Report to the

MASSACHUSETTS BAYS PROGRAM

POPULATION PROCESSES OF *MYA ARENARIA* FROM CONTAMINATED HABITATS IN MASSACHUSETTS BAYS

Prepared by

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MASSACHUSETTS BAYS PROGRAM
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FOREWORD

The roots of the Massachusetts Bays Program extend back to 1982, when the City of Quincy filed suit against the Metropolitan District Commission and the Boston Water and Sewer Commission over the chronic pollution of Boston Harbor, Quincy Bay, and adjacent waters. Outdated and poorly maintained sewage treatment plants on Deer Island and Nut Island were being overwhelmed daily by sewage from the forty-three communities in the Metropolitan Boston area. Untreated and partially treated sewage were spilling into Boston Harbor.

Litigation over the pollution of Boston Harbor culminated in 1985 when the United States Attorney filed suit on behalf of the Environmental Protection Agency against the Commonwealth of Massachusetts for violations of the Federal Clean Water Act. The settlement of this suit resulted, in 1988, in the creation of the Massachusetts Water Resources Authority, the agency currently overseeing a multi-billion dollar project to repair and upgrade Metropolitan Boston's sewage treatment system. In addition, the settlement resulted in the establishment of the Massachusetts Environmental Trust - an environmental philanthropy dedicated to improving the Commonwealth's coastal and marine resources. $2 millon in settlement proceeds were administered by the Trust to support projects dedicated to the restoration and protection of Boston Harbor and Massachusetts Bay.

The Trust provided $1.6 million to establish the Massachusetts Bays Program, a collaborative effort of public officials, civic organizations, business leaders, and environmental groups to work towards improved coastal water quality. The funding was used to support both a program of public education and a scientific research program focusing on the sources, fate, transport and effects of contaminants in the Massachusetts and Cape Cod Bays ecosystem. To maximize the efficiency of limited research funding, the sponsored research program was developed in coordination with research funded by the MWRA, the United States Geological Survey, and the Massachusetts Institute of Technology Sea Grant Program.

In April, 1990, following a formal process of nomination, the Massachusetts Bays Program became part of the National Estuary Program. The additional funding provided as part of this joint program of the Environmental Protection Agency and the Commonwealth of Massachusetts is being used to continue a coordinated program of research in the Massachusetts Bays ecosystem, as well as supporting the development of a comprehensive conservation and management plan for the coastal and marine resources of Massachusetts and Cape Cod Bays. The study described in this report addresses the potential bioavailability and biological impacts of organic contaminants in sediments on populations of <u>Mya arenaria</u> from five sites in Masachusetts and Cape Cod Bays, which represent a gradient of chemical contamination. This information is helping to meet the Massachusetts Bays Program goal of producing an area-wide management plan for water quality enhancement and protection.

The information in this document has been subject to Massachusetts Bays Program peer and administrative review and has been accepted for publication as a Massachusetts Bays Program document. The contents of this document do not necessarily reflect the views and policies of the Management Conference.

The Massachusetts Bays Program is sponsored by the Massachusetts Executive Office of Environmental Affairs through the Coastal Zone Management Office and the U.S. Environmental Protection Agency, Region I, John F. Kennedy Federal Building, Boston, MA 02203.

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Summary

We have examined the effects of lipophilic organic contaminants on population processes in the soft shell clam *Mya arenaria*, collected along a gradient of polycyclic aromatic hydrocarbon contamination in Boston Harbor and Massachusetts and Cape Cod Bays. Contaminants were detected in clam tissues and sediments but the bioavailability of specific compounds varied at different sites. Estimates of AEP (available for equilibrium partitioning) provided the best predictor of relative bioavailability for pyrogenic PAH. Clam populations at the three most contaminated sites (Fort Point Channel, Saugus, and Neponset River) showed similar patterns in a reduction in lipid accumulation in the digestive gland-gonad complex and similar patterns in reproductive development with spawning limited to a single mid-summer event. Highest levels of reproductive output were observed among clam populations from Barnstable Harbor and Wellfleet and spawning at these sites occurred from late spring to early fall. Population growth rates were determined for all populations using a deterministic matrix model. Trends in population growth rates were not related to contaminant concentrations at each site. The deterministic model was relatively insensitive to the differences in reproductive physiology and recruitment observed. High prevalences of gonadal inflammation were observed among clam populations from the three most contaminated sites, especially at Fort Point Channel where levels of hematopoietic neoplasia also reached 100% in December 1995.

General Introduction

Lipophilic organic contaminants such as PAHs (polycyclic aromatic hydrocarbons), PCBs (polychlorinated biphenyls), and other synthetic compounds for which PAHs and PCBs serve in part as model compounds, are highly resistant to degradation in the marine environment. Thus, such compounds or their metabolites may accumulate to high levels in animal tissues and interfere with normal metabolic processes that affect growth, development, and reproduction (Capuzzo et al., 1988). Disruption of reproductive processes is a common response in populations of bivalve molluscs with chronic exposure to petroleum hydrocarbons, PAHs, and other lipophilic organic contaminants. The bioavailability, bioconcentration, and toxic effects of lipophilic contaminants are related to their pharmacological and toxicological properties (Capuzzo, 1987; Widdows et al., 1987; Abernathy et al., 1986; Donkin et al., 1990). The limited capacity of bivalve molluscs to detoxify organic contaminants (Stegeman, 1985; Livingstone and Farrar, 1984) results in the uptake and accumulation of high concentrations of organic contaminants.

Sediments and biota from Boston Harbor are highly contaminated with a variety of lipophilic organic contaminants including petroleum hydrocarbons (both low molecular weight and high molecular weight hydrocarbons such as PAHs), chlorinated pesticides (total DDT, lindane, dieldrin and chlordane), and polychlorinated biphenyls (PCBs). For example, concentrations of total PAHs in tissues of the blue mussel (*Mytilus edulis*) are in the upper 15% of the most contaminated sites from the U.S. coastline surveyed in the National Status and Trends Program (MacDonald, 1991). Other contaminants that show elevated levels in mussels collected from Boston Harbor include total DDT, total PCBs, lindane, dieldrin, and total chlordane.

Although general trends in contaminant distributions in Boston Harbor/Massachusetts Bays have been defined (e.g., higher concentrations of total PAHs in the inner harbor of Boston, lesser concentrations with distance from the inner harbor), critical information on biological effects of chemical contaminants, specifically on population processes is lacking. Because harbor sediments will continue to be a major source of contaminants to the Massachusetts and Cape Cod Bays ecosystem, even with the improvement in water quality from the reduction of point source contamination, the potential risks to populations of marine biota must be defined. Recent studies of the incidence of tumors and other histopathological disorders in bottom-dwelling fish and shellfish from contaminated coastal areas have suggested a possible link between levels of lipophilic organic contaminants and the increased incidence of histopathological conditions.

Gardner and Pruell (1988) found significant histopathological lesions in soft shell clams (*Mya arenaria*) at selected contaminated sites in Quincy Bay including gill inflammation, atypical cell hyperplasia in gill and kidney, hyperparasitism with rickettsia in digestive ducts/tubules, and general parasitism. In addition, reproductive development and spawning among male and female clams appeared to be asynchronous. Kimball (1994) also observed asynchrony in reproductive development among three populations of *Mytilus edulis* in Massachusetts and Cape Cod Bays, but reductions in reproductive effort among female mussels could not be attributed to the effects of contaminants alone. Recent studies conducted by Moore et al. (1994) in Massachusetts and Cape Cod Bays revealed a suite of histopathological conditions associated with chemical contaminant exposure in fish and shellfish. Populations of *Mya arenaria* and *Mytilus edulis* collected along a gradient of PAH contamination showed evidence of a wide range of pathologies including gill hyperplasia and carcinomas, hematopoietic neoplasia, gonadal inflammation, parasitic infections in connective tissues and kidney, and kidney hyperplasia. Discriminant analysis indicated that the prevalence of these pathologies was strongly correlated with high levels of PAH contamination.

In addition to histopathological damage, sublethal toxic effects of contaminants in marine organisms include impairment of physiological processes that may alter the energy available for growth and reproduction and other effects on reproductive and developmental processes including direct genetic damage (Review by Capuzzo et al., 1988). Biological effects associated with bioconcentration of lipophilic contaminants have been attributed to the uptake of specific compounds and/or their metabolites, rather than the total body burden of hydrocarbons or chlorinated hydrocarbons (Anderson et al., 1980; Malins and Hodgins, 1981; Widdows et al., 1982, 1987; Capuzzo et al., 1984). Biological effects of organic contaminants have been observed at all levels of biological hierarchy (McIntyre and Pearce, 1980; Capuzzo, 1987; Moore et al., 1989). For bivalve molluscs, exposure to contaminants has resulted in impairment of physiological mechanisms (Capuzzo and Sasner, 1977; Gilfillan et al., 1977; Widdows, 1985); histopathological disorders (Moore, 1988; Lowe, 1988); and loss of reproductive potential (Berthou et al., 1987; Neff and Haensly, 1982).

To examine the effects of lipophilic contaminants on population processes of marine organisms in the Boston Harbor/Massachusetts bays ecosystem, we designed and executed a study of populations of the soft shell clam *Mya arenaria* L., collected along a gradient of PAH contamination. The report is divided into two parts: Part I. Partitioning and Bioaccumulation of Organic Contaminants in Massachusetts Bay Sediments; and Part II. Biological Effects of Contaminants on Populations of *Mya arenaria*.

Part I. Partitioning and Bioaccumulation of Organic Contaminants in Massachusetts Bay Sediments

a. Introduction

The accumulation of organic contaminants by aquatic organisms can be a complicated function of physical, chemical, and biological processes that influence exposure concentrations, bioavailability of contaminants, and the uptake, elimination and storage of contaminants by an organism (Fisher, 1995). In the benthic environment, nonpolar organic contaminants will partition among all accessible phases according to the capacity of each phase to accumulate the contaminant. Usually, these partitioning processes are described using equilibrium models, where equilibrium among all phases is assumed. This is the case with the equilibrium partitioning (EqP) approach that forms the basis for EPA's proposed Sediment Quality Criteria (Shea, 1988; Di Toro et al., 1991). According to EqP theory, nonpolar organic contaminants that are freely dissolved in water will partition between the water and any sorptive phase that is accessible to the dissolved contaminants (Figure I-1), that is, sediment organic carbon (SOC), colloidal organic carbon (COC), and lipid stores within an organism.

As additional sorptive phases are added or their capacity is increased, contaminants will desorb from the sediment and partition into these other phases. As long as the aggregate capacity of these additional sorptive phases is small compared to the sediment (so the sediment concentration remains constant) and the rate of desorption from sediment is not significantly less than the rate of contaminant removal from the porewater, the sediment will buffer the system and maintain equilibrium. Thus, the presence of COC will increase the total concentration in the porewater, but not the freely dissolved concentration. According to the model depicted in Figure I-1, bioaccumulation will not be affected by porewater COC and the organism will maintain equilibrium with the porewater. The existence of this equilibrium and the unavailability of COC-bound contaminants are hypotheses that require further testing.

The EqP theory shown in Figure I-1 is a simplification of what is really happening; we are using apparent macroscale equilibrium expressions to describe multiple microscale sorptive processes. However, the equilibrium partitioning approach has been successful in explaining observed sediment-porewater partitioning (Brownawell and Farrington, 1986; Chin and Gschwend, 1992), bioaccumulation (Fisher, 1995), and sediment toxicity (Di Toro et al., 1991).

One implicit assumption in the equilibrium partitioning model is that all sorptive phases are equally and completely accessible to the freely

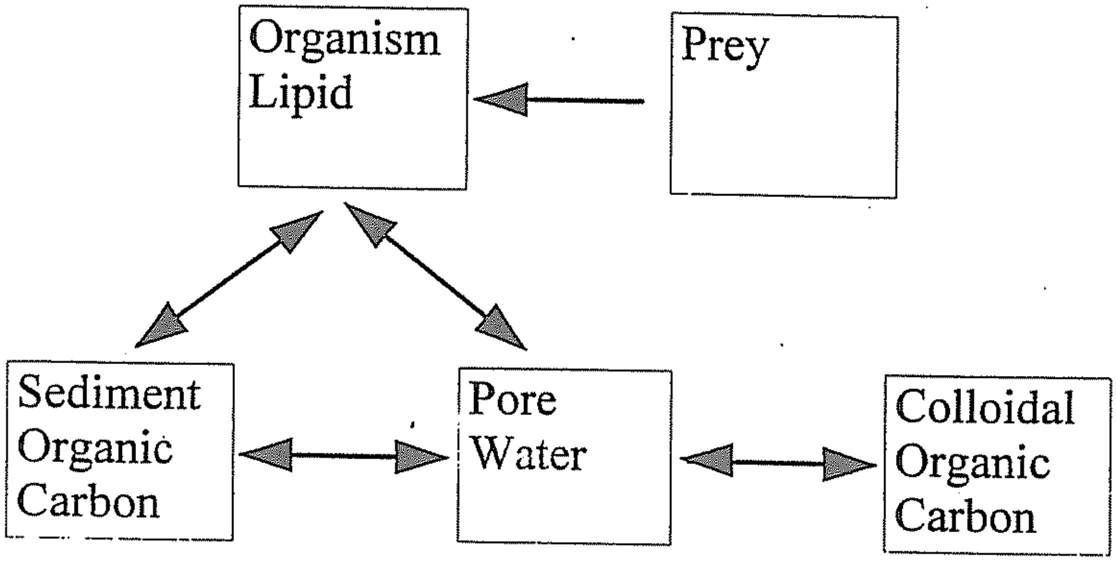


Figure I-1. Diagram of the Equilibrium Partitioning (EqP) Theory for the accumulation of nonpolar organic contaminants from sediments into benthic organisms. The EqP theory assumes that equilibrium exists between the chemical sorbed to sediment organic carbon (SOC) and chemical freely dissolved in pore water. The route of exposure does not matter as long as equilibrium exists. Colloidal organic carbon (COC) will increase the total chemical concentration in the pore water, but not the concentration freely dissolved in the pore water.

dissolved contaminant, where water essentially acts as the transport medium moving contaminants among the different sorptive phases. Recent work has shown that for some contaminants, only a fraction of the sedimentary sorptive phase (organic carbon) may be accessible or available for partitioning on the time scales relevant to bioaccumulation (McGroddy and Farrington, 1995; McGroddy et al., 1996). In sediments of Boston Harbor, the fraction that is available for equilibrium partitioning (AEP) has been found to range from less than 1% to about 40% for phenanthrene and pyrene (McGroddy and Farrington, 1995). This same study found that essentially 100% of the PCBs were available. Related studies have found that only a fraction of some sediment-bound PAH are available for uptake into benthic organisms, with freshly dosed PAH having greater bioavailability than aged PAH (Fisher, 1995; Harkey et al., 1995) and petrogenic PAH having greater bioavailability than pyrogenic PAH. Thus, the assumption of equilibrium between porewater and SOC may not be true for pyrogenic PAH.

Bioaccumulation of nonpolar organic contaminants can be influenced by the route of contaminant exposure (Fisher, 1995). Higher accumulation often takes place when exposure is via ingestion of prey or particles or via particle filtration compared to accumulation via passive diffusion across gill or cuticle membranes (Fisher, 1995). According to the EqP theory (Figure I-1), this should not happen because as an organism accumulates contaminants via ingestion it should eliminate contaminants via passive processes to maintain equilibrium with the porewater. Bioaccumulation above that which is supported by porewater concentrations probably results from slow rates of elimination relative to uptake via the gut or particle filtration. Thus, for benthic organisms such as the soft shell clam, *Mya arenaria*, bioaccumulation might be underestimated by using the EqP model and porewater concentrations.

In the present study *M. arenaria* was used as a sentinel organism to assess the effects of organic contaminants on populations of aquatic organisms in Massachusetts Bays. To further investigate the bioaccumulation of organic contaminants in *M. arenaria*, we conducted a study of the partitioning behavior of polycyclic aromatic hydrocarbons (PAH), linear alkyl benzenes (LABs), polychlorinated biphenyls (PCBs), and organochlorine pesticides (OCPs) among the phases shown in Figure I-1. This work was conducted at the same five sites used for the biological effects study (see Section II), which represent the range of contaminants likely to be encountered in the Massachusetts Bays where soft shell clams are viable (Figure I-2). Both total and the AEP fraction of contaminants in the sediment and the sediment porewater, and the total contaminants in clams and a non-living, passive accumulator of contaminants, the semipermeable membrane device (SPMD), were measured. These data, along with measurements of SOC, COC, and clam lipid, were used to model the partitioning and accumulation of organic contaminants in the benthic environment of

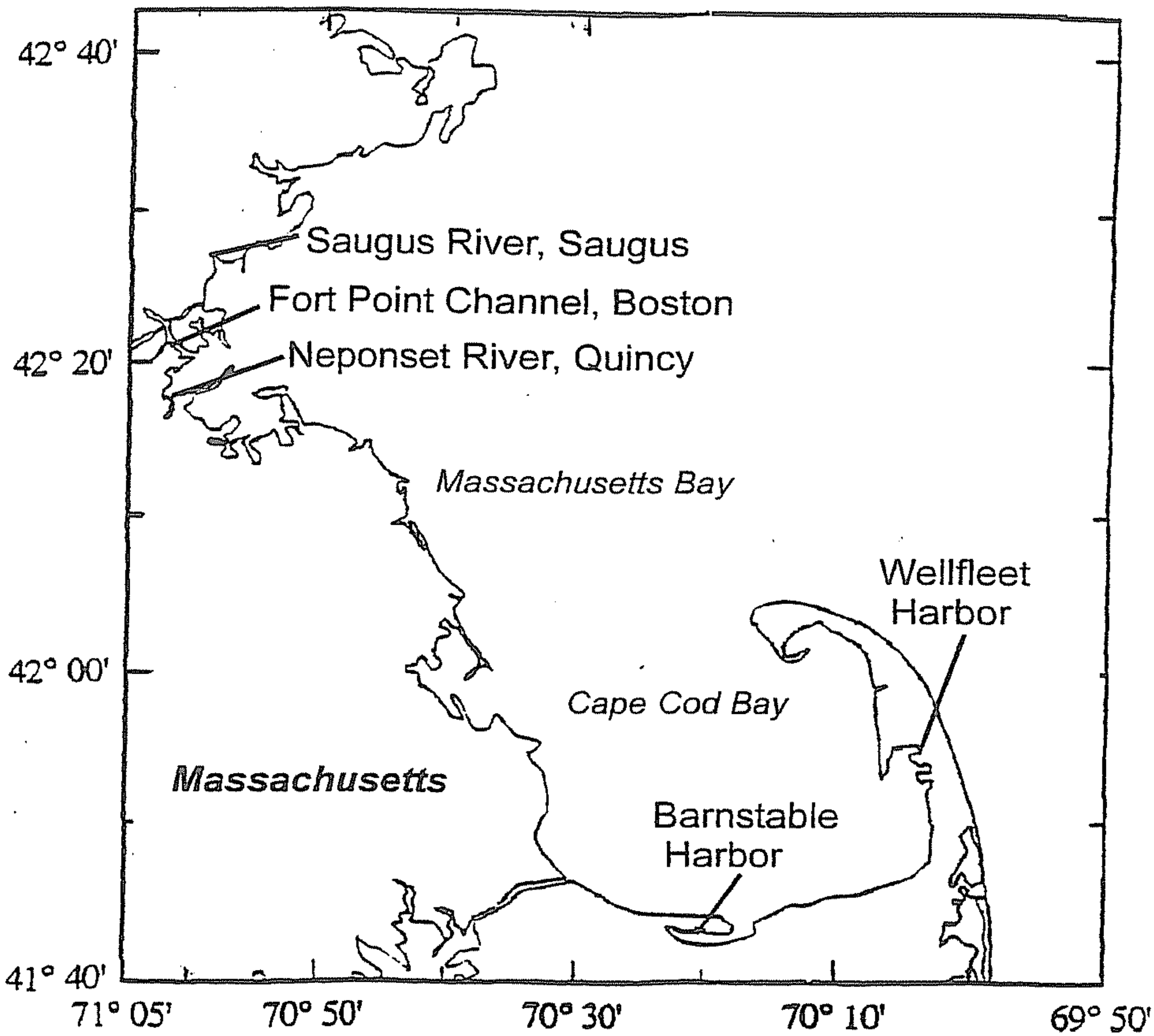


Figure I-2. Sampling Sites in Massachusetts and Cape Cod Bays.

Massachusetts Bay.

b. Experimental Section

(1) Sample Deployment and Collection. The SPMDs were constructed as described by Huckins et al. (1993) except that we used low-density polyethylene (PE) tubing approximately 75 μm thick and 900 cm^2 effective surface area (5 cm x 90 cm tubing) containing either 0.91 g of 95% triolein (Sigma Chemical Co.) or no triolein (empty PE tubing). The SPMDs (two with triolein and two without) were placed in polypropylene cages. At each site one cage was placed on the surface of the sediment and one was placed approximately 5 cm beneath the sediment-water interface by carefully digging a 5 cm hole, placing an SPMD cage into the hole, and replacing the sediment on top of the SPMDs. The SPMDs were deployed for 90 days from June to September 1995. *M. arenaria* were collected in March as described in Section II. Sediment samples were collected in March and June using a stainless steel hand scoop. Sediment was placed in glass jars, minimizing headspace, and refrigerated. The jars and all other equipment that contacted the samples were either combusted at 350^{o}C for 24 h or rinsed with deionized (DI) water, acetone, dichloromethane (DCM), and hexane. Within 24 h of sampling, the sediment was centrifuged in Teflon^{R} bottles at approximately 1000g for 30 min. Immediately following centrifugation, an aliquot of the porewater was taken up by syringe and filtered through a precombusted 0.7 μm glass fiber filter. The filtered porewater was analyzed for dissolved organic carbon, colloidal organic carbon, and the filter was analyzed for particulate organic carbon. We used the methods of Chin and Gschwend (1992) for these porewater analyses. The remaining porewater was filtered as above and frozen in a Teflon jar containing DCM to inhibit microbial degradation. The filters were placed in baked aluminum foil and then in double Ziplock bags. SPMDs and *M. arenaria* were wrapped in baked aluminum foil and then double bagged. All samples were frozen at -20^{o}C until analysis about 6 months later.

(2) Sample extraction. Clams, while still frozen, were rinsed with DI water, weighed, shells were pried open and the soft tissue was removed. Tissue was rinsed with DI water and all tissue and liquor from each site (5 clams) were composited into a single sample. The soft tissue was mixed with baked Na_2SO_4 and spiked with a surrogate internal standard (SIS) mixture (see below). This mixture was then homogenized with a blender and soxhlet extracted for 12 h in DCM. Particulate samples (sediments and filters) were spiked with SIS, mixed with baked Na_2SO_4, and soxhlet extracted in DCM for 12 h. Sulfur was removed with activated Cu turnings. SPMDs were cut up using solvent-rinsed stainless steel scissors, spiked with SIS, and the tubing and triolein (if present) was extracted with DCM by shaking for about 12 h.

An aliquot of the clam, SPMD, and sediment extracts was taken to gravimetrically determine lipid weight. Porewater samples were extracted in a separatory funnel using 150 ml of DCM.

(3) Sediment-Porewater Partitioning Experiments. Sediment and particulate organic carbon were determined using a CHN analyzer after drying and grinding. Porewater organic carbon was measured using a TOC analyzer (Ionics, Inc.) Porewater colloids were isolated using 3000 MWCO Centricon micro-concentrators (Amicon) according to the methods of Chin and Gschwend (1992). PAH-colloid binding was measured by fluorescence quenching (Chin and Gschwend, 1992). The AEP fraction was measured using the desorption procedure of McGroddy et al. (1996).

(4) Extract Cleanup and Analysis. All sample extracts were prepared and analyzed using methods of the NOAA National Status and Trends Program (Peven et a., 1996) with some modifications. Sample extracts were concentrated to about 1 mL using a rotary evaporator and then a N_2 evaporator. The concentrated extract was eluted through a 10-g 1% deactivated alumina column (with activated copper to remove sulfur) using 80-mL DCM (non-polar fraction). The non-polar fraction was concentrated as above, filtered, processed through an automated GPC clean-up step, and reduced to about 0.5 mL using nitrogen.

The PAHs and LABs were analyzed by gas chromatography with mass spectrometric detection (GC-MS) using an HP 5890 and HP 5970 MSD (Hewlett-Packard) operated in the selected ion monitoring mode. Samples were injected in the splitless mode onto a 30 m x 0.32 mm DB-5 (0.25 µm film thickness) fused-silica capillary (J&W Scientific, Inc.). The temperature was programmed from 40^{o}C to 290^{o}C at 6^{o}C/min and then held for 30 min. The injection port was set at 300^{o}C and the transfer line at 280^{o}C. Analytes were quantified using the primary ion after confirmation of their indentity with at least one other ion. Deuterated PAH were used as surrogates (naphthalene-d_8, acenaphthene-d_{10}, chrysene-d_{12}, perylene-d_{12}) and internal standards (phenanthrene-d_{10} and benzo[a]pyrene-d_{12}) for the PAH; 1-phenyl LABs were used as surrogates and internal standards for the LABs. LABs were quantified by summing the response within each isomer group (C_{10}, C_{11}, C_{12}, C_{13}, and C_{14} groups).

The PCBs and OCPs were analyzed by gas chromatography with electron capture detection (GC-ECD) using an HP 5890. Extracts were injected in the splitless mode and separated on a 30 m x 0.32 mm DB-5 (0.25 µm film thickness) fused-silica capillary (J&W Scientific, Inc.). The temperature was programmed from 60^{o}C for 1 min, 20^{o}C/min to 150^{o}C, hold for 1 min, 1^{o} C/min to 250^{o}C hold for 1 min, 3^{o}C/min to 290^{o}C, and hold for 10 min. The injector was set at 250^{o}C and the detector at 320^{o}C. The surrogates were dibromooctafluorobiphenyl (DBOFB), PCB-112 and PCB-197; the internal standard was tetrachloro-*m*-xylene (TCMX).

For all analyses, response factors were generated using a three-to-five point calibration curve and response was monitored using the mid-level calibration standard every five analyses. The relative percent difference between the mid-level check and the average response factor was usually less than 15%. Surrogate recoveries ranged from 60% - 105% for porewaters, 38% to 142% for sediments, 30% to 102% for clams, and 43% to 102% for SPMDs. Data were corrected for these recoveries. Matrix spike recoveries ranged from 62% to 93% for all sample types. Analysis of NIST Standard Reference Material (SRM) 1974 (marine mussel tissue from Dorchester Bay) yielded recoveries of 86% to 103% relative to certified values and NIST SRM 1941a (marine sediment from Baltimore Harbor) yielded recoveries of 74% to 96%.

Laboratory blank contamination was usually below detection or at least ten times less than measured amounts. However, we found higher relative blank contamination for some of the lighter weight PAHs in sediment and porewater at the Barnstable and Wellfleet sites. Blank corrections were made on these data. We also found very high blank contamination on the SPMD trip blanks for the PAHs from naphthalene through pyrene. Laboratory blanks were very low and trip blanks for the sediment and water were very low. We don't know the source of this trip blank contamination. We did not use any of the SPMD data for naphthalene through pyrene, except at the urban harbor sites where we used the pyrene data because the trip blanks were low relative to the concentrations in the SPMDs.

c. Results and Discussion

(1) Sediment Contamination. Concentrations of PCBs, OCPs, LABs, and PAHs were measured in sediments at five sites in Massachusetts Bay (Figure I-2). Concentrations of PCBs and OCPs in sediments were generally in the lower to middle part of the range reported by others for the same or similar locations in Massachusetts Bay (Shea et al., 1991; Shea et al., 1994; Long et al., 1995; Hyland and Costa, 1995; Shea et al., 1996). Highest concentrations were found at Fort Point Channel (total PCB was 35 - 84 ng/gdw; total DDT was 27 - 57 ng/gdw), intermediate concentrations at Saugus (total PCB was 11 - 13 ng/gdw; total DDT was 5 ng/gdw) and Neponset (total PCB was 2 - 4 ng/gdw; total DDT was 4 - 8 ng/gdw), and barely detectable concentrations at Barnstable (total PCB was 0.5 ng/gdw; DDT was < 0.22 ng/gdw) and Wellfleet (total PCB was <0.1 ng/gdw; total DDT was <0.3 ng/gdw). Complete data sets are given in Appendix A.

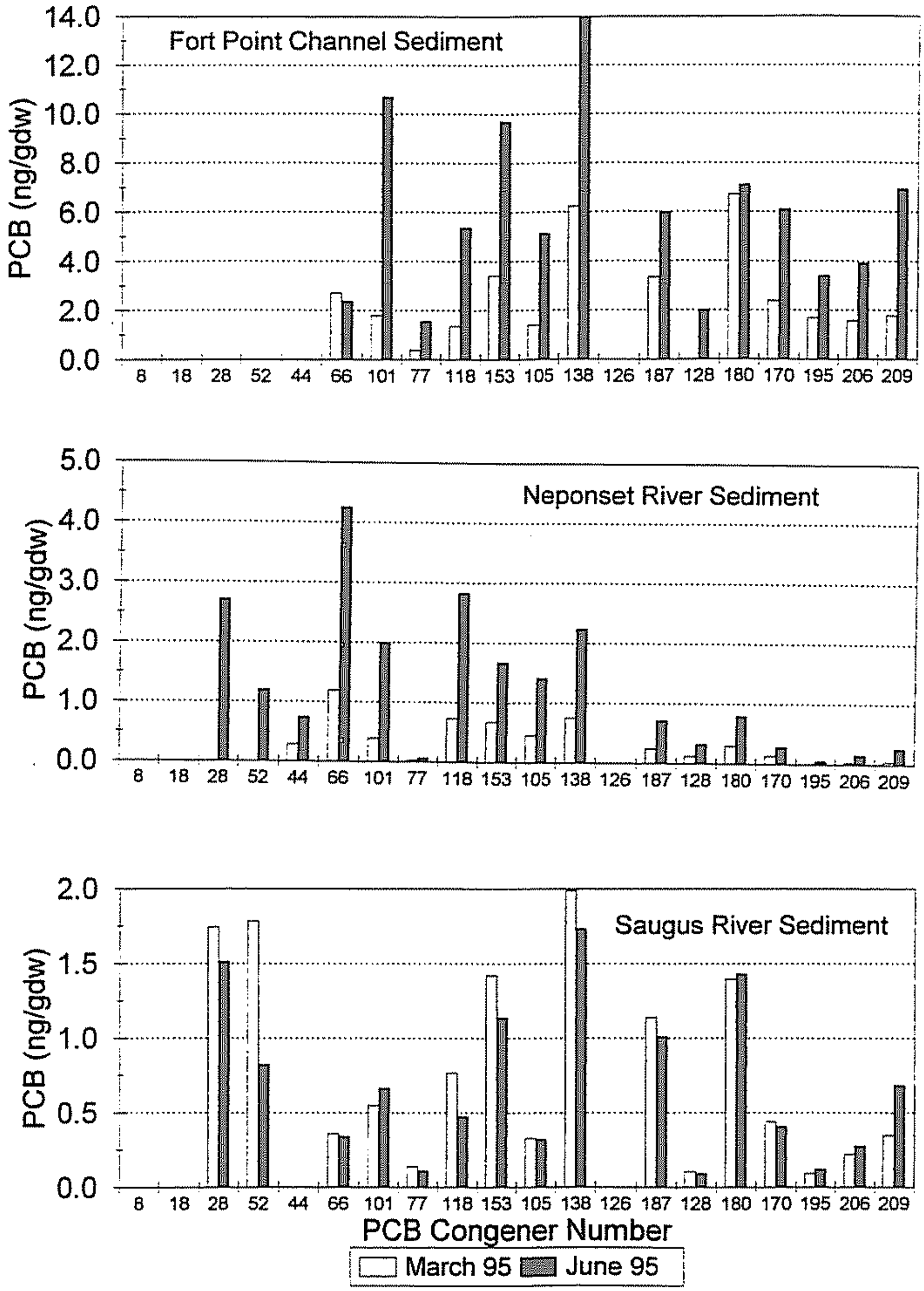


Figure I-3. Concentrations of PCBs (ng/g dry weight) in Sediments at the Urban Harbor Study Sites. Measurements were taken in March 1995 (shaded bars) and June 1995 (solid bars).

The concentrations of PCBs and OCPs in Barnstable and Wellfleet are about 10-30 times lower than those at other sites in Cape Cod Bay and at a site southeast of Stellwagen Bank in the Gulf of Maine (Shea et al., 1991; Shea et al., 1996). These very low concentrations are similar to those reported for remote areas, indicating that the only source of PCBs and OCPs to the sheltered harbors along Cape Cod Bay may be regional atmospheric deposition. Hyland and Costa (1995) reported higher concentrations of hexachlorobenzene (HCB; up to 12 ng/g), aldrin (up to 3 ng/g), lindane (up to 0.7 ng/g), total DDT and metabolites (up to 3 ng/g), and total PCBs (up to 15 ng/g) in Wellfleet Harbor than we found, but concentrations of other OCPs and many individual PCBs were similar. Based on our recent studies of organic contaminants throughout Massachusetts Bays (Shea et al., 1996) we can offer no plausible mechanism to support the HCB and aldrin concentrations reported by Hyland and Costa (1995). However, the lindane, DDT and PCB concentrations reported by Hyland and Costa (1995) are at the upper range that we would expect for remote sites within the Massachusetts Bays region based on contaminant loading estimates and fate modeling (Shea et al., 1996). For these three contaminants, the differences between our results and those reported by Hyland and Costa (1995) probably reflect the different site locations within the harbor and the different laboratories performing the analyses. There were no other major discrepancies between our PCB and OCP data and those reported by others.

The relative abundance of individual PCBs in the urban harbors matches the typical pattern found in these harbors reported previously with an enrichment of congeners 101, 138, 153, 180 and 187 (Figure I-3 and Table A1). The pattern is consistent with a mixture of weathered Aroclors 1248, 1254, and 1260 that were in use in the Massachusetts Bays region during the 1940s through early 1970s. PCB congeners 28 and 52 are enriched in the Saugus and Neponset River sediments, perhaps reflecting local inputs at those sites.

The relative abundance of pesticides in sediments at all five sites is consistent with previous studies. For example, the 4,4'-DDTs are enriched relative to the 2,4'-DDTs, as with the original pesticide formulations, although the complete absence of the 2,4' isomers in Saugus and Fort Point Channel is unusual. Concentrations of parent DDTs are the same or higher than the primary aerobic metabolite (DDEs) and anaerobic metabolite (DDDs) suggesting that there are still sources of relatively fresh DDT to the urban harbors. The chlordane pattern (heptachlor, heptachlor epoxide, cis-chlordane, and trans-nonachlor) is similar to that reported previously for Massachusetts Bay, but it is not the pattern expected based on chlordane weathering studies (R. Leidy, pers. comm.). We suspect that these chlordane patterns are an artifact of co-eluting halogenated compounds in the samples as was reported previously in studies of chlordane use in agricultural areas (R. Leidy, pers. comm.).

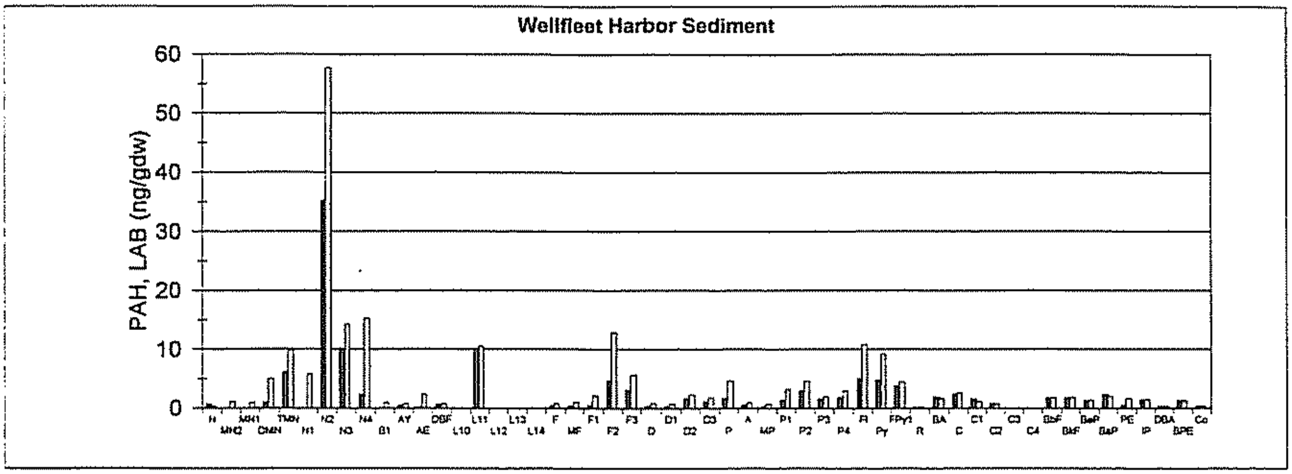
Contaminant concentrations were measured in sediments sampled during March and June to determine whether changes took place during the clam deployment period. There is very good agreement between March and June PCB and OCP concentrations at the Cape Cod sites (see Table A1 for Wellfleet and Barnstable) and at Saugus (Figure I-3). The concentrations of PCBs and OCPs were higher in June samples than in March samples at Neponset and Fort Point Channel while the relative abundance patterns were conserved (Figure I-3 and Table A1). With a few exceptions, the increases were only about a factor of 2 or 3. It is possible that spring rains brought PCB-contaminated particles or oils to the sediments during this period or that the difference is simply due to spatial variability.

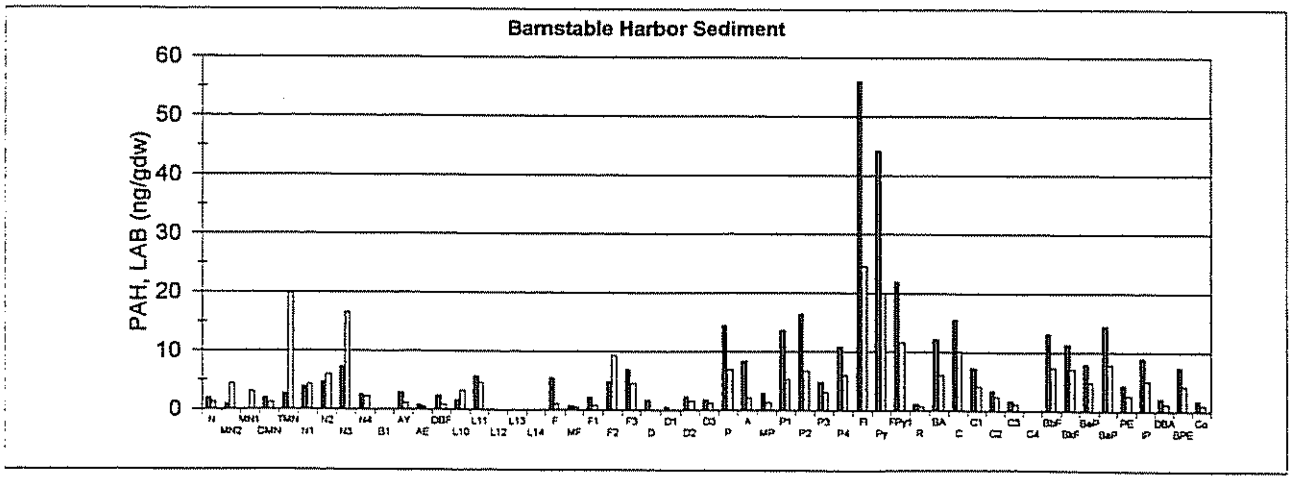
Concentrations of PAHs in sediments were generally in the range reported by others for the same or similar locations (Shea et al., 1991; Shea et al., 1994; Long et al., 1995; Hyland et al., 1995; Shea et al., 1996). Concentrations at Fort Point Channel were about 3-4 times those at Saugus, which in turn were 5-10 times higher than those at Neponset, which were about 10 times higher than those at Barnstable and Wellfleet (Figure I-4 and Table A2 in Appendix A). As with the PCBs and OCPs, the concentrations of PAH in Barnstable and Wellfleet are about 10 times lower than those at other sites in Cape Cod Bay and five times lower than in the Gulf of Maine (Shea et al., 1996). The PAH concentrations reported by Hyland et al. (1995) for Wellfleet Harbor are similar to those reported here.

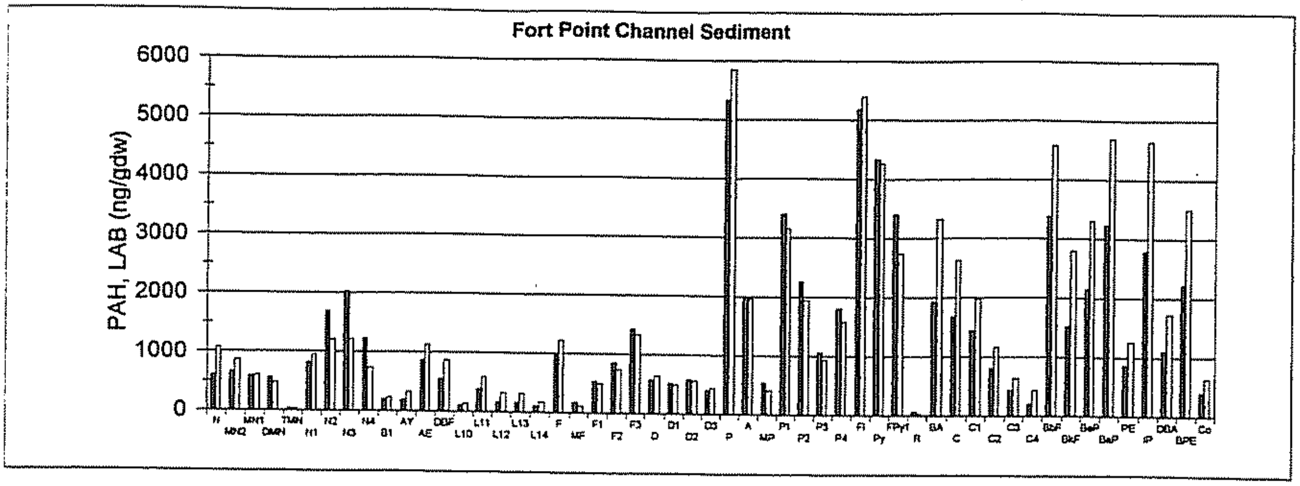
The relative abundance of individual PAHs was typical of sediments in this region with highly weathered petroleum mixed with combustion products. Wellfleet sediments were enriched in the lighter molecular weight (LMW) PAH indicative of petroleum input, whereas the urban harbor sediments, and to a lesser extent Barnstable, were enriched with the higher molecular weight (HMW) PAH indicative of combustion sources. High relative concentrations of fluoranthene, pyrene, and chrysene were found at all of the sites, with the most dramatic example being Barnstable Harbor (Figure I-3). These three PAHs are enriched in creosote, which has been used extensively to protect wood pilings in the marine environment and appears to be a major source of these PAH to harbor sediments.

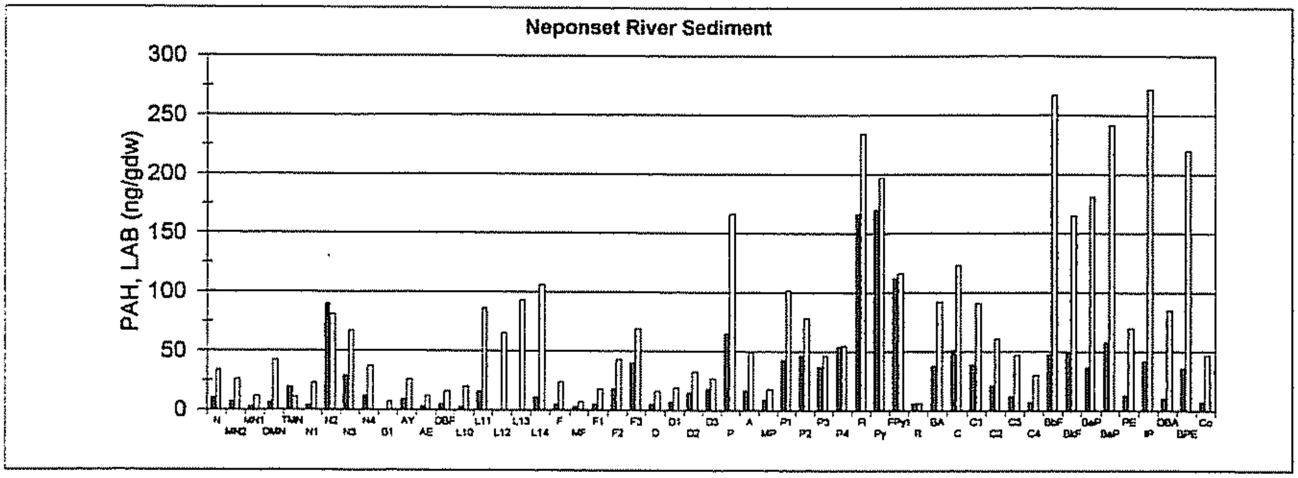
The relative abundance patterns for Saugus and Fort Point Channel were remarkably similar between March and June, with only slightly higher inputs of HMW PAH in Fort Point Channel in June. In contrast, Neponset exhibited a 150% increase in total PAH from March to June and a significant enrichment of the HMW PAH. It is likely that the spring rains that appeared to bring greater amounts of PCBs and OCPs to Neponset also brought urban dust and soot particles containing the HMW PAH (Hoffman et al., 1984). There was a dramatic increase in the linear alkyl benzenes (LABs) from March to June, implicating domestic sewage as a major source of

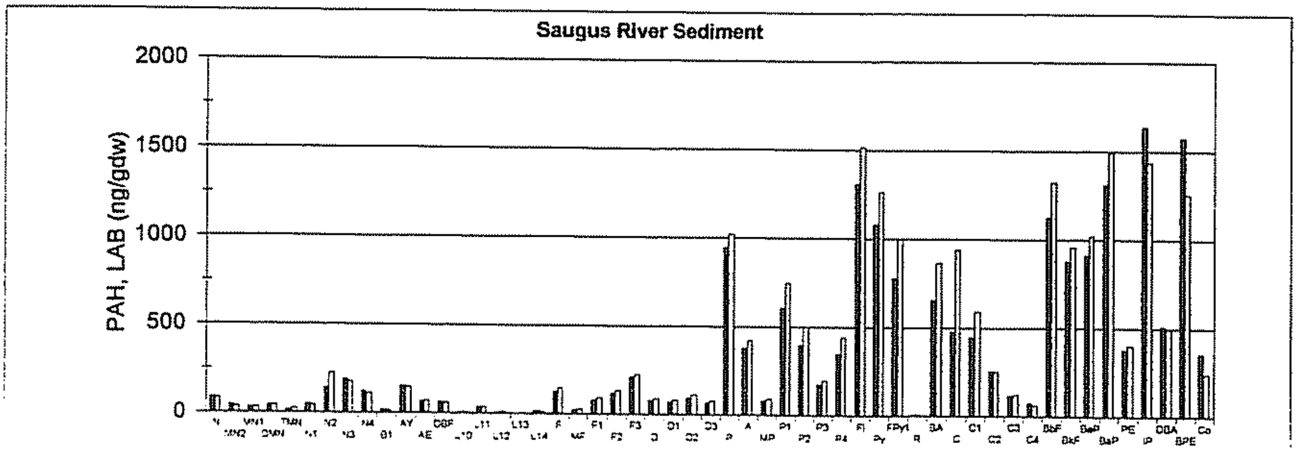
Figure I-4. Concentrations of PAHs and LABs (ng/g dry weight) in Sediments at All Study Sites. Measurements were taken in March 1995 (solid bars) and June 1995 (shaded bars). Compound codes are as follows: N-naphthalene, **MN2**-2-methylnaphthalene, **MN1**-1-methylnaphthalene, **DMN**-2,6-dimethylnaphthalene, **TMN**-2,3,5-trimethylnaphthalene, **N1**-C1-naphthalenes, **N2**-C2-naphthalenes, **N3**-C3-naphthalenes, **N4**-C4-naphthalenes, **B1**-biphenyl, **AY**-acenaphthylene, **AE**-acenaphthene, **DBF**-dibenzofuran, **L10**-phenyldecane, **L11**-phenylundecane, **L12**-phenyldodecane, **L13**-phenyltridecane, **L14**-phenyltetradecane, **F**-fluorene, **MF**-1-methylfluorene, **F1**-C1-fluorenes, **F2**-C2-fluorenes, **F3**-C3-fluorenes, **D**-dibenzothiophene, **D1**-C1-dibenzothiophenes, **D2**-C2-dibenzothiophenes, **D3**-C3-dibenzothiophenes, **P**-phenanthrene, **A**-anthracene, **MP**-1-methylphenanthrene, **P1**-C1-phenanthrenes/anthracenes, **P2**-C2-phenanthrenes/anthracenes, **P3**-C3-phenanthrenes/anthracenes, **P4**-C4-phenanthrenes/anthracenes, **Fl**-fluoranthene, **Py**-pyrene, **FPy1**-C1-fluorantheens/pyrenes, **R**-retene, **BA**-benz[a]anthracene, **C**-chrysene, **C1**-C1-chrysenes, **C2**-C2-chrysenes, **C3**-C3-chrysenes, **C4**-C4-chrysenes, **BbF**-benzo[b]fluoranthene, **BkF**-benxo[k]fluoranthene, **BeP**-benzo[e]pyrene, **BaP**-benzo[a]pyrene, **PE**-perylene, **IP**-indeno[1,2,3-c,d]pyrene, **DBA**-dibenz[a,h]anthracene, **BPE**-benzo[g,h,i]perylene, **Co**-coronene. The molecular weight of the PAH increases from left to right in the graphs.


Wellfleet Harbor Sediment
PAH, LAB (ng/gdw)
60
50
40
30
20
10
0


Barnstable Harbor Sediment
PAH, LAB (ng/gdw)
60
50
40
30
20
10
0


Fort Point Channel Sediment
PAH, LAB (ng/gdw)
6000
5000
4000
3000
2000
1000
0


Neponset River Sediment
PAH, LAB (ng/gdw)
300
250
200
150
100
50
0


Saugus River Sediment
PAH, LAB (ng/gdw)
2000
1500
1000
500
0

contaminants to Neponset in spring as the primary source of LABs to Boston Harbor is domestic sewage (Shea and Kelly, 1992).

(2) Bioaccumulation in *M. arenaria* and SPMDs. Specimens of *M. arenaria* were collected from each of the sites along with the two types of SPMDs that were deployed for approximately 90 days. The SPMD act as an in situ sampling device that accumulates lipophilic contaminants via passive diffusion through an artificial polyethylene (PE) membrane and into a lipid-like substance (Huckins et al., 1993). The two types of SPMDs were (1) PE tubing filled with triolein lipid and (2) plain polyethylene (PE) tubing, where the tubing itself acts as the lipid phase. The first configuration is the standard SPMD designed by Huckins et al. (1993) and the second configuration is a simplified design that we are testing in the laboratory and at several field sites. We deployed both types of SPMDs at the sediment-water interface and approximately 5 cm beneath this interface. The clams and both types of SPMDs accumulated PCBs, OCPs, LABs, and PAHs at all five sites (Tables A3-A8). Although we did not measure accumulation as a function of time to determine uptake rates or establish whether we had reached steady state, previous studies with *M. arenaria* and with SPMDs indicate that either steady state or true equilibrium should have been reached in this study (Hofelt and Shea, 1996). We have no previous data on contaminant accumulation in clams or SPMDs at these sites for comparison.

The clam-sediment bioaccumulation factor (BAF) and the PE or SPMD accumulation factors (AF) was calculated using

$$\text{accumulation factor} = [(C_a/f_{\text{lipid}})]/[(C_s)/(f_{\text{SOC}})]$$

where C_a is the concentration (ng/gdw) of the contaminant in the accumulator (clam or SPMD), C_s is the concentration (ng/gdw) of the contaminant in the sediment, f_{lipid} is the lipid fraction of the accumulator, and f_{SOC} is the sediment organic carbon (SOC) fraction. The lipid fraction of the clam is determined on the whole soft tissue that was extracted for contaminant analysis, while the lipid fraction for the SPMD is unity (Hofelt and Shea, 1996). We use total organic carbon (TOC) as a measure of the sediment lipid phase rather than a lipid determination because the former was more reproducible. The use of TOC may overestimate sediment lipid fraction because TOC can include significant amounts of polar carbon (e.g. high O:C ratio), leading to an overestimate of the accumulation factor.

Lipid-normalized accumulation factors for representative PAH are shown in Figure I-5 for clams and SPMDs (5 cm depth). Accumulation factors for the HMW PAH (where there was no SPMD contamination) are listed in Table I-1 for clams and PE tubing. Many of the clam-sediment BAFs in Wellfleet and Neponset are reasonably close to unity (within a factor of 2 or 3). A value of unity is expected if the clam is in true equilibrium with the sediment and the lipid and TOC measurements equally represent the sorptive capacity of the clam and sediment, respectively (Figure I-1). Given the uncertainties in this calculation, our data suggest that the clams in Wellfleet and Neponset are near equilibrium with their sedimentary environment. Extending this argument to the other sites, we find that clams in Barnstable, Saugus, and Fort Point Channel are generally undersaturated with respect to equilibrium with the sediment - that is, something is preventing the clams at these three sites from reaching equilibrium with the total contaminant mass in the sediment.

The BAFs for several petrogenic PAH in Barnstable are closer to equilibrium than the pyrogenic PAH, indicating that petroleum derived PAH might be more bioavailable in these sediments than combustion source PAH. This speculation is supported by the higher BAFs for the alkylated PAH (from Tables A2 and A4), which are predominantly petroleum derived, compared to BAFs for the nonalkylated PAH. The lower bioavailability of combustion derived PAH has been reported previously (Harkey, et al., 1995), but the availability of HMW PAH also appears to vary with particle genesis, age, and other factors (Fisher, 1995). In Saugus, fluoranthene, pyrene, and chrysene (which are enriched in creosote) have BAFs near unity. The PAH in creosote are known to be readily available for partitioning to water and organisms (Neff, 1979), explaining their enrichment in the Saugus clams relative to the other HMW PAH. Although the BAFs at Fort Point Channel are somewhat lower than those at Saugus, the pattern of BAFs at both sites (Figure I-5) are nearly identical from anthracene (A) to coronene (Co). In fact, all the sites exhibit similarities in the relative BAFs from A to Co.

Accumulation factors for the PE tubing and SPMDs were much lower than for the clams (Table I-1 and Figure I-5). We expected that the clams might accumulate higher concentrations of contaminants than the SPMDs because the clams filter large quantities of sediment particles and can accumulate contaminant via the gut and via exchange across gill membranes. In contrast, the SPMDs are a passive accumulator of contaminants that are freely dissolved in the water (or sediment porewater). If both clams and SPMDs are in equilibrium with the porewater, they will accumulate the same lipid-normalized concentration of contaminants. However, we found up to 100 times lower accumulation in the PE tubing and SPMDs compared to the clams. This was true regardless of the SPMD design (with triolein or without) and its location in the sediment (0 cm or 5 cm). The SPMDs buried in the sediment had somewhat higher AFs than those at the sediment-water interface, but they were still quite low compared to the clams. The lower AFs in the surface SPMDs probably reflects lower dissolved PAH at this interfacial region than in the sediment porewater (Table A9).

In a recently completed study in New Bedford Harbor we conducted a simultaneous deployment of SPMDs and *Mytilus edulis* in the water column

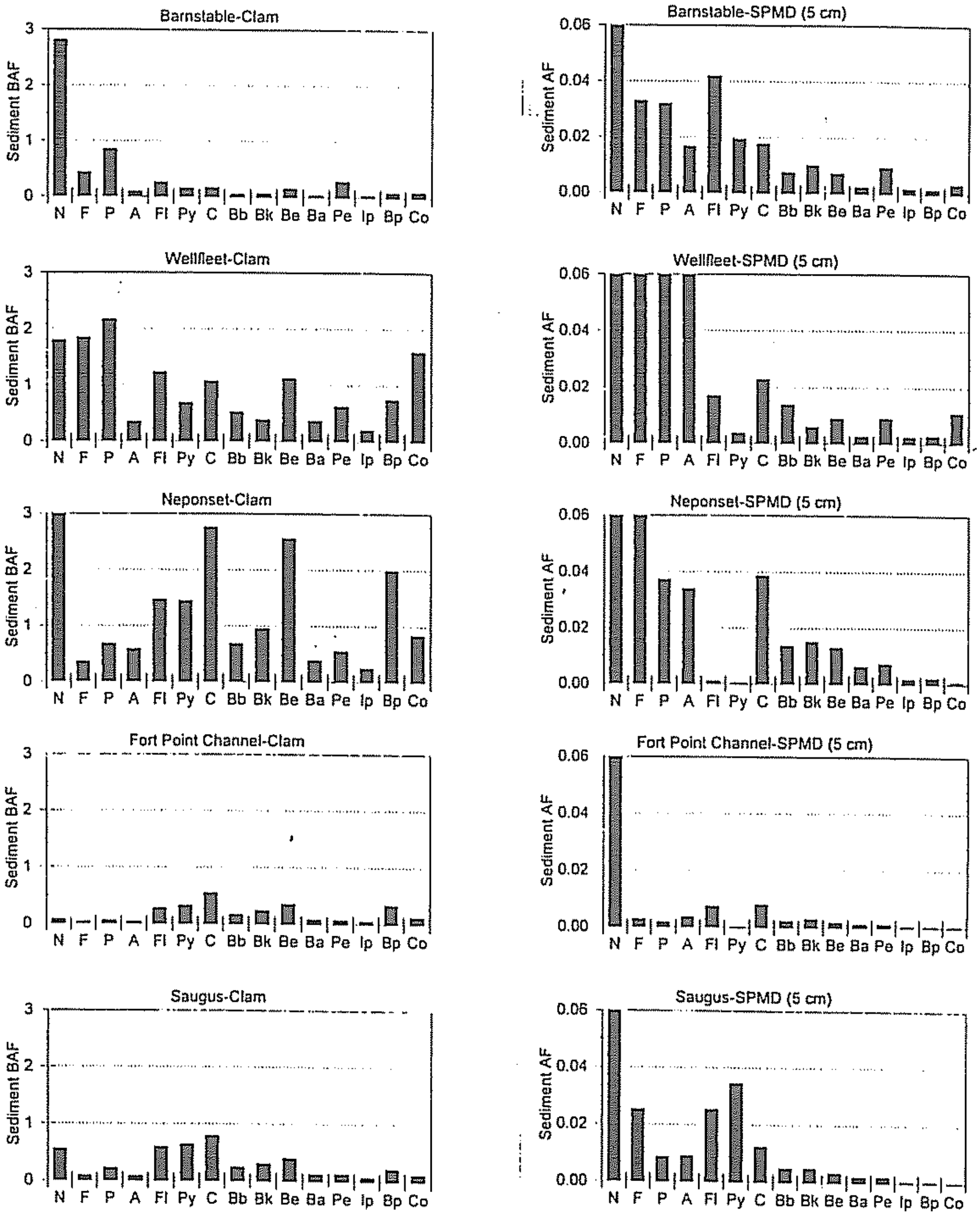


Figure I-5. Measured Sediment Accumulation Factors for Representative Compounds. Compound codes are given in the figure legend for Figure 1-4, the molecular weight of the PAH increases from left to right in the graphs. BAFs for the clam are shown in the left column of graphs and AFs for the triolein-filled SPMD (deployed at 5 cm sediment depth) are shown in the right column. Note that the scales are different for the two different accumulating substrates. The higher AFs for the lower molecular weight PAH (N, F, P, A) in the SPMDs probably are due to contamination in the field (see text for discussion).

Table I-1. Lipid Normalized Accumulation Factors.

	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel
Clam-Sediment BAFs					
chrysene	1.0745	0.1684	2.7609	0.7919	0.5493
benzo(b)fluoranthene	0.5236	0.0592	0.6857	0.2501	0.1769
benzo(k)fluoranthene	0.3926	0.0733	0.9563	0.3059	0.2431
benzo(e)pyrene	1.1278	0.1629	2.5599	0.4060	0.3606
benzo(a)pyrene	0.3721	0.0436	0.3917	0.1381	0.0957
perylene	0.6290	0.2890	0.5570	0.1380	0.0836
indeno(1,2,3-c,d)pyren	0.2116	0.0444	0.2598	0.0805	0.0552
benzo(g,h,i)perylene	0.7513	0.0969	1.9983	0.2262	0.3395
coronene	1.6086	0.1105	0.8435	0.1299	0.1328
PE-Sediment (0 cm) AFs					
chrysene	0.0957	0.0052	0.1555	0.0415	0.0276
benzo(b)fluoranthene	0.0735	0.0109	0.0339	0.0134	0.0083
benzo(k)fluoranthene	0.0587	0.0084	0.0945	0.0146	0.0089
benzo(e)pyrene	0.0283	0.0130	0.0309	0.0114	0.0080
benzo(a)pyrene	0.0218	0.0030	0.0220	0.0057	0.0038
perylene	0.0412	0.0118	0.0261	0.0066	0.0037
indeno(1,2,3-c,d)pyren	0.0222	0.0017	0.0186	0.0023	0.0017
benzo(g,h,i)perylene	0.0202	0.0011	0.0152	0.0025	0.0023
coronene	0.0276	0.0088	0.0041	0.0012	0.0009
PE-Sediment (5 cm) AFs					
chrysene	0.0533	0.2633	0.0352	0.0396	0.0367
benzo(b)fluoranthene	0.0665	0.3207	0.0502	0.0506	0.0338
benzo(k)fluoranthene	0.0385	0.3479	0.0398	0.0405	0.0312
benzo(e)pyrene	0.0201	0.1133	0.0128	0.0217	0.0138
benzo(a)pyrene	0.0183	0.1402	0.0409	0.0403	0.0352
perylene	0.0361	0.0813	0.0329	0.0399	0.0385
indeno(1,2,3-c,d)pyren	0.0303	0.1094	0.0186	0.0213	0.0205
benzo(g,h,i)perylene	0.0098	0.0436	0.0029	0.0078	0.0041
coronene	0.0172	0.0795	0.0026	0.0059	0.0074

(Hofelt and Shea, 1996). *M. edulis* accumulated about twice the PCBs on a lipid basis as did the SPMDs, with the primary differences being in the higher chlorinated PCBs in the particulate phase. We concluded that the mussels were enriched in particulate PCBs due to uptake via the gut. Thus, soft shell clams ought to accumulate even more particulate organic contaminants relative to SPMDs because of their greater exposure to sediment particles. In the present study, however, the accumulation of PCBs, OCPs, and PAHs in the clams was up to 100 times higher than in the SPMDs. Clearly, the SPMDs and clams are not both in equilibrium with the porewater and the equilibrium partitioning processes shown in Figure I-1 do not apply universally to our study.

This raises the question: Why are the clams accumulating more than the SPMDs and yet at three of the sites (Figure I-5) they are prevented from accumulating the total mass predicted from equilibrium partitioning? To help answer this question we measured the fraction of porewater PAH bound by COC to determine whether COC was limiting uptake into the SPMDs and we measured the fraction of sediment-bound contaminants that was actually available for equilibrium partitioning (AEP) to determine whether a recalcitrant fraction of PAH was limiting partitioning to porewater and uptake into the clams.

We measured the COC-bound fraction of PAH at Fort Point Channel and at Neponset using the procedure of Chin and Gschwend (1992) and found the values at both sites were within 15% of each other. Chin and Gschwend (1992) also found very little difference among their estimates of the fraction of PAH bound to COC at different sites in Boston Harbor and at different depths of sediment. We obtained values for COC-bound pyrene of 54% at Neponset and 47% at Fort Point Channel which are very close to the 44% - 52% reported by Chin and Gschwend (1992) for Fort Point Channel and nearby Spectacle Island. We used an average of the COC-bound fractions at Fort Point Channel and Neponset for all five sites: 50% for pyrene, 90% for benzo(b)- and benzo(k)-fluoranthene, 95% for benzo(e) and benzo(a)pyrene, and 99% for benzo(g,h,i)perylene. Note that these percentages increase with the hydrophobicity of the PAH as we would expect from EqP theory (Chin and Gschwend, 1992). Estimated COC-bound fractions were converted to a porewater AEP fraction by using:

porewater-AEP fraction = (1-COC bound fraction).

We calculated the sediment AEP fraction using the method of McGroddy and Farrington (1995) where:

$$\text{sediment-AEP fraction} = (C_{pw})\,(K_{d'})\;/\;(C_s)$$

where C_{pw} is the measured dissolved concentration of contaminant in the porewater, $K_{d'}$ is the apparent sediment-water distribution constant, and C_s is the total concentration of the contaminant in the sediment. We used apparent partition coefficients normalized to SOC (K_{SOC}) and to COC (K_{COC}) obtained from the literature (McGroddy and Farrington, 1995) and from a related study in our laboratory (unpublished data) to calculate $K_{d'}$ by using:

$$K_{d'} = f_{SOC} K_{SOC} / f_{COC} K_{COC}$$

We found only small (<25%) differences in the sediment-AEP fraction among the six PAHs at a given site, so an average of the six values was used. We used the estimated sediment-AEP fraction at Wellfleet (75%), Barnstable (15%), Saugus (25%), Neponset (85%), and Fort Point Channel (25%) to predict the concentration of the six PAHs in clams in equilibrium with the sediment-AEP fraction at all five sites.

The porewater-AEP and sediment-AEP results are summarized in Table I-2, where we report the lipid-normalized PAH concentrations measured in the PE tubing, SPMD, and clam; and that predicted using total porewater PAH concentrations, porewater-AEP fraction, total SOC-normalized sediment PAH, and the sediment-AEP fraction. The PE tubing and SPMD concentrations are in good agreement with the total porewater concentrations only for pyrene, which has the highest unbound fraction of the PAHs (50%). Conversely, concentrations of all six PAHs in PE tubing and SPMDs are in very good agreement with those predicted from the porewater-AEP fraction at all five sites. The sediment-AEP fraction was the best predictor of accumulation in the clams. Agreement was within a few percent at some site-PAH combinations and was within a factor of four at worst. Linear regression (n=26, zero intercept) of the predicted PAH concentrations (ng/g lipid) versus the observed concentrations yielded the best fit with the following combinations:

Accumulator	**Predictor**	**Slope**	r^2
PE Tubing	porewater-AEP	1.10+0.11	0.74
SPMD	porewater-AEP	0.68+0.07	0.67
Clam	sediment-AEP	0.84+0.10	0.5

In most cases, the observed concentrations in the accumulating phase can be predicted within a factor of two by using the estimated AEP fraction for porewater (for PE tubing and SPMDs) or sediment (for clams). The fact that we predict and observe such large differences between porewater-AEP and sediment-AEP concentrations indicates that the AEP fraction of the sediment is not in equilibrium with the AEP fraction of the porewater during the sampling period, despite the fact that the clams appear to be in equilibrium with the AEP fraction of the sediment and the PE tubing and SPMDs appear to be in equilibrium with the AEP fraction of the porewater.

Table I-2. Measured and Predicted Concentrations in Lipid Phase (ng/g lipid).

site	measured PE tubing	measured SPMD	measured clam	predicted from porewater	predicted from porewater-AEP	predicted from total sediment	predcited from sediment-AEP
				pyrene			
Fort Point Channel	3099	1882	26759	2694	1347	86000	25800
Neponset	401	276	6495	2060	1030	4600	3910
Saugus	2800	1405	21654	5230	2615	29300	7325
Barnstable	60	90	436	80	40	3200	480
Wellfleet	27	8	515	32	16	700	560
				benzo(b)fluoranthene			
Fort Point Channel	500	620	13291	5000	500	79640	23892
Neponset	130	152	8740	4950	495	3950	3358
Saugus	465	445	2636	7750	775	30600	7650
Barnstable	12	15	51	120	12	1000	150
Wellfleet	10	8	97	150	15	170	136
				benzo(k)fluoranthene			
Fort Point Channel	330	490	9850	5007	501	43120	12936
Neponset	175	225	2500	4520	452	2675	2274
Saugus	350	400	8005	6999	700	22875	5719
Barnstable	13	14	57	96	10	926	139
Wellfleet	8	6	74	100	10	176	141
				benzo(g,h,i)perylene			
Fort Point Channel	100	175	18250	36460	182	57260	17178
Neponset	35	31	6250	34236	171	3200	2720
Saugus	85	150	9134	55206	276	35350	8838
Barnstable	2	2	47	1000	5	582	87
Wellfleet	2	4	102	1000	5	127	102
				benzo(e)pyrene			
Fort Point Channel	320	425	18450	4000	200	54460	16338
Neponset	85	100	6821	3410	171	2725	2316
Saugus	280	310	11207	6340	317	24150	6038
				benzo(a)pyrene			
Fort Point Channel	270	340	7125	5002	250	79260	23778
Neponset	70	80	1440	4240	212	3750	3188
Saugus	227	260	5538	5090	255	3500	875

Although we have only a small data set, it appears that for the pyrogenic PAH studied here, the porewater-AEP fraction is driven primarily by the hydrophobicity of the contaminant, while the sediment-AEP fraction is driven mostly by the location or conditions of the sediment (i.e., source of PAH). McGroddy and Farrington (1995) found that the sediment-AEP fraction for pyrene generally increased with depth in the sediment, indicating that aging of recent PAH-laden particles could increase availability. We found that the sediment-AEP fraction in Neponset was lower in June compared to March indicating that the recent input of HMW PAH during that period was less available than the more weathered PAH sampled in March. The sediment-AEP fraction did not change in Saugus and went down only a little in Fort Point Channel in June. Therefore, it does not appear that measurements of sediment-AEP made at one point in time and space can be used universally for other times and locations. Unfortunately, the measurement of sediment-AEP fraction is not routine (McGroddy and Farrington, 1995). We are now investigating the use of various sediment extraction procedures to recover only the sediment-AEP fraction. This type of measurement would allow routine measurement of the AEP fraction and thus yield a better prediction of bioaccumulation in infaunal species such as *M. arenaria*.

II. Biological Effects of Contaminants on Populations of *Mya arenaria*

a. Introduction

Bivalve molluscs have been used extensively during the past two decades as sentinel monitors of chemical contamination (Butler, 1973; NRC, 1980; Farrington et al. 1983) and more recently as organisms in biological effects monitoring (Bayne et al., 1988). Distinguishing between natural and enhanced levels in marine biota is extremely difficult without a detailed data base on background levels for different species and the extent of natural variation in background levels as a result of both environmental and biological factors. As the relationships between levels of chemical contaminants and biological responses in bivalve molluscs continue to be explored, insight of the toxic action of specific compounds and groups of compounds have been elucidated. However, our knowledge of cause and effect relationships between tissue burdens of many contaminants and biological consequences in many species is still incomplete.

Because of the hydrophobic properties of individual lipophilic organic contaminants, these contaminants readily sorb to particles. Thus, once introduced to aquatic systems, lipophilic organic contaminants become associated with sediment deposits and may be readily accumulated by benthic organisms (see Part I). Transfer of contaminants to marine biota and the human consumer and toxicological effects on the ecosystem are dependent on the availability and persistence of these contaminants within benthic environments. The bioaccumulation of lipophilic organic contaminants is influenced by chemical factors such as solubility and particle adsorption-desorption kinetics of specific compounds; and biological factors such as the transfer of compounds through food chains and the amount of body lipid in exposed organisms.

The effects of lipophilic organic contaminants on marine bivalve molluscs have been examined extensively during the past decade. The majority of the studies have been conducted on the blue mussel *Mytilus edulis* (e.g., Bayne et al., 1985; Bayne et al., 1988) with an effort to integrate responses over several levels of biological hierarchy and to examine responses linked to specific classes of contaminants. Recent work has extended this approach to other species of bivalve molluscs, such as the subtropical turkey wing mussel, *Arca zebra* (Addison and Clarke, 1990; Widdows et al., 1990) and the soft shell clam, *Mya arenaria* (Leavitt et al., 1990; Weinberg et al., 1996; McDowell Capuzzo et al., in prep.).

Chronic exposure to chemical contaminants can result in alterations in reproductive and developmental potential of populations of marine organisms, resulting in possible changes in population structure and dynamics. Koojiman and Metz (1984) suggested that the sublethal effects of contaminant exposure should be interpreted in light of the survival probabilities and reproductive success of populations, thus bridging the gap between individual and population responses. Although a wide range of sublethal stress indices have been proposed for evaluation of chronic responses of organisms to contaminants, few have been linked to the survival potential of the individual organism or the reproductive potential of the population.

An understanding of reproductive and developmental processes provides a critical link between responses at the organismal and suborganismal levels and population consequences. Alterations in bioenergetics linked with observations of reduced fecundity and viability of larvae, abnormalities in gamete and embryological development, and reduced reproductive success provide a strong empirical basis for examination of population responses. Incorporation of these responses in demographic models may lead to new insights on adaptations of specific life history stages to contaminant perturbations and the population consequences of stage- or age-specific effects of contaminants.

We have examined the effects of lipophilic organic contaminants on population processes in the soft shell clam *Mya arenaria*, collected along a gradient of PAH contamination in Boston Harbor and Massachusetts and Cape Cod Bays. The population dynamics of bivalve species have received considerable scientific attention due to the importance of many bivalves as commercially harvested fisheries. Demographic models have been developed to examine the importance of specific life history characteristics on population processes. Such models include: (1) analysis of the sensitivity of population growth rate to life cycle perturbation, (2) life table response experiments, and (3) population projection and prediction (Caswell, 1989a,b). In addition to quantifying the impact of fishing pressure on bivalve populations, demographic models have been used to assess the importance of environmental perturbations (e.g., disease, contaminant effects, etc.) on bivalve physiology and population dynamics (Weinberg et al., 1996).

We addressed the following four questions:

1) Does environmental exposure to sub-lethal concentrations of contaminants affect the reproductive cycle of the soft shell clam *Mya arenaria*?

2) Can we correlate tissue concentrations of specific contaminants in clams collected from various sites along a defined gradient of chemical

contamination in Massachusetts and Cape Cod Bays with quantitative estimates of reproductive effort in adult clams?

3) Is there a reduction in post-settlement survival associated with the settlement of clam larvae on sediments with high concentrations of chemical contaminants?

4) Using a demographic model developed to address the interaction of environmental contaminants and population dynamics of soft shell clam populations, can the effects of contaminants on population processes in soft shell clams from Massachusetts and Cape Cod Bays be quantified?

b. Sampling Design and Methods

Site Selection - Based on documented surveys of lipophilic organic contaminant concentrations at selected sites in Boston Harbor/Massachusetts Bays (Moore et al., 1994; Shea and Seavey, 1994), we selected five sites from those previously examined by Moore et al. for histopathological conditions among soft shell clam populations. On the basis of sedimentary PAH concentrations, these sites reflect a gradient of contamination and observed histopathological effects in soft shell clam populations (Figure I-2; Table II-1). Sediment samples were also assayed for total organic matter and total organic carbon and oxygen demand. Surface sediments (0-5 cm) obtained from each station were sieved through a 1.0 mm screen to remove animals and shell material. Replicate subsamples of each sediment sample were dried at 60^{o}C and ground to a fine powder with a clean glass rod. Aliquots of sediments from each site were combusted at 450^{o}C and reweighed to determine the amount of total organic matter. Total organic carbon was determined as described in Part I.

Table II-1. Sampling Sites and Sediment Contaminant Concentrations (ng/g dry weight)

Site	Total PAH	Total PCB	Total DDT	Total LAB
Barnstable H.	352	0.5	0.2	7
Wellfleet	102	<0.1	0.2	10
Saugus	18,342	12.8	5.1	65
Neponset R.	1,450	5.4	2.0	31
Fort Point Ch.	66,121	34.8	26.8	925

Sampling : Questions 1 and 2 - To address the first question, we compared the distribution of lipophilic contaminants (Part I) with estimates of reproductive condition and lipid storage in clams collected at each of the sites in Massachusetts and Cape Cod Bays. Clams were collected five times during the year to document the annual reproductive cycle of the soft shell clam at each site and to characterize any aberrations in lipid/energy allocation to developing gonads. Clams collected at these times were also used to obtain reproductive output data to answer the second research question. (Some of these data were also used in the mathematical model; see methods for question four below.) The schedule for sampling protocols was as follows:

Collections:	**Reproductive Stage:**
Early Spring (March 1995)	Developing Gonads
Late Spring (June 1995)	Gonads Mature and Spawning
Early Fall (September 1995)	Gonads Spent
Early Winter (December 1995)	Early Stages of Gonad Development
Early Spring (March 1996)	Developing Gonads

The various stages of the reproductive cycle in *M. arenaria* are described below (Coe and Turner, 1938; Ropes and Stickney, 1965):

Development Stage:	**Description:**
Indifferent	No cellular differentiation is evident within the gonadal follicles of either males or females.
Early Developing	Oocytes and primary spermatogonia are observed forming on the basal membrane of the follicle.
Late Developing	The oocytes enlarge and extend into the lumina of the follicle with the bases constricted and the spermatogonia have divided into spermatids which are arranged in chords extending into the follicle lumina.
Ripe	Oocytes are attached with a very slender stalk , or not at all, and the spermatogonia are arranged in chords with their flagella oriented into the follicle lumen.
Spawning	A few ripe eggs and sperm are observed in the follicle lumen.
Spent	Follicle cells form a thin layer covering the basement membrane of the follicle in females and multinucleated cells are found in small groups in the male follicles.

Five clams from each of five size classes - <40 mm, 40.0-49.9 mm, 50.0-59.9 mm, 60.0-69.9 mm, and >70 mm - were collected from the intertidal area at each site at each of the five sampling periods. These clams were used for condition index analyses, biochemistry, and reproductive stage and fecundity. An additional sample of twenty five clams (five in each size class) was collected in August and analyzed for reproductive stage and fecundity only.

At the initial sampling time duplicate sediment samples were collected for chemical analysis. In addition, five clams 50-59.9 mm in length were collected at each site during March and December and analyzed for lipophilic organic contaminants (Part I). analyses from post-spawn animals are currently in progress. The analysis of adults from both pre-spawning and post-spawning periods will allow us to examine the effects of spawning on loss of lipophilic organic contaminants from bivalve tissues.

Methods: Questions 1 and 2 - The clams were brought into the laboratory where they were measured and weighed. Clams were dissected and weighed with both the whole soft tissue weight and digestive gland-gonad complex weight recorded. In addition, aliquots of digestive gland-gonad complex were prepared for lipid analysis and histological evaluation of reproductive stage and fecundity. For dry weight determinations, all tissues and the valves were dried at 60°C for 48 h. For histological preparations the digestive gland-gonad complex was weighed and fixed in 10% formalin in 0.45 μm filtered seawater.

Two indices were calculated to estimate the physiological condition of the clams: the condition index (CI) and the digestive gland-gonad index (DGGI). Calculation of these indices was based on the weight of the digestive gland-gonad complex only, because the siphon contributes most of the mass of the clam but is not important in the reproductive physiology of the clam. The formulae for these quantities are:

$$CI = (W)\ (\text{valve length})\ /\ (100)$$

$$DGGI = (W)\ (\text{wet weight of all soft tissue})\ /\ (100)$$

where W is the wet weight of the digestive gland-gonad complex.

Lipid content of the digestive gland-gonad complex of representative clams collected at each site during each sampling period was determined by gravimetric analysis after chloroform-metahnol extraction according to the procedures described by Sasaki and Capuzzo (1984). Lipid content of only the digestive gland-gonad complex was measured because preliminary data indicated that the lipid content of the soft tissue minus the gonad does not change during the annual gametogenic cycle whereas the lipid content of the gonad cycles with stage of development.

Gonad samples, collected and preserved as noted above, were used to adddress the second research question regarding quantitative effects of contamination on reproductive output. Samples were prepared for histology by lateral division into 4-5 thick sections, following methanol rinsing to remove the fixative. A randomized sample was excised from each of the 4 to 5 thick sections and processed using routine paraffin embedding following dehydration, sectioned, and stained with hematoxylin-eosin (Humason, 1972). Prepared slides from each clam were examined for gender and reproductive condition according to the criteria listed above. An abnormal inflammation of the tissues was observed in some samples, and all samples were re-examined for this condition and evaluated as to severity of the inflammation.

To estimate fecundity, sections (6-10 μm) of digestive gland-gonad complex from female clams in a late developing or ripe stage were examined under a light microscope set up with a digitizing pad, Sigma Scan software, and a camera lucida. The mean number of nucleated eggs per unit area was calculated for one section per clam, based on counts of nucleated eggs in 10 non-overlapping 10x10 unit retucule grids. The mean oocyte diameter and nuclear diameter of 25 nucleated eggs per thin section were measured. The number of eggs per unit volume of gonad were calculated by converting grid units to area (mm^2), dividing by the number of grid squares (100), and dividing by mean nuclear diameter. The total number of eggs per gonad were calculated based on the total volume of the digestive gland-gonad complex calculated from archived data on weight-to-volume ratio of the DG complex, the total percent of gonadal tissue within the digestive gland-gonad complex (data from Weinberg et al., 1993), and the number of eggs per volume of gonadal tissue. These stereological techniques are standard (Weibel, 1979), and have been used in conjunction with total digestive gland-gonad complex volume estimates to calculate the reproductive effort of ripe females in other studies (e.g. Brousseau, 1978; Weinberg et al., 1993). Fecundities estimated here were also used in the demographic model (see methods for question 4).

The histological evaluation of the gonad stages and the fecundity estimates based on stereological analysis, in addition to observations of gonadal inflammation were independently evaluated by Dr. Roxanna Smolowitz, D.V.M. from the Laboratory for Marine Animal Health at the Marine Biological Laboratory in Woods Hole, MA. Dr. Smolowitz has extensive experience in marine bivalve histopathology. Random samples of prepared gonad sections representing 20% of the total sample set were evaluated by Dr. Smolowitz and compared to the results reported by our laboratory. There were no differences in sample interpretation between Dr. Smolowitz and our laboratory.

The status of hematopoietic neoplasia was determined for clams collected during the December sampling period for site comparison. A sample of hemolymph was removed from each clam using a 25 gauge needle and a 1 ml tuberculin syringe. Hemocyte evaluation (immunoperoxidase staining) for neoplastic cells was conducted on 25 clams from each site. Hemolymph was sampled within 24 hours of collection. Methods employed were as described previously (Smolowitz and Reinisch, 1986) with some modifications. Briefly, 0.1 ml of hemolymph containing hemocytes were removed from the clams through the posterior blood sinus with a 1 ml syringe containing 0.9 ml of filtered sea water. This hemolymph mixture was placed on a poly-L-lysine coated cover slip in a multiwell plate and hemocytes were allowed to settle onto the cover slip for 30 minutes. Fluid was removed from each chamber and cells were fixed for 5 minutes in 1 part glutaraldehyde/4 parts formalin. Wells were then rinsed in phosphate buffered saline four times. Hemocytes were stained in an indirect immunoperoxidase staining method using, as the primary monoclonal antibody, MAB 1E10 (developed by Carol Reinisch, Tufts University School of Veterinary Medicine) that is specific for neoplastic cells that occur in the leukemic disease. A second peroxidase tagged antimouse antibody was then applied. Finally the peroxidase complexes were developed with diethylcarbazole to produce a brown color on the leukemic cells. Using these stained cells, a percentage of neoplastic to normal cells were determined and staged according to previously published methods (Smolowitz et al. 1989). This provides the most sensitive method of detection, and allows for precise staging of leukemic disease in *Mya arenaria* (Smolowitz and Reinisch, 1986). The accuracy and precision of the immunoperoxidase test for soft shell clam leukemia has been carefully evaluated by Smolowitz and Reinisch (1986).

Differences in all parameters between sites and sampling periods were analyzed by two-way ANOVA and Student-Newman-Keuls multiple range test (Zar, 1984).

Methods: Question 3 - We conducted a larval settlement bioassay using larvae of *M. arenaria* cultured under optimum conditions from the University of Maine aquaculture facility at Machias, NE . Challenge experiments were conducted to assess the ability of post-metamorphic larvae to settle on sediments with high concentrations of lipophilic organic contaminants. Sediment samples were collected from each of the five sites listed in Table II-1. Challenge experiments with discrete sediment and larval samples were conducted according to procedures developed in our laboratory for determining the effects of sediment contamination on metamorphosis and post-settlement survival of bivalve molluscs (Warner et al., 1990).

Sediments were collected at each site, held on ice while transported back to WHOI, and stored at 4°C until tests with larvae were begun. All sediment samples were homogenized and press-sieved through 160 μm mesh (Nytex) prior to being used in the larval tests. Metamorphic competency was assessed by treating part of the larval batch with 0. 1 mM epinephrine (EPI), a metamorphic inducer. EPI solutions were prepared from fresh stock solutions of 0.01 M EPI in 0.05 N HCl diluted 1:80 with antibiotic treated seawater following a modified method described by Coon et al. (1986). Twelve to 24 h after treatment with EPI, the percentage of larvae initiating metamorphosis (i.e., settled or beginning attachment) were estimated by visual inspection. When the majority (>50%) of the larval population appeared competent, bioassays were initiated.

After screening for competency, larvae were retreated with EPI for 12-24 h. Ninety competent larvae were then distributed equally among three replicates per treatment. Approximately 1.0 ml of sieved (160 μm) sediment was placed in each 2.75 ml well of a 24-well Falcon tissue culture dish. The sediment was then covered with approximately 1ml of EPI enriched filtered seawater containing thirty competent larvae and held at 20°C (Phelps and Warner, 1990). After 4 days, the well contents were withdrawn with an automatic pipette and filtered through 160 μm Nytex that retains the larvae. Larvae were placed in fresh seawater and stained with a 0.1% aqueous solution of neutral red (1:100 v/v in seawater), using a modification of the method by Crippen and Perrier (1974). After 2 h the larvae were rinsed in tap water then preserved in a buffered formalin solution [2:4:100 formalin (100%): sodium acetate-acetic acid (equimolar): distilled water]. Preserved larvae were then stored at 4°C for a minimum of 6 hours before counting. Live, dead, moribund, and metamorphosed larvae were scored under a dissecting scope. Larvae that stained a deep red were classified as live, whereas those that stained faint pink or colorless were considered moribund and dead, respectively. The moribund and dead larvae were combined to compute percent mortality. The metamorphosis and mortality data from all bioassays were arc sine transformed prior to being analyzed by one-way ANOVA and Student-Newman-Keuls multiple range test (Zar, 1984). The larval clam settlement bioassay was conducted on sediment samples collected from the five experimental field sites. To ensure adequate control, the sediment bioassay was also conducted using a control sediment of washed microbeads graded to the same size range as the experimental sediments. In addition a second control of no sediment was evaluated as a part of the bioassay protocol.

Methods: Question 4 - Population level effects of contaminant stress were evaluated using a matrix population model. The matrix population model can be thought of as an analytical tool that combines individual vital rate data into information about the population as a whole. If we assume that potential biochemical, cellular, and physiological changes associated with contaminant exposure are manifested in changes at the organismal level, namely in fecundity, survival, and growth, we can say that the matrix model integrates these factors and addresses their combined effect at the population level.

The matrix population model was constructed by dividing the population into categories that correspond to changes in vital rates over the life span of the animal, and writing a set of linear equations that describes how many clams will move between these categories in a given time step (Figure II-1). We grouped the clams into size-classes, since important life history traits such as predation pressure and fecundity are size-specific, and because size is more easily measured than age. Survival, transtions between size classes through growth, and contributions to the smallest size class via reproduction were measured to parameterize the projection matrix. The projection matrix, **A**, is shorthand notation for the set of linear equations which constitute the model. Each element, aij (the matrix element in the i^{th} row and j^{th} column of **A**), of the projection matrix represents contributions from class *j* to class *i* over one time step.

Adult Growth and Survival - Adult growth and survival parameters were estimated over three-month time periods, since these rates are known to change seasonally (Brousseau, 1978, 1979). We obtained such estimates at each of the study sites in a mark-recapture study. In March 1995 we collected enough clams at each site to obtain 20 in each of five size classes: 1 = < 40 mm; 2 = 40-49.9 mm; 3 = 50-59.9 mm; 4 = 60-69.9 mm: and 5 = > 70 mm. We measured valve lengths and numbered both valves in permanent ink. At this time, clams at all sites were numbered from one to one hundred. Clams (two from each size class per bag) were then poked into the mud in sediment-filled mesh onion bags, which were located in the intertidal zone (Figure II-1). The location of the clams is marked by the bags and it is easy to retrieve the clams by digging up the whole bag and sorting the clams from the sediment. Predators are not excluded by the bags, and the clams were deployed in their normal orientation and at densities (10 clams/0.0125 m^3 sediment) not outside the range found in natural clam beds (see Table II-5). This protocol was developed by us in previous studies (Weinberg et al., 1996).

At three-month intervals, the bags were dug up and growth and mortality rates determined by noting the numbers and valve lengths of the clams found alive or dead. At each sampling date enough new clams were collected and randomly mixed with the surviving clams to bring the total number deployed to approximately one hundred. New numbers were used to label the clams at each time, so that they were not confused with survivors from the previous time period (i.e. clams first deployed in June were numbered starting with 101; those first deployed in September were numbered starting with 200; and those first deployed in December were numbered starting with 300). Clams were then replaced in sediment-filled bags. In March 1996, bags were dug up for the last time. An additional set of ten bags was deployed at each site in March 1995 and not removed until March 1996.

There were clams missing from the bags most of the times we checked them, and on occasion entire bags were missing (including all winter bags in Saugus). Missing clams were most probably either washed out of bags after they had died, or were removed by predators. We found some of the valves near the bags on the surface of the sediment, so we know that some of the missing clams were dead. They cannot all be dead, however, because preliminary modelling results suggested that if this were the case, the probability of finding larger clams would be substantially lower than the frequency with which we do find them in the field. Due to this uncertainty over the fate of missing clams, we based calculation of matrix parameters only on the clams that were found.

Matrix elements were calculated for each size class and season for each site. The probabilities of surviving and staying in the same size class (the a_{ij} where $i = j$) are termed P_i, and were calculated:

> P_i = the number of clams in size class i at season s that were found alive and in size class i at season $s+1$, divided by the total number of clams in size class i at season s that were found (alive or dead) at season $s+1$.

The probabilities of surviving and growing to the next size class (the a_{ij} where $i /= j$ and $i /= 1$) are called $G_{i,j}$. These parameters were calculated:

> $G_{i,j}$ = the number of clams at size class i at season s that were found alive in size class j at $s+1$, divided by the total number of clams in size class i at season s that were found(alive or dead) at season $s+1$. (Parameters associated with classes A, B, and C are discussed with recruitment in the next section.)

Recruitment, Population Structure, and Clam Density - Reproductive contributions in matrix models (a_{ij} where i=1) are usually denoted F_i and are estimated as fecundity multiplied by the probablity that the offspring survive to the next model time step. This method is problematic for soft shell clams and other marine invertebrates that have planktonic larvae, because we know so little about transport patterns and survival during both the planktonic period and early post-settlement life. It is easy to estimate fecundity from gonad sections, but not easy to estimate larval survival. Matrix models have actually been used to estimate larval survival (Brousseau et al., 1982; Vaughan and Saila, 1976), but these models cannot also be used to obtain a population growth rate because it is necessary to assign a value of 1 to calculate larval survival.

In this study, we defined recruits as clams that had settled and survived at the study site to age one year. The ratio of recruits to adults, r, is used in the model as the basis of the reproductive contribution parameter. This method avoids the problem of not being able to quantify larval survival because it matches the time scale over which we can keep track of the juvenile clams. The parameter used here is noted R_i to emphasize this different method of estimation. R_i are calculated:

$$R_i = 0.5\ r\ M_i$$

where M_i is the proportion of population reproductive output contributed by size class *i*. This was calculated as the mean fecundity of females in class *i*, divided by the sum of mean fecundities over all size classes (values of M_i are in Table II-4). Using this factor maintains the population structure of the model. Recruitment is multiplied by 0.5 to count only females. (The sex ratio of *M. arenaria* populations is 1:1.) This method assumes that offspring from all clams have equal survival probabilities, and that the population that actually spawned the settling juveniles (not necessarily the one at the study site) has the same size structure as the study population.

Reproduction was incorporated into the model during the appropriate seasons. According to results of this study, (see Results--Question 1 and 2) clams in Barnstable Harbor and Wellfleet Harbor spawned throughout the spring and summer, while clams from the Boston area sites reproduced during a short period of time in late summer. This information was incorporated into the model by having reproduction occur during spring and summer for Barnstable and Wellfleet, and only during the summer at the Boston sites. $R_i = 0$ in seasons where reproduction is not occurring.

Stages A, B, and C are an innovation that we used in this model to align the difference in time scales between the growth and survival parameters (three months) and the recruitment parameters (one year). After clams reproduce in this model, the offspring experience a year's mortality in the three months to the next model time step. To keep them from experiencing further mortality, and to assure that the one-year old clams appear in class one at one year from birth, they move through each of the dummy stages A, B, and C with probability one.

Data collection for estimating recruitment took two steps. First, the size-range of one-year old clams was estimated by measuring > 200 clams, dug in August 1995, from Barnstable Harbor, known to have set on a flat with no other clams on it about one year prior to sampling (pers. com., Tom

Marchotti, Barnstable Shellfish Biologist). These clams ranged in size from 17 to 40 mm, with a mean of 26.49 +/- 3.98. The upper limit of this range fell so closely to the size class cut-off of 40 mm that clams less than that size were assumed to be one year old or less. This assumption probably underestimates recruitment in Barnstable Harbor, since clams that settled in the spring will be larger than this size, but overestimates recruitment at the other sites since those clams grow more slowly.

The second part of the field work was to measure recruitment. Recruitment and clam densitites in the field were measured at each site in ten replicate 30 cm across x 30 cm deep cores by measuring and counting the clams. Cores were taken randomly in areas where clams were present, as evidenced by their siphon holes at the sediment surface. All cores were taken in September 1995, about one year from the last spawning event of the previous year. Clams were sorted from the sediment, measured, and counted. The ratio of clams less than 40 mm to those larger than 40 mm (r) was calculated for each site.

Analysis of Model - Parameters for seasonal matrices at each site were calculated as described above. Seasonal matrices, $\mathbf{A}_S$, were multiplied together in sequence ($\mathbf{A}_{WINTER} \times \mathbf{A}_{FALL} \times \mathbf{A}_{SUMMER} \times \mathbf{A}_{SPRING}$) to yield an annual projection matrix, **A**. As it turned out, larger clams were growing fast enough to grow between all size classes only at Barnstable (see Figure II-15). This caused the annual matrices at the other sites to be reducible, that is, it was not possible to move into some stages. Irreducibility is required for all of the properties of eigenvalues and eignevectors described by the Perron-Frobenius theorem and the subsequent analysis of the model to hold (Caswell, 1989a).

To remedy this problem, the data were regrouped into a set of size classes that were narrower in width as the clams got larger: 1′ = <40 mm; 2′ = 40-54.9 mm; 3′ = 55-59.9 mm; 4′= 60-64.9 mm; and 5′ = >65 mm. This change caused there to be fewer clams starting in size classes 3′ and 4′í than in 3 and 4, so although the new size classes did not make Saugus, Quincy-Neponset, or Fort Point Channel matrices reducibile, there were insufficient data to subdivide the classes further. Saugus and Quincy-Neponset annual matrices were made reducible by adding 0.01 (an arbitrarily chosen small value) to the zero-valued $G_{3,4}$ parameter in the summer matrix. The data set for Fort Point Channel clams in the fall contained two animals found alive, so the problem with this matrix was a simple lack of data. Zero-valued parameters P_3, P_4, $G_{3,4}$, and $G_{4,5}$ had to be replaced with 0.01 to make the annual matrix reducible. Before the size-classes were recalculated, more than ten seasonal parameters had to be replaced with 0.01 to make all the annual matrices reducible, but using the new classes succeeded in reducing this number to six.

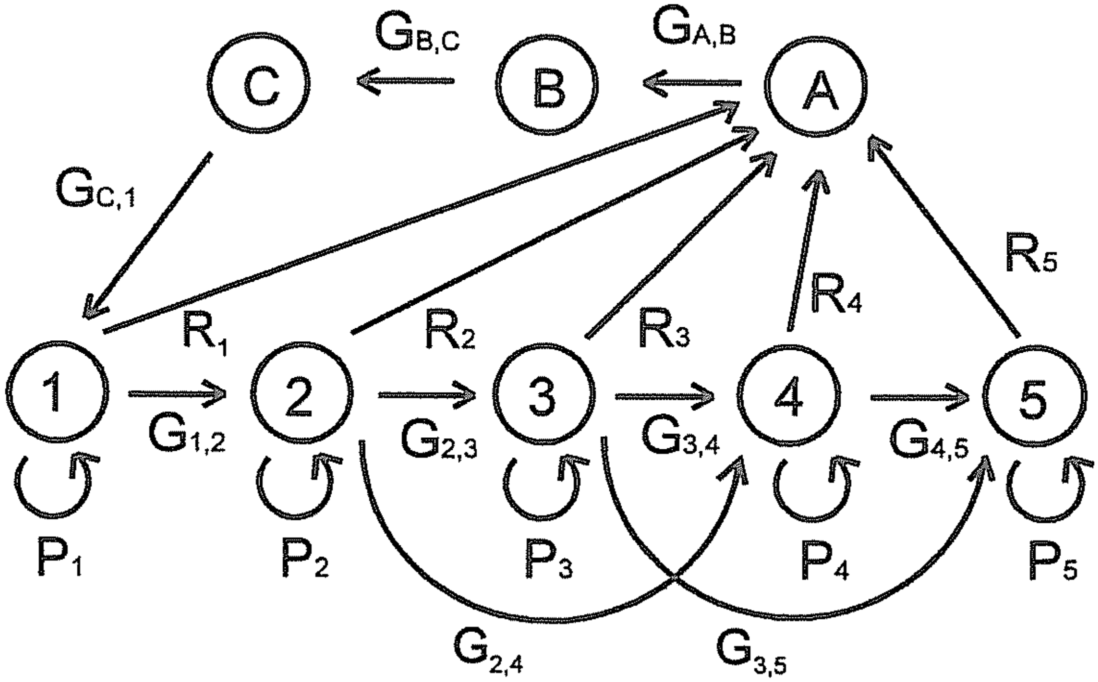
The dominant eigenvalue of **A**, λ, is the population growth rate. Population growth rates were calculated according to Caswell (1989a). Since recruitment rates are known to be variable (Goshima, 1982), some investigation of how large changes (rather than the small ones implicit in analytical sensitivity analysis) in the recruitment parameter might affect the population growth rate was desirable. This was tested numerically by calculating population growth rates using the geometric mean of recruitment over all sites to compare to that calculated with the measured site-specific recruitment rates.

c. Results and Discussion

Qusetions 1 and 2 - Clams collected at each of the sites in Massachusetts and Cape Cod Bays reflect differences in body burdens of lipohilic organic contaminants indicative of sediment contamination at each site (see detailed discussion in Part I). Samples taken during the post-spawning season reflect slight decreases in Total PCBs but no differences in other contaminant classes. Changes in condition index and the digestive gland-gonad index for each clam population at the various sampling periods reflect seasonal differences in the reproductive cycle with the highest values being detected prior to spawning (Figure II-3). There is a significant interactive effect of sampling season and site and all stations in the upper Massachusetts Bay (Saugus, Neponset River, and Fort Point Channel) have siginficantly lower ($p=0.001$) values for all sampling periods (Figure II-4). Similar trends were observed in various estimates of the physiological condition of the digestive gland-gonad complex, including the digestive gland-gonad index, dry weight of the digestive gland-gonad complex, and the lipid weight of the digestive gland-gonad complex. All three parameters reflect the changes in the digestive gland-gonad complex during the reproductive cycle (Figures II-5, II-6, and II-7).

Table II-2. Contaminant Concentrations (ng/g dry weight) in Clams Collected at Each Site in Massachusetts and Cape Cod Bays

Site	Total PAH	Total PCB	Total DDT	Total LAB
Pre-Spawning				
Barnstable H.	300	11.5	9.1	80
Wellfleet	367	14.7	0.4	360
Saugus	5,110	91.1	20.6	910
Neponset R.	1,900	130.5	14.4	1,680
Fort Point Ch.	7,370	56.7	14.4	8,400
Post-Spawning				
Barnstable H.	271	5.3	4.4	78
Wellfleet	319	6.5	0.4	108
Saugus	4,600	56.9	21.1	729
Neponset R.	1,700	81.8	18.9	2,200
Fort Point Ch.	7,320	39.1	18.5	8,200



$$
A_s = \begin{vmatrix}
- & & & R_1 & R_2 & R_3 & R_4 & R_5 \\
G_{A,B} & - & & & & & & \\
 & G_{B,C} & - & & & & & \\
 & & G_{C,1} & P_1 & & & & \\
 & & & G_{1,2} & P_2 & & & \\
 & & & & G_{2,3} & P_3 & & \\
 & & & & G_{2,4} & G_{3,4} & P_4 & \\
 & & & & & G_{3,5} & G_{4,5} & P_5
\end{vmatrix}
$$

Figure II-1. Life Cycle Graph and Projection Matrix: The circles represent size classes and the arrows represent transitions possible between them over one time step. The parameters of these transitions appear in the projection matrix $\mathbf{A}_s$. Parameters in normal text of $\mathbf{A}_s$ are shown in Table B5 (seasonal matrices, Appendix)

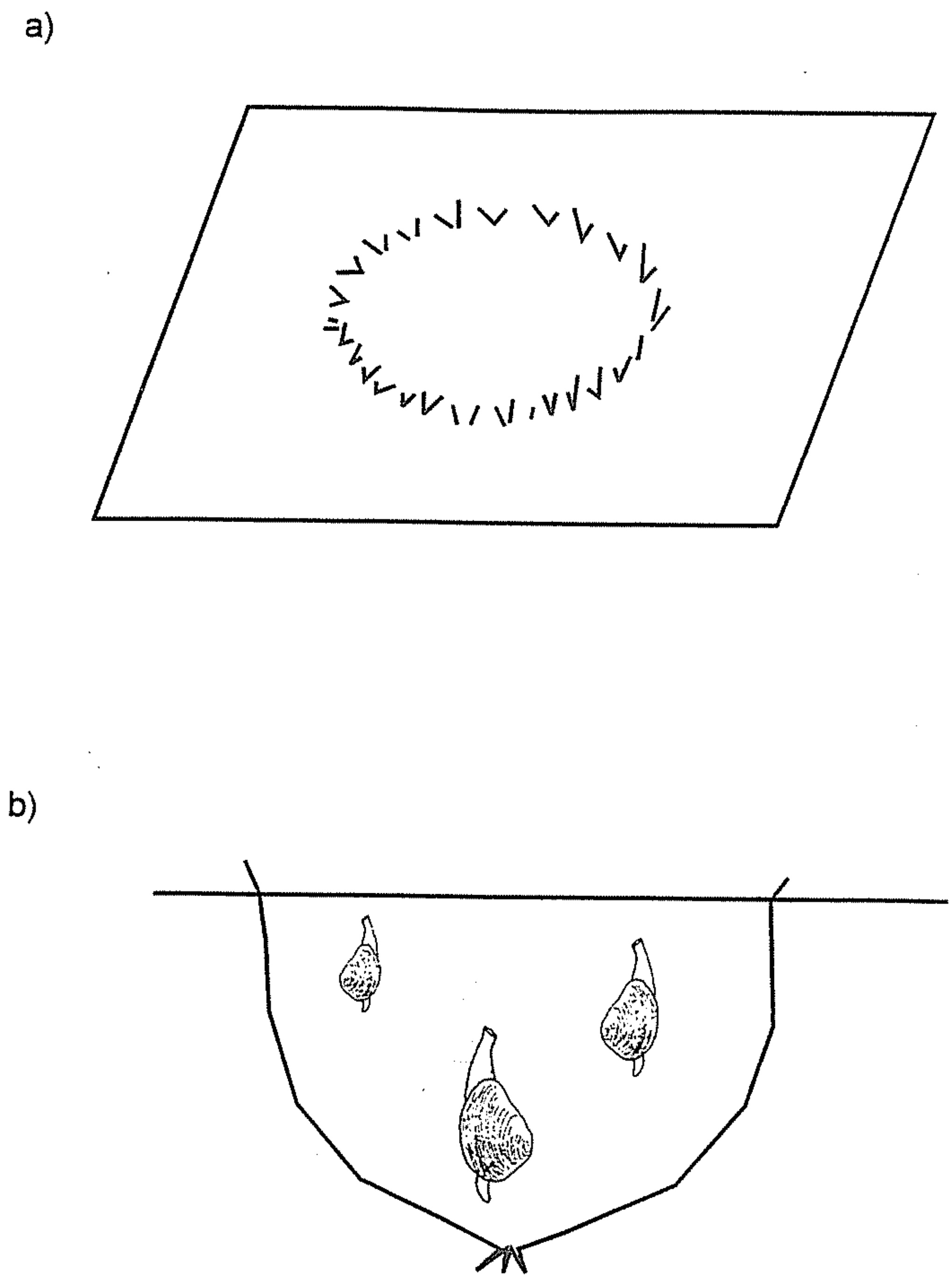


Figure II-2 Schematic of Mesh Bag Used for Adult Clam Growth and Survival Data Collection. a) View of area in which a mesh bag is situated; tips of bag are apparent, projecting above the sediment surface. b) Cross-section through center of bag in situ, showing the position of clams in relation to bag and surrounding sediment.

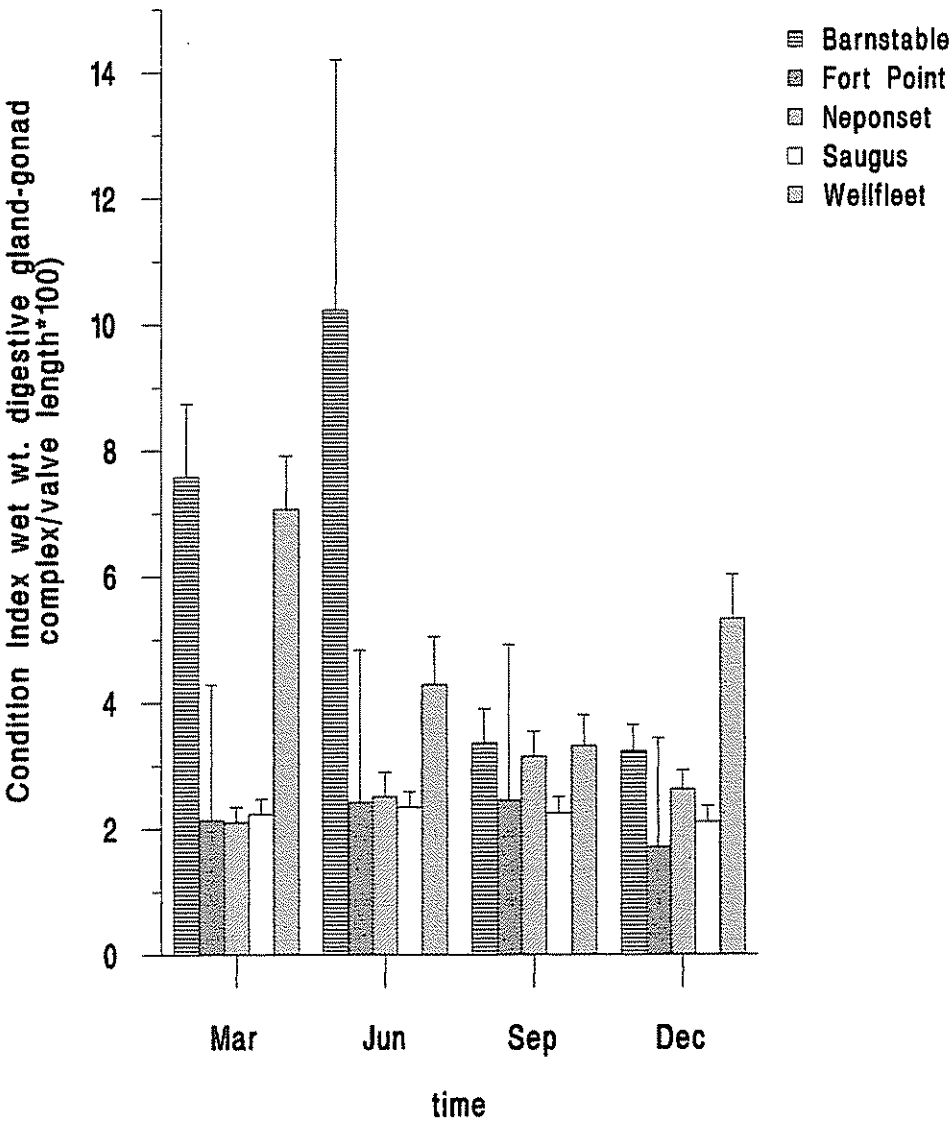


Figure II-3. Condition Index (wet weight of the digestive gland-gonad complex/valve length mm * 100) of Soft Shell Clams from Each Site During Each Sampling Period; each bar represents the mean of 25 replicates ± 1 S.E.

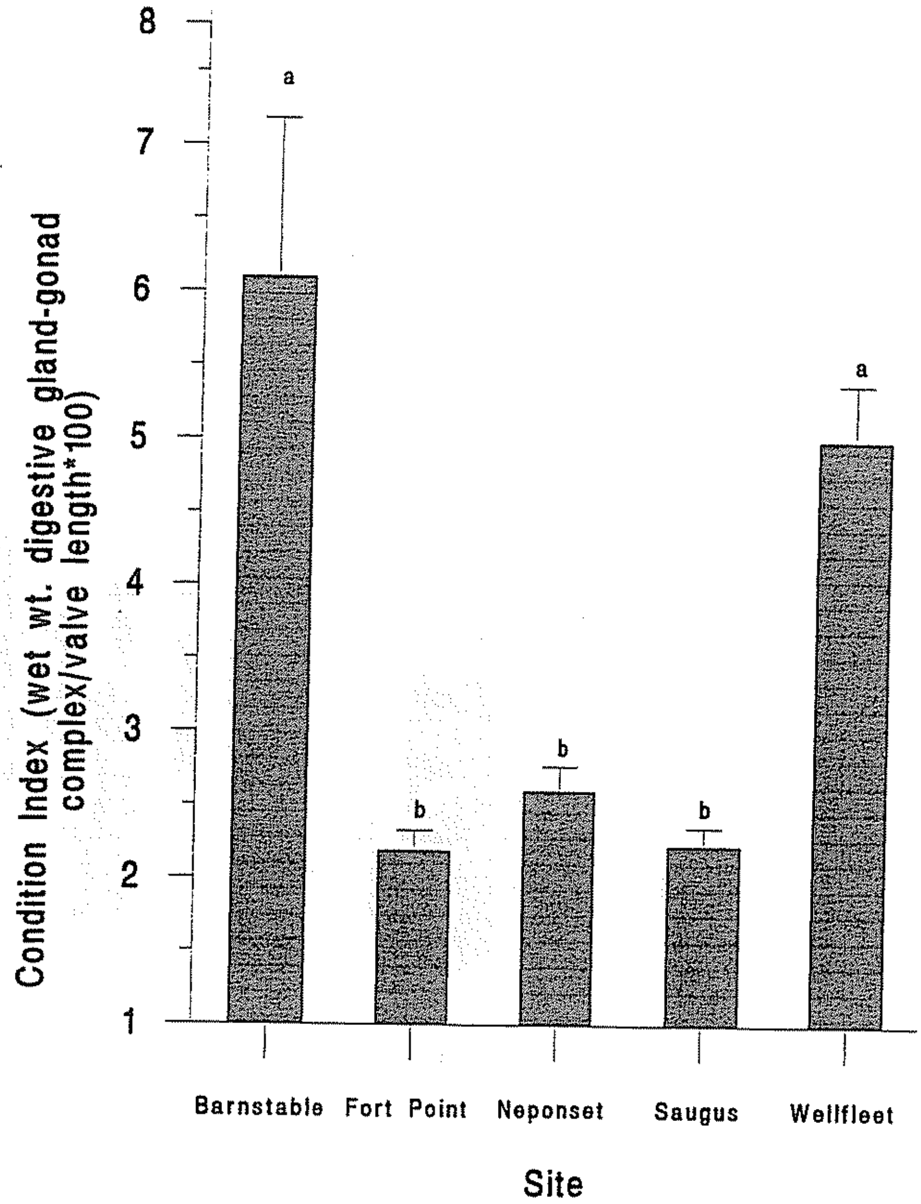


Figure II-4. Mean of All Measurements of Condition Index of Soft Shell Clams at Each Site for All Seasons; significant differences determined by two-way analysis of variance, letter denotes differences.

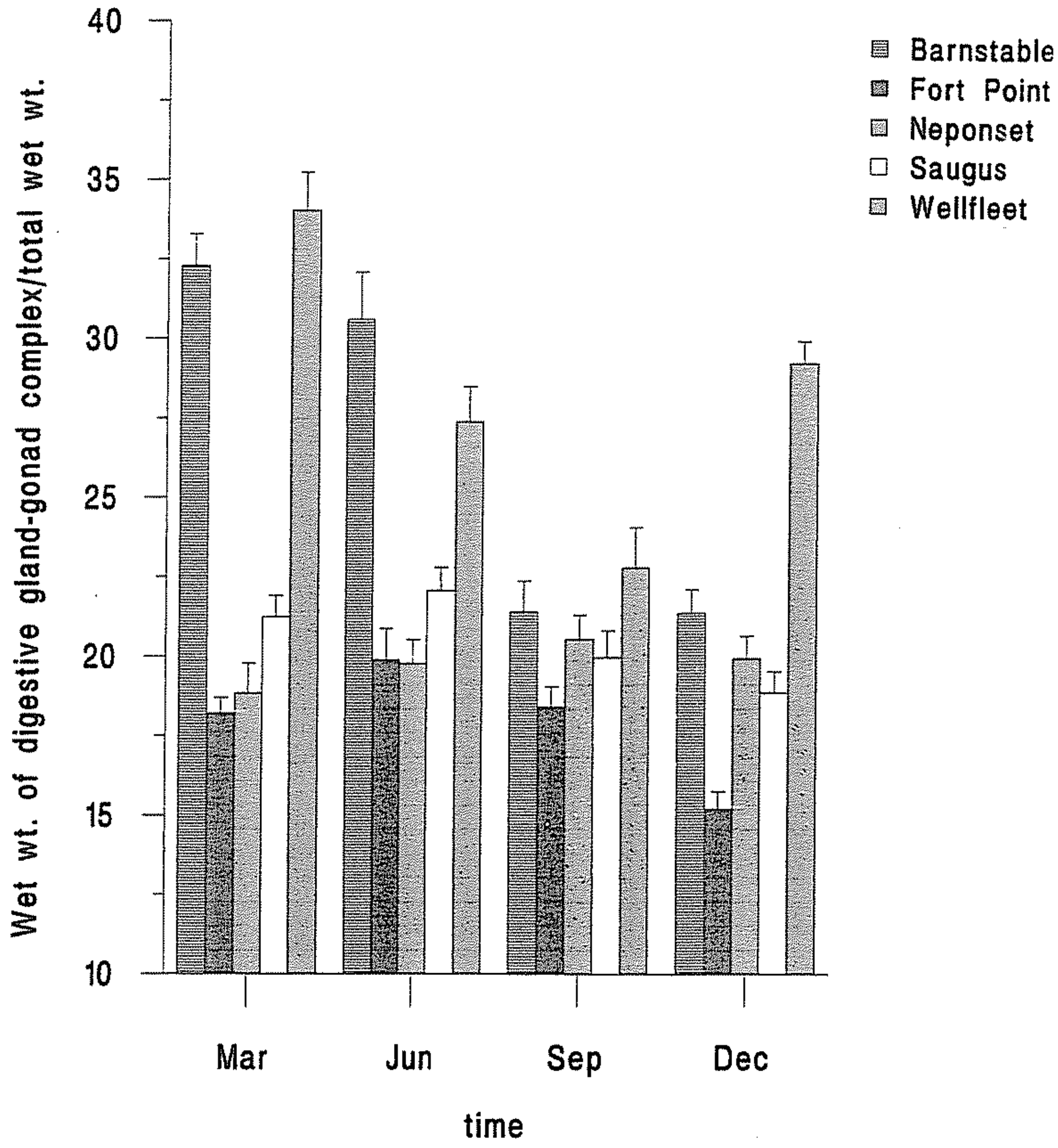


Figure II-5. Digestive Gland - Gonad Index of Soft Shell Clams (wet weight of digestive gland-gonad complex/wet weight of all soft tissues * 100) from Each Site During Each Sampling Period; each bar represents the mean of 25 replicates ± 1 S.E.

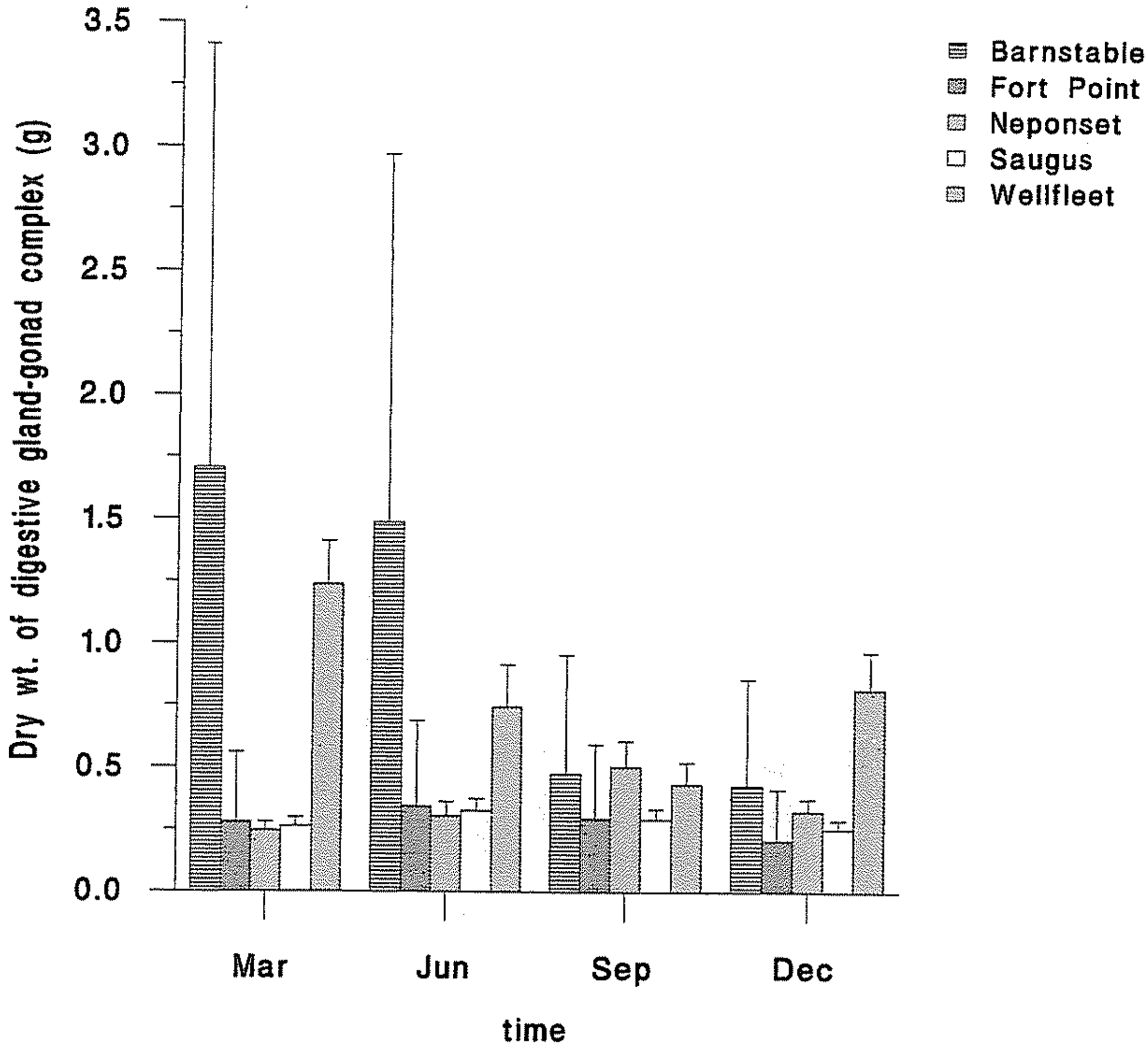


Figure II-6. Dry Weight of the Digestive Gland-Gonad Complex of Soft Shell Clams from Each Site During Each Sampling Period; each bar represents the mean of 25 replicates ± 1 S.E.

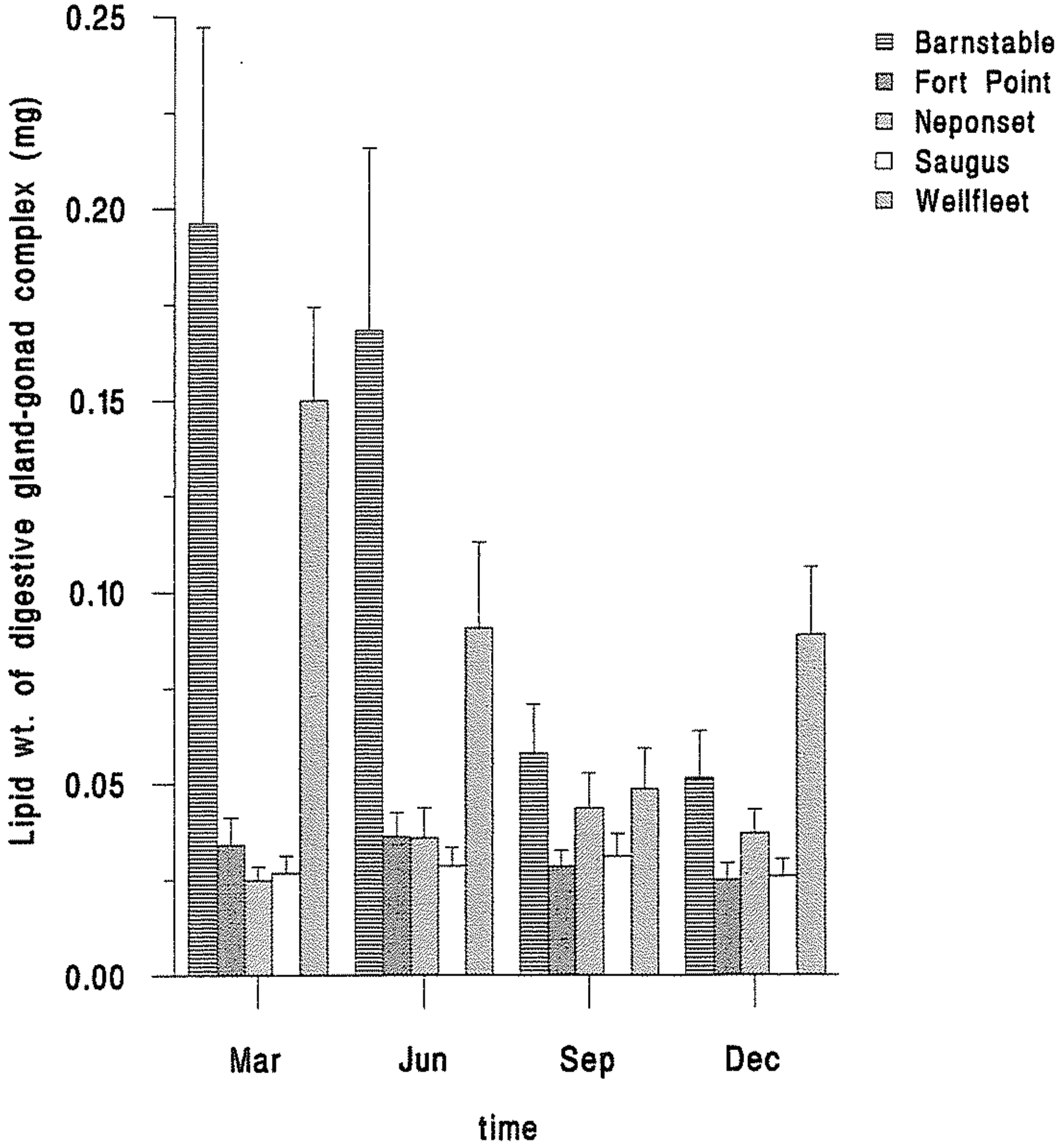


Figure II-7. Lipid Weight of the Digestive Gland-Gonad Complex of Soft Shell Clams from Each Site During Each Sampling Period; each bar represents the mean of 25 replicates ± 1 S.E.

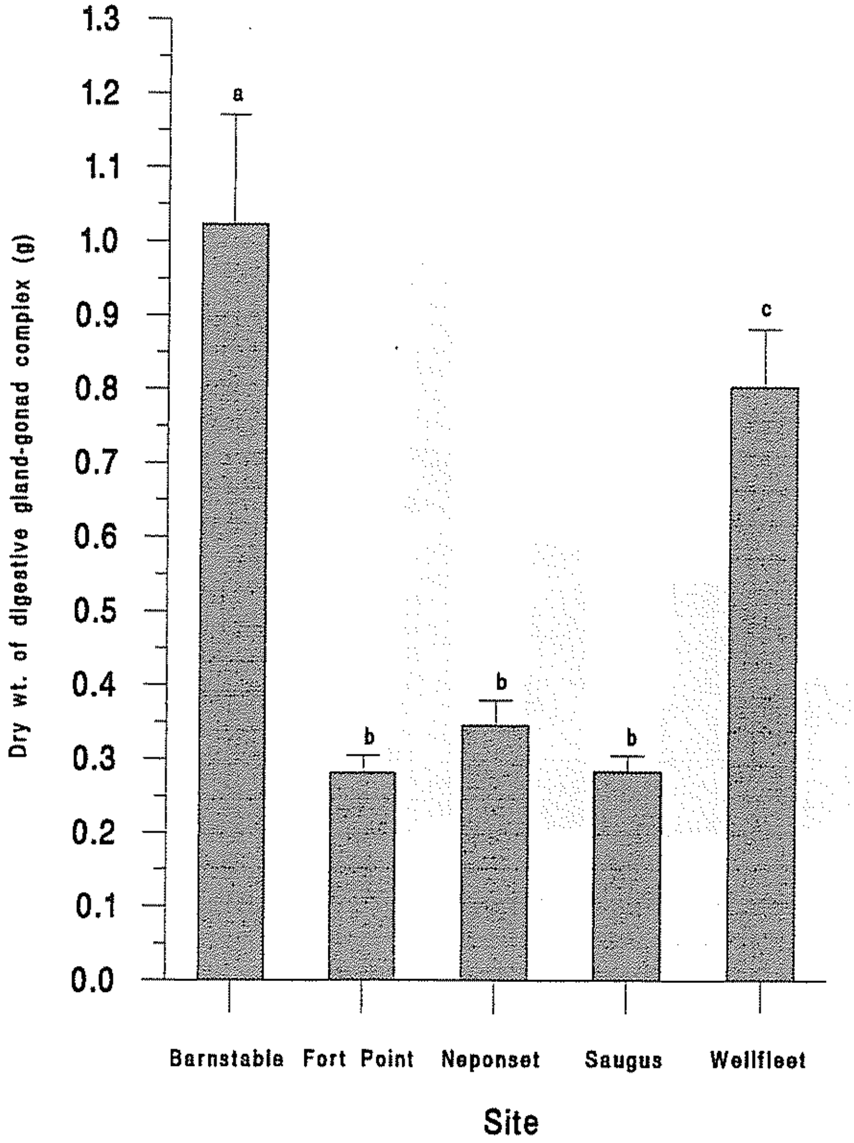


Figure II-8. Mean of All Measurements of Dry Weight of the Digestive Gland-Gonad Complex of Soft Shell Clams from Each Site for All Seasons; significant differences determined by two-way analysis of variance, letter denotes differences.

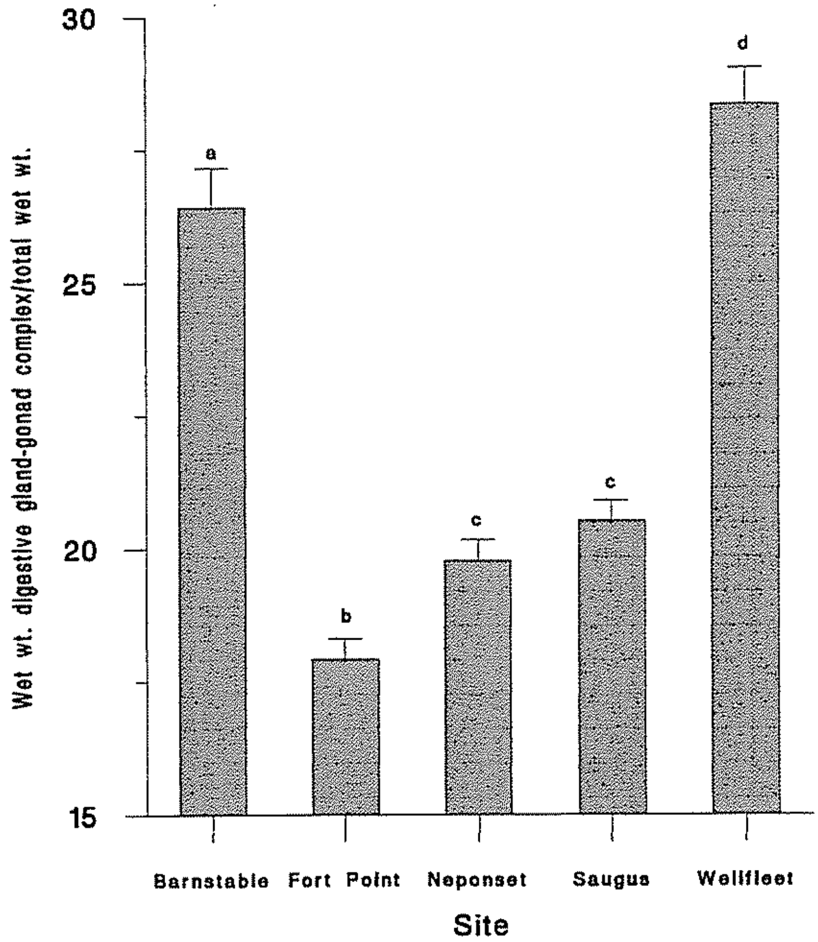


Figure II-9. Mean of All Measurements of Digestive Gland - Gonad Index of Soft Shell Clams from Each Site for All Seasons; significant differences determined by two-way analysis of variance, letter denotes differences.

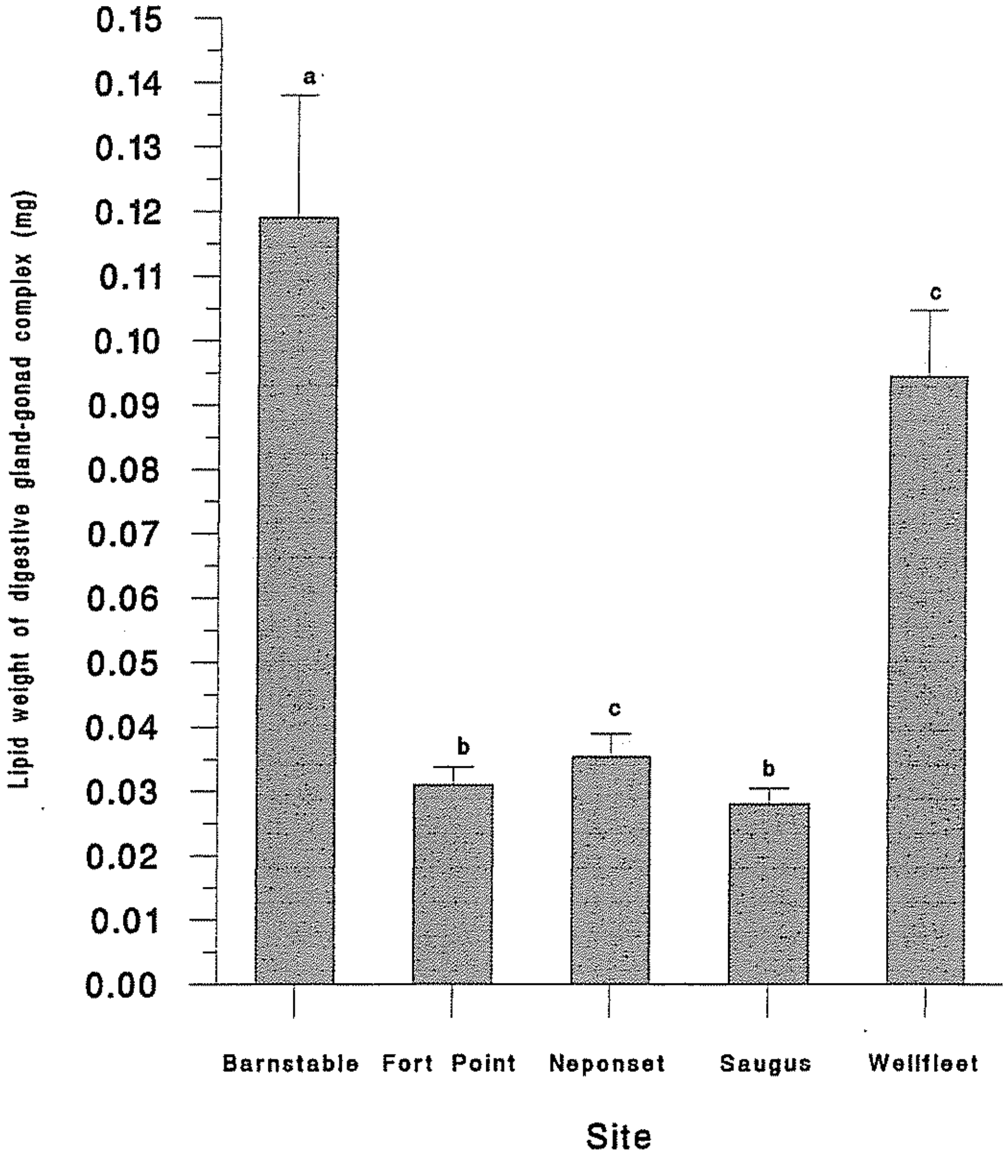


Figure II-10. Mean of All Lipid Measurements of Digestive Gland - Gonad Complex of Soft Shell Clams from Each Site for All Seasons; significant differences determined by two-way analysis of variance, letter denotes differences.

those reported by Capuzzo et al. (1989) for transplanted mussels (*Mytilus edulis*) in New Bedford Harbor where reduced condition indices and lipid accumulation correlated with reduced reproductive effort. Summary tables of all values are presented in Tables B1-B3 (Appendix).

The prevalences of hematopoietic neoplasia (Hn) and gonadal inflammation (cell proliferation) were significantly different ($p<0.001$) among clam populations from the various sampling sites with the highest values for Hn being detected at the Fort Point Channel site (100%) during the December sampling and the highest levels of gonadal inflammation being detected at the three upper Massachusetts Bay sites (Figures II-11, II-12 and II-13) in the late fall to early winter (September to December). Barnstable Harbor had the second highest level of hematopoietic neoplasia (27.3%) among the five sites; prevsalence at other sites were as follows: Wellfleet Harbor 0%, Saugus River 8.7%, and Neponset River 16.7%.

The reproductive cycle of clam populations from the five sites are depicted in Figure II-14. Both female and male clams from Barnstable Harbor and Wellfleet showed evidence of advanced stages of gamete development and spawning during the late spring through early fall. The large relative size of the digestive gland-gonad complex and accumulated lipid provided sufficient energy for this extended reproductive season. Populations from the upper Massachusetts Bay sites (Fort Point Channel, Saugus and Neponset River) did not show evidence of spawning until mid-summer and spawning occurred for only a short period of time. There did not appear to be any asynchrony between males and females at any of the five sites with respect to maturation and release of gametes. Although there were significant differences in the duration of the spawning season, there were no significant differences among the five sites in the relative contribution of each size class to the total reproductive output for each population (Table II-3). Pooled data from all populations demonstrated the relative trends depicted in Table II-3. Detailed analysis of the relative contribution of different size classes to the total reproductive output was conducted for clam populations at Neponset River and Barnstable Harbor during the summer of 1996 (D. Krakower, Woods Hole Oceanographic Institution, unpublished manuscript). There was a significant linear relationship between fecundity and body size of females with total egg output ranfing from 200,000 eggs per female for animals < 40 mm to 20 million egg per female for animals > 80 mm. No signifcant differences in the relative contribution of each size class to total reproductive output was detected between the two sites. However, significant differences in lipid content of the digestive gland-gonad complex among the various size classes were signifcantly different between the two sites, resulting in less lipid per egg being detected among clams from the Neponset River site.

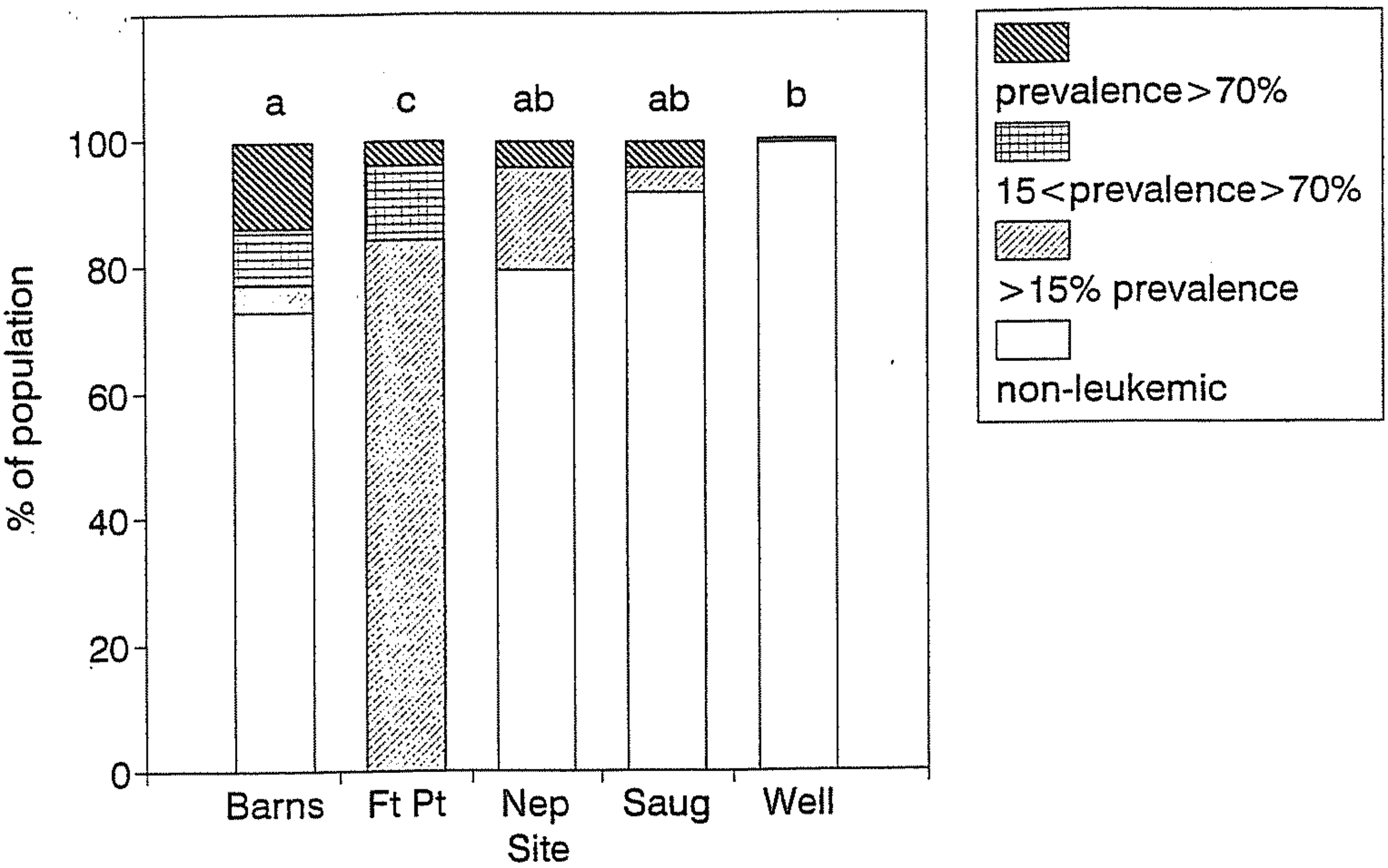


Figure II-11. Prevalence of Hematopoietic Neoplasia in Soft Shell Clams from Each Site.

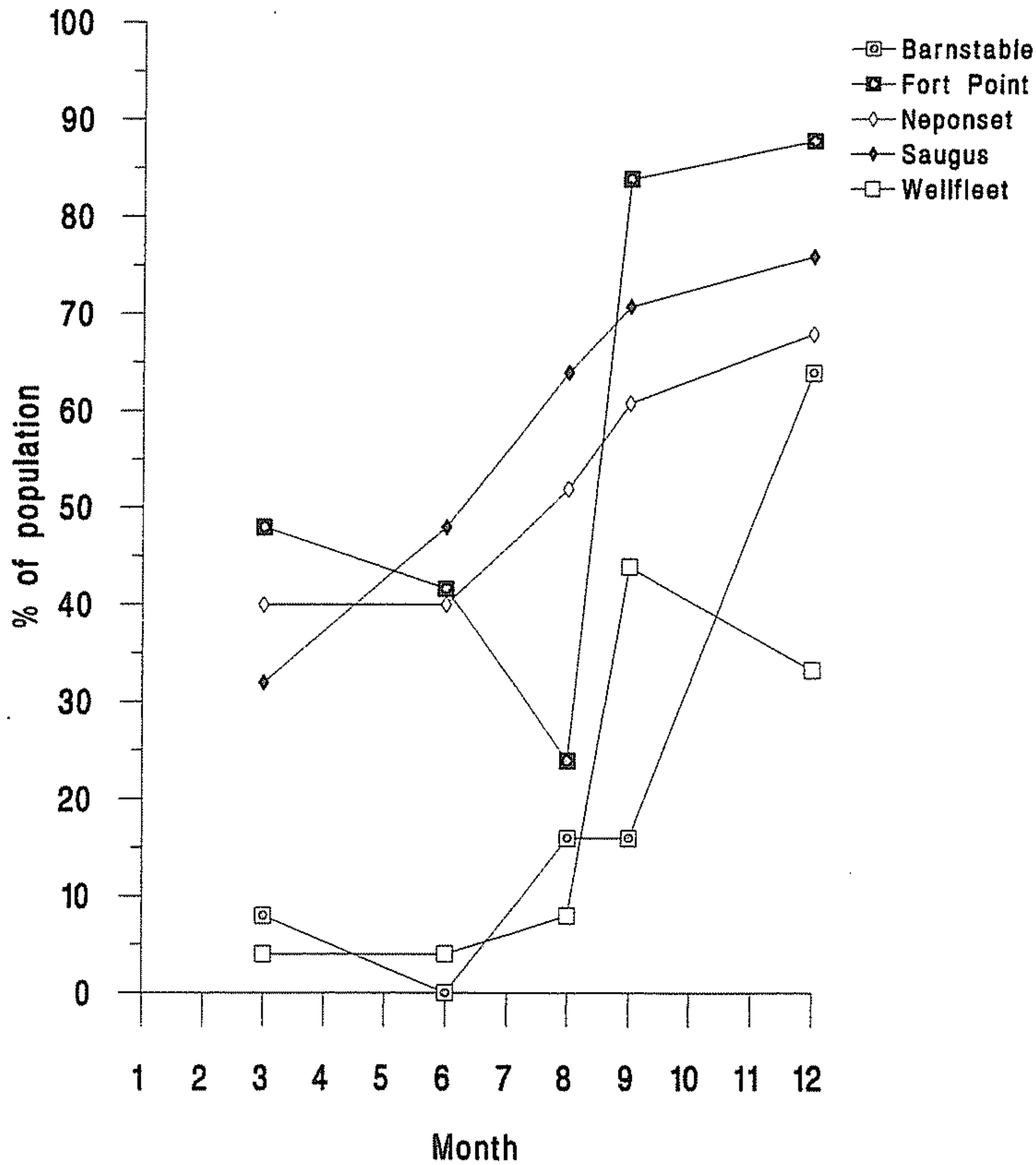


Figure II-12. Prevalence of Gonadal Inflammation in Soft Shell Clams from Each Site.

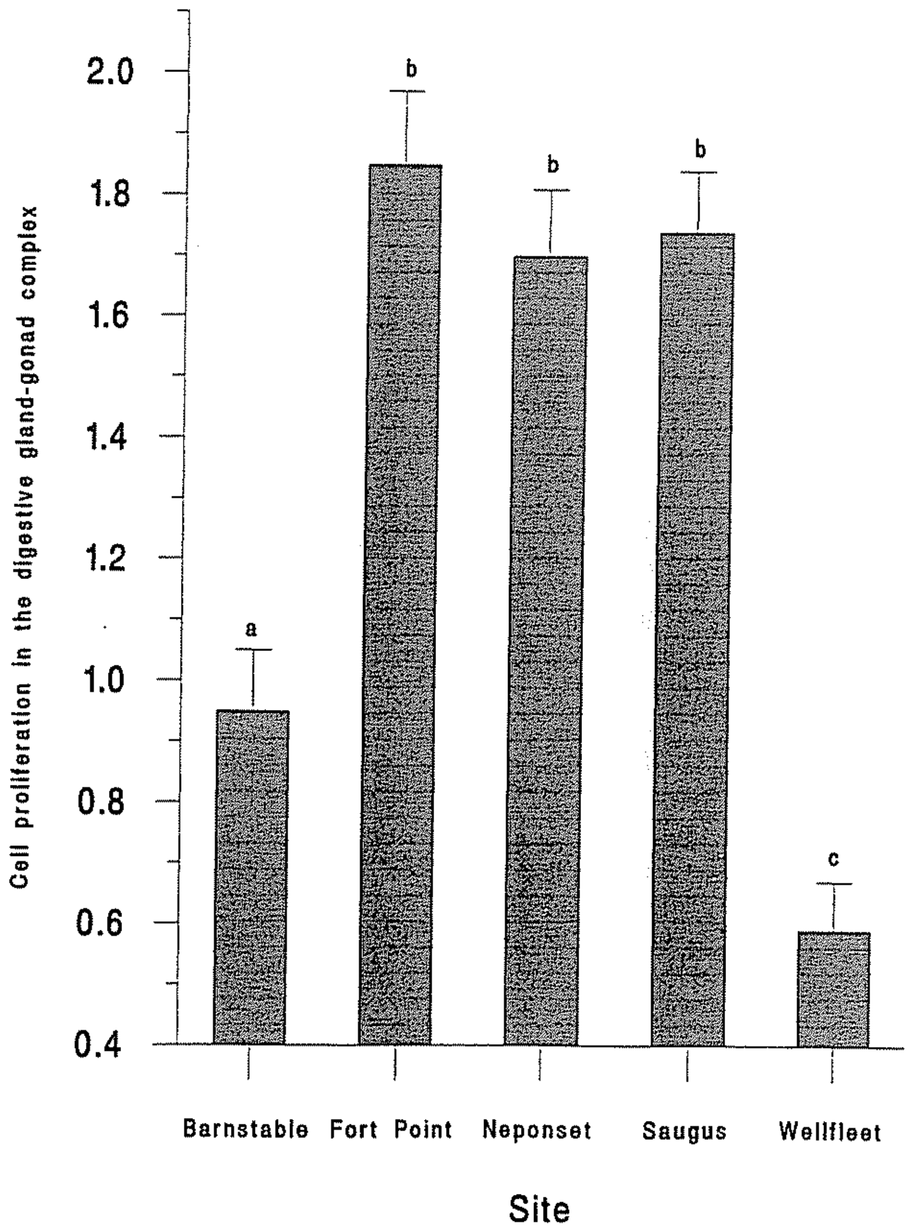


Figure II-13. Mean Values for Index of Gonadal Inflammation at Each Site for Each Sampling Period, based on the numerical criteria: 0-no inflammation, 1-slight, 2-moderate, 3-heavy, invasion of follicles, 4-gonad impaired; significant differences determined by two-way analysis of variance, letter denotes differences.

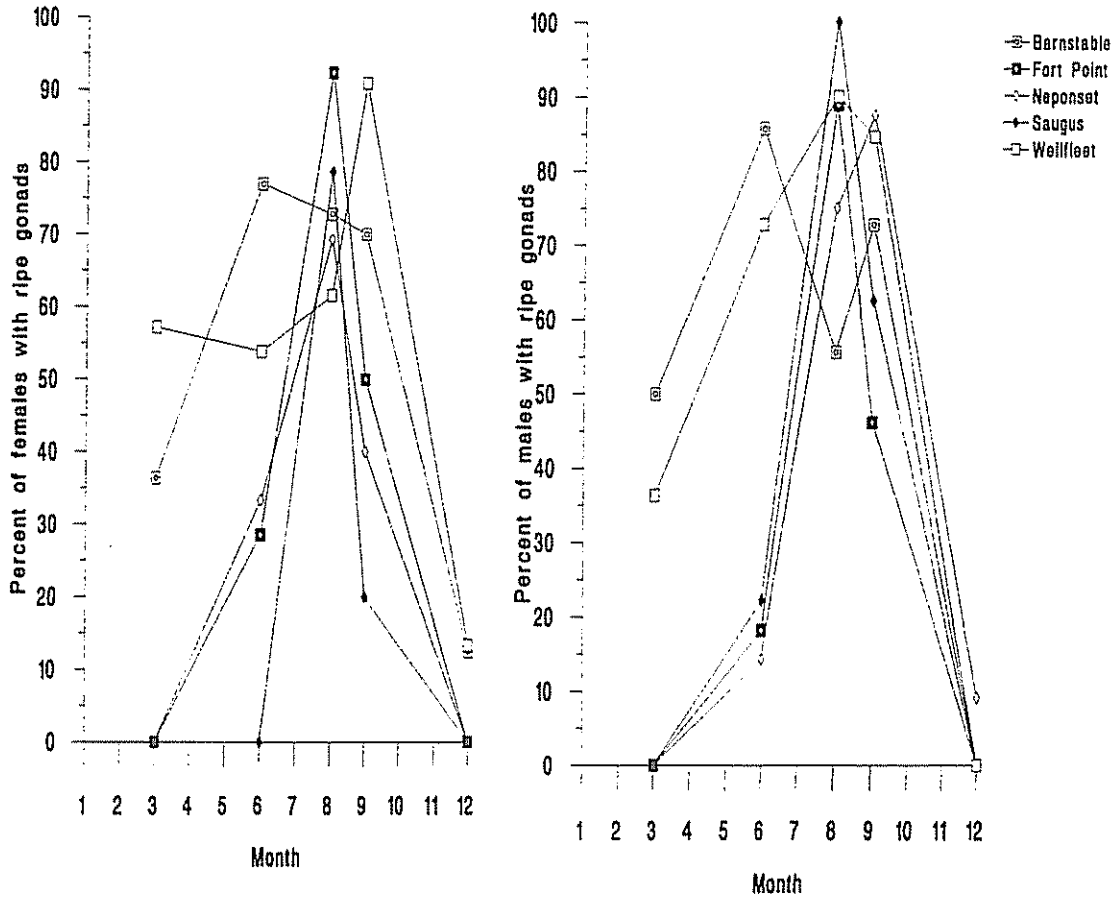


Figure II-14. Reproductive Cycle of Soft Shell Clams from Each Site: (A) Females, (B) Males; each point represents the percentage of 25 animals collected each month that exhibited ripe or spawning gonads.

differences in the relative contribution of each size class to total reproductive output was detected between the two sites. However, significant differences in lipid content of the digestive gland-gonad complex among the various size classes were significantly different between the two sites, resulting in less lipid per egg being detected among clams from the Neponset River site.

Table II-3. Relative Contribution of Females Soft Shell Clams in Various Size Classes to Total Egg Output

Size Class	% of Total
<40 mm	3
40-49 mm	8
50-59 mm	12
60-69 mm	27
>70 mm	52

Question 3 - The results of the clam settlement bioassay are presented in Figure II-15. The filtered seawater control had significantly less settlement than any either treatment - 33% of the larvae settled in the filtered seawater treatment compared to 98.2% in the control microbead sediment, indicating that the larvae required a sediment substrate for optimum settlement. Survival was 20-30% higher for larvae exposed to control treatments than for larvae exposed to test sediments. The control microbead sediment had the highest number of settled larvae, but percent settlement was not signficantly different for any of the test sediments with the exception of Wellfleet Harbor, where both high total organic matter (16.8%) and sediment oxygen demand may have contributed to the poor survial and settlement of competent larvae. Sediment grain size distribution for the five field sites are relatively similar with a predominance of fine grained silt-clay sediments. These results suggest that differences in recruitment between sites are not due to any contaminant-caused impairment of larval settlement and metamorphosis.

Question 4 - *Adult Growth and Survival* - Data on clam growth and survival are presented in Appendix Table B6. Growth of marked and recaptured clams occurred at all sites during the spring and summer and also during the fall and winter at Barnstable Harbor (Figure II-17). Growth rates were highest during the spring at Barnstable Harbor and Wellfleet and during the summer at the other three sites. Absolute differences in growth rates between sites could be due to microhabitat differences in food availability or temperature, neither of which were measured continuously in this study. Although clams at Barnstable Harbor tended to grow the fastest, Fort Point Channel clams in the smallest size class grew as fast in the summer, so contaminant exposure cannot be concluded to strongly influence growth rates.

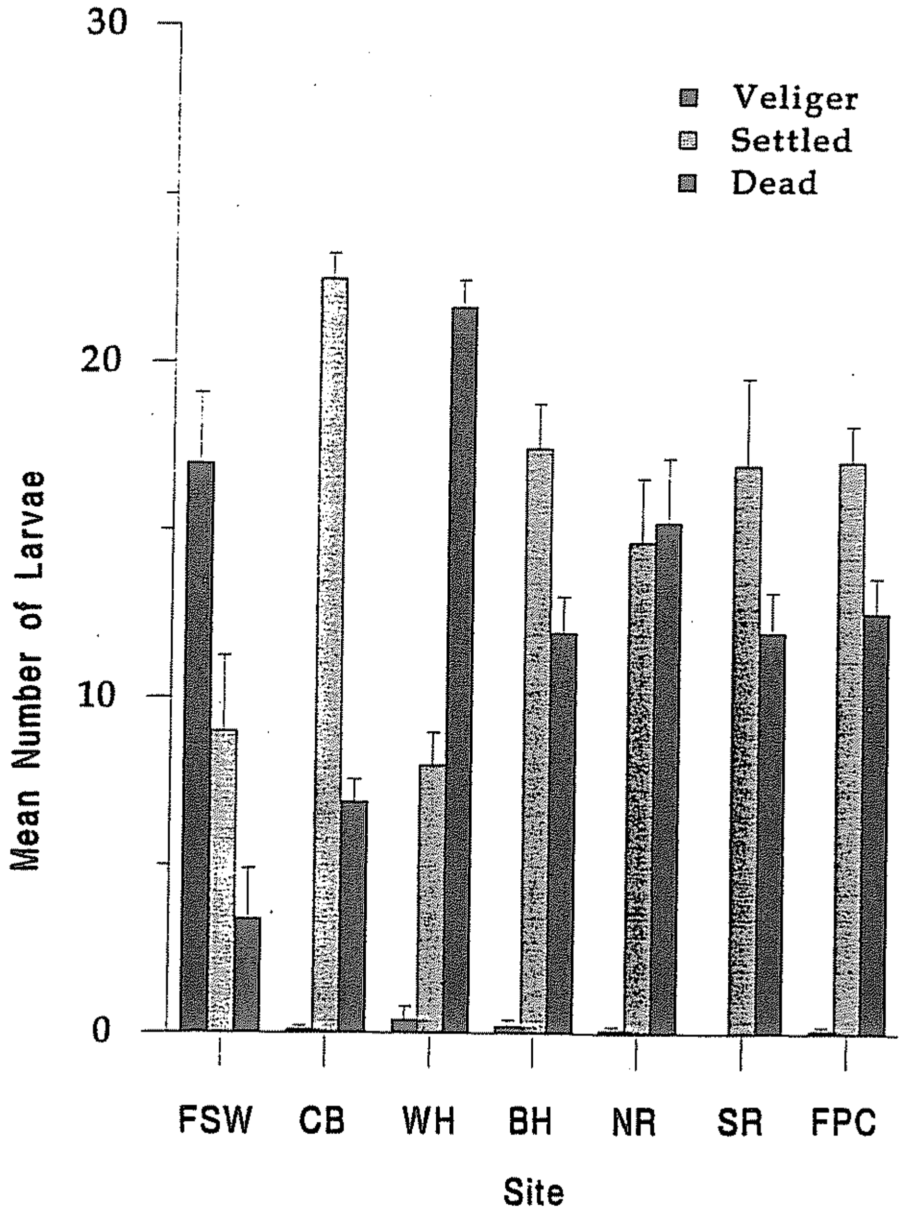


Figure II-15. Per Cent of Larvae that Settled in Sediment Bioassay Conducted with Sediments from Each Site and Control Microbeads (100 μm).

At Barnstable Harbor and Wellfleet, survival was highest during winter and lowest during summer, whereas at Neponset River and Fort Point Channel survival was highest during the spring and summer and lowest during the fall. Survival differences among sites could be due largely to different disease levels, predation rates, and recovery from post-spawning. For example, at Wellfleet 25% of summer mortality was due to moon snail predation. We know this because moon snails leave a characteristic drill hole in the shells of clams that they have eaten. Evidence of moon snail predation was never observed at the contaminated sites, so high population growth rates of clams at Neponset River and Saugus may be attributable to a lower abundance of predators.

Clams at Wellfleet Harbor were also heavily preyed upon by the milky ribbon worm, *Cerebratulus lacteus*, during the spring and summer (pers. com., Paul Sommerville, Wellfleet Shellfish Biologist). This worm appears sporadically in high abundance on clam flats and has been known to eliminate clam populations with low recruitment rates (Rowell and Woo, 1990). Although *C. lacteus* is a characteristic member of the fauna found in contaminated sites in the New York Bight (Chang et. al., 1992), it was not observed at the contaminated sites in this study. Due to the importance of predation in structuring *Mya arenaria* populations, more work is needed on the tolerance of predator species to contaminant exposure.

It is likely that survival and growth of these clams was compromised to some extent by the stress caused by digging them up, drying and handling them, and replacing them in the sediment. The impact of handling on clam survival can be obtained by comparing the number of clams deployed in March 1995 found alive in March 1996 in the four-three month bags and in the year-long bags (Table II-4).

Table II-4. Numbers of Clams Deployed in March 1995 and Found Alive in March 1996 from Four-Three Month and One Year Deployments.

Site	**Three Month Bags**	**One Year Bags**
Barnstable Harbor	4	0
Fort Point Channel	0	4
Neponset River	13	22
Saugus River	17*	41
Wellfleet Harbor	1	4

*This is the number of clams deployed in March 1995 that were alive in December 1995 because at Saugus River, all three month bags were missing in March 1996. This number is thus an overestimate of the number of clams alive in March 1996.

At all sites but Barnstable Harbor, there were more clams alive in the one-year treatments, that had been handled less. One reason for the smaller numbers of clams found in the three month deployments may be that more clams washed out of the bags. The sediments in the bags left undisturbed for a year were more compact and stable than those that had been reworked during sampling three times. Regardless of any handling stress on the clams, they were treated the same at each site, so in making comparisons among these sites we feel that handling stress is not an important factor.

Recruitment and Clam Density - Populations of clams at the five sites showed differing patterns of size-class frequencies (Figure II-16). These patterns are assumed to be due to different settlement and/or post-settlement mortality histories. Densities of clams at each site are listed in Table II-5.

Table II-5. Clam Density at Each Site: Mean Clams Per Core (ca. .021 m^3) and Standard Deviation of Ten Replicates, Sampled in September, 1995.

Site	**Mean Number of Clams**	**Standard Deviation**
Barnstable Harbor	8.9	3.4
Fort Point Channel	7.5	4.2
Quincy-Neponset River	45.2	4.2
Saugus River	15.3	5.6
Wellfleet Harbor	11.0	1.9

Mathematical Model - Parameters for the mathematical model were calculated as noted in the methods section. Since all of the winter season bags were missing at Saugus, presumably due to ice scour, the winter matrix from Quincy-Neponset River was used, since the other seasonal matrices for these two sites were the most similar. Using data from another site to fill in the gap at Saugus is likely to minimize any differences between those two sites.

The annual projection matrices summarize the differences among the various sampling sites more clearly than the seasonal matrices (Tables B4 and B5, Appendix). Matrices with more entries below the diagonal reflect faster growth rates and better survivorship. For example, these matrices show that clam populations at Wellfleet are limited by survival and growth rates are highest at Barnstable Harbor. Survival rates are highest at Neponset River and Saugus. High survival rates seem to be the most important factor in population growth, as shown by the modelling results presented in Table II-6. The Saugus, Neponset, and Fort Point Channel sites (the contaminated sites) have the highest population growth rates, whether λ is calculated from the mean recruitment or the site-specific recruitment. The changes in the matrices for these sites to compensate for reducibility did not impact the relative order of growth rates. The changes caused no difference in the Fort Point Channel population growth rate, and increased the growth rates of Neponset and Saugus 0.0014 and 0.0002, respectively.

Table II-6. Population Growth Rates Calculated Using Measured Recruitment Rates and the Geometric Mean of Measured Recruitment Rates.

Site	r	λ_r	λ_m [1]
Barnstable Harbor	0.04	0.0821	0.0855
Wellfleet	0	0.0150	0.0211
Saugus	0.09	1.0024	1.0026
Neponset R.	2.3	0.8343	0.7027
Fort Point Ch.	0.21	0.7327	0.7312

[1] Geometric Mean = 0.092

The comparison between the λ_r and λ_m shows that changes in the value used for recruitment in the model can be changed over three orders of magnitude (at Neponset) and the population growth rate is changed by less than 0.1. This suggests that errors in estimation of recruitment of several orders of magnitude would not change the trends in population growth observed. The fact that Barnstable and Wellfleet clams are reproducing in two seasons rather than one apparently had little importance, since these sites still have dramatically lower population growth rates than the upper Massachusetts Bay sites. Using the deterministic model described here, population dynamics are more dependent on adult survival and growth and relatively insensitive to differences in reproductive effort and recruitment.

These results indicate that populations may be decreasing quite quickly at most of the sites, and only growing at Saugus. This is somewhat misleading, since Ripley and Caswell (1996) have shown that using a stochastic recruitment function in a matrix model instead of a single value for recruitment allows populations to grow at a faster rate. It is hypothesized by the authors that the stochastic method represents population processes in clams more realistically than the single-value method. This technique was not used here because it requires data on the range of intensity in recruitment events over many years, which was unavailable. However, the comparison between sites would probably have the same result using the stochastic method unless variability in recruitment differs substantially between sites.

Population surveys completed at Barnstable Harbor and Wellfleet Harbor in June 1996, using the same coring technique as in this study, showed that the projections of the model were not unreasonable. A rapid decline in the Wellfleet population was expected, and in fact, zero clams were found in the study area in June 1996. The Barnstable population was also projected to decrease rapidly. Here 9.6 +/- 3.41 clams per core were found in June 1996. Of these clams, only 28% were in size classes 3, 4, and 5. This roughly translates to a population density decrease to 60% of that of the prevoius year, if recruitment is ignored. However, the total population density has increased over the previous year due to a large, successful recruitment event that we know occurred because all of the remaining clams were obviously less than a year old, due to their small size (mostly <30 mm).

d. Summary

Populations of bivalve molluscs chronically exposed to contaminated habitats may be highly resistant to contaminant effects (McDowell Capuzzo, 1996). In this study, we found high prevalance of gonadal inflammation at contaminated urban sites, but population growth was unimpaired. Even with the reductions in reproductive output observed among populations from the three urban harbor sites, the supply of larvae imported to contaminated sites from other sites may be sufficient to overcome the potential deleterious effects of reduced reproduction and high disease prevalence. The demographic model showed that reproductive and physiological impairments were not correlated to poor population growth. In fact, the sites with highest population reproductive outputs, Barnstable Harbor and Wellfleet, had the lowest population growth rates. Factors influencing population growth rate include predation, disease, and food supply. Differences between these factors at various sites may have more of an influence on the population dynamics of clam populations than contaminant exposure.

Gonadal inflammation is very high at the upper Massachusetts Bay sites, especially at Fort Point Channel, and this high level of tissue degeneration in addition to the high level of hematopoietic neoplasia evident at Fort Point Channel certainly contributed to the higher mortality rates observed among clams at this site. Site specific hydrographic and hydrodynamic features may also contribute to population differences. Flushing rates are relatively high at the Wellfleet and Barnstable Harbor sites contributing to the low recruitment rates observed. Interannual variability in larval supply and recruitment success may further complicate intersite comparisons. The two Cape Cod sites are located on Cape Cod Bay and would experience the same seasonal temperature patterns as the upper Massachusetts Bay sites, but small variations in temperature profiles at each site would not be unexpected. Temperature differences may have influenced the timing and duration of the spawning season to some extent at each site but would not have a strong influence on lipid accumulation patterns as the dominant season for lipid accumulation would be the winter and early spring.

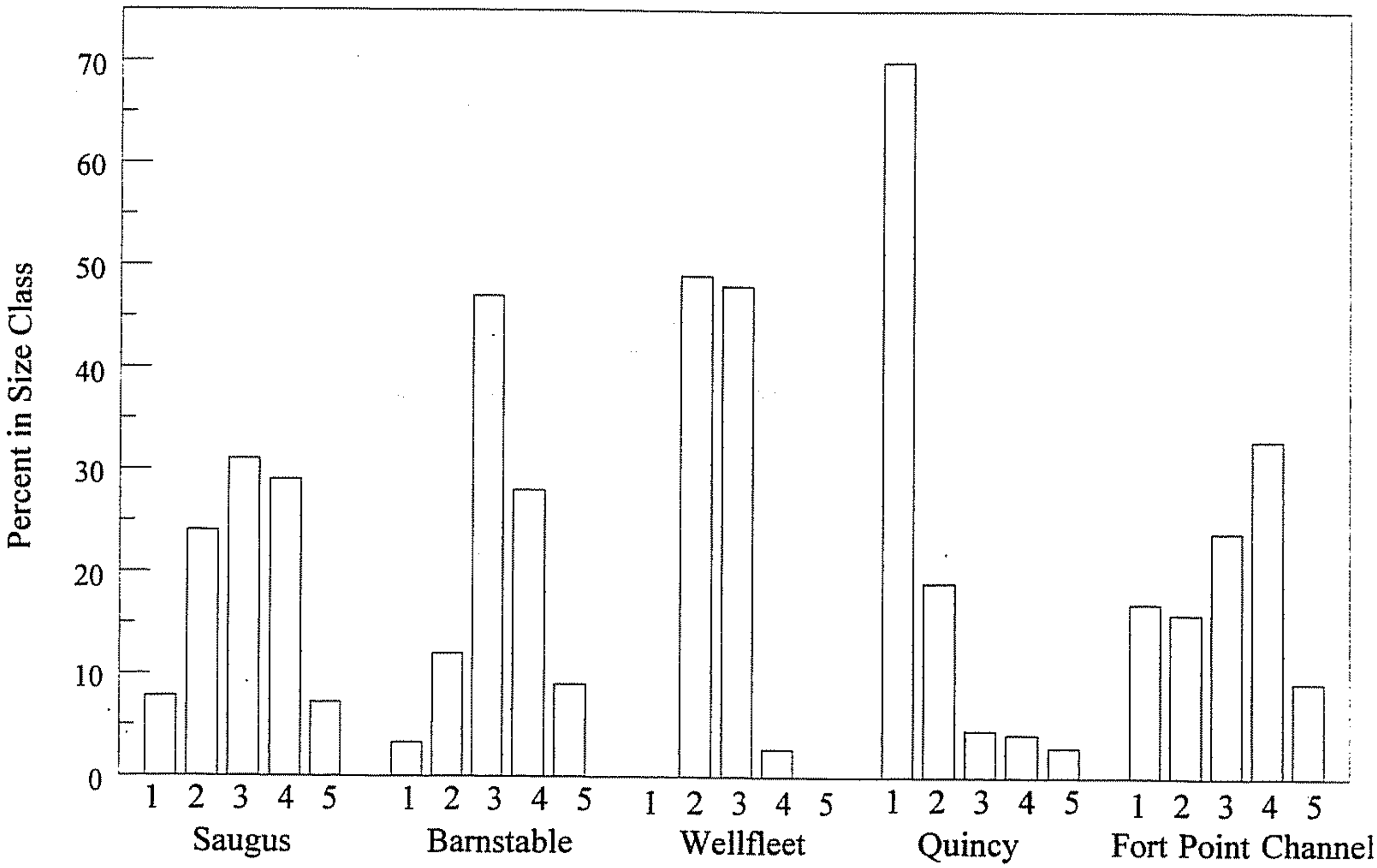


Figure II-16. Size Class Frequency Distributions for Each Site from Core Samples taken in September 1995: Size Class 1 = <40 mm, 2 = 40-49.9 mm, 3 = 50-59.9 mm, 4 = 60-69.9 mm, 5 = > 70 mm.

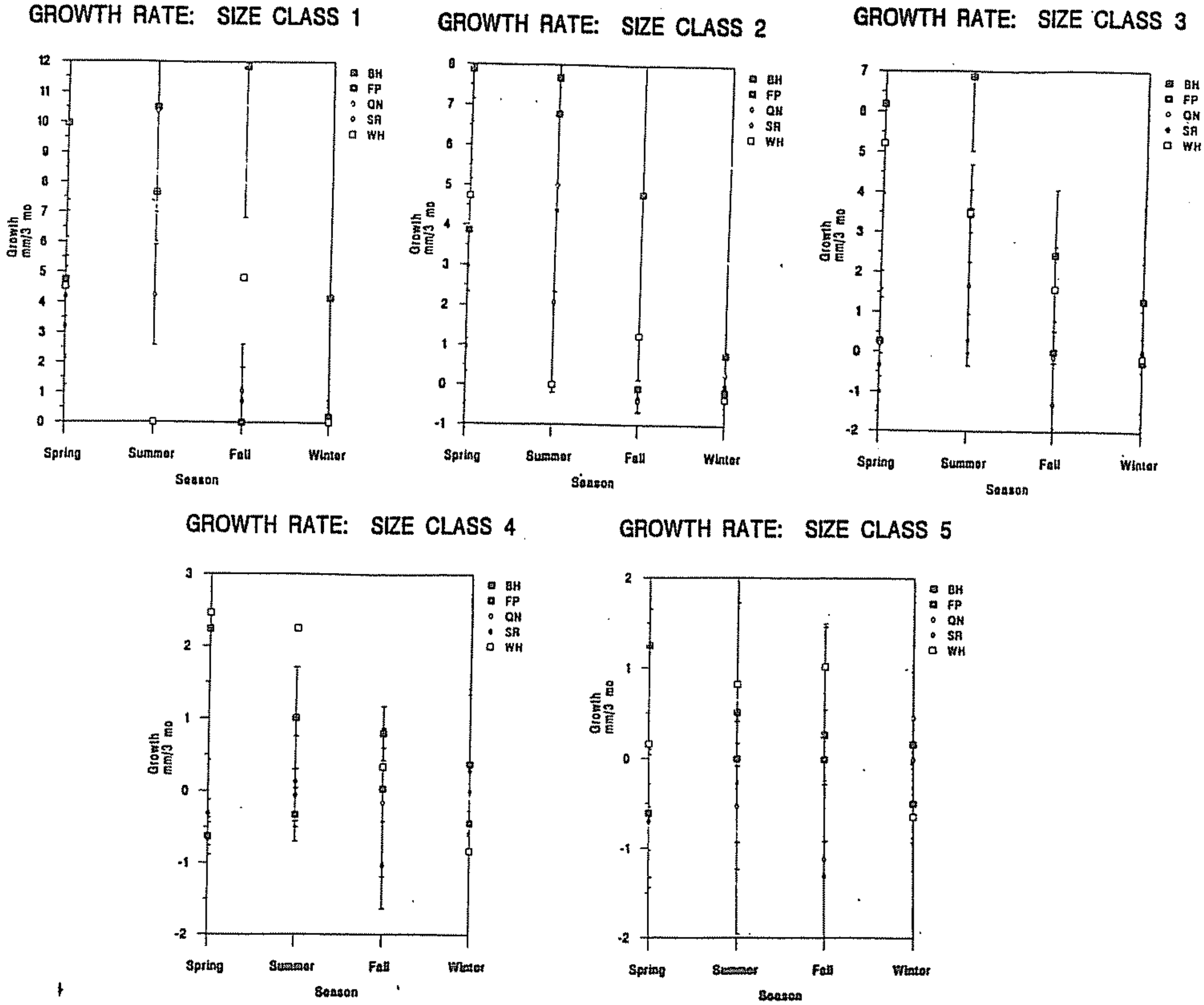


Figure II-17. Seasonal Growth Rates for Each Size Class of Clams. Spring is March-June 1995, summer is June-September 1995, fall is September-December 1995, and winter is December 1995-March 1996. Sites are coded as: BH=Barnstable Harbor; FP=Fort Point Channel; QN=Quincy-Neponset River; SR=Saugus River; and WH=Wellfleet Harbor. Error bars represent one standard deviation. The number of clams represented by each point varies from 1-18. Points with no error bars have an n of 1. Points indicating that growth=0 have an n of 0. (a) Size class 1; (b) Size class 2; (c) Size class 3; (d) Size class 4; (e) Size class 5. Note the difference in y-axis scales between plots.

Ayers (1956) suggested that larval mortality was one of the most important considerations in monitoring the population dynamics of *M. arenaria*, an observation consistent with numerous studies of bivalve species (Brousseau, 1978a; Brousseau et al., 1982; Weinberg et al., 1986). Brousseau et al. (1982) suggested that larval mortality could be further separated into mortality that occurred during (a) fertilization, (b) the free-swimming larval phase, or (c) early post-larval attachment. Using sensitivity analysis Brousseau and Baglivo (1984) addressed changes in the population growth rate attributable to changes in settlement rates of larvae and in age-specific fecundity and survivorship rates of the soft shell clam. They concluded that population growth rate was insensitive to absolute values in egg production and most sensitive to changes in egg and larval viability which contribute to the success of larval settlement. Malinowski and Whitlatch (1988) further documented that population growth rates were two to three orders of magnitude more sensitive to changes in survivorship in larval and juvenile stages of the life cycle than proportional changes in either survivorship or fecundity in adult size classes. Field estimates of egg and larval viability are difficult to make and may be uncoupled from successful recruitment events. We are currently evaluating differences in egg and larval viability of successful spawnings from clams collected at each of the five sites. The most significant variable, however, may be the survival of post-recruitment juveniles. Field sampling scheduled at each of the five sites for early summer through early fall will be directed at further quantification of the < 1 year old clams.

Conclusions

1. Contaminants were detected in clam tissues and sediments collected along a gradient of polycyclic aromatic hydrocarbon contamination in Boston Harbor and Massachusetts and Cape Cod Bays, but the bioavailability of specific compounds varied at different sites. Estimates of AEP (available for equilibrium partitioning) provided the best predictor of relative bioavailability of pyrogenic PAHs.

2. Clam populations at the three most contaminated sites (Fort Point Channel, Saugus, and Neponset River) showed similar patterns in a reduction in lipid accumulation in the digestive gland-gonad complex and similar patterns in reproductive development with spawning limited to a single mid-summer event. Highest levels of reproductive output were observed among clam populations from Barnstable Harbor and Wellfleet and spawning at these sites occurred from late spring to early fall.

3. Population growth rates were determined for all populations using a deterministic matrix model. Trends in population growth rates were not related to contaminant concentrations at each site since the deterministic model was relatively insensitive to the differences in reproductive physiology and recruitment observed.

4. High prevalences of gonadal inflammation were observed among clam populations from the three most contaminated sites, especially at Fort Point Channel where levels of hematopoietic neoplasia also reached 100% during December 1995.

Recommendations

The results of this study confirm and extend the observations of several other investigations conducted in the Massachusetts Bays ecosystem (McElroy et al., 1994; Moore et al., 1994; Hyland and Costa, 1995; McGroddy et al., 1995): (1) lipophilic organic contaminants are readily accumulated by marine biota, yet processes limiting bioavailability, especially at sites such as Fort Point Channel, are not yet explained; (2) alterations in reproduction and bioenergetics and increased prevalence of histopathological disorders are observed among populations of marine biota in contaminated habitats, but site specific differences in population dynamics are the result of interactive effects of several microhabitat features; (3) shellfish resources at several urban sites in Massachusetts Bay show elevated concentrations of lipophilic organic contaminants, especially PAHs, and the ramifications of harvesting or remediating these resources must consider effective management of these contaminated stocks.

The information generated in this study can provide the basis for development of solutions to management concerns on the presence of contaminants in harvestable resources and habitats by providing the initial assessment of ecological and human health risks associated with PAH contamination in Massachusetts Bays. The potential for trophic transfer of PAHs from shellfish to higher-level consumers, including humans, is very high. Specific recommendations for further study are as follows:

1. Develop sediment guidelines for the relative bioavailability and bioaccumulation of PAHs in marine biota using sediment AEP factors.

2. Characterize interannual and intersite variability in recruitment and survival of new recruits and incorporate these data in stochastic models of population dynamics of clam populations at contaminated and uncontaminated sites.

3. Determine the interaction of contaminant exposure with natural disease defense mechanisms in bivalve mollusc populations as high disease prevalence continues to be a common observation in contaminated habitats.

4. Evaluate the depuration kinetics of PAHs from contaminated shellfish resources when such stocks are transferred to uncontaminated conditions.

5. Establish human health advisories on the harvesting of shellfish with high body burdens of PAHs.

References

Abernathy, S., A.M. Bobra, W.Y. Shiu, P.G. Wells, and D. Mackay. 1986. Acute lethal toxicity of hydrocarbons and chlorinated hydrocarbons to two planktonic crustaceans: The key role of organism-water partitioning. Aquat. Toxicol. 8:163-174.

Addison, R.F. and K.R. Clarke. 1990. The IOC/GEEP Bermuda Workshop. J. Exp. Mar. Biol. Ecol. 138:1-8.

Anderson, J.W., S.L. Kiesser, and J.W. Blaylock. 1980. The cumulative effect of petroleum hydrocarbons on marine crustaceans during constant exposure. Rapp. P. v. Reun. Cons. Int. Explor. Mer 179:62-70

Ayers, J.C. 1956. Population dynamics of the marine clam, *Mya arenaria*. Limnol.Oceanogr. 1:26-34.

Bayne, B.L., R.F. Addison, J.M. Capuzzo, K.R. Clarke, J.S. Gray, M.N. Moore, and R.M. Warwick. 1988. An overview of the GEEP workshop. Mar. Ecol. Prog. Ser. 46:235-243.

Bayne, B.L., D.A. Brown, K. Burns, D.R. Dixon, A. Ivanovici, D. Livingstone, D.M. Lowe, M.N. Moore, AR.D. Stebbing, and J. Widdows. 1985. The effects of stress and pollution on marine animals. Praeger, New York. 381pp.

Berthou, F., G. Balouet, G. Bodennec, and M. Marchand. 1987. The occurrence of hydrocarbons and histopathological abnormalities in oysters for seven years following the wreck of the Amoco Cadiz in Brittany (France). Mar. Environ. Res. 23:103-133.

Brousseau, D.J. 1978. Population dynamics of the soft-shell clam *Mya arenaria*. Mar. Biol. 50:63-71.

Brousseau, D.J. 1979. Analysis of growth rate in *Mya arenaria* using the von Bertalanffy equation. Mar. Biol. 51:221-227.

Brousseau, D.J. and J.A. Baglivo. 1984. Sensitivity of the population growth rate to changes in single life history parameters: its application to *Mya arenaria* (Mollusca:Pelecypoda). Fish. Bull. 82:537-541.

Brousseau, D.J., J.A. Baglivo, and G.E. Lang, Jr. 1982. Estimation of equilibrium settlement rates for benthic marine invertebrates: its application to *Mya arenaria* (Mollusca:Pelecypoda). Fish. Bull. 80:642-648.

Brownawell, B.J. and J.W. Farrington. 1986. Biogeochemistry of PCBs in interstitial waters of a coastal marine sediment. Geochim. Cosmochim. Acta 50: 157.

Butler, P.A. 1973. Residue in fish, wildlife and estuaries. Organochlorine residues in estuarine mollusks, 1965-72. National Pesticide Monitoring Program. Pest. Monit. J. 6:238-246.

Capuzzo, J. McDowell. 1996. Biological effects of contaminants on shellfish populations in coastal habitats: A case history of New Bedford, MA. In: the Northeast Shelf: Assessment, Sustainability, and Management. Butterworth-Heinemann.

Capuzzo, J.M. 1987. Biological effects of petroleum hydrocarbons: Assessments from experimental results. Pages 343-410 in D.F. Boesch and N.N. Rabalais, editors. Long-term Environmental Effects of Offshore Oil and Gas Development. Elsevier Applied Science, London.

Capuzzo, J. M. and J. J. Sasner. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: F. J. Vernberg, A. Calabrese, F. P. Thurberg and W. B. Vernberg (Eds.), Physiological responses of marine biota to pollutants. Academic Press, New York. pp. 225-237.

Capuzzo, J. McDowell, J.W. Farrington, P. Rantamaki, C.H. Clifford, B.A. Lancaster, D.F. Leavitt, and X. Jia. 1989. The relationship between lipid composition and seasonal differences in the distribution of PCBs in *Mytilus edulis* L. Mar. Environ. Res. 28:259-264.

Capuzzo, J. McDowell, M.N. Moore, and J. Widdows. 1988. Effects of toxic chemicals in the marine environment: Predictions of impacts from laboratory studies. Aquat. Toxicol. 11:303-311.

Capuzzo, J.M., B.A. Lancaster, and G.C. Sasaki. 1984. The effects of petroleum hydrocarbons on lipid metabolism and energetics of larval development and metamorphosis in the American lobster (*Homarus americanus* Milne Edwards). Mar. Environ. Res. 14:201-228.

Caswell, H. 1989a. Matrix Population Models. Sinauer Associates, Inc. Publishers. Sunderland, MA. 328p.

Caswell, H. 1989b. The analysis of life table response experiments. I. Decomposition of treatment effects on population growth rate. Ecol. Model. 46:221-237.

Chang, S., F. W. Steimle, R. N. Reid, S. A. Fromm, V. S. Zdanowicz and R. A. Pikanowski. 1992. Association fo benthic macrofauna with habitat types and quality in the New York Bight. Mar. Ecol. Prog. Ser. 89:237-251.

Chin, Y-P, P.M. and P.M. Gschwend. 1992. Partitioning of polycyclic aromatic hydrocarbons to marine porewater colloids. Environ. Sci. Technol. 26: 1621-1626.

Coe, W.R. and H.J. Turner. 1938. Development of the gonads and gametes in the soft-shell clam (*Mya arenaria*). J. Morphol. 62:91-111.

Coon, S.L., Bonar, D.B. & Weiner, R.M. (1986). Chemical production of cultchless oyster spat using epinephrine and norepinephrine. Aquaculture 58:255-262.

Crippen, R.W. & Perrier, J.L. (1974). The use of neutral red and Evans blue for live-dead determination of marine plankton. Stain Technology 49:97-104.

Di Toro, D.M., C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.E. Thomas, P.R. Paquin. 1991. Technical basis for establishing sediment quality criteria for nonionic organic chemicals using equilibrium partitioning. Environ. Toxicol. Chem. 10: 1541-1583.

Donkin, P., J. Widdows, S.V. Evans, C.M. Worrall, and M. Carr. 1990. Quantitative structure-activity relationships for the effect of hydrophobic chemicals on rate of feeding by mussels (*Mytilus edulis*). Aquat. Toxicol. 14:277-294.

Farrington, J.W., E.D. Goldberg, R.W. Risebrough, J.H. Martin, and V.T. Bowen. 1983. U.S. "Mussel Watch" 1976-1978: An overview of the trace metal, DDE, PCB, hydrocarbon and artificial radionuclide data. Environ. Sci. Technol. 17:490-496.

Fisher, S.W. 1995. Mechanisms of Bioaccumulation in Aquatic Systems. In Reviews of Environmental Contamination and Toxicology. 142: 87-117.

Gardner, G.R. and R.J. Pruell. 1988. A histopathological and chemical assessment of winter flounder, lobster and soft-shelled clam indigenous to Quincy Bay, Boston Harbor and an in situ evaluation of oysters including sediment (surface and cores) chemistry. U.S. Environmental Protection Agency, Environmental Research Laboratory, Narragansett, RI.

Gilfillan, E.S., D.W. Mayo, D.S. Page, D. Donovan, and S. Hanson. 1977. Effects of varying concentrations of petroleum hydrocarbons in sediments on carbon flux in *Mya arenaria*. Pages 299-314 in F.J. Vernberg, A. Calabrese, F.P.

Thurberg, and W.B. Vernberg, editors. Physiological Responses of Marine Biota to Pollutants. Academic Press, New York.

Harkey, G.A., P.L. Van Hoof, P.F. Landrum. 1995. Bioavailability of polycyclic aromatic hydrocarbons from a historically contaminated sediment core. Environ. Toxicol. Chem. 14: 1551-1560.

Hofelt, C. and D. Shea. 1996. Accumulation of organochlorine pesticides and PCBs by semipermeable membrane devices (SPMDs) and *Mytilus edulis* in New Bedford Harbor. Environ. Sci. Technol. (In Press).

Hoffman, E.J., G.L. Mills, J.S. Latimer and J.G. Quinn. 1984. Urban runoff as a source of polycyclic aromatic hydrocarbons to coastal waters. Environ. Sci. Technol. 18: 580-587.

Huckins, J. N., G.K. Manuweera, J.D. Petty, D. Mackay, and J.A. Lebo. 1993. Lipid-containing semipermeable membrane devices for monitoring organic contaminants in water. Environ. Sci. Technol. 27: 2489-2496.

Hyland, J.L. and H. Costa. 1995. Examining linkages bewteen contaminant inputs and their impacts on living marine resources of the Massachusetts Bay ecosystem through application of the sediment quality triad method. MBP-95-03. Report to the Massachusetts Bays Program.

Humason, G. 1972. Animal Tissue Techniques. W.H. Freeman and Co., San Francisco, CA., 641p.

Kimball, D.M. 1994. The reproductive cycle in three populations of the blue mussel, *Mytilus edulis*, from Boston Harbor and Cape Cod Bay. Ph.D. Dissertation, University of Massachusetts-Boston, Boston, MA.

Koojiman, S.A.L.M. and J.A.J. Metz. 1984. On the dynamics of chemically stressed populations: The deduction of population consequences from effects on individuals. Ecotoxicol. Environ. Safety 8: 254-274.

Leavitt, D.F., B.A. Lancaster, A.S. Lancaster, and J. McDowell Capuzzo. 1990. Changes in the biochemical composition of a subtropical bivalve, *Arca zebra*, in response to contaminant gradients in Bermuda. J. Exp. Mar. Biol. Ecol. 138:85-98.

Livingstone, D.R. and S.V. Farrar. 1984. Tissue and subcellular distribution of enzyme activities of mixed-function oxygenase and benzo[a]pyrene metabolism in the common mussel *Mytilus edulis* L. Sci. Tot. Environ. 39:209-235.

Long, E.R., G.M. Sloane, R.S. Carr, K.J. Scott, G.B. Thursby, and T. Wade. 1995. Sediment Toxicity in Boston Harbor: Magnitude, Extent, and Relationships with Chemical Toxicants. NOAA Tech. Memo. NOS ORCA.

Lowe, D.M. 1988. Alterations in cellular structure of *Mytilus edulis* resulting from exposure to environmental contaminants under field and experimental conditions. Mar. Ecol. Prog. Ser. 46:91-100.

MacDonald, D.A. 1991. Status and trends in concentrations of selected contaminants in Boston Harbor sediments and biota. NOAA Technical Memorandum NOS OMA 56, Seattle, WA.

Malinowski, S. and R.B. Whitlatch. 1988. A theoretical evaluation of shellfish resource management. J. shellfish. Res. 7: 95-100.

Malins, D.C. and H.O. Hodgins. 1981. Petroleum and marine fishes: A review of uptake, disposition, and effects. Environ. Sci. Technol. 15:1272-1280.

McElroy, A.E., M. Shiaris, J. McDowell Capuzzo, B. Howes, and J. Molongoski. 1994. Bioavailability and biotransformation of polycyclic aromatic hydrocarbons in benthic environments of coastal Massachusetts. Report to the Massachusetts Bays Program, MBP 95-02S.

McGroddy, S.E. and J.W. Farrington. 1995. Sediment porewater partitioning of polycylic aromatic hydrocarbons in three cores from Boston Harbor, MA. Environ. Sci. Technol. 29: 1542-1550.

McGroddy, S.E., J.W. Farrington, and P.M. Gschwend. 1996. Comparison of the in situ and desorption sediment - water partitioning of polycyclic aromatic hydrocarbons and polychlorinated biphenyls. Environ. Sci. Technol. 30: 172-177.

McIntyre, A.D. and J.B. Pearce, editors. 1980. Biological Effects of Marine Pollution and the Problems of Monitoring. Rapp. P.-V. Reun. Cons. Int. Explor Mer 179:1-346.

Moore, M.J., R.M. Smolowitz, D.F. Leavitt, and J.J. Stegeman. 1994. Evaluation of chemical contaminant effects in the Massachusetts Bays. Final Reprort to the Massachusetts Bays Program, Boston, MA.

Moore, M.N. 1988. Cytochemical responses of the lysosomal system and NADPH-ferrihemoprotein reductase in molluscan digestive cells to environmental and experimental exposure to xenobiotics. Mar. Ecol. Prog. Ser. 46:81-89.

Moore, M.N., D.R. Livingstone and J. Widdows. 1989. Hydrocarbons in marine molluscs: Biological effects and ecological consequences. Pages 291-328 in U. Varanasi, editor. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. CRC Press, Boca Raton, FL.

National Research Council. 1980. The International Mussel Watch. National Academy Press, Washington, DC. 248pp.

Neff, J.M. 1979. Polycylic aromatic hydrocarbons in the aquatic environment. Applied Science Publishers, Ltd., Essex, England, 262 pp.

Neff, J.M. and W.E. Haensly. 1982. Long-term impact of the *Amoco Cadiz* oil spill on oysters *Crassostrea gigas* and plaice *Pleuronectes platessa* from Aber-Benoit and Aber-Wrach, Brittany, France. Pages 269-328 in Ecological Study of the Amoco Cadiz Oil Spill. NOAA-CNEXO Report.

Peven, C.S., A.D. Uhler, and F.J. Querzoli. 1996. Caged mussels and semipermeable membrane devices as indicators of organic contaminant uptake in Dorchester and Duxbury Bays, Massachusetts. Environ. Toxicol. Chem. 15: 144-149.

Phelps, H.L. and Warner, K.A. 1990. Estuarine sediment bioassay with oyster pediveliger larvae (*Crassostrea gigas*). Bull. Env. Cont. Toxicol. 44:197-204.

Ripley, B.J. and H. Caswell. 1996. A theoretical analysis of the role of recruitment variability in structuring populations of the steamer clam, *Mya arenaria*. 24th Annual Benthic Ecology Meetings, March 7-10, University of South Carolina, Columbia, SC.

Ropes, J.W. and A.P. Stickney. 1965. The reproductive cycle of *Mya arenaria* in New England. Biol. Bull. 128:315-327.

Rowell, T.W. and P. Woo. 1990. Predation by the Nemertian worm, *Cerebratulus lacteus* Verill, on the soft-shell clam, *Mya arenaria* Linnaeus, 1758, and its apparent role in the destruction of a clam flat. J. Shellfish Res. 2:291-297.

Sasaki, G.C. and J.M. Capuzzo. 1984. Degradation of *Artemia* lipids under storage. Comp. Biochem. Physiol., Vol. 78B, pp. 525-531.

Shea, D. 1988. Developing national sediment quality criteria: Equilibrium partitioning of contaminants as a means of evaluating sediment quality. Environ. Sci. Technol. 22: 1256-1261.

Shea, D., D.A. Lewis, B.E. Buxton, D.C. Rhoads, and J.M. Blake. 1991. The Sedimentary Environment of Massachusetts Bay: Physical, Chemical, and

Biological Characteristics. ENQUAD Tech. Rpt No. 91-6. MWRA, Boston, MA.

Shea, D. and J. Kelly. 1992. Transport and Fate of Toxic Contaminants Discharged by MWRA into Massachusetts Bay. ENQUAD Tech. Rpt No. 92-. MWRA, Boston, MA.

Shea, D. 1994. Annual Review of Toxic Contaminants In Massachusetts Bay: ENQUAD Tech. Rpt No. 93-18. MWRA, Boston, MA.

Shea, D. 1996. Accumulation, inventory and budget of polycylic aromatic hydrocarbons in Massachusetts Bays Sediments. MBP-96-. Report to the Massachusetts Bays Program. (In Review).

Shea, D. and J. Seavey. 1994. Quality Assurance Project Plan: Inventories and Concentrations of Organic Contaminants in Sediment Cores from Massachusetts and Cape Cod Bay. Prepared for the Massachusetts Bays Program, Boston, MA.

Smolowitz, R. M., Miosky, D. L. and Reinisch, C. L. (1989). Ontogeny of leukemic cells of the soft shell clam. J. Invert. Pathol. 53: 41-51.

Smolowitz, R. M. and Reinisch, C. L. (1986). Indirect peroxidase staining using monoclonal antibodies specific for *Mya arenaria* neoplastic cells. Journal of Invertebrate Pathology 48: 139-145.

Stegeman, J.J. 1985. Benzo(a)pyrene oxidation and microsomal enzyme activity in the mussel (*Mytilus edulis*) and other bivalve mollusc species from the Western North Atlantic. Mar. Biol. 89:21-30.

Vaughan, D.S., and S.B. Saila. 1976. A method for determining mortality rates using the Leslie matrix. Trans. Am. Fish. Soc. 3:380-383.

Warner, K., J. McDowell Capuzzo, J. Gentile, and H. Phelps. 1990. Development and deployment of a sediment bioassay using metamorphosing larvae of the genus *Crassostrea.* Summer Student Fellowship Report, Woods Hole Oceanographic Institution, Woods Hole, MA.

Weibel, E.R. 1979. Stereological Methods. Vol. 1. Practical Methods for Biological Morphometry. Academic Press, New York, NY 410p.

Weinberg, J.R., D.F. Leavitt, B.A. Lancaster and J. McDowell Capuzzo. 1996. Experimental studies with *Mya areanria* (Bivalvia) on the transmission, prevalence and effect of hematopoietic neoplasia. Submitted to J. Inv. Pathology.

Weinberg, J.R., D.F. Leavitt, and J. McDowell Capuzzo 1993. Use of Demographic Theory to Determine Impact of Disease and Chemical Contamination of Soft Shell Clam Population Properties. Final Report submitted to the U.S. Environmental Protection Agency, Washington, DC.

Weinberg, J.R., H. Caswell, and R.B. Whitlatch. 1986. Demographic importance of ecological interactions: how much do statistics tell us? Mar. Biol. 93:305-310.

Widdows, J. 1985. Physiological responses to pollution. Mar. Pollut. Bull. 16:129-134.

Widdows, J., K.A. Burns, N.R. Menon, D.S. Page, and S. Soria. 1990. Measurement of physiological energetics (scope for growth) and chemical contaminants in mussels (*Arca zebra*) transplanted along a contamination gradient in Bermuda. J. Exp. Mar. Biol. Ecol. 138:99-117.

Widdows, J., P. Donkin, and S.V. Evans. 1987. Physiological responses of *Mytilus edulis* during chronic oil exposure and recovery. Mar. Environ. Res. 23:15-32.

Widdows, J., T. Bakke, B.L. Bayne, P. Donkin, D.R. Livingstone, D.M. Lowe, M.N. Moore, S.V. Evans, and S.L. Moore. 1982. Responses of *Mytilus edulis* on exposure to the water accommodated fraction of North Sea oil. Mar. Biol. 67:15-31.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, NJ. 718p.

APPENDICES

Appendix A - Data Tables from Chemical Analyses

Appendix B - Data Tables from Physiological and Population Analyses

Table A1. PCBs and OCPs in Massachusetts Bays Sediments (ng/gdw).

Sample Name:	PB-CP	WHO3	WHO6	BHO3	BHO6	NRO3	NRO6	SAU03	SAU06	FPC03	FPC06
Sample Location	Procedural Blank	Wellfleet Harbor	Wellfleet Harbor	Barnstable Harbor	Barnstable Harbor	Neponset River	Neponset River	Saugus	Saugus	Four Point Channel	Four Point Channel
Sampling Date:		March 95	June 95	March 95	June 95	March 95	June 95	March 95	June 95	March 95	June 95
Sample Dry Wt. (g):	21.07	18.69	22.84	22.59	23.28	19.17	22.50	22.43	23.29	17.32	18.60
PCBs											
Cl2(08)	0.42	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cl3 (18)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cl3(28)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	2.71	1.74	1.51	<0.10	<0.10
Cl4(52)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	1.20	1.78	0.82	<0.10	<0.10
Cl4 (44)	<0.10	<0.10	<0.10	<0.10	<0.10	0.28	0.75	<0.10	<0.10	<0.10	<0.10
Cl4(66)	0.97	<0.10	<0.10	<0.10	<0.10	1.19	4.26	0.36	0.34	2.71	2.39
Cl5(101)	<0.10	<0.10	<0.10	0.05	0.14	0.39	2.00	0.55	0.67	1.79	10.70
Cl4(77)	<0.10	<0.10	<0.10	<0.10	<0.10	0.03	0.06	0.14	0.11	0.39	1.56
Cl5(118)	<0.10	<0.10	<0.10	0.07	0.11	0.73	2.83	0.77	0.47	1.35	5.38
Cl6(153)	0.16	<0.10	<0.10	0.09	0.14	0.67	1.67	1.42	1.14	3.43	9.71
Cl5(105)	<0.10	<0.10	<0.10	<0.10	<0.10	0.46	1.42	0.33	0.32	1.40	5.14
Cl6(138)	<0.10	<0.10	<0.10	0.09	0.07	0.75	2.24	1.99	1.73	6.24	13.99
Cl5(126)	0.64	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cl7(187)	<0.10	<0.10	<0.10	0.07	0.06	0.25	0.72	1.14	1.01	3.35	5.99
Cl6(128)	<0.10	<0.10	<0.10	<0.10	0.05	0.13	0.33	0.10	0.09	<0.10	2.02
Cl7(180)	<0.10	<0.10	<0.10	<0.10	<0.10	0.30	0.80	1.39	1.43	6.71	7.12
Cl7(170)	<0.10	<0.10	<0.10	0.05	0.05	0.14	0.28	0.44	0.41	2.39	6.12
Cl8(195)	<0.10	<0.10	<0.10	0.07	<0.10	<0.10	0.06	0.09	0.12	1.68	3.41
Cl9(206)	<0.10	<0.10	<0.10	<0.10	<0.10	0.03	0.16	0.22	0.28	1.58	3.93
Cl10(209)	<0.10	<0.10	<0.10	<0.10	<0.10	0.04	0.26	0.35	0.68	1.78	6.95
Total PCB	2.20	<0.10	<0.10	0.49	0.62	5.39	21.75	12.81	11.14	34.80	84.41
Pesticides											
Hexachlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lindane (gamma-HCH)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Heptachlor	<0.10	<0.10	1.05	<0.10	<0.10	0.71	1.13	0.83	4.25	3.51	<0.10
Aldrin	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Heptachlor epoxide	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
cis-Chlordane	<0.10	<0.10	<0.10	<0.10	<0.10	0.38	1.29	0.59	0.57	1.59	5.45
trans-Nonachlor	<0.10	<0.10	0.81	0.57	<0.10	0.46	0.72	0.66	0.77	5.24	8.69
Dieldrin	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	1.06	<0.10	0.19	1.66	5.07
Endrin	<0.10	<0.10	0.54	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mirex	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
DDT and Metabolites											
2,4'-DDE	<0.10	<0.10	<0.10	<0.10	<0.10	0.72	0.31	0.29	<0.10	<0.10	<0.10
4,4'-DDE	0.06	<0.10	0.29	0.22	<0.10	0.33	1.29	1.41	1.04	3.71	13.31
2,4'-DDD	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
4,4'-DDD	<0.10	<0.10	<0.10	<0.10	<0.10	0.24	1.03	1.47	1.47	9.02	20.49
2,4'-DDT	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
4,4'-DDT	0.03	0.17	<0.10	<0.10	<0.10	0.73	1.66	1.95	2.03	14.10	22.80
Total DDTs	0.20	0.17	0.29	0.22	<0.10	2.02	4.29	5.13	4.54	26.84	56.60
Surrogate Recoveries (%)											
DBOFB	76	79	84	66	80	86	123	117	93	133	142
Cl5 (112)	123	64	73	69	69	70	67	70	77	75	78
Cl8 (197)	149	70	51	60	65	71	69	71	66	68	77

Table A2. PAHs in Massachusetts Bays Sediments (ng/gdw).

Sample Name:	PB-CP	WH03	WH06	BH03	BH06	NR03	NR06	SAU03	SAU06	FPC03	FPC06
Sample Location:	Procedural	Wellfleet	Wellfleet	Barnstable	Barnstable	Neponset	Neponset	Saugus	Saugus	Fort Point	Fort Point
	Blank	Harbor	Harbor	Harbor	Harbor	River	River	River	River	Channel	Channel
Sampling Date:	NA	March 95	June 95	March 95	June 95	March 95	June 95	March 95	June 95	March 95	June 95
Sample Dry Wt (g):	21.34	18.69	22.84	22.59	23.28	19.17	22.50	22.43	23.29	17.32	18.60
Analyte											
naphthalene1	12.47	0.62	0.30	1.89	1.30	10	34	86	82	602	1069
2-methylnaphthalene1	4.60	ND	1.10	0.82	4.37	7	26	45	36	658	857
1-methylnaphthalene1	2.20	ND	0.92	ND	3.05	3	12	32	30	588	605
2,6-dimethylnaphthalene1	ND	0.93	4.97	1.95	1.18	6	42	43	42	559	478
2,3,5-trimethylnaphthalene1	ND	6.09	9.78	2.66	19.80	19	11	15	23	31	30
C1-naphthalenes1	7.02	ND	5.76	3.85	4.26	4	23	48	41	814	953
C2-naphthalenes1	ND	35.16	57.60	4.65	5.99	90	81	140	224	1685	1205
C3-naphthalenes1	ND	10.07	14.20	7.24	16.58	29	67	188	175	2022	1211
C4-naphthalenes1	ND	2.32	15.25	2.54	2.25	12	37	123	108	1226	729
biphenyl1	3.91	ND	0.95	ND	ND	0	7	17	13	197	231
acenaphthylene2	ND	0.45	0.73	2.88	1.11	9	26	151	147	188	325
acenaphthene2	ND	0.21	2.31	0.84	0.49	3	12	65	70	854	1134
dibenzofuran2	ND	0.58	0.70	2.38	0.86	5	16	64	59	548	870
phenyldecanes5	ND	ND	ND	1.65	3.29	3	20	6	7	108	135
phenylundecanes5	ND	10.12	10.48	5.75	4.68	16	86	35	36	386	589
phenyldodecanes5	11.52	ND	ND	ND	ND	ND	65	6	10	166	319
phenyltridecanes5	24.22	ND	ND	ND	ND	ND	93	0	4	159	309
phenyltetradecanes5	7.27	0.04	ND	ND	ND	11	106	17	10	106	172
fluorene2	ND	0.46	0.81	5.58	1.11	5	24	127	146	974	1224
1-methylfluorene2	ND	0.36	0.99	0.75	0.49	3	7	24	28	173	114
C1-fluorenes2	ND	0.42	2.08	2.17	0.79	5	18	78	92	534	495
C2-fluorenes2	ND	4.62	12.83	4.82	9.43	18	43	119	135	849	741
C3-fluorenes2	ND	3.07	5.62	6.92	4.54	40	69	211	223	1427	1335
dibenzothiophene2	1.29	0.33	0.83	1.67	ND	5	16	79	87	568	637
C1-dibenzothiophenes2	1.64	0.30	0.73	0.50	ND	7	19	69	83	520	493
C2-dibenzothiophenes2	ND	1.68	2.23	2.32	1.58	15	33	96	111	588	561
C3-dibenzothiophenes2	ND	1.11	1.77	1.72	1.22	18	27	65	76	400	435
phenanthrene2	2.49	1.69	4.63	14.46	6.96	65	166	945	1021	5331	5849
anthracene2	ND	0.57	0.92	8.38	2.11	17	49	377	420	1963	1958
1-methylphenanthrene2	0.20	0.29	0.62	2.85	1.29	9	18	80	92	541	409
C1-phenanthrenes/anthracenes2	0.86	1.38	3.21	13.66	5.30	43	102	607	746	3396	3149
C2-phenanthrenes/anthracenes2	ND	2.95	4.57	16.39	6.69	46	78	395	499	2255	1945
C3-phenanthrenes/anthracenes2	ND	1.55	1.96	4.73	3.05	37	46	174	196	1062	935
C4-phenanthrenes/anthracenes2	ND	1.77	3.01	10.87	5.99	54	55	348	442	1802	1580
fluoranthene2	0.62	5.00	10.76	56.01	24.58	166	234	1308	1515	5179	5391
pyrene2	0.48	4.79	9.17	44.16	19.95	170	197	1080	1264	4332	4265
C1-fluoranthenes/pyrenes2	ND	3.71	4.45	21.89	11.56	112	116	778	998	3406	2739
retene2	ND	0.13	0.24	1.05	0.62	6	6	7	4	57	25
benz[a]anthracene3	ND	1.94	1.59	12.10	6.06	38	92	655	865	1931	3325
chrysene3	ND	2.43	2.60	15.58	10.17	51	123	474	941	1670	2621
C1-chrysene3	ND	1.54	1.10	7.34	4.16	39	91	444	593	1439	1982
C2-chrysenes3	ND	0.82	0.61	3.43	2.37	21	61	252	251	809	1167
C3-chrysenes3	ND	ND	ND	1.67	1.10	12	47	116	120	441	637
C4-chrysenes3	ND	ND	ND	ND	ND	7	30	75	61	204	433
benzo[b]fluoranthene4	ND	1.67	1.74	13.18	7.39	48	267	1124	1324	3379	4585
benzo[k]fluoranthene4	ND	1.68	1.84	11.30	7.22	49	165	876	955	1517	2795
benzo[e]pyrene4	ND	1.30	1.33	8.03	4.82	37	181	911	1021	2145	3302
benzo[a]pyrene4	ND	2.28	1.98	14.38	7.84	58	242	1310	1490	3228	4697
perylene4	ND	0.49	1.62	4.37	2.60	13	70	375	400	867	1257
indeno[1,2,3-c,d]pyrene4	ND	1.42	1.48	8.98	5.08	42	272	1634	1435	2784	4644
dibenz[a,h]anthracene4	ND	0.31	0.30	2.13	1.20	10	85	510	495	1108	1725
benzo[g,h,i]perylene4	ND	1.24	1.30	7.40	4.24	36	220	1574	1255	2223	3504
coronene4	ND	0.31	0.36	1.73	1.00	7	47	354	240	400	635
Total LAB	43	10	10	7	8	31	370	65	68	925	1524
Total PAH	27	102	184	352	202	1450	3566	18342	20346	66121	77667
Surrogate Recoveries (%)											
naphthalene-d8(1)	39	41	38	39	41	40	47	49	44	46	90
acenapthene-d10(2)	44	50	44	52	50	49	61	57	52	78	117
chrysene-d12(3)	51	60	57	67	65	54	77	88	77	107	138
perylene-d12(4)	76	69	63	64	61	52	50	47	44	58	81
1-phenyldodecane(5)	73	66	60	63	60	55	68	95	77	82	111
Footnotes 1, 2, 3, 4, and 5 denote which surrogate is used to correct data.											

Table A3. PCB and OCPs in Massachusetts Bay Clams Collected March 1995 (ng/gdw).

Sample Name	BLBL	WFHI-395	BHI-395	QNI-395	SRI-395	FPC-395
Sample Location	Procedural Blank	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel
Sample Dry Wt. (g)	3.81	6.59	7.98	2.30	2.86	2.57
Sample Lipid Wt. (g)		0.41	0.48	0.08	0.11	0.10
Percent Lipid		6.21	6.07	3.68	3.81	3.98
PCBs						
Cl2(08)	0.01	0.00	0.00	0.00	0.00	0.00
Cl3 (18)	0.00	0.00	0.00	0.00	0.00	0.00
Cl3(28)	0.00	0.48	0.52	5.48	3.74	2.86
Cl4(52)	0.00	0.00	2.00	7.13	4.60	1.91
Cl4 (44)	0.00	0.00	0.00	6.17	2.98	2.51
Cl4(66)	0.00	0.00	0.00	28.20	3.85	3.17
Cl5(101)	0.00	3.24	1.40	17.73	5.05	4.82
Cl4(77)	0.05	0.00	0.00	0.00	0.00	0.00
Cl5(118)	0.00	3.25	0.72	14.52	9.46	7.77
Cl6(153)	0.12	5.10	3.53	20.90	23.27	18.65
Cl5(105)	0.00	1.03	0.79	8.03	4.40	0.94
Cl6(138)	0.00	1.65	0.00	16.21	13.80	8.18
Cl5(126)	0.00	0.00	0.28	0.83	1.11	0.92
Cl7(187)	0.00	0.00	1.16	5.29	11.41	4.26
Cl6(128)	0.00	0.00	0.59	0.00	1.67	0.00
Cl7(180)	0.00	0.00	0.47	0.00	5.73	0.72
Cl7(170)	0.00	0.00	0.00	0.00	0.00	0.00
Cl8(195)	0.11	0.00	0.00	0.00	0.00	0.00
Cl9(206)	0.00	0.00	0.03	0.00	0.00	0.00
Cl10(209)	0.00	0.00	0.00	0.00	0.00	0.00
Total PCB	0.30	14.74	11.49	130.49	91.08	56.71
PESTICIDES						
Hexachlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00
Lindane (gamma-HCH)	0.00	0.00	0.00	0.00	0.00	0.00
Heptachlor	0.00	0.17	0.12	3.25	0.00	1.52
Aldrin	0.00	0.00	0.00	0.00	0.00	0.00
Heptachlor epoxide	0.00	0.00	0.00	3.27	0.00	0.00
cis-Chlordane	0.00	0.74	0.00	0.00	0.00	0.00
trans-Nonachlor	0.00	0.28	0.00	0.00	0.00	0.00
Dieldrin	0.00	3.33	1.26	6.69	3.70	5.91
Endrin	0.00	0.00	0.00	0.00	0.00	0.00
Mirex	0.00	0.00	0.00	0.00	0.00	0.00
DDT and Metabolites						
2,4'-DDE	0.00	0.00	0.00	0.00	0.00	0.00
4,4'-DDE	0.00	0.35	1.85	9.22	9.37	6.18
2,4'-DDD	0.20	0.00	0.36	0.00	1.18	0.00
4,4'-DDD	0.00	0.00	6.90	5.18	10.10	8.21
2,4'-DDT	0.00	0.00	0.00	0.00	0.00	0.00
4,4'-DDT	0.00	0.00	0.00	0.00	0.00	0.00
Total DDT	0.20	0.35	9.10	14.40	20.64	14.39
Surrogate Recoveries (%)						
DBOFB	38	45	52	43	53	46
Cl5 (112)	62	53	58	49	64	57
Cl8 (197)	68	57	51	56	62	56

Table A4. PAHs in Massachusetts Bay Clams Collected March 1995 (ng/gdw).

Sample Name	BLBL	WFHI-395	BHI-395	QNI-395	SRI-395	FPC-395
Sample Location	Procedural Blank	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel
Sample Dry Wt. (g)	3.81	6.59	7.98	2.30	2.86	2.57
Sample Lipid Wt. (g)		0.41	0.48	0.08	0.11	0.10
Percent Lipid		6.21	6.07	3.68	3.81	3.98
Analyte						
naphthalene	6.21	30.06	22.73	60.04	51.50	50.79
2-methylnaphthalene	1.57	16.62	17.21	20.88	19.38	21.29
1-methylnaphthalene	0.74	11.22	11.18	13.26	12.62	12.45
2,6-dimethylnaphthalene	0.20	9.40	35.65	10.88	16.58	33.75
biphenyl	0.66	5.61	5.93	8.08	6.76	7.31
acenaphthylene	0.18	1.80	1.93	9.65	15.88	22.90
acenaphthene	0.11	3.90	1.68	5.13	8.87	20.27
dibenzofuran	0.55	8.56	7.71	7.87	10.78	17.33
fluorene	0.29	7.86	7.40	4.72	14.73	35.25
1-methylfluorene	0.24	4.46	3.89	7.57	17.45	43.30
dibenzothiophene	0.20	3.90	2.86	6.25	17.23	27.32
phenanthrene	1.90	54.24	46.50	70.26	244.98	273.49
anthracene	0.00	1.72	2.63	17.26	38.74	64.56
1-methylphenanthrene	0.22	11.65	7.58	24.46	49.78	123.42
fluoranthene	0.26	65.15	53.41	265.64	924.00	1135.91
pyrene	0.99	32.03	26.44	239.44	824.77	1064.57
retene	2.28	34.54	6.87	28.59	29.38	74.21
benz[a]anthracene	0.00	3.82	3.34	80.56	313.56	483.81
chrysene	0.00	18.05	10.96	215.58	609.49	884.98
benzo[b]fluoranthene	0.00	5.96	3.08	96.98	333.21	529.02
benzo[k]fluoranthene	0.00	4.61	3.43	91.99	304.78	393.67
benzo[e]pyrene	0.49	9.89	5.30	250.59	427.06	737.51
benzo[a]pyrene	0.17	5.28	2.45	52.74	210.50	284.72
perylene	0.00	4.45	5.09	20.78	58.17	66.66
indeno[1,2,3-c,d]pyrene	0.00	2.05	1.58	36.62	134.46	153.85
dibenz[a,h]anthracene	0.00	0.00	0.00	7.83	27.76	29.95
benzo[g,h,i]perylene	0.00	6.36	2.85	229.96	348.17	730.01
coronene	0.09	3.62	0.76	20.55	42.01	51.59
Total PAH	17	367	300	1904	5113	7374
phenyldecanes	0.63	42.00	11.90	158.88	149.05	1296.97
phenylundecanes	1.66	27.91	17.90	405.74	236.34	3827.65
phenyldodecanes	0.99	43.23	7.78	256.92	138.25	1663.20
phenyltridecanes	3.85	37.40	20.19	345.06	170.91	1196.96
phenyltetradecanes	0.00	209.80	22.10	516.57	215.70	415.39
Total LAB	7	360	80	1683	910	8400
Surrogate Recoveries (%)						
naphthalene-d8	33	39	30	43	56	52
acenaphthene-d10	47	62	72	61	80	73
1-phenyldodecane	59	91	102	73	91	82
chrysene-d12	68	68	78	56	66	55
perylene-d12	30	55	66	48	59	50

Table A5. PAHs in PE Tubing at Sediment Surface (ng/g lipid).

Sample Name	PB	WFHI-395	BHI-395	QNI-395	SRI-395	FPC-395	TB
Sample Location	Procedural Blank	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel	Trip Blank
Analyte							
naphthalene	18.97	887	14129	1094	620	279	328
2-methylnaphthalene	3.21	103	2561	161	82	50	138
1-methylnaphthalene	1.62	44	1280	73	40	34	72
2,6-dimethylnaphthalene	0.91	41	461	55	44	72	90
biphenyl	1.14	17	125	27	12	14	61
acenaphthylene	0.00	4	17	34	60	122	12
acenaphthene	0.00	10	45	37	41	192	96
dibenzofuran	1.59	14	65	41	30	71	215
fluorene	0.63	25	105	67	49	101	266
1-methylfluorene	0.00	9	405	20	66	607	131
dibenzothiophene	0.00	8	38	28	23	45	109
phenanthrene	3.75	89	222	334	186	278	1035
anthracene	0.39	6	21	81	119	309	81
1-methylphenanthrene	1.31	11	23	32	36	172	47
fluoranthene	2.50	108	8	827	2662	3319	148
pyrene	1.98	46	1	401	2735	3099	73
retene	0.74	104	227	150	125	314	18
benz[a]anthracene	0.00	9	11	159	464	629	7
chrysene	0.00	26	6	330	839	1119	3
benzo[b]fluoranthene	0.00	13	9	130	468	627	6
benzo[k]fluoranthene	0.00	11	6	247	383	363	5
benzo[e]pyrene	0.00	4	7	82	314	411	5
benzo[a]pyrene	0.00	5	3	81	230	286	3
perylene	0.00	5	3	26	72	74	5
indeno[1,2,3-c,d]pyrene	0.00	3	1	71	100	119	0
dibenz[a,h]anthracene	0.00	0	1	7	33	27	0
benzo[g,h,i]perylene	0.00	3	1	48	102	125	0
coronene	0.00	0	0	3	10	9	0
Total PAH	39	1605	19780	4646	9945	12866	2951
phenyldecanes	0.00	168	2206	138	1826	949	557
phenylundecanes	0.00	207	7676	223	8131	5575	1555
phenyldodecanes	0.00	902	1598	1753	6013	4667	886
phenyltridecanes	0.00	1199	5587	2877	2744	8431	1750
phenyltetradecanes	0.00	na	na	na	na	na	na
Total LAB	0	2475	17067	4992	18715	19622	4747
Surrogate Recoveries (%)							
naphthalene-d8	45%	46%	27%	46%	35%	35%	40%
acenaphthene-d10	72%	60%	57%	75%	62%	70%	74%
1-phenyldodecane	92%	87%	65%	79%	72%	72%	91%
chrysene-d12	104%	106%	57%	73%	69%	63%	114%
perylene-d12	59%	50%	43%	50%	47%	49%	49%

Table A6. PAHs in PE Tubing at 5 cm Sediment Depth (ng/g lipid).

Sample Name	WFHI-395	BHI-395	QNI-395	SRI-395	FPC-395
Sample Location	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel
		NEP-Sed.		BAR-Sed.	SAR-Sed.
Analyte					
naphthalene	12352	1038	10990	17132	6817
2-methylnaphthalene	7875	150	2735	3268	1557
1-methylnaphthalene	3784	65	1178	1542	678
2,6-dimethylnaphthalene	1498	71	590	612	437
biphenyl	432	15	137	151	117
acenaphthylene	34	5	33	60	66
acenaphthene	75	16	51	148	154
dibenzofuran	171	14	68	119	92
fluorene	238	23	117	247	145
1-methylfluorene	639	115	534	450	386
dibenzothiophene	66	6	47	138	78
phenanthrene	425	72	263	619	513
anthracene	38	18	68	259	331
1-methylphenanthrene	54	25	25	64	60
fluoranthene	36	354	14	2575	1847
pyrene	7	130	5	2900	12
retene	815	68	1006	524	473
benz[a]anthracene	25	30	114	404	515
chrysene	15	48	206	633	816
benzo[b]fluoranthene	6	16	132	442	450
benzo[k]fluoranthene	3	20	99	324	309
benzo[e]pyrene	3	10	87	244	256
benzo[a]pyrene	2	6	59	223	252
perylene	3	7	19	61	64
indeno[1,2,3-c,d]pyrene	0	3	19	75	79
dibenz[a,h]anthracene	0	1	4	16	15
benzo[g,h,i]perylene	0	2	18	71	76
coronene	0	1	1	7	10
Total PAH	28596	2329	18617	33306	16603
phenyldecanes	2825	1095	3060	2476	2567
phenylundecanes	12152	5347	11004	9821	7264
phenyldodecanes	9039	5074	10617	6764	6091
phenyltridecanes	3998	6404	7155	4316	2816
phenyltetradecanes	na	na	na	na	na
Total LAB	28013	17920	31836	23377	18738
Surrogate Recoveries (%)					
naphthalene-d8	28%	41%	35%	37%	40%
acenaphthene-d10	69%	63%	71%	69%	67%
1-phenyldodecane	100%	77%	81%	77%	71%
chrysene-d12	109%	79%	100%	78%	81%
perylene-d12	52%	54%	51%	50%	45%

Table A7. PAHs in SPMDs at 0 cm Sediment Depth (ng/g lipid).

Sample Name	PB	WFHI-395	BHI-395	QNI-395	SRI-395	FPC-395	TB
Sample Location	Procedural Blank	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel	Trip Blank
Analyte							
naphthalene	18.97	2779	34844	841	956	1469	1018
2-methylnaphthalene	3.21	519	5422	182	209	223	231
1-methylnaphthalene	1.62	245	2566	82	104	135	114
2,6-dimethylnaphthalene	0.91	197	715	95	124	229	111
biphenyl	1.14	81	262	32	23	50	77
acenaphthylene	0.00	5	41	40	38	63	14
acenaphthene	0.00	45	77	48	105	456	114
dibenzofuran	1.59	54	132	65	120	228	262
fluorene	0.63	71	188	111	188	254	308
1-methylfluorene	0.00	105	685	119	77	1075	158
dibenzothiophene	0.00	11	56	24	87	86	147
phenanthrene	3.75	121	429	380	570	778	1394
anthracene	0.39	5	40	127	168	261	112
1-methylphenanthrene	1.31	138	35	40	184	296	65
fluoranthene	2.50	65	220	849	2957	3558	199
pyrene	1.98	8	104	276	1405	1882	99
retene	0.74	34	455	77	93	95	28
benz[a]anthracene	0.00	8	24	233	386	587	8
chrysene	0.00	15	7	431	703	997	7
benzo[b]fluoranthene	0.00	15	13	152	406	606	0
benzo[k]fluoranthene	0.00	10	9	325	389	560	0
benzo[e]pyrene	0.00	5	8	106	291	458	0
benzo[a]pyrene	0.00	3	5	89	205	380	0
perylene	0.00	2	5	25	70	99	0
indeno[1,2,3-c,d]pyrene	0.00	5	4	93	128	287	0
dibenz[a,h]anthracene	0.00	0	2	0	36	71	0
benzo[g,h,i]perylene	0.00	0	3	42	128	282	0
coronene	0.00	0	2	3	14	31	0
Total PAH	39	4546	46356	4888	10166	15497	4465
phenyldecanes	0.00	0	3246	675	1809	3034	338
phenylundecanes	0.00	1735	13051	4471	5635	6926	1715
phenyldodecanes	0.00	2791	9257	4378	4112	7267	1102
phenyltridecanes	0.00	2725	8572	4079	5928	5251	577
phenyltetradecanes	0.00	na	na	na	na	na	na
Total LAB	0	7251	34125	13602	17484	22478	3733
Surrogate Recoveries (%)							
naphthalene-d8	45%	47%	42%	42%	50%	58%	61%
acenaphthene-d10	72%	73%	80%	67%	79%	83%	91%
1-phenyldodecane	92%	91%	91%	84%	89%	79%	102%
chrysene-d12	104%	109%	71%	94%	68%	57%	126%
perylene-d12	59%	48%	57%	44%	54%	53%	52%

Table A8. PAHs in SPMDs at 5 cm Sediment Depth (ng/g lipid).

Sample Name	WFHI-395	BHI-395	QNI-395	SRI-395	FPC-395
Sample Location	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel
Analyte					
naphthalene	43339	2964	14470	26698	13603
2-methylnaphthalene	9780	604	3394	5201	2677
1-methylnaphthalene	4457	257	1492	2567	1073
2,6-dimethylnaphthalene	1629	197	725	1009	596
biphenyl	541	43	227	280	178
acenaphthylene	43	6	45	79	119
acenaphthene	81	26	74	220	252
dibenzofuran	212	38	115	212	145
fluorene	253	69	167	396	252
1-methylfluorene	585	354	477	483	550
dibenzothiophene	88	32	61	183	190
phenanthrene	482	237	439	1129	657
anthracene	32	21	94	327	506
1-methylphenanthrene	42	175	28	83	50
fluoranthene	4	0	11	0	55
pyrene	7	82	7	0	3
retene	640	80	789	404	646
benz[a]anthracene	24	27	149	227	610
chrysene	43	46	256	472	1308
benzo[b]fluoranthene	3	20	152	500	642
benzo[k]fluoranthene	3	21	127	412	430
benzo[e]pyrene	2	12	99	325	397
benzo[a]pyrene	0	7	72	328	296
perylene	25	7	19	73	74
indeno[1,2,3-c,d]pyrene	0	5	22	172	77
dibenz[a,h]anthracene	0	0	3	54	15
benzo[g,h,i]perylene	0	5	21	184	75
coronene	0	2	2	31	8
Total PAH	62314	5337	23536	42049	25483
phenyldecanes	4191	2836	2794	1801	2820
phenylundecanes	12019	8558	10494	10693	10910
phenyldodecanes	11071	7881	7958	7119	7949
phenyltridecanes	6916	9289	4007	3091	3591
phenyltetradecanes	na	na	na	na	na
Total LAB	34196	28565	25253	22704	25270
Surrogate Recoveries (%)					
naphthalene-d8	32%	47%	42%	47%	53%
acenaphthene-d10	76%	73%	74%	76%	83%
1-phenyldodecane	100%	85%	86%	81%	89%
chrysene-d12	106%	69%	106%	70%	107%
perylene-d12	50%	56%	47%	51%	51%

Table A9. PAHs in Massachusetts Bays Sediment Porewater and Bottom Water (ng/L).

			Porewater				Bottom Water				
Sample Name:	PB-CP	WHPW	BHPW	NRPW	SRPW	FPCPW	WHBW	BHBW	NRBW	SRBW	FPCBW
Sample Location:	Procedural Blank	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel	Wellfleet Harbor	Barnstabl Harbor	Neponset River	Saugus River	Fort Point Channel
Analyte											
naphthalene1	4.27	26	4.8	17	45	56	<0.1	<0.1	3	4	8
2-methylnaphthalene1	1.29	<0.1	<0.1	<0.1	1.8	2	<0.1	<0.1	<0.1	<0.1	<0.1
1-methylnaphthalene1	0.61	<0.1	0.58	1.35	3.6	3	<0.1	<0.1	<0.1	<0.1	<0.1
2,6-dimethylnaphthalene1	0.54	<0.1	<0.1	<0.1	0.8	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,3,5-trimethylnaphthalene1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
C1-naphthalenes1	1.31	5.5	9.9	12	14	13	<0.1	<0.1	2	1	6
C2-naphthalenes1	0.87	<0.1	<0.1	5	6.3	8	<0.1	<0.1	3	2	3
C3-naphthalenes1	<0.1	<0.1	<0.1	<0.1	<0.1	5	<0.1	<0.1	<0.1	<0.1	<0.1
C4-naphthalenes1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
biphenyl1	0.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
acenaphthylene2	0.29	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
acenaphthene2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
dibenzofuran2	0.63	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
phenyldecanes5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
phenylundecanes5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
phenyldodecanes5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
phenyltridecanes5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
phenyltetradecanes5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
fluorene2	0.6	3	5.9	13	17	1.6	<0.1	<0.1	<0.1	<0.1	<0.1
1-methylfluorene2	0.63	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
C1-fluorenes2	0.94	<0.1	<0.1	<0.1	<0.1	2.1	<0.1	<0.1	<0.1	<0.1	<0.1
C2-fluorenes2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
C3-fluorenes2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
dibenzothiophene2	1.17	<0.1	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	<0.1	<0.1
C1-dibenzothiophenes2	<0.1	<0.1	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.1	<0.1	<0.1
C2-dibenzothiophenes2	<0.1	<0.1	<0.1	<0.1	<0.1	14	<0.1	<0.1	<0.1	<0.1	<0.1
C3-dibenzothiophenes2	<0.1	<0.1	<0.1	<0.1	<0.1	18	<0.1	<0.1	<0.1	<0.1	<0.1
phenanthrene2	3.59	<0.1	<0.1	1	2	4	<0.1	<0.1	<0.1	<0.1	<0.1
anthracene2	0.68	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1-methylphenanthrene2	0.76	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
C1-phenanthrenes/anthracenes2	1.91	<0.1	1.33	15	23	30	<0.1	<0.1	4	6	5
C2-phenanthrenes/anthracenes2	1.45	<0.1	0.59	11	22	24	<0.1	<0.1	4	2	4
C3-phenanthrenes/anthracenes2	<0.1	<0.1	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.1	<0.1	2
C4-phenanthrenes/anthracenes2	<0.1	<0.1	<0.1	<0.1	<0.1	12	<0.1	<0.1	<0.1	<0.1	<0.1
fluoranthene2	1.37	<0.1	0.12	12	36	11	<0.1	<0.1	1	2	1
pyrene2	1.05	0.2	0.5	13	33	17	<0.1	<0.1	1	5	3
C1-fluoranthenes/pyrenes2	<0.1	<0.1	<0.1	14	21	10	<0.1	<0.1	1	1	1
retene2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
benz[a]anthracene3	<0.1	<0.1	<0.1	<0.1	4.9	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
chrysene3	0.21	0.14	0.22	4.4	8.8	4	<0.1	<0.1	1	6	1
C1-chrysene3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
C2-chrysenes3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
C3-chrysenes3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
C4-chrysenes3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
benzo[b]fluoranthene4	<0.1	0.15	0.12	4.9	8	5	<0.1	<0.1	<0.1	<0.1	<0.1
benzo[k]fluoranthene4	<0.1	0.1	0.1	4.5	7	5	<0.1	<0.1	<0.1	<0.1	<0.1
benzo[e]pyrene4	<0.1	<0.1	<0.1	3.4	6.3	4	<0.1	<0.1	<0.1	<0.1	<0.1
benzo[a]pyrene4	<0.1	<0.1	<0.1	4.2	5.1	5	<0.1	<0.1	<0.1	<0.1	<0.1
perylene4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
indeno[1,2,3-c,d]pyrene4	0.35	<0.1	<0.1	1.4	4.4	1.9	<0.1	<0.1	<0.1	<0.1	<0.1
dibenz[a,h]anthracene4	<0.1	<0.1	<0.1	1.2	1.8	1.4	<0.1	<0.1	<0.1	<0.1	<0.1
benzo[g,h,i]perylene4	<0.1	0.2	0.2	4.3	6.9	4.6	<0.1	<0.1	<0.1	<0.1	<0.1
coronene4	<0.1	<0.1	<0.1	2.6	3.5	3.1	<0.1	<0.1	<0.1	<0.1	<0.1
Surrogate Recoveries (%)											
naphthalene-d8(1)	91	67	68	72	70	68	71	59	65	67	71
acenapthene-d10(2)	85	62	70	72	71	72	69	60	70	68	66
chrysene-d12(3)	105	90	97	97	93	90	92	82	88	95	89
perylene-d12(4)	72	62	73	69	63	67	64	64	65	69	70
1-phenyldodecane(5)	74	65	75	72	64	69	68	64	68	71	72

Footnotes 1, 2, 3, 4, and 5 denote which surrogate is used to correct data.

Table A10. PCB and OCPs in Massachusetts Bay Clams Collected December 1995 (ng/gdw)

Sample Location	Procedural Blank	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel
Sample Dry Wt. (g)	5.14	5.21	5.06	5.40	4.92	5.10
PCBs						
Cl2(08)	0.01	0.00	0.00	0.00	0.00	0.00
Cl3 (18)	0.00	0.00	0.00	0.00	0.00	0.00
Cl3(28)	0.00	0.25	0.36	3.02	2.55	2.09
Cl4(52)	0.00	0.00	0.94	4.09	3.23	1.27
Cl4 (44)	0.00	0.10	0.00	3.54	2.40	1.65
Cl4(66)	0.00	0.12	0.00	14.20	2.05	1.09
Cl5(101)	0.00	0.80	0.71	10.10	3.70	3.21
Cl5(118)	0.00	1.31	0.40	8.90	7.25	4.45
Cl6(153)	0.02	2.75	1.85	14.70	16.40	13.45
Cl5(105)	0.00	0.49	0.51	7.14	4.80	2.55
Cl6(138)	0.00	0.65	0.33	12.50	10.90	6.62
Cl7(187)	0.00	0.00	0.15	3.56	2.60	2.20
Cl6(128)	0.00	0.00	0.00	0.00	0.44	0.13
Cl7(180)	0.00	0.00	0.00	0.00	0.61	0.35
Cl7(170)	0.00	0.00	0.00	0.00	0.00	0.00
Cl8(195)	0.00	0.00	0.00	0.00	0.00	0.00
Cl9(206)	0.00	0.00	0.03	0.00	0.00	0.00
Cl10(209)	0.00	0.00	0.00	0.00	0.00	0.00
total PCB	0.04	6.47	5.28	81.75	56.93	39.06
PESTICIDES						
Hexachlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00
Lindane (gamma-HCH)	0.00	0.00	0.00	0.00	0.00	0.00
Heptachlor	0.00	0.00	0.08	1.15	0.53	0.67
Aldrin	0.00	0.00	0.00	0.00	0.00	0.00
Heptachlor epoxide	0.00	0.00	0.00	0.73	0.15	0.09
cis-Chlordane	0.00	0.41	0.00	0.00	0.00	0.00
trans-Nonachlor	0.00	0.18	0.00	0.00	0.00	0.00
Dieldrin	0.00	0.62	0.95	2.80	2.43	3.41
Endrin	0.00	0.00	0.00	0.00	0.00	0.00
Mirex	0.00	0.00	0.00	0.00	0.00	0.00
DDT and Metabolites						
2,4'-DDE	0.00	0.00	0.00	0.17	0.20	0.26
4,4'-DDE	0.00	0.14	1.34	11.50	12.20	7.80
2,4'-DDD	0.00	0.00	0.12	0.10	0.35	0.77
4,4'-DDD	0.00	0.26	2.90	7.10	8.30	9.70
2,4'-DDT	0.00	0.00	0.00	0.00	0.00	0.00
4,4'-DDT	0.00	0.00	0.00	0.00	0.00	0.00
total DDT	0.00	0.40	4.36	18.87	21.05	18.53
Surrogate Recoveries (%)						
DBOFB	101	95	93	97	92	98
Cl5 (112)	81	94	89	81	84	80
Cl8 (197)	85	82	93	93	84	86

Table A11. PAHs in Massachusetts Bay Clams Collected December 1995 (ng/gdw)

Sample Location	Procedural Blank	Wellfleet Harbor	Barnstable Harbor	Neponset River	Saugus River	Fort Point Channel
Sample Dry Wt. (g)	5.14	5.21	5.06	5.40	4.92	5.1
naphthalene	2.80	26.20	21.70	94.00	46.10	81.00
2-methylnaphthalene	1.10	12.60	15.90	28.00	17.40	42.00
1-methylnaphthalene	0.62	9.00	11.20	18.60	14.60	21.00
2,6-dimethylnaphthalene	0.11	6.50	33.30	15.90	14.50	26.00
fluorene	0.15	7.00	6.10	7.20	12.90	39.00
1-methylfluorene	0.09	4.10	3.00	9.00	15.00	52.00
biphenyl	0.14	4.50	7.20	5.10	6.20	4.60
acenaphthylene	0.08	0.90	1.50	14.10	17.50	28.00
acenaphthene	0.00	3.30	2.00	7.00	8.10	18.00
dibenzofuran	0.00	8.10	6.50	4.80	6.00	11.20
dibenzothiophene	0.10	4.20	3.40	12.50	21.40	41.00
phenanthrene	0.45	40.70	38.80	92.20	211.00	310.00
retene	0.35	36.80	7.30	27.40	27.00	56.00
perylene	0.00	3.60	4.10	24.10	72.00	72.00
dibenz[a,h]anthracene	0.00	0.30	0.20	6.50	30.00	26.00
anthracene	0.00	1.40	2.90	16.20	36.00	57.00
1-methylphenanthrene	0.00	10.90	7.40	36.90	41.70	161.00
fluoranthene	0.00	48.00	44.60	196.00	804.00	1320.00
pyrene	0.28	35.00	22.00	185.00	751.00	1110.00
benz[a]anthracene	0.00	3.40	3.00	72.00	324.00	456.00
chrysene	0.00	15.60	8.70	160.00	559.00	807.00
benzo[b]fluoranthene	0.00	6.40	2.80	81.00	267.00	492.00
benzo[k]fluoranthene	0.00	5.70	2.80	84.00	248.00	420.00
benzo[e]pyrene	0.00	7.50	5.80	189.00	408.00	670.00
benzo[a]pyrene	0.09	4.20	3.70	72.00	214.00	291.00
indeno[1,2,3-c,d]pyrene	0.00	2.10	1.80	40.00	119.00	152.00
benzo[g,h,i]perylene	0.00	7.20	2.90	178.00	322.00	525.00
coronene	0.00	3.60	0.80	17.40	29.00	31.00
Total PAH	6.00	319	271	1694	4642	7320
phenyldecanes	0.24	12.00	8.20	208.00	75.00	978.00
phenylundecanes	0.71	19.00	11.00	535.00	129.00	2952.00
phenyldodecanes	0.62	27.00	18.00	478.00	164.00	2321.00
phenyltridecanes	1.10	24.00	22.00	570.00	201.00	1405.00
phenyltetradecanes	0.10	26.00	19.00	430.00	160.00	511.00
Total LAB	3.00	108	78	2221	729	8167
Surrogate Recoveries						
naphthalene-d8	70	76	81	84	78	79
acenaphthene-d10	91	97	85	80	88	85
1-phenyldodecane	79	98	90	94	94	101
chrysene-d12	88	102	108	98	99	102
perylene-d12	85	96	95.0	87	89	90

Table B1. Length, Weight and Condition Indices for Clams Collected at Each Site and Each Sampling Period; D-G - digestive gland-gonad complex, DM - dry matter.

Mass Bays Project
Index Analyses

Barnstable Harbor
Collected: 7 April 1995
Processed 10 April 1995
Dry wts: 12 April 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (SI)	condition index (CI)
BH-1											
1	34.25	5.381	2.196	0.616	0.197	2.48	7.76	32.0	0.980	28.05	1.80
2	35.61	5.361	2.572	0.800	0.243	3.53	11.64	30.3	1.125	31.09	2.25
3	35.89	4.955	2.313	0.739	0.246	2.30	6.91	33.3	1.068	31.96	2.06
4	38.26	6.744	2.746	0.628	0.182	1.60	5.54	28.9	1.390	22.88	1.64
5	38.97	7.953	3.508	0.860	0.256	2.61	8.76	29.8	1.716	24.52	2.21
6	41.30	9.942	4.611	1.659	0.568	2.65	7.72	34.3	2.467	35.97	4.02
7	41.31	7.665	3.848	1.050	0.359	2.88	8.42	34.2	1.504	27.29	2.54
8	42.26	8.062	2.213	0.454	0.074	1.39	8.53	16.3	1.701	20.50	1.07
9	46.93	14.911	7.472	2.487	0.733	3.23	10.95	29.5	3.346	33.28	5.30
10	49.16	12.962	6.402	1.873	0.613	1.73	5.29	32.8	2.744	29.25	3.81
11	53.14	15.881	7.982	2.456	0.785	2.39	7.48	32.0	2.938	30.77	4.62
12	53.41	19.617	8.962	2.744	0.900	3.51	10.72	32.8	4.304	30.62	5.14
13	55.51	24.672	11.571	4.586	1.463	3.25	10.20	31.9	5.624	39.64	8.26
14	56.73	26.105	11.789	3.841	1.155	2.68	8.91	30.1	5.518	32.58	6.77
15	59.35	27.174	12.578	4.257	1.246	0.31	1.06	29.3	6.056	33.84	7.17
16	60.47	27.913	13.305	5.017	1.498	4.46	14.93	29.9	5.730	37.70	8.30
17	62.35	30.890	14.536	4.903	1.743	4.68	13.15	35.6	6.549	33.73	7.86
18	63.74	32.605	17.387	5.905	2.006	3.98	11.71	34.0	7.757	33.96	9.26
19	66.90	36.974	16.696	6.786	2.225	4.01	12.23	32.8	7.644	40.65	10.14
20	69.67	34.101	17.706	6.022	2.090	3.62	10.42	34.7	7.502	34.01	8.64
21	85.25	83.407	31.159	9.313	2.583	2.60	9.39	27.7	24.919	29.89	10.92
22	89.92	106.185	40.348	14.220	4.257	2.99	10.00	29.9	33.006	35.24	15.81
23	96.90	119.855	49.120	18.351	5.214	2.86	10.05	28.4	30.618	37.36	18.94
24	96.98	141.805	53.413	19.726	5.362	4.28	15.76	27.2	39.977	36.93	20.34
25	101.98	162.260	58.957	20.867	6.628	4.71	14.83	31.8	49.011	35.39	20.46
mean						2.99	9.69	30.8		32.28	7.57
stds						1.07	3.27	3.8		4.98	5.85

Mass Bays Project
Index Analysis

Barnstable Harbor II
Collected: 2 June 1995
Processed: 5 June 1995
Dry wts: 8 June 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
BH-2											
1	34.99	4.789	2.362	0.647	0.152	3.34	14.18	23.6	1.057	27.38	1.85
2	33.20	4.354	1.937	0.426	0.120	1.80	6.43	28.1	1.091	22.02	1.28
3	35.54	5.526	2.296	0.464	0.137	2.49	8.43	29.6	1.538	20.19	1.30
4	37.48	5.453	2.534	0.634	0.204	2.51	7.82	32.1	1.409	25.03	1.69
5	32.12	4.547	1.604	0.256	0.068	2.25	8.43	26.7	1.064	15.97	0.80
6	40.78	7.453	3.579	0.741	0.237	1.52	4.75	31.9	1.772	20.70	1.82
7	42.35	9.564	4.412	1.019	0.347	1.98	5.81	34.1	2.266	23.09	2.41
8	44.56	10.203	4.517	1.431	0.337	3.19	13.54	23.6	2.445	31.69	3.21
9	46.86	11.828	5.430	1.278	0.419	3.13	9.56	32.8	2.990	23.54	2.73
10	49.03	11.589	4.542	1.142	0.254	1.69	7.58	22.2	2.624	25.14	2.33
11	51.82	15.295	6.692	1.983	0.403	2.64	12.97	20.3	3.647	29.63	3.83
12	52.58	18.411	8.754	2.714	0.687	3.93	15.53	25.3	4.054	31.00	5.16
13	54.58	22.728	11.136	4.061	0.961	3.57	15.09	23.7	5.383	36.47	7.44
14	58.29	21.280	10.370	3.161	0.887	4.09	14.57	28.1	5.637	30.48	5.42
15	59.93	29.419	12.790	3.867	1.210	3.71	11.85	31.3	6.456	30.24	6.45
16	61.82	27.308	12.046	3.835	0.996	3.39	13.05	26.0	6.743	31.83	6.20
17	64.38	32.452	14.675	4.538	1.328	2.99	10.21	29.3	7.570	30.92	7.05
18	67.44	33.861	16.574	6.165	1.568	1.78	7.01	25.4	7.669	37.19	9.14
19	66.62	35.642	15.888	6.505	1.862	2.56	8.93	28.6	8.627	40.94	9.76
20	69.57	40.808	16.329	5.303	1.200	2.78	12.27	22.6	9.403	32.48	7.62
21	70.80	42.465	19.919	7.271	2.106	2.91	10.04	29.0	9.547	36.50	10.27
22	78.19	61.256	27.648	10.902	2.762	2.19	8.66	25.3	16.155	39.43	13.94
23	89.33	105.411	44.427	17.570	5.231	4.54	15.23	29.8	28.424	39.55	19.67
24	26.00	142.260	58.676	26.508	7.397	3.31	11.86	27.9	41.292	45.18	101.95
25	103.26	159.950	59.923	23.079	6.230	2.66	9.87	27.0	45.401	38.51	22.35
mean						2.84	10.55	27.4		30.60	10.23
stds						0.79	3.18	3.6		7.45	19.90

Mass Bays Project
Index Analysis

Barnstable Harbor III
Collected: September 12, 1995
Processed:
Dry wts:

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
BH-3											
1	81.24	68.833	22.124	6.780	1.245	3.09	16.83	18.4	17.408	30.65	8.35
2	81.08	96.844	31.076	9.728	2.020	2.38	11.47	20.8	29.584	31.30	12.00
3	75.73	50.338	18.072	4.351	0.809	2.14	11.48	18.6	13.588	24.08	5.75
4	73.44	53.228	18.712	4.348	1.115	1.65	6.43	25.7	12.357	23.24	5.92
5	70.88	44.527	15.719	4.474	1.224	3.39	12.39	27.4	10.320	28.46	6.31
6	68.95	33.904	12.425	3.360	0.550	3.07	18.79	16.4	8.701	27.04	4.87
7	67.12	32.552	10.864	1.610	0.284	2.47	14.00	17.6	7.929	14.82	2.40
8	67.11	36.919	13.881	2.783	0.585	2.97	14.15	21.0	10.128	20.05	4.15
9	65.87	43.792	14.583	2.880	0.688	3.01	12.59	23.9	9.188	19.75	4.37
10	63.58	30.300	9.339	1.959	0.400	2.90	14.19	20.4	6.431	20.97	3.08
11	55.80	22.295	8.654	1.716	0.338	2.84	14.39	19.7	5.208	19.82	3.07
12	53.63	19.425	6.500	1.319	0.322	1.78	7.29	24.4	5.652	20.29	2.46
13	53.10	19.770	7.175	1.428	0.361	1.88	7.42	25.3	4.578	19.90	2.69
14	51.93	16.028	6.214	1.046	0.268	2.52	9.82	25.6	4.311	16.84	2.01
15	51.75	17.460	5.149	1.250	0.257	3.15	15.29	20.6	4.772	24.28	2.42
16	49.99	13.575	4.059	0.663	0.148	1.65	7.40	22.4	3.003	16.34	1.33
17	49.49	14.108	5.103	0.998	0.245			24.6	4.421	19.56	2.02
18	48.12	14.654	4.414	1.234	0.310	3.09	12.28	25.1	4.492	27.96	2.57
19	47.38	15.863	5.998	1.438	0.303	1.62	7.67	21.1	4.168	23.98	3.04
20	40.44	8.449	2.727	0.552	0.138	1.60	6.41	24.9	2.001	20.23	1.36
21	37.72	5.500	2.379	0.394	0.094	1.41	5.91	23.8	1.360	16.57	1.05
22	33.05	4.639	1.858	0.375	0.087	2.09	8.98	23.2	0.968	20.20	1.14
23	32.42	4.145	1.423	0.247	0.054	1.68	7.61	22.1	0.954	17.32	0.76
24	25.76	2.341	0.911	0.166	0.038	1.37	5.94	23.1	0.526	18.23	0.64
25	20.21	1.959	0.629	0.087	0.020	1.72	7.66	22.4	0.398	13.89	0.43
mean						2.31	10.68	22.3		21.43	3.37
stds						0.66	3.79	2.8		4.77	2.69

Mass Bays Project
Index Analysis

BARNSTABLE HARBOR IV
Collected: DECEMBER 01 1995
Processed: DECEMBER 06 1995
Dry Weight DECEMBER 11, 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
BH-4											
1	82.96	85.762	26.107	6.640	1.492	3.28	14.59	22.5	29.569	25.43	8.00
2	81.64	62.387	21.432	5.371	1.053	1.87	9.56	19.6	17.765	25.06	6.58
3	80.96	52.960	19.552	5.254	1.081	3.84	18.66	20.6	12.205	26.87	6.49
4	78.08	54.414	20.675	4.541	1.013	3.23	14.48	22.3	13.069	21.96	5.82
5	70.62	43.407	15.448	4.269	0.716	2.89	17.24	16.8	11.054	27.64	6.05
6	69.24	41.493	16.106	2.886	0.595	1.73	8.38	20.6	10.627	17.92	4.17
7	66.60	36.340	11.814	2.482	0.373	2.11	14.08	15.0	9.944	21.00	3.73
8	63.72	31.867	10.401	2.814	0.487	2.13	12.32	17.3	8.196	27.05	4.42
9	63.97	36.431	13.997	3.393	0.759	2.05	9.17	22.4	9.426	24.24	5.31
10	60.90	25.101	7.890	1.886	0.271	1.26	8.79	14.4	6.708	23.90	3.10
11	58.34	22.627	8.349	1.901	0.306	1.54	9.55	16.1	5.174	22.76	3.26
12	57.53	20.844	7.904	1.422	0.260	1.51	8.25	18.3	6.645	17.98	2.47
13	56.10	25.077	9.158	1.797	0.379	2.00	9.49	21.1	7.299	19.62	3.20
14	54.64	20.635	7.953	1.918	0.478	2.08	8.33	24.9	5.025	24.11	3.51
15	52.01	13.421	4.286	0.696	0.153	1.61	7.32	21.9	3.359	16.24	1.34
16	48.60	14.778	4.923	1.046	0.278	2.17	8.16	26.6	4.148	21.24	2.15
17	47.82	10.651	3.647	0.649	0.130	2.05	10.24	20.1	2.823	17.80	1.36
18	44.79	11.447	4.380	1.059	0.257	2.39	9.85	24.2	2.839	24.18	2.37
19	41.39	9.047	3.161	0.632	0.144	1.50	6.57	22.8	2.146	19.99	1.53
20	40.53	8.056	3.134	0.673	0.179	1.58	5.94	26.5	1.881	21.49	1.66
21	36.23	5.447	2.306	0.458	0.092	1.47	7.28	20.2	1.191	19.86	1.26
22	35.09	5.761	2.478	0.420	0.095	1.76	7.81	22.6	1.366	16.93	1.20
23	31.39	4.145	1.703	0.246	0.056	2.03	8.99	22.6	0.823	14.46	0.78
24	26.64	2.503	1.000	0.195	0.043	2.25	10.21	22.1	0.640	19.48	0.73
25	24.79	1.933	0.620	0.107	0.026	1.89	7.69	24.6	0.451	17.32	0.43
mean						2.09	10.12	21.0		21.38	3.24
stds						0.63	3.28	3.3		3.66	2.13

Mass Bays Project
Index Analysis

Fort Point Channel
Collected: 20 March 1995
Processed: 24 March 1995
Dry Weight:

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
FPC-I											
1	27.51	2.174	0.709	0.129		2.51			0.710	18.21	0.47
2	31.22	3.497	1.196	0.215	0.046	1.82	8.58	21.3	1.173	17.97	0.69
3	37.85	5.744	2.145	0.460	0.101	2.43	11.10	21.9	1.878	21.42	1.21
4	36.84	6.873	1.802	0.273	0.063	2.17	9.34	23.3	2.471	15.15	0.74
5	39.98	9.304	3.106	0.528	0.116	3.54	16.11	22.0	3.532	16.99	1.32
6	41.25	9.147	2.504	0.447	0.092	6.42	31.03	20.7	3.010	17.83	1.08
7	41.28	8.599	2.770	0.511	0.099	1.86	9.64	19.3	2.575	18.44	1.24
8	41.17	8.472	1.674	0.256	0.050	2.88	14.79	19.5	3.466	15.26	0.62
9	45.66	10.914	3.568	0.538	0.105	4.62	23.58	19.6	3.838	15.07	1.18
10	49.86	13.597	4.051	0.669	0.155	1.84	7.90	23.2	4.838	16.51	1.34
11	50.98	15.760	5.213	0.948	0.232	2.52	10.29	24.5	4.942	18.19	1.86
12	56.03	23.367	5.665	0.908	0.180	5.57	28.17	19.8	9.702	16.03	1.62
13	54.13	21.680	4.988	0.872	0.174	1.05	5.28	19.9	7.875	17.49	1.61
14	55.27	22.234	4.707	0.873	0.156	3.96	22.13	17.9	8.567	18.54	1.58
15	55.03	25.963	5.589	1.137	0.232	2.99	14.66	20.4	10.838	20.33	2.07
16	60.33	29.828	6.765	0.925	0.168	0.77	4.26	18.2	11.385	13.68	1.53
17	61.18	28.366	8.267	1.412	0.279	2.43	12.30	19.7	9.309	17.09	2.31
18	63.39	35.812	7.308	1.571	0.230	1.61	10.95	14.7	15.165	21.49	2.48
19	70.43	39.823	10.638	1.992	0.397	0.95	4.78	19.9	14.205	18.72	2.83
20	68.69	40.460	12.705	3.124	0.574	1.62	8.79	18.4	14.984	24.59	4.55
21	70.78	59.695	14.633	2.398	0.540	3.91	17.34	22.5	24.371	16.39	3.39
22	75.17	47.967	14.123	2.900	0.595	1.42	6.94	20.5	18.395	20.53	3.86
23	77.43	64.586	13.894	2.561	0.428	2.43	14.56	16.7	30.189	18.43	3.31
24	77.95	61.407	16.336	3.064	0.550	2.70	15.07	17.9	22.796	18.76	3.93
25	84.80	78.180	26.208	5.713	1.147	2.81	13.99	20.1	24.608	21.80	6.74
mean						2.67	13.40	20.08		18.20	2.14
stds						1.38	7.02	2.21		2.48	1.47

Mass Bays Project
Index Analysis

Fort Point Channel 2
Collected: 6 June 1995
Processed: 9 June 1995
Dry Wghts: 12 June 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
FPC-2											
1	75.36	57.912	15.557	3.659	0.862	3.19	13.55	23.6	21.595	23.52	4.86
2	72.62	49.089	9.298	1.451	0.235	2.28	14.08	16.2	19.149	15.60	2.00
3	70.43	43.404	10.797	2.131	0.467	2.33	10.60	21.9	16.342	19.74	3.03
4	70.24	46.633	12.171	2.493	0.534	2.67	12.48	21.4	16.773	20.48	3.55
5	70.31	49.994	9.057	1.706	0.276	2.14	13.19	16.2	16.983	18.84	2.43
6	69.82	47.741	9.265	1.186	0.220	2.12	11.46	18.5	18.719	12.80	1.70
7	69.52	54.921	14.568	4.378	0.887	1.80	8.89	20.3	18.530	30.05	6.30
8	68.49	57.464	12.066	2.856	0.660	2.51	10.85	23.1	23.699	23.67	4.17
9	67.02	42.201	12.175	3.172	0.744	2.20	9.39	23.5	13.152	26.05	4.73
10	65.47	52.432	14.527	3.737	0.758	2.43	11.96	20.3	23.175	25.73	5.71
11	59.56	30.775	7.852	1.814	0.404	1.40	6.28	22.3	10.648	23.10	3.05
12	58.67	30.812	8.156	1.769	0.524	2.61	8.80	29.6	12.318	21.70	3.02
13	58.81	27.411	6.356	1.140	0.213	2.04	10.94	18.7	10.784	17.94	1.94
14	56.88	28.079	5.284	0.732	0.116	2.15	13.52	15.9	10.425	13.65	1.29
15	52.12	22.237	5.108	0.807	0.228	2.70	9.58	28.2	8.633	15.80	1.55
16	48.36	17.386	3.168	0.315	0.062	2.30	11.74	19.5	7.187	9.93	0.65
17	46.57	13.978	3.884	1.109	0.612	3.62	6.57	55.1	5.357	28.56	2.38
18	44.13	14.234	4.314	1.039	0.238	3.73	16.31	22.9	5.283	24.09	2.36
19	42.32	12.522	3.106	0.633	0.185	3.06	10.47	29.2	4.564	20.37	1.50
20	41.82	10.887	3.088	0.473	0.130	1.66	6.01	27.6	3.433	15.31	1.13
21	35.62	7.062	1.946	0.358	0.081	2.19	9.73	22.6	2.356	18.38	1.00
22	31.11	3.767	1.224	0.190	0.042	1.75	7.98	21.9	1.009	15.54	0.61
23	28.44	2.863	0.741	0.139	0.030	1.81	8.30	21.6	0.966	18.70	0.49
24	29.32	2.869	0.875	0.174	0.041	1.41	6.02	23.4	0.761	19.84	0.59
25	29.02	2.837	0.798	0.143	0.032	1.10	5.02	22.0	0.806	17.95	0.49
mean						2.29	10.15	23.4		19.90	2.42
stds						0.65	2.89	7.6		4.93	1.67

Mass Bays Project
Index Analysis

Fort Point Channel III
Collected: September 8, 1995
Processed: September 15, 1995
Dry Wghts: September 15, 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
FPC-3											
1	80.25	77.756	14.871	3.138	0.633	1.54	7.61	20.2	24.996	21.10	3.91
2	72.02	44.965	13.289	3.931	0.633	1.81	11.26	16.1	12.344	29.58	5.46
3	78.02	61.207	19.741	3.888	0.817	1.86	8.84	21.0	18.113	19.70	4.98
4	70.82	63.020	19.561	3.386	0.794	1.62	6.90	23.5	22.540	17.31	4.78
5	70.51	67.523	17.387	2.280	0.407	2.06	11.56	17.8	23.273	13.11	3.23
6	68.53	53.365	14.189	2.618	0.462	1.74	9.86	17.6	22.508	18.45	3.82
7	68.99	39.119	11.514	2.194	0.293	2.06	15.38	13.4	13.343	19.05	3.18
8	65.70	43.694	9.563	1.284	0.308	2.28	9.51	24.0	17.634	13.43	1.95
9	65.18	43.344	11.022	1.728	0.374	2.10	9.71	21.7	15.984	15.68	2.65
10	60.40	43.452	10.394	2.094	0.301	1.98	13.81	14.4	17.266	20.15	3.47
11	59.13	28.397	7.740	1.598	0.286	1.56	8.73	17.9	10.342	20.65	2.70
12	58.59	30.074	6.797	1.409	0.244	1.95	11.26	17.3	11.759	20.72	2.40
13	55.28	27.927	5.940	0.954	0.187	1.55	7.92	19.6	11.181	16.06	1.73
14	53.70	27.914	6.452	0.988	0.198	2.19	10.94	20.1	12.087	15.32	1.84
15	53.23	23.519	6.658	1.186	0.259	1.59	7.26	21.9	8.427	17.81	2.23
16	49.35	17.629	5.906	1.057	0.190	2.15	12.00	18.0	6.000	17.89	2.14
17	48.44	13.389	3.967	0.751	0.158	1.79	8.52	21.0	4.244	18.93	1.55
18	46.53	17.572	4.433	0.785	0.199	1.82	7.16	25.4	6.367	17.71	1.69
19	42.51	10.272	3.448	0.682	0.146	2.05	9.59	21.4	3.117	19.77	1.60
20	42.13	11.416	3.133	0.538	0.094	1.61	9.22	17.4	3.358	17.17	1.28
21	38.43	6.571	1.888	0.313	0.067	1.81	8.43	21.5	2.248	16.55	0.81
22	35.99	6.717	1.844	0.389	0.081	2.00	9.60	20.8	2.065	21.07	1.08
23	34.77	5.285	1.554	0.301	0.065	1.48	6.90	21.5	1.307	19.40	0.87
24	35.08	7.108	2.709	0.473	0.144	3.74	12.26	30.5	2.604	17.46	1.35
25	33.88	5.394	1.704	0.284	0.065	2.27	9.89	23.0	1.613	16.66	0.84
mean							9.77	20.27	11.0	18.43	2.46
stds							2.15	3.61	7.7	3.19	1.34

Mass Bays Project
Index Analysis

Fort Point C FORT POINT CHANNEL IV
Collected: DECEMBER 18, 1995
Processed: DECEMBER 22, 1995
Dry Wghts: DECEMBER 26, 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
FPC-4											
1	81.10	82.347	17.715	2.886	0.584	3.44	16.99	20.2	30.092	16.29	3.56
2	75.67	59.316	13.028	1.833	0.307	2.39	14.28	16.8	25.099	14.07	2.42
3	75.02	50.957	10.776	1.434	0.274	2.77	14.52	19.1	18.767	13.30	1.91
4	71.40	42.703	10.331	2.147	0.354	1.72	10.42	16.5	17.475	20.78	3.01
5	71.36	60.849	12.120	1.518	0.304	2.95	14.70	20.1	23.473	12.53	2.13
6	68.82	48.572	13.878	2.117	0.378	1.85	10.38	17.9	20.022	15.26	3.08
7	66.28	40.600	10.883	1.294	0.241	2.68	14.42	18.6	14.425	11.89	1.95
8	65.38	34.767	9.482	1.722	0.379	2.21	10.06	22.0	11.670	18.16	2.63
9	64.12	29.114	7.410	1.201	0.189	1.58	10.00	15.8	10.397	16.20	1.87
10	61.10	39.253	9.338	1.621	0.387	2.75	11.50	23.9	14.386	17.36	2.65
11	58.45	29.602	8.129	0.907	0.186	2.58	12.56	20.5	12.839	11.16	1.55
12	56.67	20.989	5.861	0.685	0.176	1.94	7.56	25.7	7.325	11.68	1.21
13	52.71	18.693	3.980	0.693	0.104	1.24	8.27	15.0	6.669	17.41	1.31
14	52.36	18.433	5.219	0.999	0.203	2.87	14.10	20.4	7.166	19.14	1.91
15	50.56	17.624	4.683	0.689	0.141	1.57	7.68	20.5	6.668	14.71	1.36
16	49.12	15.538	5.068	0.959	0.212	3.94	17.86	22.1	5.265	18.92	1.95
17	46.46	12.025	4.097	0.598	0.140	1.48	6.31	23.4	3.668	14.59	1.29
18	44.11	10.240	3.211	0.654	0.114	1.32	7.57	17.5	2.741	20.36	1.48
19	43.73	13.560	3.411	0.531	0.126	2.73	11.48	23.8	5.442	15.58	1.22
20	40.58	8.649	2.302	0.327	0.069	1.56	7.39	21.1	2.839	14.19	0.80
21	39.23	6.620	2.226	0.305	0.071	2.04	8.74	23.3	2.068	13.70	0.78
22	38.06	6.767	2.491	0.316	0.079	1.73	6.93	25.0	2.147	12.67	0.83
23	36.21	6.425	2.140	0.293	0.063	1.77	8.27	21.4	1.848	13.69	0.81
24	33.74	5.235	1.646	0.226	0.050	1.92	8.73	22.0	1.943	13.74	0.67
25	32.37	4.308	1.572	0.201	0.047	1.91	8.16	23.4	1.421	12.80	0.62
mean						2.15	10.50	20.6		15.16	1.64
stds						0.65	3.12	3.0		2.79	0.74

Mass Bays Project
Index Analysis

Quincey/Neponset
Collected: April 12, 1995
Processed: April 14, 1995
Dry wts: April 18, 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
NEP-1											
1	35.69	6.770	1.852	0.282	0.062	1.92	8.66	22.2	2.378	15.22	0.79
2	36.65	6.085	1.733	0.296	0.102	1.78	5.17	34.4	2.234	17.07	0.81
3	37.25	5.655	1.665	0.279	0.068	1.69	6.93	24.4	1.934	16.74	0.75
4	38.06	7.085	2.062	0.342	0.066	1.59	8.21	19.4	2.393	16.59	0.90
5	39.81	7.892	2.036	0.322	0.064	1.92	9.58	20.0	3.943	15.82	0.81
6	43.61	10.915	2.986	0.534	0.102	1.48	7.78	19.1	4.306	17.90	1.23
7	44.55	11.892	3.089	0.560	0.114	1.63	8.01	20.4	3.493	18.14	1.26
8	46.14	14.580	4.065	0.816	0.232	3.91	13.77	28.4	6.035	20.08	1.77
9	46.41	12.667	3.797	0.965	0.183	1.17	6.18	19.0	5.415	25.41	2.08
10	46.47	11.471	3.129	0.557	0.130	1.85	7.95	23.3	4.488	17.79	1.20
11	53.58	20.397	4.840	0.960	0.190	1.38	6.94	19.8	8.558	19.83	1.79
12	55.52	31.984	4.550	0.782	0.161	2.56	12.44	20.5	16.150	17.19	1.41
13	56.57	24.774	5.778	0.998	0.205	1.82	8.88	20.5	10.302	17.27	1.76
14	55.84	27.691	5.162	1.429	0.216			15.1	11.355	27.68	2.56
15	58.28	29.957	5.814	0.855	0.188	2.88	13.08	22.0	12.592	14.71	1.47
16	61.37	32.984	8.107	1.820	0.360	2.29	11.55	19.8	13.320	22.45	2.97
17	64.83	39.035	9.140	1.534	0.365	1.94	8.13	23.8	15.784	16.78	2.37
18	67.50	35.580	8.927	1.785	0.274	2.05	13.34	15.4	13.860	20.00	2.64
19	65.24	47.099	9.639	2.079	0.295	1.79	12.66	14.2	19.710	21.57	3.19
20	67.61	40.439	7.393	1.570	0.234	2.39	16.02	14.9	16.255	21.24	2.32
21	71.16	42.970	12.571	2.862	0.452	1.57	9.93	15.8	16.934	22.77	4.02
22	72.35	48.496	15.036	3.414	0.565	1.60	9.68	16.5	18.856	22.71	4.72
23	73.35	47.272	11.794	2.615	0.465	1.33	7.46	17.8	16.611	22.17	3.57
24	74.83	45.355	12.845	2.426	0.426	2.15	12.24	17.5	16.948	18.89	3.24
25	78.12	62.547	15.550	2.964	0.662	1.98	8.87	22.3	21.795	19.06	3.79
mean						1.94	9.73	20.3		19.40	2.14
stds						0.58	2.78	4.5		3.22	1.14

Mass Bays Project
Index Analysis

Quincy/Neponset II
Collected: June 5,1995
Processed: June 7,1995
Dry wts: June 11,1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
Nep-2											
1	87.30	83.154	23.769	5.167	0.830	2.35	14.62	16.1	29.524	21.74	5.92
2	83.86	75.621	20.884	4.408	0.728	1.94	11.75	16.5	27.442	21.11	5.26
3	81.27	76.395	28.209	4.815	0.750	1.55	9.94	15.6	29.689	17.07	5.92
4	79.59	65.876	19.057	6.053	1.020	2.45	14.53	16.9	24.514	31.76	7.60
5	76.97	65.775	14.798	3.608	0.713	2.65	13.40	19.8	25.275	24.38	4.69
6	69.77	38.521	7.313	1.595	0.211	2.45	18.57	13.2	15.129	21.81	2.29
7	66.65	36.587	8.893	1.826	0.351	1.99	10.35	19.2	13.858	20.53	2.74
8	66.15	43.735	7.836	1.473	0.249	2.50	14.79	16.9	16.880	18.80	2.23
9	64.33	35.665	8.493	1.585	0.375	1.99	8.41	23.6	13.410	18.66	2.46
10	62.52	34.703	8.982	2.045	0.362	2.36	13.33	17.7	12.462	22.77	3.27
11	59.17	30.177	5.598	1.024	0.158	1.54	9.99	15.4	11.839	18.29	1.73
12	59.07	29.202	6.583	1.616	0.245	1.56	10.33	15.1	12.744	24.55	2.74
13	57.73	22.031	6.525	1.214	0.311	2.18	8.53	25.6	6.182	18.60	2.10
14	55.23	21.314	5.917	0.921	0.192	1.75	8.39	20.9	6.527	15.56	1.67
15	53.62	20.161	5.422	1.057	0.262	1.88	7.60	24.8	6.549	19.49	1.97
16	46.71	10.959	3.230	0.576	0.143	1.91	7.72	24.8	3.257	17.84	1.23
17	46.15	11.808	3.225	0.566	0.104	1.52	8.30	18.3	3.251	17.55	1.23
18	43.22	12.157	3.163	0.512	0.106	2.52	12.19	20.7	3.997	16.20	1.19
19	40.73	7.932	2.356	0.578	0.111	1.51	7.90	19.1	2.095	24.53	1.42
20	40.16	7.518	2.339	0.414	0.088	1.51	7.10	21.3	2.006	17.71	1.03
21	39.56	6.878	2.396	0.413	0.092	1.46	6.55	22.3	1.741	17.24	1.04
22	38.62	6.712	1.934	0.386	0.078	1.92	9.50	20.2	1.639	19.96	1.00
23	34.93	4.685	1.518	0.253	0.053	1.91	9.18	20.8	1.164	16.67	0.72
24	34.84	4.520	1.628	0.257	0.050	1.77	9.16	19.3	1.073	15.79	0.74
25	34.49	4.215	1.440	0.232	0.044	2.07	10.93	19.0	1.096	16.12	0.67
mean						1.97	10.52	19.3		19.79	2.51
stds						0.38	2.96	3.3		3.72	1.90

Mass Bays Project
Index Analysis

Quincy/Neponset III
Collected: September 7, 1995
Processed: September 12, 1995
Dry wts: September 14,1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
Nep-3											
1	89.09	88.495	27.194	5.842	1.159	1.73	8.70	19.8	25.327	21.48	6.56
2	84.15	81.923	26.016	4.511	1.060	1.75	7.46	23.5	25.048	17.34	5.36
3	80.26	62.588	22.051	3.611	0.727	1.72	8.54	20.1	18.001	16.38	4.50
4	77.57	56.633	17.472	2.853	0.736	1.55	6.01	25.8	17.916	16.33	3.68
5	93.26	89.993	29.941	7.990	2.478	2.76	8.89	31.0	25.211	26.69	8.57
6	67.92	39.470	14.823	3.960	0.855	2.28	10.56	21.6	9.997	26.72	5.83
7	69.61	43.284	10.951	2.569	0.546	2.35	11.04	21.3	12.406	23.46	3.69
8	64.50	41.564	11.521	1.675	0.294	2.23	12.74	17.5	15.620	14.54	2.60
9	64.38	30.848	11.766	3.289	0.878	1.89	7.08	26.7	8.103	27.95	5.11
10	68.33	46.109	12.109	2.795	0.639	1.75	7.64	22.9	16.700	23.09	4.09
11	57.14	32.504	7.632	1.414	0.237	2.70	16.10	16.8	13.895	18.52	2.47
12	57.73	19.751	8.811	2.075	0.443	2.04	9.55	21.3	4.678	23.55	3.59
13	55.40	20.470	6.730	1.750	0.330	2.43	12.90	18.9	5.511	26.00	3.16
14	54.42	20.698	6.966	1.647	0.382	1.94	8.33	23.2	5.991	23.64	3.03
15	52.07	17.283	6.314	1.239	0.331	1.74	6.50	26.7	3.718	19.62	2.38
16	45.50	11.519	4.859	0.898	0.234	1.63	6.26	26.1	2.333	18.49	1.97
17	45.53	10.244	3.822	0.694	0.174	1.81	7.22	25.1	2.744	18.16	1.52
18	45.49	11.714	4.209	1.009	0.239	2.45	10.35	23.7	3.558	23.97	2.22
19	43.04	10.162	3.727	0.704	0.214	2.19	7.19	30.4	2.782	18.88	1.63
20	42.79	9.136	3.603	0.735	0.186	1.43	5.64	25.3	2.289	20.40	1.72
21	39.99	8.499	2.786	0.547	0.148	1.96	7.25	27.0	2.448	19.63	1.37
22	37.78	7.257	2.579	0.406	0.087	1.79	8.38	21.4	2.069	15.75	1.07
23	34.44	4.980	1.702	0.288	0.067	1.39	5.98	23.2	1.411	16.91	0.84
24	34.23	6.119	2.184	0.388	0.088	1.46	6.47	22.6	1.853	17.77	1.13
25	32.23	4.142	1.398	0.263	0.076	1.89	6.52	29.0	1.235	18.80	0.82
mean						1.95	8.53	23.6		20.56	3.16
stds						0.38	2.56	3.7		3.84	1.97

Mass Bays Project
Index Analysis

QUINCY/NEPONSET IV
Collected: DECEMBER 04, 1995
Processed: DECEMBER 07, 1995
Dry wts: DECEMBER 11, 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
NEP-4											
1	80.98	59.418	19.891	5.172	1.005	2.21	11.36	19.4	19.439	26.00	6.39
2	80.38	69.691	19.440	4.029	0.865	2.61	12.16	21.5	27.563	20.73	5.01
3	78.55	70.886	17.501	4.006	0.617	1.56	10.11	15.4	28.416	22.89	5.10
4	75.98	63.636	14.407	2.283	0.417	2.42	13.23	18.3	21.732	15.85	3.01
5	72.94	55.038	14.057	2.520	0.421	2.01	12.02	16.7	21.214	17.93	3.46
6	69.39	46.190	10.346	2.819	0.398	2.36	16.71	14.1	18.962	27.24	4.06
7	69.18	47.483	12.058	2.186	0.439	2.12	10.56	20.1	19.205	18.13	3.16
8	64.92	39.939	9.731	1.778	0.272	1.99	13.02	15.3	16.015	18.27	2.74
9	65.77	41.380	11.726	2.822	0.497	2.14	12.13	17.6	17.712	24.06	4.29
10	61.60	31.970	7.641	1.531	0.295	2.44	12.64	19.3	11.955	20.04	2.49
11	57.44	24.322	7.583	1.545	0.296	2.32	12.10	19.2	8.941	20.38	2.69
12	54.84	20.525	6.217	1.088	0.219	2.03	10.09	20.1	6.124	17.50	1.98
13	54.06	17.792	6.817	1.743	0.401	1.83	7.97	23.0	4.927	25.57	3.22
14	51.52	16.388	5.066	1.159	0.314	4.16	15.35	27.1	4.534	22.88	2.25
15	51.05	17.362	5.765	1.115	0.198	2.13	12.01	17.8	4.924	19.34	2.18
16	49.71	15.505	5.404	1.197	0.336	3.74	13.29	28.1	4.430	22.14	2.41
17	49.29	14.248	5.994	1.020	0.251	1.81	7.36	24.6	4.234	17.01	2.07
18	48.37	14.334	4.382	0.770	0.192	1.72	6.93	24.9	4.213	17.58	1.59
19	47.80	15.196	4.630	0.987	0.240	2.86	11.76	24.3	4.246	21.32	2.06
20	43.12	9.274	3.023	0.530	0.126	1.81	7.62	23.7	2.458	17.52	1.23
21	39.54	7.719	2.442	0.426	0.096	0.16	0.70	22.6	2.600	17.43	1.08
22	36.98	6.917	2.201	0.373	0.087	1.87	7.98	23.4	2.330	16.95	1.01
23	37.05	6.356	1.785	0.293	0.073	1.95	7.85	24.8	1.895	16.39	0.79
24	32.74	4.868	1.385	0.290	0.065	1.75	7.83	22.4	1.600	20.94	0.89
25	34.40	4.576	1.291	0.190	0.048	1.71	6.71	25.5	1.393	14.71	0.55
mean						2.15	10.38	21.2		19.95	2.63
stds						0.73	3.36	3.8		3.37	1.48

Mass Bays Project
Index Analysis

Saugus
Collected: April 25,1995
Processed: April 28,1995
Dry wts: May 1,1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
SAUGUS-1											
1	33.67	4.769	1.371	0.252	0.056	2.06	9.32	22.1	1.382	18.41	0.75
2	36.92	4.817	1.577	0.292	0.063	1.99	9.22	21.6	2.489	18.51	0.79
3	37.41	6.101	1.620	0.280	0.063	1.55	6.95	22.4	2.029	17.28	0.75
4	38.61	7.253	2.176	0.495	0.081	1.75	10.62	16.4	2.369	22.75	1.28
5	39.99	7.812	2.409	0.414	0.071	1.51	8.74	17.3	2.461	17.17	1.03
6	42.94	7.539	2.138	0.355	0.072	1.44	7.08	20.3	2.475	16.62	0.83
7	44.26	10.583	2.505	0.506	0.097	1.54	8.01	19.2	4.247	20.18	1.14
8	46.60	12.451	4.103	0.717	0.119	1.52	9.17	16.5	4.351	17.47	1.54
9	46.65	13.652	3.797	0.820	0.198	1.93	8.01	24.1	4.515	21.61	1.76
10	47.41	15.155	3.778	0.841	0.156	1.75	9.44	18.5	5.603	22.27	1.77
11	52.25	18.076	4.725	1.099	0.251	1.65	7.21	22.8	6.320	23.27	2.10
12	53.76	18.235	4.262	0.812	0.164	1.81	8.98	20.2	6.821	19.04	1.51
13	54.72	20.543	5.056	1.284	0.240	1.78	9.50	18.7	8.004	25.40	2.35
14	56.20	20.625	5.186	0.924	0.194	1.63	7.76	21.0	7.741	17.81	1.64
15	58.56	24.575	5.368	1.166	0.185	1.81	11.42	15.8	10.441	21.71	1.99
16	60.29	26.371	6.982	1.538	0.261	2.28	13.39	17.0	9.291	22.03	2.55
17	61.99	29.623	6.572	1.407	0.410	2.49	8.55	29.2	12.187	21.40	2.27
18	62.38	33.687	9.124	2.013	0.524	2.21	8.50	26.0	11.990	22.06	3.23
19	65.72	35.010	7.963	1.538	0.271	1.96	11.10	17.6	12.883	19.31	2.34
20	69.33	39.742	9.192	2.611	0.444	1.52	8.91	17.0	15.505	28.41	3.77
21	70.27	47.711	12.046	3.121	0.569	1.71	9.38	18.2	19.390	25.91	4.44
22	71.82	47.059	12.508	2.459	0.417	1.69	9.98	17.0	19.686	19.66	3.42
23	74.85	43.993	12.804	3.223	0.590	2.22	12.15	18.3	15.164	25.17	4.31
24	76.81	49.467	13.205	3.614	0.619	2.46	14.38	17.1	16.291	27.37	4.71
25	78.30	54.035	13.259	2.712	0.441	1.93	11.87	16.3	18.746	20.45	3.46
mean						1.85	9.59	19.6		21.25	2.23
stds						0.30	1.91	3.4		3.29	1.22

Mass Bays Project
Index Analysis

Saugus II
Collected: June 5,1995
Processed: June 9,1995
Dry wts: June 12,1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
SR2											
1	74.83	45.521	12.313	3.381	0.981	2.70	9.30	29.0	13.605	27.46	4.52
2	73.05	45.341	13.110	3.094	0.678	1.84	8.42	21.9	13.605	23.60	4.24
3	72.33	41.952	9.916	2.419	0.618	2.27	8.90	25.5	13.605	24.40	3.34
4	71.67	48.036	9.611	2.225	0.383	2.22	12.93	17.2	13.605	23.15	3.11
5	71.76	41.692	11.188	2.617	0.609	1.53	6.55	23.3	13.605	23.39	3.65
6	69.93	48.046	10.886	2.511	0.444	1.57	8.89	17.7	13.605	23.06	3.59
7	69.47	44.365	9.870	2.659	0.551	1.78	8.60	20.7	13.605	26.94	3.83
8	69.39	39.038	9.024	2.239	0.480	2.59	12.08	21.4	13.605	24.81	3.23
9	65.84	38.275	9.840	2.380	0.590	1.90	7.68	24.8	13.605	24.19	3.62
10	65.61	38.126	9.138	2.338	0.441	2.39	12.67	18.9	13.605	25.58	3.56
11	57.44	23.118	6.821	1.578	0.296	1.52	8.10	18.8	13.605	23.13	2.75
12	54.56	20.622	5.374	1.287	0.321	1.27	5.12	24.9	13.605	23.95	2.36
13	53.57	20.313	5.481	1.012	0.216	1.80	8.41	21.4	13.605	18.46	1.89
14	50.91	17.713	5.256	0.911	0.186	1.69	8.28	20.4	13.605	17.32	1.79
15	50.83	15.561	4.344	0.780	0.174	1.56	6.99	22.4	13.605	17.95	1.53
16	46.33	9.510	3.118	0.622	0.138	1.62	7.29	22.2	13.605	19.94	1.34
17	44.20	11.284	3.525	0.657	0.151	1.55	6.73	23.0	13.605	18.64	1.49
18	43.94	11.357	3.421	0.753	0.203	1.96	7.27	26.9	13.605	22.02	1.71
19	41.17	8.473	2.477	0.597	0.169	2.20	7.78	28.4	13.605	24.11	1.45
20	40.64	8.003	2.083	0.400	0.111	1.83	6.63	27.6	13.605	19.19	0.98
21	39.62	7.717	2.338	0.661	0.170	2.06	8.01	25.7	13.605	28.28	1.67
22	38.71	5.456	1.697	0.358	0.092	2.01	7.77	25.8	13.605	21.07	0.92
23	35.56	4.575	1.385	0.246	0.068	2.46	8.88	27.7	13.605	17.75	0.69
24	34.32	3.827	1.144	0.235	0.062	2.33	8.80	26.4	13.605	20.52	0.68
25	32.61	4.255	1.477	0.192	0.046	1.89	7.88	24.0	13.605	12.99	0.59
mean						1.94	8.40	23.4		22.08	2.34
stds						0.37	1.83	3.4		3.64	1.23

Mass Bays Project
Index Analysis

Saugus III
Collected: September 22, 1995
Processed: September 25, 1995
Dry wts: September 29, 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
SR3											
1	78.420	56.361	13.902	2.971	0.477	2.17	13.49	16.1	17.105	21.37	3.79
2	77.330	56.993	14.412	2.108	0.326	1.95	12.62	15.4	20.412	14.63	2.73
3	74.725	58.612	14.671	3.427	0.807	2.42	10.28	23.5	18.509	23.36	4.59
4	72.195	49.779	13.281	3.928	0.710	3.24	17.94	18.1	17.220	29.57	5.44
5	72.055	51.255	14.222	2.404	0.571	1.97	8.30	23.7	16.957	16.90	3.34
6	68.970	38.644	9.957	2.243	0.508	2.99	13.19	22.7	13.016	22.53	3.25
7	67.830	36.462	9.628	1.686	0.313	1.86	10.00	18.5	12.482	17.51	2.49
8	64.945	31.014	8.180	1.721	0.274	1.46	9.16	15.9	11.781	21.04	2.65
9	63.420	31.157	8.007	1.718	0.415	1.61	6.65	24.2	10.286	21.45	2.71
10	60.360	29.970	6.617	1.139	0.289	2.35	9.28	25.4	10.901	17.22	1.89
11	59.700	25.309	6.024	1.214	0.286	1.75	7.41	23.6	8.705	20.14	2.03
12	59.420	26.123	8.094	2.299	0.510	2.04	9.21	22.2	8.517	28.40	3.87
13	56.345	22.569	6.727	1.305	0.212	1.73	10.62	16.3	6.987	19.41	2.32
14	54.290	25.572	6.210	1.269	0.239	1.75	9.31	18.8	9.253	20.44	2.34
15	50.860	19.373	4.212	0.974	0.219	1.90	8.41	22.5	7.334	23.12	1.92
16	48.780	12.655	4.672	1.112	0.241	3.08	14.25	21.6	3.562	23.81	2.28
17	47.850	11.504	4.078	0.702	0.201	1.98	6.94	28.6	2.808	17.22	1.47
18	45.605	11.639	3.206	0.672	0.157	1.87	8.03	23.3	3.299	20.95	1.47
19	43.865	9.790	3.405	0.623	0.170	2.06	7.57	27.2	2.531	18.29	1.42
20	42.250	8.128	2.808	0.477	0.133	1.79	6.44	27.8	2.562	16.98	1.13
21	37.105	6.985	2.017	0.513	0.124	2.72	11.27	24.1	2.379	25.41	1.38
22	35.850	6.182	1.967	0.313	0.068	1.70	7.77	21.8	2.080	15.93	0.87
23	26.605	2.000	0.592	0.086	0.022	1.47	5.63	26.0	0.419	14.47	0.32
24	25.310	1.729	0.585	0.095	0.022	1.60	6.85	23.4	0.508	16.20	0.37
25	24.370	1.565	0.469	0.062	0.016	1.69	6.60	25.6	0.422	13.27	0.26
mean						2.05	9.49	22.3		19.99	2.25
stds						0.49	2.95	3.8		4.18	1.30

Mass Bays Project
Index Analysis

Saugus IV
Collected: DECEMBER 05 1995
Processed: DECEMBER 08, 1995
Dry wts: DECEMBER 11, 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
SR4											
1	76.730	51.746	11.172	2.456	0.319	1.57	12.12	13.0	17.826	21.99	3.20
2	75.335	57.850	13.615	3.329	0.491	1.96	13.30	14.7	22.413	24.45	4.42
3	73.785	54.371	14.093	3.167	0.743	2.79	11.91	23.5	19.537	22.47	4.29
4	72.730	46.796	13.930	3.718	0.661	1.74	9.77	17.8	17.323	26.69	5.11
5	70.660	44.861	13.293	2.527	0.399	1.49	9.45	15.8	15.320	19.01	3.58
6	68.020	38.412	9.415	1.610	0.306	1.86	9.77	19.0	14.785	17.10	2.37
7	67.395	31.393	5.140	0.855	0.124	1.61	11.06	14.5	11.288	16.64	1.27
8	64.515	33.036	8.973	2.021	0.423	2.73	13.06	20.9	12.711	22.52	3.13
9	63.270	28.634	7.419	1.156	0.213	1.65	8.94	18.4	10.184	15.58	1.83
10	62.340	28.693	8.034	1.515	0.314	2.14	10.31	20.7	10.493	18.85	2.43
11	57.770	23.706	7.746	1.477	0.388	2.19	8.32	26.3	8.078	19.06	2.56
12	55.685	21.779	5.608	1.279	0.357	3.01	10.78	27.9	8.144	22.81	2.30
13	55.880	19.271	5.859	1.429	0.316	1.54	6.97	22.1	5.994	24.39	2.56
14	54.355	23.323	6.899	1.108	0.218	1.87	9.48	19.7	8.838	16.06	2.04
15	50.595	15.703	4.920	0.754	0.138	1.77	9.66	18.3	5.307	15.32	1.49
16	49.145	14.963	4.247	0.775	0.175	1.76	7.78	22.6	5.158	18.24	1.58
17	46.570	10.695	3.489	0.628	0.134	1.37	6.43	21.3	3.830	17.99	1.35
18	44.485	10.358	3.164	0.619	0.126	2.66	13.05	20.4	3.165	19.55	1.39
19	42.150	8.938	2.456	0.410	0.071	2.07	12.02	17.3	3.410	16.68	0.97
20	40.560	7.685	2.522	0.391	0.077	1.32	6.76	19.6	2.445	15.50	0.96
21	38.860	5.412	2.045	0.337	0.079	1.55	6.60	23.5	1.630	16.50	0.87
22	38.795	7.009	2.146	0.349	0.085	1.75	7.15	24.4	2.550	16.26	0.90
23	38.070	6.567	1.721	0.261	0.060	1.76	7.71	22.8	2.233	15.18	0.69
24	36.460	5.004	1.875	0.292	0.070	1.33	5.55	23.9	1.566	15.55	0.80
25	34.210	4.261	1.358	0.234	0.056	1.53	6.37	24.0	1.360	17.21	0.68
mean						1.88	9.37	20.5		18.86	2.11
stds						0.47	2.36	3.7		3.36	1.26

Mass Bays Project
Index Analysis

Wellfleet harbor
Collected: 27 March 1995
Processed: 30-31 March 1995
Dry Weights: 4 April

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
WH-1											
1	30.45	3.852	1.937	0.572	0.351	2.67	4.35	61.3	0.964	29.56	1.88
2	35.53	6.055	2.491	0.740	0.225	3.45	11.37	30.3	1.976	29.72	2.08
3	35.66	5.036	2.480	0.613	0.167	3.06	11.21	27.3	1.537	24.73	1.72
4	38.73	7.653	2.428	0.548	0.145	2.24	8.49	26.4	2.474	22.57	1.41
5	38.39	8.737	3.584	1.088	0.328	3.61	11.99	30.1	2.607	30.35	2.83
6	41.43	8.433	3.865	1.193	0.338	3.72	13.13	28.3	2.440	30.87	2.88
7	40.53	10.491	4.995	1.643	0.546	3.49	10.51	33.2	2.758	32.90	4.05
8	43.84	13.560	6.716	2.902	0.796	4.09	14.90	27.5	3.706	43.21	6.62
9	48.54	16.259	6.977	2.217	0.737	3.47	10.45	33.2	4.574	31.77	4.57
10	46.66	13.622	5.953	2.015	0.540	2.84	10.60	26.8	3.641	33.85	4.32
11	50.22	18.716	7.964	2.597	0.764	2.87	9.76	29.4	5.002	32.61	5.17
12	54.25	18.433	9.101	3.198	1.020	4.28	13.43	31.9	5.155	35.14	5.90
13	57.34	24.724	11.623	3.394	1.036	3.10	10.15	30.5	6.840	29.20	5.92
14	54.76	23.192	10.902	3.879	1.143	3.89	13.20	29.5	6.164	35.58	7.08
15	59.83	27.160	11.943	3.936	1.202	3.17	10.39	30.5	7.419	32.95	6.58
16	62.27	35.376	17.936	7.938	1.914	2.89	11.97	24.1	7.800	44.26	12.75
17	60.46	32.836	11.918	4.176	1.083	3.35	12.90	25.9	8.460	35.04	6.91
18	61.73	38.484	15.966	7.004	1.953	2.91	10.42	27.9	11.101	43.87	11.35
19	61.47	37.238	16.000	7.483	1.916	4.58	17.88	25.6	12.316	46.77	12.17
20	60.35	29.660	14.554	4.847	1.467	2.65	8.75	30.3	7.249	33.30	8.03
21	74.30	66.555	23.559	7.969	2.372	3.24	10.87	29.8	18.480	33.82	10.73
22	84.37	92.017	30.029	8.783	2.452	3.51	12.58	27.9	33.257	29.25	10.41
23	82.03	81.339	29.957	10.841	2.577	3.39	14.28	23.8	26.996	36.19	13.22
24	80.84	82.068	31.177	12.844	3.075	3.45	14.42	23.9	23.922	41.20	15.89
25	82.59	96.517	31.283	10.156	1.913	2.68	14.21	18.8	30.976	32.47	12.30
mean						3.30	11.69	29.4		34.05	7.07
stds						0.55	2.63	7.4		5.94	4.20

Mass Bays Project
Index Analysis

Wellfleet Harbor II
Collected: 9 June 1995
Processed: 13 June 1995
Weighed: 19 June 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
WH-2											
1	92.73	123.775						29.9	40.754		
2	86.33	101.370	34.500	13.090	3.613	3.10	11.21	27.6	32.498	37.94	15.16
3	82.93	95.287	28.741	10.457	2.046	2.23	11.42	19.6	29.556	36.38	12.61
4	77.19	65.730	19.268	4.958	1.271	2.57	10.02	25.6	20.357	25.73	6.42
5	71.30	70.118	22.964	8.251	2.278	4.79	17.36	27.6	22.183	35.93	11.57
6	65.90	40.305	11.926	3.745	0.974	3.61	13.88	26.0	12.359	31.41	5.68
7	63.87	46.787	9.869	2.801	0.637	2.43	10.67	22.7	16.788	28.38	4.39
8	62.14	28.977	8.654	2.385	0.684	3.81	13.29	28.7	7.732	27.56	3.84
9	62.64	32.978	11.562	3.339	0.887	2.58	9.70	26.6	8.435	28.88	5.33
10	60.38	34.063	12.342	4.155	1.136	4.16	15.21	27.3	8.276	33.66	6.88
11	59.08	26.005	7.253	1.752	0.434	2.53	10.21	24.8	6.504	24.15	2.97
12	58.66	28.358	9.627	2.708	0.731	3.07	11.38	27.0	7.519	28.13	4.62
13	56.77	26.612	8.429	2.399	0.611	2.81	11.04	25.5	6.686	28.46	4.23
14	54.95	26.120	7.282	2.070	0.498	2.20	9.14	24.1	8.180	28.43	3.77
15	50.13	19.177	6.129	1.772	0.495	2.55	9.13	28.0	6.516	28.91	3.54
16	47.02	15.645	4.298	1.104	0.293	3.09	11.65	26.6	3.994	25.68	2.35
17	43.89	12.270	3.283	0.691	0.150	1.92	8.87	21.7	3.479	21.04	1.57
18	41.86	11.072	3.037	0.497	0.102	1.26	6.17	20.5	3.260	16.38	1.19
19	41.06	10.299	3.121	0.862	0.210	2.29	9.39	24.4	2.760	27.62	2.10
20	40.89	9.714	3.665	1.110	0.220	2.93	14.84	19.8	2.927	30.30	2.72
21	39.50	9.818	3.291	0.965	0.258	4.14	15.48	26.7	3.129	29.31	2.44
22	38.09	9.785	2.717	0.538	0.135	1.69	6.76	25.0	2.737	19.80	1.41
23	33.71	5.593	1.788	0.399	0.086	2.74	12.73	21.5	1.862	22.29	1.18
24	32.73	4.581	1.265	0.282	0.078	2.01	7.30	27.6	1.038	22.32	0.86
25	25.43	1.895	0.575	0.108	0.028	1.73	6.58	26.3	0.379	18.70	0.42
mean						2.76	10.98	25.2		27.39	4.47
stds						0.86	2.97	2.8		5.53	3.81

Mass Bays Project
Index Analysis

Wellfleet Harbor III
Collected: September 12, 1995
Processed: September 18, 1995
Weighed: September 20, 1995

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
WH-3											
1	79.98	72.025	16.070	3.543	0.956	1.87	6.95	27.0	24.300	22.05	4.43
2	79.44	76.437	21.744	4.923	1.032	2.09	9.97	21.0	21.587	22.64	6.20
3	76.45	74.757	19.219	7.551	1.864	3.10	12.57	24.7	29.199	39.29	9.88
4	75.45	63.441	17.434	5.079	0.797	2.00	12.74	15.7	19.448	29.13	6.73
5	71.18	55.559	15.210	3.349	0.765	2.37	10.37	22.9	16.766	22.02	4.71
6	67.68	49.905	11.334	2.265	0.538	1.41	5.92	23.7	17.234	19.98	3.35
7	67.04	44.428	13.273	5.178	0.867	2.96	17.65	16.7	16.794	39.01	7.72
8	65.57	47.236	10.440	2.131	0.508	3.39	14.20	23.9	12.722	20.41	3.25
9	64.94	44.084	12.554	3.094	0.481	2.05	13.18	15.5	14.532	24.64	4.76
10	61.91	34.782	9.877	2.516	0.346	1.13	8.22	13.7	9.986	25.47	4.06
11	59.91	34.213	11.177	2.480	0.566	1.97	8.64	22.8	8.850	22.19	4.14
12	57.59	27.382	6.572	1.099	0.190	2.64	15.24	17.3	7.605	16.73	1.91
13	56.58	27.134	7.485	1.420	0.243	1.90	11.07	17.1	6.954	18.97	2.51
14	56.63	31.479	9.366	2.718	0.475	1.31	7.47	17.5	8.821	29.02	4.80
15	55.05	18.106	5.025	1.078	0.235	2.42	11.12	21.8	9.048	21.46	1.96
16	47.80	18.289	5.294	1.153	0.203	2.13	12.11	17.6	5.320	21.79	2.41
17	47.36	18.260	4.501	0.832	0.134	1.87	11.61	16.2	5.930	18.49	1.76
18	44.79	11.531	2.964	0.354	0.069	1.65	8.48	19.5	3.787	11.94	0.79
19	43.08	11.564	2.991	0.501	0.110	2.03	9.26	21.9	3.756	16.75	1.16
20	42.30	1.906	2.334	0.577	0.116	1.96	9.80	20.1	3.363	24.71	1.36
21	38.58	9.075	1.872	0.347	0.070	2.29	11.40	20.1	3.123	18.56	0.90
22	38.65	7.488	1.717	0.456	0.071	3.01	19.28	15.6	2.212	26.56	1.18
23	37.85	8.702	2.589	0.458	0.093	2.81	13.84	20.3	2.630	17.68	1.21
24	36.58	6.758	1.965	0.457	0.091	2.43	12.16	20.0	1.668	23.25	1.25
25	35.75	5.477	1.436	0.249	0.052	1.59	7.71	20.7	1.475	17.37	0.70
mean						2.18	11.24	19.7		22.80	3.33
stds						0.57	3.24	3.4		6.32	2.41

Mass Bays Project
Index Analysis

WELLFLEET HARBOR IV
Collected: JANUARY 16, 1996
Processed: JANUARY 19, 1996
Weighed: FEBRUARY 1, 1996

Clam #	Length (mm)	Live Weight (g)	Wet Soft Weight (g)	D-G Complex (g)	D-G Dry Wgt (g)	% Lipid Wet Wgt	% Lipid Dry Wgt	% DM	Dry shell (g)	d-g index (si)	condition index (CI)
WH-4											
1	92.25	110.315	44.059	11.957	2.840	2.47	10.39	23.8	33.675	27.14	12.96
2	81.53	69.384	34.284	12.968	3.066	2.95	12.48	23.6	23.372	37.82	15.91
3	79.04	58.414	19.951	4.838	0.795	1.87	11.35	16.4	19.007	24.25	6.12
4	75.23	69.282	26.961	7.501	1.480	2.66	13.51	19.7	20.293	27.82	9.97
5	70.98	50.265	16.400	5.412	1.128	2.68	12.85	20.8	16.861	33.00	7.62
6	69.01	35.203	14.669	4.101	0.967	1.92	8.13	23.6	9.079	27.95	5.94
7	68.94	41.738	14.711	4.399	0.995	2.66	11.75	22.6	9.863	29.90	6.38
8	66.66	46.959	16.081	4.878	1.105	2.19	9.67	22.6	16.613	30.34	7.32
9	62.34	30.418	10.861	3.349	0.897	2.52	9.40	26.8	9.944	30.83	5.37
10	60.60	30.225	11.392	3.281	0.827	2.60	10.30	25.2	9.357	28.80	5.41
11	59.79	35.497	11.926	3.496	0.881	2.47	9.79	25.2	10.747	29.32	5.85
12	58.47	30.100	12.450	4.400	1.108	2.10	8.36	25.2	8.242	35.34	7.53
13	55.27	20.553	6.772	2.019	0.494	2.90	11.84	24.5	5.743	29.81	3.65
14	53.14	20.949	8.202	2.595	0.688	3.06	11.53	26.5	6.484	31.64	4.88
15	51.93	16.231	5.554	1.399	0.344	2.33	9.48	24.6	4.876	25.18	2.69
16	49.96	14.009	4.591	0.954	0.217	2.22	9.73	22.8	4.161	20.77	1.91
17	48.90	14.120	5.647	1.542	0.338	2.90	13.22	21.9	3.717	27.30	3.15
18	47.68	13.171	5.611	1.480	0.376	2.83	11.12	25.4	3.812	26.38	3.10
19	43.09	9.168	4.319	1.419	0.409	2.29	7.94	28.8	2.605	32.86	3.29
20	42.15	9.339	4.325	1.365	0.345	3.06	12.11	25.2	2.553	31.56	3.24
21	39.80	9.078	3.505	1.042	0.308	3.62	12.25	29.5	2.969	29.74	2.62
22	38.96	7.595	2.858	0.789	0.242	2.38	7.77	30.6	2.335	27.60	2.02
23	37.78	8.499	3.342	1.003	0.281	2.24	8.01	28.0	2.279	30.00	2.65
24	34.48	7.699	2.739	0.765	0.185	2.35	9.71	24.2	2.434	27.93	2.22
25	31.89	4.821	1.736	0.479	0.135	2.27	8.09	28.1	1.490	27.60	1.50
mean						2.54	10.43	24.6		29.23	5.33
stds						0.40	1.80	3.1		3.51	3.52

Table B2. Summary Statistics of Condition Index and Digestive Gland-Gonad Complex Parameters for Clams Collected at Each Site and Each Sampling Period.

site		time	
1	Barnstable	1	March 1995
2	Fort Point Channel	2	June 1995
3	Neponset	3	September 1995
4	Saugus	4	December 1995
5	Wellfleet		

mean and stds: by site

	Site	length	live wt	wet soft	DG wet	p-DM	DG dry	DG lipid	p-lipid-w	p-lipid-d	shell	dg index	ci
mean	1	55.88	31.552	12.3086 a	3.8359 a	25.38 a	1.0235 a	0.1191 a	2.56 a	10.26 ab	8.2627	26.43 a	6.10 a
stds		18.28	34.553	13.1150	5.1151	5.16	1.4687	0.1894	0.88	3.36	10.0967	7.35	10.77
mean	2	54.98	28.628	7.3264 b	1.3643 b	21.11 b	0.2815 c	0.0310 c	2.28 b	10.99 a	10.5804	17.93 b	2.19 b
stds		14.89	20.715	5.2485	1.1238	4.73	0.2305	0.0278	0.89	4.41	7.8834	3.82	1.38
mean	3	56.58	29.243	8.1701 b	1.7037 b	21.10 b	0.3453 c	0.0355 c	2.00 c	9.79 b	10.3090	19.78 c	2.60 b
stds		15.63	22.717	6.6759	1.5222	4.12	0.3381	0.0351	0.54	2.99	8.2940	3.95	1.68
mean	4	54.87	24.331	6.3764 b	1.3840 b	21.46 b	0.2838 c	0.0281 c	1.93 c	9.21 b	9.8813	20.54 c	2.23 b
stds		14.36	16.775	4.1433	1.0169	3.84	0.2060	0.0243	0.42	2.32	5.7139	3.79	1.24
mean	5	56.04	32.174	10.5890 a	3.2752 a	24.37 a	0.8049 b	0.0946 b	2.69 a	11.15 a	9.8734	28.38 d	5.00 a
stds		15.79	27.451	8.9389	3.1603	4.33	0.7786	0.1025	0.73	2.63	8.9871	6.72	3.77
stat sig		n.s.	n.s.	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p<0.0001	n.s.	p<0.0001	p<0.0001

means and stds: by time

	Time	length	live wt	wet soft	DG wet	p-DM	DG dry	DG lipid	p-lipid-w	p-lipid-d	shell	dg index	ci
mean	1	56.07	29.722	9.733	2.8352 a	23.75 a	0.7457 a	0.0869 a	2.56 a	10.86	9.8869	24.92 a	4.22 *
stds		15.97	27.985	10.172	3.7465	5.86	1.0882	0.1461	1.03	4.12	9.0931	8.15	4.18
mean	2	55.31	30.465	9.084	2.5990 ab	23.76 a	0.6398 a	0.0717 ab	2.36 b	10.11	10.9823	23.92 a	4.36 *
stds		16.46	28.428	9.755	3.8834	5.15	1.0657	0.1295	0.74	2.90	9.0274	6.74	9.50
mean	3	55.65	29.240	8.554	1.8836 b	21.65 b	0.4008 b	0.0419 c	2.08 c	9.94	9.1612	20.64 b	2.91 *
stds		15.81	22.646	6.616	1.7372	3.72	0.3979	0.0456	0.53	3.08	7.3364	4.74	2.04
mean	4	55.64	27.314	8.434	1.9272 b	21.59 b	0.4068 b	0.0457 b	2.17 c	10.21	9.1150	20.93 b	3.01 *
stds		15.09	21.341	6.946	2.0229	3.69	0.4527	0.0561	0.63	2.89	7.6706	5.69	2.40
stat sig		n.s.	n.s.	n.s.	p<0.011	p<0.0001	p<0.0001	p<0.0001	p<0.0001	n.s.	n.s.	p<0.0001	p<0.031

* no two times different

Table B3. Summary Statistics for the Interaction of Site and Sampling Time for the Parameters Reported in Table B2.

site		time	
1	Barnstable	1	March 1995
2	Fort Point Channel	2	June 1995
3	Neponset	3	September 1995
4	Saugus	4	December 1995
5	Wellfleet		

means and stds: time by site

	Site	Time	length	live wt	wet soft	DG wet		p-DM		DG dry		DG lipid		p-lipid-w		p-lipid-d		shell	dg index		ci	
mean	Barn	Mar	59.05	38.935	16.136	5.6064	a	30.77	a	1.7051	a	0.1962	a	2.99	ab	9.69	bc	10.2078	32.26	ab	7.57	ab
stds			20.76	45.612	16.911	6.1738		3.79		1.8107		0.2557		1.07		3.27		13.6288	4.98		5.85	
mean	FPC	Mar	54.97	26.938	7 223	1.3769	c	20.08	ef	0.2796	b	0.0342	c	2.67	bcd	13.40	a	10.1929	18.20	e	2.14	d
stds			15.82	21.532	6.128	1.3041		2.21		0.2552		0.0356		1.38		7.02		8.4294	2.48		1.47	
mean	Nep	Mar	55.63	26.864	6.542	1.3102	c	20.26	def	0.2450	b	0.0248	c	1 94	ef	9.73	bc	10.6260	18.83	de	2.11	cd
stds			13.53	16.834	4.336	0.9628		4.49		0.1678		0.0179		0.58		2.78		6.4841	4.77		1.18	
mean	Saug	Mar	55.26	23.955	6.149	1.3797	c	19.63	f	0.2622	b	0.0267	c	1.85	f	9.59	bc	8.8952	21.25	de	2.23	cd
stds			13.61	15.820	4.027	1.0253		3.36		0.1848		0.0224		0.30		1.91		5.9699	3.29		1.22	
mean	Well	Mar	55.46	31.920	12.613	4.5031	ab	28.05	b	1.2378	a	0.1500	ab	3.30	a	11.99	ab	9.5124	34.05	a	7.07	abc
stds			16.03	28.702	9.705	3.6035		3.32		0.8503		0.1220		0.55		2.19		9.5280	5.94		4 20	
mean	Barn	Jun	54 86	34.554	14.762	5.4199	a	27.36	b	1.4841	a	0.1682	a	2.84	b	10.55	bc	8.9706	30.60	ab	10.23	a
stds			18.80	41 622	16.479	7.0286		3.58		1.9628		0.2374		0.79		3.18		11.9182	7.45		19.90	
mean	FPC	Jun	54.48	29.180	7.015	1.5041	c	23.43	cde	0.3432	b	0.0361	c	2.29	cde	10.15	bc	10.9058	19.90	de	2.42	d
stds			15.68	19.533	4 746	1.2505		7 57		0.2799		0.0311		0.65		2.89		7.5721	4.93		1.67	
mean	Nep	Jun	56.90	30.252	8.060	1.7037	c	19.32	f	0.3050	b	0.0358	c	1.97	ef	10.52	bc	10.9337	19.79	de	2.51	d
stds			16.68	25.212	7 477	1 7097		3.26		0.2798		0 0393		0.38		2.96		9.7458	3.72		1 90	
mean	Saug	Jun	54 73	24 087	6.194	1.4460	c	23.44	cde	0.3271	b	0.0286	c	1 94	ef	8.40	c	13.6052	22.08	de	2.34	d
stds			14 45	16.711	3.916	1.0232		3.40		0.2410		0.0233		0.37		1.83		0.0000	3.64		1.23	
mean	Well	Jun	55.56	34.253	9.399	2.9349	bc	25.24	b	0.7439	b	0.0906	c	2.76	bc	10.98	bc	10.3962	27.39	c	4.29	bcd
stds			17.60	32.715	9.814	3.3073		2.83		0.8486		0.1113		0.86		2.97		10.7213	5.53		3.83	
mean	Barn	Sep	54.63	26.858	9.200	2.2075	c	22.33	cde	0.4762	b	0.0561	c	2.31	cde	10.68	bc	5.8977	21.43	de	3.37	cd
stds			16.86	22.974	7.582	2.2867		2.83		0.4793		0.0630		0.66		3.79		6.4392	4.77		2.69	
mean	FPC	Sep	55.50	31.065	8 228	1.5299	c	20.27	def	0.2962	b	0.0286	c	1.95	ef	9.77	bc	10.9887	18.43	f	2.46	d
stds			14.37	21.724	5.678	1.1325		3.61		0.2189		0.0199		0.45		2.15		7.6612	3.19		1 34	
mean	Nep	Sep	57.47	31.015	10.047	2.1260	c	23.64	cd	0.5044	b	0.0437	c	1.95	ef	8.53	c	9.2337	20.56	de	3.16	cd
stds			17.89	26.858	8.453	1.9141		3.71		0.5205		0.0459		0.38		2.56		8.1935	3.84		1.97	
mean	Saug	Sep	54.35	25.263	5.718	1 4024	c	22.26	cde	0.2923	b	0.0311	c	2.05	ef	9.49	bc	8.4014	19.99	de	2.25	d
stds			16.33	18.502	4 627	1 0476		3.83		0.2089		0.0293		0.49		2.95		6.2966	4.18		1.30	
mean	Well	Sep	56.32	32.001	8.578	2.1523	c	19.73	f	0.4348	b	0.0487	c	2.18	def	11.24	bc	10.2844	22.60	d	3.33	cd
stds			14.40	23.436	8 099	1 9241		3.37		0.4288		0.0537		0.57		3.24		7 7725	6.32		2.41	
mean	Barn	Dec	54.98	25.861	9.137	2.1101	c	21.04	def	0.4286	b	0.0516	c	2.09	ef	10.12	bc	6.9749	21.38	de	3.24	cd
stds			17.21	21.479	7.238	1.8546		3.31		0.3884		0.0608		0.63		3.28		6.5675	3.66		2.13	
mean	FPC	Dec	54 98	27.327	5.840	1 0462	c	20.63	def	0.2071	b	0.0250	c	2.20	def	10.76	bc	10.2341	15.21	f	1.72	d
stds			14.51	21.016	4 485	0.7128		2.93		0.1356		0.0217		0.69		3.32		8.2892	2.74		0.82	
mean	Nep	Dec	56.30	28.841	8.031	1.6748	c	21 17	def	0.3268	b	0.0372	c	2.15	def	10.38	bc	10.4425	19.95	de	2.63	d
stds			15.00	21.863	5.588	1.3023		3.83		0.2353		0.0296		0.73		3.36		8.8244	3.37		1.48	
mean	Saug	Dec	55.13	24.018	6.446	1.3078	c	20.50	def	0.2537	b	0.0259	c	1.88	f	9.37	bc	5.6234	18.86	df	2.11	d
stds			13.75	16.960	4.200	1.0294		3.75		0.1892		0.0226		0.47		2.36		6.3246	3.36		1.26	
mean	Well	Dec	56.79	30.521	11.718	3.4971	bc	24.63	c	0.8180	b	0.0889	bc	2.54	bcd	10.43	bc	9.3003	29.23	bc	5.33	bcd
stds			15.91	25.646	10.450	3.2500		3.15		0.7411		0.0883		0.40		1.80		8.1295	3.51		3.52	
stat sig			n.s	n.s.	n.s	p<0.0001		p<0.0001		p<0.0001		p<0.0001		p<0.0001		p=0.011		n.s.	p<0.0001		p<0.0001	

Table B4. Annual Matrix for Clam Populations at Each Site.

Barnstable Harbor

0	0	0	0	0	0	0	0
0	0.0005	0.0001	0.0005	0.0007	0.0014	0.0007	0.0024
0	0	0.0005	0.0014	0.0016	0.0062	0.0035	0.0079
1	0.11	0	0	0	0	0	0
0	0.3036	0.0267	0.0374	0.0116	0	0	0
0	0	0.0074	0.0267	0.0083	0	0	0
0	0	0.0016	0.0059	0.0018	0	0	0
0	0	0	0	0	0.0396	0.023	0.0801

Wellfleet Harbor

0	0	0	0	0	0	0	0
0	0.0001	0	0	0	0.0001	0.0001	0.0001
0	0	0.0001	0.0001	0.0001	0.0004	0.0008	0.0009
1	0	0	0	0	0	0	0
0	0.0864	0	0	0	0	0	0
0	0	0	0.0034	0.0029	0	0	0
0	0	0	0.002	0.0084	0.0178	0	0
0	0	0	0	0.0012	0.0085	0.0179	0.0144

Quincy-Neponset

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0.0345	0.0391	0.0883	0.1007	0.3105	0.3349
0.83	0.5561	0.1223	0.1126	0	0	0	0
0.083	0.2906	0.7971	0.7913	0.6948	0	0	0
0	0	0	0.0072	0.0864	0.5329	0	0
0	0	0	0	0	0.0055	0.375	0
0	0	0	0	0	0.0018	0.125	0.1779

Saugus River

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0.0013	0.0019	0.0033	0.0051	0.0115	0.0206
0.83	0.6889	0.1171	0.0808	0	0	0	0
0.083	0.2287	0.6687	0.7353	0.7776	0	0	0
0	0	0	0.0186	0.1228	1	0	0
0	0	0	0	0.0005	0.0075	0.5625	0
0	0	0	0	0.0002	0.0025	0.3627	0.4041

Fort Point Channel

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0.0031	0.0049	0.0078	0.0126	0.0284	0.0431
1	0	0	0	0	0	0	0
0	0	0.25	0.4975	0.73	0	0	0
0	0	0	0	0.0007	0.005	0	0
0	0	0	0	0.001	0.0075	0.0045	0
0	0	0	0	0.0005	0.004	0.0048	0.0158

Table B5. Seasonal Matrices for Clam Populations at Each Site.

Barnstable Harbor

Spring	0	0	0	0	0
	1	0.31	0	0	0
	0	0.38	0.14	0	0
	0	0.07	0.43	0.25	0
	0	0	0.43	0.25	0.87
Summer	0	0	0	0	0
	0.1	0.14	0	0	0
	0	0.05	0	0	0
	0	0.05	0.3	0	0
	0	0	0	0	0.3
Fall	0.11	0	0	0	0
	0.33	0.29	0	0	0
	0	0.09	0.4	0	0
	0	0	0	0	0
	0	0	0	0	0.33
Winter	1	0	0	0	0
	0	0.92	0	0	0
	0	0	0.82	0	0
	0	0	0.18	0.89	0
	0	0	0	0	0.93

Wellfleet Harbor

Spring	0.08	0	0	0	0
	0.31	0.26	0	0	0
	0	0.18	0.5	0	0
	0	0.07	0.5	0.6	0
	0	0	0	0.4	0.75
Summer	0	0	0	0	0
	0	0	0	0	0
	0	0.03	0	0	0
	0	0	0.2	0	0
	0	0	0	0.08	0.09
Fall	0	0	0	0	0
	0.09	0.06	0	0	0
	0	0	0.4	0	0
	0	0	0.2	0.2	0
	0	0	0	0	0.22
Winter	1	0	0	0	0
	0	0.96	0	0	0
	0	0	0.92	0	0
	0	0	0.08	0.89	0
	0	0	0	0	0.97

Quincy-Neponset

Spring	0.92	0	0	0	0
	0.08	0.96	0	0	0
	0	0	0.72	0	0
	0	0	0	1	0
	0	0	0	0	0.56
Summer	0.22	0	0	0	0
	0.78	0.77	0	0	0
	0	0.09	0.73	0	0
	0	0	.01	0.5	0
	0	0	0	0	0.68
Fall	0.67	0	0	0	0
	0.25	1	0	0	0
	0	0	1	0	0
	0	0	0	1	0
	0	0	0	0	0.64
Winter	0.83	0	0	0	0
	0.08	0.94	0	0	0
	0	0	1	0	0
	0	0	0	0.75	0
	0	0	0	0.25	0.73

Saugus River

Spring	0.69	0	0	0	0
	0.31	0.89	0	0	0
	0	0.08	1	0	0
	0	0	0	1	0
	0	0	0	0	0.93
Summer	0.17	0	0	0	0
	0.67	0.94	0	0	0
	0	0.06	1	0	0
	0	0	.01	0.75	0
	0	0	0	0.25	0.62
Fall	0.83	0	0	0	0
	0.17	1	0	0	0
	0	0	1	0	0
	0	0	0	1	0
	0	0	0	0	0.96
Winter	No Data				

Fort Point Channel

Spring	0.67	0	0	0	0
	0.33	0.73	0	0	0
	0	0.13	1	0	0
	0	0	0	1	0
	0	0	0	0	0.79
Summer	0.5	0	0	0	0
	0.25	1	0	0	0
	0	0	0.5	0	0
	0	0	0.5	0.6	0
	0	0	0	0	0.5
Fall	0	0	0	0	0
	0	1	0	0	0
	0	0	.01	0	0
	0	0	.01	.01	0
	0	0	0	.01	0.05
Winter	1	0	0	0	0
	0	1	0	0	0
	0	0	1	0	0
	0	0	0	0.75	0
	0	0	0	0	0.8

Table B6. Adult Clam Growth and Survival from March 1995 to March 1996. In each table, clam length at the time clams are deployed is to the left of the vertical bar, fate (M=missing, A=alive, D=dead) of clams at time of recovery is just to the right of the vertical bar, length of clams at time of recovery is in the next column, and growth over the time period is in the final column. The size at the end of one time period is the size at the beginning of the next time period for living clams. Spaces in the tables demarcate the size classes at the starting time. Data is sorted so that the lengths at the end time are in ascending order. a) Three month deployments in Barnstable Harbor b) Three month deployments in Fort Point Channel c) Three month deployments in Quincy-Neponset River d) Three month deployments in Saugus River e) Three month deployments in Wellfleet Harbor f) One year deployments at all sites.

WELLFLEET HARBOR — Three Month Deployments

March (t=0)		June (t=1)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
19	35.35	M		
5	35.54	M		
18	39.45	M		
7	35.05	M		
1	33.15	M		
16	36.75	M		
11	36.22	M		
17	32.00	D	31.71	-0.29
23	35.40	D	34.62	-0.79
6	36.13	D	34.83	-1.29
4	35.14	D	36.36	1.22
9	35.99	D	35.88	1.58
13	38.37	D	39.14	0.77
3	34.95	A	39.41	4.46
15	38.50	A	41.52	3.02
2	34.23	D	41.65	7.42
14	38.10	D	42.34	3.24
10	38.71	A	43.95	5.24
8	39.01	A	44.37	5.36
12	39.47	A	44.39	4.92
27	42.57	M		
24	47.80	M		
33	43.71	M		
32	42.24	D	42.14	-0.14
29	40.50	D	46.50	6.00
40	45.77	D	46.76	0.99

SAUGUS RIVER — Three Month Deployments

March (t=0) clam #	length (mm)	June (t=1) fate	length (mm)	growth (mm/3 mo)
7	30.02	M		
6	37.29	M		
8	30.00	M		
2	35.67	M		
19	31.70	A	31.64	-0.13
11	26.11	A	34.12	8.01
15	30.29	A	35.00	4.81
18	30.76	A	36.00	5.34
10	32.69	A	36.86	4.17
16	32.85	A	37.54	4.69
12	33.97	A	38.71	4.74
14	35.39	A	38.83	3.44
3	33.19	A	39.14	5.95
9	34.87	A	39.29	4.42
4	39.65	A	39.57	-0.08
5	37.90	A	41.07	3.17
20	38.19	A	41.06	3.47
13	38.21	A	42.51	4.30
1	37.77	A	42.58	4.81
17	39.23	A	44.97	5.74
23	40.30	M		
34	48.17	M		
37	40.70	A	41.24	0.54
23	40.20	A	43.31	3.12
32	43.10	A	46.12	3.02
28	44.74	A	47.00	2.26
39	47.55	A	47.15	-0.40
31	41.45	A	47.29	5.84
36	46.25	D	47.48	1.23
33	41.52	A	47.67	6.16
21	48.12	A	47.65	-0.27
27	48.69	A	48.29	-0.40
22	48.72	A	49.08	0.36
28	44.35	A	49.75	5.41
29	48.46	A	50.03	1.57
40	47.78	A	50.12	2.34
38	41.73	A	50.13	8.40
35	48.15	A	50.13	1.98
30	44.40	A	51.06	6.67
24	48.31	A	52.26	3.95
44	51.73	M		
55	57.40	M		
48	53.62	M		
42	52.08	M		
52	58.69	M		
54	50.97	A	50.57	-0.40
57	51.84	A	52.12	0.28
46	52.72	A	52.61	-0.11
51	54.14	A	53.74	-0.40
49	54.33	A	54.35	0.02
59	54.97	A	54.86	-0.11
45	56.45	A	55.70	-0.75
41	54.03	A	56.22	2.20
50	56.54	A	56.40	-0.14
53	52.79	A	56.46	3.67
47	57.15	A	56.64	-0.51
43	58.27	A	57.22	-1.05
60	57.47	A	57.55	0.08
58	58.92	A	58.77	-0.14
56	58.79	A	58.97	0.19
74	66.19	M		
63	61.54	M		
71	61.89	A	61.48	-0.42
61	63.56	A	62.97	-0.81
70	64.00	A	64.10	0.15
63	63.41	A	64.30	-1.11
75	64.97	A	64.50	-0.47
78	64.58	A	64.94	0.36
64	65.11	A	64.98	-0.13
66	67.26	A	66.53	-0.72
72	67.20	A	66.80	-0.39
73	67.96	A	67.29	-0.66
67	69.04	A	67.75	-1.29
62	67.98	A	67.79	-0.19
79	68.55	A	68.23	-0.32
69	68.52	A	68.27	-0.25
80	68.20	A	68.44	0.25
76	68.71	A	68.65	-0.06
77	69.02	A	68.80	-0.22
68	68.76	A	69.23	0.47
89	78.25	M		
94	73.39	A		
95	70.21	M		
82	70.00	A	69.54	-0.46
81	70.02	A	69.72	-0.29
86	71.23	D	69.74	-1.49
87	71.12	D	69.83	-1.29
97	70.45	A	69.91	-0.54
93	70.80	A	70.40	-0.40
91	71.97	A	70.51	-1.46
98	70.45	A	70.53	0.08
85	72.00	A	70.63	-1.37
96	72.35	A	72.23	-0.12
83	73.09	A	72.45	-0.63
92	74.65	A	73.44	-1.21
88	75.12	A	73.55	-1.57
90	75.70	A	74.70	-1.00
84	73.56	A	74.73	1.17

June (t=1) clam #	length (mm)	September (t=2) fate	length (mm)	growth (mm/3 mo)
106	36.36	M		
18	37.54	M		
16	36.09	M		
109	38.24	M		
8	39.29	M		
4	39.57	M		
12	38.71	M		
3	39.14	M		
100	32.70	M		
104	34.05	M		
107	33.06	M		
105	35.82	M		
15	35.00	M		
11	34.12	M		
108	34.59	D	34.46	-0.13
19	31.64	A	35.63	3.99
102	37.42	A	40.24	2.82
101	37.54	A	40.29	2.75
10	36.86	A	41.23	4.37
14	38.83	A	46.16	7.33
110	46.20	M		
26	49.75	M		
31	47.29	M		
39	47.15	M		
21	47.65	M		
22	49.08	M		
13	42.51	M		
37	41.24	M		
23	43.31	M		
1	42.58	M		
5	41.07	A	41.92	0.85
20	41.08	A	44.63	3.03
17	44.97	A	45.68	0.71
28	47.00	A	46.24	-0.76
111	46.93	A	47.81	0.88
33	47.67	A	48.13	0.46
27	48.29	A	49.19	0.90
113	46.93	A	50.40	3.47
112	47.29	A	50.93	3.64
32	46.12	A	53.63	7.51
51	53.74	M		
41	56.22	M		
24	52.26	M		
45	53.70	M		
59	54.86	M		
58	58.97	M		
57	52.12	M		
40	50.12	M		
29	50.03	M		
60	57.55	M		
50	56.40	M		
54	50.57	A	50.20	-0.37
35	50.13	A	52.13	2.00
46	52.61	A	52.50	-0.11
30	51.06	A	53.81	2.75
38	50.13	A	54.49	4.36
47	56.64	A	56.99	0.35
49	54.35	A	58.12	3.77
43	57.22	A	58.15	0.93
58	58.77	A	58.52	-0.25
53	56.46	A	59.68	3.22
73	67.29	M		
64	64.98	M		
67	67.75	M		
69	68.27	M		
79	68.23	M		
63	64.30	M		
61	62.97	M		
71	61.48	A	61.65	0.19
70	64.10	A	63.85	-0.33
75	64.50	A	64.88	0.38
78	64.94	A	65.23	0.29
72	66.80	A	66.70	-0.10
66	66.53	A	66.82	0.29
80	68.44	A	67.85	-0.59
76	68.65	A	67.88	-0.77
77	68.80	D	67.94	-0.86
62	67.79	A	68.02	0.23
68	69.23	A	69.17	-0.06
81	69.72	A	69.34	-0.38
82	69.54	A	69.68	0.14
97	69.91	D	69.93	0.02
90	74.70	M		
117	71.85	M		
88	73.55	M		
118	74.60	M		
115	71.36	M		
91	70.51	M		
85	70.63	M		
98	70.53	A	70.04	-0.49
93	70.40	D	70.25	-0.15
96	72.23	D	71.13	-1.10
99	72.68	D	71.94	-0.74
119	72.30	A	72.10	-0.11
83	72.45	A	72.42	-0.03
84	74.73	A	72.83	-1.90
92	73.44	A	73.33	-0.11
120	76.82	D	76.79	-0.03

September (t=2) clam #	length (mm)	December (t=3) fate	length (mm)	growth (mm/3 mo)
206	39.35	M		
214	38.06	M		
19	35.63	M		
208	39.38	M		
209	39.85	M		
207	39.52	M		
202	39.47	M		
217	33.56	M		
200	33.38	M		
205	33.64	M		
215	34.34	M		
204	32.19	M		
210	34.98	M		
213	34.86	M		
218	37.35	A	36.61	-0.74
203	33.39	A	36.90	3.51
216	38.87	A	38.91	0.04
212	39.72	A	39.47	-0.25
201	38.63	A	39.78	1.15
211	38.04	A	40.63	2.63
27	49.19	M		
226	49.26	M		
17	45.68	M		
28	46.24	M		
223	47.80	M		
225	49.14	M		
227	46.80	M		
5	41.92	M		
101	40.29	M		
102	40.24	M		
222	43.61	M		
20	44.63	M		
221	43.51	M		
10	41.23	A	40.86	-0.37
14	46.16	A	45.93	-0.23
220	46.05	A	46.12	0.07
224	47.24	A	46.86	-0.38
111	47.81	A	47.11	-0.70
33	48.13	A	47.34	-0.79
38	54.49	M		
232	54.29	M		
43	58.15	M		
233	58.28	M		
56	58.52	D		
53	59.68	M		
112	50.93	M		
113	50.40	M		
54	50.20	M		
32	53.63	M		
46	52.50	M		
35	52.13	M		
30	53.81	A	52.59	-1.22
49	58.12	A	55.04	-3.08
234	55.49	A	55.82	0.33
231	57.91	A	55.99	-1.92
47	56.99	A	56.21	-0.78
235	57.78	A	57.20	-0.58
230	59.77	A	57.86	-1.91
70	63.85	M		
243	63.47	M		
241	63.32	M		
76	67.88	M		
245	66.42	M		
240	63.06	M		
71	61.65	M		
246	60.96	A	60.52	-0.44
242	61.64	A	61.07	-0.57
244	63.08	A	62.61	-0.47
75	64.88	A	63.34	-1.54
66	66.82	A	64.08	-2.74
78	65.23	A	64.63	-0.60
72	66.70	A	65.49	-1.21
247	67.39	A	66.38	-1.01
80	67.85	A	66.65	-1.20
62	68.02	A	67.01	-1.01
81	69.34	A	68.65	-0.69
82	69.68	A	68.77	-0.91
68	69.17	D	68.77	0.40
92	73.33	M		
253	70.79	M		
119	72.10	M		
200	70.04	M		
250	70.15	M		
98	70.04	A	68.78	-1.26
252	70.96	A	68.83	-2.13
251	70.45	A	69.03	-1.42
231	72.17	A	71.28	-1.89
258	72.87	A	71.37	-1.50
257	72.51	A	71.78	-0.73
83	72.42	A	72.13	-0.29
84	72.83	A	72.33	-0.50
256	76.17	A	72.83	-3.34
255	73.73	A	72.85	-0.88
254	73.10	A	73.13	0.03
253	76.07	A	75.81	-0.26
250	76.59	A	76.33	-0.26
118	77.25	A	76.61	-0.64
260	82.37	A	80.58	-1.79

December (t=3) clam #	length (mm)	March (t=4) fate	length (mm)	growth (mm/3 mo)
NO DATA				

QUINCY-NEPONSET RIVER   Three Month Deployments

March (t=0) clam #	length (mm)	June (t=1) fate	length (mm)	growth (mm/3 mo)
14	30.13	M		
9	29.03	M		
8	29.03	M		
11	35.80	M		
13	35.34	M		
1	29.72	M		
20	33.12	M		
3	37.47	M		
16	27.70	A	28.66	0.965
19	31.67	A	31.64	-0.03
17	28.23	A	31.66	3.43
2	31.55	A	31.91	0.365
18	28.02	A	33.61	5.595
10	30.11	A	34.00	3.87
4	32.54	A	36.28	3.745
15	30.95	A	36.59	5.645
5	37.10	A	38.35	1.255
7	33.35	A	38.63	5.28
6	34.54	A	38.68	4.14
12	38.94	A	43.01	4.075
31	46.51	M		
32	43.83	M		
28	46.09	M		
24	40.23	A	41.56	1.33
23	40.59	A	41.78	1.195
40	43.15	A	42.84	-0.31
25	43.60	A	43.23	-0.365
30	43.00	A	43.56	0.56
22	41.50	A	43.66	2.16
37	44.75	A	44.25	-0.5
36	41.15	A	44.98	3.83
33	43.03	A	45.16	1.475
29	43.60	A	45.18	-0.42
38	44.45	A	45.51	1.06
26	42.10	A	46.26	4.16
35	45.34	D	46.43	1.095
21	45.69	A	46.54	0.85
29	47.64	A	47.90	0.255
27	49.09	A	48.42	-0.665
34	49.12	A	49.78	0.66
47	53.07	M		
46	57.31	D		
48	58.04	D		
60	56.77	M		
50	57.53	D		
42	50.38	A	50.33	-0.05
49	51.56	A	51.29	-0.27
51	52.25	A	52.13	-0.115
41	52.60	A	52.37	-0.23
52	52.40	A	52.57	0.17
54	54.27	A	53.61	-0.655
55	54.17	A	53.83	-0.335
44	55.17	A	54.72	-0.443
45	55.54	A	55.01	-0.525
53	55.56	A	55.24	-0.330
56	56.16	A	55.62	-0.535
57	56.01	A	55.8	-0.205
43	56.44	A	56.45	0.015
58	58.50	A	57.42	-1.075
59	58.62	A	58.16	-0.46
78	61.49	M		
67	66.90	M		
77	67.89	D		
75	63.49	M		
76	66.99	D		
66	65.33	D		
61	61.25	A	60.57	-0.68
69	62.53	A	61.73	-0.8
62	63.60	A	63.01	-0.68
80	63.70	A	63.24	-0.46
79	64.39	A	63.44	-0.945
63	64.81	A	64.19	-0.615
70	65.14	A	64.24	-0.895
71	66.01	A	65.23	-0.78
65	67.20	D	65.96	-1.235
74	67.34	A	66.32	-1.015
68	67.40	A	67.11	-0.285
64	69.02	A	68.6	-0.42
72	69.01	A	69.03	-0.575
73	69.89	A	69.5	-0.385
89	71.17	M		
88	71.90	M		
90	75.70	M		
98	73.41	D		
94	73.63	D		
82	84.44	M		
81	93.89	D		
96	71.89	D	70.59	-1.3
93	72.06	A	71.15	-0.905
87	74.96	A	73.97	-0.985
95	74.89	A	74.76	-0.13
97	76.00	A	75.23	-0.765
83	76.50	D	75.85	-0.65
86	78.73	A	78.09	-0.635
99	79.43	A	79.46	0.035
85	82.27	D	80.46	-1.81
100	82.21	D	81.8	-0.405
92	82.84	A	81.89	-0.95
91	88.00	A	87.09	-0.905
84	82.32	D	87.81	5.29

June (t=1) clam #	length (mm)	September (t=2) fate	length (mm)	growth (mm/3 mo)
101	24.75	M		
19	31.64	A	32.67	1.03
109	30.86	A	38.72	7.86
2	31.91	A	39.28	7.37
104	30.17	A	39.56	9.40
17	31.66	A	40.28	8.62
103	28.47	A	40.33	11.86
102	27.58	A	40.58	13.00
16	28.66	A	41.09	12.43
108	29.74	A	41.45	11.71
105	37.23	A	43.49	6.26
15	36.59	A	44.19	7.60
18	33.61	A	44.65	11.04
10	34.08	A	44.72	10.64
107	31.80	A	45.63	13.83
106	32.33	A	47.14	14.81
4	36.28	A	48.73	12.45
6	38.60	A	49.78	11.10
7	38.63	A	53.08	14.45
112	49.44	M		
22	43.66	M		
27	48.42	M		
38	45.51	M		
34	49.78	M		
40	42.84	M		
37	44.25	A	44.19	-0.06
111	41.56	A	44.84	3.29
33	45.18	D	45.02	-0.16
25	43.23	A	46.80	3.57
24	41.56	A	47.10	5.54
33	45.16	A	48.46	3.30
23	41.78	A	49.53	7.75
29	47.09	A	48.84	1.05
30	43.56	A	49.96	6.40
110	47.54	A	50.49	2.95
36	44.98	A	50.78	5.80
12	43.01	A	51.94	8.93
26	46.26	A	53.59	7.33
21	46.54	A	55.04	8.50
52	52.57	M		
41	52.37	M		
134	52.00	M		
116	53.08	M		
49	51.29	M		
42	50.33	A	49.96	-0.37
115	50.99	A	50.29	-0.70
53	55.24	D	50.54	-4.70
51	52.13	A	52.31	0.18
54	53.61	D	53.53	-0.08
132	54.50	A	54.07	-0.43
113	54.63	A	54.71	0.08
55	53.83	A	54.72	0.89
45	55.01	A	55.49	0.48
57	55.80	A	55.82	0.02
44	54.72	A	55.90	1.18
56	55.62	A	55.91	0.29
114	57.30	D	57.00	-0.30
59	58.16	A	57.96	-0.20
43	56.45	A	58.03	1.58
58	57.42	A	58.36	0.94
71	65.23	M		
63	64.19	M		
121	60.42	M		
61	60.57	A	60.94	0.37
120	62.91	D	61.29	-1.62
79	63.44	A	62.31	-1.13
119	61.52	D	62.39	0.87
62	63.01	D	62.68	-0.33
68	61.73	A	62.80	1.07
80	63.24	A	63.80	0.56
70	64.24	D	63.95	-0.29
117	66.54	A	63.69	-0.65
74	66.52	A	66.87	0.35
69	67.11	A	67.03	-0.08
118	66.64	A	67.05	0.41
136	69.00	D	68.98	-0.10
64	68.60	A	69.06	0.46
73	69.50	A	69.62	0.12
72	69.03	D	69.73	0.70
97	73.23	M		
95	74.78	M		
96	78.00	M		
122	80.04	M		
126	80.03	M		
131	72.92	D	70.33	-2.59
93	71.15	A	71.76	0.61
130	72.99	A	72.72	-0.27
133	70.56	D	73.58	3.02
124	74.94	D	73.60	-1.34
87	73.97	A	74.81	0.84
132	79.78	D	79.26	-0.52
99	79.46	A	79.33	-0.13
92	81.89	A	81.77	-0.12
128	83.02	A	82.00	-1.02
129	85.66	D	85.10	-0.56
91	87.09	A	85.68	-1.41
123	86.60	A	86.29	-0.31
125	93.17	A	92.60	-0.57

September (t=2) clam #	length (mm)	December (t=3) fate	length (mm)	growth (mm/3 mo)
204	37.19	M		
211	36.32	M		
201	36.49	M		
205	36.36	M		
200	36.96	M		
212	35.43	M		
19	32.67	M		
207	36.11	M		
213	35.22	A	35.21	-0.01
206	35.97	A	36.31	0.34
209	37.09	A	37.21	0.12
210	36.96	D	37.32	0.36
214	36.06	A	36.43	-0.01
109	36.72	A	36.34	0.62
202	36.50	A	36.41	-0.09
215	36.70	A	36.68	-0.02
2	38.20	A	38.96	0.60
104	39.66	A	40.88	1.22
203	38.36	A	41.73	3.37
200	39.64	A	41.92	2.28
24	47.10	M		
25	48.00	M		
107	45.63	M		
33	48.46	M		
29	46.84	M		
4	48.73	M		
23	49.53	M		
15	44.19	M		
102	40.58	M		
18	44.65	M		
10	44.72	M		
103	40.33	A	39.59	-0.74
108	41.43	A	40.63	-0.80
37	44.19	A	44.18	-0.01
111	44.84	A	44.81	-0.03
106	47.14	A	47.05	-0.09
6	49.78	A	49.25	-0.53
30	48.96	A	48.45	-0.51
42	49.90	A	49.89	-0.01
45	53.40	M		
44	55.90	M		
113	54.71	M		
55	54.72	M		
58	58.30	M		
220	58.23	M		
221	57.01	M		
50	57.96	M		
115	50.29	M		
12	51.94	M		
125	54.07	M		
26	53.29	M		
36	50.78	A	48.67	-2.11
110	50.49	A	50.46	-0.03
7	53.08	A	51.99	-1.09
51	52.31	A	52.17	-0.14
57	53.82	A	53.04	-0.78
56	55.91	A	55.19	-0.72
43	58.03	A	57.46	-0.57
21	55.04	A	59.31	4.27
233	64.80	M		
74	66.87	M		
230	65.65	M		
231	68.67	M		
64	69.06	M		
61	60.94	M		
79	62.21	M		
232	67.11	M		
237	62.56	M		
68	62.80	A	62.36	-0.44
80	63.80	A	62.66	-1.14
234	63.53	A	63.53	0.00
117	63.69	A	64.65	-1.04
118	67.05	D	65.13	-1.92
69	67.03	A	66.66	-0.37
236	67.15	A	66.91	-0.24
239	65.82	A	68.21	2.39
73	68.62	A	68.16	-0.46
90	79.33	M		
240	72.15	M		
83	71.76	M		
244	70.35	D	69.29	-1.06
243	70.84	A	69.78	-1.06
130	72.72	A	71.34	-1.38
242	76.16	A	72.23	-3.93
248	76.91	D	75.32	-1.59
242	78.82	A	76.93	-1.89
247	78.46	A	78.01	-0.45
126	82.80	A	81.59	-1.21
82	81.77	D	81.65	0.08
240	89.47	D	83.11	-6.36
249	83.24	D	83.17	-0.07
91	85.68	D	85.67	-0.01
123	86.29	A	85.99	-0.30
250	88.48	A	87.74	-0.74
241	88.60	A	87.76	-0.84
125	92.60	D	90.75	-1.85

December (t=3) clam #	length (mm)	March (t=4) fate	length (mm)	growth (mm/3 mo)
210	37.32	M		
2	38.96	M		
206	36.31	M		
103	39.59	M		
202	32.41	M		
302	38.73	M		
214	38.43	M		
304	35.31	M		
306	35.31	D		
309	33.60	M		
307	33.62	A	33.89	0.27
303	34.82	A	35.19	0.37
213	35.21	A	35.50	0.29
311	35.42	A	36.05	0.63
310	36.36	A	36.27	-0.09
209	37.21	A	37.66	0.45
305	37.31	A	37.73	0.42
308	38.25	A	38.35	0.10
301	39.66	A	39.37	-0.29
109	39.34	A	39.68	0.34
215	39.68	A	40.05	0.37
36	48.67	M		
203	41.73	M		
42	49.95	M		
37	44.18	M		
106	47.05	M		
315	45.26	M		
108	40.63	A	40.50	-0.09
104	40.88	A	41.00	0.12
200	41.92	A	41.69	-0.23
317	41.85	D	41.91	0.06
310	40.85	A	42.06	1.21
300	41.35	A	42.36	0.01
111	44.81	A	44.69	-0.12
312	44.57	A	45.13	0.56
314	46.31	A	46.90	0.59
313	46.63	A	47.01	0.38
27	46.31	A	46.56	0.25
30	49.45	A	49.25	-0.20
6	49.25	A	49.30	0.05
320	51.92	M		
319	53.27	M		
330	56.80	M		
329	57.32	M		
7	51.99	M		
323	50.30	M		
324	50.63	M		
318	51.85	M		
110	50.46	A	50.69	0.23
51	52.17	A	51.99	-0.18
325	52.64	A	52.93	0.29
321	54.07	A	54.12	0.05
326	54.00	A	54.41	0.41
21	59.31	A	54.78	-4.53
57	53.04	A	53.19	0.15
56	55.19	A	55.52	0.33
327	56.19	A	56.42	0.23
328	56.45	A	56.54	0.09
43	57.46	A	56.78	-0.68
322	57.49	A	58.02	0.53
331	59.13	A	59.22	0.09
334	67.32	M		
339	65.01	M		
338	66.91	M		
332	65.19	M		
345	68.98	M		
330	62.34	M		
333	67.89	M		
335	60.49	A	60.64	0.15
80	62.66	A	63.33	0.67
234	63.53	A	63.51	-0.02
337	63.48	A	63.98	-1.50
343	63.87	A	64.98	-0.89
236	66.21	D	63.51	-2.70
117	64.65	A	65.83	1.18
69	66.66	A	66.77	0.11
336	66.66	A	67.22	0.56
73	68.16	A	68.94	-0.22
340	66.54	A	69.67	3.13
245	69.78	A	69.77	-0.01
126	81.59	M		
348	73.54	M		
247	78.01	M		
351	82.46	M		
349	90.29	D		
241	87.76	M		
123	85.99	M		
242	76.93	M		
347	70.00	M		
344	71.92	A		
130	71.34	D		
353	72.19	M		
243	72.23	M		
350	72.21	M		
352	74.43	A	75.61	1.18
342	84.03	D	83.17	-0.86
341	86.80	A	86.99	0.19
250	87.74	A	87.76	0.02

FORT POINT CHANNEL Three Month Deployments

March (t=0)		June (t=1)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
9	29.55	M		
8	23.04	M		
7	33.07	M		
13	33.10	M		
11	24.20	M		
14	30.26	M		
3	31.42	M		
2	33.19	M		
4	22.00	M		
6	27.31	M		
5	31.80	M		
15	27.57	A	32.42	4.85
10	28.86	A	32.90	4.33
17	38.33	A	35.72	-0.61
1	30.54	A	36.71	0.17
12	29.69	A	37.97	8.29
16	38.15	A	39.44	1.29
20	34.47	A	40.61	6.14
19	36.82	A	42.19	5.38
18	37.76	A	44.63	6.83
31	49.23	M		
30	46.56	M		
29	46.81	M		
33	43.68	M		
38	49.77	M		
37	47.07	M		
35	43.22	M		
26	48.96	M		
27	39.95	M		
23	42.49	M		
34	42.23	A	47.37	4.84
28	46.36	A	47.44	1.09
25	44.23	A	48.26	4.03
40	49.57	A	49.75	0.19
36	49.73	A	50.27	0.54
39	49.95	A	51.20	1.26
24	44.37	A	51.20	6.83
32	46.18	A	51.72	5.53
22	48.83	A	53.60	4.77
21	48.49	A	56.03	7.55
48	54.54	M		
47	50.75	M		
50	58.50	M		
55	51.79	M		
54	55.59	M		
43	57.24	M		
45	59.45	M		
41	51.69	D	51.43	-0.26
44	52.82	D	51.71	-1.10
52	54.91	A	54.15	-0.76
57	54.43	A	54.73	0.30
51	55.07	A	55.23	0.16
59	56.72	A	55.60	-1.12
46	56.08	A	55.99	-0.09
49	56.83	A	56.33	-0.50
53	56.03	A	56.56	0.53
60	56.04	A	57.00	-0.43
58	54.39	A	58.03	3.64
42	59.44	A	58.85	-0.59
56	57.39	A	59.19	1.80
75	65.59	M		
70	63.71	M		
69	63.06	M		
80	62.60	M		
79	68.15	M		
78	64.06	M		
67	64.34	M		
65	62.56	M		
61	66.94	M		
77	68.12	D	56.31	-11.81
66	61.81	A	61.17	-0.64
71	62.60	A	61.37	-1.23
62	62.15	A	61.72	-0.43
72	64.31	A	64.00	-0.31
63	64.88	A	64.07	-0.81
76	63.62	D	63.32	-0.30
73	66.48	A	65.72	-0.76
68	66.38	A	65.86	-0.52
74	69.27	A	68.88	-0.39
64	69.51	A	68.92	-0.58
92	81.11	M		
94	83.83	M		
90	83.26	M		
91	80.58	M		
95	83.90	M		
96	73.62	M		
100	83.53	M		
96	83.03	M		
97	79.95	M		
85	74.76	M		
88	87.77	M		
89	81.33	M		
93	76.34	A	74.15	-2.18
82	74.36	A	74.24	-0.12
87	78.16	A	73.71	-0.45
99	78.07	A	78.96	0.11
84	82.07	A	81.20	-0.86
86	85.99	D	81.24	-4.75
83	81.83	A	81.86	0.03
81	68.15	A	67.60	-0.55

June (t=1)		September (t=2)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
1	30.71	M		
145	37.02	M		
143	34.68	M		
17	33.72	M		
12	37.97	M		
144	39.52	M		
147	39.54	M		
149	35.40	M		
148	36.94	M		
153	31.38	M		
15	32.42	M		
157	29.44	M		
154	29.05	M		
156	29.29	M		
10	32.90	M		
158	33.82	M		
151	33.10	D	35.73	2.63
16	39.44	A	43.61	4.17
150	33.03	A	46.96	13.93
146	37.34	A	50.71	13.37
25	48.26	M		
129	48.76	M		
28	47.44	M		
142	48.30	M		
34	47.37	M		
130	40.49	M		
40	40.75	M		
133	49.43	M		
131	49.14	M		
132	49.40	M		
139	41.78	M		
20	40.81	M		
140	40.87	M		
136	41.74	M		
137	45.83	M		
138	43.87	M		
18	44.63	M		
135	42.82	A	46.66	3.84
134	41.76	A	48.58	6.82
141	42.51	A	43.23	0.72
53	58.56	M		
60	57.00	M		
127	56.05	M		
49	56.33	M		
58	58.03	M		
126	59.21	M		
125	59.47	M		
128	58.24	M		
42	58.85	M		
21	56.03	M		
24	31.20	M		
32	51.72	M		
36	50.27	M		
39	51.20	M		
22	53.60	M		
51	55.23	M		
57	54.73	M		
52	54.15	M		
48	55.99	A	58.97	2.98
56	59.19	A	63.23	4.04
63	63.86	M		
116	66.73	M		
124	65.49	M		
120	63.57	M		
118	67.22	M		
117	65.34	M		
115	65.39	M		
114	65.85	M		
64	68.92	M		
119	62.59	M		
72	64.00	M		
122	65.25	M		
62	61.72	M		
66	61.17	D	60.52	-0.65
123	61.01	A	60.69	-0.32
121	62.59	A	61.94	-0.65
71	61.37	A	62.24	0.87
65	64.07	D	63.32	-0.75
73	65.72	A	65.99	0.27
74	68.88	A	68.28	-0.60
103	80.37	M		
101	80.49	M		
107	78.71	M		
102	77.59	M		
84	81.20	M		
81	87.60	M		
113	69.50	M		
83	81.86	M		
105	85.97	M		
106	78.40	M		
104	72.13	M		
109	72.93	M		
108	71.96	M		
112	71.96	M		
93	74.15	M		
87	73.71	M		
111	74.90	M		
82	74.24	M		
110	73.51	D	72.42	-1.09
99	78.96	D	80.11	1.15

September (t=2)		December (t=3)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
210	23.01	M		
211	26.15	M		
214	26.42	M		
213	26.97	M		
205	27.35	M		
202	30.20	M		
216	30.83	M		
219	31.58	M		
215	32.27	M		
209	33.07	M		
212	33.28	M		
206	34.21	M		
208	34.67	M		
207	35.05	M		
204	35.85	M		
203	36.18	M		
201	36.30	M		
200	36.65	M		
217	38.75	M		
218	39.63	D	39.90	0.07
232	40.81	M		
221	41.61	M		
233	41.63	M		
235	41.91	M		
224	42.24	M		
223	42.42	M		
229	43.24	M		
18	43.61	M		
220	43.64	M		
228	45.03	M		
223	45.26	M		
226	45.89	M		
231	46.06	M		
222	46.10	M		
230	46.53	M		
135	46.66	M		
150	46.96	M		
134	46.58	M		
227	47.22	M		
234	47.01	A	46.93	-0.08
243	53.25	M		
241	53.25	M		
248	54.28	M		
251	55.78	M		
254	59.54	M		
48	58.97	M		
245	56.01	M		
243	51.34	M		
246	51.80	M		
244	50.83	M		
146	50.71	M		
253	54.19	M		
242	53.34	M		
141	52.23	M		
250	55.55	D	54.00	-1.55
252	55.74	D	55.18	-0.56
247	56.44	D	55.93	-0.51
253	57.40	D	57.03	-0.37
256	56.19	D	57.22	0.97
240	58.04	D	57.40	-0.64
290	63.14	M		
269	62.41	M		
71	62.24	M		
73	65.99	M		
265	63.87	M		
56	63.23	M		
293	62.00	M		
294	60.75	M		
123	60.69	M		
121	61.94	M		
283	60.81	M		
292	60.32	D	59.25	-1.07
267	60.38	D	59.33	-1.05
291	64.37	D	62.17	2.20
280	64.82	D	64.01	0.81
296	65.25	D	64.36	-0.89
295	65.75	D	65.59	0.16
288	66.70	A	67.04	0.34
74	68.28	D	67.91	0.37
294	68.63	D	68.00	0.54
278	72.79	M		
262	71.60	M		
269	78.84	M		
272	73.90	M		
268	70.42	M		
260	70.22	M		
276	70.56	D	67.09	-3.47
263	71.25	D	69.43	-1.82
285	71.70	D	70.82	-0.88
280	72.78	D	71.13	-1.65
274	72.79	D	71.42	-1.37
261	71.07	D	71.83	0.76
273	72.57	D	73.05	0.48
270	73.90	D	73.32	-0.67
277	74.80	D	73.87	-0.93
267	73.91	D	74.42	0.51
271	77.80	D	78.07	0.27
264	82.96	D	80.31	-2.65
279	83.64	D	83.25	-0.39
275	87.30	D	87.57	0.27

December (t=3)		March (t=4)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
308	22.37	M		
304	26.67	M		
312	36.42	M		
307	33.20	M		
314	26.11	A	26.63	0.52
319	27.06	A	27.13	0.07
315	30.21	A	29.79	-0.42
317	30.73	A	30.45	-0.28
320	30.86	A	30.94	0.08
316	29.74	A	31.49	1.75
306	31.41	A	32.30	0.90
318	32.44	A	32.74	0.30
309	33.29	A	32.76	-0.53
311	34.86	A	35.03	0.17
302	36.06	A	35.76	-0.30
313	36.66	A	36.67	0.01
301	36.55	A	36.67	0.12
310	38.34	A	38.84	0.50
303	39.70	A	39.50	-0.20
305	39.30	A	39.72	0.42
336	44.98	M		
322	42.22	M		
325	44.13	M		
331	47.12	M		
334	40.93	M		
332	45.30	M		
338	41.52	M		
326	40.65	A	40.64	-0.01
329	41.37	A	41.00	-0.28
333	42.01	A	41.23	-0.78
327	42.55	A	42.07	-0.48
330	41.89	A	42.50	0.62
328	44.40	A	43.84	-0.64
323	44.13	A	44.04	-0.09
324	44.13	A	44.11	-0.02
323	43.96	A	44.51	0.55
339	43.22	A	44.80	-0.42
337	46.54	A	46.68	0.14
321	47.96	A	47.72	-0.24
334	48.81	A	48.62	-0.19
360	52.03	M		
352	56.46	M		
348	55.11	M		
343	54.07	M		
358	50.71	A	50.13	-0.58
351	51.18	A	50.71	-0.48
354	51.42	A	51.28	-0.14
359	51.46	A	51.37	-0.09
349	53.88	A	53.67	-0.21
342	54.07	A	53.89	-0.18
357	54.61	A	54.53	-0.08
356	54.85	A	54.63	-0.22
347	55.61	A	55.39	-0.22
343	56.97	A	56.56	-0.41
350	57.61	A	57.15	-0.46
346	58.61	A	57.79	-0.82
344	58.63	A	58.63	0.03
341	59.08	A	58.82	-0.26
355	58.68	A	58.85	0.17
353	59.15	A	59.01	-0.14
380	67.04	M		
379	68.70	M		
372	65.96	M		
370	65.92	M		
371	68.26	M		
377	60.79	M		
373	63.53	M		
362	60.69	A	60.27	-0.42
374	63.76	A	63.30	-0.46
368	63.84	D	63.41	-0.43
375	64.61	A	64.23	-0.38
365	65.74	A	65.29	-0.45
369	66.02	A	65.40	-0.62
378	66.17	A	65.60	-0.57
376	69.41	D	65.95	-3.46
361	66.66	A	66.12	-0.54
364	66.87	A	66.86	-0.01
366	67.95	A	67.29	-0.66
363	68.54	A	68.12	-0.42
367	69.02	A	68.69	-0.33
392	72.43	M		
384	71.97	M		
398	73.03	M		
400	74.04	M		
389	78.00	M		
388	70.37	M		
385	70.14	M		
394	70.45	M		
391	70.45	M		
390	70.00	A	69.73	-0.36
399	70.75	D	70.26	-0.49
397	70.92	A	70.30	-0.62
382	70.99	D	70.42	-0.57
396	71.15	A	70.47	-0.68
383	71.13	D	70.65	-0.48
381	72.07	A	71.99	-0.08
387	73.17	A	72.84	-0.33
386	74.07	A	72.84	-1.23
393	73.21	A	73.30	0.09
395	73.04	A	74.34	-0.70

BARNSTABLE HARBOR Three Month Deployments

March (t=0)		June (t=1)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
13	33.93	M		
10	36.64	M		
18	35.70	M		
16	36.79	M		
4	29.16	M		
3	30.02	A	41.00	10.98
2	38.18	A	41.92	3.73
5	32.91	A	42.08	9.17
15	35.50	A	43.78	8.29
11	31.85	A	44.00	12.70
20	38.51	A	44.80	6.29
9	36.72	A	43.26	6.54
8	37.62	A	45.37	7.75
14	38.47	A	46.08	7.61
17	34.19	A	46.91	12.72
1	38.72	A	47.53	8.81
19	36.83	A	49.93	13.10
6	36.54	A	49.96	13.43
7	39.33	A	51.35	12.02
12	39.20	A	53.44	14.24
30	40.53	M		
36	40.27	M		
37	43.75	M		
38	41.31	A	42.34	1.03
34	43.01	D	43.84	2.83
22	44.21	D	46.30	1.99
33	40.22	A	46.39	6.17
35	40.90	A	48.06	7.13
31	43.08	A	50.40	6.63
24	43.36	A	51.46	8.11
26	46.52	A	53.29	6.76
29	47.75	A	53.35	5.60
32	44.77	A	54.06	9.30
40	44.37	D	54.27	9.90
39	42.96	A	54.68	11.71
27	43.31	A	55.47	12.17
21	49.48	A	56.36	6.88
23	46.57	A	56.89	10.32
25	48.01	A	57.29	9.28
28	49.23	A	58.30	9.07
46	51.19	M		
60	53.05	M		
41	56.53	M		
53	51.59	A	55.91	4.32
50	52.18	D	57.12	4.94
51	53.29	A	57.20	3.90
59	53.63	D	57.27	3.64
48	52.12	A	57.89	5.77
56	56.12	A	57.96	1.84
45	53.87	A	58.20	4.33
47	51.83	A	58.71	6.88
54	53.35	A	58.91	5.56
49	52.51	A	61.09	8.58
43	53.92	A	61.59	7.67
57	56.96	A	61.73	4.77
58	55.87	A	63.20	7.34
44	58.17	A	63.59	5.42
52	58.08	A	63.36	6.28
42	56.59	A	63.43	6.84
55	57.77	A	68.88	11.11
67	62.26	M		
62	60.71	D	60.02	-0.69
62	61.32	D	61.64	0.32
72	63.09	A	62.97	-0.12
64	61.29	A	63.53	2.26
79	63.44	D	62.78	-1.60
80	60.79	D	63.83	3.04
76	64.90	D	65.22	0.27
66	65.75	A	66.05	0.30
71	67.02	A	66.14	-0.88
75	66.28	D	66.37	0.09
77	61.78	A	67.34	5.56
61	66.33	A	68.04	1.71
70	66.52	A	68.33	1.81
74	65.25	A	68.52	3.27
63	62.89	A	69.10	6.22
73	67.09	A	69.32	2.23
65	69.94	A	69.32	-0.32
78	68.93	A	69.77	0.83
69	65.70	A	71.94	6.25
93	84.10	M		
83	71.30	D	72.77	1.47
87	74.43	A	73.19	0.76
81	73.40	A	77.72	4.32
85	77.14	A	77.95	0.81
88	79.01	A	78.40	-0.60
89	76.11	A	78.74	2.63
82	74.92	A	79.81	4.89
86	82.37	A	80.75	-1.62
91	81.32	A	81.55	0.23
90	79.24	A	82.15	2.92
92	81.62	A	83.22	1.60
95	83.06	A	82.90	-0.16
84	84.91	A	86.27	1.36
97	87.53	A	87.26	-0.27
94	87.35	A	87.37	0.02
98	84.56	A	87.66	3.10
96	83.93	A	83.17	-0.76
99	82.15	A	84.10	1.95
100	99.72	D	100.27	0.55

June (t=1)		September (t=2)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
106	33.51	M		
115	30.48	M		
114	39.30	M		
108	34.65	M		
112	39.17	M		
100	39.90	M		
101	24.13	M		
119	19.35	M		
102	27.89	M		
104	24.82	M		
120	20.00	D	24.50	4.50
103	34.15	D	36.33	2.18
118	39.95	D	40.51	0.56
107	33.76	A	41.42	7.66
110	32.02	D	42.07	10.05
117	39.54	D	44.06	4.52
111	39.34	D	46.67	7.33
109	32.94	D	50.81	17.87
113	30.99	D	51.26	14.27
116	39.50	D	55.99	16.09
8	45.37	M		
1	47.53	M		
14	46.08	M		
5	42.08	D	40.09	-1.99
38	42.34	D	42.35	0.01
123	43.09	D	42.50	-0.59
2	41.92	D	43.72	1.80
9	45.26	D	44.45	-0.81
15	43.78	D	44.83	1.05
124	44.19	D	45.46	1.27
20	44.80	D	45.72	0.92
19	43.93	D	40.37	-1.56
122	41.93	D	48.89	6.96
23	46.30	D	48.83	2.54
121	43.16	A	48.98	5.82
11	44.55	D	49.40	4.85
6	49.96	D	49.80	-0.16
3	41.00	A	51.02	10.02
25	48.08	A	51.82	3.74
17	46.91	A	56.43	9.52
32	54.06	M		
29	53.35	M		
27	55.47	M		
28	54.63	M		
126	51.62	M		
127	53.28	M		
7	51.35	D	50.73	-0.62
24	51.46	D	52.76	1.30
12	53.44	D	54.97	1.53
39	57.29	D	56.64	-0.64
47	58.71	D	59.30	0.59
54	58.91	D	59.34	0.43
55	55.91	A	60.33	4.42
33	56.89	D	60.61	3.72
35	58.30	D	61.30	3.00
29	53.28	A	62.17	8.89
48	57.89	D	62.75	4.86
125	57.34	D	64.08	6.74
56	57.96	D	64.51	6.55
43	58.20	A	65.50	7.30
66	66.05	M		
77	67.34	M		
128	68.84	M		
49	61.09	M		
58	63.20	D	62.72	-0.48
72	62.97	D	63.67	0.70
52	63.36	D	64.33	1.03
74	65.22	D	62.91	-2.61
43	61.59	D	66.60	3.00
64	63.53	D	67.22	3.67
42	63.43	A	67.32	1.89
57	61.73	D	67.34	5.61
70	68.33	A	68.38	0.05
73	69.32	D	69.20	-0.12
61	68.04	A	69.40	1.36
65	69.55	D	69.91	0.36
78	69.77	A	70.00	0.22
71	66.14	D	70.53	4.39
69	69.10	D	70.53	1.43
44	63.58	D	70.96	7.38
130	73.50	M		
83	71.94	D	74.05	2.11
87	73.19	D	73.45	0.26
84	86.27	D	76.06	-10.21
81	77.73	A	76.17	-1.56
82	79.74	D	76.91	-1.83
89	78.40	D	78.02	-0.38
88	80.75	D	80.11	-0.64
82	79.81	D	81.02	1.21
91	81.55	D	82.92	1.37
85	77.95	A	82.07	4.12
129	85.00	D	83.26	-1.74
93	83.80	A	83.80	0.00
92	83.22	A	84.69	1.47
94	87.37	D	85.09	-2.28
90	82.15	D	85.62	3.47
96	87.66	A	86.16	-1.50
97	87.26	D	88.49	1.23
86	89.17	D	89.48	0.31
99	94.10	D	94.74	0.64

September (t=2)		December (t=3)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
219	36.08	M		
217	31.43	M		
209	29.72	M		
208	36.01	M		
200	35.89	M		
202	33.30	M		
214	27.97	M		
205	28.10	M		
201	30.00	M		
218	29.41	M		
210	28.35	M		
211	28.96	A	34.62	3.06
203	37.92	D	38.34	0.42
216	33.76	D	39.01	5.25
207	31.88	D	39.61	7.73
206	33.00	D	40.00	7.00
204	36.07	D	41.01	4.94
215	32.84	A	43.28	10.44
212	35.04	A	46.72	11.08
213	28.13	A	47.73	19.60
229	46.31	M		
228	48.29	M		
232	49.50	M		
225	49.90	D		
229	49.83	M		
237	42.83	M		
233	44.92	M		
107	41.42	M		
222	45.85	D	47.37	1.52
230	48.55	D	47.64	-0.91
223	44.60	D	47.83	3.23
121	48.98	A	48.40	-0.58
231	47.15	A	49.15	2.00
221	48.28	A	49.28	1.00
234	49.55	D	49.71	0.16
224	49.60	D	51.46	2.06
227	48.45	A	52.79	4.34
220	49.78	D	53.81	4.03
230	43.76	A	53.87	10.11
236	45.00	A	56.87	11.87
239	55.10	M		
248	52.40	M		
242	53.74	M		
247	54.59	M		
25	51.82	M		
3	51.02	M		
240	52.00	M		
251	52.34	D	51.05	-1.29
245	51.61	D	53.10	1.49
253	52.12	D	53.24	1.12
238	53.41	A	53.73	0.32
243	53.64	D	54.22	0.58
246	55.76	D	56.21	-0.55
249	53.41	D	56.23	2.82
252	56.92	D	56.64	-0.28
250	53.47	D	56.64	3.17
241	55.71	A	57.16	1.45
244	53.94	A	58.47	4.53
17	56.43	A	59.79	3.36
254	57.63	D	60.00	2.37
70	68.38	M		
260	63.73	M		
43	65.50	M		
264	66.38	M		
257	63.51	D		
259	62.50	M		
256	63.50	M		
55	60.33	D	60.43	0.10
26	62.17	D	62.63	0.46
255	63.83	D	63.39	-0.44
260	65.26	D	63.42	-1.84
261	64.97	D	64.72	-0.25
263	65.40	D	65.15	-0.25
265	65.36	D	65.47	0.11
42	67.32	D	65.49	-1.83
262	66.49	D	65.84	-0.65
267	65.11	A	66.28	1.17
258	66.97	D	66.33	-0.64
266	68.61	D	67.04	-1.57
61	69.40	A	69.84	0.44
92	84.69	M		
81	76.17	M		
273	74.67	M		
278	74.00	M		
269	71.01	M		
268	70.11	M		
78	70.00	M		
282	73.02	M		
69	70.53	M		
281	71.17	D	70.64	-0.53
275	72.13	D	72.06	-0.07
270	73.44	D	72.56	-0.88
271	70.18	A	72.82	2.64
276	75.30	D	73.86	-1.44
279	75.05	D	74.15	-0.90
277	77.44	A	77.08	-0.36
272	78.67	A	78.21	-0.46
274	79.62	D	78.33	-1.29
83	83.07	A	82.66	-0.41
93	83.80	A	83.72	-0.08
90	80.16	D	80.36	0.20

December (t=3)		March (t=4)		
clam #	length (mm)	fate	length (mm)	growth (mm/3 mo)
304	30.38	M		
315	24.54	M		
301	30.47	M		
317	30.14	M		
312	20.04	M		
303	14.65	M		
313	20.78	A	25.51	4.73
316	25.34	A	27.80	2.46
314	22.81	A	28.16	5.35
309	28.23	A	29.57	1.34
305	30.73	A	32.79	2.06
311	28.85	A	33.29	4.44
308	31.31	A	33.41	2.10
319	33.74	A	34.11	-0.63
306	30.30	A	32.16	2.06
302	36.47	A	39.23	2.76
211	34.62	A	40.13	5.51
318	39.42	A	40.22	0.80
307	39.66	A	42.64	2.98
310	24.51	A	51.42	26.91
323	44.32	M		
332	42.67	M		
231	49.15	A	28.15	-21.00
330	40.76	A	41.57	0.81
326	45.11	A	44.25	-0.86
320	42.11	A	44.89	2.78
327	42.28	A	45.08	2.80
215	43.28	A	45.55	2.27
321	44.85	A	46.22	1.37
329	42.03	A	46.41	4.38
325	46.86	A	47.20	0.34
322	46.08	A	48.01	1.93
121	48.40	A	48.74	0.34
212	46.72	A	49.42	2.70
328	47.18	A	49.49	2.31
333	45.49	A	49.50	4.02
331	46.02	A	49.73	3.71
221	49.28	A	50.21	0.93
213	47.73	A	50.43	2.60
324	48.18	A	50.69	2.31
236	56.07	M		
342	51.00	D	51.53	0.03
230	53.87	A	53.41	-0.46
336	52.84	A	53.47	0.63
337	52.57	A	53.91	1.34
339	52.40	A	53.90	1.52
227	52.79	D	54.19	1.40
334	50.90	A	54.25	3.36
238	53.73	A	54.67	0.94
346	55.27	A	55.66	0.39
344	55.79	A	57.17	1.38
341	55.81	A	57.42	1.61
340	57.68	A	58.57	0.89
244	58.47	A	58.73	0.26
338	57.92	A	58.97	1.05
343	57.21	A	59.60	2.39
335	59.02	A	59.82	0.80
241	57.16	A	59.82	2.66
345	57.96	A	60.37	2.41
17	59.79	A	60.49	0.70
347	60.87	M		
301	63.11	M		
348	60.49	A	59.85	-0.64
354	60.81	A	60.89	0.08
350	60.29	A	60.92	0.63
349	61.48	A	61.04	-0.44
352	61.49	A	62.44	0.95
353	63.46	A	62.69	-0.77
351	60.92	A	63.71	2.79
357	64.23	A	64.06	-0.17
363	63.87	A	63.02	-0.85
364	65.63	A	65.87	0.24
355	65.27	A	66.56	1.29
359	67.15	D	66.62	-0.53
360	67.17	A	66.96	-0.21
267	66.28	A	68.33	2.05
356	68.05	A	69.06	1.01
358	69.69	A	69.62	-0.07
362	69.71	A	69.92	0.21
61	69.84	A	70.19	0.35
378	70.49	A	70.34	-0.15
372	73.42	D	72.36	-1.06
371	72.96	A	72.79	-0.17
377	70.87	A	72.92	2.05
369	72.17	A	73.02	0.85
365	74.38	A	73.49	-0.89
375	70.50	A	73.67	3.08
370	74.71	A	73.90	-0.81
367	73.60	A	73.97	0.37
374	75.78	A	75.48	-0.30
277	77.08	A	76.25	-0.83
373	78.54	A	78.42	-0.12
366	78.06	A	78.24	0.18
368	79.04	A	79.29	0.25
272	78.21	A	79.56	1.35
376	81.14	A	79.88	-1.26
95	83.72	A	82.72	-1.00
380	83.09	A	83.07	-0.02
83	82.66	A	83.94	1.28
379	84.70	A	84.11	-0.63

BARNSTABLE HARBOR

March '95 (t=0) stem #	length (mm)	March '96 fate	length (mm)	growth (mm/?mo)
1019	38.71	M		
1010	34.43	M		
1007	35.65	D		
1020	30.05	M		
1017	36.40	M		
1015	35.53	M		
1001	35.00	M		
1019	37.66	D	37.35	0.27
1014	36.83	D	42.27	5.34
1002	37.59	D	42.58	5.00
1004	30.91	D	42.77	11.86
1003	30.00	D	44.61	14.62
1006	37.52	D	45.26	7.74
1012	39.45	D	45.36	5.94
1009	36.42	D	45.79	9.37
1011	40.00	D	46.63	6.63
1016	39.84	D	49.26	9.42
1006	38.87	D	53.29	14.41
1000	37.46	D	53.77	16.30
1018	37.00	D	61.56	24.56
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FORT POINT CHANNEL

March '95 (t=0) stem #	length (mm)	March '96 fate	length (mm)	growth (mm/?mo)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NO DATA

QUINCY-NEPONSET RIVER

March '95 (t=0) stem #	length (mm)	March '96 fate	length (mm)	growth (mm/?mo)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SAUGUS RIVER

March '95 (t=0) stem #	length (mm)	March '96 fate	length (mm)	growth (mm/?mo)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WELLFLEET HARBOR

March '95 (t=0) stem #	length (mm)	March '96 fate	length (mm)	growth (mm/?mo)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]