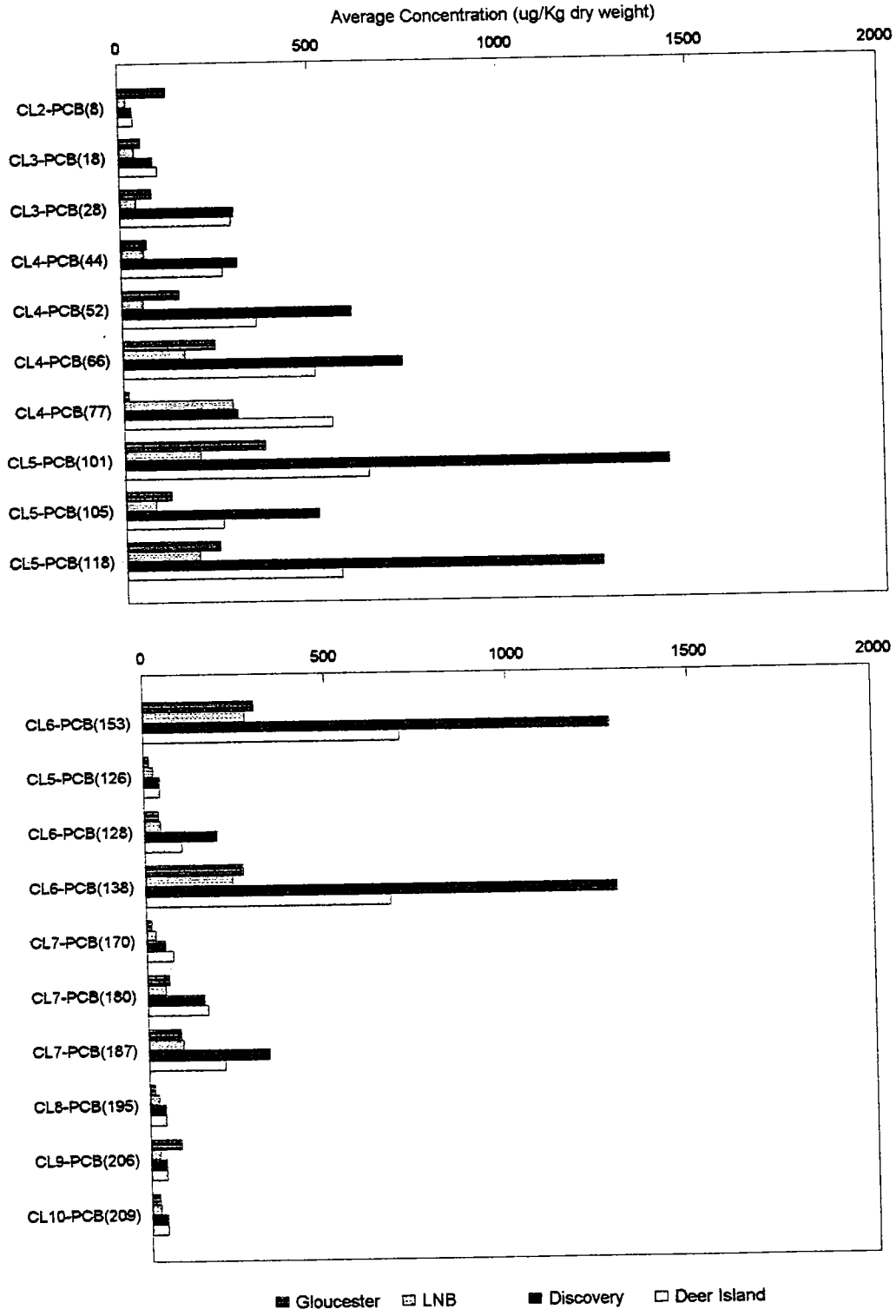

Figure 10. Lipid adjusted average concentration of polychlorinated biphenyls in mussel tissue collected from the four stations.

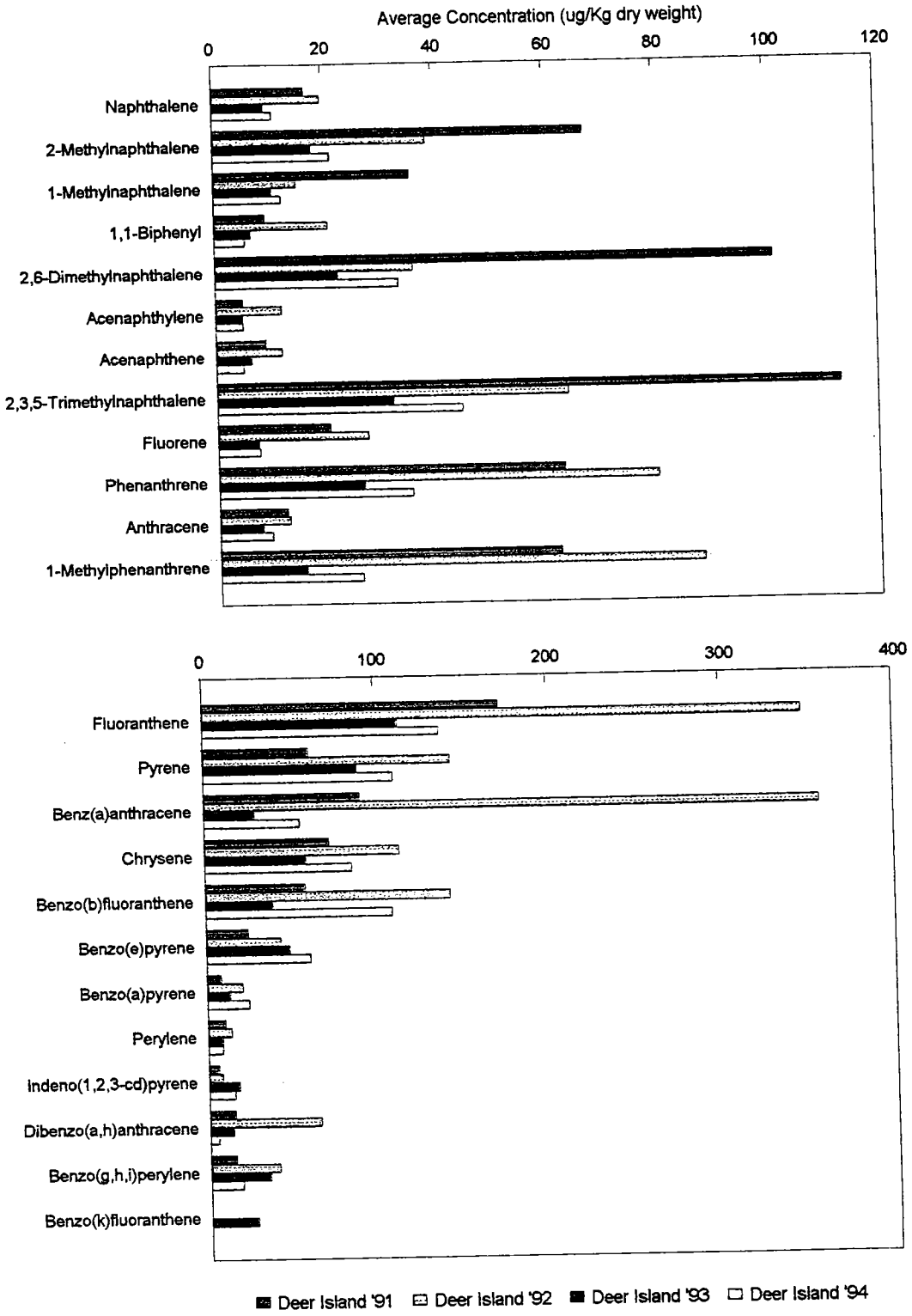

Figure 11. Average concentrations of polynuclear aromatic hydrocarbons in mussel tissue collected from Deer Island, 1991 - 1994.

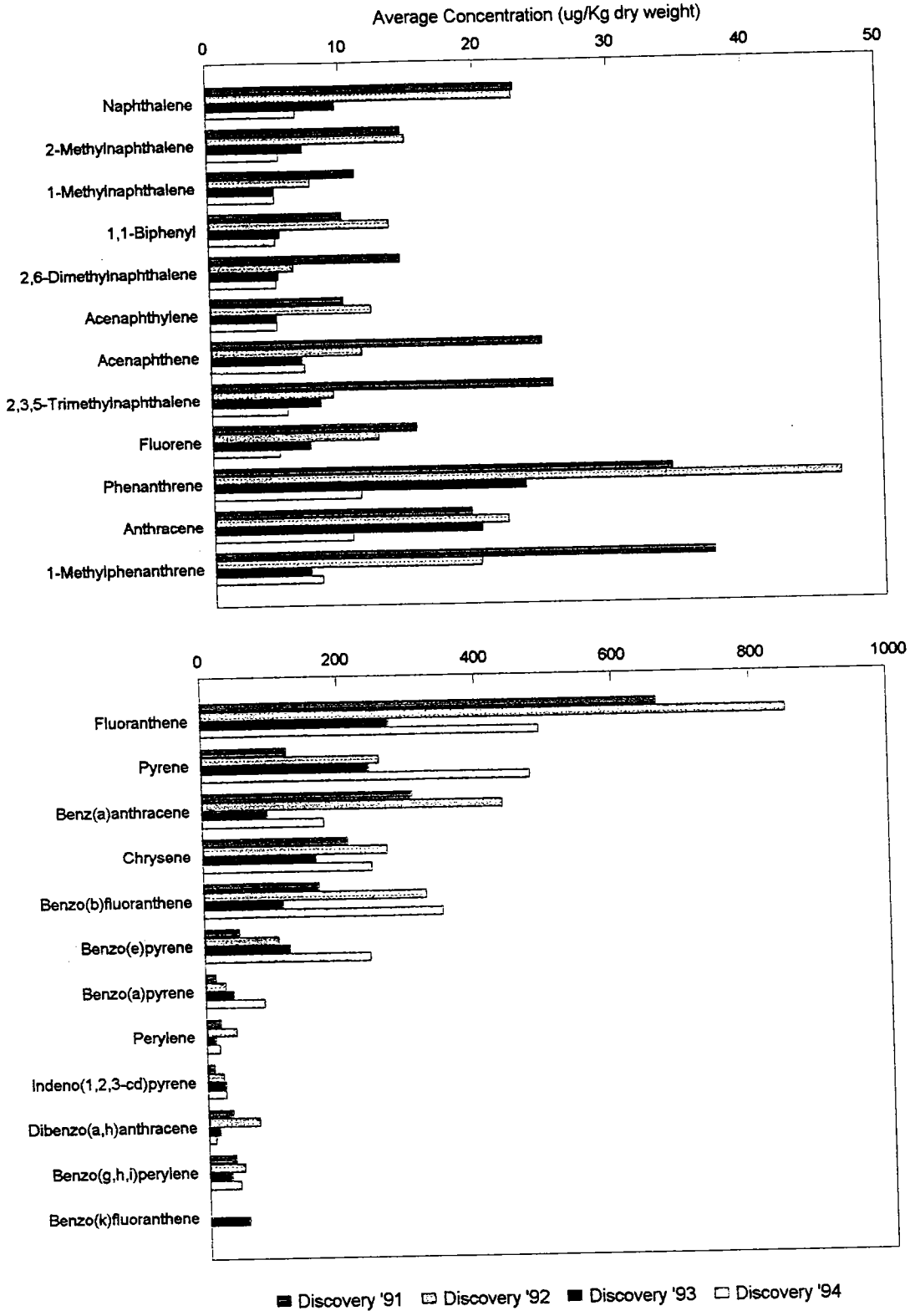

Figure 12. Average concentrations of polynuclear aromatic hydrocarbons in mussel tissue collected from Discovery, 1991 - 1994.

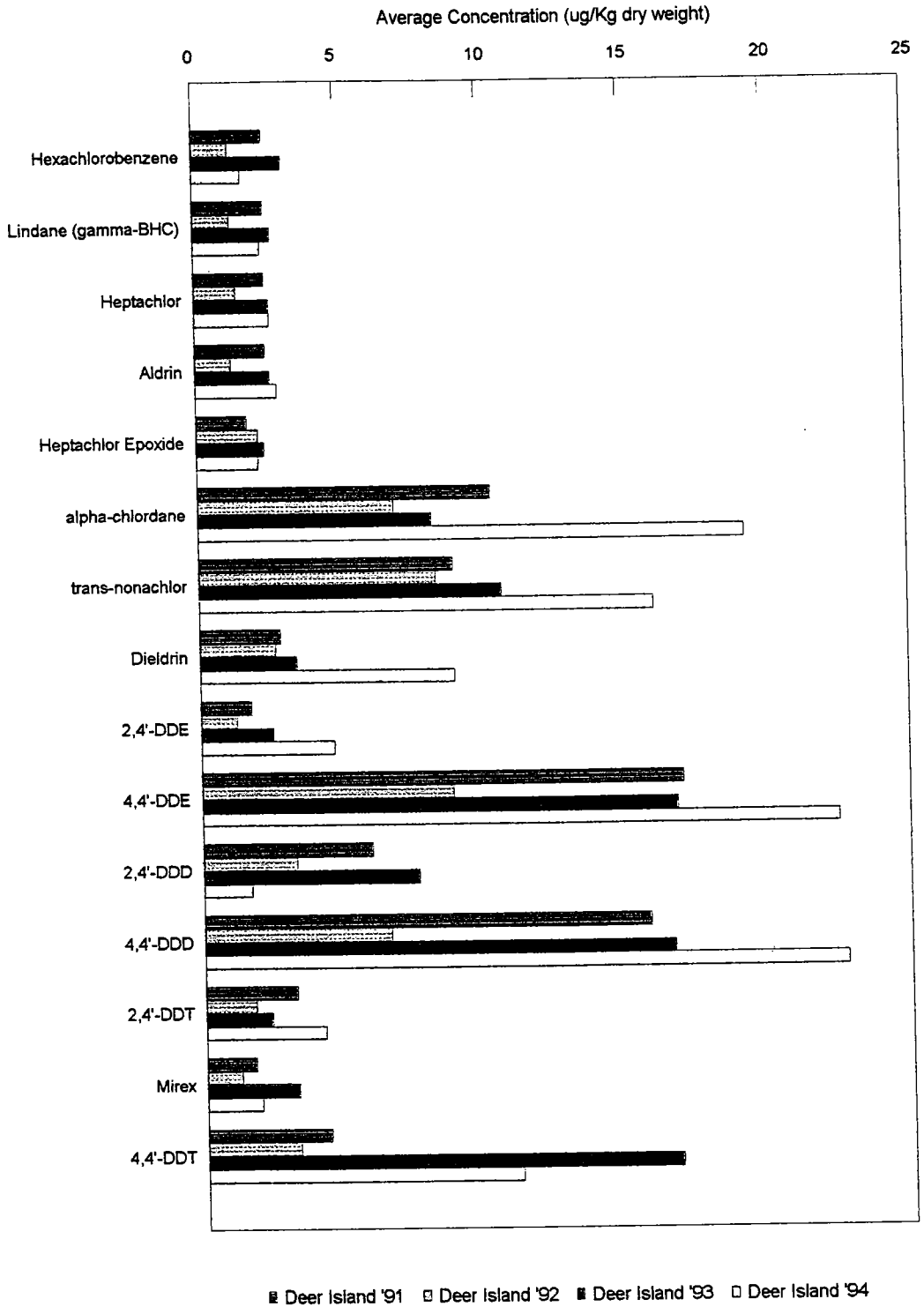

Figure 13. Average concentrations of pesticides in mussel tissue collected from Deer Island, 1991 - 1994.

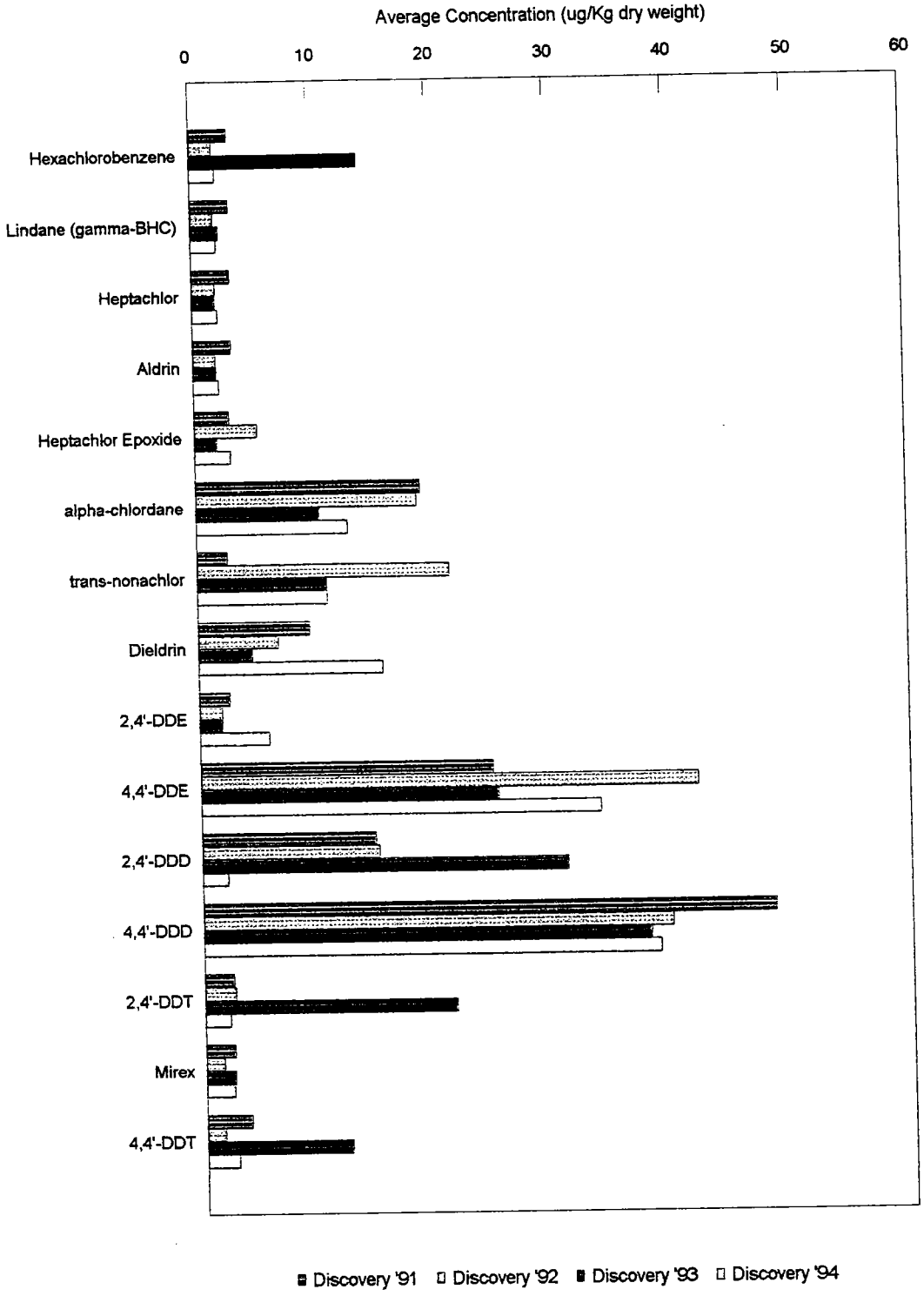

Figure 14. Average concentrations of pesticides in mussel tissue collected from Discovery, 1991 - 1994.

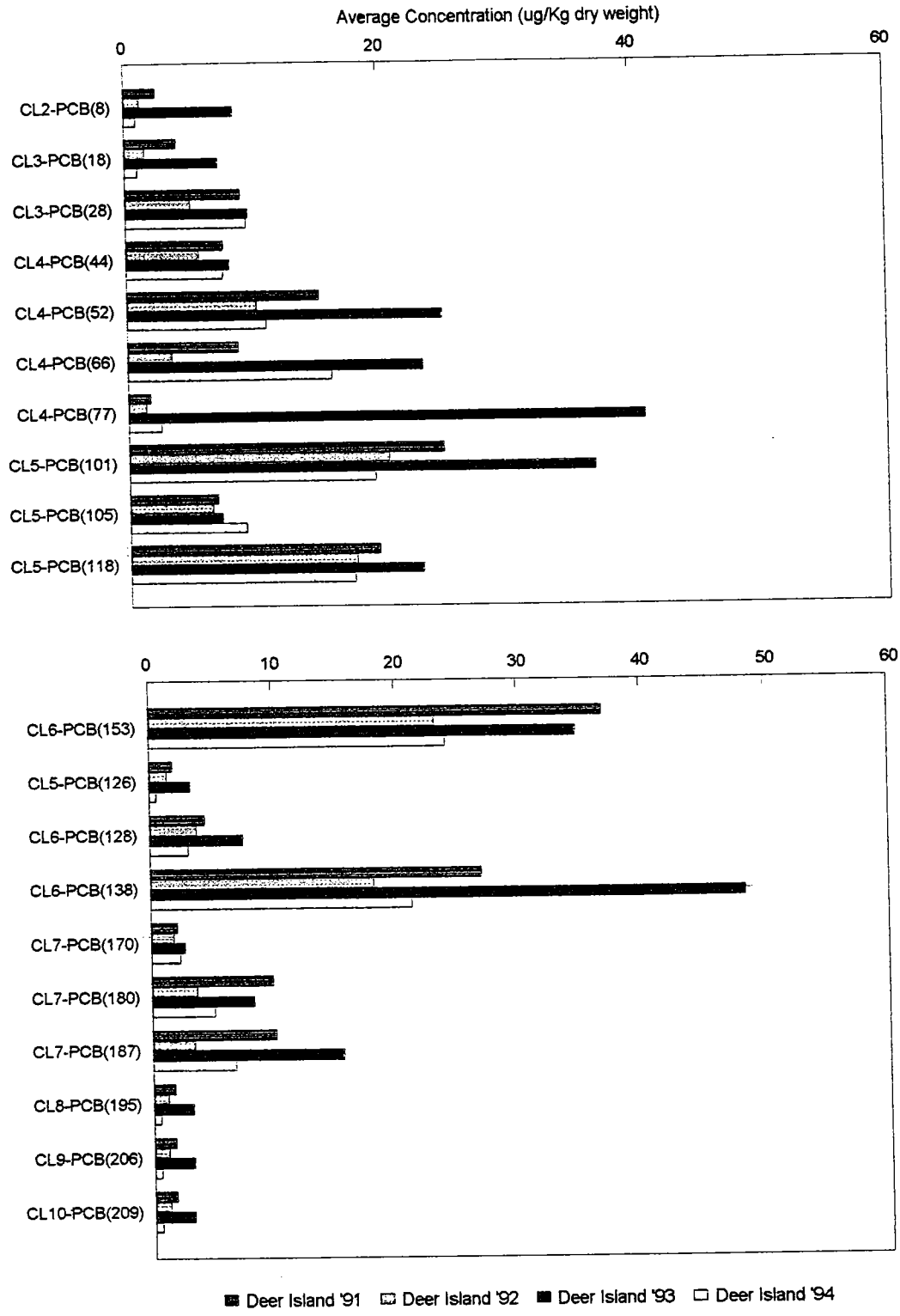

Figure 15. Average concentrations of polychlorinated biphenyls in mussel tissue collected from Deer Island, 1991 - 1994.

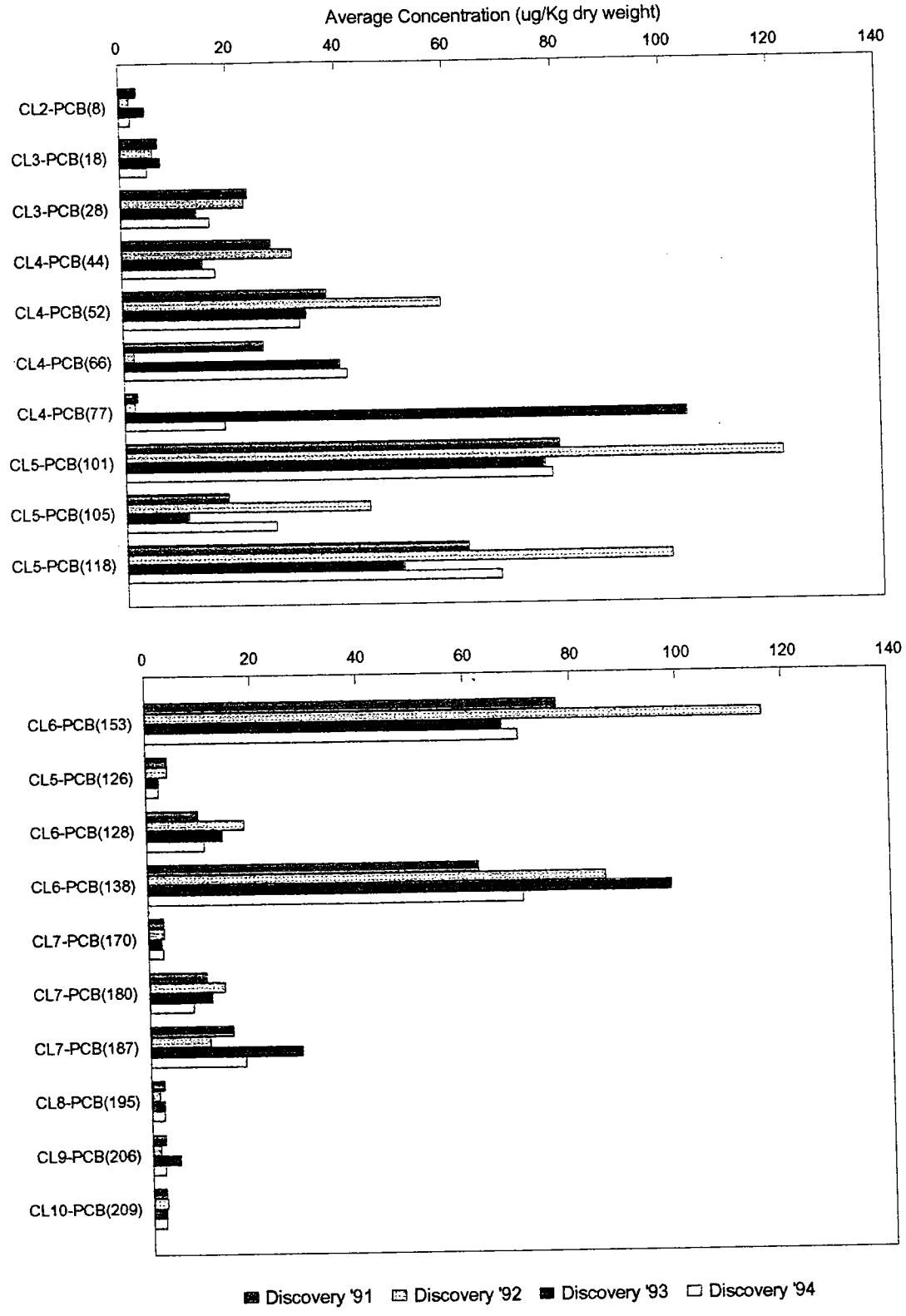

Figure 16. Average concentrations of polychlorinated biphenyls in mussel tissue collected from Discovery, 1991 - 1994.

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