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Bioaccumulation of selected organic compounds in mussels deployed near Deer Island discharge and in Massachusetts Bay, 1992

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Bioaccumulation of selected organic compounds in mussels deployed near Deer Island discharge and in Massachusetts Bay, 1992

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EXECUTIVE SUMMARY

A mussel (Mytilus edulis) bioaccumulation study was conducted in 1992 for the Massachusetts Water Resources Authority (MWRA). This 1992 study was a continuation of a previous study (Downey and Young 1992) which was conducted in 1991 under the same contract. The objectives of the 1992 study were to determine whether selected Polynuclear Aromatic Hydrocarbons (PAHs), pesticides, and Polychlorinated Biphenyls (PCBs) bioaccumulate in mussels deployed near the Deer Island Publicly Owned Treatment Works (POTW) and to obtain background data on uptake of target compounds by mussels deployed offshore near the projected new Deer Island outfall.

Mussels harvested from Hodgkins Cove (Gloucester) were deployed on June 25 and 26 at 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 deployment as the 'test' location, and the LNB deployment for 'background' measurements of contamination near the proposed new offshore outfall.

The sixty day mussel harvest occurred on August 24 and 25. Even though several arrays (deployed groups of 120 mussels each) were harvested from Deer Island and LNB locations, only one array at each location was used for all of the analyses. At the Discovery location, one array was harvested and used.

A random subsample (generally 30 mussels) was selected from each array and used to determine the average shell length, average wet weight, the proportion of females and males present, sexual maturity, and two condition indices for each location. The remaining mussels from each array were used to make composite samples consisting of 10 mussels per sample. Five Gloucester initial analyses (in June) and eight composite samples each from Deer Island and LNB locations were analyzed for PAHs, pesticides and PCBs. Five composite samples were analyzed from the Discovery location.

The gonadal and soft tissue dry weights of the LNB mussels were more than 40 percent higher than mussels harvested from the Deer Island or Discovery locations. One possible factor that contributed to this relatively good growth rate was the deployment of these mussels at a depth where there was likely an abundance of food (i.e., the deployment depth was the depth range of maximum chlorophyll a concentrations).

The total shell length of the LNB mussels was not significantly larger than total shell length for mussels from the other two locations. Also, increased shell length growth (1.6-1.7mm) calculated for mussels from June through August for the three locations, was nonsignificant.

Total tissue PAH concentrations were highest in the mussels harvested from Discovery (3545 ug/Kg). Deer Island mussels also exhibited significantly higher total PAH concentrations (1934 ug/Kg) than Gloucester (collected in June) and LNB, but were significantly less than Discovery mussels. The LNB total PAH tissue concentrations were low with most of the individual compounds below detection levels.

The Discovery tissue concentrations of High Molecular Weight (HMW) PAHs (average 3347 ug/Kg total HMW PAHs) were significantly higher than Deer Island HMW PAHs (average 1507 ug/Kg total HMW PAHs). The Low Molecular Weight (LMW) PAHs were highest in Deer Island mussels (average 427 ug/Kg total LMW PAHs) which was more than twice the average LMW PAH Discovery mussel concentrations (198 ug/Kg).

Hexachlorobenzene, lindane, heptachlor, aldrin, 2,4'DDE and mirex were found at or near the detection levels in mussels from all four locations. Total DDTs (sum of individual DDD, DDE and DDT isomers) were highest in Discovery mussels (103 ug/Kg). Deer Island mussels also contained elevated total DDT tissue levels (25.1 ug/Kg) while LNB mussels were low (11.7 ug/Kg). The compounds, 2,4'-DDD, 4,4'-DDE, and 4,4' DDD, accounted for most of the DDTs detected.

Total PCB tissue concentrations were highest in Discovery mussels (652 ug/Kg) followed by statistically lower Deer Island mussel concentrations (133 ug/Kg). The LNB mussel concentrations (44.4 ug/Kg) were the lowest observed and were statistically lower than the 'background' mussel concentrations (65.2 ug/Kg) of the Gloucester mussels collected in June. This lower average total PCB concentrations suggest that the LNB mussels may have depurated their tissues of PCBs during the 60-day deployment.

The analytical results from this 1992 study confirmed the same general tissue concentrations reported for the Discovery and Deer Island harvested mussels in 1991; total and HMW PAHs, total pesticides, and total PCBs were highest at Discovery while LMW PAHs were higher at Deer Island.

While tissue contaminant concentrations displayed little change for all target analytes between the 1991 and 1992 pre-deployment mussels (Gloucester), the total PCBs and total pesticide tissue concentration patterns were noticeably different for the Discovery and Deer Island locations. For the Discovery deployed mussels, several pesticides and total PCBs were found in higher tissue concentrations in 1992 when compared to 1991 results.

For Deer Island deployed mussels, lower but nonsignificant average concentrations of selected pesticides and total PCBs were noted in 1992. The LMW PAHs which account for more than 90 percent of the reported PAHs in Deer Island effluent were found in lower average concentrations in 1992 Deer Island tissues than in 1991, although these lower average concentrations were generally nonsignificant.

In contrast, HMW PAHs were found in higher concentrations in mussels deployed at the Deer Island and Discovery locations in 1992. The concurrent increases in HMW PAH during the 1992 study suggest that these increased body burdens were not the direct result of the Deer Island effluent. Several unique conditions in 1992 which may have contributed to these elevated levels are examined in the report discussion.

Results of the 1992 study generally were consistent with reported 1991 trends (Downey and Young 1992) of reduced body burdens in Deer Island mussels compared to 1987 results (MWRA 1988). Even though there are important differences between the 1987 and the 1991/1992 studies (such as length of deployment and analytical techniques), the results of the 1991 and 1992 studies suggest that exposure concentrations of LMW PAHs, pesticides and PCBs near Deer Island (and by implication in the Deer Island effluent) may have declined during the period from 1987 to 1992.

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1.0 OVERVIEW

This 1992 bioaccumulation study was conducted for the Massachusetts Water Resources Authority (MWRA) as part of Aquatec, Inc.'s 1991 contract (Number S084) with MWRA. The 1992 study was a continuation of a previous study (Downey and Young 1992) conducted in 1991 under the same contract. The objective of these two studies was to use the mussel (Mytilus edulis) as a test organism to determine whether selected compounds bioaccumulate in the tissue of mussels deployed near the outfalls of Deer Island Publicly Owned Treatment Works (POTW). An additional objective of the 1992 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. One study conducted by the MWRA in 1987 (MWRA 1988) used caged mussels deployed at the outfalls for 30-60 days to assess mussel tissue concentrations of selected organic compounds and heavy metals. In addition to the Deer Island sampling location, the projected off-shore discharge location and the Discovery location were also sampled as part of this 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 completed 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 mussels exposed at the two control locations to glean apparent trends in mussel tissue concentrations of target compounds among mussels exposed at the three locations.

The current 1992 study was designed to mimic the 1991 Aquatec study and the 1987 MWRA study. Mussels were deployed at three locations in June 1992 with the Deer Island and Discovery locations again part of the 1992 study. Although the Gloucester location at Hodgkins Cove served as the source of mussels for this study, mussels were not deployed at this location in 1992. Instead, another location, 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. Tissue analyses were conducted using methods similar to those employed in 1991.

2.0 METHODS

2.1 Mussel Collection

On June 23 and 24, 1992, approximately 1,280 mussels were collected for testing purposes from the University of Massachusetts' Research Station at Hodgkins Cove in Gloucester, Massachusetts (Table 1). This area was chosen because mussels from this location had been used in previous bioaccumulation studies: for the South Essex Sewage District (Camp, Dresser, and McKee, Inc. 1988), New Bedford, Massachusetts (MRI 1989) and the 1991 Deer Island study (Downey and Young 1992).

A total shell length (mm from umbo to distal gape) was measured with Vernier calipers (0.1 mm) on 600 representative mussels reserved for deployment at the bioaccumulation study sites. Only mussels which fell into the 55-70 mm size range were used in the study. Forty mussels were randomly distributed to each of 30 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 Research Station. Cages were coded and numbered so that each batch (replicate) of 40 mussels could be tracked throughout the study. A subsample of 110 mussels was transported unfrozen on ice to Aquatec on 25 June for initial biological and chemical analyses.

2.2 Mussel Deployment

On 25 and 26 June, mussels in cages were deployed from Aquatec's 25' Research Vessel "Profile" at the following three sites (Figure 1):

1) Large Navigation Buoy, (LNB) located approximately 1 nautical mile (NM) south of the projected MWRA offshore discharge installation. This LNB site provided pre-discharge baseline data.

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

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

Each deployment array consisted of three replicate cages containing 40 mussels each for a total of 120 mussels per array. Cages were attached to polypropylene line with nylon cable ties, spaced approximately 0.2 m apart. Steel mooring weights, subsurface, and surface buoys were used to stabilize the location of each array in the water column. Deployment positions were documented using on-board Loran-C readings in latitude and longitude.

Three mooring systems (arrays) with a total of 360 mussels, (120 per array) were deployed at the Deer Island light. Two hundred and forty mussels were suspended from one array off the Discovery. Three arrays of 120 mussels each were deployed at the LNB while an additional 240 mussels, in 6 cages (comparable to 2 arrays), were attached to the Large Navigation Buoy chain at a depth of 11-13 meters.

On 25 June, two arrays (3 cages per array) were deployed near the LNB using a mooring and suspension system in conjunction with hydroacoustic releases. The two release arrays consisted of a 30 cm Styrofoam subsurface buoy tethered with nylon rope to one end of the release and anchored with approximately 45 Kg of weight. The cages were attached to the nylon rope between the buoy and release approximately 2 meters below the subsurface buoy. When deployed, the cages were positioned approximately 13-14 meters below the surface.

A third array without a hydroacoustic release was deployed in the same manner as the two hydroacoustic arrays. A 13 cm 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. These cages were located approximately 14 meters below the surface.

Two additional arrays were deployed on 26 June on the chain securing the LNB as authorized by the U.S. Coast Guard (Letter from C.C. Beck Commander U.S. Coast Guard received by Maurice Hall, MWRA on 29 May 1992). These cages were attached by divers using tie-wraps to the chain at 11-13 meters below the surface.

The location and water depths for each array at the LNB was as follows:

	Corrected Latitude	Corrected Longitude	Total Water Depth (m)	Cage Depth (m)
Acoustic Array Code 'C'	42° 22.67'N	70° 46.67'W	32	13-14
Acoustic Array Code 'D'	42° 22.72'N	70° 46.80'W	30	13-14
Surface Buoy	42° 22.77'N	70° 46.76'W	27	14
LNB Mooring Chain	--	--	--	11-13

On 25 June 1992, three arrays were transported to an area east of the Deer Island Light. Each array consisted of a mooring and suspension system with about 27 Kg of weight and a 25 cm Styrofoam subsurface buoy tethered to the anchor with polypropylene rope. The exact positioning of each array east of the Deer Island light was made the next day, 26 June. About 75m length of polypropylene line tethered each array anchor to the riprap surrounding the light to facilitate later retrieval. The arrays at Deer Island were deployed at a depth of about 4-6 meters MLW, approximately 75 meters east of Deer Island light. The subsurface buoy was located about 3 meters from the bottom and the three cages per array were fastened about 1 meter below the buoy (cage depth approximately 2 m from bottom).

On 26 June, 240 mussels were suspended on a nylon line from the stern of Discovery (New England Aquarium). The six cages were arranged at two pods of three cages each with one pod approximately 2-2.5 meters from the bottom (at MLW) and the other pod about 3-3.5 meters from the bottom.

2.3 Mussel Retrieval

On 27 July, one array (120 mussels) each was collected from the LNB (acoustic release code 'C'), Discovery and Deer Island light. Exposure time was as follows: Discovery, 31 days; Deer Island, 31; and LNB, 32 days. 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 24 and 25 August from the three stations. Two arrays, approximately 240 mussels, were recovered from Deer Island Light. At Discovery, approximately 120 mussels were recovered while about 440 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 separately in labeled plastic bags in coolers and kept cold during transport.

After reaching the dock on 25 August, mussels for chemical analyses were separated from the biological samples and frozen on dry ice. On 26 August, all mussels were transported to Aquatec and stored frozen (for chemical analyses) or refrigerated (for biological analyses).

2.4 Biological Analyses

Mussels for biological analyses were processed to obtain total shell length, total wet weight, reproductive condition, and condition index data. Ten mussels from each of the 3 cages (one array) were measured for a total of 30 mussels per location except for Deer Island where only 29 mussels were used.

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) and the total weight (to the nearest 0.1g) was measured on an electronic balance.

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 sex and sexual maturity. Sexually mature males were identified by sperm motility and immature males by lack of sperm motility. Sexually mature females were identified by presence of eggs with a diameter greater than 60 microns; otherwise the mussel was identified as an immature female.

The gonad and mantle tissue was then separated from the remaining soft body tissue with a scalpel and transferred to a pre-weighed weighing pan labeled "Gonad." The remaining soft body tissues were removed and placed in a weighing pan labeled "Soft." The shell was placed in a third weighing pan labeled "Shell." When all ten mussels from each cage (3 cages per

station, 30 mussels total) were processed as described above, they were placed as a group in a drying oven at 105°C and dried for 24 hours. Dry weights of the gonad tissue, soft body tissue, and shell for each mussel were then obtained by weighing each pan and contents on a balance (±0.0001g).

Based on the dry weight of the gonad-mantle tissue, non-gonadal soft tissue and the shell, two condition factors were calculated. The Gonadal Condition Index was calculated as the weight of the gonad-mantle tissue divided by the weight of all the soft tissue (including gonad-mantle) and multiplied by 100. The total soft/shell Condition Index was determined as the total weight of soft tissue (non-gonadal and gonad-mantle) divided by the shell dry weight and multiplied by 1000. The condition indices were calculated on thirty mussels collected before deployment, referred to as "Gloucester Initial" and from thirty mussels collected from the LNB, Deer Island light, and the Discovery stations after 59-60 days deployment. These indices were referred to as "Sixty-day" in tables.

2.5 Chemical Analyses

Mussels were prepared for low-level organic chemical analyses by dissection using disposable Teflon-coated stainless steel blades rinsed with methanol and deionized water prior to use. Individual mussels were rinsed with deionized water and the shell surface was scrubbed to remove attached material. The total shell length was measured and the adductor mussels were severed. Sexing of the mussels was accomplished by removal of an aliquot of gonadal tissue/fluid with the Teflon coated blade and examination of the material with a microscope. Although this reduced each mussels total wet weight, this effect was deemed minimal. Byssal threads were removed and all soft tissue including fluids were shucked directly into an amber 500-ml I-Chem Certified clean bottle. When possible, male soft tissue was bottled separately from female soft tissue resulting in a 10 mussel composite sample of same sex tissue.

The tissues were then refrozen and held until chemical extraction was initiated. Five composite samples were analyzed for the June Gloucester and August Discovery retrieval. Eight composite samples each, from the Deer Island and from Large Navigation Buoy, were analyzed.

The extraction and analytical procedures generally followed National Status and Trends Methodologies (Figure 2). 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). Internal control compounds were spiked into each sample prior to extraction as part of the analysis for more representative quantification of the PAH, PCB, and pesticide target analytes. The polychlorinated biphenyls were referred to by level of chlorination followed by the BZ congener number designation in parenthesis. The spiked analytes were as follows:

<u>PAH Internal Standards</u>:

Naphthalene-d_8
Acenaphthene-d_{10}
Phenanthrene-d_{10}
Chrysene-d_{12}
Perylene-d_{12}

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

Dibromooctafluorobiphenyl
Cl_5-PCB(121)
Cl_8-PCB(204)

The sample-specific experimental recoveries (summarized in Appendixes C and D) were used for correction of the reported results for target analytes in the mussels.

Blank analyses, laboratory matrix spike (MS) and matrix spike duplicates (MD) were conducted routinely. For each analysis, MS and MD analyses were conducted for approximately 10 percent quality control sampling. Three samples of Standard Reference Material (SRM) 1974 (Organics in Mussel Tissue) from the National Institute of Standards & Technology (NIST) containing certified concentrations of polynuclear aromatic hydrocarbons were analyzed as part of the quality control program. NIST noncertified concentrations of pesticides and PCBs were also reported for this SRM 1974. Lipid determinations were completed following the National Status and Trends Methodologies.

2.6 Statistical Analyses

Both parametric and non-parametric statistics were used for evaluation of the data. Biological measurements (i.e., condition indices) were analyzed using Analysis of Variance (ANOVA) 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 non-parametric 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).

Results were reported on a dry weight basis. Total PAHs, PCBs, and pesticides (i.e., sum of individual sample analytes) were calculated using the detection limit value for the analyte as an estimated concentration for those analytes not detected. Lipid adjusted 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 values were plotted for comparison among the stations. This calculation differed from last years study since the 1991 results (Downey and Young 1992) were normalized on a wet weight lipid basis.

3.0 RESULTS

3.1 1992 Biological

3.1.1 Survival

On 27 July (31 days and 32 days post deployment) one array of cages 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 and individual mussels. No abnormalities were observed and survival was high at all stations (≥98 percent).

Fouling was minimal after 30 days of exposure. At the Discovery location, cages were covered with fine silt and slime with virtually no occlusion of the spaces between the bars of the cage. Deer Island cages had slight amounts of bryozoans. The LNB cages also had light bryozoan growth. Mussels obtained from the three locations were harvested, enumerated, and stored frozen in the laboratory. Since the August retrieval was successful, these mussels were not used for biological or chemical analyses.

Mussels were harvested at the end of the nominal 60-day exposure from the three locations. Deer Island and LNB were harvested on 24 August (59 and 60 days deployed, respectively) while the Discovery mussels were harvested on 25 August (60 days deployed). Mussel survival was very high for all three locations; 98 percent of the Discovery and LNB mussels and 99 percent of the Deer Island mussels survived (Table 2).

Cages retrieved from the LNB in August were lightly coated with bryozoans predominantly attached to and covering the bars of the cage. With the exception of light bryozoan infestation of several mussel shells (estimated at less then 5 percent of the mussels) and several barnacles on the shells, fouling was judged to be low. 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 other parasites noted.

Deer Island cages from both arrays were extensively covered with bryozoans and fine silt-like fouling. Mussels within the cages were also fouled with fine silt-like material. One array (the backup cages not used for analyses) was also partially fouled with the brown kelp Laminaria sp. which apparently had drifted onto and become entangled on two of the three cages. 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.

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 mussels had barnacles attached to the shell, probably acquired prior to deployment.

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 male was more of a yellow color.

For the 30 mussels examined from Gloucester in June, 12 of the 14 females were mature while 14 of the 16 males were mature. The number of mature females was very similar in August; 12 females from Discovery and from Deer Island and 13 females from the LNB being reported. Deer Island and the LNB each had 15 mature males and 2 immature males. The stage of maturity of males collected from the Discovery location differed from the other two locations. Immature males were predominant, with only 7 of the 17 males examined from this location being mature.

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. Although no abnormalities were observed among mussels from different locations, visual differences in tissue definition and quality were noticeable. The various

organs of individuals collected from the Discovery and Deer Island were flaccid and appeared more 'fluid' than LNB harvested mussels which appeared turgid.

3.1.3 Growth and Condition

Nearly 600 mussels representing approximately 50 percent of the total number deployed were measured initially in June and assigned to 30 labeled cages in an effort to obtain location specific growth rates (Table 3). The average overall length was 61.1 mm in June.

At the end of the 60 day deployment, a minimum of three cages from each location were retrieved and 10 mussels (approximately 25 percent of the cage total) were randomly selected to estimate the mean size of mussels within the individual cage. Estimated growth rates per cage for the 60 day deployment ranged from 0.2 to 3.3 mm with no differences detected among the three locations.

Although the estimated mean size increased by 1.6 to 1.7 mm during the deployment at each location (combined cages) these increases were not statistically significant ($P>0.05$). The results of this study suggest that the experimental design selected, namely, initial size range of 15 mm (55-70 mm total length) and measuring 50 percent of the initial sample and 25 percent of the final sample population, would only be sufficiently sensitive to detect, statistically, an apparent location specific growth rate of mussels of 2.2-2.6 mm during the 60-day deployment period.

Gonadal and soft tissue dry weights were significantly higher ($P<0.05$) in the LNB mussels (Table 4). The 0.9g average gonadal and the 1.27g average non-gonadal soft tissue dry weights were approximately 50 percent higher than both the Deer Island and Discovery mussel dry weight measurements. Gonadal and non-gonadal soft tissue dry weights were comparable for the Deer Island and Discovery mussels ($P>0.05$). Shell weights, 13.4g for LNB mussels, 13.9g for Discovery mussels, and 13.5 for Deer Island mussels were not statistically different from the three locations ($P>0.05$).

The Gonadal Condition Indices of 38.1 for Discovery, 38.3 for Deer Island and 41.4 for LNB mussels were similar (P>0.05) (Table 4). There were no statistical differences detected between the Gonadal Condition Indices in mussels deployed at these three locations and the Gonadal Condition Index of 38.2 for the initial mussel sample from Gloucester obtained in June.

The total soft tissue to shell indices for the Discovery (104.5) and Deer Island (120.1) were not statistically different from each other nor the initial Gloucester sample (114.5) (P>0.05). The total Soft/Shell Condition Index for the LNB (168.1) was significantly higher than Discovery, Deer Island and Gloucester indices (P<0.05). This difference was attributable to the increased mass of the total soft tissue (gonadal and non-gonadal) in the mussels at the LNB location.

3.2 1992 Tissue Concentrations

3.2.1 Lipids and Solids

The percent lipids present in mussel tissue was similar among mussels from the four locations (P>0.05); 4.8, 4.2, 5.1, 5.1 percent for Gloucester, LNB, Deer Island, and Discovery mussels, respectively (Table 5).

The amount of solids present in mussels was statistically different for each location (P<0.05) (Table 5). The highest average solid percentage was in the LNB mussels (15.8 percent) while the lowest was in the Discovery mussels (9.4 percent).

3.2.2 Polynuclear Aromatic Hydrocarbons

Matrix spike (MS) and matrix spike duplicate (MD) analyses were conducted on three samples obtained during this study (Table 6). Overall, there was good agreement between the duplicate recovery determinations for the samples. Some compounds (fluoranthene, pyrene and chrysene) displayed a negative recovery. For samples 164491MS and 164491MD, the concentration of these three compounds was less than that measured in sample 164491, suggesting that the 164491 subsample may have been biased high for these

three compounds. Recoveries for PAH compounds were generally 100 percent or greater, with one exception. Sample 164486MS concentrations of the 4, 5 & 6 ring PAHs were typically less than 100 percent.

NIST Certified mussel tissue was analyzed in triplicate in 1992 for polynuclear aromatic hydrocarbons (Table 7). Certified values reported by NIST are based upon results obtained from the NIST analysis of this material using two different analytical techniques. The uncertainty reported was obtained from a 95 percent confidence interval plus an allowance for systematic error between the methods used (NIST 1991).

The results of the comparison of nine certified PAHs generally indicated that the triplicate determinations for the compounds trended high relative to the certified values (Table 7). Four compounds (Phenanthrene, Fluoranthene, Pyrene, Benzo(b)fluoranthene) averaged within the 95% confidence intervals reported by NIST for the certified material. The remaining five compounds exceeded the 95% confidence interval but were not significantly different from the triplicate analyses conducted in 1991. The results were similar to that observed last year, suggesting that if a systematic reporting bias was occurring the individual reported compound concentration is generally conservative, i.e., reported values are likely to be higher than actual tissue concentrations.

Mean concentrations of triplicate analyses of the NIST Standard Reference Material were generally comparable to the noncertified values reported by NIST (Table 8). One compound, Indeno (1,2,3-cd) pyrene, was found in a much higher concentrations in all three analyses yielding a mean concentration of 2.8 ug/Kg which was nearly six times higher than the mean noncertified concentration reported for the SRM. Although the comparison of analytical results to SRM noncertified concentrations provide some quantitative information on analytical techniques, NIST "does not recommend that this noncertified information be used for calibration, bias evaluation, or similar purposes for which values are used."

Twenty-six determinations of mussel tissue concentrations were completed for composite samples from the four locations (Table 9); eight determinations were completed on Deer Island and LNB mussels and five determinations were completed on the Gloucester (Initial) and Discovery mussels.

Review of the data provided generally consistent trends among replicates from the four locations with the exception of sample 164495 from the LNB. This sample displayed appreciable concentrations of many of the PAH target compounds, particularly the High Molecular Weight (HMW) (4, 5 and 6 ringed) compounds. This sample was reanalyzed several times in the laboratory to confirm the instrument readings. A reanalysis was also conducted on a backup (second) extract with similar results. It is probable that this composite sample was inadvertently contaminated in the laboratory or field prior to extraction. It is also possible that a mussel (or mussels) were exposed to these target compounds in the environment. Regardless, these data were reviewed as not being representative of bioaccumulation rates at the LNB in 1992 and this sample although reported in Table 9 was not used in any figures or calculations of average LNB tissue concentrations.

Mussels harvested in August from the LNB (N=7) generally did not have detectable concentrations of most of the target PAHs. These mussels had lower average concentrations of both the Low Molecular Weight (LMW) (2 & 3 ring) and HMW PAHs than all other locations including the initial Gloucester mussels harvested in June ($P<0.05$) (Table 9; Figure 3). The average total PAH concentration for the LNB was 129 ug/Kg dry weight while Gloucester tissue concentrations averaged nearly double, 216 ug/Kg dry weight.

Total PAH tissue concentrations were significantly higher in Deer Island mussel tissue (average concentration 1934 ug/Kg) than Gloucester and LNB mussels but were significantly less than average total PAH mussels from Discovery which averaged 3545 ug/Kg dry weight ($P<0.05$) (Table 9). However, the Deer Island mussel concentrations of LMW PAHs which averaged 427 ug/Kg were significantly higher than the average of 199 ug/Kg tissue

concentrations of the LMW PAHs in the Discovery mussels (P<0.05) (Table 9; Figure 3). For HMW PAHs, the 3347 ug/Kg average for the Discovery mussels was significantly greater than the 1507 ug/Kg measured in the Deer Island mussels (P<0.05).

The methylnaphthalene PAHs (2-methylnaphthalene, 1-methylnaphthalene, 2,6-dimethylnaphthalene, 2,3,5-trimethylnaphthlene), fluorene, phenanthrene and 1-methylphenanthrene tissue concentrations were significantly higher in the Deer Island tissues than in the Discovery mussels (P<0.05) (Figure 4). With the exception of perylene, every HMW PAH was found in significantly higher tissue concentrations in the Discovery mussels (P<0.05). Correction for differences in lipid percentages for the two locations in PAH concentrations did not appreciably affect the trends observed based on the dry weight concentrations; the lipid adjusted LMW PAHs (predominantly the methylnaphthalenes) were higher in the Deer Island mussels while the lipid adjusted HMW PAHs were higher in the Discovery mussels (Figure 5).

3.2.3 Pesticides

Matrix spike analyses for pesticides were conducted on three mussel tissue samples during the study (Appendix D). However, these samples were spiked at relatively low levels relative to actual tissue concentrations and percent recovery was, consequently, highly variable. There were also three replicate analyses conducted on the NIST SRM 1974 material for noncertified compounds for quantitative information on analytical techniques used in the study (Table 10). Generally, there was good agreement between mean concentrations and NIST average concentrations for the specific compounds.

Eight composite samples of mussel tissue were analyzed for pesticides for the LNB and the Deer Island locations, while five composite samples were analyzed each from the Gloucester and Discovery locations (Table 11). One Deer Island replicate, 164483, was analyzed using a backup archived subsample due to inadvertent loss of the original subsample concentrate. This archived subsample was one-tenth the sample volume of the original subsample (and the other 25 samples analyzed) resulting in calculated detection levels approximately a factor of 10 higher than target detection

levels. Because these higher reported levels would bias the estimation of mean concentrations, this sample was not used in subsequent calculations of mean concentrations of pesticides in the Deer Island sample population.

Hexachlorobenzene, lindane, heptachlor, aldrin, 2,4'DDE and mirex were found at or near the detection levels in mussels from all four locations (Table 11; Figure 6). Total DDTs (sum of all the DDE, DDD, DDT isomers) was lowest in mussels collected at Gloucester (15.1 ug/Kg dry weight) and harvested from LNB (11.7 ug/Kg dry weight). Deer Island mussels total DDT concentrations (25.1 ug/Kg dry weight) were significantly higher than LNB and Gloucester collected mussels but were significantly less than the Discovery mussels (103 ug/Kg dry weight) ($P<0.05$). The isomers, 2,4'-DDD, 4,4'-DDE, and 4,4'-DDD, represented most of the total DDTs found and were found in highest concentrations in Discovery mussels.

Alpha-chlordane was found in similar concentrations in Gloucester (1.9 ug/Kg) and LNB (1.7 ug/Kg) ($P<0.05$). Alpha-chlordane was found in the highest concentrations (18.7 ug/Kg) in Discovery mussels ($P<0.05$). Deer Island mussel also had elevated alpha-chlordane (6.9 ug/Kg) concentrations relative to Gloucester and LNB, but significantly less than Discovery concentration ($P<0.05$).

Tissue concentrations of trans-nonachlor followed the same trend of highest concentrations in Discovery (21.3 ug/Kg) and significantly lower body burdens in Deer Island mussels (8.3 ug/Kg) ($P<0.05$). The Gloucester tissue concentrations (2.1 ug/Kg) and LNB (2.5 ug/Kg) were similar ($P>0.05$). The dieldrin/aldrin group also displayed this same statistical trend with average concentrations ranging from 8.7 ug/Kg in Discovery mussels, 3.9 ug/Kg in Deer Island mussels and generally not detected in the Gloucester and LNB mussels.

Lipid adjusted average concentrations for the target pesticides displayed the same trends observed for dry weight comparisons (Figure 7). Many of the lipid adjusted pesticides, heptachlor epoxide, alpha-chlordane, trans-nonachlor, dieldrin, 4,4'DDE, 2,4'DDD, 4,4'DDD, were all found in the highest concentrations in the Discovery mussel tissues.

3.2.4 Polychlorinated Biphenyls

Matrix spike analyses for PCBs were conducted on three mussel tissue samples during the study (Appendix D). These samples were spiked at low levels relative to the actual tissue concentrations for many compounds and percent recovery calculations were highly variable (Appendix D). To qualitatively examine the analytical methods used in the study three replicate analyses of the NIST SRM 1974 reference material for noncertified PCB compounds were undertaken (Table 12). Mean concentrations determined for the selected compounds generally were in agreement with the NIST reported mean concentrations. Interestingly, the mean concentration of one analyte (CL2-PCB (28)) was about twice as high as the NIST reported average. However, the NIST analytical results reported also varied by a factor of two (61-62 ug/Kg by GC-ECD to 159 ug/Kg by GC-MS) for this noncertified value.

Twenty-six composite samples of mussel tissue were analyzed for PCB congeners by level of chlorination (Table 13). As discussed previously, the Deer Island sample, 164483, was analyzed using an archived sample and reported detection levels were nearly ten-fold higher than all other samples. This sample analysis was not used in any calculations of average tissue concentrations of the Deer Island sample population.

Total PCB concentrations in the LNB mussels (44.4 ug/Kg) were significantly less than in mussels from the remaining three locations, Gloucester (65.2 ug/Kg), Deer Island (133 ug/Kg), and Discovery (652 ug/Kg) ($P<0.05$). Discovery, Deer Island and Gloucester tissue concentrations were all statistically different from each other ($P<0.05$). The Discovery mussel tissues contained nearly a four-fold and more than twelve-fold higher total PCB tissue concentrations than Deer Island and Gloucester mussels, respectively.

Seven congeners, CL2-PCB(8), CL4-PCB(66), CL4-PCB(77), CL5-PCB(126), CL8-PCB(195), CL9-PCB(206), CL10-PCB(209), were observed at or near detection levels in all samples from the four locations (Table 13; Figure 8). Four congeners, CL5-PCB(101), CL6-PCB(153), CL5-PCB(118), and CL6-PCB(138), accounted for one-half to two-thirds of the total PCB concentrations in the samples from the four locations. These four

congeners as well as CL5-PCB(105) and CL4-PCB(52) were significantly higher in Deer Island mussel tissues than Gloucester and the LNB tissues ($P<0.05$). The Discovery mussel concentrations of these congeners were the highest observed, exceeding the Deer Island tissue concentrations of these individual congeners by at least three-fold ($P<0.05$).

Lipid adjusted tissue concentrations of individual PCB congeners displayed the same trend observed for the dry weight comparisons (Figure 9). The Discovery mussel concentrations were the highest observed while Deer Island lipid adjusted tissue concentrations of many of the lipid adjusted individual congeners (those found above detection levels) were elevated above the Gloucester and LNB lipid adjusted concentrations.

3.3 1991 and 1992 Comparisons

3.3.1 Gloucester

Mussels from Gloucester were harvested prior to deployment (June) in both 1991 and 1992 to measure initial or 'background' conditions. Since the analyses on 'background' tissue concentrations were conducted on mussels from the same location and during the same season (June), comparison of these two sets of data is useful in examining the consistency in analyses between the years (assuming that annual variations are relatively minor between 1991 and 1992).

Although Gloucester mussels selected in June 1991 averaged nearly 4 mm smaller than 1992 Gloucester mussels, these size differences were not statistically significant ($P>0.05$) (Table 14). Gonad-mantle dry weight was more than twice as high in 1992 compared to 1991 ($P<0.05$). Gonad/Total Soft Condition Index for 1992 mussels was much higher than the 1991 Condition Index ($P<0.05$). The non-gonadal dry weight, shell dry weight and the Total Soft/Shell Condition Index did not differ between the two years ($P>0.05$).

The tissue analyses for target analytes showed good agreement between the two years. There were no significant differences in average total PAHs, total pesticides and total PCBs ($P>0.05$). The dieldrin/aldrin group did display significant differences between average concentrations

for the two years but this difference may have been due in part to the relatively low concentrations found. The results obtained during 1991 and 1992 suggest that the data (and analyses) were generally comparable.

3.3.2 Deer Island

Mussels harvested from Deer Island in 1991 and 1992 were similar in average shell length and wet weight (Table 14). The gonad-mantle, the non-gonadal soft tissue and shell dry weights were also in agreement for both years (P>0.05). There were statistical differences in Condition Indices (Gonad/Total Soft, Total Soft/Shell) with both Indices higher in 1992. It is unknown what the biological importance of this observation may be, since spawning does occur in early summer and differences in spawning conditions may be a factor. However, these differences are noted since it provides context for the body burden analyses conducted.

Total PAHs in 1991 Deer Island tissue averaged about 20 percent less than in 1992; this difference was not statistically significant (P>0.05) (Figure 10). The LMW PAHs were similar between the two years (P>0.05). For HMW PAHs, the 1992 Deer Island concentrations (1507 ug/Kg dry weight) averaged more than 80 percent higher than 1991 Deer Island concentrations (829 ug/Kg) (P<0.05). In both 1991 and 1992 Deer Island tissues the methylnapthalenes (2-methylnaphthalene, 1-methylnapthalene, 2,6-dimethyl-naphthalene, and 2,3,5-trimethylnaphthalene, phenanthrene and 1-methylphenanthrene), displayed significant increases in tissue concentrations (Figure 11). The compounds of 2,6-dimethylnaphthalene, and 2,3,5-trimethylnaphthalene were present at lower concentrations in 1992 Deer Island tissue than in 1991.

Total pesticide and total PCB tissue concentrations were similar for both years (Table 14). The 1992 DDD/DDE/DDT average tissue concentrations (25 ug/Kg) were significantly lower than average tissue concentrations (46 ug/Kg) observed for 1991 Deer Island mussels (P<0.05).

There was generally good agreement between the individual pesticide concentrations found in the 1992 and 1991 Deer Island mussels (Figure 12). The 1992 tissue concentrations of 4,4'-DDE and 4,4'-DDD were significantly lower than 1991 tissue concentrations (P<0.05) and were the major reason for statistical differences in total DDTs observed.

Slightly lower PCB tissue concentrations (particularly CL6-PCB(153) and CL6-PCB(138)) were observed in 1992 tissues but overall generally good agreement of average tissue concentrations were observed for the two years of data from Deer Island mussels (Figure 13).

3.3.3 Discovery

The mussels deployed in 1991 at the Discovery location were smaller than 1992 Discovery deployment mussels (and smaller average size than all other deployed mussels in 1991 and 1992) ($P<0.05$) (Table 14). Soft tissue (gonad-mantle and non-gonadal) dry weights were similar for the two years ($P>0.05$) while the shell dry weight was significantly less for the 1991 mussels reflecting the smaller size of mussels deployed. The condition indices displayed some variability between the two years with the Gonad/Total Soft Condition Index higher in 1992 and the Total Soft/Shell Condition Index higher in 1991. There were no significant differences in either the average percent lipids or percent solids between the two years at this location.

The differences in total PAH tissue concentrations of nearly one-third higher in 1992 (3545 ug/Kg) than in 1991 (2569 ug/Kg) were not significantly different ($P>0.05$) (Table 14; Figure 10). Most of the increased 1992 total PAH tissue concentrations were the result of HMW PAH concentrations being found in significantly higher concentrations (Figure 11).

The total Discovery pesticide tissue concentrations did not vary significantly between the two years ($P>0.05$). Several pesticide concentrations, notably trans-nonachlor and 4,4'-DDE, were higher in 1992 ($P<0.05$) (Figure 12).

The total PCB tissue concentrations were not different for the two years at the Discovery location ($P>0.05$). In 1992, concentrations of CL4-PCB(52), three CL5-PCBs(101, 105, 118) and two CL6-PCBs(153, 138) were higher than the comparable 1991 body burdens (Figure 13).

4.0 DISCUSSION

There was an overall uniformity of size of mussels (shell length) among the three locations after the 60-day exposure in 1992. The LNB mussels had significantly more soft tissue (both gonadal and non-gonadal) than mussels exposed at either Deer Island and Discovery. Consequently, the Total Soft/Shell Condition Index for LNB mussel was appreciably higher suggesting that the LNB mussels growth, measured as the increase in total soft tissue, outperformed the mussels from the other two locations. The LNB mussels, deployed at 11-13 m below the surface, were located in the euphotic zone (10-20 m depth) where algal concentrations (as measured by Chlorophyll a) were maximum (M. Hall personal communication).

Growth, as measured by increased shell length was not sensitive enough to detect differences among the three stations. Biological Condition Indices of mussels harvested in 1992 were generally similar to 1991 mussels harvested from the same locations.

The analyses of 'background' conditions of the June 1991 and 1992 Gloucester mussels were viewed as providing a measure of consistency between the sampling and analytical experimental designs employed during the two years. The good agreement that was observed for these two annual replicates does suggest a high degree of comparability of the data, particularly since annual variability could confound this comparison. Triplicate analyses of the NIST SRM 1974 for certified PAH compounds suggested that the analytical methodologies used trended high with values outside the upper confidence limits reported for certified PAH concentrations. Even though this conservative trend was noted in 1991, the 1992 trend was more pronounced.

The analytical results from the 1992 study confirmed the same tissue concentration trends observed among the locations in 1991. The Discovery mussels contained the highest body burdens of HMW PAHs, total pesticides, and total PCBs. Concentrations of these three groups of contaminants were also significantly higher at Deer Island than in either Gloucester (initial) or LNB mussels but were significantly less than Discovery mussel concentrations. The concentrations of LMW PAHs were highest in the Deer Island mussels. Individual methylnaphthalene compounds were routinely highest in Deer Island mussel tissues.

The LNB mussels harvested in August contained body burdens that were comparable to or less than background tissue concentrations reported for the June-harvested Gloucester mussels. The LMW and HMW PAHs, and total PCBs were significantly less in LNB mussels in August than in the Gloucester mussels harvested in June, perhaps due to elimination or depuration of these compounds within the tissues. Reduced total PCB mass concentration resulting from the increased growth of soft tissue in these mussels could also have occurred.

A similar pattern of reduced tissue concentrations after deployment was observed in 1987 when organic contaminants were lower in mussels deployed in Massachusetts Bay (near LNB) than in background mussels collected from Sandwich, Massachusetts (MWRA 1988). However, the average tissue concentrations of many pesticides and PCBs in these 1987 mussels were several times higher than the LNB mussels of the 1992 study. One possible explanation for these apparent differences is the loss of tissue contaminants by depuration in 1987 may not have been as complete as in 1992 due to differences between the studies: the 1987 Sandwich mussels contained higher background tissue concentrations than the 1992 Gloucester mussels; and the mussels were deployed for less time (30 days) in 1987. It is also possible that ambient water concentrations of PCBs and pesticides in Massachusetts Bay were higher in 1987 than in 1992.

The trend of lower body burdens of target analytes observed in the 1991 Deer Island study when compared to the 1987 Deer Island study was supported by the 1992 Deer Island study results for most compounds (Table 15). With the exception of total PAHs, all of the 1992 average body burdens were less than or equal to 1991 estimates. The total PAH concentrations for 1992 mussels was approximately 20 percent higher than 1991; however, the average 1992 total PAHs concentration was nearly 20 percent less than 1987 average concentrations.

While tissue contaminant concentrations displayed little change for all target analytes between the 1991 and 1992 pre-deployment mussels (Gloucester), the total PCB and the total pesticide tissue concentration patterns were noticeably different for the Deer Island and Discovery locations. For the Discovery deployed mussels, several pesticides and PCBs

were found in higher tissue concentrations in 1992 when compared to 1991. As stated previously, for Deer Island deployed mussels, lower but nonsignificant average concentrations of pesticides and PCBs were noted in 1992.

HMW PAHs were observed in higher concentrations in mussels deployed at the Deer Island and Discovery locations in 1992 than in 1991. The 1992 Deer Island tissue concentrations ranged from 66 to more than 300 percent higher than 1991 Deer Island individual PAH concentrations. The HMW PAH tissue concentrations in the 1992 Deer Island mussels were also higher than 1987 Deer Island mussel tissue concentrations.

The reason(s) for the apparent higher HMW PAHs observed in 1992 in the Deer Island and Discovery mussels is unknown. However, there are several plausible explanations for this apparent increase in HMW PAHs in the 1992 Deer Island and Discovery mussels. It is possible that these increased concentrations may in fact reflect the variability in analytical precision experienced between 1991 and 1992. Although the estimates of tissue concentrations in the NIST SRM 1974 material did not differ substantially between years, the 1992 SRM 1974 analytical results displayed a consistent trend of conservatively (higher than the certified values) measuring individual PAHs in the SRM 1974 materials. It is possible that this more conservative trend could account for much of the difference between years.

Another explanation for differences may be annual variations in the overall water quality that the mussels were exposed to in the Inner Harbor. In 1992, there were several activities which may have increased sediment suspension and may have increased the load of target analytes directly to the water column. Dredging of the Inner Harbor throughout the 1992 study occurred near the southeasterly runway of Logan Airport approximately one mile from the Discovery location and more than three miles from the Deer Island location. This dredging could have increased the suspension of contaminated Inner Harbor sediments into the water column thereby increasing the exposure of the mussels at both Harbor deployment locations. Also, the increased boat traffic that occurred during the visit of the tall ships to Boston (approximately two weeks after the deployment of the

mussels) may have increased water column contaminants either by increased sediment suspension or the discharge of combustion by products from powerboat engines.

Regardless of the mechanism that may have contributed to possible annual differences in mussel exposure scenarios, higher total PAH concentrations, due to higher HMW PAH concentrations, occurred in 1992 in mussels from both locations, Deer Island and Discovery. This 1992 study result suggests that the increased HMW PAH body burdens at Deer Island was not primarily due to exposure to the Deer Island effluent.

In contrast to the HMW PAHs, the LMW PAHs, which account for more than 90 percent of the reported PAHs in Deer Island effluent, were found in lower average concentrations in 1992 Deer Island tissues than in 1991, although these differences were generally nonsignificant. Even though PAH analytical methods in 1992 were believed to be conservative, i.e., biased high for individual PAHs, the Deer Island mussel LMW PAHs were also significantly less than tissue concentrations reported for 1987 LMW PAHs (Table 16).

Results of the 1992 study were generally consistent with reported 1991 trends of reduced body burdens in Deer Island mussels since 1987 (Downey and Young 1992). Even though there are important differences between the 1987 and the 1991/1992 studies (such as length of deployment and analytical techniques), the results of these 1991 and 1992 studies suggest that exposure concentrations of LMW PAHs, pesticides and PCBs near Deer Island (and by implication in the Deer Island effluent) may have declined during the period from 1987 to 1992.

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Table 1. Mussel harvest and analysis experimental design summary.

Location	Deployment Method	Initial Deployment and Analyses: Deployment Arrays (N)	Deployment Mussels (N)	Analyses Body Burden[1] (N)	Analyses Biology[2] (N)	Thirty-Day Harvest: Harvest Arrays (N)	Harvest Mussels (N)	Sixty-Day Harvest: Harvest Arrays (N)	Harvest Mussels (N)	Analyses Body Burden[1] (N)	Analyses Biology[2] (N)
Gloucester	--	--	80	5	30	--	--				
Discovery	Suspended	2	240	--	--	1	120	1	120	5	30
Deer Island Light	Subsurface Buoy Array	3	360	--	--	1	120	1	120	5	30
Off-Shore	Subsurface Buoy Array	3	360	--	--	--	--	1	120	8	30
	Chain Attachment	2	240	--	--	1	120	1	120	8	30
	Total Mussels		**1,280**								

1. Body burden included the chemical analyses of mussel tissue. Each body burden sample consisted of ten mussels composited. Each composite sample consisted of the same sex mussels (male or female) when possible. In addition, the total shell length of each mussel in the composite was measured. Samples were stored frozen until analysis.

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

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Table 2. Survival and stage of gametogenesis of mussels determined before deployment for "initial" Gloucester, and during the "thirty" and "sixty"-day retrieval from the three stations.

	Num.	% Survival	Sample size	Females		Males	
				Mature	Immature	Mature	Immature
"Initial"							
Gloucester	--	--	30	12	2	14	2
"Thirty"-day							
Discovery	81	100	--	--	--	--	--
Deer Island	118	99	--	--	--	--	--
LNB	120	100	--	--	--	--	--
"Sixty"-day							
Discovery	117	98	30	12	1	7	10
Deer Island	155	99	29	12	0	15	2
LNB	318	98	30	13	0	15	2

-- Not applicable

Table 3. Cage-specific length (mm) at harvest for selected mussels from the four stations, 1992. For the initial (June) average length of mussels per cage, 20 mussels (out of 40 total) were measured. For the August cage retrieval, 10 mussels (out of the total that survived) were randomly selected and measured.

	Initial Gloucester June 1992				Retrieval August 1992				
Cage #	Avg.	SD	Min.	Max.	Avg.	SD	Min.	Max.	Deployment Location
1	61.9	4.4	55.4	70.1	62.1	2.8	57.9	66.1	Discovery
2	61.4	3.1	55.2	66.2	63.3	2.4	59.7	67.9	Discovery
3	61.6	5.5	55.0	69.8					
4	62.1	3.7	56.3	68.2	62.3	3.6	57.6	68.9	LNB
5	62.9	3.9	54.6	68.6					
6	61.5	4.2	55.0	70.3					
7	59.5	3.7	54.8	68.8					
8	60.1	2.7	56.1	65.5					
9	61.1	3.9	55.9	69.7					
10	61.3	4.3	55.0	69.9					
11	59.5	3.5	54.8	68.4	61.2	3.4	55.9	67.2	LNB
12	62.2	4.9	54.9	69.8					
13	63.0	3.7	57.9	70.3					
14	60.1	4.2	54.6	70.0					
15	60.0	3.5	55.2	68.3					
16	61.8	4.0	55.1	67.8					
17	63.1	4.2	55.4	69.7					
18	62.7	4.1	55.6	69.9					
19	60.8	4.4	54.8	69.4					
20	61.5	3.9	55.4	69.8	64.2	3.4	57.6	69.0	Discovery
21	59.8	4.2	54.8	69.9	61.4	4.7	56.1	70.3	Deer Island
22	60.2	3.8	54.8	67.9	63.5	3.7	58.1	71.2	LNB
23	60.2	3.5	54.9	67.5					
24	59.4	4.1	54.8	66.9					
25	60.9	4.5	55.1	68.5					
26	60.0	3.3	55.0	65.8					
27	60.0	3.3	55.2	67.7					
28	61.2	3.8	55.8	70.4					
29	61.8	3.7	56.7	69.4	64.2	3.2	58.8	68.8	Deer Island
30	61.5	4.1	55.4	69.4	62.4	3.8	57.3	69.4	Deer Island

Initial Sample Size	Avg.	SD	Min.	Max.	Retrieval Sample Size	Avg.	SD	Min.	Max.	
60	61.6	3.8	55.2	70.1	30	63.2	2.9	57.6	69.0	Discovery
60	61.0	4.0	54.8	69.9	30	62.7	4.0	56.1	70.3	Deer Island
60	60.6	3.8	54.8	68.4	30	62.3	3.6	55.9	71.2	LNB
599	61.1	3.9	55.3	68.8						Overall

Table 4. Summary of various biological measurements expressed as mean values for mussels. "Initial" Gloucester represents measurements on mussels at beginning of study and retrieval represent values at end of study. Condition factors represent overall average of individual condition factor calculations. Sample size is listed in parentheses following the location.

Location	Mean Shell Length (mm)	Mean Total Wet Weight (g)	Mean Dry weight (g)			Mean Condition Index	
			Gonad-Mantle	Non-gonadal Soft Tissue	Shell	Gonadal Condition Index	Total Soft/Shell Condition Index
"Initial"							
Gloucester (30)	60.54	25.47	0.51	0.82	11.79	38.22	114.5
Retrieval							
Discovery (30)	63.18	28.85	0.56	0.84	13.93	38.13	104.5
Deer Island (29)	62.66	29.49	0.62	0.96	13.49	38.34	120.1
LNB (30)	62.34	28.78	0.90	1.27	13.35	41.44	168.1

Table 5. Percent lipid and solids in mussels collected from four locations, 1992. On several samples duplicate (and triplicate) analyses were conducted. These replicate analyses were averaged and the average value for the sample was used in calculating mean population concentrations listed below.

		Tissue Composition					
		Percent Lipids			Percent Solids*		
Location	N	Mean	SD	Range	Mean	SD	Range
Gloucester	5	4.8	1.6	3.6-7.5	14.3	1.2	12.8-15.9
LNB	8	4.2	0.9	3.1-5.4	15.8	0.8	14.5-16.6
Deer Island	8	5.1	1.0	3.6-7.1	12.2	2.0	10.5-16.8
Discovery	5	5.1	0.7	4.1-5.8	9.4	0.7	5.7-11.0

* All mean values for solids were statistically different from each other ($P<0.05$; Mann-Whitney U Test).

Table 6. **Percent recovery for matrix spike analyses conducted for selected polynuclear aromatic hydrocarbons. Matrix spikes are designated with a MS suffix on laboratory ID while matrix spike duplicates were designated with a MSD suffix.**

Laboratory ID:	164486MS	164486MD	164491MS	164491MD	164499MS	164499MD
Matrix Spike (ug/Kg)	86.6	100	30.8	30.2	20.5	21.0
Parameter						
Naphthalene	107	114	106	115	114	108
2-Methylnaphthalene	141	150	144	174	144	138
1-Methylnaphthalene	127	137	126	137	130	127
1,1-Biphenyl	127	154	118	142	146	148
2,6-Dimethylnaphthalene	127	132	118	107	109	120
Acenaphthylene	96	129	113	95	106	107
Acenaphthene	112	115	99	91	105	107
2-3-5-Trimethylnaphthalene	118	119	112	100	135	122
Fluorene	109	110	124	119	133	121
Phenanthrene	102	119	127	126	95	97
Anthracene	113	113	110	103	114	113
1Methylphenanthrene	96	110	07	188	119	123
Fluoranthene	105	131	--	--	87	79
Pyrene	99	127	--	--	85	81
Benzo(a)anthracene	66	90	86	--	114	113
Chrysene	33	71	--	--	97	96
Benzo(b)fluoranthene*	97	123	194	194	117	108
Benzo(e)pyrene	88	98	245	116	117	117
Benzo(a)pyrene	54	67	107	234	78	64
Perylene	94	99	140	153	125	120
Indeno(1,2,3-cd)pyrene	99	102	108	218	109	101
Dibenz(a,h)anthracene	89	92	94	129	105	105
Benzo(g,h,i)perylene	69	83	86	201	64	340
Benzo(k)fluoranthene	75	83	157	186	***[1]	***[1]

[1] - These samples reported Benzo(k)floranthene as coeluting with Benzo(b)fluoranthene.

-- - Indicates results not reported. The MS and MD were spiked at such low levels relative to the actual sample concentration that percent recovery calculations were not meaningful.

Table 7. Triplicate analyses of NIST certified mussel tissue 1991 and 1992. All results are reported on a wet weight (ug/Kg) basis.

	NIST Certified Values	1991 Triplicate Analyses[1]	1992 Triplicate Analyses	
Parameter	**Mean(95% CI)**	**Mean(SD)**	**Mean(SD)**	**Range**
Phenanthrene	5.6(±1.4)	5.5(0.6)	7.9(3.3)	5.6-11.7
Anthracene	0.75(±0.21)	1.1(0.3)	1.8(1.4)	0.3-3.1
Fluoranthene	33.6(±5.8)	37.8(3.6)	38.4(0.7)	37.8-39.1
Pyrene	34.1(±3.7)	37.0(3.3)	37.5(3.3)	34.0-40.5
Perylene	1.05(±0.29)	1.6(0.9)	1.9(1.0)	1.0-3.0
Benzo(b)fluoranthene	6.5(±1.2)	12.2*(0.7)	7.3(1.4)	5.7-8.3
Benzo(a)pyrene	2.29(±0.47)	3.2(0.6)	4.0(0.4)	3.7-4.5
Benzo(g,h,i)perylene	2.47(±0.28)	2.6(0.2)	3.9(0.9)	3.1-4.8
Indeno(1,2,3-cd)pyrene	1.8(±0.33)	1.5(0.5)	2.8(1.2)	2.1-4.2

*The reference value applies to the concentration of benzo(b)fluorathene only. In the triplicate analyses, benzo(b/k)fluoranthene co-eluted.

[1] Data taken from Downey and Young 1992.

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Table 8. Triplicate analyses of NIST noncertified concentrations of PAHs in SRM 1974. All results are reported on a wet weight (ug/Kg) basis.

Compound	NIST Noncertified Values		1992 Triplicate Analyses			
	Mean	SD	Mean	SD	Min.	Max.
2-Methylnaphthalene	2.1	0.5	2.7	0.5	2.0	3.2
1-Methylnaphthalene	1.1	0.2	1.3	0.2	1.1	1.5
1-Methylphenanthrene	2.8	0.6	3.3	1.2	2.2	5.0
2,6-dimethylphenanthrene	4.6	0.9	1.5	0.3	1.1	1.5
Flourene	1.6	0.2	1.4	0.3	1.0	1.7
Benz[a]anthracene	4.6	0.4	8.2	0.4	5.8	6.1
Benzo[k]fluoranthene	3.0	0.1	4.8	0.5	4.2	4.7
Benzo(e)pyrene	10.0	1.0	10.6	2.0	7.8	12.0
Ideno(1,2,3-cd)pyrene	0.5	0.1	2.8	1.0	2.1	2.1
Dibenz(a,h)fluoranthene	0.4	0.0	1.1	0.0	1.1	1.2

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Table 9. Polynuclear aromatic hydrocarbon (ug/Kg dry weight) concentrations in mussels exposed from the four stations. The total PAHs and total PAHs summed by group (ie. 2 & 3 ring and 4, 5 & 6 ring) were calculated using the detection limit value as an estimated concentration when individual analytes were not detected.

	Gloucester (Initial)					LNB							
Laboratory ID:	162679	162680	162681	162682	162683	164499	164498	164497	164496	164495	164494	164493	164492
Parameter	F	M	M	F	M / F	M(3)-F(7)	M(1)-F(9)	F	M	F	M	F	M
Naphthalene	<5	<5	<5	<5	<5	<5	<5	<5	5.4	<5	<5	<5	<5
2-Methylnaphthalene	9.6	6.7	12.0	7.2	11.9	<5	<5	<5	<5	<5	<5	<5	<5
1-Methylnaphthalene	8.9	6.7	5.2	<5	6.8	<5	<5	<5	<5	<5	<5	<5	<5
1,1-Biphenyl	<5	5.0	<5	<5	<5	<5	<5	<5	5.9	8.0	<5	<5	<5
2,6-Dimethylnaphthalene	6.2	6.7	<5	<5	5.1	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthylene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthene	8.9	5.0	6.7	<5	5.9	<5	<5	<5	<5	<5	<5	<5	<5
2,3,5-Trimethylnaphthalene	6.9	9.2	<5	5.6	6.6	<5	<5	<5	<5	<5	<5	<5	<5
Fluorene	5.5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Phenanthrene	15.7	11.8	12.0	9.5	14.4	7.9	5.6	5.0	<5	26.7	<5	<5	5.4
Anthracene	6.6	6.7	6.7	<5	<5	<5	<5	<5	5.1	<5	<5	<5	<5
1-Methylphenanthrene	5.5	6.7	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Total of 2 & 3 ring groups	92.9	79.7	77.7	67.3	81.0	62.9	60.6	60.0	61.4	86.7	60.0	60.0	60.4
Fluoranthene	28.7	21.9	18.7	23.0	22.9	9.4	6.6	6.9	7.1	88.9	7.1	7.5	14.9
Pyrene	21.9	17.7	12.0	15.1	15.3	7.4	6.6	6.6	<5	201	5.6	<5	21.4
Benz(a)anthracene	10.9	8.4	5.2	<5	5.9	<5	<5	<5	<5	29.8	<5	<5	5.1
Chrysene	21.2	17.7	9.0	10.3	11.0	<5	<5	<5	<5	60.0	<5	<5	6.3
Benzo(b)fluoranthene	15.7	12.6	<5	<5	5.9	17.1	7.6	8.1	<5	71.2	<5	9.9	7.7
Benzo(e)pyrene	17.8	19.3	7.5	7.2	8.5	<5	<5	<5	<5	131	<5	<5	5.7
Benzo(a)pyrene	14.4	13.5	5.2	<5	5.9	6.0	<5	<5	<5	156	<5	<5	<5
Perylene	11.6	15.1	12.7	13.5	12.7	<5	<5	<5	<5	57.0	<5	<5	6.6
Indeno(1,2,3-cd)pyrene	16.7	15.1	<5	<5	5.1	<5	<5	<5	<5	63.9	<5	<5	<5
Dibenzo(a,h)anthracene	<5	<5	<5	<5	<5	<5	<5	<5	<5	11.8	<5	<5	<5
Benzo(g,h,i)perylene	17.6	17.7	<5	<5	5.1	<5	<5	<5	<5	296	<5	<5	5.4
Benzo(k)fluoranthene	12.3	13.5	6.0	5.6	5.9	***	***	***	<5	40.7	<5	***	<5
Total of 4, 5 & 6 ring groups	193	177	96.3	105	109	75.0	60.8	61.6	62.1	1208	62.7	62.4	95.1
Total PAH's	286	257	174	172	190	138	121	122	124	1294	123	122	156

	Discovery					Deer Island							
Laboratory ID:	164491	164490	164489	164488	164487	164486	164485	164484	164483	164482	164481	164480	164479
Parameter	M(8)-F(2)	F	M	F	M	M(5)-F(5)	M	F	M	F	M	F	M
Naphthalene	18.3	14.5	9.0	9.9	62.5	17.0	11.5	13.0	17.0	26.5	44.3	18.2	10.9
2-Methylnaphthalene	11.9	9.4	8.0	7.8	36.9	31.6	22.2	35.9	25.3	50.4	80.7	45.1	19.1
1-Methylnaphthalene	6.2	<5	<5	<5	17.3	13.0	8.8	13.5	12.2	20.4	28.3	17.6	7.0
1,1-Biphenyl	13.4	8.2	<5	<5	35.9	22.6	18.0	17.0	9.2	25.9	33.9	25.4	14.5
2,6-Dimethylnaphthalene	<5	6.2	<5	<5	11.4	43.2	21.8	48.2	26.6	46.7	36.0	48.0	17.5
Acenaphthylene	13.2	13.2	6.1	12.5	13.4	24.1	11.9	7.7	<5	12.7	13.4	10.7	11.1
Acenaphthene	12.9	14.8	7.3	9.7	11.9	7.7	<5	8.5	7.8	18.8	26.0	11.6	10.5
2,3,5-Trimethylnaphthalene	9.0	9.1	<5	5.8	16.7	92.6	41.7	90.3	43.0	77.9	50.1	86.8	26.4
Fluorene	10.8	14.6	<5	10.7	20.8	35.0	19.3	24.6	19.1	36.8	43.0	28.7	13.6
Phenanthrene	51.3	47.1	26.2	34.4	75.4	76.2	48.0	75.7	60.0	112.5	139.1	87.9	41.6
Anthracene	23.6	29.4	13.3	16.7	25.0	7.0	6.8	7.0	16.2	15.1	31.9	8.9	10.9
1-Methylphenanthrene	18.1	23.2	11.9	17.5	28.8	118.7	89.2	106.1	66.0	105.7	79.7	112.7	45.9
Total of 2 & 3 ring groups	194	194	109	142	356	489	284	448	307	550	608	502	231
Fluroanthene	845	1171	482	719	860	250	179	183	179	288	222	251	146
Pyrene	1003	1220	534	766	740	436	302	347	274	461	327	439	192
Benz(a)anthracene	291	352	172	226	260	182	112	114	141	209	131	157	104
Chrysene	489	576	280	357	489	446	316	299	348	501	344	376	223
Benzo(b)fluoranthene	276	334	179	255	304	133	86.6	82.6	113	156	123	127	81.9
Benzo(e)pyrene	326	414	230	267	380	160	124	100	146	199	160	151	102
Benzo(a)pyrene	114	137	69.2	93.3	126	52.2	31.2	30.8	43.2	62.8	49.2	48.6	30.4
Perylene	30.6	36.1	19.6	28.4	33.0	19.0	15.7	12.8	18.2	30.4	28.7	26.0	13.8
Indeno(1,2,3-cd)pyrene	44.1	55.6	28.6	33.5	60.6	14.4	9.9	7.7	14.2	16.3	17.6	17.1	12.0
Dibenzo(a,h)anthracene	22.9	28.4	14.2	18.2	37.3	9.2	5.3	5.7	7.4	9.7	10.2	10.7	8.3
Benzo(g,h,i)perylene	79.2	87.1	47.7	60.1	101	34.9	25.3	26.1	59.6	53.6	262	41.2	17.3
Benzo(k)fluoranthene	118	158	89.8	86.5	167	45.8	33.1	23.0	39.1	57.5	47.8	45.5	29.7
Total of 4, 5 & 6 ring groups	3741	4570	2146	2910	3366	1786	1242	1231	1382	2046	1722	1690	960
Total PAH's	3934	4764	2255	3052	3722	2274	1526	1679	1689	2596	2328	2191	1191

Note: *** = Merged with Benzo(b)fluoranthene

Table 10. Triplicate analyses of NIST noncertified pesticide concentrations in SRM 1974. All results are reported on a wet weight (ug/Kg) basis.

Compound	NIST Noncertified Values Mean	SD	1992 Triplicate Analyses Mean	SD	Min.	Max.
Alpha-chlordane	3.2	0.2	3.6	0.3	3.2	4.0
trans-nonachlor	2.6	0.6	4.0	1.1	2.8	5.5
Dieldrin	1.0	0.5	1.1	0.0	1.0	1.1
2,4'-DDE	0.7	0.1	2.6	0.7	2.0	3.5
4,4'-DDE	5.9	0.2	7.0	2.2	4.9	10
2,4'-DDD	2.5	0.9	2.2	0.2	2.0	2.4
4,4'-DDD	8.4	0.4	6.7	1.1	5.4	8.0
2,4'-DDT	0.4	0.2	--	--	<0.3	<0.7
4,4'-DDT	0.3	0.3	--	--	<0.3	<0.8

-- No average was calculated (all results below detection).

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Table 11. Pesticide (ug/Kg dry weight) concentrations in mussels exposed from the four stations. The total Pesticides were calculated by using the detection limit value as an estimated concentration when individual analytes were not detected.

	Gloucester (Initial)					LNB							
Laboratory ID:	162679	162680	162681	162682	162683	164499	164498	164497	164496	164495	164494	164493	164492
Parameter	F	M	M	F	M / F	M(3)-F(7)	M(1)-F(9)	F	M	F	M	F	M
Hexachlorobenzene	<0.75	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
Lindane (gamma-BHC)	<0.75	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
Heptachlor	<0.75	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
Aldrin	<0.75	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
Heptachlor Epoxide	<0.75	<1.18	<0.82	<1.11	<1.02	1.23	<0.92	1.18	<1.00	0.99	1.12	1.20	1.14
alpha-chlordane	1.64	1.56	1.71	1.97	2.56	2.21	1.49	1.43	<1.00	1.40	2.17	1.62	2.26
trans-nonachlor	2.71	2.72	2.99	<1.11	<1.02	2.94	1.75	1.71	3.90	1.66	2.81	2.13	3.02
Dieldrin	0.86	<1.18	0.85	<1.11	<1.02	1.50	0.94	1.06	1.59	<0.88	1.30	0.96	1.35
2,4'-DDE	<0.75	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	0.45	<0.88	<0.96	<0.74	<1.10
4,4'-DDE	5.27	5.60	6.50	6.80	9.80	5.33	3.53	3.71	6.65	3.24	5.56	3.97	5.24
2,4'-DDD	2.90	2.73	2.79	3.20	4.54	1.36	1.07	0.94	1.61	0.95	1.19	1.04	1.20
4,4'-DDD	8.87	8.03	8.68	9.85	13.16	4.15	3.22	2.88	<1.00	2.77	3.91	3.35	3.92
2,4'-DDT	<0.75	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
Mirex	<0.75	<1.09	<0.82	<1.03	<0.93	<1.20	<0.92	<0.91	<0.73	<0.91	<0.82	<0.71	<0.92
4,4'DDT	<0.75	2.38	<0.82	<1.03	3.12	<1.20	<0.92	<0.91	<0.73	<0.91	<0.82	<0.71	<0.92
Dieldrin/Aldrin group	1.61	1.18	1.67	1.11	1.02	2.70	1.86	1.83	2.59	1.76	2.26	1.70	2.45
Chlordane group	5.11	5.46	5.53	3.08	3.58	7.58	5.08	5.09	6.90	4.95	7.06	5.69	7.52
DDD/DDE/DDT	13.25	14.56	14.78	14.44	18.41	14.46	10.58	9.98	11.44	9.63	13.42	10.55	13.48

	Discovery					Deer Island							
Laboratory ID:	164491	164490	164489	164488	164487	164486	164485	164484	164483	164482	164481	164480	164479
Parameter	M(8)-F(2)	F	M	F	M	M(5)-F(5)	M	F	M	F	M	F	M
Hexachlorobenzene	<2.90	<2.10	<1.40	<1.30	<1.90	<2.40	<0.92	<1.20	<32.00	<1.50	<1.10	<0.95	<0.79
Lindane (gamma-BHC)	<2.90	<2.10	<1.40	<1.30	<1.90	<2.40	<0.92	<1.20	<32.00	<1.50	1.12	<0.95	<0.79
Heptachlor	<2.90	<2.10	1.57	<1.30	<1.90	<2.40	1.24	<1.20	<32.00	<1.50	1.43	1.59	0.87
Aldrin	<2.90	<2.10	<1.40	<1.30	<1.90	<2.40	<0.92	<1.20	<32.00	<1.50	<1.10	<0.95	<0.79
Heptachlor Epoxide	7.22	7.00	3.86	3.60	4.76	3.48	0.92	<1.20	<32.00	2.50	1.89	2.66	2.44
alpha-chlordane	25.49	24.45	14.40	11.73	17.29	8.04	6.87	5.40	29.11	8.17	7.82	6.37	5.74
trans-nonachlor	29.17	25.30	17.46	12.83	21.82	8.39	9.27	4.46	25.89	9.36	10.09	6.30	8.49
Dieldrin	9.06	9.41	4.77	5.08	5.33	3.66	2.47	1.72	<32.00	2.75	2.29	3.37	2.39
2,4'-DDE	<2.90	<2.10	<1.40	<1.30	<1.90	<2.40	<0.92	<1.20	<32.00	<1.50	<1.10	<0.95	<0.79
4,4'-DDE	63.15	71.77	1.71	36.17	47.76	12.52	<0.92	7.00	23.74	12.64	12.90	2.49	13.64
2,4'-DDD	20.61	19.73	11.50	9.33	14.05	4.26	2.98	2.87	<32.00	3.84	3.84	2.78	2.51
4,4'-DDD	46.27	56.05	26.86	27.74	42.22	10.34	2.03	6.63	35.42	9.25	9.60	6.68	1.77
2,4'-DDT	3.22	3.28	2.38	1.82	2.37	<2.40	2.63	<1.20	<32.00	<1.50	<1.10	<0.95	2.61
Mirex	<2.00	<2.20	<0.96	<1.00	<1.60	<2.30	<0.79	<1.20	<13.00	<1.50	<1.00	<0.98	<0.83
4,4'DDT	<2.00	<2.20	<0.96	<1.00	<1.60	<2.30	7.99	<1.20	<13.00	<1.50	<1.00	8.13	<0.83
Dieldrin/Aldrin group	11.96	11.51	6.17	6.38	7.23	6.06	3.39	2.92	64	4.25	3.39	4.32	3.18
Chlordane group	64.78	56.85	37.16	29.56	45.79	22.31	17.98	12.26	119	21.53	21.02	16.28	17.46
DDD/DDE/DDT	128	155	44.83	77.36	109.9	34.22	17.47	20.1	168	30.23	29.54	21.98	22.15

Table 12. Triplicate PCB analyses of NIST noncertified mussel tissue, 1992. All results are reported on a wet weight (ug/Kg) basis. Individual PCBs are identified by their BZ number which is in parentheses.

Compound	NIST Noncertified Values Mean	NIST Noncertified Values SD	1992 Triplicate Analyses Mean	1992 Triplicate Analyses SD	1992 Triplicate Analyses Min.	1992 Triplicate Analyses Max.
PCB(18)	3.0	1.0	4.5	1.1	3.5	5.9
PCB(28)	7.6	0.4	16.6	1.2	15.4	18.3
PCB(44)	8.0	3.0	11.6	0.6	11.0	12.4
PCB(52)	12.0	5.0	18.6	1.2	16.9	19.6
PCB(88)	13.6	0.6	14.0	3.4	9.5	17.8
PCB(105)	5.6	0.4	7.6	0.9	6.6	8.7
PCB(118)	13.6	0.6	15.0	2.6	11.6	17.7
PCB(153)	18.0	1.0	13.6	2.6	10.1	16.3
PCB(180)	1.7	0.2	1.6	0.3	1.3	2.0

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Table 13. Polychlorinated biphenyl (ug/Kg dry weight) concentrations in mussels exposed from the four stations. The total PCBs were calculated using the detection limit value as an estimated concentration when individual analytes were not detected.

Laboratory ID:	Gloucester (Initial)					LNB							
	162679	162680	162681	162682	162683	164499	164498	164497	164496	164495	164494	164493	164492
Parameter	F	M	M	F	M / F	M(3)-F(7)	M(1)-F(9)	F	M	F	M	F	M
CL2-PCB(8)	<0.75	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
CL3-PCB(18)	1.05	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
CL3-PCB(28)	1.76	1.56	1.18	1.68	2.04	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
CL4-PCB(44)	2.83	2.35	1.97	2.80	3.41	<1.24	<0.92	0.86	1.20	<0.88	1.11	1.09	1.19
CL4-PCB(52)	3.45	3.35	2.98	4.84	5.20	2.24	1.87	1.63	2.45	1.49	2.14	1.68	2.15
CL4-PCB(66)	1.79	3.06	2.20	4.39	4.06	2.41	1.74	<0.77	<1.00	1.44	2.17	1.78	2.32
CL4-PCB(77)	<0.75	<1.18	<0.82	<1.11	<1.02	<1.20	<0.92	<0.77	<1.00	<0.88	<0.96	<0.74	<1.10
CL5-PCB(101)	6.78	6.53	6.27	8.67	10.77	5.96	4.16	4.25	<1.00	3.58	5.95	4.49	6.23
CL5-PCB(105)	3.17	2.87	2.83	3.65	4.16	2.35	1.69	1.69	<1.00	1.26	2.35	1.74	2.40
CL5-PCB(118)	6.19	6.63	6.36	8.20	9.82	5.94	4.29	4.39	6.95	3.64	6.17	4.62	6.26
CL6-PCB(153)	11.26	10.91	10.88	12.18	15.27	9.88	6.62	6.94	11.88	5.44	11.62	7.75	11.55
CL5-PCB(126)	<0.75	<1.09	<0.82	<1.03	<0.93	<1.20	<0.92	<0.91	<0.73	<0.91	<0.82	<0.71	<0.92
CL6-PCB(128)	1.42	<1.09	1.42	1.85	2.08	1.56	1.07	1.28	1.28	<0.91	1.44	1.07	1.54
CL6-PCB(138)	7.96	7.67	7.56	9.95	9.34	8.39	5.67	6.62	7.85	5.71	7.90	5.97	8.39
CL7-PCB(170)	1.21	<1.09	<0.82	<1.03	<0.93	<1.20	<0.92	<0.91	<0.73	<0.91	<0.82	<0.71	<0.92
CL7-PCB(180)	2.61	1.35	<0.82	<1.03	0.89	<1.20	<0.92	<0.91	<0.73	<0.91	0.98	<0.71	<0.92
CL7-PCB(187)	4.07	3.68	3.80	4.03	4.76	<1.20	1.58	1.89	2.06	1.38	2.39	<0.71	2.37
CL8-PCB(195)	<0.75	<1.09	<0.82	<1.03	<0.93	<1.20	<0.92	<0.91	<0.73	<0.91	<0.82	<0.71	<0.92
CL9-PCB(206)	<0.75	<1.09	<0.82	<1.03	<0.93	<1.20	<0.92	<0.91	<0.73	<0.91	<0.82	<0.71	<0.92
CL10-PCB(209)	<0.75	<1.09	<0.82	<1.03	<0.93	<1.20	<0.92	<0.91	<0.73	<0.91	<0.82	<0.71	<0.92
Total PCB's	60.04	80.25	54.47	71.57	79.53	53.27	38.61	38.86	45.03	34.89	52.16	38.12	54.32

Laboratory ID:	Discovery					Deer Island							
	164491	164490	164489	164488	164487	164486	164485	164484	164483	164482	164481	164480	164479
Parameter	M(8)-F(2)	F	M	F	M	M(5)-F(5)	M	F	M	F	M	F	M
CL2-PCB(8)	<2.90	<2.10	<1.40	<1.30	<1.90	<2.40	<0.92	<1.20	<32.00	<1.50	<1.10	<0.95	<0.79
CL3-PCB(18)	6.08	10.01	4.07	4.79	5.49	<2.40	1.28	<1.20	<32.00	1.77	2.43	1.41	0.81
CL3-PCB(28)	28.86	36.33	14.98	17.54	16.51	5.52	4.53	4.55	<32.00	6.57	4.91	5.98	3.83
CL4-PCB(44)	38.76	48.45	25.09	25.93	19.64	6.34	5.32	4.88	<32.00	7.53	5.81	5.83	4.43
CL4-PCB(52)	81.16	84.80	42.78	39.72	45.97	11.69	9.43	7.73	22.89	11.88	10.53	12.20	8.51
CL4-PCB(66)	<2.90	<2.10	<1.40	<1.30	<1.90	<2.40	<0.92	<1.20	20.05	9.87	8.51	<0.95	<0.79
CL4-PCB(77)	<2.90	<2.10	<1.40	<1.30	<1.90	<2.40	1.11	<1.20	<32.00	<1.50	1.96	0.97	<0.79
CL5-PCB(101)	182	155	99.09	74.94	98.28	19.63	21.18	13.24	40.68	23.47	23.44	21.79	21.28
CL5-PCB(105)	67.20	58.85	36.28	32.04	40.98	7.25	6.81	4.70	19.05	7.72	7.22	6.23	6.04
CL5-PCB(118)	140	131	85.74	64.74	83.53	17.79	16.55	11.66	35.05	19.58	20.51	19.24	18.31
CL6-PCB(153)	155	137	103	79.73	108	23.10	22.78	14.05	31.58	25.29	26.61	24.15	27.11
CL5-PCB(126)	<2.00	9.67	<0.96	<1.00	6.71	<2.30	<0.79	<1.20	<13.00	1.96	1.94	<0.98	<0.83
CL6-PCB(128)	19.03	29.83	14.10	11.66	17.51	4.35	3.44	2.57	<13.00	4.27	4.21	3.61	4.13
CL6-PCB(138)	105	124	62.14	58.45	82.05	19.43	15.71	12.10	16.22	22.41	23.30	20.60	13.70
CL7-PCB(170)	2.48	4.11	2.32	1.57	4.11	<2.30	1.20	<1.20	<13.00	<1.50	2.01	3.02	1.47
CL7-PCB(180)	10.90	23.07	11.35	8.03	18.23	4.38	3.89	2.35	<13.00	<1.50	5.19	3.70	4.75
CL7-PCB(187)	22.03	<2.20	18.30	12.50	<1.60	4.85	4.66	<1.20	<13.00	<1.50	<1.00	4.84	6.03
CL8-PCB(195)	<2.00	<2.20	<0.96	<1.00	<1.60	<2.30	<0.79	<1.20	<13.00	<1.50	<1.00	<0.98	<0.83
CL9-PCB(206)	<2.00	<2.20	<0.96	<1.00	<1.60	<2.30	<0.79	<1.20	<13.00	<1.50	<1.00	<0.98	<0.83
CL10-PCB(209)	<2.00	<2.20	<0.96	6.42	<1.60	<2.30	<0.79	<1.20	7.02	<1.50	<1.00	1.08	<0.83
Total PCB's	885	866	527	445	559	145	125	89.83	443	154	154	139	126

Table 14. Comparison of 1991 and 1992 biological and chemical measurements of mussel tissues from three locations. The 1991 Deer Island results reported are for the Deer Island combined (Shallow and Deep) locations.

	Gloucester (June) 1991		1992		Deer Island (August) 1991		1992		Discovery (August) 1991		1992	
	N	Mean(SD)	N	Mean(SD)	N	Mean(SD)	N	Mean(SD)	N	Mean(SD)	N	Mean(SD)
Shell Length(mm)	30	56.9(7.8)	30	60.5(3.7)	30	62.9(5.3)	29	62.7(4.0)	30	53.6(8.0)	30	63.2(2.9)
Wet Weight(g)	30	18.9(9.4)	30	25.5(6.0)	30	25.2(7.1)	29	29.5(6.2)	30	16.7(6.2)	30	28.9(5.9)
Dry Weight												
Gonad-Mantle (g)	30	0.21(0.13)	30	0.51(0.17)	30	0.43(0.24)	29	0.62(0.24)	30	0.38(0.24)	30	0.56(0.29)
Non-Gonadal (g)	30	0.83(0.37)	30	0.82(0.22)	30	0.93(0.38)	29	0.96(0.21)	30	0.85(0.38)	30	0.84(0.19)
Shell (g)	30	10.0(4.4)	30	11.8(1.3)	30	14.7(3.9)	29	13.5(2.9)	30	8.7(3.7)	30	13.9(3.1)
Condition Indices												
Gonad/Total Soft	30	19.2(7.5)	30	38.2(5.5)	30	30.0(9.9)	29	38.3(5.9)	30	29.1(9.3)	30	38.1(8.0)
Total Soft/Shell	30	108(34.3)	30	114(28.2)	30	94.1(32.6)	29	120.1(29.3)	30	144.0(43.4)	30	104.5(42.5)
Tissue Composition												
Lipids (Percent)	5	4.6(2.3)	5	4.8(1.6)	8	3.3(0.7)	8	5.1(1.0)	5	5.8(1.5)	5	5.1(0.7)
Solids (Percent)	5	13.4(0.5)	5	14.3(1.2)	8	13.0(1.2)	8	12.2(2.0)	5	11.2(2.5)	5	9.4(0.7)
PAH (ug/Kg)												
2,3 Ring	5	113(36.0)	5	79.7(9.1)	8	516(243)	8	427(136)	4	239(28.9)	5	199(945)
4,5,6 Ring	5	104(42.1)	5	136(45.3)	8	691(206)	8	1507(360)	4	2330(411)	5	3347(906)
Pesticides (ug/Kg)												
Dieldrin/Aldrin	5	2.9(1.0)	5	1.3(0.3)	8	5.3(1.8)	7	3.9(1.1)	5	12.2(2.5)	5	8.7(2.8)
Chlordane Group	5	7.1(2.3)	5	5.6(1.1)	8	23.5(8.4)	7	18.7(3.4)	5	27.5(3.9)	5	47.2(14.7)
DDD/DDE/DDT	5	28.3(13.3)	5	15.1(2.0)	8	48.2(13.7)	7	25.1(6.2)	5	93.6(22.7)	5	103(43.1)
Polychlorinated Biphenyls												
PCB, Total (ug/Kg)	5	76.6(33.8)	5	65.2(10.2)	8	199(33.0)	7	133(22.5)	5	477(74.8)	5	652(199)

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Table 15. Comparison of 1987, 1991 and 1992 mussel bioaccumulation results. The 1987 organic means were based on 3 analyses. The 1991 means were based on 8 analyses at Deer Island (Shallow and deep) and in 1992, the PAHs were based on 8 analyses while the PCB and pesticides were based on 7 analyses.

Year Exposure Parameter (ug/Kg)	1987 Study 30-days Mean (SD)	1991 Study 60-days Mean (SD)	1992 Study 60-days Mean (SD)
Total PAHs	2343 (251)	1207 (439)	1934 (480)
LMW PAHs	1221 (184)	516 (243)	427 (136)
HMW PAHs	1123 (165)	691 (206)	1507 (366)
Total PCBs	630 (264)	199 (33)	133 (22.5)
Total DDTs	62.6 (33.7)	48.2 (13.7)	25.1 (6.2)
Dieldrin	11.4 (3.9)	2.9 (0.7)	2.7(0.7)
Alpha-chlordane	21.5 (5.6)	10.3 (3.6)	6.9 (1.1)
Trans-nonachlor	18.0 (3.7)	8.9 (2.9)	8.3 (1.8)

Table 16. **Comparison of selected polynuclear aromatic hydrocarbon concentrations (ug/Kg dry weight) found in Deer Island mussel samples in 1987, 1991 and 1992.**

Year Sample Size Parameter	1987 3 Mean (SD)	1991 4 Mean (SD)	1992 8 Mean (SD)
2-Methylnaphthalene	120 (30.1)	100 (33.4)	39 (20.1)
1-Methylnaphthalene	81 (3.5)	53 (16.8)	15 (6.9)
2,6-Dimethylnaphthalene	291 (56.6)	143 (39.9)	36 (12.5)
2,3,5-Trimethylnaphthalene	383 (37.2)	155 (48.0)	64 (25.7)
Phenanthrene	151 (26.5)	85 (20.9)	80 (8.5)
Fluoranthene	315 (68.6)	200 (49.7)	212 (48.4)
Pyrene	356 (95.5)	200 (49.7)	347 (93.3)
Benzo(a)anthracene	81 (9.2)	80 (22.2)	144 (37.1)
Chrysene	152 (6.6)	112 (28.7)	357 (86.7)
Benzo(b,k)fluoranthene	72 (59.0)	91 (24.7)	154 (38.1)
Benzo(e)pyrene	58 (9.2)	69 (17.2)	143 (33.1)

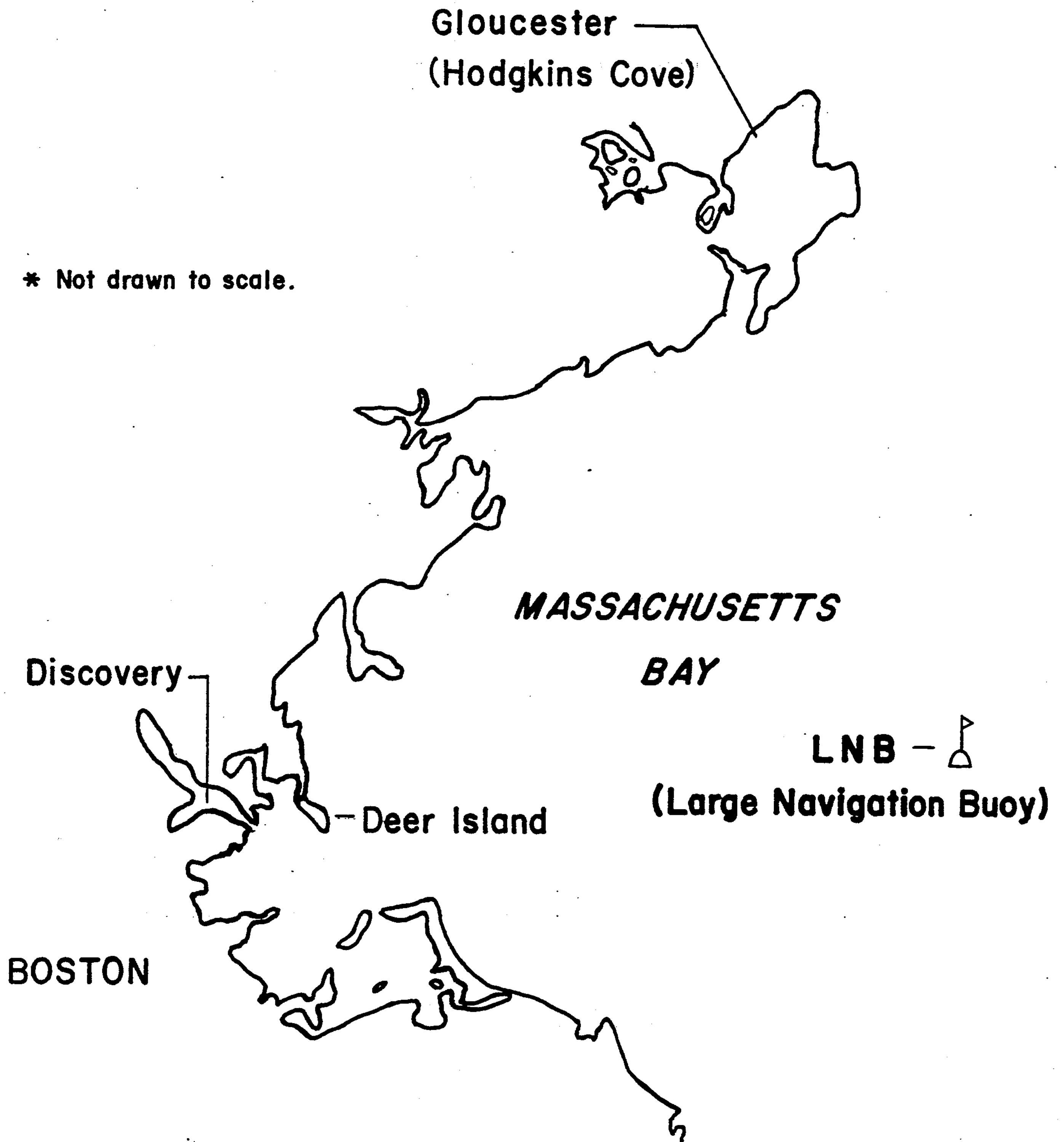


Figure I. The mussel deployment locations for the 1992 bioaccumulation study. The Gloucester location was the source of all mussels for the study.

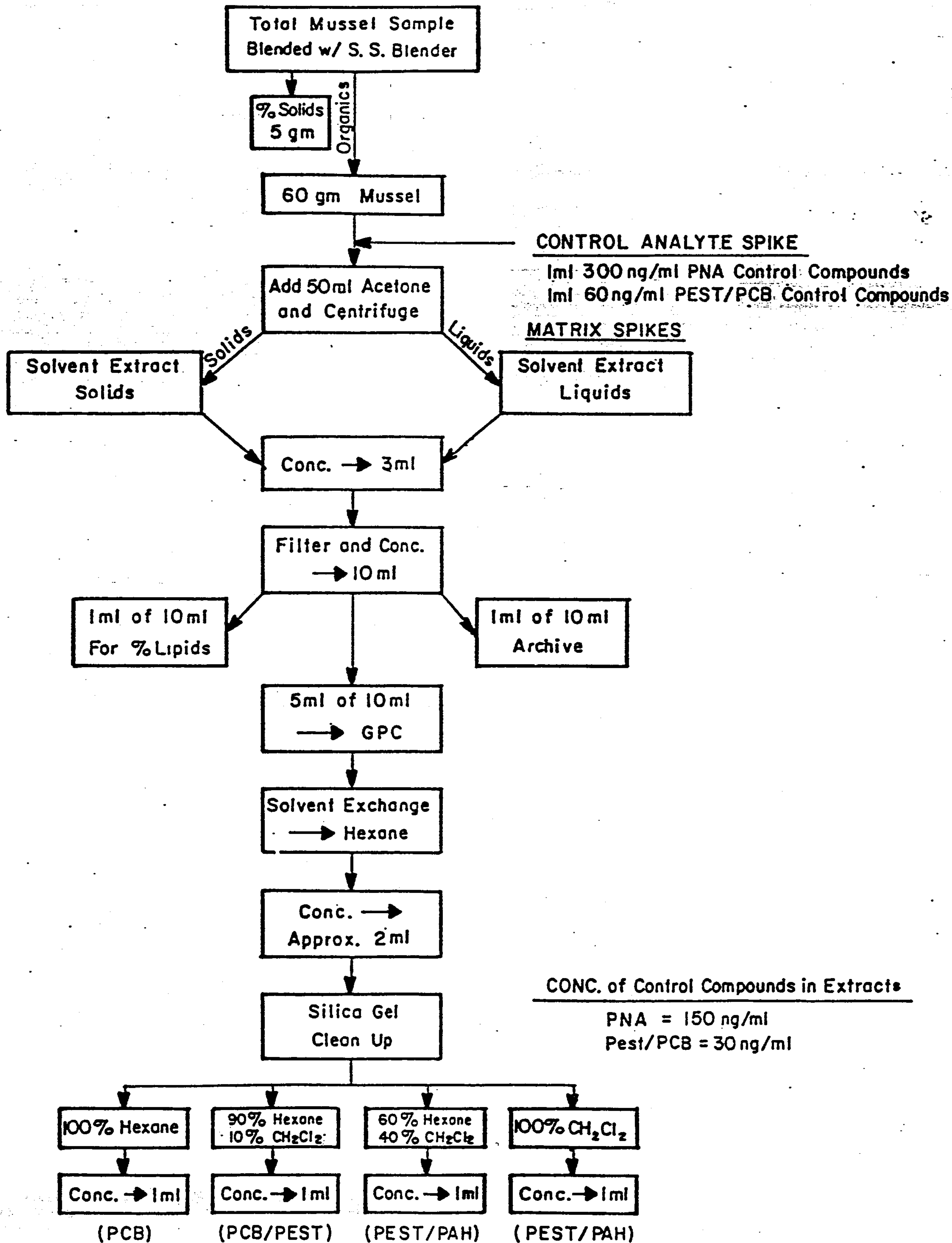


Figure 2. Extraction procedures and analytical methods for organic compounds.

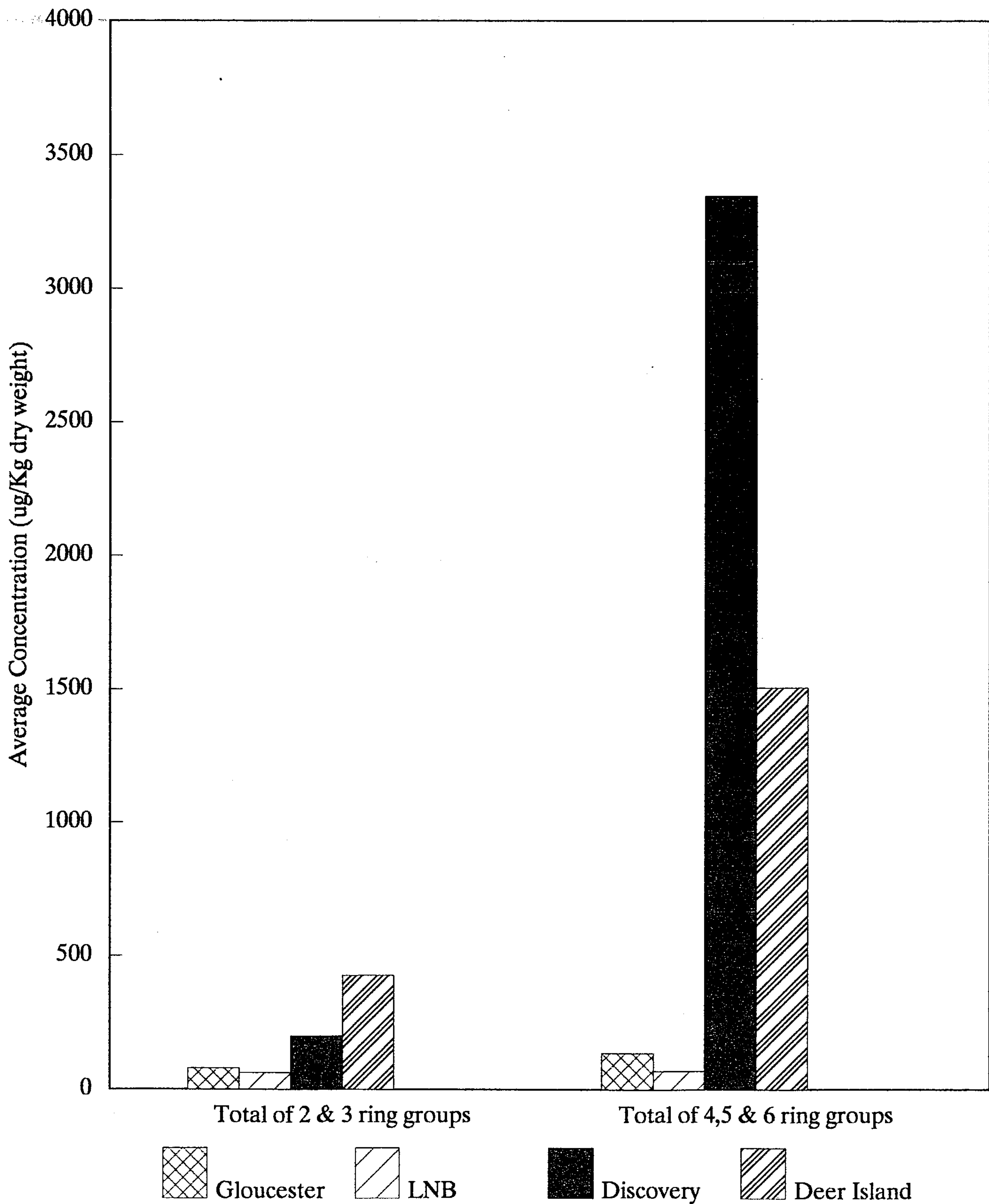


Figure 3. Average concentration of two groups (2 & 3 ring; 4, 5 & 6 ring) of polynuclear aromatic hydrocarbons in mussel tissue collected from the four stations.

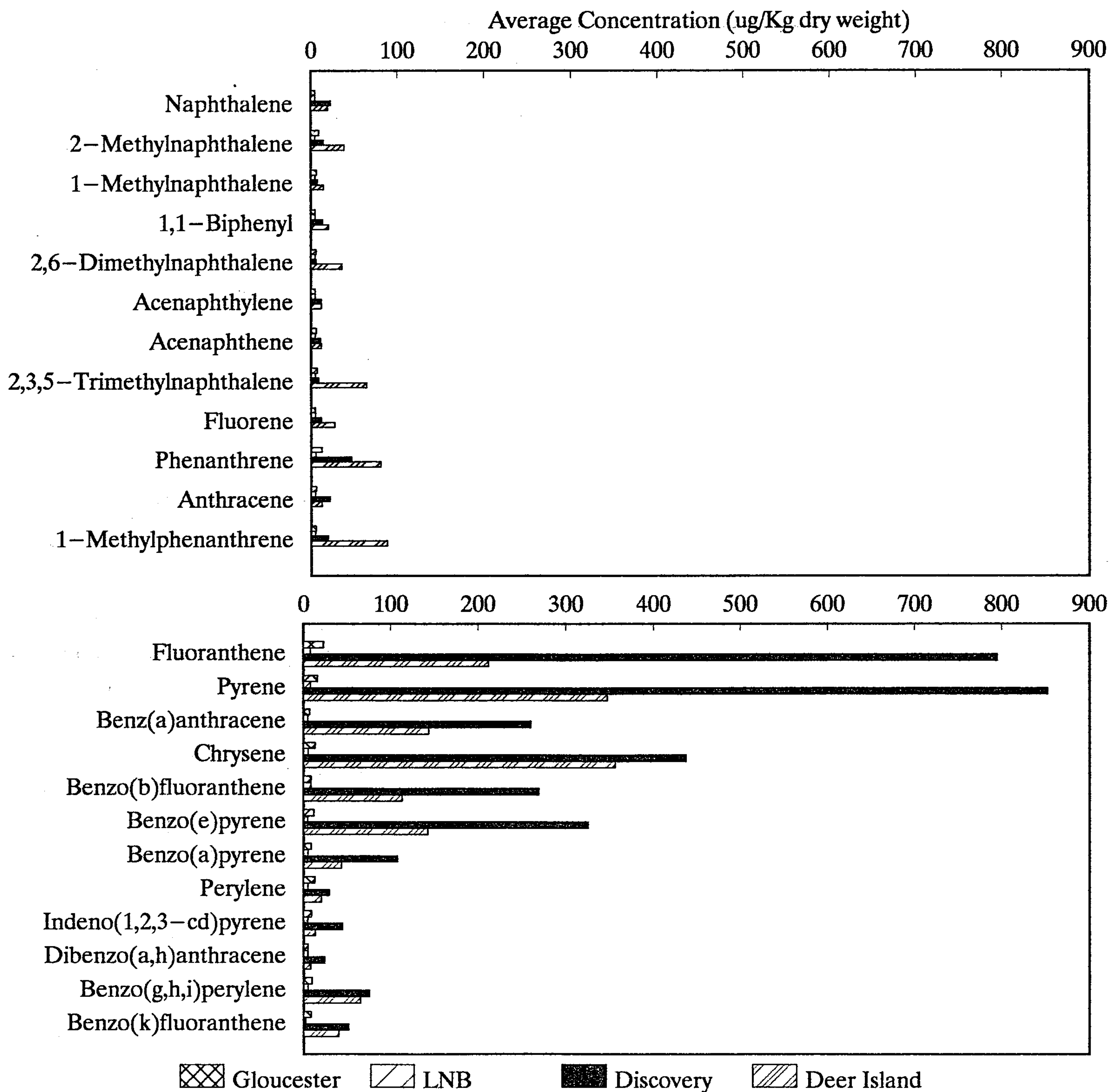


Figure 4. Average concentration of polynuclear aromatic hydrocarbons in mussel tissue collected from the four stations.

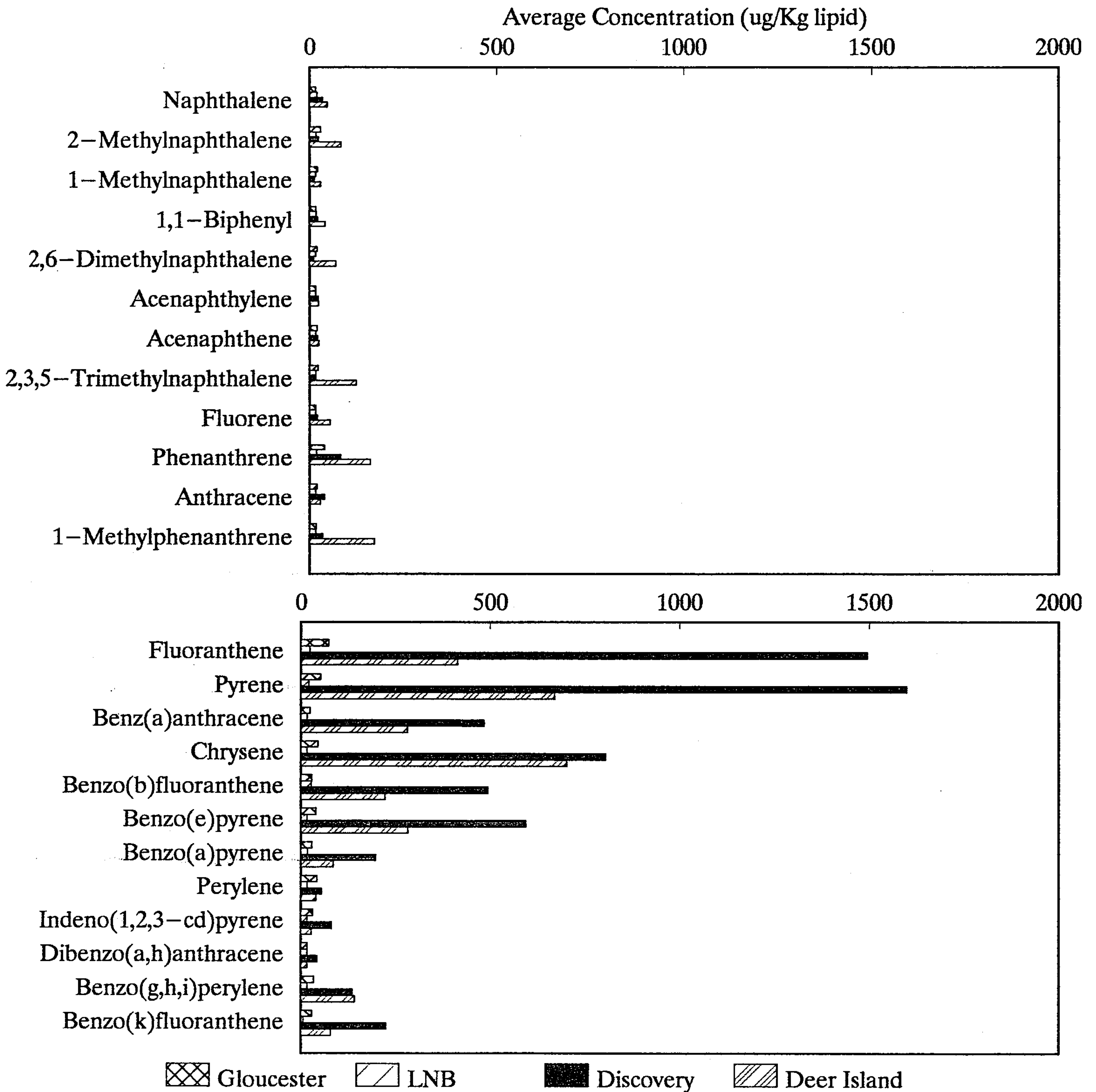


Figure 5. Lipid adjusted average polynuclear aromatic hydrocarbon concentrations in mussel tissue collected from the four stations.

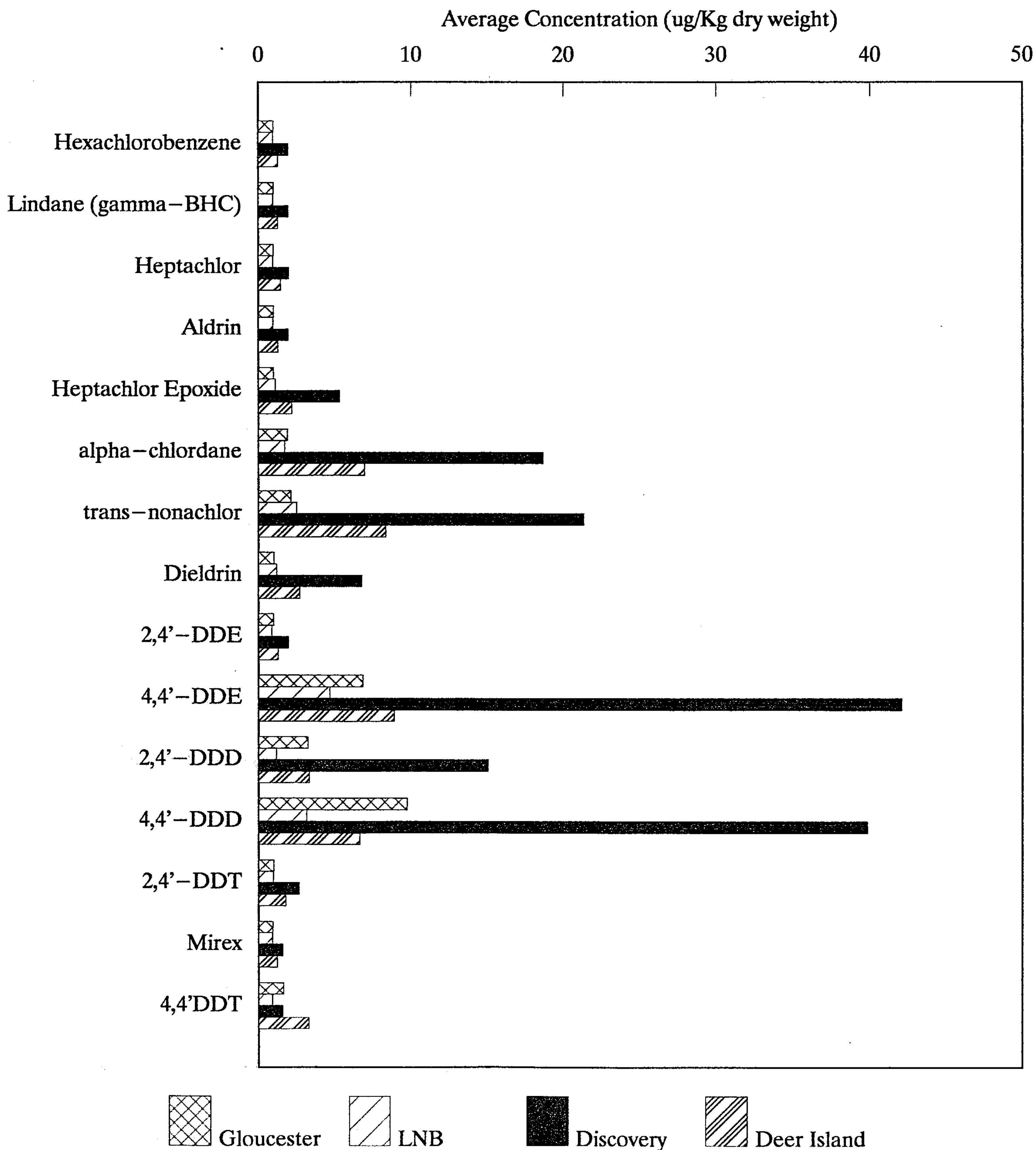


Figure 6. Average concentration of pesticides in mussel tissue collected from the four stations.

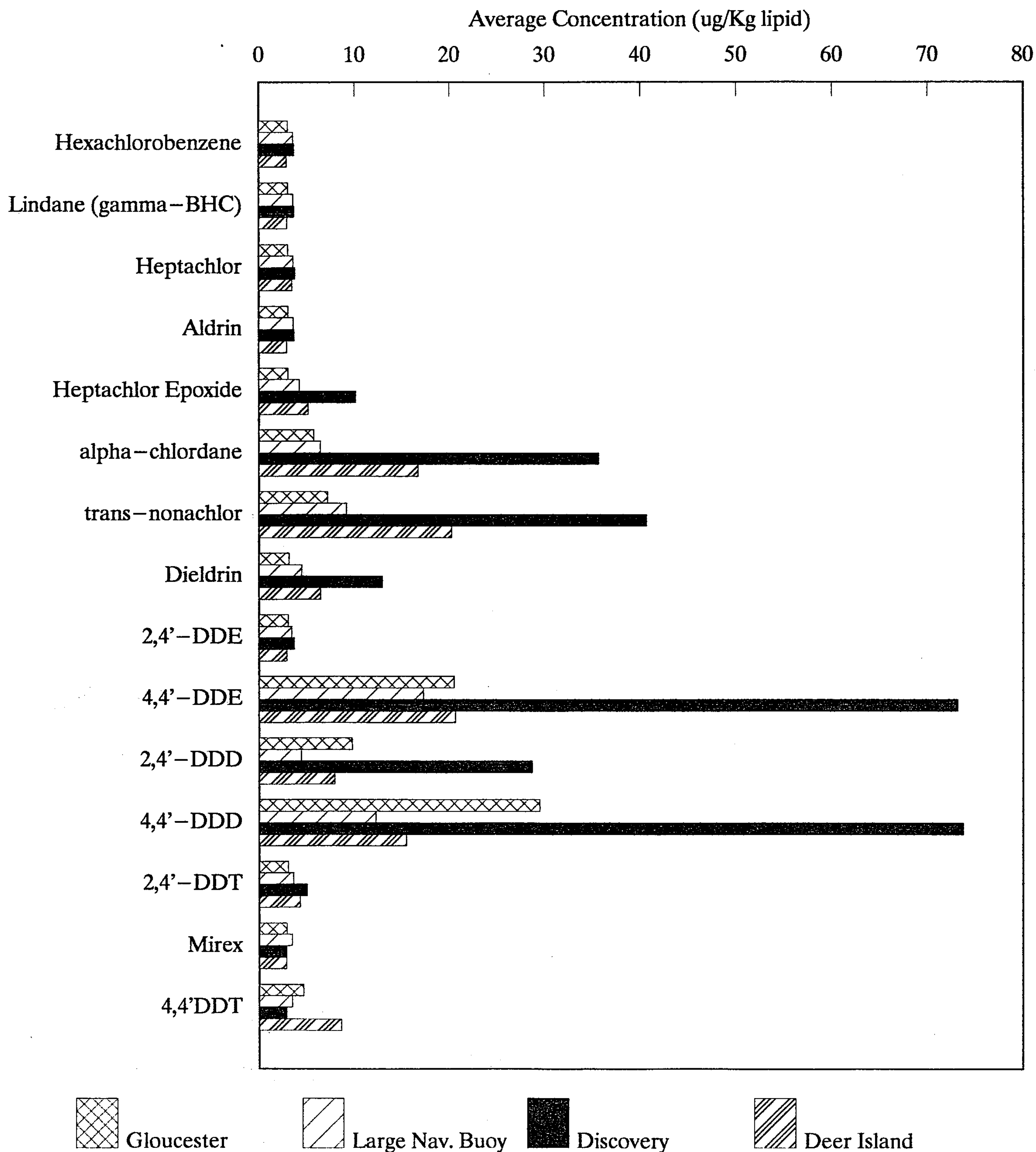


Figure 7. Lipid adjusted average pesticide concentrations in mussel tissue collected from the four stations.

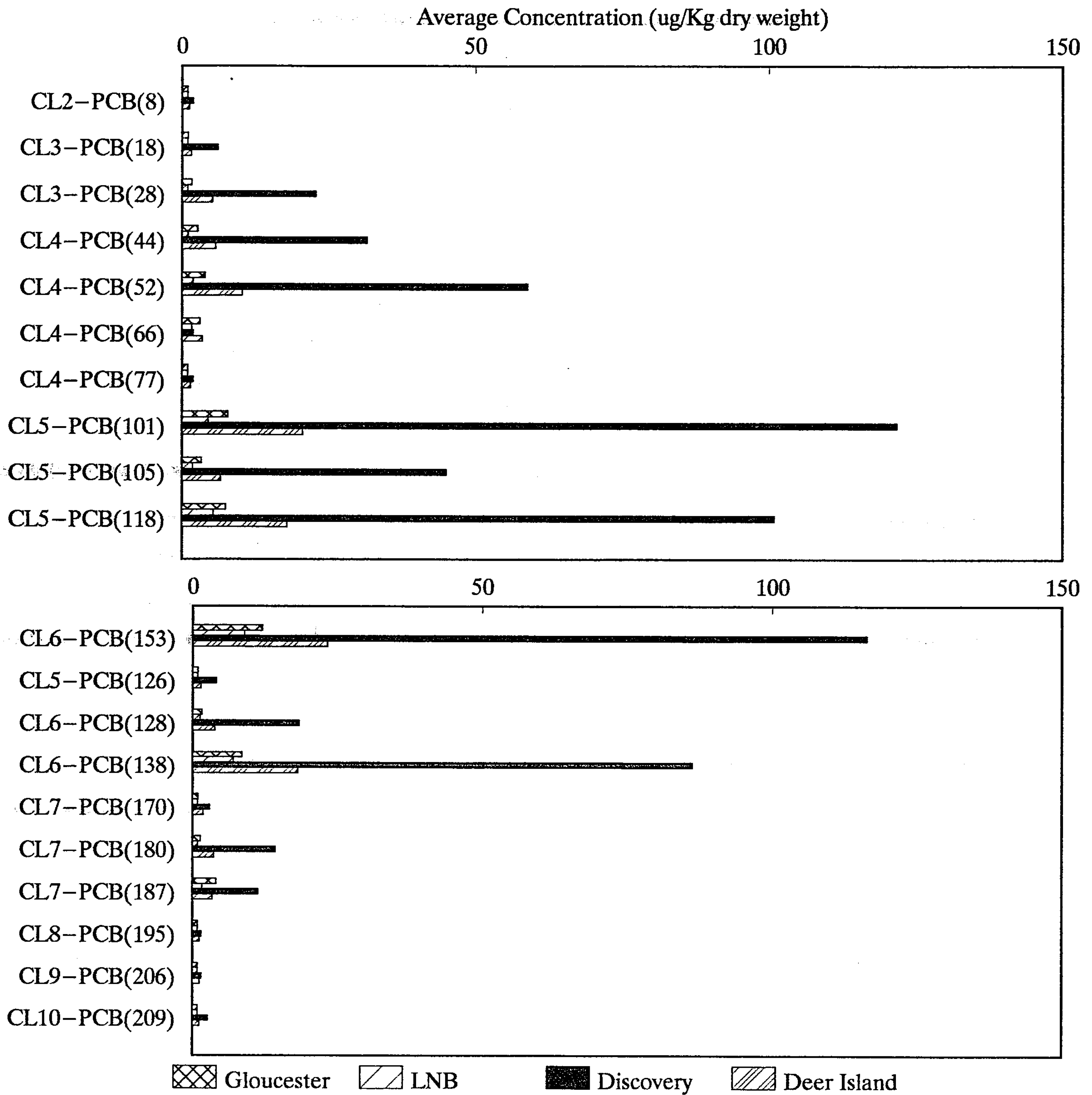


Figure 8. Average concentration of polychlorinated biphenyls in mussel tissue collected from the four stations.

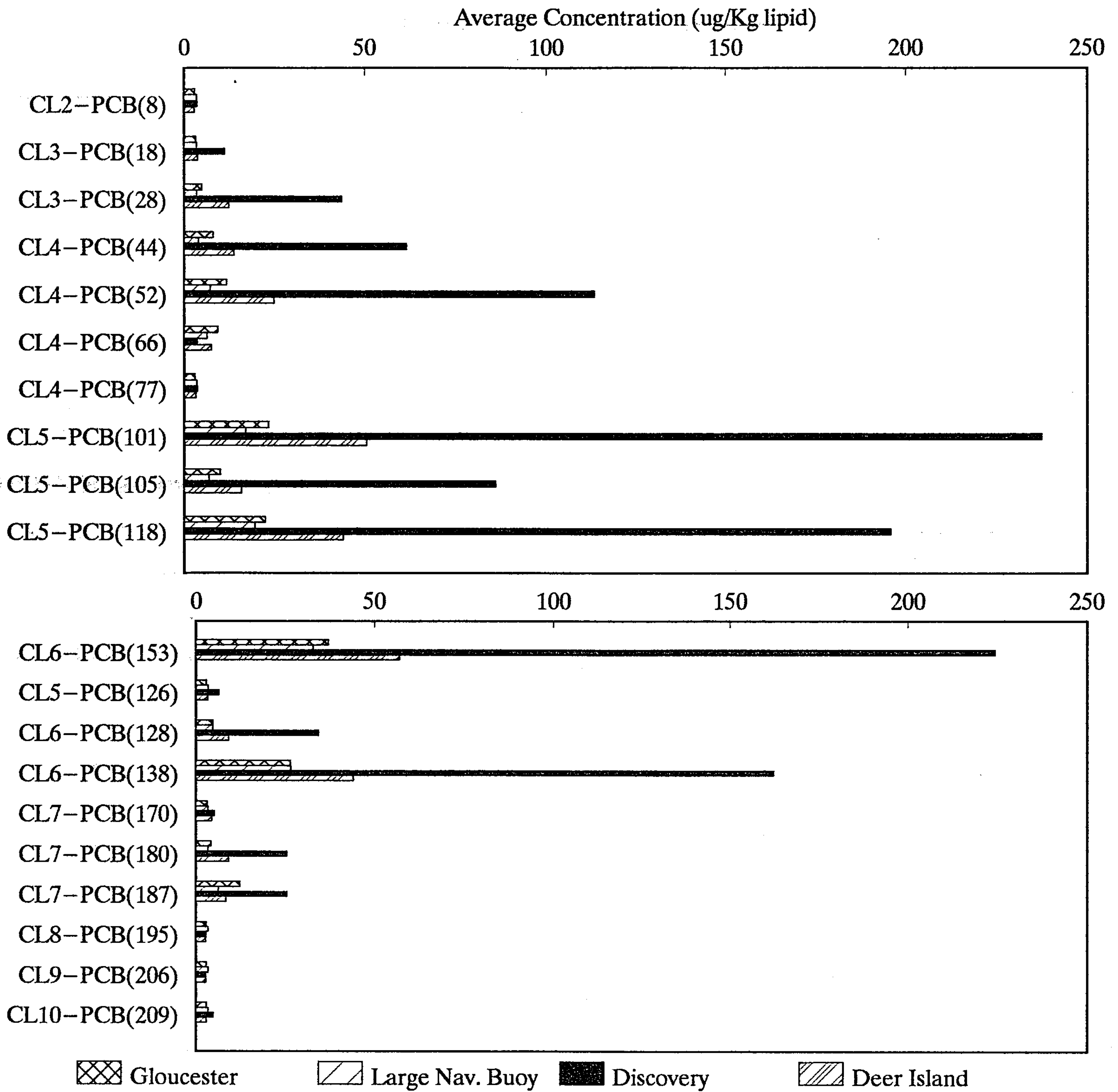


Figure 9. Lipid adjusted average polychlorinated biphenyl concentrations in mussel tissue collected from the four stations.

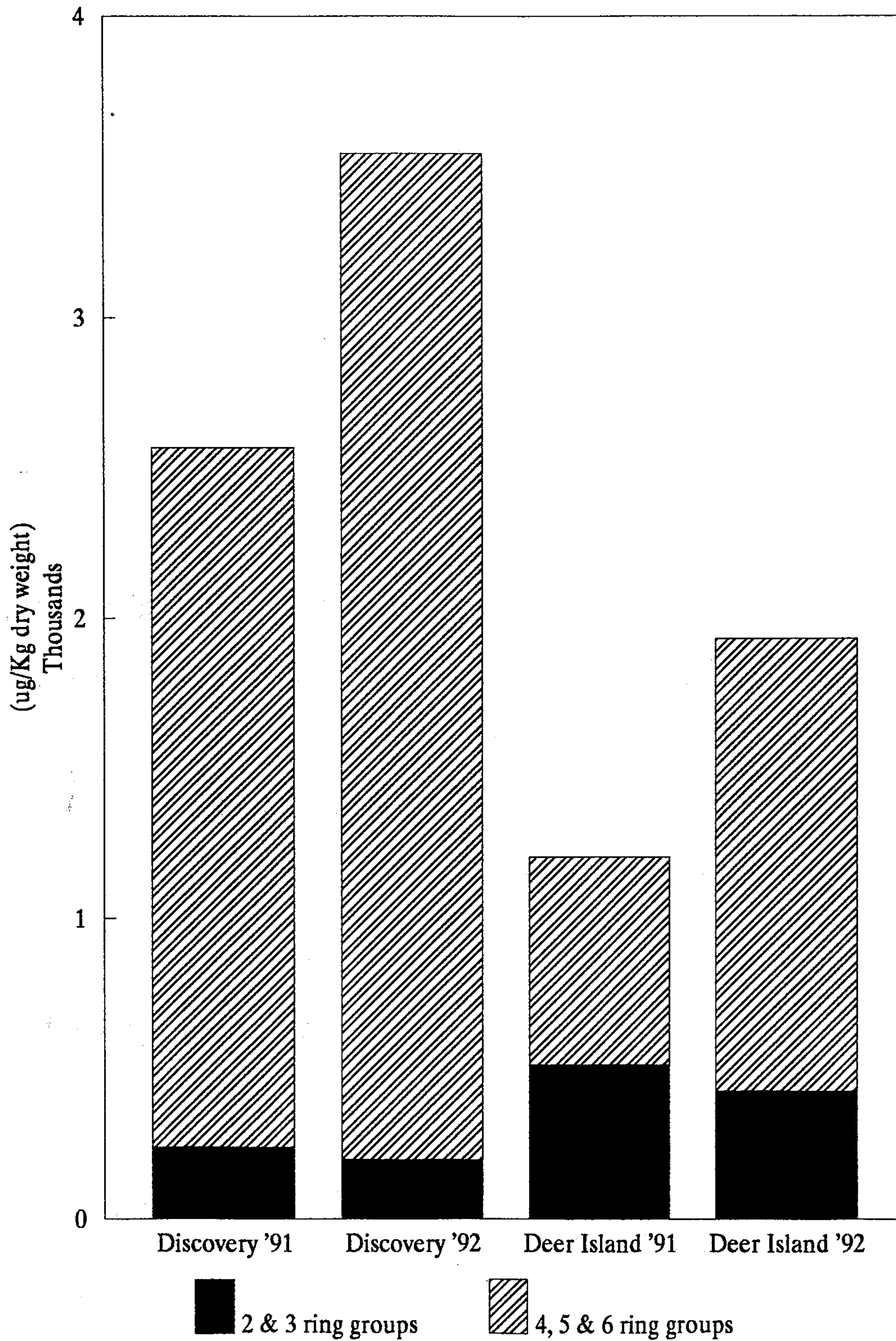


Figure 10. Average concentration of two groups (2 & 3 ring; 4, 5 & 6 ring) of polynuclear aromatic hydrocarbons in mussel tissue collected from two stations, 1991 and 1992.

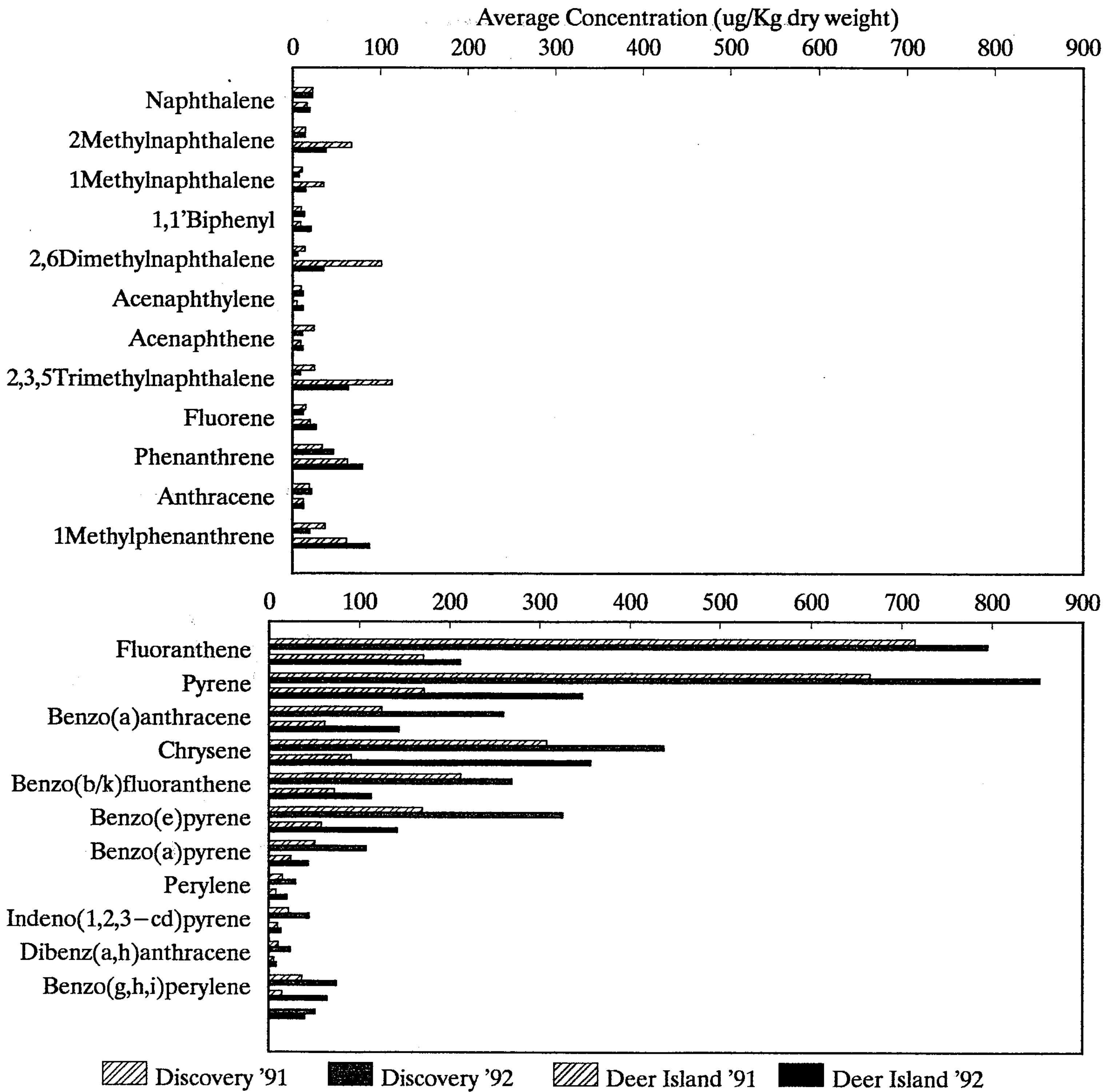


Figure 11. Average concentration of polynuclear aromatic hydrocarbons in mussel tissue collected from two stations, 1991 and 1992.

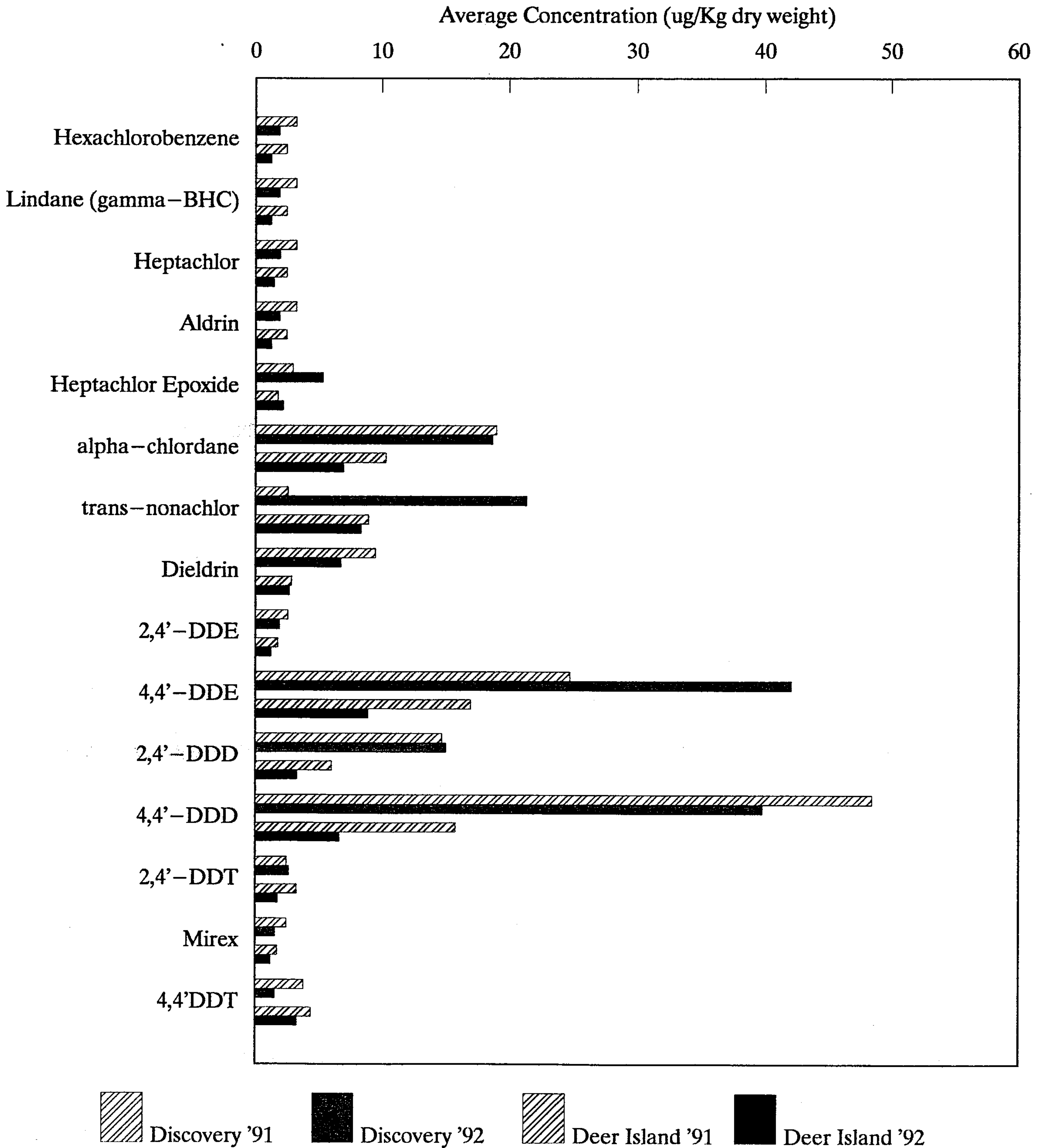
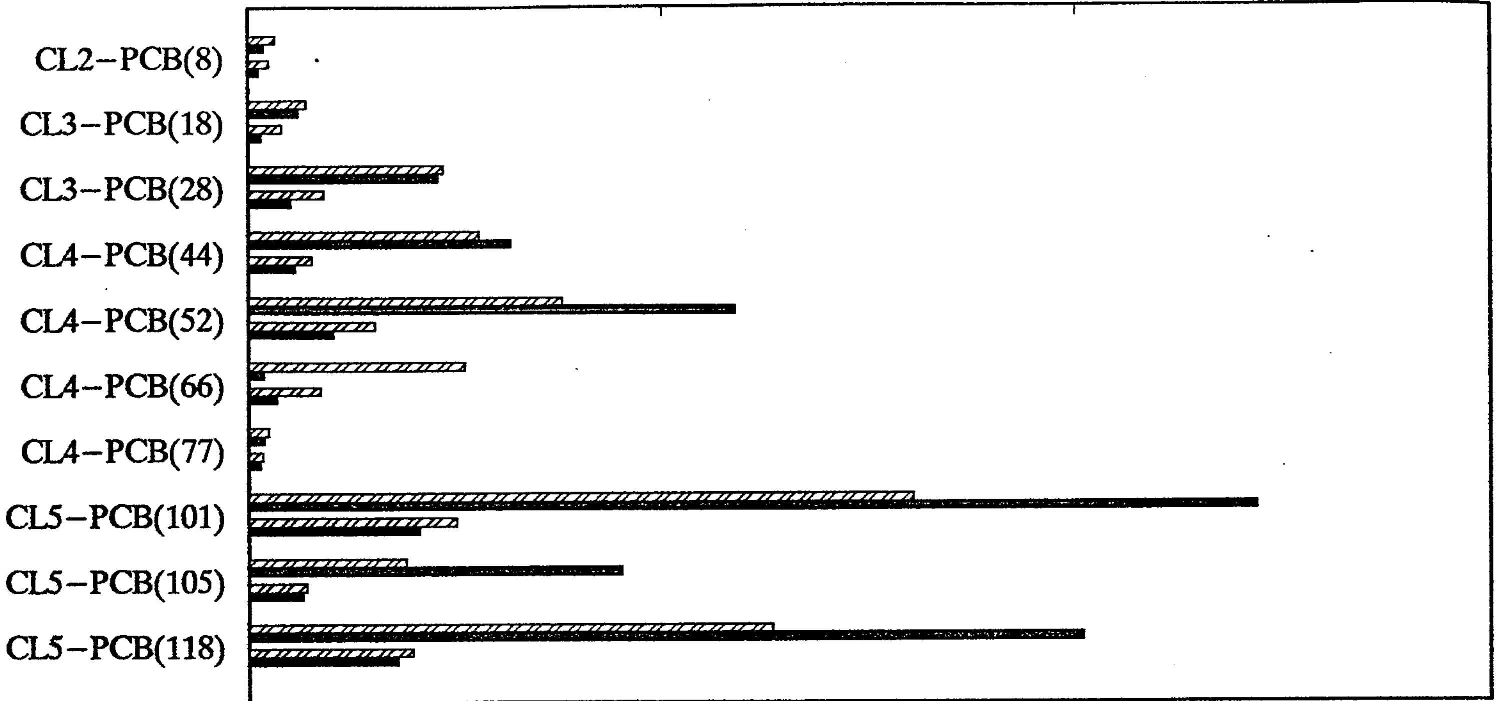


Figure 12. Average concentration of pesticides in mussel tissue collected from two stations, 1991 and 1992.



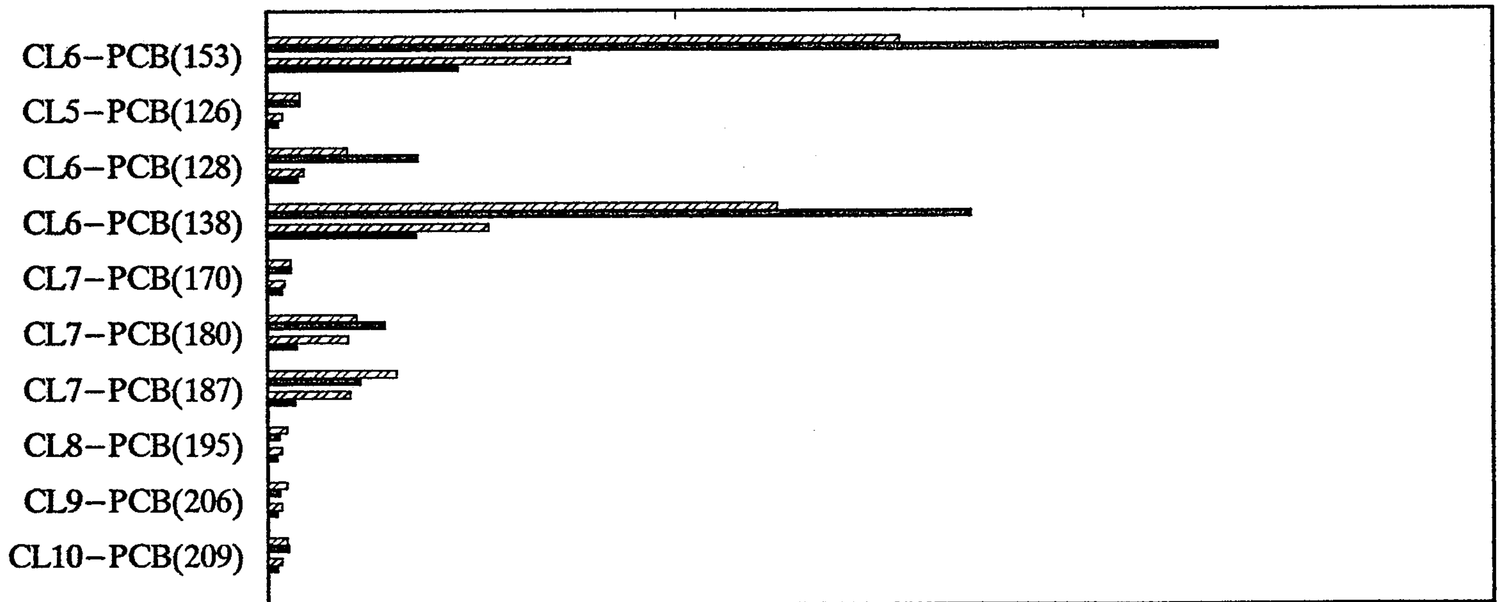


Figure 13. Average concentration of polychlorinated biphenyls in mussel tissue collected from two stations, 1991 and 1992.

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