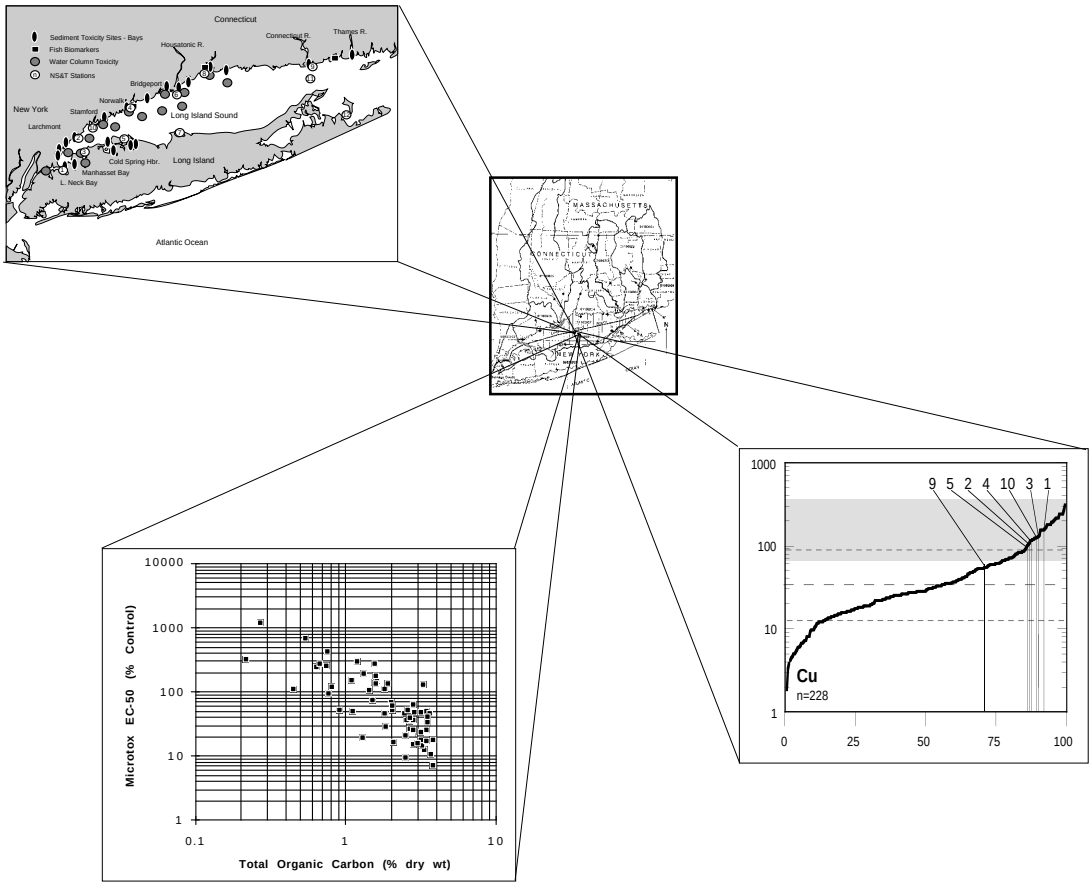
NOAA Technical Memorandum NOS ORCA 80

National Status and Trends Program
for Marine Environmental Quality

Biological Effects of Toxic Contaminants in Sediments from Long Island Sound and Environs



Silver Spring, Maryland
August, 1994

noaa National Oceanic and Atmospheric Administration

National Ocean Service
Office of Ocean Resources Conservation and Assessment
Coastal Monitoring and Bioeffects Assessment Division

NOAA Coastal Ocean Office

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Notice

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Table of Contents

List of Tables

List of Figures

BIOLOGICAL EFFECTS OF TOXIC CONTAMINANTS IN SEDIMENTS FROM LONG ISLAND SOUND AND ENVIRONS

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ABSTRACT

A survey of sediment toxicity was carried out by NOAA's National Status and Trends Program in the coastal bays that surround Long Island Sound in New York and Connecticut. The survey objectives were to determine the spatial distribution and severity of toxicity, and to analyze the relationships between toxicity and chemical contamination in the sediments. Sediment samples from three stations in each of 20 coastal bays and one Long Island Sound site were tested for toxicity with three independent protocols: (1) a 10-day amphipod survival test of the whole, solid-phase sediments with *Ampelisca abdita*, (2) a 48-hour exposure of clam larvae, *Mulinia lateralis*, to sediment elutriates, with normal development and survival as the endpoints, and (3) a microbial bioluminescence test (Microtox^{R}) using solvent extracts of the sediments. Separate samples from these same stations were analyzed chemically for a broad suite of potentially toxic contaminants, including heavy metals, polynuclear aromatic hydrocarbons (PAH), chlorinated pesticides and polychlorinated biphenyls. Additional sediment samples were obtained from up to six additional stations in a few of the coastal bays; these samples were examined only for heavy metals contamination and the data are included in an appendix to this report.

The survey results indicate that sediment toxicity is widespread in the coastal bays of Long Island Sound. Significant toxicity was indicated for the sediments from at least one of the stations in each of the 20 coastal bays sampled in this survey. Manhassett Bay, Oyster Bay, and Little Neck Bay, New York were the three most toxic bays, respectively, as indicated by the incidence of significant toxicity from the three tests on samples from three stations. Only 11 of the 60 stations showed no significant toxicity in any of the three tests. Branford Harbor and the Connecticut River were indicated as the least toxic bays by this approach. About one-fifth of the total area (79.1 km^{2}) sampled within the 20 embayments was indicated as significantly toxic by all three tests (survival of amphipods and larval bivalves, and Microtox^{TM}).

Although the observed toxicity tended to correlate with contaminant levels in the sediments, the various contaminant classes covaried quite strongly with each other and the toxicity therefore could not be readily attributed to any particular contaminant at any of the sampling locations. The concentrations of mercury and silver (and to a lesser extent lead, zinc, and copper) most frequently exceeded levels commonly associated with toxicity (ER-M values), but molar ratios of metals to acid-volatile sulfide suggested that these metals were unlikely to be contributing to substantial toxicity in these samples. Among the organic contaminants, PAHs most frequently exceeded ER-M values, but chlorinated pesticides including DDT/DDE, chlordane and dieldrin often accompanied the PAH at levels exceeding ER-M values as well. Shifts in the strength of correlative relationships between toxicity and contaminant concentrations with and without normalization either to total organic carbon (TOC) or to the content of fine sediments further indicated that the observed toxicity was most likely due to organic contamination in the sediments.

Cluster analysis and principal component analysis of these data demonstrated that the toxicity observed in these samples was strongly influenced not only by gross contaminant content, but also by intrinsic sample characteristics such as grain size and TOC content. These characteristics varied widely among stations within most of the bays in the sample set, and, coupled with the small number of samples in each bay, hindered the association of specific contaminants with toxicity for individual bays. The most contaminated bays based on numbers of ERM exceedances, however, were Little Neck Bay, Manhasset Bay, Pelham Bay, in New York, and Housatonic River, in Connecticut. Except for Manhasset Bay, at least one sample from each of these bays showed exceedances of the ER-Ms for PAHs along with chlordane or dieldrin. Manhasset Bay, by contrast, showed exceedances for a variety of chlorinated organic compounds. The ERM for mercury was also exceeded at all of the stations in three of these four bays, but not in any from the Housatonic River. Principal component analysis suggested that hexachlorobenzene might be associated with toxicity observed at selected stations in Oyster Bay, Centerport Harbor, and Larchmont Harbor, New York.

INTRODUCTION

This report summarizes results of studies conducted under NOAA sponsorship on the biological effects of contaminants in Long Island Sound (LIS). Long Island Sound is one of several coastal regions selected for study under the Intensive Bioeffects monitoring surveys of NOAA's National Status and Trends (NS&T) Program (Wolfe et al. 1993). With support from NOAA's Coastal Ocean Program, such intensive bioeffects surveys are conducted in areas where chemical data from the NS&T Program (or from related programs) indicate greatest potential for contaminant-related biological effects. To date, studies have been carried out or are underway in San Francisco Bay (1983-1990), Long Island Sound (1986-1991), Boston Harbor (1986-1993), Tampa Bay (1990-1993), Hudson-Raritan Estuary (1990-1993), and Southern California Bight (Los Angeles and San Diego Harbors: 1992-1994). Related studies were initiated during 1993 in coastal South Carolina (Charleston Harbor) and the northern Gulf coast of Florida (Pensacola to Appalachicola Bays). In each of these areas, the surveys have been conducted along postulated contaminant gradients: (1) to document the effects of contaminants on endemic feral organisms to contaminants, and (2) to determine the areal extent of contaminant-related sediment toxicity. The surveys also provide a means for comparing different toxicity tests and testing promising new bioeffects indicators under operational field conditions (Long et al. 1990a, Wolfe 1992; Wolfe et al. 1993). As in other areas, our surveys in Long Island Sound are based initially on results of the NS&T Program studies on contaminant distributions (e.g. Turgeon and O'Connor 1991; Robertson et al. 1991), and have included extensive sediment toxicity surveys and measurement of selected indicators of contaminant effects in resident fish and mollusks (e.g. Gronlund et al. 1991; Nelson et al. 1991; Johnson et al. 1992, 1993, 1994). Sediment toxicity surveys generally provide finer resolution on the spatial distribution of potential contaminant effects than is possible from the responses in mobile feral organisms (Long et al. 1992, Wolfe et al. 1993).

In 1985 the U.S. Environmental Protection Agency (EPA) initiated the Long Island Sound Study (LISS), to carry out initial studies of the pollution problems facing the Sound, and to develop a comprehensive plan for improved management of the Sound. The Long Island Sound Study is part of the National Estuary Program, which was established in 1984 by the U.S. Congress to improve the environmental quality of the nation's most important estuaries, and includes 20 other major U.S. estuarine systems. In close association with the LISS, the National Oceanic and Atmospheric Administration (NOAA) sponsored and carried out a number of studies of contaminant effects in the Sound during 1988-1991. This work was conducted either under a special congressional appropriation for the study of Long Island Sound or as part of the National Status and Trends Program, in cooperation with the LISS. Results from many of the earlier NOAA-supported studies have been published in a special dedicated issue of the journal Estuaries (Wolfe 1991).

This report focuses primarily on an extensive survey of sediment toxicity conducted during August, 1991, in twenty of the coastal bays surrounding Long Island Sound. Although preliminary accounts of this work have appeared elsewhere (Wolfe et al. 1992, Bricker et al. 1993), this report provides the first comprehensive analysis of the data. In this report we also provide a brief overview of other studies not previously published, and interpret those results in relation to the principal categories and sources of pollution in Long Island Sound.

Long Island Sound: The Physical Setting

Long Island Sound (LIS) is one of the major estuarine systems on the Atlantic coast of the United States. About 175 km in length, the LIS provides vital transportation links for commercial interests, and recreational opportunities (swimming, sailing, sportfishing) for millions of residents and tourists. The productivity of the rich fishing and shellfishing grounds in the Sound is threatened both by overfishing and by declining environmental quality due to pollution associated with the ever-growing surrounding human population. LIS comprises the entire marine coastline of Connecticut and is bordered to the south by Long Island, New York (Figure 1). The Sound is a large embayment with a total surface area of about 337,000 hectares, and a total volume of approximately 64 x 10^9 m^3. The mean depth is about 20 m, but maximum depths exceed 90 m at its eastern boundary where it connects with the Atlantic Ocean via Block Island Sound. Inputs of deeper oceanic water to the western sound are modulated by the Eastern Sill, which crosses the Sound at approximately at 72° 30' W longitude and rises to

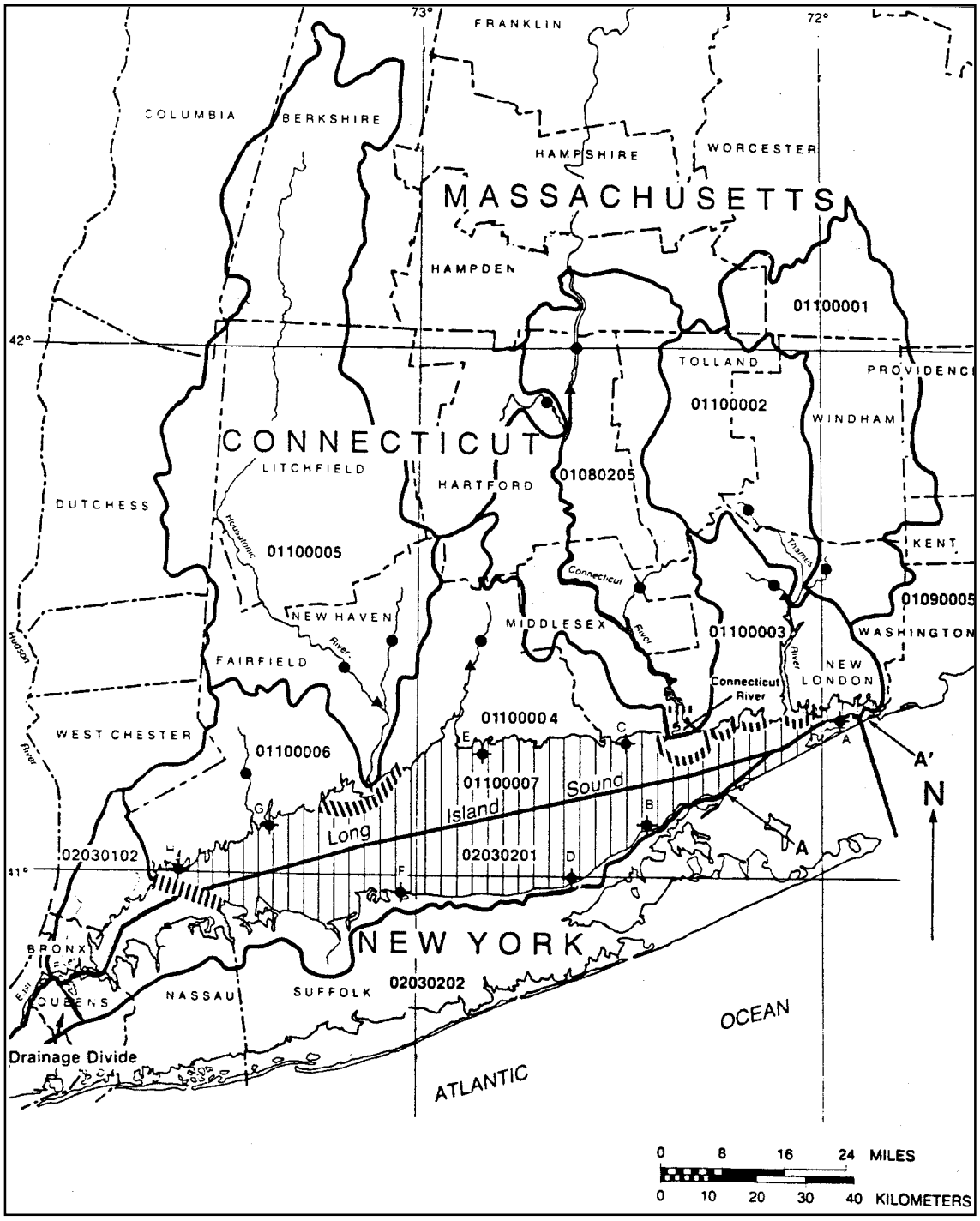

Fig. 1. Base map of the Long Island Sound area, showing the coastal counties, and the USGS Hydroloic Cataloging Units in the Estaurine Drainage Area (modified from SAB 1985).

a depth of about 21 m (Koppelman et al. 1976). At its western end, Long Island Sound is connected with New York Harbor through a tidal strait, the East River (Swanson et al. 1982). Nearly two-thirds of the total 44,100 km^2 drainage area of the Sound is in the Connecticut River basin (28,800 km^2). Freshwater enters the Sound from 4 major tributaries (Thames, Connecticut, Quinnipiac, and Housatonic Rivers) in Connecticut, and from coastal runoff and drainage along the Connecticut and Long Island shores. Because it enters well to the east of the Eastern Sill, the Connecticut River contributes only moderately to the overall estuarine circulation of the Sound, even though it accounts for about 70% of the total freshwater flow.

The coastal counties surrounding Long Island Sound are populated by approximately 9 million residents, and about 6 million more reside nearby in New York City (Culliton et al. 1990, Wolfe et al. 1991). The regional population swelled dramatically after the 1940's (e.g., a total increase of nearly 16% between 1960 and 1970 alone). About 12% (1,565 $km^{2)}$ of the total LIS watershed area in New York and Connecticut consists of sewered urban areas which service approximately 70% of the area's population (Langstaff 1990). The balance of the LIS regional population resides mainly in residential and rural areas serviced by individual septic systems. By the year 2010, the population is projected to increase by another 4 to 7 percent, with the greatest proportionate growth in the coastal counties of Connecticut and Rhode Island and Suffolk County on Long Island (Langstaff 1990, Terleckyj and Coleman 1989). These population trends suggest that associated development and density-dependent pollution pressures and other environmental demands on LIS will continue, and are likely to increase. Although proportionately larger population increases are projected for areas around the central and eastern portions of the Sound, significant numbers of people will also be added in the west. The earliest and most visible effects of these population trends should still be expected in the western parts of the Sound, where contaminant residence times are longer, and the present effects of relatively high contaminant inputs are most likely to be exacerbated (Turgeon and O'Connor 1991). To minimize these effects on the environmental quality of the Sound, adequate steps toward mitigation and restoration must be identified and implemented.

Concerns about the degradation of environmental quality of LIS are not new. The discharge and dumping of waste materials into the waters of New York Harbor and the East River were recognized as a problem within 50 years of the settlement of Manhattan Island. (Gross 1976; Squires 1981). Shortly after its establishment in 1906, the New York Metropolitan Sewerage Commission surveyed New York Harbor, and concluded that the East River, as an oscillating tidal strait, was unsatisfactory for sewage disposal (Squires 1981). No concerted effort was focused on the water quality problems of LIS, however, until the early 1970's, when the Nassau-Suffolk Regional Planning Board (Koppelman et al. 1976) identified the following problems related to surface water quality:

- Closure of waters which were once deemed suitable for the growth of shellfish; and closure of bathing beaches because of high bacteria counts;
- Adverse effects of nutrient loadings in marine and fresh surface waters, including eutrophication of marine waters in bays;
- Modified salinity regimes resulting from decreased stream flow and low groundwater levels;
- Inadequately treated wastewater discharged by the City of New York into the East River;
- Runoff of untreated urban stormwater;
- Uncontrolled development, including channelization, leading to increased urban runoff, decreased water circulation, and impaired water quality.

Processed effluents and wastes are currently discharged directly into the waters of the Sound by 44 sewage treatment plants and many industries (Wolfe et al. 1991). Many additional point sources discharge into the rivers entering the Sound. Understanding the significance of these various pollutant sources and managing their inputs, is complicated by a wide variety of non-point source pollutant contributions to the Sound, including atmospheric contaminants and local runoff from urban areas. Furthermore, much of the riverine flow to the Sound comes from drainages in Massachusetts, New Hampshire, and Vermont, creating jurisdictional issues and expanding the purview of marine environmental management to include issues of agricultural land-use practices and pesticide applications in these upland areas.

Data for categories of land use within the LIS watershed (Figure 1) have been compiled by USGS (1971-1984). Table 1 summarizes those data for the "Estuarine Drainage Area" (EDA) of LIS, which represents essentially those portions of the overall watershed which drain most directly into the estuary, and generally includes all of the USGS Hydrologic Cataloging Units from the seaward estuarine boundaries to the heads of tide in rivers (SAB 1985, 1987). In addition to the LIS portions of the coastal counties of New York, the EDA for Long Island Sound includes nearly all of Connecticut, as well as portions of southern Massachusetts and adjacent upstate counties in New York and Rhode Island (Figure 1).

Table 1. Land use in the Estuarine Drainage Area (EDA) of Long Island Sound (From Strategic Assessments Branch 1987). See Figure 1 for boundaries of the EDA.

Land-use Categories	Area (km^2)	Percent
Urban and Built Up	3698	25.09
Residential	2558	17.35
Commercial Services	443	3.01
Industrial	140	0.95
Transportation/Communication	161	1.09
Industrial/Commercial Complex	13	0.09
Mixed Urban	96	0.65
Other Urban	287	1.95
Agriculture	2128	14.44
Cropland/Pasture	2074	14.07
Other	54	0.37
Range (shrub/brushland)	135	0.92
Forest	8134	55.18
Deciduous	7060	47.90
Evergreen	582	3.95
Mixed	492	3.34
Wetland	435	2.95
Forested	295	2.00
Non-forested	140	0.95
Barren	211	1.43
Beaches	2.6	0.02
Other Sandy Areas	<2.6	<0.02
Mines/Quarries	127	0.86
Transitional Areas	80	0.54
Total	14740	100.00

Sources of Contaminants to Long Island Sound

In conjunction with the LISS, the Strategic Assessment Branch of NOAA estimated pollutant loadings to Long Island Sound. These estimates were drawn from an existing database, the National Coastal Pollutant Discharge Inventory (NCPDI), after updating the point-source estimates to reflect 1984 discharges (Farrow et al. 1986). Developed originally as a strategic tool for comparison and evaluation of loadings among different estuarine systems, the NCPDI has limited management utility for identification of “problem” pollutant loadings within LIS. The details of the estimation procedures and the many assumptions used in compiling the NCPDI data (Farrow et al. 1986) are critical for understanding its limitations. Nonetheless, certain insights can be drawn from this database. The NCPDI database for LIS includes 86 wastewater treatment plants, 255 industrial facilities discharging directly into the estuarine drainage area, 16 steam electric power plants, and 14 water treatment plants. The NCPDI also includes estimates (for the base year 1982) for three nonpoint pollution sources: stormwater runoff from urban areas, as well as from agricultural and forested nonurban areas. Atmospheric inputs, however, are not included. Table 2 shows discharge estimates for 7 categories of pollutants in the 6 major categories of sources, and in upstream riverine sources.

Table 2. Estimates of the annual loadings for selected pollutants to Long Island Sound by seven major source categories (from Farrow et al. 1986).

Constituent	Total Annual Discharge	Major Sources[a] (as percent of total) A	B	C	D	E	F	G
Flow ($m^3 \times 10^6$)	33,900	4.2	0.5	26.6	3.1	0.6	0.9	64.1
Conventional								
BOD_5 (kg x 10^6)	100	24.2	5.2	-[b]	14.9	3.0	0.1	52.6
TSS (kg x 10^6)	794	3.4	0.3	<0.1	25.4	50.0	3.7	17.2
Nutrients								
TN (kg x 10^6)	46	37.6	2.1	<0.1	7.3	3.7	0.1	49.2
TP (kg x 10^6)	6.8	66.2	0.1	0.1	7.9	0.5	<0.1	25.2
Heavy Metals								
As (kg x 10^3)	60	51.7	<0.1	1.7	8.1	3.4	<0.1	35.1
Cd (kg x 10^3)	36	28.2	<0.1	<0.1	5.1	<0.1	<0.1	66.7
Cr (kg x 10^3)	216	18.9	4.2	0.4	7.1	8.0	0.4	61.0
Cu (kg x 10^3)	367	31.9	3.4	5.2	7.2	1.2	0.2	50.9
Fe (kg x 10^3)	21,600	4.9	<0.1	<0.1	15.7	34.8	2.2	42.4
Hg (kg x 10^3)	7.3	25.4	0.6	0.1	7.3	<0.1	<0.1	66.6
Pb (kg x 10^3)	242	14.7	2.3	<0.1	43.0	<0.1	<0.1	40.0
Zn (kg x 10^3)	927	22.6	2.9	1.6	12.8	1.9	0.1	58.2
Oil & Grease (kg x 10^6)	27	66.6	0.4	0.3	32.7	-	-	-
Chlorinated HCs								
CHP (kg)	977	90.3	1.3	-	5.4	3.0	-	-
PCB (kg)	0	-	0.0[c]	-	-	-	-	-
Fecal Coliforms (cells x 10^{12})	826,000	1.0	<0.1	-	47.3	-	-	51.7
Sludge (kg x 10^6)	56	100	-	-	-	-	-	-

[a] A= wastewater treatment plants; B= industrial discharges; C= power plants; D= urban runoff; E= Cropland runoff; F= forestland runoff; G= upstream sources.
[b] (-) indicates no estimates made for this pollutant in this category.
[c] Zero discharge estimated for this pollutant in this source category.

Riverine Sources. Upstream sources are the single largest contributing category of potential pollutants to LIS (Table 2; Farrow et al. 1986). The Connecticut River contributes about 70% of the total upstream load of most pollutants. For naturally occurring substances in Table 2, much of the riverine load must be viewed as background flux resulting from natural erosional processes. The estimation procedure (mean concentration of total pollutant times mean flow) used by Farrow et al. (1986) does not distinguish natural and anthropogenic contributions, and furthermore does not accurately represent the different pollutant transport mechanisms that operate under high and low flow conditions.

Because the suspended sediment load (and associated pollutant transport) to estuaries vary greatly with river discharge (Schubel et al. 1986), the NCPDI values, which are based on mean flow conditions, may underestimate or, in some cases, overestimate the actual contaminant fluxes from upstream sources. For example, more than 5% of the annual discharge of suspended solids from the Susquehanna River has been observed in a single day, and 30% of the annual load has occurred in one week (Troup and Bricker 1975). Variability of contaminant concentrations in suspended material with flow, however, is not well known, and would affect the actual contaminant flux associated with particulate materials.

Soluble metals discharged into streams may rapidly become associated with particulate materials and sediments. For example, water from the Housatonic River below the confluence with the Naugatuck River did not exhibit elevated levels of silver and cobalt, despite the heavy industrialization along the Naugatuck and the known sources of the the metals there (Turekian 1971). Concentrations of silver in the sediments of the Quinnipiac River decreased downstream from significant sources, indicating rapid association and sedimentation of the element on particulate material, which accumulates in quiescent areas such as behind dams (Turekian et al. 1980). Similar distributional patterns have been found for PCBs and other organic pollutants released into the Hudson River system (O'Connor et al. 1982; Brown et al. 1985). Although sedimentation of suspended particulate material at river-mouths serves to remove contaminant metals from the water column, the partitioning of contaminants between dissolved and particulate phases may be influenced by salinity changes in the mixing zone of estuaries, with resolubilization of some metals over the salinity range of 5-15 ppt (Wolfe et al. 1975; Evans et al. 1977). In further evaluation of riverine sources, it could also be important to distinguish between dissolved and particulate forms of trace metals, and between free ionic forms and complexed (either organic or inorganic) forms. The free ionic forms of copper and zinc are implicated as mediators for the biological toxicities associated with these metals (Sunda et al. 1987, 1990).

Waste-Water Treatment Facilities. Excluding pollutant loads from rivers entering LIS, publicly-owned wastewater treatment plants (WWTPs) account for over 50% of the total loads for 11 different contaminants (Table 2). Although Bronx and Queens account for less than 5% of the surface area of coastal counties bordering LIS, the four WWTPs that serve these boroughs contribute 68% of the nitrogen, 15% of the phosphorus, 44% of the chromium, 79% of the copper, 38% of the lead, and 54% of the zinc being discharged to the Sound by WWTPs (Farrow et al. 1986). These four WWTPs (Tallman Island, Hunts Point, Bowery Bay, and Wards Island) discharge into the Upper East River, while the Newtown Creek WWTP (with a daily flow of $>1.1 \times 10^6$ $m^{3)}$ is located on the East River just outside the LIS study area. Tilt (1984) suggested however that the Newtown Creek plant is also near enough to influence LIS water quality. The cumulative average daily flux of total nitrogen from these 5 WWTPs to the East River approximately doubled between 1960 and 1984 (Carpenter 1986), far outpacing the rate of population increase in the region for the same period. Because the flow patterns and hydrodynamics in the East River are poorly understood, the significance of sources to the west of Hell's Gate is very difficult to estimate. Nonetheless, the concentrations of nitrogen in surface waters (Carpenter 1986) and of metallic and organic contaminants in sediments (Turgeon and O'Connor 1991) show strong west-to-east gradients in the sound, with highest concentrations in the vicinity of Throgs Neck.

Direct discharges from industrial facilities constituted a relatively small portion of the total flux for any category of contaminants. In decreasing order the greatest industrial contributions were for BOD_5, chromium, copper, and zinc. Except for the contributions of copper and zinc corroded from the cooling systems, the 16 steam electric power plants in the area contribute very small contaminant loads to the LIS system. While the fluxes appear to be minor on a Sound-wide basis, these industrial discharges may nonetheless be of local significance.

Runoff. The NCPDI identified urban runoff as the third largest source of many contaminant discharges to LIS (Table 2). Urban runoff accounted for about the same fraction of total lead as upstream riverine sources (43% vs 40%, respectively). Urban runoff also contributed significant proportions of the total loads of BOD_5, suspended solids, nutrients, metals, and petroleum hydrocarbons to LIS. About 80% of this total urban runoff arose from coastal cities and towns from western Suffolk County through New Haven County in the western half of LIS.

For the base year, runoff from nonurban land uses accounted for over 50% and about 37% of the total estimated loads to LIS of suspended solids and iron, respectively, (Table 2). Excluding upstream sources, runoff from cropland also accounted for about 20%, 7%, and 5% of the total loads of chromium, nitrogen, and arsenic, respectively. Contributions of other contaminants from runoff were minor.

Accurate estimation of loadings from runoff requires reliable data on land use, runoff coefficients, and concentrations of contaminants in runoff, and is subject to highly variable rainfall patterns and levels; and therefore considerable interannual variation should be expected around the NCPDI estimates (which were based on 1982 runoff).

Atmospheric Inputs. Until 1993, specific data on atmospheric deposition are almost entirely lacking for the LIS region. Under the LISS, studies have been undertaken to develop direct estimates of atmospheric inputs of contaminants to the Sound. For the nearby, heavily urbanized Hudson-Raritan Estuary, however, atmospheric sources have been estimated to contribute 0.9% of the total load of nitrogen, 3-9% of the PCB load, 3.5% of the lead load, and 2.1% of the zinc load (Mueller et al. 1982). To estimate the atmospheric loadings of contaminants to LIS, atmospheric depositional rates from other study areas were examined and applied to the surface area (3370 km^2) of the Sound (Wolfe et al. 1991).

Based on average atmospheric fluxes of: (a) conventional and metal contaminants estimated for the period 1976-1979 at rural locations in the New York City area (Toonkel et al. 1980); and (b) organic contaminants (Galloway et al. 1980), the atmospheric flux to LIS for several contaminants was estimated to be on the same order of magnitude as the flux from WWTP's (Table 3). In parts of the Sound, however, urban deposition rates may be more applicable and the total atmospheric flux to the Sound could be somewhat higher relative to the WWTP flux than indicated in Table 4. More recent, independent estimates for atmospheric flux of selected contaminants, based on deposition rates for Lake Erie (Gatz et al. 1989, Strachan and Eisenreich 1987), or on deposition in a salt marsh in Farm River, Connecticut (McCaffrey and Thomson 1980) give similar (i.e. within a factor of 2-3) estimates for wet deposition of nitrogen and cadmium, but substantially lower estimates of lead deposition (Table 4). The fluxes estimated from deposition in the Connecticut salt marsh are generally higher than the other estimates, perhaps reflecting a higher (urban) rate of deposition along the coastal fringe compared to the LIS overall. Turekian et al. (1980) compared the contents of various metals with that of ^{210}Pb in a sediment core from the Farm River salt marsh site, and estimated that essentially all the lead and half the copper and zinc in the core were of atmospheric origin. These various estimates suggest that atmospheric deposition represents a significant proportion of the total input of several contaminants, and furthermore, that atmospheric sources must be taken into consideration in the development of control strategies.

Table 3. Estimated total annual flux of atmospheric contaminants to Long Island Sound, based on separate applications of rural and urban deposition rates (estimated for 1976-1979) to the LIS Area (3370 km^2).

Contaminant	Total Deposition (metric tons yr^{-1}) Urban	Rural	Percent of WWTP load[a]
Nutrients[b]			
NH_3-N	1300	1700	—[c]
NO_3-N	3400	2300	23
ortho-P	32	100	2.2
Metals[d]			
As	2.6	4.2	14
Cd	3.2	1.5	15
Cr	19	2	4.9
Fe	260	85	8.0
Pb	280	100	280
Zn	380	110	53
Toxic Organics[e]			
Hexachlorobenzene	0.06-0.8	.03	—
Dibutylphthalate	0.6-8	0.3	—
Total PAHs	10-100	6	33
Aldrin	0.08-2	0.04	—[c]
Dieldrin	0.02-0.2	0.01	—[c]
Chlordane	0.04-0.4	0.02	—[c]
Total DDT	0.04-0.2	0.02	—[c]

Table 3 continued.

Contaminant	Total Deposition (metric tons yr^{-1}) Urban	Rural	Percent of WWTP load[a]
Heptachlor	0.5-10	0.2	—[c]
Lindane (gamma-BHC)	0.6-10	0.3	—[c]
Toxaphene	0.4-5	0.2	—[c]
CHP[a] (sum of 7)	1.7-28	0.8	90
Total PCB	0.4-4	0.2	—

[a]Comparison of annual atmospheric flux estimates (rural) as % of annual discharge from WWTPs in NCPDI (Table 3). NH_3-N and NO_3-N are combined as total N; values for chlorinated pesticides (CHP) are also summed.
[b]Toonkel et al. (1980); 36-38 samples.
[c]Combined with other constituents.
[d]Toonkel et al. (1980); 11-12 samples, soluble metals only. Total metals may be higher by about 2x.
[e]Galloway et al. (1980). The rural values represent minimal estimates, based on average wet deposition and the low end of the velocity range for dry deposition. Urban fluxes are 2x-4x the rural fluxes, including an estimated 10-fold range of variability in dry depositional rate, and are rounded to one significant figure.

Table 4. Other estimates of annual atmospheric deposition (metric tons yr^{-1}) in LIS and the N. Atlantic Ocean, NR = not reported.

Constituent	wet deposition[a]	total[b]	total[c]	open N. Atlantic[d]
Nitrogen (total)	2500	NR	NR	823
Cadmium	1.1	0.6	NR	0.16
Copper	NR	NR	168	2.0
Iron	NR	NR	1010	473
Lead	19	30	570	3.5
Zinc	NR	NR	436	9.0

[a]Gatz et al. (1989) estimates for Lake Erie applied to LIS area of 3370 km^2.
[b]Strachan and Eisenreich (1987) estimates for Lake Erie applied to LIS area.
[c]McCaffrey and Thomson (1980) estimated deposition in Connecticut salt marshes, extended to entire LIS area.
[d]GESAMP (1989) estimates based on element-to-lead ratios in aerosols (except N), applied to the area of LIS.

Distribution of Contaminants in Long Island Sound

Since 1986 the NS&T Program has routinely monitored the concentrations of a broad range of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCB) congeners, chlorinated pesticides including DDT and its breakdown products DDD and DDE, and heavy metals in surficial sediments and soft tissues of bivalve molluscs or fish from more than 300 coastal sites nationwide (Turgeon and O'Connor 1991). Twelve of these NS&T sites (Figure 2) are in or near Long Island Sound (Robertson et al. 1991). Grain size is a predominant factor influencing contaminant levels in sediments from these sites, and variation in grain size composition among samples confounds interpretation of contaminant levels among sites (Turgeon and O'Connor 1991). Nonetheless, concentrations of organic and metallic contaminants in both sediments and mussels were generally higher at the sites in the western Sound (Throgs Neck and Hempstead Harbor) than at the less populous easterly sites. Elevated contaminant concentrations were also noted however in sediments and mussels from the Housatonic River site (Figure 2). These observations supported earlier conclusions (Greig et al. 1977, Turekian et al. 1980) that sediments in the vicinities of Throgs Neck, the Housatonic River, and New Haven were contaminated by human activities around the Sound.

Figure 3 illustrates the concentrations of copper, lead, PCBs, and total DDTs (including DDD and DDE) in NS&T samples of mussel tissue and sediments from Long Island Sound sites in terms of their percentile distributions relative to all the other comparable NS&T results from the rest of the U.S.

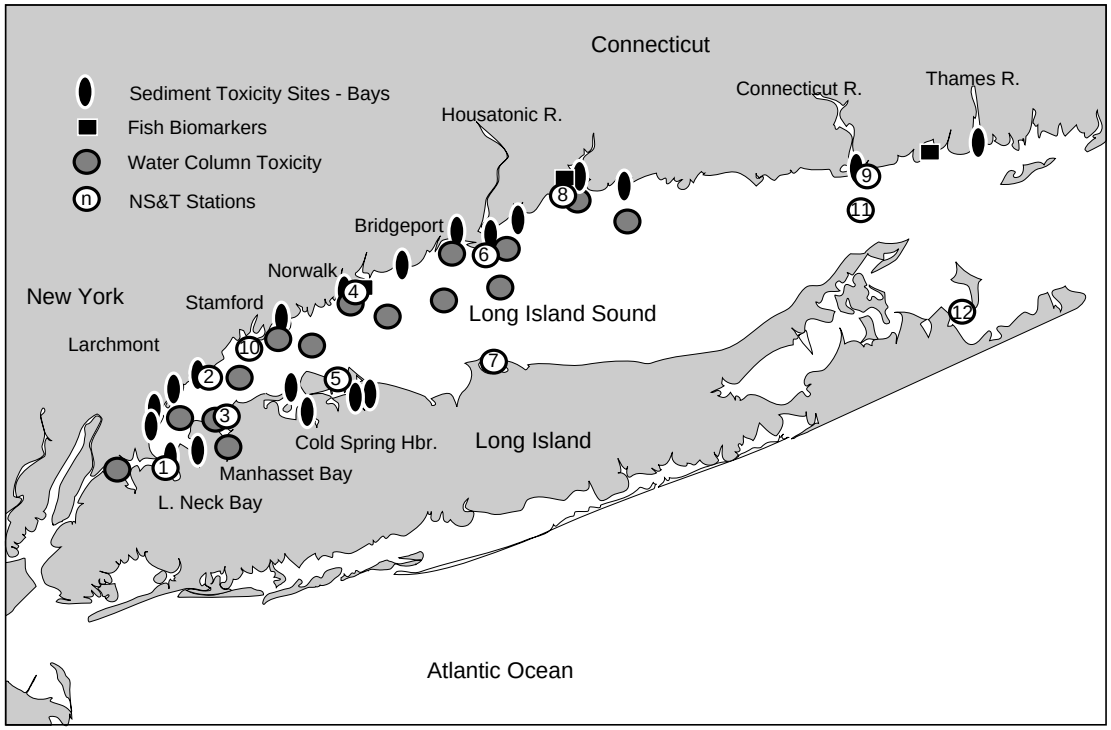

Figure 2. Sampling locations in Long Island Sound for different studies described in this paper. NS&T station numbers are used also in Figure 3.

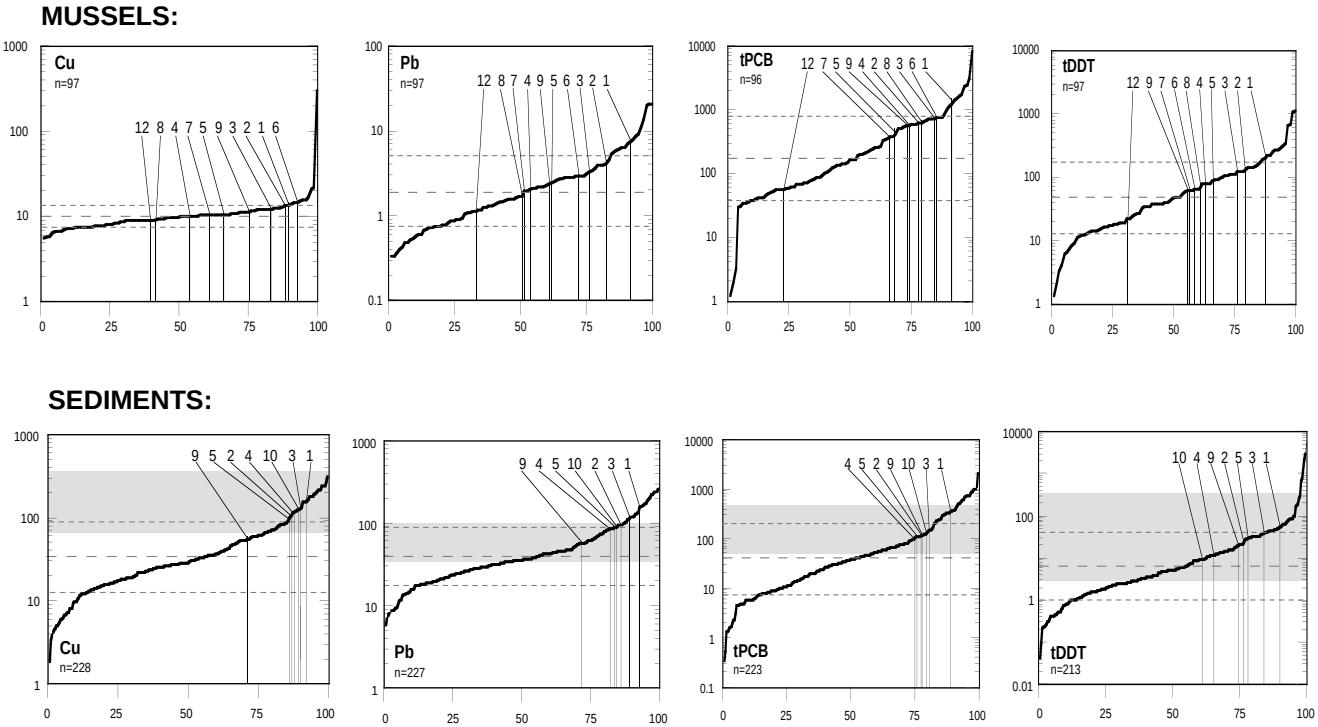

Figure 3. Concentrations of selected contaminants in NS&T samples from Long Island Sound (Site Numbers refer to Fig. 1), and their percentile ranks among NS&T sites nationwide. The lower and upper bounds of the shaded areas represent ER-L and ER-M values from Long and Morgan (1990). See text.

Figure 3 demonstrates that Long Island Sound sites are frequently in the upper 25th percentile of nationwide NS&T sites for contaminant levels, and that concentrations show a decreasing pattern from west to east in the Sound. Several other contaminants exhibited patterns very similar to those represented in Figure 3. For example, silver, cadmium, chromium, and nickel exhibited distributions very similar to those shown for Cu and Pb (Robertson et al. 1991). Mercury showed similar distributions in sediments, but in mussel tissues, 7 of the 10 LIS sites were in the lowest 20th percentile of nationwide sites, and all were in the lower 50th percentile. Total chlordane, dieldrin, and PAHs showed patterns generally similar to those illustrated for PCBs and DDT (Fig 2), except that for dieldrin the LIS sediments showed a broader and lower (20-80th percentiles) distribution relative to sites nationwide (Robertson et al. 1991).

Riverine inputs are estimated to be the predominant source of most of the measured contaminants to the LIS, but inputs from publically-owned wastewater treatment works (POTWs) may also account for substantial fractions (e.g. 15-50%) of the total loadings (Wolfe et al. 1991). The relative contributions of PAHs and Pb from urban runoff, and of Pb and chlorinated hydrocarbons from atmospheric inputs, however, may rival or exceed those from POTWs.

For the NS&T sediments from LIS, Fig 2 also illustrates the concentration ranges found in an extensive survey of existing data (Long and Morgan 1990, Long 1992, MacDonald et al. 1994) to be associated with biological effects, as measured in a variety of toxicity tests and field situations. The Effects Range-Low (ERL) represents a contaminant level below which effects are rarely seen, while the Effects Range-Median (ERM) represents a level above which effects are usually seen. These values do not imply causal relationships between a particular contaminant and the observed effects, but merely that sediments containing these levels of a particular contaminant, usually elicit biological effects of one kind or another in various tests, based on cumulative contaminant load in the sediment. As seen in Fig 2, some of the NS&T sites, most particularly Throgs Neck (site 1), approach or exceed the ERM for lead and/or PCBs, suggesting that contaminant-related biological effects are possible in these regions of LIS.

SEDIMENT TOXICITY SURVEY

The general objectives of NOAA's NS&T Program are to assess the extent of contamination and its effects in U.S. coastal waters, and to determine whether the degree of contamination is increasing or decreasing (Robertson et al. 1993). In areas where contaminant concentrations are sufficiently high that biological effects are likely, intensive bioeffects surveys are carried out to assess the magnitude and extent of contaminant-related effects (Wolfe et al. 1993). Sediment toxicity surveys (Long et al. 1992) are an integral part of these surveys, complementing measurements of biological effects in resident organisms. The first sediment toxicity surveys carried out under this program were conducted in San Francisco Bay (Long et al. 1989, 1990). Subsequent efforts were carried out at about the same time (1991-1992) in Tampa Bay (Long et al. 1994a), Hudson-Raritan Estuary (Long et al. 1994b), and (as described here) Long Island Sound. Preliminary results of this study have appeared elsewhere (Wolfe et al. 1992, Bricker et al. 1994). More recently, sediment toxicity surveys have been completed also in Southern California (1992-94), Boston Harbor (1993), Northwestern Florida coastal Bays (1993-94), and Charleston Harbor and other South Carolina bays (1993-94). Results of these later efforts will appear in following years.

The sampling design for the Long Island Sound study deviated from that employed in other areas. In most areas, sampling stations have been widely dispersed throughout the area of concern, more recently using a stratified random approach, that enables an estimate of the areal extent of degraded habitat (Long et al. 1992). In Long Island Sound, however, in response to recommendations from the Toxics Subcommittee of the LISS Management Committee, this study was designed to determine the relative quality of sediments in selected bays surrounding Long Island Sound. In each of these bays, sediment samples were taken, usually along the upstream-downstream gradient of potential contaminant distribution, for toxicity testing and/or for chemical analyses.

METHODS

Sediment Sampling. Sediment samples were collected for sediment toxicity testing and chemical analysis during August 4-12, 1991 from 63 stations at 21 sites (Figure 4) within the coastal bays and harbors of Long Island

Sound (SAIC 1991). In ten of these bays, sediment samples were taken at six additional sites only for analysis of metallic contaminants, to support a more comprehensive understanding of contaminant distribution. Coordinates and depths for all of the individual sampling stations are provided in Appendix Table 1. Sampling was conducted from the NOAA ship Ferrel or from its 23-foot workboat (Sea Ox), using either a Smith-MacIntyre grab or a modified Van Veen grab, respectively. Sediment samples had also been collected previously (1990) for testing with the amphipod survival assay (NOAA, unpublished data). These samples came largely from several sites in the central axis of LIS, and from a few coastal embayments as well (Figure 5).

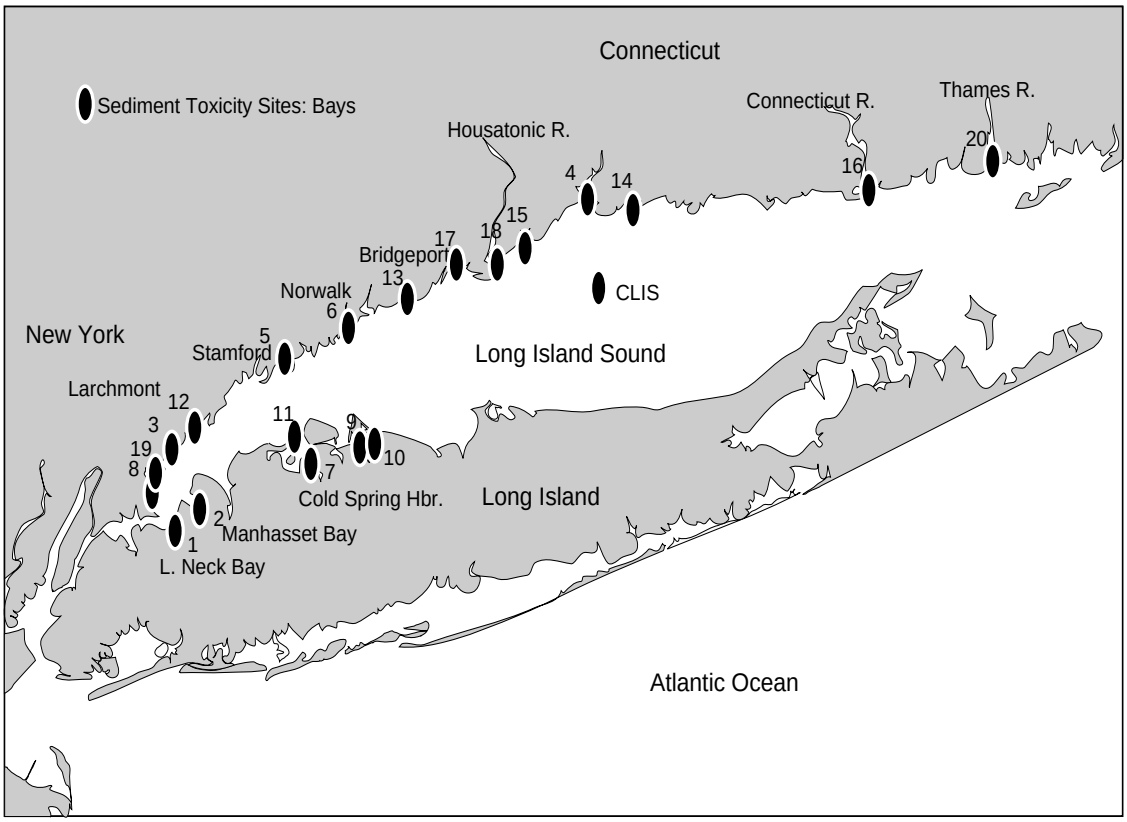

Figure 4. Long Island Sound sites where sediment samples were taken (August 4-10, 1991; three stations per site) for sediment toxicity assessment. Site locations are as follows: 1. Little Neck Bay, NY; 2. Manhasset Bay, NY; 3. Echo Bay, New Rochelle, NY; 4. New Haven Harbor, CT; 5. Stamford Harbor, CT; 6. Norwalk Harbor, CT; 7. Cold Spring Harbor, NY; 8. Eastchester Bay, NY; 9. Centerport Harbor, NY; 10. Northport Harbor, NY; 11. Oyster Bay, NY; 12. Larchmont Harbor, NY; 13. Southport Harbor, CT; 14. Branford Harbor, CT; 15. Milford Harbor, CT; 16. Connecticut River, CT; 17. Bridgeport Harbor, CT; 18. Housatonic River, CT; 19. Pelham Bay, NY; 20. Thames River, CT; 21. CLIS (reference site). Station coordinates are described in Appendix Table 1.

At each station, samples of surficial (1-3 cm) sediments were taken from the grabs for the following analyses or tests: 1) acid-volatile sulfide (AVS) and simultaneously extracted metals (SEM); 2. inorganic and organic contaminants and total organic carbon (TOC); 3. grain size; and 4. sediment toxicity. Prior to each sample collection, the grabs and sampling scoops were cleaned by successive rinses with dichloromethane, acetone, and deionized water. For AVS/SEM analysis, surficial sediment was quickly removed (using a teflon or Kynar-coated scoop) from three to five sectors of the grab sample and placed in a 100-mL wide-mouth glass jar with a teflon-lined cap. The container was filled completely, sealed securely, and stored on ice or refrigerated (not frozen) until shipment by overnight delivery to the analytical laboratory. After collection of the AVS/SEM sample, sediments were removed from the grab (and from successive grabs) until approximately 5 L of sediment had been accumulated in a Kynar coated container. The cumulative sample was then thoroughly mixed with a teflon or Kynar-coated implement, and subsamples were taken for the other analyses. Samples for analysis of metals, organics and TOC were placed in a 500 mL teflon jar and kept frozen until they were split and analyzed at the laboratory. Samples for grain size analysis were placed in Whirl-pak bags, and those for toxicity testing (3.5 L) were placed in polypropylene containers, stored immediately on ice and later refrigerated at 4°C until testing. Subsamples for Microtox™ testing were separated after the toxicity samples had been press sieved, and frozen until extraction.

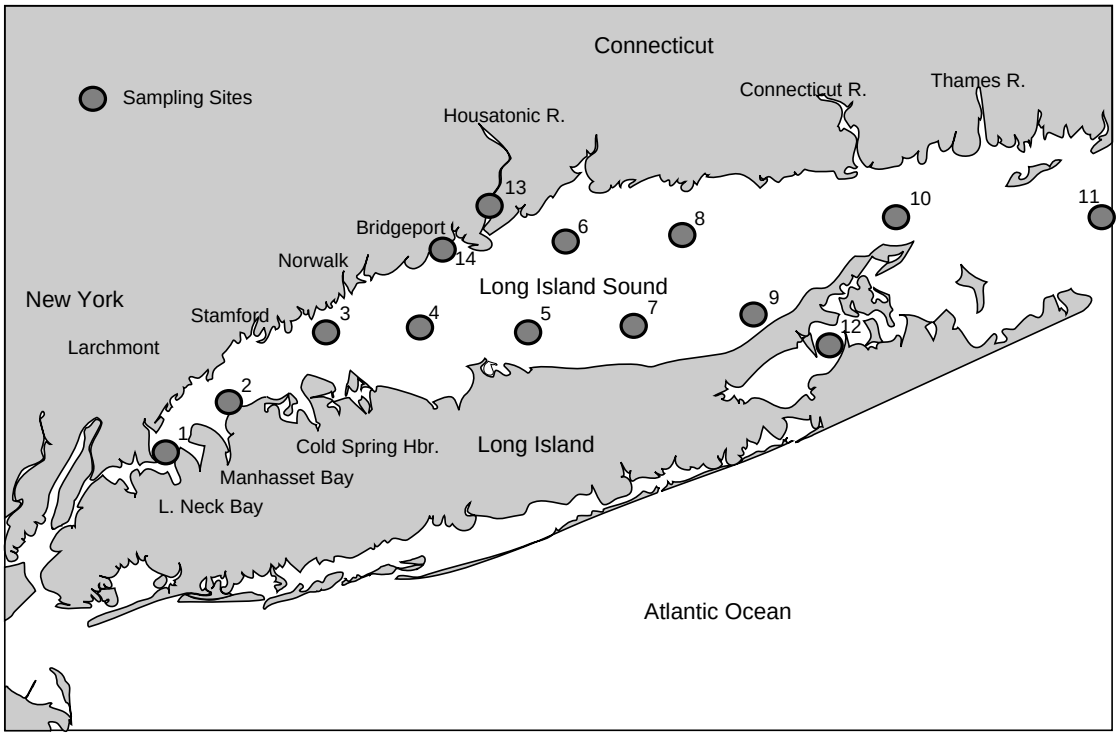

Figure 5. Locations in the mainstem of Long Island Sound where sediment samples were obtained for toxicity testing with *Ampelisca abdita.*

Amphipod Tests. The ten-day, whole sediment toxicity test with amphipods (*Ampelisca abdita*) was performed by Science Applications International Corporation (SAIC 1992) following published protocols (ASTM 1990a). Amphipods were collected from the estuarine tidal flats of the Pettaquamscutt River in Narragansett Bay, Rhode Island. Surface sediments (down to ~10cm) were sieved (0.5 mm mesh) and the amphipods were collected with a dip net, and transported to the laboratory where their taxonomic identification was confirmed. Prior to testing, the amphipods were held in presieved uncontaminated sediment from the collection site and fed, *ad libitum*, laboratory-cultured diatoms *Phaeodactylum tricornutum*. Half the water in the holding containers was replaced every other day, and the animals were acclimated to the assay temperature (20°C) at the rate of 2 to 4°C per day.

Control sediments were obtained from the Central Long Island Sound Reference Station (Figure 4). These sediments are fine-grained (>90% silt-clay) with about 2% total organic carbon, and have consistently been non-toxic in solid phase tests with *Ampelisca abdita.*

Test sediments were press-seived through a 2.0-mm mesh stainless steel screen, and if amphipods were present, through a 1.0 mm mesh seive. Sediments (200 mL.) were then added to exposure containers (quart-sized glass canning jars with an inverted glass dish as a cover) and then covered with about 600 mL filtered seawater. Twenty subadult amphipods were distributed randomly into 100-mL beakers containing 20°C seawater, and these were then added to the test chambers. After one hr, non-burrowing amphipods were removed from the test chambers and replaced, and aeration was restarted. The animals were not fed during the 10-day tests, and lighting was continuous to inhibit swimming behavior. The number of dead or moribund animals on the sediment surface and at the water surface was recorded daily and dead animals were removed. Temperature was monitored daily, and salinity, dissolved oxygen, and pH were measured twice during each test. At the end of the test, surviving amphipods were enumerated in the exposure chambers, and data were entered into computer spreadsheets pending statistical analysis. Tests were considered acceptable when control survival was at least 90%.

Bivalve Larvae Tests. A 48-hr test of survival and normal development of bivalve (*Mulinia lateralis*) embryos exposed to elutriates of test sediments was also conducted by SAIC (1992), following standard protocols (ASTM 1990b). Adult clams, offspring from a Narragansett Bay population, were induced through temperature manipulation to spawn. Eggs and sperm were collected and mixed in standard proportions. Fertilization was allowed to

proceed for at least 35 minutes before separation of the embryo stock from the residual sperm. Percent fertilization and embryo density of approximately 1200 per mL were confirmed visually in subsamples.

After homogenization, 100 g (wet weight) portions of test sediments were placed into glass containers and refrigerated overnight, prior to addition of 500 mL seawater (28-30 ppt) from the Narragansett Pier. The slurry was mixed by aeration and stirring for 30 minutes, and then allowed to settle for at least one hour prior to filtration through a 0.4 um cellulose nitrate filter in a polystyrene housing. Enough elutriate from each sample was filtered to produce five replicate samples of 15 mL each. Approximately 900 *Mulinia* embryos (0.75 mL well mixed stock suspension) were added to each test vial, and the vials were incubated at 22°C for 48 hrs. Embryo densities were reconfirmed by initial counts (6 replicates) performed during subsampling of the embryo stock suspension. Tests were terminated by addition of 0.75 mL buffered formalin, and the numbers and developmental stages of of embryos were determined in 1-mL subsamples (after thorough mixing) for each vial. Numbers of shelled, abnormally shelled, and non-shelled embryos were enumerated among the surviving organisms. Percent survival in the test vials at the end of the exposure period was based on the mean initial embryo count. Tests were considered acceptable if at least 80% of the embryos introduced into seawater controls survived and at least 80% of the survivors showed normal development.

Microtox™ Tests. Microtox™ assays were performed on organic extracts of the test sediments (Schiewe et al. 1985). Sediment extractions and Microtox™ assays were performed by Parametrix, Inc. in Seattle, WA (SAIC 1992). On the day of extraction, frozen samples were thawed, excess water was poured off, sediments were homogenized, and 3 g (wet weight) samples were placed into 50 mL centrifuge tubes (Teflon) for extraction. After 5 min centrifugation at 1900 rpm, aqueous layers were again discarded, and 15 g anhydrous sodium sulfate and 30 mL dichloromethane were added to each sample. Samples were tumbled end over end for 16 hours and centrifuged, and the extracts were decanted into amber glass bottles with Teflon-lined caps. This extraction process was repeated a second and third time with additional 30 mL volumes of dichloromethane which were combined with the first, following tumbling and centrifugation each time. Half of the accumulated extract was then reduced to <5 mL at 75 °C in a jacketed Kuderna-Danish apparatus. Absolute ethanol (12.5 mL) was added, and the sample was again reduced to < 5 mL to completely eliminate dichloromethane, and the sample was brought to 5 mL with ethanol and stored in a clean vial under nitrogen. Microtox™ assays were performed using a Microtox™ Model 500 instrument according to standard methods (Microbics 1992).

Chemical Analyses. The suite of organic and inorganic chemicals measured in the sediment samples were those routinely measured by the NS&T Program, including polycyclic aromatic hydrocarbons (PAHs), DDT and its metabolites, chlorinated pesticides other than DDT, polychlorinated biphenyls (PCBs), and 16 trace and heavy metals (Robertson et al. 1993). Procedures for analysis of organic chemicals are outlined in MacLeod et al. (1985), Battelle Ocean Sciences (1991), and Lauenstein and Cantillo (1993). Briefly, PAHs, PCBs, and chlorinated pesticides are analyzed by electron capture gas chromatography or selective ion Gas Chromatography-Mass Spectrometry. Methods for inorganic chemical analyses (total element) are described in Battelle Ocean Sciences (1991) and Lauenstein and Cantillo (1993). Concentrations of different metals were determined either by cold vapor atomic absorption, hydride generation atomic absorption, graphite furnace atomic absorption, or inductively coupled plasma/mass spectrometry. Analyses for Acid-Volatile Sulfide (AVS) used selective generation of hydrogen sulfide, cryogenic trapping, gas chromatographic separation, and photoionization detection (Cutter and Oates 1987, Allen et al. 1991). Following AVS analysis, the HCl digestate was filtered, and simultaneously extracted metals (SEM: cadmium, copper, lead, mercury, nickel, and zinc) were analyzed by flame atomic absorption. Total organic carbon content was determined using a LECO carbon analyzer after first removing inorganic carbon with 6N HCl. Grainsize was determined using a standard seive and pipette method (Battelle Ocean Sciences 1991).

RESULTS

Toxicity Tests. Control-corrected results are shown in Table 5 for the four endpoints with the three toxicity tests used in the study of LIS coastal embayments. Raw data from these three sediment toxicity tests are summarized in Appendix Tables 2.1-2.3. Sediment toxicity to amphipods was measured for 10 sites in the mainstem of the sound (Figure 5), as well as in the twenty coastal bays. These sediment samples from the LIS mainstem exhibited little or no toxicity (Table 6). Although modest toxicity occurred in samples from Throgs Neck (Figure 5, site 1), the area off Mattituck Creek (site 9) and Block Island Sound (site 11), none of the sediments from the central mainstem of LIS reduced survival of test amphipods below 80% of control values (Table 6). By contrast

three inshore samples collected and assayed concomitantly with the mainstem samples (sites 12-14) all exhibited significant toxicity with survivals less than 80% of control values (Table 6). Two of these latter samples were from sites (#13, Housatonic River; and #14, Bridgeport Harbor) near areas sampled in the LIS Bays study (stations 18A and 17I, respectively), with similar results (Tables 5 and 6).

In sharp contrast to the mainstem LIS samples, 48 of the 60 samples (80%) collected from the coastal embayments were statistically significantly toxic to test amphipods relative to the control sediment from central LIS (Table 5 and Figure 6). Of the 48 toxic samples, 16 were marginally toxic, with survivals equal to at least 80% of control values. The other 32 samples (53.3% of the total), however, ranged from 9.9% survival (station 13A, in Southport Harbor) to 79.1% (stations 8A, 15C, and 20G). The stations that were most toxic in the amphipod assay were 13A (Southport Harbor, 9.9% survival), 18.B (Housatonic River, 16.2%), 2G (Manhasset Bay, 36.7%), 3C (Echo Bay, 38.9%), 11B (Oyster Bay, 41.8%), and 1D (Little Neck Bay, 46.6%). In addition, however, two of the three samples taken from the Central Long Island Sound (CLIS) site were also toxic, and one of these reduced amphipod survival to 71.4% of control values (Table 5). The distribution of samples toxic in the amphipod test is shown in Figure 6, and the distribution of samples toxic in one or more tests is shown in Figure 7.

Table 5 Results of three sediment toxicity tests with the samples from Long Island Sound coastal embayments.

Station	*Ampelisca* survival as % of control	*Mulinia* survival as % of control	*Mulinia* Normal as % of Control	Microtox™ EC50 % of Control
1-A	86.7	117.7	106.8	12.3**
1-C	72.6**	57.0**	109.0	22.6**
1-D	46.6**	45.6**	105.4	49.3**
2-A	75.6**	31.3**	99.3	17.7**
2-E	75.6**	53.7**	103.1	24.8**
2-G	36.7**	12.9**	102.8	46.6**
3-A	81.1*	124.5	109.0	10.6**
3-C	38.9**	76.9	108.3	26.2**
3-F	66.7**	119.0	106.4	15.8**
4-A	83.5*	110.1	88.6*	62.1
4-D	82.2*	110.7	102.1	28.0**
4-G	74.6**	105.4	102.3	139.6
5-A	54.4**	101.4	108.3	23.0**
5-D	76.7**	108.9	107.9	34.9**
5-H	80.0	88.4	106.9	147.7
6-A	90.8*	89.6	102.1	9.5**
6-B	83.2*	118.9	100.8	45.9**
6-F	68.1**	121.2	99.6	51.3**
7-A	82.4*	106.9	100.8	51.3
7-B	93.4	29.7**	100.6	36.4**
7-C	70.3**	23.9**	100.8	21.0**
8-A	79.1**	104.8	102.5	1169.9
8-B	62.8**	110.9	108.3	35.8**
8-C	61.1**	94.6	102.3	129.7
9-A	92.3	88.8	95.6*	14.7**
9-B	59.3**	26.7**	99.5	16.4**
9-C	86.8	89.7	98.3	24.7**
10-A	93.4	81.8	95.0	50.6**

Table 5 continued.

Station	*Ampelisca* survival as % of control	*Mulinia* survival as % of control	*Mulinia* Normal as % of Control	Microtox™ EC50 % of Control
10-B	89.0*	80.2	93.7	67.0
10-C	91.2	86.9	97.9*	108.8
11-A	73.5**	106.4	99.9	47.1**
11-B	41.8**	54.9**	99.8	38.6**
11-C	34.1**	37.7**	98.9	45.4**
12-A	70.0**	97.3	105.4	32.6**
12-B	82.2*	137.4	107.8	17.9**
12-C	66.7**	27.2**	91.9	14.9**
13-A	9.9**	48.7**	98.9	319.9
13-B	99.5	105.0	100.8	249.3
13-C	89.7*	101.7	98.4*	74.7
14-A	93.4	136.2	102.0	93.1
14-B	95.6	93.0	101.8	105.2
14-C	95.6	124.0	102.3	48.5**
15-A	76.9**	112.5	102.2	108.1
15-B	90.8*	113.8	102.2	190.1
15-C	79.1**	114.2	99.3	237.5
16-A	86.8*	134.5	101.8	685.9
16-B	81.3*	134.8	101.0	19.3**
16-C	80.2*	119.1	99.7	272.8
17-A	91.9*	135.3	102.3	118.3
17-F	87.6*	110.7	102.3	60.2
17-I	53.0**	56.6**	83.0*	46.1**
18-A	75.7**	71.4**	100.8	139.9
18-B	16.2**	111.9	102.2	133.3
18-D	69.2**	109.1	101.0	426.9
19-A	85.6*	85.0	103.6	7.0**
19-C	74.8**	57.8**	107.6	40.2**
19-F	63.9**	109.5	108.1	17.2**
20-A	91.2	104.2	101.0	15.4**
20-D	87.9*	127.5	101.5	151.2
20-G	79.1**	106.8	102.3	272.4
CLIS-A	81.3	96.4	100.8	173.1
CLIS-B	83.5*	88.3	98.8	132.4
CLIS-C	71.4**	105.5	100.3	289.3

*Statistically significant reduction relative to control, one-way test, alpha = 0.05.
**Statistically significant reduction, as above, and 80% or less of control response for Ampelisca and Mulinia, or 70% or less of control for Microtox™.
LIS.stations.sedtox (adobe illustrator file)

Table 6. Sediment toxicity results with the *Ampelisca abdita* assay for the mainstem LIS and associated sites (Figure 5).

LIS Station #	Percent Mortality	% of Control Survival	Significance[a]
1	22.0	86	*
2	8.0	101	
3	2.5	104	
4	2.0	104	
5	5.0	101	
6	5.0	101	
7	1.7	105	
8	9.0	102	
9	13.5	89	*
10	11.0	98	
11	23.8	82	*
12	53.0	52	**
13	24.4	77	**
14	99.0	1	**

a *Statistically significant reduction relative to control, one-way test, alpha = 0.05; **Statistically significant reduction, as above, and 80% or less of control response.

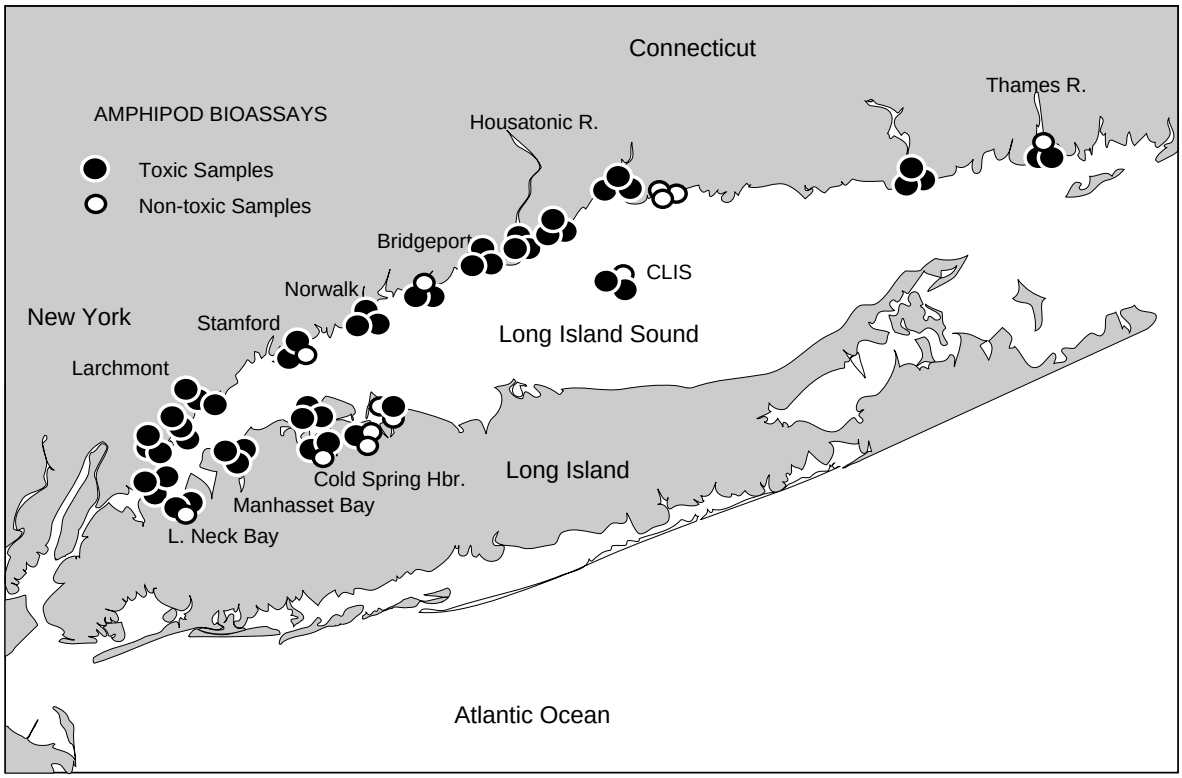

Figure 6. Sampling stations in Long Island Sound bays in which sediments were toxic or not toxic in the *Ampelisca bioassay.*

Survival of *Mulinia lateralis* embryos was not as sensitive as the amphipod survival endpoint for the samples from LIS embayments. Fifteen of the 60 samples (25%) were significantly toxic and all of these reduced embryo survival to less than 80% of control values. The samples most toxic to *Mulinia* survival were 2G (Manhasset Bay @ 12.9% survival), 7C (Cold Spring Harbor @ 23.9%), 9B (Centerport Harbor @ 26.7%), 12C (Larchmont

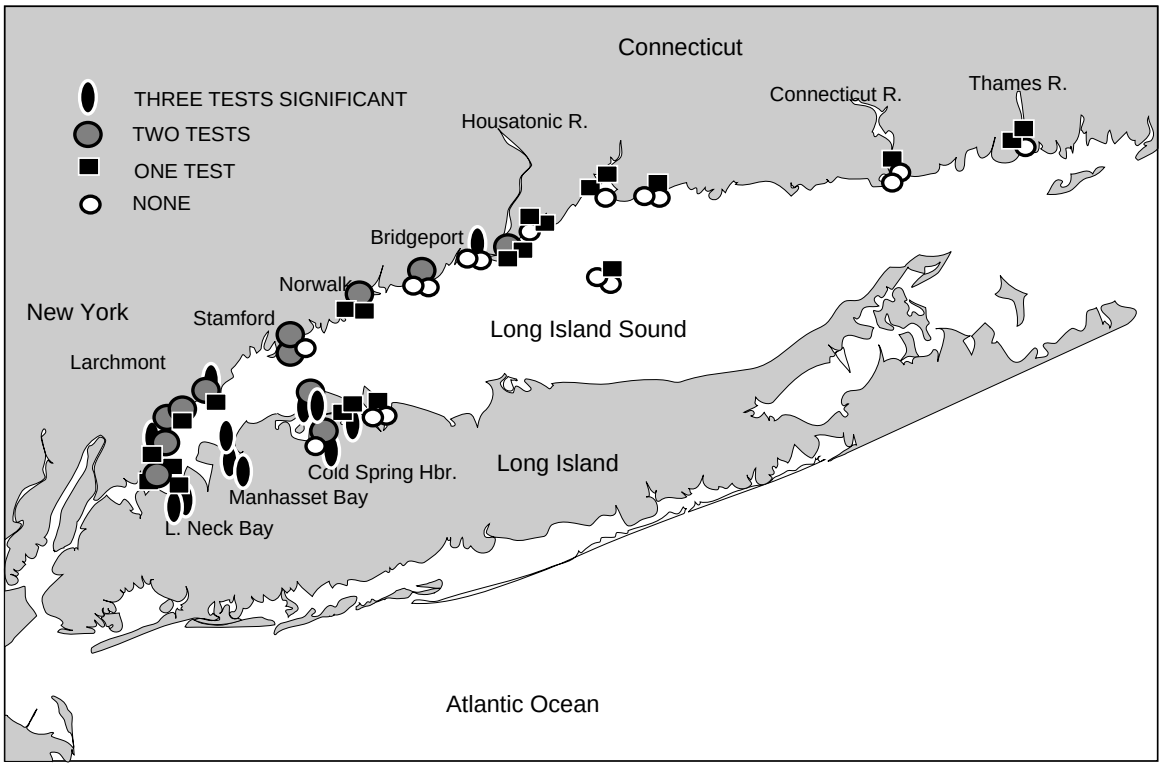

Figure 7. Sampling locations in Long Island Sound where sediments were significantly toxic in three, two, one, or no tests. "Significant" includes statistically significant (p = .05) reduction from and <80% of control survival for *Ampelisca* and *Mulinia* or <70% of control for Microtox™.

Harbor @ 27.2%), 7B (Cold Spring Harbor @ 29.7%), 2A (Manhasset Bay @ 31.3%) and 11C (Oyster Bay @ 37.7%). While the sensitivity of the *Mulinia* test was substantially lower than that of the amphipod test for these samples, the sites with reduced *Mulinia* survival were highly consistent with both the amphipod survival (14/15) and Microtox™ (13/15) endpoints. All but one of the 15 samples significantly toxic to *Mulinia* also reduced amphipod survival to less than 80%. Of the 15 samples significantly toxic to *Mulinia* survival, twelve were toxic also to both Microtox™ and amphipod survival, and one of these (17I) was significantly toxic also to *Mulinia* development. Two of the remaining three samples significantly toxic to *Mulinia* survival were toxic to amphipod survival, while the third was significantly toxic to Microtox™.

Although the normal development and survival endpoints for *Mulinia lateralis* were positively correlated with each other (Table 7), the normal development endpoint was neither sensitive nor concordant with other endpoints. Only 5 of the 60 sediment samples (8.33%) from LIS bays showed statistically significant reductions of normal development. The lowest value (83% of the control rate of normalcy; station 17I, Bridgeport Harbor) coincided with significant toxicity to both the amphipod and *Mulinia* survival endpoints. Only two of the other four samples that showed reduced normal development were toxic to Ampelisca and both these samples had greater that 80% survival. None of these four samples were toxic to the *Mulinia* embryo survival endpoint.

With 35 significant reductions of EC-50 (58%), the Microtox™ endpoint was about equally sensitive as amphipod survival for the sediment samples from LIS bays (Table 5). However, these two endpoints were not significantly correlated with one another (Table 7), and the concordance between Microtox™ and amphipod survival was not nearly as strong overall as between *Mulinia* survival and amphipod survival. Of the six most toxic stations with Microtox™ (19A, Pelham Bay @ 7.0%; 6A, Norwalk Harbor @9.5%; 3A, Echo Bay @ 10.6%; 1A, Little Neck Bay @ 12.3%; 9A, Centerport Harbor @ 14.7%; and 12C, Larchmont Harbor @ 14.9%), two were not toxic to amphipods, and only one (12C) reduced amphipod survival to less than 80%. Nonetheless, of the 35 stations toxic to Microtox™, 28 (75%) were toxic also to amphipod survival and 21 (60%) reduced amphipod survival to less than 80%. Viewed conversely, only 28 (58.3%) of the 48 stations significantly toxic to amphipods

were also significantly toxic to Microtox™; and only 21 (66%) of the 32 stations causing less than 80% survival in amphipods were significantly toxic to Microtox™. The lack of consistency among toxicity test results is not unexpected: it reflects differences in sensitivity among test organisms, as well as differences in mode of exposure and contaminant bioavailability among the tests.

Table 7. Spearman Rank Correlations (Rho) among toxicity results (as Percent of Control Values) for rour endpoints tested at three stations each from 21 sites in Long Island Sound coastal embayments (N=63).

	Mulinia lateralis		Microtox™
	Survival	Normal Development	EC-50
A. abdita Survival	0.333**	0.190	0.081
M. lateralis Survival	—-	0.386**	0.205
M. lateralis Normal Development	—-	—-	0.125

*p<0.05; **p<0.01; ***p<0.001

Relationships Among Toxicity and Sediment Contamination. The toxicities estimated by Microtox™ were very highly significantly correlated (Spearman rank) with %TOC in the sediments, and with the % fines (clay plus silt) and a broad suite of organic (PAHs, PCBs, DDTs, and other chlorinated pesticides) and inorganic (Cd, Cr, Cu, Hg, Pb, and Sn) contaminants in the sediments (Table 8 and Figure 8). Of 35 samples with TOC greater than 2.0%, 34 were significantly toxic with Microtox™, whereas only 6 of the 28 samples with TOC < 2.0% were toxic with Microtox™. Toxicities measured by the other three endpoints were correlated to a much lesser degree with %TOC and were also significantly correlated with the suite of metals, but generally not with % fines; and their correlations with organic contaminants were much lower and more variable than for Microtox™. Of the 35 samples with TOC>2.0%, 20 (57.1 %) were significantly toxic (with less than 80% survival) to amphipods, and a similar fraction (12/28, or 42.9%) of those samples with TOC<2.0% were also toxic. Or, viewed another way, 20 (62.5%) of the 32 samples toxic to amphipods were among the 35 samples out of 63 (55.6 %) samples with TOC > 2.0%. Table 9 shows, however, that essentially all of the metallic and organic contaminants analyzed in this study are consistently very highly correlated with one another and with TOC. Using mercury, PCBs and PAH as examples, Figure 9 illustrates this high degree of covariance among contaminants. This very strong co-variance among the contaminants precludes any firm conclusions about the specific causal relationships between toxicity and particular contaminants. From correlative analyses alone, however, one can nonetheless gain considerable insight on the relative responsiveness of the three most sensitive toxicity assays to different contaminant categories.

Table 8. Spearman Rank Correlations (Rho) between sediment contaminant concentrations and toxicity results (as Percent of Control Values) for four endpoints tested at three stations each from 21 Sites in Long Island Sound coastal embayments (N=63).

	A. abdita	**Mulinia lateralis**		**Microtox™**
Contaminant	**Survival**	**Survival**	**Norm Development**	**EC-50**
Metals				
Arsenic	-0.213	-0.256	-0.120	-0.494***
Cadmium	-0.360**	-0.270*	-0.346**	-0.671***
Chromium	-0.292*	-0.197	-0.200	-0.525***
Copper	-0.320**	-0.281*	-0.251*	-0.535***
Lead	-0.299*	-0.354**	-0.300**	-0.687***

Table 8 continued.

Contaminant	*A. abdita* Survival	Mulinia lateralis Survival	Mulinia lateralis Norm Development	Microtox™ EC-50
Mercury	-0.237	-0.310*	-0.222	-0.712***
Selenium	-0.163	-0.319*	-0.314*	-0.601***
Silver	-0.330**	-0.226	-0.181	-0.639***
Tin	-0.305*	-0.251*	-0.215	-0.636***
Zinc	-0.335**	-0.329**	-0.278*	-0.686***
Organics				
tPAHs	-0.267*	-0.066	-0.207	-0.495***
tPCBs	-0.328**	-0.132	-0.212	-0.486***
tDDT	-0.209	-0.073	-0.095	-0.520***
tCHClP	-0.108	-0.431***	-0.378**	-0.552***
Other				
%TOC	-0.258*	-0.346**	-0.308*	-0.757***
% Fines	+0.134	-0.076	-0.079	-0.411***

*p<0.05; **p<0.01; ***p<0.001

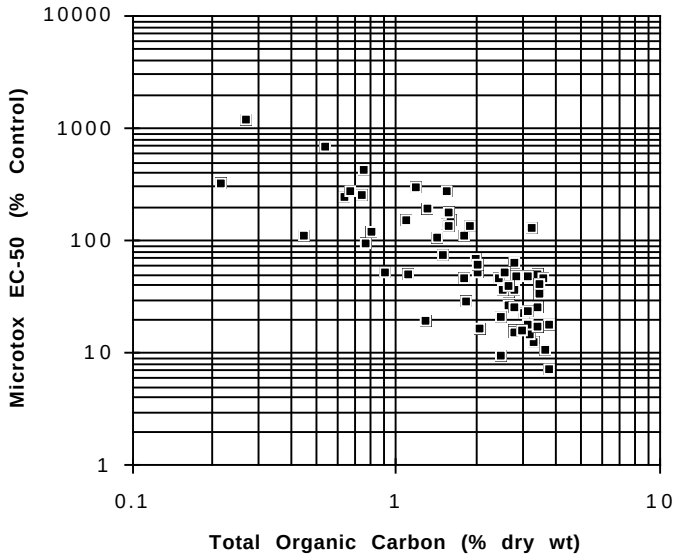

Figure 8. Scatterplot, on a logarithmic scale, of Microtox™ response, as percent of control, against total organic carbon in sediments from Long Island Sound embayments, illustrating the highly significant negative correlations between toxicity and concentrations of most contaminants (which co-varied strongly with TOC).

Table 9. Spearman Rank Correlations (Rho) among sediment contaminant concentrations in sediments collected at three stations Each from 21 sites in Long Island Sound coastal embayments (N=63).

Contaminant	Cadmium	Lead	tPAH	%TOC	% Fines
Metals					
Arsenic	+0.513***	+0.687***	+0.484***	+0.650***	+0.360**
Chromium	+0.718***	+0.875***	+0.675***	+0.833***	+0.495***
Copper	+0.776***	+0.846***	+0.740***	+0.815***	+0.363**
Mercury	+0.820***	+0.940***	+0.784***	+0.922***	+0.540***
Selenium	+0.786***	+0.869***	+0.555***	+0.885***	+0.477***
Silver	+0.802***	+0.902***	+0.693***	+0.868***	+0.475***

Table 9 continued.

Contaminant	Cadmium	Lead	tPAH	%TOC	% Fines
Metals					
Tin	+0.828***	+0.938***	+0.738***	+0.884***	+0.439***
Zinc	+0.854***	+0.952***	+0.695***	+0.936***	+0.532***
Organics					
tPCBs	+0.677***	+0.718***	+0.880***	+0.734***	+0.353**
tDDT	+0.694***	+0.756***	+0.873***	+0.739***	+0.353**
tCHClP	+0.476***	+0.618***	+0.342**	+0.657***	+0.421***

*p<0.05; **p<0.01; ***p<0.001

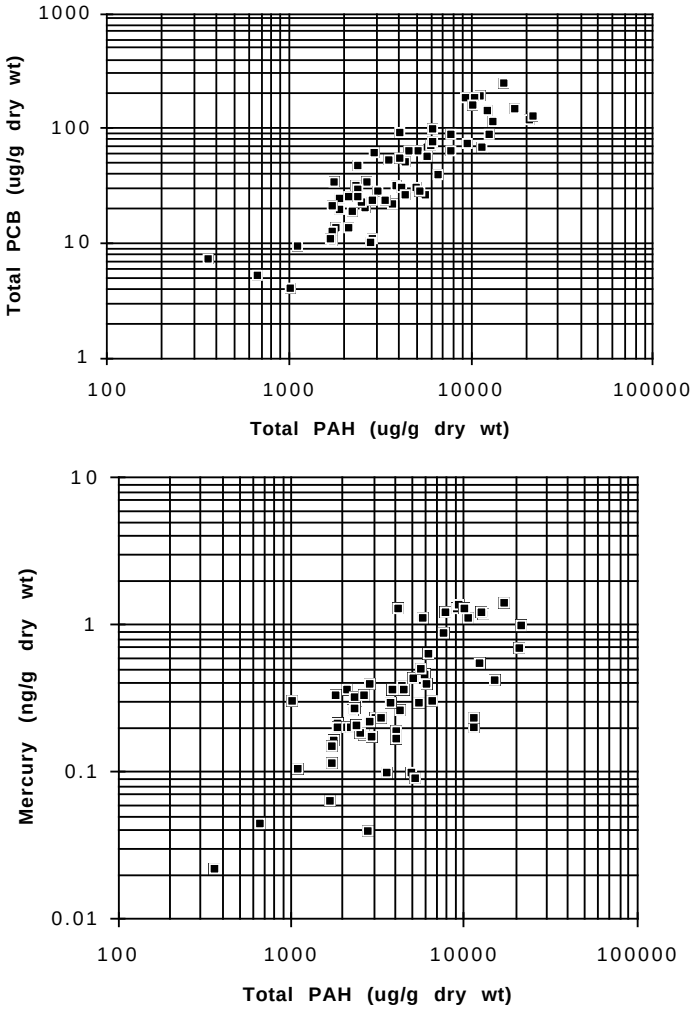

Figure 9. Scatterplots, on a logarithmic scale, of total PCB (top) and mercury (bottom) concentrations against total PAH in sediments from Long Island Sound embayments, illustrating the strong covariance among various contaminant classes in these sediments.

Table 10 shows the shifts in correlative strength between the results for the individual toxicity assays, and the concentrations of chemical contaminants, normalized either to dry weight of sediments, to the content of fine-grained (silt + clay) sediments, or to the aluminum (metals) or total organic carbon (organic contaminants) contents. Spearman rank correlations (Rho) are also compared in Table 10 for the full suite of sediment samples from all 63 sites against the subset of 49 non-sandy (<42% sand content) sites.

Table 10.1. Spearman Rank Correlations (Rho) for results of the Microtox^{R} assay with various contaminants and contaminant categories, normalized either to dry weight, percent silt plus clay, total organic carbon, or aluminum content of the sediments, for 63 stations sampled in peripheral bays of Long Island Sound, and for the 49 non-sandy (<42% sand) stations considered alone.

	dry wt	% fines	Aluminum or TOC	dry wt	% fines	Aluminum or TOC
	63 stas	**63 stas**	**63 stas**	**49 stas**	**49 stas**	**49 stas**
Silver (Ag)	-0.639***	-0.250	-0.635***	-0.509***	-0.510***	-0.526***
Cadmium (Cd)	-0.671***	-0.162	-0.630***	-0.610***	-0.590***	-0.601***
Copper (Cu)	-0.535***	-0.123	-0.529***	-0.561***	-0.493***	-0.627***
Mercury (Hg)	-0.712***	-0.406**	-0.699***	-0.599***	-0.586***	-0.628***
Lead (Pb)	-0.687***	-0.167	-0.667***	-0.578***	-0.584***	-0.600***
Zinc (Zn)	-0.686***	-0.122	-0.667***	-0.609***	-0.577***	-0.610***
tPAH	-0.495***	-0.139	+0.089	-0.485***	-0.491***	-0.159
Sum PCB	-0.486***	-0.110	+0.044	-0.483***	-0.457**	-0.196
Sum DDT	-0.522***	-0.229	+0.233	-0.513***	-0.503***	-0.138
Sum Pesticides	-0.552***	-0.311*	-0.203	-0.473***	-0.488***	-0.274
TOC	-0.757***			-0.659***		
%silt+clay	-0.411***			-0.044		
Aluminum (Al)%	-0.020			+0.040		

Table 10.2. Spearman Rank Correlations (Rho) for results of the whole sediment toxicity assay with *Ampelisca abdita* survival, with various contaminants and contaminant categories, normalized either to dry weight, percent silt plus clay, total organic carbon, or aluminum content of the sediments, for 63 stations sampled in peripheral bays of Long Island Sound, and for the 49 non-sandy (<42% sand) stations considered alone.

	dry wt	% fines	Aluminum or TOC	dry wt	% fines	Aluminum or TOC
	63 stas	**63 stas**	**63 stas**	**49 stas**	**49 stas**	**49 stas**
Silver (Ag)	-0.330**	-0.531***	-0.167	-0.429**	-0.527***	-0.408**
Cadmium (Cd)	-0.360**	-0.471***	-0.157	-0.464**	-0.555***	-0.356*
Copper (Cu)	-0.320**	-0.437***	-0.202	-0.370**	-0.505***	-0.367**
Mercury (Hg)	-0.237	-0.401**	-0.261*	-0.359*	-0.470***	-0.363**
Lead (Pb)	-0.299*	-0.479***	-0.286*	-0.420**	-0.512***	-0.423**
Zinc (Zn)	-0.335**	-0.500***	-0.233	-0.440**	-0.617***	-0.422**
tPAH	-0.267*	-0.318*	-0.085	-0.360*	-0.429**	-0.123
Sum PCB	-0.328**	-0.432***	-0.270*	-0.423**	-0.525***	-0.294*
Sum DDT	-0.209	-0.320**	-0.071	-0.312*	-0.400**	-0.060
Sum Pesticides	-0.108	-0.193	-0.050	-0.160	-0.189	-0.060
TOC	-0.258*			-0.411**		
%silt+clay	+0.134			+0.127		
Aluminum (Al)%	+0.018			-0.020		

Table 10.3. Spearman Rank Correlations (Rho) for results of the sediment elutriate toxicity assay with *Mulinia lateralis* survival, with various contaminants and contaminant categories, normalized either to dry weight, percent silt plus clay, total organic carbon, or aluminum content of the sediments, for 63 stations sampled in peripheral bays of Long Island Sound, and for the 49 non-sandy (<42% sand) stations considered alone.

	dry wt	% fines	Aluminum or TOC	dry wt	% fines	Aluminum or TOC
	63 stas	**63 stas**	**63 stas**	**49 stas**	**49 stas**	**49 stas**
Silver (Ag)	-0.226	-0.131	-0.286*	-0.097	-0.173	-0.109
Cadmium (Cd)	-0.270*	-0.092	-0.228	-0.272	-0.356*	-0.179
Copper (Cu)	-0.281*	-0.179	-0.274*	-0.224	-0.314*	-0.230
Mercury (Hg)	-0.310*	-0.249	-0.188	-0.206	-0.304*	-0.250
Lead (Pb)	-0.354**	-0.203	-0.266*	-0.247	-0.332*	-0.263
Zinc (Zn)	-0.329**	-0.140	-0.257*	-0.253	-0.424**	-0.243
tPAH	-0.066	+0.053	+0.263*	-0.004	-0.094	+0.202
Sum PCB	-0.132	-0.084	+0.068	-0.058	-0.147	+0.065
Sum DDT	-0.073	-0.006	+0.284*	+0.017	-0.078	+0.302*
Sum Pesticides	-0.431***	-0.370**	-0.318*	-0.254	-0.306*	-0.180
TOC	-0.348**			-0.240		
%silt+clay	-0.076			+0.215		
Aluminum (Al)%	-0.071			-0.077		

The highly significant correlation of the Microtox™ response with contaminants expressed on a dry weight basis for the 63 stations was essentially eliminated by normalization of the contaminant concentrations either to percent fines or to % TOC (organics), but was not substantially affected by normalization (metals) to aluminum content (Table 10.1). This suggests that the Microtox™ assay is responsive to total contaminant content of the sediments, independent of other potential normalizing factors. Because the Microtox™ procedure involves an organic extraction, the test bacteria are exposed to the total load of toxic organics and extractable TOC content from the original sediments. Any mediating effect of grain size would therefore be eliminated, and one would not necessarily expect a mediating effect of the TOC on the toxic effect within the exposure chamber. Except for lipid-soluble, organic-metal complexes (such as methyl mercury or organotins), the metals are probably extracted less efficiently than the organic contaminants. The Microtox™ test most likely is responding mainly to some combination of organic contaminants, and the correlation with metals is largely the result of covariance with the organic contaminants. The metal most significantly correlated with Microtox™ response was mercury, which occurs partially in a highly toxic and lipid-soluble organic form; and the most significantly correlated organic contaminant class was total pesticides, which remained negatively correlated even upon normalization to TOC (unlike the other organic categories). The significance of the contaminant correlations with Microtox™ response was also lower for the 49 non-sandy stations considered alone than for all of the sites together, although for this subset of stations, correlations remained significantly negative after normalization to % fines. In these 49 stations, the total range of fines content is 37.1-99% (with 0.77-3.83% TOC), compared to 4.4-99% (and 0.22-3.83%) in the full set of 63 samples.

The pattern of correlations with contaminants was strikingly different for either of the survival endpoints than for Microtox™ (Tables 10.2 and 10.3). First, the initial correlations with contaminant contents based on dry weight were much lower for survival of *Ampelisca* and *Mulinia* than for Microtox™. For amphipod survival, the significance of correlations with all contaminants increased substantially upon normalization to % fines, while it consistently (except for mercury) dropped with normalization either to Al or TOC (Table 10.2). The shifts in correlative strength between amphipod survival and contaminants upon normalization of the data to percent fines are illustrated in Figures 10-12 for tPCHs, mercury, and lead, respectively. Contrary to the pattern with Microtox™, the strength of all the correlations was also greater in the subset of 49 non-sandy stations. These findings suggest a marked effect of the content of fine-grain size sediments on the bioavailability and toxicity of the contaminants, as one might expect with the whole sediment bioassay. With amphipod survival, mercury was the least strongly correlated metal contaminant and total pesticides was least correlated among the classes of organic contaminants, again in direct contrast to the pattern of correlations with Microtox™. When normalized to percent fines, tPAH, tPCB, and tDDT were significantly correlated with amphipod survival, and tPCB was significantly correlated also after normalization to TOC (Table 10.2).

In the elutriate toxicity test, survival of *Mulinia* larvae was correlated most strongly with total pesticides, lead, zinc, and mercury (Table 10.3). The correlative strength was markedly reduced by normalization either to percent fines or to TOC, and also was reduced somewhat by normalization to aluminum. The correlations with all contaminants were weaker in the subset of 49 non-sandy stations than in the full set, although normalization to percent fines in these samples brought the correlations back to a statistically significant ($p<0.05$) level for total pesticides and for several of the metals. Like the Microtox™ results, this pattern is suggestive of a relationship with the total amounts of contaminants in the sediments, but unlike Microtox™, this relationship was weak to non-existent for tPAH, tPCB, and tDDT. This result is consistent with the conditions of the test protocol, as these lipid-soluble contaminants would not be extracted efficiently into the saline elutriate used to test toxicity to *Mulinia*. Within the total pesticides component, by contrast, much of the range of variability arises from hexachlorobenzene, which exhibits significant solubilities in water, and may account for the stronger correlation of total pesticides with this test.

To examine further the potential contribution of the metallic elements to the observed toxicity, we calculated the molar ratios of simultaneously-extracted metals to acid-volatile sulfide (SEM/AVS) for the LIS samples (Figure 13). DiToro et al. and Landrum et al. have shown that excess AVS lowers the bioavailability (and therefore the toxicity) of many metals in sediments, and that unless the cumulative molar ratio for Cd, Cu, Hg, Ni, Pb, and Zn exceeds 1.0 these metals are unlikely to have toxic effects to organisms exposed to the sediments. The SEM/AVS argument is pertinent mainly to the amphipod assay, as it was the only one in which the test organisms were exposed directly to the sediments. Raw data for the individual SEMs and AVS in LIS sediments are shown in Appendix Table 5. The SEM/AVS exceeded a value of 1.0 in only three samples (stations 18A @ 3.4; 16A @ 2.3; and 20D @1.005. The next three highest SEM/AVS ratios were recorded at CLIS-A, CLIS-B, and CLIS-C, respectively, with ratios between 0.59 and 0.96. Notably, the sediments at stations 18A and 16A consisted predominantly of sand (82.5 and 87.9%, respectively), and contained the lowest AVS concentrations of all the samples. The sediments from station 20D and CLIS also had AVS concentrations among the lowest observed at any of the sites. Despite the consistently high correlations between metallic elements and toxicity (Table 8), therefore, the SEM/AVS ratios suggest that the observed toxicity to amphipods was not caused primarily by

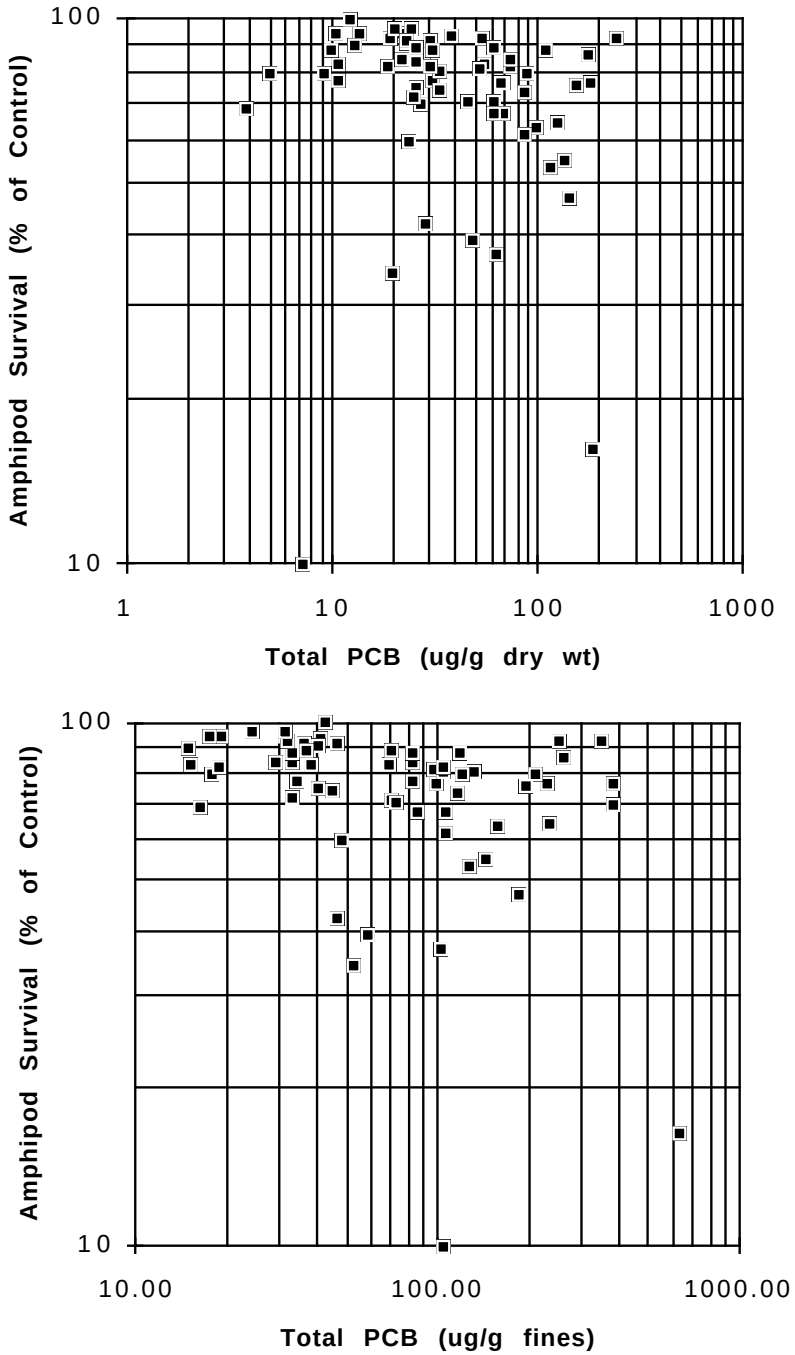

Figure 10. Scatterplot, on a logarithmic scale, of amphipod survival versus total PCB concentration, expressed on a dry weight basis (top) and normalized to silt plus clay content (bottom), in sediments from Long Island Sound embayments.

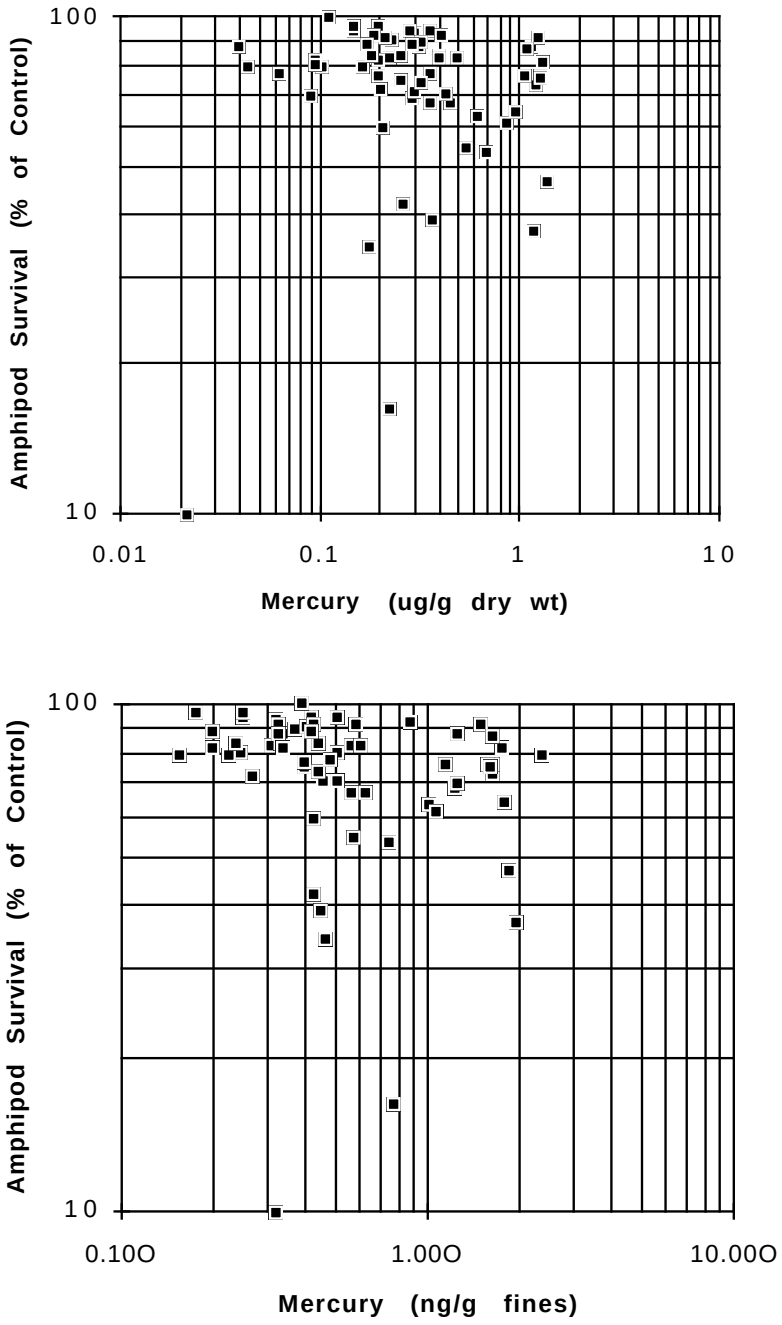

Figure 11. Scatterplot, on a logarithmic scale, of amphipod survival versus mercury concentration, expressed on a dry weight basis (top) and normalized to silt plus clay content (bottom), in sediments from Long Island Sound embayments.

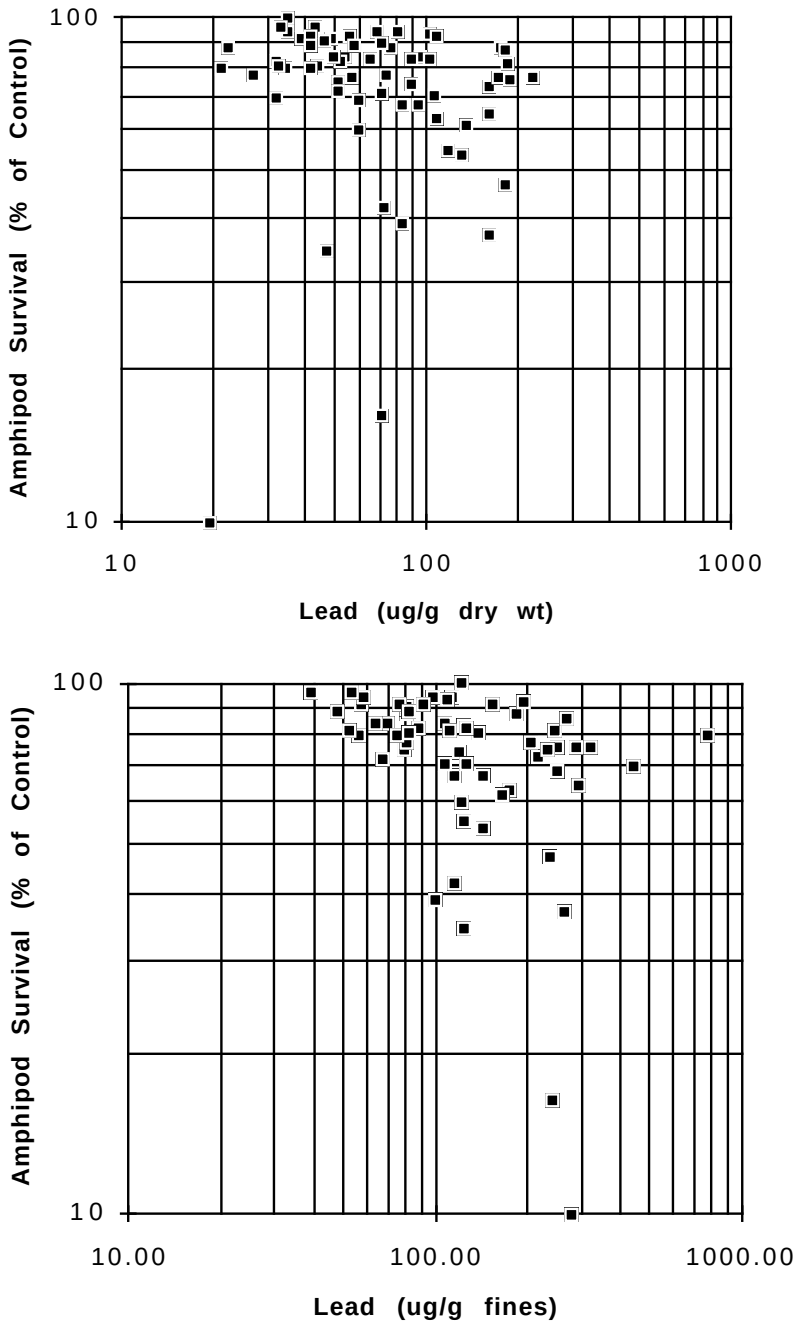

Figure 12. Scatterplot, on a logarithmic scale, of amphipod survival versus lead concentration, expressed on a dry weight basis (top) and normalized to silt plus clay content (bottom), in sediments from Long Island Sound embayments.

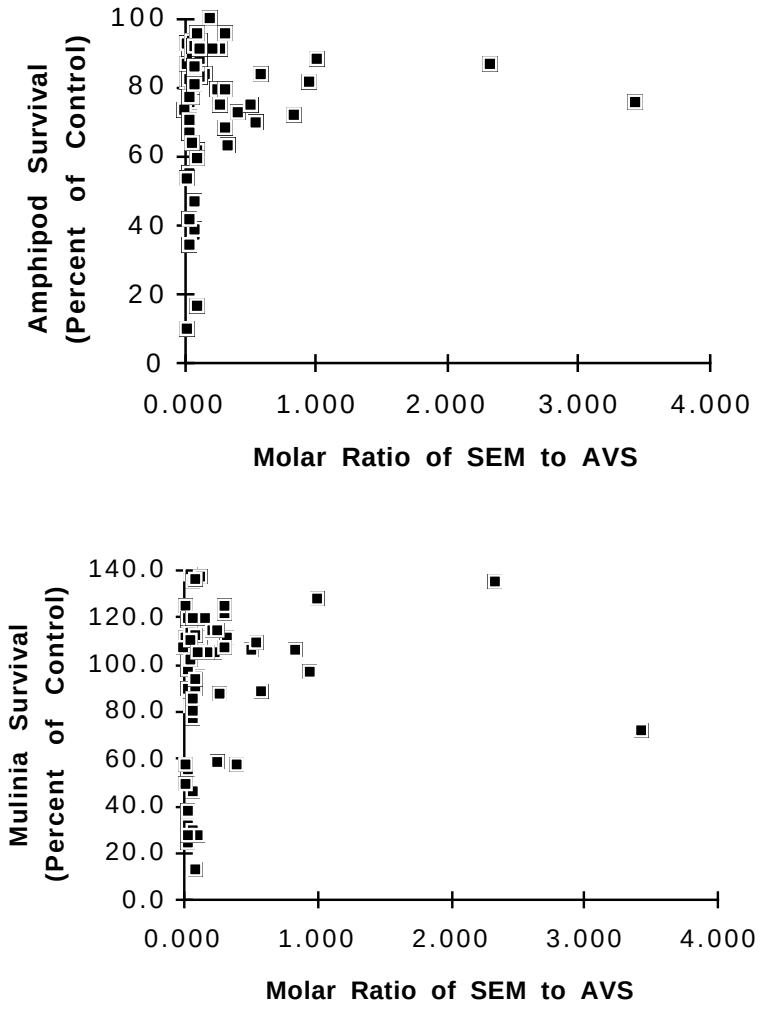

Figure 13. Relationship between sediment toxicity and the ratio of simultaneously-extracted metals to acid-volatile sulfide in the sediments: for 10-day amphipod survival (top) and 48-hr clam larval survival (bottom).

metals. While sample 18A with the highest SEM/AVS ratio was mildly toxic to amphipods and to bivalve larvae, the other samples with relatively high SEM/AVS ratios were generally non-toxic in both tests (Figure 13).

To examine further how the observed sediment toxicity related to the sediment chemistry, we compared the contaminant concentrations in LIS sediments to those concentrations that have been associated with toxicity in previous studies. The Effects Range-Low and Effects Range-Median values developed by Long and Morgan (1990) and by Long et al. (1994) were used for this purpose (Table 11). Two approaches were used in this comparison. First, the LIS sediment chemistry was compared against the ERMs in Table 11 on a constituent-by-constituent basis to determine the number of exceedances for each contaminant. Secondly, cumulative hazard factors were calculated for each sample as follows. The effects range bounded below by the ERL and above by the ERM was assigned a value of 1.0 for each of the 33 contaminants (or groups of contaminants) listed in Table 11, and a fractional value was derived for each contaminant in each LIS sediment sample. Concentrations less

than the ERM were assigned a value of zero, and concentrations that exceeded the ERM received an proportionately scaled value greater than 1.0. For each sample, then, the individual contaminant values were summed to give composite hazard factors. Separate composite hazard factors were calculated for the 10 metals (taken together), the 7 chlorinated hydrocarbon components, and the 12 individual PAH constituents, as well as for all 33 components together. The results are presented and compared in Table 12.

Table 11. Values for Effects Range-Low (ERL) and Effects Range-Median (ERM) criteria used in this report to scale the cumulative risk factors for evaluating sediment toxicity. Values (ug/g dry wt.) are from Long et al. (1994) or Long and Morgan (1990).

Chemical	ERL	ERM
Silver (Ag)	1	3.7
Arsenic (As)	8.2	70
Cadmium (Cd)	1.2	9.6
Chromium (Cr)	81	370
Copper (Cu)	34	270
Mercury (Hg)	0.15	0.71
Nickel (Ni)	20.9	51.6
Lead (Pb)	46.7	218
Antimony (Sb)	2	25
Zinc (Zn)	150	410
Alpha- Chlordane	0.5	6
Dieldrin	0.02	8
Endrin	0.02	45
P,P'-DDE	2.2	27
P,P'-DDD	2	20
Sum DDT	1.58	46.1
Sum PCB	22.7	180
Naphthalene	160	2100
Acenaphthylene	44	640
Acenaphthene	16	500
Fluorene	19	540
Phenanthrene	240	1500
Anthracene	85.3	1100
Fluoranthene	600	5100
Pyrene	665	2600
Benz[a]anthracene	261	1600
Chrysene	384	2800
Benzo[a]pyrene	430	1600
Dibenz[a,h]anthracene	63.4	260
Sum of PAH	4020	44800
tLmw PAH	552	3160
tHmw PAH	1700	9600

Table 12. Cumulative Hazard Factors (HF, as Fraction of the ER-L to ER-M RANGE) for 33 Potentially Toxic Chemicals (or Groups of Chemicals), for which ERLS & ERMS are Specified. Values of 0.00 are at or below ER-L Levels.

Station & Toxicity[a]		Metals (10)	CHCIP (7)	PAH (13)	tPAH	tLMW PAH	tHmw PAH	Cum HF(33)	ERMs Exceeded
1-A	m	5.59	5.45	4.26	0.23	0.84	1.21	17.58	tHmwPAH, Hg, Zn, chlordane
1-C	abm	5.97	2.63	4.49	0.22	0.84	1.15	15.30	tHmwPAH, Hg, Ag
1-D	abm	6.59	3.36	6.98	0.33	1.35	1.61	20.22	tHmw&tLmw, Hg, Ag
2-A	abm	6.75	10.45	1.98	0.13	0.35	0.85	20.51	DDE, tDDT, tPCB, Hg, Pb, chlordane, dieldrin
2-E	abm	6.04	2.17	0.66	0.04	0.26	0.41	9.57	Hg, Ag
2-G	abm	5.36	1.79	1.76	0.09	0.41	0.63	10.04	Hg
3-A	m	7.09	3.02	2.17	0.14	0.31	0.89	13.61	Hg, Ag
3-C	abm	2.4	1.87	0.2	0.01	0.08	0.28	4.84	none
3-F	am	2.9	2.23	0.63	0.05	0.16	0.47	6.44	none
4-A	m	3.65	3.29	0.66	0.05	0.16	0.5	8.32	tDDT, Ag
4-D	m	1.29	0.57	0.05	0	0	0.15	2.06	none
4-G	a	0.7	0.58	0.05	0	0	0.04	1.37	none
5-A	am	4.32	5.44	3.65	0.2	0.5	1.22	15.33	tHmwPAH, chlordane
5-D	am	2.25	0.68	0.11	0 0.04	0.23	3.31		none
5-H	NT	0.18	0.11	0.01	0	0	0	0.30	none
6-A	m	2.42	2.31	0.12	0	0.03	0.27	5.14	Hg, dieldrin
6-B	m	0.68	0.94	0.2	0.01	0.07	0.28	2.18	none
6-F	am	1.02	0.05	0.01	0	0	0	1.08	none
7-A	m	1.8	0.67	0.04	0	0	0.11	2.63	none
7-B	bm	1.82	0.54	0.02	0	0	0.03	2.41	none
7-C	abm	1.58	0.76	0.02	0	0	0.05	2.41	none
8-A	a	0	0.06	0.01	0	0	0	0.06	none
8-B	am	3.2	2.79	0.85	0.06	0.22	0.49	7.60	none
8-C	a	4.75	1.65	1.58	0.09	0.39	0.63	9.09	Hg, Ag
9-A	m	1.94	1.37	0.81	0.06	0.1	0.57	4.84	none
9-B	abm	0.83	0.31	0.01	0	0	0	1.16	none
9-C	m	1.9	0.35	0.01	0	0	0.06	2.31	none
10-A	m	0.74	0.75	0.06	0	0	0.22	1.78	none
10-B	m	1.46	0.22	0.01	0	0	0	1.69	none
10-C	NT	0.43	0.24	0.01	0	0	0	0.68	none

Table 12 continued.

Station & Toxicity[a]		Metals (10)	CHClP (7)	PAH (13)	tPAH	tLMW PAH	tHmw PAH	Cum HF(33)	ERMs Exceeded
11-A	am	2.01	0.72	0.03	0	0	0.09	2.85	none
11-B	abm	1.34	0.37	0.01	0	0	0.05	1.77	none
11-C	abm	0.14	0.24	0.1	0	0.02	0.06	0.56	none
12-A	am	3.3	1.26	0.35	0.03	0.1	0.38	5.40	none
12-B	m	3.43	1.40	0.59	0.04	0.15	0.44	6.06	none
12-C	abm	2.47	1.12	0.18	0.01	0.07	0.31	4.17	none
13-A	ab	0	0.08	0.01	0	0	0	0.08	none
13-B	NT	0.09	0.17	0.01	0	0	0	0.27	none
13-C	NT	0.68	0.20	0.06	0	0	0.18	1.11	none
14-A	NT	0.1	0.14	0.01	0	0	0	0.25	none
14-B	NT	0.73	0.46	0.01	0	0	0.04	1.23	none
14-C	m	0.07	0.36	0.01	0	0	0	0.44	none
15-A	a	0	0.23	0.01	0	0	0	0.24	none
15-B	NT	0.41	0.57	0.01	0	0	0.12	1.11	none
15-C	a	0	0.11	0.01	0	0	0	0.11	none
16-A	NT	0	0.11	0.03	0	0	0.11	0.24	none
16-B	m	0.22	0.57	0.49	0.03	0.12	0.35	1.78	none
16-C	NT	0.3	0.42	0.09	0	0	0.2	1.01	none
17-A	NT	0.73	2.55	0.18	0	0.08	0.24	3.77	tDDT
17-F	m	1.41	0.64	0.59	0.04	0.12	0.43	3.24	none
17-I	abm	5.29	1.34	8.02	0.42	1.49	2.02	18.59	tHmw&tLmwPAH, Cu
18-A	ab	1.65	3.84	3.24	0.18	0.52	1.07	10.50	tHmwPAH, chlordane
18-B	a	3.1	2.67	3.19	0.18	0.49	1.08	10.70	tHmwPAH, tPCB, Cu
18-D	a	0.47	0.73	0.54	0.03	0.09	0.39	2.25	none
19-A	m	6.29	5.39	2.86	0.16	0.58	0.96	16.24	Hg, Zn, dieldrin
19-C	abm	6.51	3.83	2.67	0.15	0.6	0.9	14.67	Hg,Ag
19-F	am	5.36	3.36	8.99	0.44	1.51	2.14	21.81	tHmw&tLmwPAH, Hg, Ag
20-A	m	2.18	3.57	4.65	0.28	0.64	1.53	12.85	tHmwPAH, tPCB
20-D	NT	0.77	0.69	0.05	0	0	0.12	1.63	none
20-G	a	0.2	1.09	0.19	0	0.04	0.25	1.78	none
CLIS-A	NT	0.66	0.40	0.05	0	0	0.04	1.15	none
CLIS-B	NT	0.59	0.22	0.03	0	0	0.08	0.93	none
CLIS-C	a 0.64	0.44	0.02	0	0	0.06	1.16		none

[a]Significant toxicity is indicated as: (a) amphipod survival < 80% of controls, (b) bivalve larval survival < 80% of controls, and (m) Microtox^{R} EC-50 < 70% of controls. NT = non-toxic.

The concentrations of some contaminants exceeded ERMs in several (19) of the 63 LIS sediment samples (Table 12). The ERM for mercury (0.71 ug/g) was exceeded most frequently (in 11 of 63 samples). In many of these same 11 samples, the ERMs for zinc, silver, and/or lead were also exceeded. All three of the samples obtained from Sites 1 (Little Neck Bay), 2 (Manhasset Bay), and 19 (Pelham Bay) exceeded the ERM for Hg, along with exceedances of ERMs for some combination of other metals and organic compounds. The ERMs for sum of HMW and/or LMW PAHs were exceeded at nine stations in 6 different bays, while those for tDDT or DDE were exceeded at three stations (2-A, 4-A, and 17-A). The ERMs for chlordane and dieldrin were exceeded at four (1-A, 2-A, 5-A, and 18-A) and three (2-A, 6-A, and 19-A) stations, respectively, and were approached at other sites as well (3-A and 19-A for chlordane, and 1-A, 1-D, 19-C, and 20-A for dieldrin). Substantial concentrations of trans-nonachlor usually accompanied chlordane in these samples. Concentrations of tPCB also exceeded the ERM at three stations (2-A, 18-B, and 20-A). Sediments from station 2-A (in Manhasset Bay) exceeded the greatest number (seven) of ERMs, but a number of other stations exceeded either three (1-C, 17-I, 18-B, and 19-A) or four (1-A, 1-D and 19-F).

Eighteen of the 19 (94.7%) samples in which one or more contaminant exceeded the ERM were toxic in at least one test. Seven of these 18 samples (38.9%) were toxic in all three tests (amphipod and bivalve survival, and Microtox™), three (16.7%) were toxic in two tests, six (33.3%) were toxic only to Microtox™, and two (11.1%) were toxic only to amphipods. The sole non-toxic sample that exceeded an ERM was 17-A, in which the tDDT concentration was nearly twice the ERM value. There were 13 samples altogether which were non-toxic in all tests, and 12 of these (92.3%) had no exceedances of ERM values. In the remaining 32 samples (which exhibited no exceedences of ERM values), 6 (18.7%) were toxic in all three tests, 8 (25.0%) were toxic in two tests), 11 (34.4%) were toxic only to Microtox™, and 7 (21.9%) only to amphipods. While these figures suggest that exceedance of ERM values is a very strong indicator of sediment toxicity, the converse is not true. Only 18 (36%) of the 50 samples that were toxic in at least one test exceeded one or more ERM value.

Although the correlations between composite hazard factors and the toxicity endpoints (Table 13) mirrored the correlations with the individual contaminants (Table 8), the composite hazard factors provided more reliable prediction of sediment toxicity than did ERM exceedances alone, suggesting that some toxicants may act either additively or synergistically. Thirty-eight of the sediment samples had a composite hazard factor greater than 1.0 for either the 10 metals, the 7 chlorinated hydrocarbon components, or some combination of PAHs. Only one of these samples (sample 20-G) exceeded a composite hazard factor of 1.0 for one or more of the organic constituents without also exceeding 1.0 for the composite hazard factor for metals. Of the 38 samples with at least one composite hazard factor >1.0, 37 (97.3%) were toxic in at least one test (the exception was again sample 17-A). Thirty-seven (74%) of the 50 samples that were toxic in at least one test exceeded at least one composite hazard factor of 1.0. Of the 13 samples that were non-toxic in any test, 12 (92.3%) were well below a composite hazard factor of 1.0 for any class of constituents. Of the 13 remaining samples (i.e., those that were

Table 13. Spearman rank correlations (Rho) between composite hazard factors (based on contaminant concentrations and ERLs/ERMs) and toxicity results (as percent of control values) for three endpoints tested at three stations each from 21 sites in Long Island Sound coastal embayments (N=63).

Contaminant Grouping	*A. abdita* Survival	Mulinia lateralis Survival	Microtox™ EC-50
Metals sum	-0.306*	-0.282*	-0.682***
Chlordane&Dieldrin	-0.205	-0.177	-0.597***
tDDT	-0.216	-0.086	-0.519***
tPCB	-0.364**	-0.091	-0.465***
tClCHs	-0.211	-0.101	-0.556***
PAH sum (13)	-0.311*	-0.067	-0.459***
tPAH	-0.344**	-0.103	-0.478***
LMW PAH	-0.350**	-0.097	-0.491***
HMW PAH	-0.273*	-0.041	-0.475***
cum HF	-0.288*	-0.202	-0.634***

*p<0.05; **p<0.01; ***p<0.001

toxic in at least one test, but were below a composite hazard factor of 1.0 for any consitutent class), two (15.4%) were toxic in all three tests; one (7.7%) was toxic in two of the tests; 4 (30.8%) were toxic only to Microtox™; and 6 (46.1%) were toxic only to amphipods (but three of these had survivals greater than 75% of controls). Most notable among these toxic samples without any known corresponding contamination were stations 9-B (Centerport Harbor), 11-C (Oyster Bay), and 13-A (Southport Harbor); which showed substantial toxicity in at least two of the tests, but which had consistently low reported concentrations of contaminants. Two of these samples (9-B and 11-C) contained unusually high proportions of gravel (particle size > 2mm, @ 28.1% and 21%, respectively), while sample 13-A contained consisted predominantly (92.9%) of sand-sized particles.

A portion of the measured sediment toxicity, especially to amphipods, may have been related to sediment particle-size. Of the 28 samples with TOC<2.0%, 3 samples (13-A, 18-D, and 8-A) contained 92.2 to 92.9 % sand-sized particles. All three of these samples contained very low TOC concentrations; none were toxic with Microtox™; none approached any cumulative hazard factors of 1.0; yet al.l were among the samples (12 out of the 28) that were significantly toxic to amphipods. Of the 28 samples with TOC<2.0%, 4 additional samples (the three above, plus 15-A, 16-A, 17-A, and18-A) contained between 80% and 90% sand-sized particles. Three of these samples also contained very low TOC concentrations, and none were toxic with Microtox™. Samples 16-A and 17-A were non-toxic to amphipods; whereas 15-A and 18-A were significantly toxic (<80% survival). Sample 18-A, with 1.56% TOC, exceeded the ERM for tHMWPAH, as well as the cumulative hazard factors for metals, tClChs and sumPAHs. None of the 35 samples with TOC>2.0% had sand contents in excess of 35% or silt + clay contents lower than 49%.

Of the 63 total samples, 11 contained more than 10% gravel-sized particles, and all of these were significantly toxic to amphipods. Samples with high gravel contents usually also had relatively high levels of TOC and moderate to low sand contents <35%. Nine of these 11 (excepting stations 11-C and 4-G) were among the 35 samples that contained more than 2.0% TOC, of which only 20 samples total were toxic to amphipods.

To facilitate visualization of these relationships among toxicity and contaminants, the data were examined further through the use of cluster analysis. Data for the 63 stations were analyzed using the “complete linkage clustering” option in the Datadesk 4.0 software package (Data Description, Inc., Ithaca, NY). Under this option, the software calculates the Euclidean distance between points and then between clusters, and minimizes the maximum intracluster distance at each stage in the cluster analysis. The data were clustered on the basis of selected chemical and physical data alone (Figure 14) and on the basis of that same chemical and physical data, plus the toxicity data (Figure 15).

On the basis of the physical and chemical parameters alone, 3 major clusters were defined (Figure 14):

(A) The uppermost cluster in the diagram contains most of the stations with the lowest contents of TOC and silt and clay, i.e. the samples with the greatest content of sand. These stations generally had lower concentrations of organic and inorganic contaminants associated with them. Only one of these samples exceeded an ERM value (station17-A, with 79% sand, exceeded the ERM for tDDT), and it fell out into a separate cluster all by itself.

(B) The center cluster in the diagram contains the stations with the greatest concentrations of both organic and metallic contaminants, usually in combination with high amounts of TOC. All of the samples in this group exceeded at least one ERM value.

(C) The last of the three major clusters contains stations with intermediate contents of silt-clay and TOC, and with variable combinations of contaminant concentrations that were generally lower than ERM values (the sole exception was station 6-A, which exceeded the ERMs for mercury and dieldrin).

For several of the Long Island Sound bays, all three of the separate stations within the bay appear within the same major cluster in Figure 14. Cluster A includes all the stations from sites 13 (Southport Harbor, CT), 15 (Milford Harbor, CT), and 16 (Connecticut River, CT); cluster B includes those from sites 1 (Little Neck Bay, NY), 2 (Manhasset Bay, NY), and 19 (Pelham Bay,NY); while cluster C contained all the stations from sites 7 (Cold Spring Harbor, NY) and CLIS (central Long Island Sound). Many of the stations from within a single site also appeared adjacent to each other in the diagram, indicating strong inter-station affinities (stations 3C & 3F, 7B & 7C, 11A & 11B, 12B & 12C, 14A & 14C, 18A &18B,19A & 19C, 20D & 20G, and CLISA, B & C). For five of the bays (numbers 4, 5, 8, 9, and 17), however, the three stations were divided across all three major clusters in Figure 14, indicating major physical and chemical differences among stations.

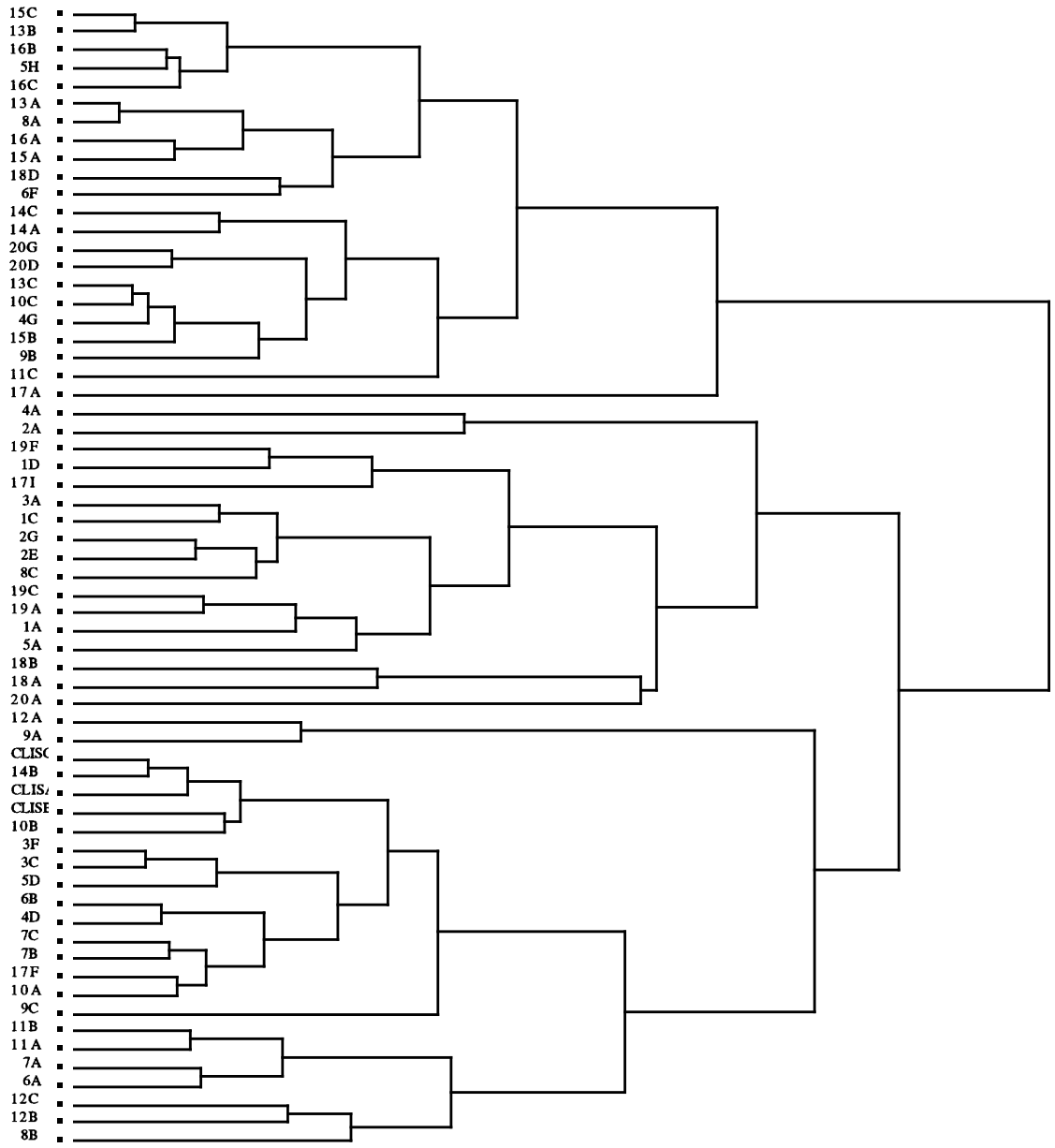

Figure 14. Cluster diagram for the 63 stations sampled in the coastal bays of Long Island Sound, based on %Al; %TOC, % silt plus clay; Hg plus Ag; sum of Cu, Pb, & Zn; total DDTs; total other pesticides; total PCBs; and total PAH.

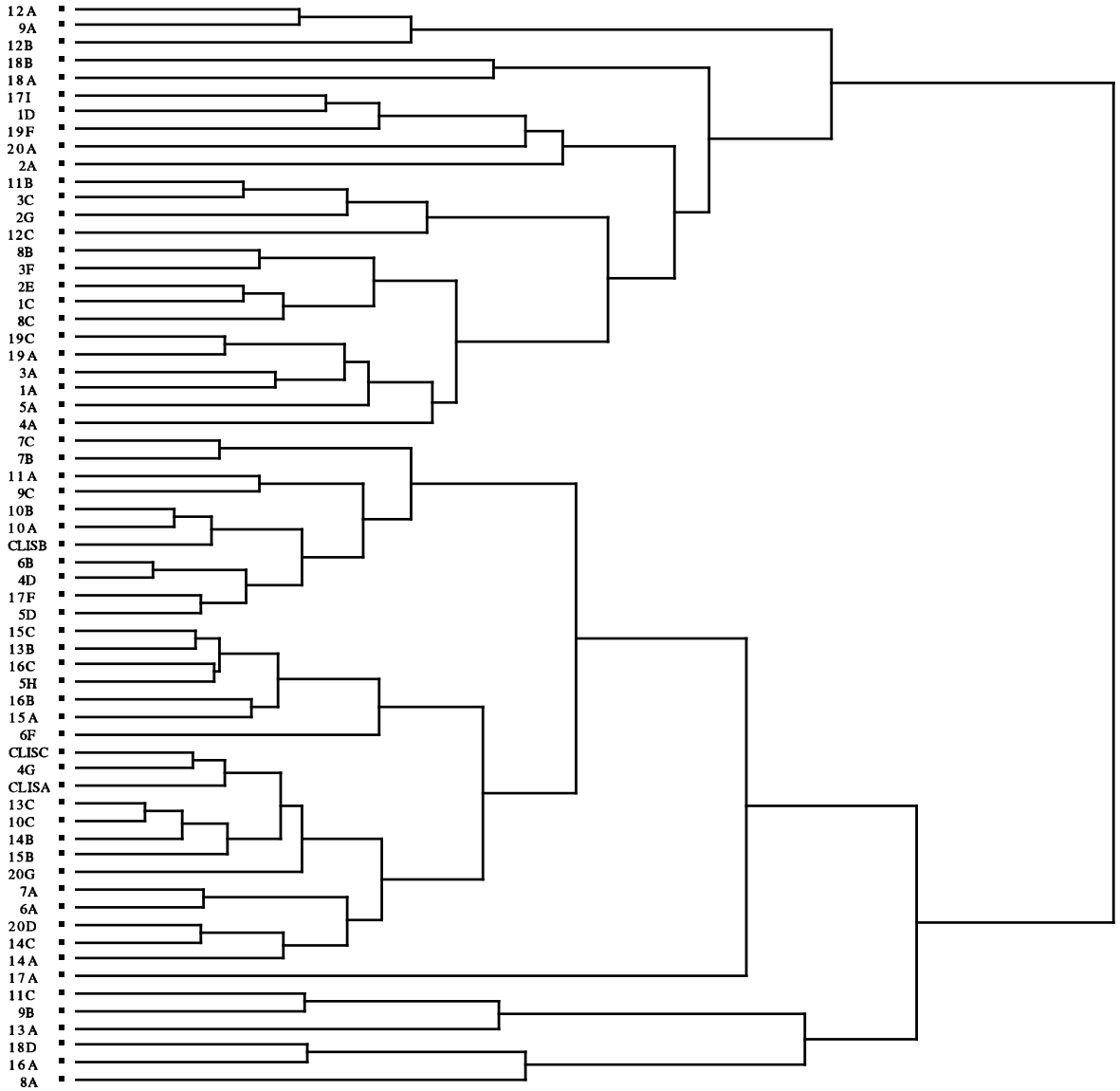

Figure 15. Cluster diagram for the 63 stations sampled in the coastal bays of Long Island Sound, based on the same physical and chemical parameters used in Table 14, plus the results of toxicity tests on survival of Ampelisca abdita and Mulinia lateralis and on inhibition of bioluminescence (Microtox^{R}), all expressed as percent of control values.

When the toxicity results were brought into the cluster analysis, the stations were resolved into two major clusters (Figure 15):

(A) The upper cluster contains the most highly contaminated stations, including all the stations from cluster (B) in the first analysis, as well as most of the stations that exhibited significant toxicity in more than one test. None of the stations from cluster (A) in the first analysis were included, and none of the samples were non-toxic in all of the tests.

(B). The lower cluster contains all of the stations that were non-toxic in any test, most of the stations that were toxic in only one test, and those stations (11-C, 9-B, 13-A, 18-D, and 8-A; all clustered together in the bottommost subcluster of the diagram) at which significant toxicity was noted without any notable corresponding measurements of contamination. Station 17-A, notably non-toxic despite exceedance of the ERM value for tDDT, appears within this major cluster as a separate subcluster unto itself.

These two cluster analyses confirm the overall pattern of correspondence between toxicity and contaminant distributions, while at the same time highlighting the exceptions. The two clusters in Figure 15 very accurately represent the cumulative hazard factors (CHF) presented in Table 12. The mean CHF for cluster A (Figure 15) is 11.44 ± 5.73, while that for cluster B is 1.52 ± 1.16. Cluster A contains 8 stations with no ERM exceedances, all but one (sta. 11B, with CHF=1.77) of which have CHF > 4.0. Cluster B contains only two stations with ERM exceedances (6A [Hg], CHF = 5.14; and 17A [DDT], CHF = 3.77), and only one (6A) with CHF > 4.0.

Using Datadesk software, a principal components analysis was run on the correlation matrix of the same twelve variables used for the second cluster analysis above (Figure 15). Table 14 shows the variance values for all twelve eigenvalues, along with the eigenvectors for the first six values, which together account for 87.2% of the total variance. The first eigenvector, which accounts for 42.3 % of the total variation, is dominated by the strong primary covariation among the various contaminants (notably the metals, tPAH, tPCB, and tDDT), TOC, and toxicity (especially Microtox™). The second eigenvector, with 13.7 % of the total variation, shows amphipod survival covarying strongly with % silt + clay (and with tPesticides) and interacting negatively with Microtox™ response, supporting the previously suggested interactions between amphipod toxicity and grain size distribution. The third eigenvector, with 11.7 % of the total variation, shows very strong affinities between amphipod survival and bivalve larval survival, but associates these only weakly with the various contaminants (i.e., in different directions and with variable strengths).

Table 14. Results of Principal Component Analysis on aspects of sediment contamination (%Al, %TOC, % silt + clay, Ag+Hg, Cu+Pb+Zn, tDDT, tPesticides, tPCB, and tPAH) and toxicity (Survival of Amphipods and bivalve larvae, and Microtox™ response, all expressed as percent of control values).

EigenValues

	Variance Values	Variance Proportion		Variance Values	Variance Proportion
e1	5.076	42.3	e7	0.512	4.3
e2	1.639	13.7	e8	0.386	3.2
e3	1.402	11.7	e9	0.306	2.5
e4	1.103	9.2	e10	0.168	1.4
e5	0.681	5.7	e11	0.117	1.0
e6	0.557	4.6	e12	0.053	0.4

EigenVectors

	V1	V2	V3	V4	V5	V6
Aa %CS	0.100	-0.479	0.467	0.172	0.159	-0.135
Ml %CS	0.149	-0.155	0.640	0.124	-0.245	-0.046
MCTX %C	0.263	0.346	0.122	0.194	-0.375	-0.484
Al%	-0.056	-0.223	0.127	-0.791	-0.478	0.129
%silt+clay	-0.259	-0.506	-0.019	-0.016	0.240	-0.325
Ag+Hg	-0.390	0.078	0.066	0.037	0.084	-0.194
Cu+Pb+Zn	-0.417	0.039	-0.033	-0.031	-0.102	-0.046
TOC	-0.415	-0.165	-0.117	0.059	-0.006	-0.148
tPest	-0.128	-0.345	-0.294	0.501	-0.651	0.222
tDDT	-0.266	0.178	0.388	0.172	0.113	0.660
tPCB	-0.347	0.264	0.213	0.047	-0.098	-0.071
tPAH	-0.351	0.257	0.197	-0.047	-0.156	-0.269

This initial PC Analysis also suggested that Aluminum, with no substantial involvement in the first three eigenvectors, accounted for very little of the overall variation in these toxicity and chemistry data. Based on the results of this PCA, the dataset was reanalyzed: (a) after removal of the 14 stations for which the sand content exceeded 60%; and (b) without data for Al. These 14 high-sand samples correspond to the 11 stations in the uppermost cluster of figure 14, plus stations 17-A, 18-A, and 18-B. All of these stations except 18-A and 18-B had very low concentrations of the measured contaminants. Since the next highest sand content in the remaining 49 stations was only 41.9%, the homogeneity of sediment texture was much greater within this subset of samples than among the original 63 stations, and it was hypothesized that subtle contaminant interactions might become more evident upon further analysis. Without these 14 sandy samples, Spearman rank correlations were much stronger among contaminants than for the total dataset of 63 stations (Table 15). Upon reanalysis of the modified dataset by PCA (Table 16), the first three eigenvectors accounted for 73.7% of the total variation in the data (compared with 67.7% the first analysis), but the second eigenvector still showed very strong positive interactions among grain size and toxicity to both amphipods and bivalve larvae, suggesting that survival of both test organisms increased with increasing silt and clay content of the sediments.

The PCA was therefore conducted again on this abbreviated dataset after normalization of all of the contaminant data to % Silt + Clay. Results are shown in Table 17 for three separate PCA's, using the normalized contaminant data with toxicity data from each of the three tests. The first three EigenValues accounted for about 84% of the total variation for each of these tests (Table 17). The first EigenValue, which indicated strong covarying contributions from all contaminants except tPesticides, accounted for 57.0% (*Mulinia*) to 59.7% (Microtox™) of the total variation. The second Eigenvector in each analysis arose primarily from interactions between toxicity and tPesticides. Six stations (9-A, 9-C, 11-A, 12-A, 12-B, and 12-C) account for most of the variation along the tPesticide axis, and hexachlorobenzene (HCB) accounted for most of the tPesticide signal in these samples. While all six of these samples exhibited significant toxicity with Microtox™, and three were toxic also to amphipods, no clear dose-responsiveness was apparent in the relationship between toxicity and tPesticides for any test.

Figure 16 illustrates the cluster analysis that corresponds to Table 17, based on the 49 non-sandy samples and three toxicity endpoints, TOC, and the selected chemical contaminant data normalized to percent clay plus silt. Four main clusters are evident:

(A) The uppermost cluster contains all (except 6-A) of the samples with ERM exceedances, and all samples in the cluster were toxic (16 of the 17 with Microtox™, and 11 with amphipods, of which 7 were toxic with all three tests).

(B) The second cluster contains four samples, all toxic, all with cumulative hazard factors > 4.0 (Table 12), and all with relatively high values for tPesticides.

(C) The third cluster contains generally the least contaminated samples, including all eight of the non-toxic samples remaining after exclusion of the sandy samples and four samples significantly toxic either only to amphipods (3) or only to Microtox™ (1); and cumulative hazard factors ranged up to only 1.78.

(D) The lowermost cluster contains samples with intermediate values for contaminants (cumulative hazard factors range from 0.56 to 5.14 [6A]); all 15 samples were toxic with Microtox™, seven were toxic also with amphipods, six were toxic with *Mulinia*, and five were toxic in all three tests.

The major affinities identified in this cluster diagram (Figure 16) are much the same as those in Figure 14, except that the stations with relatively high tpesticide concentrations (cluster B) were brought together at a much higher level, and the positions of a few other stations were realigned as a result of the normalization of contaminant concentrations to the silt-clay level in the sediments. The most notable of these shifts was that the CLIS stations and 14B joined the other relatively non-contaminated stations within cluster A of Figure 16.

Tables 18-20 compare the mean concentrations of contaminants and other sediment characteristics in the sediment samples that were toxic and non-toxic in each of the three tests, i.e., either with amphipods, *Mulinia*, or Microtox™. Mean concentrations of chlorinated pesticides in samples toxic to either amphipods or Mulinia were usually less than twice the mean concentrations in samples that were non-toxic, and these means were generally highly variable and not significantly different (Table 18). The greatest differences in mean pesticide concentrations between toxic and nontoxic samples for amphipods and *Mulinia* were for heptachlor, chlordane, and a-nonachlor. Mean concentrations of DDT metabolite isomers (p,p' DDE; o,p DDD, and p,p' DDD) were elevated in samples toxic to amphipods and *Mulinia* over those in non-toxic samples by factors of 1.4-1.7, but concentrations of parent DDT isomers were generally higher in the non-toxic samples, and the amounts of tDDT were about the same in toxic and nontoxic samples (Table 19). Mean concentrations of PAH and PCB were about 1.4-1.8X higher in toxic samples than in nontoxic samples for amphipods and *Mulinia*.

Table 15. Spearman Rank Correlations (Rho) among sediment toxicity and chemical constituents of sediments from Long Island Sound coastal embayments, after exclusion of fourteen samples with sand contents greater than 60 percent.

	Aa%CS	Ml%CS	MCTX	Ag	Cd	Cu	Hg	Pb	Zn	Ag+Hg	Cu+Pb+Zn	TOC	tPest	tDDT	tPCB	tPAH	%S+C
Aa %CS	1.000																
Ml %CS	0.354	1.000															
MCTX %C	0.165	0.164	1.000														
Silver	-0.429	-0.097	-0.509	1.000													
Cadmium	-0.464	-0.272	-0.610	0.809	1.000												
Copper	-0.370	-0.224	-0.561	0.852	0.891	1.000											
Mercury	-0.359	-0.206	-0.599	0.824	0.846	0.906	1.000										
Lead	-0.420	-0.247	-0.578	0.863	0.886	0.912	0.900	1.000									
Zinc	-0.440	-0.253	-0.609	0.847	0.897	0.954	0.866	0.928	1.000								
Ag+Hg	-0.399	-0.138	-0.573	0.974	0.837	0.889	0.909	0.877	0.871	1.000							
Cu+Pb+Zn	-0.434	-0.256	-0.600	0.872	0.912	0.978	0.900	0.960	0.986	0.895	1.000						
TOC	-0.411	-0.240	-0.659	0.817	0.891	0.916	0.881	0.950	0.934	0.849	0.954	1.000					
tPesticides	-0.160	-0.254	-0.473	0.344	0.421	0.412	0.435	0.479	0.477	0.374	0.474	0.523	1.000				
Sum DDT	-0.312	0.017	-0.513	0.821	0.750	0.805	0.803	0.845	0.769	0.822	0.812	0.793	0.330	1.000			
Sum PCB	-0.423	-0.058	-0.483	0.753	0.677	0.689	0.721	0.759	0.678	0.760	0.725	0.775	0.293	0.831	1.000		
tPAH	-0.360	-0.004	-0.485	0.719	0.717	0.780	0.795	0.794	0.699	0.753	0.765	0.796	0.231	0.861	0.875	1.000	
%silt+clay	0.127	0.215	-0.044	0.109	0.129	0.210	0.169	0.156	0.238	0.151	0.205	0.208	0.111	0.186	0.187	0.161	1.000

Table 16. Principal Component Analysis of selected chemistry and toxicity data from 49 non-sandy LIS sites (maximum sand content = 41.9%). Variables are otherwise the same as in previous PCA except that Al, which explained only a small portion of the variance in the first three eigen vectors, was deleted.

EigenValues

	Variance Values	Variance Proportion		Variance Values	Variance Proportion
e1	5.052	45.9	e7	0.437	4.0
e2	1.724	15.7	e8	0.328	3.0
e3	1.335	12.1	e9	0.152	1.4
e4	0.722	6.6	e10	0.115	1.0
e5	0.591	5.4	e11	0.044	0.4
e6	0.500	4.5			

EigenVectors

	V1	V2	V3	V4	V5	V6
Aa %CS	0.167	0.525	-0.053	0.543	0.015	-0.408
Ml %CS	0.127	0.591	0.142	0.101	-0.261	0.603
MCTX %C	0.261	0.102	0.391	-0.603	-0.322	-0.347
TOC	-0.415	-0.002	-0.217	-0.023	0.002	0.071
Ag+Hg	-0.394	0.036	0.128	0.010	0.086	0.018
Cu+Pb+Zn	-0.419	-0.007	-0.075	-0.039	0.142	-0.026
tPesticides	-0.082	0.102	-0.729	-0.164	-0.584	-0.124
tDDT	-0.337	0.205	0.197	0.120	0.028	-0.434
tPCB	-0.354	0.102	0.275	0.015	-0.374	-0.189
tPAH	-0.363	0.055	0.263	-0.054	-0.226	0.322
%Silt+Clay	-0.084	0.545	-0.202	-0.534	0.518	-0.008

Table 17. Summary of the results of Principal Components Analyses of the toxicity data and sediment chemistry data from 49 non-sandy stations in Long Island Sound (as in Table 16, except that contaminant concentrations have been normalized to the silt-clay content of the sediments). Separate analyses were performed with the toxicity results from the three different tests (amphipod and bivalve larval survival, and Microtox™. Values and proportions of the variance are given for all the EigenValues of the three analyses; and the first three Eigen vectors are shown for each analysis.

Eigen-Value	Ampelisca Values	Ampelisca Proportion	Mulinia Values	Mulinia Proportion	Microtox™ Values	Microtox™ Proportion
e1	4.628	57.8	4.559	57.0	4.767	59.6
e2	1.160	14.5	1.257	15.7	1.326	16.6
e3	0.937	11.7	0.926	11.6	0.644	8.1
e4	0.454	5.7	0.439	5.5	0.414	5.2
e5	0.349	4.4	0.387	4.8	0.404	5.0
e6	0.213	2.7	0.209	2.6	0.194	2.4
e7	0.147	1.8	0.141	1.8	0.137	1.7
e8	0.111	1.4	0.082	1.0	0.114	1.4

EigenVectors	Ampelisca V1	Ampelisca V2	Ampelisca V3	Mulinia V1	Mulinia V2	Mulinia V3	Microtox™ V1	Microtox™ V2	Microtox™ V3
Toxicity (%C)	0.201	0.170	-0.878	0.151	0.521	-0.741	0.269	0.456	-0.659
AgHg/fines	-0.422	0.048	0.024	-0.424	0.058	0.033	-0.411	0.105	0.057
3Me/fines	-0.424	-0.113	0.123	-0.430	-0.165	0.163	-0.417	-0.059	0.142
TOC	-0.398	-0.305	-0.072	-0.402	-0.246	-0.173	-0.403	-0.264	0.024
Pest/fines	-0.054	-0.862	-0.276	-0.059	-0.692	-0.607	-0.071	-0.735	-0.618
tDDT/fines	-0.373	0.181	-0.288	-0.378	0.218	-0.134	-0.369	0.191	-0.121
tPCB/fines	-0.384	0.197	-0.221	-0.389	0.213	-0.081	-0.372	0.249	-0.361
tPAH/fines	-0.391	0.221	-0.007	-0.390	0.255	-0.021	-0.377	0.265	-0.123

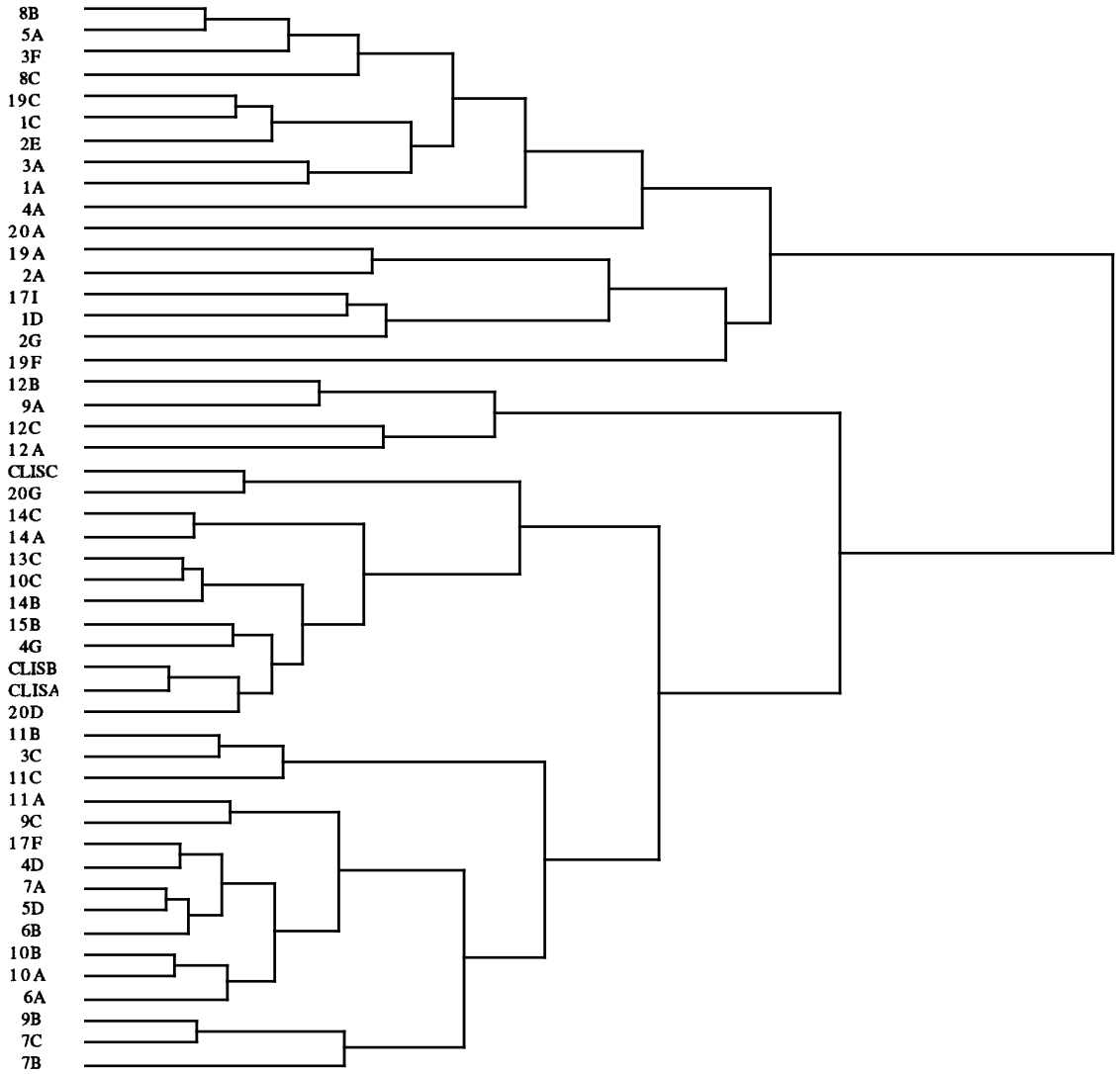

Figure 16. Cluster Analysis for the 49 non-sandy LIS stations, clustered on the basis of the three toxicity endpoints, TOC, and selected chemical contaminant data normalized to percent clay plus silt, as in Table 17.

Although the ratios of mean organic contaminant concentrations in samples that were significantly toxic versus non-toxic to Microtox™ were generally greater than for either of the toxicity tests with macroorganisms (Tables 18 and 19), these values also exhibited considerable variability and differences were generally not significant The greatest ratios were associated with hexachlorobenzene (HCB, 6.0) and tPesticides (4.0), but both of these ratios were influenced greatly by 17 samples containing 4.3 to 209 ug/g HCB. Sixteen of these samples were from sites 7, 8, 9, 10, 11, 12, and 13, (raising suspicion of the possibility of contamination during collection or analysis: CLIS-B was the other sample above 4.3; all 24 samples with detectable HCB except one [4G] were from sites 7-15 and CLIS).

The ratios of mean concentrations of metal contaminants in toxic and non-toxic samples were greatest for Microtox™, and lower for *Mulinia* and amphipod toxicity, respectively (Table 20). For all three toxicity tests, the ratios for silver, cadmium, copper, mercury, lead, and tin were consistently higher than those for aluminum, arsenic, chromium, iron, manganese, nickel, and selenium; while zinc, selenium, and antimony exhibited intermediate ratios. The highest ratios were generally associated with mercury, cadmium, lead, and silver; but as with the organic contaminants, the variability around mean values was high and differences were generally not significant.

Table 18. Comparisons of mean sediment toxicity, sediment characteristics, and pesticide concentrations in Long Island Sound sediment samples that were toxic and non-toxic in each of three toxicity tests.

	Ampelisca	Mulinia	Microtox	% Sand	TOC %dw	HCB	Lindane	Hptachlr	a -Chlrdane	t-Nonachlr	Dieldrin	tPesticide
	Percent of Control Values											
Samples Toxic to Amphipods												
toxic avg (32)	61.7	78.82	126.06	34.58	2.32	14.59	0.24	0.31	3.06	3.1	2.43	24.2
std dev	18.27	34.47	217.67	28.72	1.1	41.35	0.32	0.74	4.67	3.93	1.81	41.44
non-toxic avg (31)	87.75	105.53	99.48	31.27	2.0	13.75	0.20	0.14	1.57	1.7	2.74	20.03
std dev	5.3	22.92	129.82	23.43	0.94	34.73	0.26	0.22	2.39	2.14	3.26	35.07
ratio TOX/NONTOX	0.7	0.75	1.27	1.11	1.16	1.06	1.22	2.24	1.95	1.82	0.89	1.21
Samples Toxic to Mulinia												
toxic avg (15)	59.07	42.35	58.65	28.47	2.69	11.49	0.22	0.34	4.25	3.61	2.93	22.08
std dev	21.79	16.54	78.33	25.14	0.96	27.3	0.33	0.99	6.33	4.82	2.28	27.6
non-toxic avg (48)	79.34	107.47	129.96	34.35	2.0	15.02	0.22	0.19	1.76	2.01	2.47	21.2
std dev	14.97	15.66	197.94	26.49	1.0	40.9	0.29	0.32	2.39	2.46	2.72	41.16
ratio TOX/NONTOX	0.74	0.39	0.45	0.83	1.35	0.76	1.04	1.83	2.41	1.79	1.19	1.04
Samples Toxic to Microtox												
toxic avg (35)	71.65	82.13	28.81	21.68	2.79	22.53	0.22	0.12	3.24	3.39	3.33	33.29
std dev	17.3	36.89	14.02	14.77	0.74	49.05	0.33	0.24	4.49	3.8	3.17	47.9
non-toxic avg (28)	78.09	104.25	218.2	47.03	1.37	3.74	0.21	0.36	1.15	0.99	1.57	8.22
std dev	20.23	19.2	229.4	30.31	0.76	8.33	0.24	0.77	2.17	1.08	0.9	9.79
ratio TOX/NONTOX	0.92	0.79	0.13	0.46	2.03	6.03	1.07	0.34	2.8	3.42	2.12	4.05

Table 19. Comparisons of mean concentrations of DDT and related isomers, total polynuclear aromatic hydrocarbons, and total PCB in Long Island Sound sediment samples that were toxic and non-toxic in each of three toxicity tests.

	OPDDE	PPDDE	OPDDD	PPDDD	OPDDT	PPDDT	Sum DDT	t PAH	tLmwPAH	tHmwPAH	tPCB
Samples Toxic to Amphipods											
toxic avg (32)	0.83	7.41	1.61	6.34	2.01	1.74	15.77	6596	1238	5737	67.48
std dev	0.85	6.36	1.7	6.05	1.29	1.48	13.33	5729	1213	4842	52.91
non-toxic avg (31)	1.38	5.19	0.95	3.76	4.05	5.94	14.94	4464	722	4001	45.25
std dev	1.6	4.69	1.18	3.88	6.33	16.24	19.41	3413	604	3017	51.18
ratio TOX/NONTOX	0.6	1.43	1.69	1.69	0.5	0.29	1.06	1.48	1.72	1.43	1.49
Samples Toxic to Mulinia											
toxic avg (15)	1.02	8.05	1.59	6.7	1.56	1.53	17.14	7513	1505	6427	72.56
std dev	1.02	7.49	1.8	7.29	1.45	0.81	15.6	6210	1359	5170	54.69
non-toxic avg (48)	1.1	5.77	1.19	4.5	3.86	4.8	14.81	4932	821	4400	51.53
std dev	1.35	4.94	1.39	4.27	5.68	13.84	16.85	4184	793	3650	51.82
ratio TOX/NONTOX	0.92	1.39	1.33	1.49	0.4	0.32	1.16	1.52	1.83	1.46	1.41
Samples Toxic to Microtox											
toxic avg (35)	1.37	8.33	1.34	6.91	1.56	1.54	17.49	7151	1310	6255	72.15
std dev	1.29	6.49	1.41	6	1.45	1.03	13.44	5494	1167	4648	57.94
non-toxic avg (28)	0.66	3.79	1.24	2.61	3.86	7.67	12.71	3541	575	3168	37.03
std dev	1.12	2.97	1.65	2.35	5.68	18.74	19.55	2786	476	2469	38.4
ratio TOX/NONTOX	2.08	2.2	1.08	2.64	0.41	0.2	1.38	2.02	2.28	1.97	1.95

Table 20. Comparisons of mean concentrations of metals in Long Island Sound sediment samples that were toxic and non-toxic in three sediment toxicity assays.

	Al	Ag	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sb	Se	Si	Sn	Zn
Samples Toxic to Amphipods																
toxic avg (32)	6	2.02	7.63	1.38	109.8	133	3.24	0.5	720	33.25	93.78	0.74	0.62	25.83	12.79	212.8
std dev	0.79	1.43	2.42	0.93	41.18	83.61	0.84	0.42	174	10.69	55.32	0.45	0.33	3.79	7.79	85.9
non-toxic avg (31)	6.15	1.35	6.52	0.92	96.02	89.73	3.33	0.37	709	31.92	70.13	0.56	0.52	26.44	9.29	177.9
std dev	0.8	1.24	2.24	0.64	28.18	47.13	0.49	0.35	153	8.17	43.65	0.27	0.27	2.83	6.25	69.3
ratio TOX/NONTOX	0.98	1.5	1.17	1.5	1.14	1.48	0.97	1.38	1.01	1.04	1.34	1.33	1.19	0.98	1.38	1.2
Samples Toxic to Mulinia																
toxic avg (15)	5.87	2.29	7.88	1.73	116.7	153.1	3.36	0.67	726	35.61	114.4	0.76	0.69	25.07	15.34	239.9
std dev	0.88	1.51	1.64	1.03	46.5	83.51	0.9	0.51	222	11.29	63.24	0.31	0.37	3.21	8.79	82.4
non-toxic avg (48)	6.13	1.5	6.82	0.97	98.74	98.74	3.27	0.36	711	31.65	72.06	0.61	0.53	26.46	9.73	181.8
std dev	0.76	1.28	2.52	0.66	31.1	62.11	0.62	0.32	143	8.76	42.37	0.39	0.27	3.34	6.2	74.1
ratio TOX/NONTOX	0.96	1.52	1.16	1.79	1.18	1.55	1.03	1.85	1.02	1.13	1.59	1.24	1.3	0.95	1.58	1.32
Samples Toxic to Microtox																
toxic avg (35)	6.07	2.25	7.81	1.57	117.2	133.4	3.57	0.62	706	36.76	107.9	0.8	0.71	24.18	14.4	240.1
std dev	0.86	1.38	1.99	0.83	31.94	59.07	0.44	0.43	152	8.06	51.95	0.4	0.27	1.56	7.35	64
non-toxic avg (28)	6.07	0.98	5.91	0.63	85.33	84.58	2.93	0.21	726	27.39	49.96	0.44	0.37	28.57	6.91	140
std dev	0.72	0.99	2.49	0.43	32.74	76.27	0.78	0.16	178	8.6	25	0.23	0.24	3.39	4.46	59.8
ratio TOX/NONTOX	1	2.29	1.32	2.49	1.37	1.58	1.22	2.98	0.97	1.34	2.16	1.8	1.9	0.85	2.08	1.72

Comparisons of mean contaminant concentrations in toxic and non-toxic samples probably were more valid in previous survey areas such as Tampa Bay (Long et al. 1994) or Hudson-Raritan Estuary (Long et al. 1994, Wolfe et al. 1994), where sediment samples were more likely to have represented a single hydrographic and contaminant regime. As indicated by the distribution of contaminants and the exceedances of ERM values (Table 12), contaminant sources and inputs probably vary considerably among the bays surrounding Long Island Sound, making generalization from averages based on the entire dataset more tenuous. The presence of additional contaminants, not analyzed in this study, probably contributes also to the toxicity measured in these samples. While the concentration ratios (Tables 18-20) do not point to any particular contaminants as a primary source of toxicity, the consistent elevation of an extensive suite of contaminants in the toxic samples for all three tests broadly supports a contaminant basis for the toxicity observed in Long Island Sound.

DISCUSSION AND CONCLUSIONS

These results indicate that sediment toxicity is widespread in the coastal bays of Long Island Sound; only 11 of the 60 bay stations showed no significant toxicity in any of three tests (amphipod survival, *Mulinia* survival, and Microtox™) and none of the 20 bays was non-toxic in all tests at all three stations. The bay indicated to have the greatest sediment toxicity in this survey was Manhasset Bay, NY, with all three stations significantly toxic in all three tests. Several other bays gave multiple hits at the three stations with the three tests, as well: Oyster Bay, NY (8 hits); Little Neck Bay, NY (7); Echo Bay, Cold Spring Harbor, Larchmont Harbor and Pelham Bay (all NY, 6). All three stations in the Housatonic River CT (4) were toxic to amphipods, while one station (17I) in Bridgeport Harbor, CT was toxic in all three tests.

The least toxic bays included Branford Harbor and Connecticut River, CT, each with only one hit at one station; along with Northport Harbor NY, Southport Harbor CT, Milford Harbor CT, and Thames River, CT, each with only two hits. The Central Long Island Sound (CLIS) control site also showed one hit at one of its three stations.

Most of the stations (and bays) that exhibited toxicity also showed demonstrable contamination for the chemical analytes reported here, and many of the stations exceeded the reported ERMs for one or more chemicals. The most contaminated sites, in terms of a cumulative hazard factor based on those chemicals for which ERLs and ERMs have been calculated, were Little Neck Bay, Pelham Bay, Manhasset Bay (all NY), and Housatonic River, CT, respectively. Relatively high cumulative hazard factors were also observed at single stations within Echo Bay, NY, and Stamford Harbor, Thames River, and New Haven Harbor, CT.

Most of the contaminants analyzed covaried quite strongly with one another across sites, making it difficult to attribute the observed toxicity to any particular class of contaminants in any of the bays. Among the organic contaminants, tPAH and HMW PAH most frequently exceeded their ERM values, but various pesticides, including DDT/DDE, chlordane and dieldrin often accompanied the PAH at levels greater than ERM values as well.

Although the concentrations of toxic metals often exceeded their respective ERMs (most frequently mercury and silver, and occasionally lead, zinc, and copper), the ratio of SEM/AVS only rarely exceeded 1.0, indicating that the metals were not a primary source of sediment toxicity in these systems. In the three samples where the SEM/AVS exceeded 1.0, the AVS concentrations were among the lowest observed at any station, and the samples were predominantly sand. One of these three samples (18A) exhibited moderate toxicity to amphipods and *Mulinia* larvae; the other two were non-toxic in all tests.

The three sediment toxicity tests employ different modes of exposure to three different test organisms; therefore, the observed differences in sensitivity were not unexpected among tests. The Microtox™ response to organic extracts of sediments appears to respond to bulk chemical contaminant concentrations, independent of the TOC content of the sediments. Although organic materials probably contribute most or all of this toxicity, the metals typically covary strongly with the organics (and with the proportion of clay/silt and TOC) in the sediments. Results of the solid phase sediment toxicity test with amphipods by contrast showed stronger correlations with contaminant concentrations after normalization to TOC or fine sediments than with concentrations based on dry weight, indicating an effect of both grain size and TOC on toxicity. This effect probably results from differences in the bioavailability of contaminants, and, along with the SEM/AVS data, suggests that the toxicity was due mainly to organic contaminants. The elutriate test with *Mulinia* showed an intermediate degree of TOC-modulating effect, but still suggested that this test, like Microtox™, was largely responsive to bulk contaminant levels in the sediments.

Principal component analysis supported the deductions based on simple correlations and normalization procedures, showing the primary component of variability in the toxicity data to result from the strongly covarying concentrations of many sediment contaminants. The PCA, however, identified a minor second component related to total pesticide content, that affected the toxicity at selected stations in Centerport Harbor, Oyster Bay, and Larchmont Harbor, NY. The contaminant contributing most to the variability of tPesticide at these stations was hexachlorobenzene.

These affiliations among stations were illustrated through cluster analysis of the toxicity and chemical data. Like the principal component analysis, however, the cluster analysis demonstrated substantial effects of sediment grain size and TOC on the resultant clustering of stations. Although the cluster diagrams supported the primary associations between toxicity and chemical contamination, they also illustrated the conclusion that with only a few exceptions, contamination and associated toxicity were distributed across many of the bays, and were frequently more dependent on sediment characteristics at the individual stations than upon baywide contamination characteristics.

Contaminant Effects in Resident Biota**.** Observations on the incidence of contaminant-related indicators of exposure and biological effects provide important complementary support for sediment toxicity data. A number of contaminant-related bioeffects, reviewed briefly below, have been noted in resident feral marine organisms in the Long Island Sound area, reinforcing and lending credibility to the implicit premise that toxicity tests using laboratory or wild-stock organisms exposed under laboratory conditions may be representative of potential exposures and effects under actual field conditions

Gronlund et al. (1991) examined contaminant concentrations, and several biomarkers of contaminant exposure and effects in tissues of winter flounder (*Pseudopleuronectes americanus*) from 3 sites in LIS. A correlation was observed between sediment contaminant levels and certain biomarkers, including the incidences of histopathological lesions, formation of adducts between DNA and xenobiotic compounds, and the levels of macrophage aggregates. Fish from New Haven (Figure 1) were most affected compared to those from the relatively uncontaminated reference site at Niantic. Liver neoplasms were found (in one of 30 fish) only at the New Haven (Morris Cove) site. One liver neoplasm was also found in one of 90 fish taken from the western Benthic Surveillance site in LIS (site 10, Figure 21) during 1984-1986, while none were found in fish from the other LIS Benthic Surveillance site (site 11) (MURCHELANO-ZDANOWISC?). Two additional liver neoplasms were found among 87 fish taken during 1987-1989 near site 10 in western LIS off Lloyd Point, NY (Johnson et al. 1993). In related work, Johnson et al. (1992, 1994) examined prespawning female winter flounder from sites between New York Harbor and Boston Harbor. No significant relationship was found between a sometimes substantial degree of contaminant exposure (as indicated by elevated AHH and DNA adducts) and ovarian maturation or reproductive steroid levels in fish from these areas. This finding was in sharp contrast to field studies in Puget Sound with English sole (Johnson et al. 1988) where contaminant exposure was linked to disrupted or inhibited ovarian development and altered steroid metabolism. Nelson et al. (1991) also collected late prespawning female winter flounder from 7 sites in LIS, spawned them in the laboratory, and then compared rates of fertilization and hatching success and incidence of abnormal larvae. Fish from New Haven Harbor consistently produced lower viable hatch rates and smaller larvae, compared to other LIS sites, but these differences were not correlated with concentrations of PCBs or metals either in the livers of the spawned fish or in the eggs.

Water-Column Toxicity Huntsman and Sunda (1992) measured the toxicity of seawater to sea urchin embryos, along with the activities of free cupric ion in seawater, from 26 LIS locations, including 9 in the central and western Sound and the balance in various coastal bays (Figure 1). In laboratory bioassays, development of sea urchin embryos to the pluteus larval stage was significantly inhibited by exposure to free cupric ion activities greater than 10^{-11} Molar. Similar cupric ion toxicities had previously been demonstrated for the marine copepod *Acartia tonsa* and other species (Sunda et al. 1987, 1990). Seawater from several of the LIS coastal sites, including Black Rock Harbor, Bridgeport Harbor, and Stamford Harbor, (as well as from numerous sites in the Hudson-Raritan Estuary) contained ambient activities of free cupric ion in the range of 10^{-11} to 10^{-10} Molar. Toxicity bioassays, however, indicated widespread toxicity to urchin embryos, pervasive in ambient seawater samples throughout the area sampled and only partly ascribable to chelatable metals (Huntsman and Sunda 1992).

Management Implications. While the primary criteria for selection of study areas for NOAA's intensive bioeffects surveys have generally been the degree of contamination and the likelihood of toxicant-related bioeffects, secondary criteria include the scarcity of existing data, the lack of duplicative research activities, and the potential for collaboration with other federal, state and local agencies. Many participating agencies have identified management needs for the types of information to be generated, and have shown willingness to assist in the planning, financial support, and implementation of the program. The work described in this report was planned and conducted in cooperation with the Toxic Contaminants SubCommittee of the LISS Management Committee. Such cooperation and collaboration have led to a larger and more effective program than could have been carried out solely under NOAA support, and have helped to ensure that the program results have direct utility to regional environmental managers.

Environmental quality issues related to inputs and distribution of toxic contaminants are intimately entwined with other environmental management issues, including population growth, development and land use. If urban land-use (Table 2) shows an increase commensurate with the projected population increase, one might project that approximately 2.5% of the land in the EDA could be removed from other categories through 2010. Though this value may seem acceptably small to some, it should be obvious that large-scale and long-term planning is necessary to ensure that certain sensitive and already rare categories of land-use are protected from significant further infringements over the entirety of the LIS drainage area. Examples are wetlands and beaches, which have great value as habitat for fish and wildlife, and for recreation, respectively. Careful planning is also required to guide any future development into approaches that will minimize future inputs of contaminants and nutrients into the LIS. It should be noted too that development and pollutant loads are related to living standards, and they may not increase in direct proportion to population numbers. Smaller family size, single family dwellings, and second homes, for example, could contribute to disproportionate development with increased population, whereas expanded use of such commodities as private vehicles and lawn-care fertilizers, herbicides, and pesticides could increase pollutant loads even if population were to remain stable.

Effective management of environmental quality in LIS requires not only reliable scientific quantification of different pollutant sources and their effects, but also requires recognition of the policies and practices of existing management infrastructures related to those sources, along with careful planning of approaches for environmental improvement. Environmental planning, environmental research, and environmental management should therefore go hand-in-hand (Koppelman 1987; Wolfe et al. 1987). Identification and integration of prospective management alternatives are often lacking in the planning phases of applied environmental research, yet are an essential aspect of any effective decision-analytic framework for environmental management (Wolfe 1988). For these reasons, it is important that the scientists conducting the LISS continue to work very closely with environmental planners and/or managers who will use the information to be generated.

Recent actions taken with regard to limitation of nutrient inputs to the Sound may offer a model for prospective management of toxic contaminants in the Sound. Briefly, nutrient inputs are believed to cause blooms of algae that sink to the bottom and decay causing low dissolved oxyygen conditions in bottom waters. Monitoring data from the Western Narrows of the Sound (LISS 1990) have shown consistently low concentrations of dissolved oxygen during the summer months in this region. Concentrations have routinely fallen below the 5 mg/l level believed to be the threshold concentration below which marine life is threatened. In August 1987, bottom waters of the Western Narrows became anoxic (0 mg/l) and in late summer 1989, more than 63% of the Sound's bottom experienced dissolved oxygen concentrations less than 5 mg/l. Parker (1991) has shown that the area subject to hypoxia in the Western LIS has increased over time, and anthropogenic nutrient loading has been a major contributing factor.

In response to the apparently increasing degradation, the LISS (1990) established a "no net increase" policy for nitrogen inputs to the bay as a preliminary measure designed to protect the Sound against further degradation. It is clear that this policy is at best only a stopgap measure, that reduction of inputs must be achieved in order to restore dissolved oxygen concentrations to acceptable levels. Coupled water quality and hydrodynamic models will eventually be used to estimate the level of reduction necessary to raise dissolved oxygen concentrations to acceptable levels and to identify where these reductions will be most effective. Likewise, contaminant concentrations in sediments and the associated effects on marine organism health will decline only if inputs are reduced. The models developed for nutrient management may provide a useful basis for planning of toxic contaminant management.

Loadings of nutrients arise from multiple sources as do those of toxic contaminants, and appropriate management of the different sources will necessarily involve different infrastructure and implementation strategies. Some considerations for planning various management options are: What are the management options for reduction of the overall loadings? How, where and when can these options be most cost effectively applied (i.e. balancing the actual implementation costs against the potential net benefits to LIS)? Given the complex dynamics of nutrient exchange processes between estuarine sediments and water, as well as the various source inputs and transport pathways, how will specific source reductions affect the actual concentrations of nutrients that lead to excessive production and low dissolved oxygen concentrations? This question applies to toxics as well, which derive from the same sources as nutrients (Table 2), however, the model parameters for determination of affects will necessarily be weighted differently for nutrients and toxic contaminants.

For instance, as shown in Table 2, the principle sources of nitrogen and phosphorus to LIS are from WWTP's and upstream sources. While management of the point-source discharges from WWTP's is probably the simpler and less expensive way to decrease loadings, significant reduction of the nutrient levels through technological upgrades in treatment, from for example secondary to tertiary treatment, is still likely to require modifications to the plants at substantial cost. This would be true also for removal of toxics which are largely removed by industries prior to discharge to the WWTP's. The toxics not removed during pre-treatment are reduced by virtue of their affinity to particles that settle out during the primary treatment process, in general there is no active removal of toxics during waste treatment so that these upgrades would also be very costly.

In contrast to the one-time high cost upgrades to the treatment process, management options for upstream riverine source reduction such as the following may be less costly on the short term but as or more costly on a long term basis. These might include: a) seasonal testing of agricultural croplands (and suburban lawns) to determine actual fertilizer requirements and thereby to avoid excessive applications; b) construction of on-site treatment systems to remove nutrients (and toxics) arising from agricultural applications and animal wastes; and c) improved land management practices, including appropriate buffer zones to prevent excessive erosion and runoff to stream channels. This latter option may be pertinent not only to agriculture land-use, but also to future urban development.

Although some of the foregoing options for upstream source reduction are not likely to involve great financial outlay, the costs of alternative land use could be significant for small landowners. Gaining widespread acceptance, therefore, could require a high degree of cooperation from the agricultural community and other landowners, achievable over time through effective public information and incentive programs. In urban areas, where residential property values or commercial profit margins are so highly dependent on location, constraints on land-use or development could have substantial implications both for individual landowners and for the tax base of the community.

Many of these considerations will ultimately influence the combination of management options selected to limit nutrient and toxic inputs to Long Island Sound. Since the major sources of toxic contaminants and nutrients are similar (Table 2), some of the planning for nutrient management may be useful as a model for management of contaminants. Balancing the ever rising costs of environmental regulation and land-use management against the prospect of continued deteriorating environmental quality is the growing challenge before politicians, environmental managers, environmental scientists, developers, and the concerned public in the region of Long Island Sound.

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BIOLOGICAL EFFECTS OF TOXIC CONTAMINANTS IN SEDIMENTS FROM LONG ISLAND SOUND AND ENVIRONS

APPENDICES

Table of Contents

Appendix Table 1. Positions and depths for all Stations Sampled for Sediments in Long Island Sound Coastal Bays.

SITE NAME	STATION NO	LATITUDE	LONGITUDE	Depth (ft)
Little Neck Bay NY	1A	40° 46.60N	73° 45.40W	7
	1B	40° 47.10N	73° 45.40W	8
	1C	40° 47.91N	73° 45.37W	12
	1D	40° 48.30N	73° 45.70W	15
	1E	40° 47.00N	73° 45.20W	6
	1F	40° 48.10N	73° 46.20W	12
	1G	40° 47.70N	73° 46.00W	8
	1H	40° 47.50N	73° 45.30W	10
	1I	40° 47.10N	73° 45.80W	8
Manhassett Bay, NY	2A	40° 48.47N	73° 42.67W	10
	2B	40° 49.13N	73° 42.15W	15
	2C	40° 50.98N	73° 42.14W	9
	2D	40° 49.53N	73° 43.23W	17
	2E	40° 49.91N	73° 43.60W	26
	2F	40° 50.59N	73° 44.49W	21
	2G	40° 50.34N	73° 43.99W	22
	2H	40° 51.32N	73° 42.42W	11
	2I	40° 49.47N	73° 42.31W	16
Echo Bay, CT	3A	40° 54.54N	73° 45.60W	10
	3B	40° 54.63N	73° 45.15W	15
	3C	40° 54.14N	73° 44.99W	31
	3D	40° 54.10N	73° 45.40W	25
	3E	40° 54.39N	73° 45.32W	21
	3F	40° 54.37N	73° 45.07W	25
	3G	40° 54.48N	73° 45.70W	11
	3H	40° 54.71N	73° 45.81W	7
	3I	40° 53.84N	73° 45.60W	28
New Haven Harbor, CT	4A	41° 16.51N	72° 15.78W	11
	4B	41° 16.20N	72° 54.51W	23
	4C	41° 15.47N	72° 15.75W	20
	4D	41° 15.21N	72° 54.83W	17
	4E	41° 14.29N	72° 54.79W	24
	4F	41° 14.04N	72° 55.30W	26
	4G	41° 13.50N	72° 56.32W	24
	4H	41° 14.00N	72° 56.40W	26
	4I	41° 17.24N	72° 54.21W	16

Appendix Table 1 (Continued). Positions and depths for all Stations Sampled for Sediments in Long Island Sound Coastal Bays.

SITE NAME	STATION NO	LATITUDE	LONGITUDE	Depth (ft)
Stamford Harbor, CT	5A	41° 02.21N	73° 32.28W	16
	5B	41° 02.21N	73° 31.81W	10
	5C	41° 01.93N	73° 31.98W	6
	5D	41° 01.64N	73° 31.78W	7
	5E	41° 01.60N	73° 32.28W	10
	5F	41° 01.35N	73° 31.77W	9
	5G	41° 01.21N	73° 32.46W	19
	5H	41° 01.07N	73° 31.77W	13
	5I	41° 00.89N	73° 33.35W	16
Norwalk Harbor, CT	6A	41° 05.54N	73° 24.18W	9
	6B	41° 05.03N	73° 23.71W	17
	6C	41° 04.56N	73° 23.90W	12
	6D	41° 03.96N	73° 24.47W	10
	6E	41° 04.04N	73° 23.57W	12
	6F	41° 04.14N	73° 24.06W	18
	6G	41° 04.66N	73° 23.90W	12
	6H	41° 04.83N	73° 23.84W	10
	6I	41° 04.39N	73° 23.29W	19
Cold Spring Hrbr, NY	7A	40° 52.47N	73° 28.25W	18
	7B	40° 53.70N	73° 29.30W	25
	7C	40° 54.50N	73° 29.60W	29
Pelham Harbor, NY	8A	40° 51.66N	73° 48.41W	10
	8B	40° 51.30N	73° 48.29W	10
	8C	40° 50.79N	73° 48.26W	13
Centerport Harbor, NY	9A	40° 53.89N	73° 22.41W	13
	9B	40° 55.01N	73° 23.05W	25
	9C	40° 54.57N	73° 22.85W	35
Northport Harbor, NY	10A	40° 53.58N	73° 21.32W	3
	10B	40° 54.60N	73° 21.55W	9
	10C	40° 55.01N	73° 21.70W	9
Oyster Bay, NY	11A	40° 53.02N	73° 30.65W	15
	11B	40° 53.50N	73° 30.90W	42
	11C	40° 54.60N	73° 30.10W	37
Larchmont Harbor, CT	12A	40° 55.73N	73° 44.05W	9
	12B	40° 55.46N	73° 44.20W	9
	12C	40° 55.28N	73° 43.81W	13

Appendix Table 1 (Continued). Positions and depths for all Stations Sampled for Sediments in Long Island Sound Coastal Bays.

SITE NAME	STATION NO	LATITUDE	LONGITUDE	Depth (ft)
Southport Harbor, CT	13A	41° 07.50N	73° 16.98W	8
	13B	41° 06.91N	73° 17.91W	17
	13C	41° 06.82N	73° 16.40W	19
Branford Harbor, CT	14A	41° 14.71N	72° 49.55W	9
	14B	41° 14.27N	72° 49.24W	12
	14C	41° 14.36N	72° 49.73W	10
Milford Harbor, CT	15A	41° 12.65N	73° 02.58W	6
	15B	41° 11.73N	73° 02.40W	24
	15C	41° 11.74N	73° 02.85W	22
Connecticut River, CT	16A	41° 17.96N	72° 20.65W	3
	16B	41° 16.80N	72° 21.00W	10
	16C	41° 18.89N	72° 21.20W	6
Bridgeport Harbor, CT	17A	41° 09.98N	73° 10.27W	10
	17B	41° 09.57N	73° 10.45W	26
	17C	41° 09.78N	73° 10.40W	24
	17D	41° 09.37N	73° 10.34W	22
	17E	41° 09.83N	73° 09.89W	19
	17F	41° 08.70N	73° 10.80W	36
	17G	*	*	
	17H	41° 10.17N	73° 10.50W	39
	17I	41° 10.41N	73° 10.55W	32
“Housatonic River, CT”	18A	41° 11.89N	73° 06.46W	7
	18B	41° 11.17N	73° 07.01W	19
	18C	41° 12.08N	73° 06.37W	nd
18D	41° 11.43N	73° 06.86W	8	
	18E	41° 09.48N	73° 05.23W	25
	18F	41° 10.32N	73° 06.71W	7
	18G	41° 10.88N	73° 06.71W	7
	18H	41° 11.26N	73° 06.83W	21
	18I	41° 11.58N	73° 06.40W	7
Eastchester Bay, NY	19A	40° 48.15N	73° 48.61W	13
	19B	40° 50.59N	73° 47.49W	9
	19C	40° 50.05N	73° 48.11W	10
	19D	40° 49.72N	73° 48.21W	12
	19E	40° 49.52N	73° 47.99W	10
	19F	40° 49.56N	73° 47.11W	18

Appendix Table 1 (Continued). Positions and depths for all Stations Sampled for Sediments in Long Island Sound Coastal Bays.

SITE NAME	STATION NO	LATITUDE	LONGITUDE	Depth (ft)
Eastchester Bay, NY	19G	40° 50.27N	73° 47.35W	11
	19H	40° 50.48N	73° 48.52W	8
	19I	40° 51.10N	73° 47.50W	9
Thames River, CT	20A	41° 21.18N	72° 05.01W	24
	20B	41° 20.72N	72° 05.45W	13
	20C	41° 20.88N	72° 05.27W	21
	20D	41° 20.10N	72° 05.03W	22
	20E	41° 19.47N	72° 05.42W	13
	20F	41° 19.73N	72° 04.98W	21
	20G	41° 18.87N	72° 05.02W	28
	20H	41° 18.67N	72° 05.13W	29
	20I	41° 19.91N	72° 05.45W	10
Central Long Island	CLIS-A	41° 07.90N	72° 52.40W	82
Sound	CLIS-B	41° 07.30N	72° 53.90W	82
	CLIS-C	41° 07.40N	72° 51.50W	88

Appendix Table 2.1. Toxicity of LIS Sediments to *Ampelisca abdita*.

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
Contr-1	20	20	100	92.3	7.52	100
Contr-1	20	17	85			
Contr-1	20	20	100			
Contr-1	20	17	85			
Contr-1	23	21	91.3			
1-A	20	20	100	80	12.75	86.7
1-A	20	16	80			
1-A	20	15	75			
1-A	20	13	65			
1-A	20	16	80			
1-C	20	11	55	67	15.25	72.6
1-C	20	17	85			
1-C	20	10	50			
1-C	20	16	80			
1-C	20	13	65			
1-D	20	10	50	43	12.55	46.6
1-D	20	11	55			
1-D	20	5	25			
1-D	20	10	50			
1-D	20	7	35			
8-A	20	11	55	73	14.4	79.1
8-A	20	17	85			
8-A	20	14	70			
8-A	20	13	65			
8-A	20	18	90			
8-B	20	11	55	58	13.51	62.8
8-B	20	9	45			
8-B	20	10	50			
8-B	20	12	60			
8-B	20	16	80			
19-A	20	16	80	79	5.48	85.6
19-A	20	14	70			
19-A	20	16	80			
19-A	20	17	85			
19-A	20	16	80			
19-C	20	12	60	69	8.94	74.8
19-C	20	14	70			
19-C	20	15	75			
19-C	20	12	60			
19-C	20	16	80			

Appendix Table 2.1 (cont'd). Toxicity of LIS Sediments to *Ampelisca abdita*..

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
19-F	20	10	50	59	12.94	63.9
19-F	20	11	55			
19-F	20	15	75			
19-F	20	14	70			
19-F	20	9	45			
Contr-2	20	19	95	90	5	100
Contr-2	20	18	90			
Contr-2	20	17	85			
Contr-2	20	17	85			
Contr-2	20	19	95			
2-A	20	16	80	68	10.37	75.6
2-A	20	14	70			
2-A	20	12	60			
2-A	20	11	55			
2-A	20	15	75			
2-E	20	12	60	68	6.71	75.6
2-E	20	15	75			
2-E	20	13	65			
2-E	20	15	75			
2-E	20	13	65			
2-G	20	4	20	33	14.83	36.7
2-G	20	8	40			
2-G	20	10	50			
2-G	20	8	40			
2-G	20	3	15			
3-A	20	15	75	73	10.37	81.1
3-A	20	18	90			
3-A	20	14	70			
3-A	20	13	65			
3-A	20	13	65			
3-C	20	14	70	35	35	38.9
3-C	20	14	70			
3-C	20	0	0			
3-C	20	0	0			
3-C	20	7	35			
3-F	20	11	55	60	11.18	66.7
3-F	20	13	65			
3-F	20	15	75			
3-F	20	12	60			
3-F	20	9	45			

Appendix Table 2.1 (cont'd). Toxicity of LIS Sediments to Ampelisca abdita.

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
5-A	20	8	40	49	6.52	54.4
5-A	20	11	55			
5-A	20	10	50			
5-A	20	11	55			
5-A	20	9	45			
5-D	20	13	65	69	4.18	76.7
5-D	20	13	65			
5-D	20	14	70			
5-D	20	14	70			
5-D	20	15	75			
5-H	20	13	65	72	21.1	80
5-H	20	17	85			
5-H	20	19	95			
5-H	20	8	40			
5-H	20	15	75			
8-C	20	12	60	55	6.12	61.1
8-C	20	12	60			
8-C	20	9	45			
8-C	20	11	55			
8-C	20	11	55			
12-A	20	13	65	63	12.55	70
12-A	20	16	80			
12-A	20	12	60			
12-A	20	13	65			
12-A	20	9	45			
12-B	20	13	65	74	10.25	82.2
12-B	20	15	75			
12-B	20	15	75			
12-B	20	18	90			
12-B	20	13	65			
12-C	20	8	40	60	14.14	66.7
12-C	20	14	70			
12-C	20	12	60			
12-C	20	14	70			
12-C						
Contr-3	20	19	95	91	6.52	100
Contr-3	20	17	85			
Contr-3	20	17	85			
Contr-3	20	18	90			
Contr-3	20	20	100			

Appendix Table 2.1 (cont'd). Toxicity of LIS Sediments to *Ampelisca abdita*.

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
CLIS-A	20	9	45	74	23.29	81.3
CLIS-A	20	20	100			
CLIS-A	20	16	80			
CLIS-A	20	11	55			
CLIS-A	20	18	90			
CLIS-B	20	17	85	76	8.22	83.5
CLIS-B	20	13	65			
CLIS-B	20	16	80			
CLIS-B	20	16	80			
CLIS-B	20	14	70			
CLIS-C	20	19	95	65	19.69	71.4
CLIS-C	20	13	65			
CLIS-C	20	9	45			
CLIS-C	20	10	50			
CLIS-C	20	14	70			
7-A	20	18	90	75	10.61	82.4
7-A	20	13	65			
7-A	20	16	80			
7-A	20	13	65			
7-A	20	15	75			
7-B	20	16	80	85	7.07	93.4
7-B	20	19	95			
7-B	20	16	80			
7-B	20	18	90			
7-B	20	16	80			
7-C	20	9	45	64	15.57	70.3
7-C	20	16	80			
7-C	20	14	70			
7-C	20	15	75			
7-C	20	10	50			
9-A	20	10	50	84	20.43	92.3
9-A	20	20	100			
9-A	20	19	95			
9-A	20	16	80			
9-A	20	19	95			
9-B	20	7	35	54	18.51	59.3
9-B	20	16	80			
9-B	20	8	40			
9-B	20	13	65			
9-B	20	10	50			

Appendix Table 2.1 (cont'd). Toxicity of LIS Sediments to Ampelisca abdita.

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
9-C	20	14	70	79	13.42	86.8
9-C	20	12	60			
9-C	20	18	90			
9-C	20	17	85			
9-C	20	18	90			
10-A	20	15	75	85	6.12	93.4
10-A	20	17	85			
10-A	20	17	85			
10-A	20	18	90			
10-A	20	18	90			
10-B	20	14	70	81	6.52	89
10-B	20	16	80			
10-B	20	17	85			
10-B	20	17	85			
10-B	20	17	85			
10-C	20	17	85	83	11.51	91.2
10-C	20	17	85			
10-C	20	15	75			
10-C	20	14	70			
10-C	20	20	100			
11-B	20	10	50	38	19.56	41.8
11-B	20	10	50			
11-B	20	1	5			
11-B	20	10	50			
11-B	20	7	35			
11-C	20	0	0	31	37.98	34.1
11-C	20	19	95			
11-C	20	5	25			
11-C	20	1	5			
11-C	20	6	30			
13-A	20	3	15	9	6.52	9.9
13-A	20	3	15			
13-A	20	2	10			
13-A	20	0	0			
13-A	20	1	5			
Contr-4	20	18	90	92.5	2.89	100
Contr-4	20	18	90			
Contr-4	20	19	95			
Contr-4	20	19	95			
Contr-4						

Appendix Table 2.1 (cont'd). Toxicity of LIS Sediments to *Ampelisca abdita*.

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
4-D	20	16	80	76	9.62	82.2
4-D	20	17	85			
4-D	20	12	60			
4-D	20	16	80			
4-D	20	15	75			
4-G	20	13	65	69	13.87	74.6
4-G	20	13	65			
4-G	20	17	85			
4-G	20	10	50			
4-G	20	16	80			
6-A	20	16	80	84	7.42	90.8
6-A	20	17	85			
6-A	20	19	95			
6-A	20	17	85			
6-A	20	15	75			
6-B	20	11	55	77	14.83	83.2
6-B	20	18	90			
6-B	20	18	90			
6-B	20	16	80			
6-B	20	14	70			
6-F	20	10	50	63	16.43	68.1
6-F	20	12	60			
6-F	20	16	80			
6-F	20	16	80			
6-F	20	9	45			
11-A	20	15	75	68	18.23	73.5
11-A	20	13	65			
11-A	20	14	70			
11-A	20	18	90			
11-A	20	8	40			
13-B	20	17	85	92	5.7	99.5
13-B	20	18	90			
13-B	20	18	90			
13-B	21	21	100			
13-B	20	19	95			
13-C	20	16	80	83	5.7	89.7
13-C	20	17	85			
13-C	20	18	90			
13-C	20	15	75			
13-C	20	17	85			

Appendix Table 2.1 (cont'd). Toxicity of LIS Sediments to Ampelisca abdita.

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
15-B	20	17	85	84	6.52	90.8
15-B	20	16	80			
15-B	20	16	80			
15-B	20	19	95			
15-B	20	16	80			
17-A	20	17	85	85	6.12	91.9
17-A	20	15	75			
17-A	20	17	85			
17-A	20	18	90			
17-A	20	18	90			
17-F	20	16	80	81	5.48	87.6
17-F	20	15	75			
17-F	20	18	90			
17-F	20	16	80			
17-F	20	16	80			
17-I	20	8	40	49	6.52	53
17-I	20	9	45			
17-I	20	11	55			
17-I	20	10	50			
17-I	20	11	55			
18-A	20	14	70	70	18.71	75.7
18-A	20	8	40			
18-A	20	16	80			
18-A	20	14	70			
18-A	20	18	90			
18-B	20	4	20	15	8.66	16.2
18-B	20	3	15			
18-B	20	0	0			
18-B	20	4	20			
18-B	20	4	20			
18-D	20	10	50	64	13.87	69.2
18-D	20	11	55			
18-D	20	14	70			
18-D	20	17	85			
18-D	20	12	60			
Contr-5	20	19	95	91	9.62	100
Contr-5	20	20	100			
Contr-5	20	19	95			
Contr-5	20	15	75			
Contr-5	20	18	90			

Appendix Table 2.1 (cont'd). Toxicity of LIS Sediments to *Ampelisca abdita*.

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
4-A	20	16	80	76	6.52	83.5
4-A	20	15	75			
4-A	20	14	70			
4-A	20	14	70			
4-A	20	17	85			
14-A	20	17	85	85	9.35	93.4
14-A	20	14	70			
14-A	20	17	85			
14-A	20	19	95			
14-A	20	18	90			
14-B	20	18	90	87	10.95	95.6
14-B	20	20	100			
14-B	20	18	90			
14-B	20	14	70			
14-B	20	17	85			
14-C	20	15	75	87	8.37	95.6
14-C	20	17	85			
14-C	20	19	95			
14-C	20	17	85			
14-C	20	19	95			
15-A	20	13	65	70	5.77	76.9
15-A	20	13	65			
15-A	20	15	75			
15-A	20	15	75			
15-A						
15-C	20	11	55	72	14.4	79.1
15-C	20	16	80			
15-C	20	12	60			
15-C	20	15	75			
15-C	20	18	90			
16-A	20	15	75	79	6.52	86.8
16-A	20	16	80			
16-A	20	15	75			
16-A	20	18	90			
16-A	20	15	75			
16-B	20	18	90	74	12.94	81.3
16-B	20	15	75			
16-B	20	11	55			
16-B	20	14	70			
16-B	20	16	80			

Appendix Table 2.1 (cont'd). Toxicity of LIS Sediments to *Ampelisca abdita*.

Station	# Exposed	# Surv	% Surv	Mean % Surv	std dev	%Contr Surv
16-C	20	11	55	73	16.43	80.2
16-C	20	18	90			
16-C	20	12	60			
16-C	20	18	90			
16-C	20	14	70			
20-A	20	18	90	83	5.7	91.2
20-A	20	15	75			
20-A	20	17	85			
20-A	20	16	80			
20-A	20	17	85			
20-D	20	16	80	80	7.91	87.9
20-D	20	17	85			
20-D	20	18	90			
20-D	20	14	70			
20-D	20	15	75			
20-G	20	16	80	72	15.25	79.1
20-G	20	16	80			
20-G	20	9	45			
20-G	20	16	80			
20-G	20	15	75			

Appendix Table 2.2. Toxicity of LIS Sediments to *Mulinia lateralis*.

Station	Mean % Survival	Std Dev	Control Survival	Std Dev	% Control Survival	Mean % Normal	Std Dev
1A	71.80	12.85	61	23.6	117.70	98.0	2.78
1C	34.78	14.52	61	23.6	57.01	100.0	0.00
1D	27.80	7.13	61	23.6	45.57	96.7	4.56
2A	19.10	11.50	61	23.6	31.31	91.1	10.28
2E	32.80	11.69	61	23.6	53.77	94.6	4.02
2G	07.90	6.30	61	23.6	12.95	94.3	12.78
3A	76.00	14.05	61	23.6	124.59	100.0	0.00
3C	46.90	21.35	61	23.6	76.89	99.3	1.49
3F	72.70	20.39	61	23.6	119.18	97.5	2.54
4A	87.40	15.08	79.4	16.7	110.08	69.3	1.61
4D	87.90	12.13	79.4	16.7	110.71	99.8	0.35
4G	83.70	12.74	79.4	16.7	105.42	100.0	0.00
5A	61.90	13.00	61	23.6	101.48	99.4	1.40
5D	66.40	19.08	61	23.6	108.85	98.9	1.47
5H	54.00	25.85	61	23.6	88.52	98.1	4.26
6A	71.10	20.10	79.4	16.7	89.55	99.8	0.34
6B	108.30	16.51	91.1	12.3	118.88	100.0	0.00
6F	110.40	15.17	91.1	12.3	121.19	98.9	1.03
7A	97.40	27.81	91.1	12.3	106.92	100.0	0.00
7B	27.10	25.90	91.1	12.3	29.75	99.8	0.40
7C	21.70	8.96	91.1	12.3	23.82	100.0	0.00
8A	63.90	13.24	61	23.6	104.75	94.0	6.45
8B	67.70	7.43	61	23.6	110.98	99.4	1.40
8C	57.70	21.34	61	23.6	94.59	93.9	4.61
9A	80.90	14.04	91.1	12.3	88.80	94.8	2.98
9B	24.30	7.59	91.1	12.3	26.67	98.8	2.80
9C	81.70	17.09	91.1	12.3	89.68	97.6	3.45
10A	74.50	25.36	91.1	12.3	81.78	94.3	6.05
10B	73.00	18.74	91.1	12.3	80.13	93.0	10.90
10C	79.10	13.71	91.1	12.3	86.83	97.2	0.45
11A	97.00	18.16	91.1	12.3	106.48	99.1	1.23
11B	50.00	20.22	91.1	12.3	54.88	99.0	2.13
11C	34.30	11.44	91.1	12.3	37.65	98.1	4.26
12A	59.40	17.03	61	23.6	97.38	96.7	3.94
12B	83.90	10.85	61	23.6	137.54	98.9	1.53
12C	16.60	5.29	61	23.6	27.21	84.3	14.42
13A	44.30	14.30	91.1	12.3	48.63	98.2	2.54
13B	95.70	13.13	91.1	12.3	105.05	100.0	0.00
13C	92.60	8.08	91.1	12.3	101.65	97.6	1.62

Appendix Table 2.2 (con't.). Toxicity of LIS Sediments to *Mulinia lateralis*.

Station	Mean % Survival	Std Dev	Control Survival	Std Dev	% Control Survival	Mean % Normal	Std Dev
14A	108.20	19.77	79.4	16.7	136.27	99.7	0.62
14B	73.90	9.10	79.4	16.7	93.07	99.5	1.04
14C	98.50	5.96	79.4	16.7	124.06	100.0	0.00
15A	89.40	17.63	79.4	16.7	112.59	99.9	0.23
15B	90.40	9.41	79.4	16.7	113.85	99.9	0.29
15C	90.70	11.19	79.4	16.7	114.23	97.1	1.42
16A	106.80	20.52	79.4	16.7	134.51	99.6	0.67
16B	107.10	8.22	79.4	16.7	134.89	98.8	1.61
16C	94.60	8.01	79.4	16.7	119.14	97.5	1.84
17A	107.50	13.33	79.4	16.7	135.39	100.0	0.00
17F	87.90	20.12	79.4	16.7	110.71	100.0	0.00
17I	45.00	9.06	79.4	16.7	56.68	81.2	7.32
18A	56.70	9.67	79.4	16.7	71.41	98.5	2.00
18B	88.80	12.54	79.4	16.7	111.84	99.9	0.26
18D	86.60	26.76	79.4	16.7	109.07	98.7	1.98
19A	51.90	19.25	61	23.6	85.08	95.1	4.70
19C	35.30	16.01	61	23.6	57.87	98.7	2.98
19F	66.90	18.59	61	23.6	109.67	99.1	1.94
20A	82.70	13.29	79.4	16.7	104.16	98.7	1.31
20D	101.20	9.41	79.4	16.7	127.46	99.2	1.05
20G	84.80	11.53	79.4	16.7	106.80	100.0	0.00
CLIS-A	87.80	21.17	91.1	12.3	96.38	100.0	0.00
CLIS-B	80.40	16.12	91.1	12.3	88.25	98.1	3.11
CLIS-C	96.10	17.89	91.1	12.3	105.49	99.6	0.97
Cont-1	61.00	23.61	61	23.6	100.00	91.7	5.83
Cont-2	91.10	12.32	91.1	12.3	100.00	98.9	1.25
Cont-3	79.40	16.71	79.4	16.7	100.00	97.4	0.91
NSW-1	83.46	8.73	61	23.6	136.82	87.9	10.52
NSW-2	90.20	5.17	91.1	12.3	99.01	98.8	1.43
NSW-3	79.30	9.33	79.4	16.7	99.87	98.5	1.38

Appendix Table 2.3. Toxicity of LIS Sediments in the Microtox^{R} Assay.

Station	EC50 mg dw/ml	EC50 % Control	Station	EC50 mg dw/ml	EC50 % Control
1-A	0.005	12.3	11-A	0.021	47.1
1-C	0.010	22.6	11-B	0.017	38.6
1-D	0.022	49.3	11-C	0.020	45.4
2-A	0.008	17.7	12-A	0.014	32.6
2-E	0.011	24.8	12-B	0.008	17.9
2-G	0.021	46.6	12-C	0.007	14.9
3-A	0.005	10.6	13-A	0.141	319.9
3-C	0.012	26.2	13-B	0.110	249.3
3-F	0.007	15.8	13-C	0.033	74.7
4-A	0.027	62.1	14-A	0.041	93.1
4-D	0.012	28.0	14-B	0.046	105.2
4-G	0.062	139.6	14-C	0.021	48.5
5-A	0.010	23.0	15-A	0.048	108.1
5-D	0.015	34.9	15-B	0.084	190.1
5-H	0.065	147.7	15-C	0.105	237.5
6-A	0.004	9.5	16-A	0.303	685.9
6-B	0.020	45.9	16-B	0.009	19.3
6-F	0.023	51.3	16-C	0.120	272.8
7-A	0.023	51.3	17-A	0.052	118.3
7-B	0.016	36.4	17-F	0.027	60.2
7-C	0.009	21.0	17-I	0.020	46.1
8-A	0.517	1169.9	18-A	0.062	139.9
8-B	0.016	35.8	18-B	0.059	133.3
8-C	0.057	129.7	18-D	0.189	426.9
9-A	0.007	14.7	19-A	0.003	7.0
9-B	0.007	16.4	19-C	0.018	40.2
9-C	0.011	24.7	19-F	0.008	17.2
10-A	0.022	50.6	20-A	0.007	15.4
10-B	0.030	67.0	20-D	0.067	151.2
10-C	0.048	108.8	20-G	0.120	272.4
CLIS-A	0.076	173.1			
CLIS-B	0.058	132.4			
CLIS-C	0.128	289.3			

Appendix Table 3. Long Island Sound sediment toxicity study—Sediment grain size analysis (%) and TOC (% dry weight).

Sample	% Gravel	% Sand	% Silt	% Clay	TOC
1-A	0	6.6	55.0	38.4	3.33
1-B	0	12.4	46.4	41.2	3.38
1-C	10.6	15.3	39.3	34.8	3.08
1-D	5.5	18.3	44.3	31.9	3.45
1-E	0	21.4	43.9	34.7	2.63
1-F	18.6	51.3	13.6	16.6	2.75
1-G	0.2	10.7	45.2	43.9	3.24
1-H	9.5	25.9	37.1	27.5	2.24
1-I	0	6.2	54.8	38.9	3.26
2-A	1.9	20.1	42.1	36.0	3.81
2-B	0.3	22.4	39.2	38.2	3.62
2-C	0	11.7	44.1	44.2	3.65
2-D	2.4	38.1	27.5	32.1	3.02
2-E	17.6	13.4	32.7	36.2	3.46
2-F	27.0	12.7	26.8	33.6	3.27
2-G	16.2	22.4	27.1	34.2	3.17
2-H	4.5	27.7	35.1	32.7	3.38
2-I	0	24.2	41.8	34.0	3.22
3-A	1.1	23.5	44.0	31.4	3.69
3-B	1.9	57.7	22.7	17.7	1.46
3-C	1.3	15.5	46.8	36.4	2.68
3-D	2.9	33.4	37.1	26.6	2.40
3-E	2.3	27.9	39.4	30.3	2.41
3-F	0	19.7	48.7	31.6	2.81
3-G	1.2	57.1	24.5	17.1	2.29
3-H	0.6	28.0	43.4	28.0	6.72
3-I	2.7	29.3	39.9	28.1	2.88
4-A	0.1	10.4	57.4	32.1	2.80
4-B	14.3	33.3	31.2	21.3	2.66
4-C	0	9.1	55.7	35.2	2.50
4-D	3.8	22.6	45.5	28.1	1.85
4-E	2.8	13.9	49.4	34.0	1.86
4-F	3.9	70.7	12.8	12.6	0.97
4-G	15.2	20.8	44.2	19.8	1.60
4-H	20.4	5.1	46.8	27.7	1.86
4-I	0	10.5	51.5	38.0	3.65

Appendix Table 3 (Con't.). Long Island Sound sediment toxicity study—Sediment grain size analysis (%) and TOC (% dry weight).

Sample	% Gravel	% Sand	% Silt	% Clay	TOC
5-A	0.2	5.1	53.5	41.2	3.15
5-B	0	22.8	50.5	26.7	3.46
5-C	0	10.9	53.6	35.5	2.62
5-D	0	9.7	56.3	34.0	2.67
5-E	0	17.2	56.3	26.5	2.52
5-F	0.7	84.9	8.3	6.2	0.47
5-G	2.3	57.4	25.2	15.1	1.37
5-H	0.4	67.6	20.6	11.4	1.11
5-I	1.5	80.2	11.1	7.1	0.70
6-A	0	15.5	54.1	30.4	2.51
6-B	2.9	19.7	44.8	32.6	2.48
6-C	5.2	27.1	37.1	30.6	2.16
6-D	12.8	31.1	30.5	25.6	2.05
6-E	1.5	45.8	31.7	21.1	1.71
6-F	5.3	71.0	14.4	9.4	0.91
6-G	4.8	54.8	24.8	15.6	1.41
6-H	1.2	36.5	39.4	22.9	1.79
6-I	10.0	73.7	9.6	6.8	0.83
7-A	1.4	27.8	39.4	31.3	2.59
7-B	7.3	22.3	39.7	30.7	2.56
7-C	15.9	17.9	42.7	23.6	2.50
8-A	3.4	92.2	1.5	2.9	0.27
8-B	18.2	19.2	35.3	27.3	2.80
8-C	2.3	16.1	44.3	37.3	3.29
9-A	0	6.4	57.8	35.8	3.22
9-B	28.1	22.9	28.3	20.8	2.07
9-C	0	6.3	55.9	37.8	2.81
10-A	1.1	29.8	43.6	25.5	2.05
10-B	1.2	10.6	52.9	35.2	2.00
10-C	0.7	38.3	35.7	25.3	1.81
11-A	5.7	19.9	39.2	35.3	2.87
11-B	22.4	15.1	36.9	25.5	2.69
11-C	21.0	41.3	19.7	18.0	1.83
12-A	0	15.9	29.6	54.4	3.49
12-B	0.2	18.9	34.4	46.5	3.18
12-C	26.5	16.4	24	33.1	2.81

Appendix Table 3 (Con't.). Long Island Sound sediment toxicity study—Sediment grain size analysis (%) and TOC (% dry weight).

Sample	% Gravel	% Sand	% Silt	% Clay	TOC
13-A	0.3	92.9	1.5	5.4	0.22
13-B	0.3	70.8	3.3	25.5	0.74
13-C	0.3	41.7	45.5	12.5	1.52
14-A	5.9	34.6	11.2	48.2	0.77
14-B	2.2	18.3	23	56.5	1.43
14-C	1.7	13.5	63.4	21.3	1.12
15-A	4.3	82.6	6.7	6.4	0.45
15-B	7.4	41.9	16.4	34.2	1.32
15-C	4.3	67.4	17.1	11.1	0.64
16-A	0.1	87.9	7.8	4.3	0.54
16-B	0	71.4	20.8	7.8	1.29
16-C	0	60.5	30.8	8.8	0.67
17-A	0	78.7	14.9	6.4	0.81
17-B	4.7	25.2	52.3	17.8	2.32
17-C	0	19.7	58.4	21.9	2.65
17-D	1.4	89.2	6.8	2.6	0.55
17-E	0	48.0	38.3	13.6	1.78
17-F	0	29.2	51.9	18.8	2.05
17-G	1.0	10.8	68.6	19.5	2.94
17-H	0	13.6	64.2	22.2	3.02
17-I	0	9.6	67	23.4	3.62
18-A	0	82.5	14.7	2.8	1.56
18-B	0.5	70.1	23.8	5.5	1.91
18-C	0	86.0	11.6	2.4	2.55
18-D	0	92.8	6.1	1.1	0.76
18-E	0.2	91.8	5.5	2.4	0.82
18-F	33.2	54.4	10.6	1.7	0.87
18-G	9.6	84.9	3.5	2.0	1.11
18-H	0	82.8	10.3	6.9	1.28
18-I	2.3	92.2	3.3	2.3	0.72
19-A	0	32.4	38.6	29.0	3.83
19-B	23.1	12.7	32.9	31.3	3.62
19-C	3.7	16.7	45.4	34.1	3.48
19-D	1.7	11.2	46.8	40.3	3.52
19-E	11.2	26.4	33.5	28.9	3.18

Appendix Table 3. (Con't.). Long Island Sound sediment toxicity study—Sediment grain size analysis (%) and TOC (% dry weight).

Sample	% Gravel	% Sand	% Silt	% Clay	TOC
19-F	10.7	35.4	29.3	24.6	3.42
19-G	22.3	15.7	33.3	28.7	3.16
19-H	6.6	23.3	38.9	31.2	3.16
19-I	15.3	18.1	37.0	29.6	3.22
20-A	0.8	29.2	50.7	19.3	3.02
20-B	9.4	32.3	46.9	11.4	3.37
20-C	14.3	21.2	50.0	14.5	2.28
20-D	0	12.7	68.9	18.4	1.63
20-E	0.6	16.9	65.3	17.2	2.37
20-F	0	21.2	63.3	15.5	1.43
20-G	1.1	25.2	56.8	16.9	1.56
20-H	0	46.1	45.7	8.2	0.46
20-I	0.9	65.5	29.0	4.6	1.42
CLIS-A	0.2	0.8	64.6	34.4	1.60
CLIS-B	3.9	19.4	49.0	27.7	1.58
CLIS-C	1	23	47.9	28.1	1.19

Appendix Table 4.1. Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Aluminum (Al)%	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)%	Mercury (Hg)
1-A	5.88	4.04	7.9	1.89	131.0	160.3	4.01	1.164
1-B	4.81	3.11	11.5	1.86	155.0	180.7	4.09	1.292
1-C	6.47	4.31	11.2	1.88	140.0	171.0	3.98	1.218
1-D	5.45	4.46	6.9	2.13	157.0	180.2	3.87	1.404
1-E	6.77	4.23	6.9	1.73	122.0	128.9	3.83	0.847
1-F	5.18	3.07	8.1	1.61	95.0	97.2	2.81	0.838
1-G	5.87	4.28	11.3	1.94	151.0	188.2	3.96	1.450
1-H	6.26	3.46	9.1	1.68	123.0	107.1	3.57	0.734
1-I	5.11	2.93	12.3	2.27	171.0	194.0	4.17	1.396
2-A	4.92	2.83	8.7	3.99	141.0	242.0	3.84	1.282
2-B	6.21	4.12	10.0	2.98	172.0	232.0	3.97	1.455
2-C	7.00	3.34	8.7	2.65	157.0	215.0	4.01	1.111
2-D	6.19	2.49	7.5	2.24	160.0	165.1	3.62	0.958
2-E	6.07	4.18	7.6	2.26	153.0	195.0	3.99	1.087
2-F	5.82	4.30	10.7	1.94	146.0	183.0	4.02	1.097
2-G	6.32	2.77	8.0	2.05	144.0	172.2	3.91	1.207
2-H	5.95	2.23	8.8	2.06	157.0	141.8	3.80	0.663
2-I	5.60	3.32	8.8	2.32	175.0	246.0	4.13	1.444
3-A	6.30	4.74	5.8	2.77	167.0	210.0	3.97	1.335
3-B	5.98	1.34	7.2	1.36	98.0	67.5	3.74	0.267
3-C	6.63	2.27	9.4	1.45	106.5	106.8	3.68	0.375
3-D	6.44	2.39	8.3	1.87	116.0	119.4	3.58	0.598
3-E	6.34	2.04	8.1	2.14	111.0	104.2	3.68	0.489
3-F	6.71	2.35	8.4	1.61	117.0	121.4	3.64	0.458

Appendix Table 4.1 (Con't.). Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Aluminum (Al)%	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)%	Mercury (Hg)
3-G	4.51	1.14	7.2	2.13	461.0	109.5	3.97	0.676
3-H	4.77	2.06	< 4.3	3.22	111.0	222.0	3.44	0.706
3-I	5.18	2.23	7.4	2.06	138.0	128.1	3.66	0.516
4-A	5.95	4.20	7.3	1.49	147.0	154.4	4.08	0.396
4-B	6.35	1.38	5.9	0.89	92.0	81.6	2.87	0.388
4-C	7.71	2.44	7.6	0.52	120.0	107.5	4.17	0.331
4-D	7.82	1.34	7.0	0.64	120.0	87.2	3.61	0.228
4-E	6.46	1.08	6.7	0.44	99.0	79.9	3.76	0.239
4-F	4.58	0.43	4.7	0.23	59.0	33.1	1.91	0.099
4-G	6.12	1.09	6.2	0.55	100.0	80.2	3.20	0.256
4-H	6.07	1.06	6.7	0.42	84.0	79.4	3.36	0.278
4-I	7.19	6.45	6.3	2.24	162.0	219.0	3.90	0.492
5-A	7.30	3.62	8.1	2.49	108.0	179.3	3.90	0.548
5-B	6.01	7.01	6.9	5.36	176.0	250.0	3.84	0.922
5-C	7.10	2.35	7.4	1.29	112.0	139.8	3.81	0.425
5-D	6.81	1.82	9.1	1.04	135.0	117.7	3.65	0.362
5-E	5.36	1.80	5.5	1.09	119.0	111.2	3.53	0.345
5-F	6.64	0.48	< 1.4	0.45	39.0	32.0	1.71	0.073
5-G	7.12	0.81	4.4	0.54	81.0	62.8	2.81	0.200
5-H	6.49	0.68	4.2	0.64	69.0	52.1	2.62	0.164
5-I	5.78	0.36	3.1	0.28	75.0	29.6	2.32	0.060
6-A	5.05	0.70	4.8	0.85	89.0	101.0	2.88	1.262
6-B	7.84	0.84	6.4	0.72	84.0	89.5	3.22	0.258
6-C	6.45	0.36	3.5	0.46	41.0	38.7	1.99	0.110
6-D	7.38	1.32	6.8	0.91	110.0	145.1	3.69	0.459

Appendix Table 4.1 (Con't.). Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Aluminum (Al)%	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)%	Mercury (Hg)
6-E	6.41	1.24	5.2	1.02	134.0	135.7	3.58	0.509
6-F	4.94	0.94	6.8	0.80	87.0	96.9	3.32	0.296
6-G	5.70	0.81	7.2	0.71	91.0	81.2	3.17	0.242
6-H	5.65	0.85	6.6	0.68	104.0	85.1	3.13	0.362
6-I	5.75	0.42	4.2	0.53	52.0	45.2	2.44	0.127
7-A	5.33	0.98	10.2	1.42	99.0	102.4	3.38	0.397
7-B	6.86	1.26	8.8	1.29	99.0	112.2	3.77	0.359
7-C	6.79	1.38	8.5	1.16	96.0	96.2	3.34	0.304
8-A	4.83	0.33	1.7	0.80	76.0	19.7	1.48	0.104
8-B	5.61	2.60	10.8	1.87	122.0	111.0	3.64	0.631
8-C	6.14	4.34	11.2	1.79	128.0	149.4	4.06	0.870
9-A	5.29	1.00	7.3	1.74	101.0	119.9	3.61	0.299
9-B	5.20	0.95	5.7	0.99	82.0	75.0	2.91	0.209
9-C	6.91	1.24	8.2	1.20	114.5	115.1	3.95	0.317
10-A	6.76	0.49	6.5	0.93	84.0	97.7	3.27	0.289
10-B	6.53	0.82	7.8	0.86	98.0	93.0	3.90	0.326
10-C	6.21	0.66	6.8	0.52	66.0	69.7	3.23	0.201
11-A	6.04	1.51	4.9	0.43	106.0	109.8	3.40	0.328
11-B	6.07	1.30	9.0	1.30	89.0	92.1	3.17	0.264
11-C	3.88	0.65	5.6	0.98	62.0	55.2	1.99	0.177
12-A	5.82	2.38	10.2	1.86	123.0	146.0	3.78	0.429
12-B	5.02	2.43	9.6	1.80	118.0	135.5	3.82	0.493
12-C	6.17	2.27	8.6	1.42	120.0	115.6	3.67	0.362
13-A	4.87	0.23	< 1.2	0.15	17.3	13.3	0.81	0.022
13-B	6.64	0.54	2.7	0.29	58.0	56.5	2.80	0.112
13-C	6.28	0.97	5.5	0.33	99.0	86.2	2.97	0.233

Appendix Table 4.1 (Con't.). Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Aluminum (Al)%	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)%	Mercury (Hg)
14-A	4.59	0.82	6.1	0.66	54.0	44.8	2.55	0.149
14-B	6.29	1.60	7.1	0.40	90.0	54.5	3.39	0.199
14-C	5.15	0.88	4.7	0.37	69.0	50.8	3.03	0.150
15-A	5.93	0.30	< 1.3	0.54	41.0	33.0	1.62	0.063
15-B	5.87	0.86	6.5	0.55	89.0	67.7	2.89	0.217
15-C	6.60	0.25	4.2	0.24	51.0	29.9	2.32	0.044
16-A	5.26	0.22	< 1.6	0.41	58.0	20.0	2.61	0.040
16-B	6.62	0.57	3.6	0.68	65.0	32.7	3.05	0.097
16-C	6.73	0.71	1.6	0.98	67.0	34.1	3.13	0.097
17-A	5.47	0.59	1.9	0.98	92.0	84.9	2.24	0.188
17-B	5.60	1.25	8.5	0.79	119.0	155.7	3.63	0.376
17-C	6.94	1.39	11.1	1.15	153.0	176.9	3.69	0.405
17-D	5.06	0.34	3.0	0.28	57.0	66.9	1.63	0.068
17-E	6.73	1.15	5.0	1.28	115.0	136.8	3.13	0.243
17-F	6.70	1.07	8.3	0.37	124.0	131.8	3.63	0.294
17-G	6.30	1.59	8.8	1.39	162.0	186.9	3.90	0.419
17-H	6.05	1.84	7.1	2.13	168.0	212.0	3.86	0.449
17-I	6.06	2.17	5.4	3.60	209.0	324.0	3.92	0.685
18-A	7.21	0.91	< 1.7	0.72	95.0	252.0	3.08	0.201
18-B	7.43	1.67	4.1	1.22	169.0	366.0	3.12	0.229
18-C	3.79	0.97	1.7	0.98	113.0	264.0	2.61	0.173
18-D	5.86	0.57	< 1.4	0.32	54.0	145.4	2.14	0.090
18-E	5.83	0.35	2.9	0.19	38.0	87.3	1.81	0.051
18-F	5.62	0.14	1.5	0.27	50.0	32.6	2.47	0.014

Appendix Table 4.1 (Con't.). Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Aluminum (Al)%	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)%	Mercury (Hg)
18-G	4.74	0.38	< 1.6	0.31	29.2	72.7	1.33	0.050
18-H	5.61	0.71	2.1	0.34	69.0	149.5	2.78	0.099
18-I	5.74	1.03	< 1.4	0.32	77.0	164.0	2.24	0.238
19-A	6.28	4.32	9.3	2.18	147.0	196.0	3.95	1.109
19-B	5.89	4.83	9.1	1.89	150.0	181.8	4.03	1.167
19-C	5.77	4.60	8.4	2.05	146.0	201.0	4.10	1.281
19-D	5.33	4.45	5.5	2.00	154.0	201.0	4.04	1.205
19-E	6.19	4.78	11.7	1.92	152.0	188.1	4.00	1.138
19-F	6.18	4.26	11.9	1.77	154.5	167.5	3.86	0.966
19-G	4.71	4.96	9.0	1.49	142.0	171.9	3.95	1.058
19-H	4.78	4.54	8.9	2.13	184.0	196.0	4.14	1.366
19-I	5.88	4.26	10.3	2.24	135.0	181.3	3.99	1.087
20-A	5.43	1.32	10.3	0.65	114.0	84.7	3.40	0.410
20-B	4.96	1.05	4.5	0.88	82.0	78.7	2.89	0.543
20-C	5.18	0.84	7.5	0.58	79.0	54.9	2.98	0.317
20-D	5.54	0.58	7.6	0.44	78.0	37.0	3.13	0.173
20-E	6.22	1.04	5.0	0.41	94.0	64.3	3.22	0.455
20-F	4.81	0.58	4.8	0.35	59.0	37.4	2.93	0.143
20-G	5.36	0.65	5.9	0.34	68.0	36.6	2.72	0.165
20-H	5.57	0.31	3.8	0.15	51.0	20.9	2.31	0.061
20-I	4.81	0.85	3.1	0.51	26.0	35.8	2.05	0.564
CLIS-A	6.29	0.69	5.5	0.19	103.0	52.7	3.69	0.198
CLIS-B	7.18	0.59	6.4	0.19	83.0	47.2	3.52	0.183
CLIS-C	6.37	0.63	7.0	0.24	116.0	53.8	3.68	0.206

Appendix Table 4.2. Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Manganese (Mn)	Nickel (Ni)	Lead (Pb)	Antimony (Sb)	Selenium (Se)	Silica % (Si)	Tin (Sn)	Zinc (Zn)
1-A	709.5	41.6	175.0	0.97	0.67	22.8	22.80	267.0
1-B	756.0	41.9	172.1	1.17	0.96	22.2	28.90	264.0
1-C	703.0	44.8	162.6	1.30	0.87	26.0	25.70	271.0
1-D	737.0	46.8	180.7	1.12	1.06	21.6	25.40	269.0
1-E	656.0	38.2	131.4	0.71	0.76	25.3	18.40	228.0
1-F	582.0	34.3	110.8	0.78	0.38	21.0	21.00	201.0
1-G	711.0	42.3	171.5	0.98	0.77	23.1	26.30	274.0
1-H	673.0	31.9	102.0	0.73	0.58	25.3	15.70	196.0
1-I	739.0	44.4	180.7	1.09	0.87	22.5	27.40	284.0
2-A	526.0	44.7	226.0	0.86	1.35	23.5	23.20	357.0
2-B	520.0	45.6	199.0	0.96	1.16	22.5	25.90	338.0
2-C	586.0	48.2	171.9	0.93	0.97	23.7	23.20	338.0
2-D	603.0	41.1	152.4	0.71	0.86	23.7	21.50	287.0
2-E	723.0	45.3	174.0	0.85	1.25	23.6	23.10	305.0
2-F	739.0	42.0	163.4	0.97	0.87	23.5	24.00	296.0
2-G	701.0	42.3	161.5	0.83	0.95	25.1	21.60	293.0
2-H	678.0	68.3	150.6	2.24	0.77	23.0	21.10	299.0
2-I	561.0	45.2	211.0	1.07	1.35	23.5	27.60	313.0
3-A	607.0	44.7	185.6	0.95	1.06	23.1	27.60	351.0
3-B	1015.0	38.6	58.7	0.44	0.39	25.5	10.20	186.0
3-C	759.0	37.6	84.4	0.54	0.63	23.6	15.65	232.5
3-D	906.0	42.0	100.8	0.61	0.48	25.1	15.40	261.0
3-E	768.0	46.7	93.4	0.61	0.48	22.1	13.60	235.0
3-F	740.0	40.3	93.9	0.69	0.58	23.9	14.00	252.0

Appendix Table 4.2 (Con't.). Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Manganese (Mn)	Nickel (Ni)	Lead (Pb)	Antimony (Sb)	Selenium (Se)	Silica % (Si)	Tin (Sn)	Zinc (Zn)
3-G	756.0	227.0	137.6	0.74	0.29	22.3	19.80	298.0
3-H	480.0	59.1	461.0	1.42	0.67	18.5	22.50	507.0
3-I	735.0	49.1	111.7	0.86	0.58	22.0	16.00	261.0
4-A	631.0	38.2	96.1	0.74	0.87	24.6	20.40	256.0
4-B	640.0	27.6	55.2	0.36	0.39	26.5	10.50	157.9
4-C	726.0	37.8	78.6	0.62	0.58	25.4	11.90	209.0
4-D	732.0	33.5	65.2	0.38	0.39	24.3	11.10	191.1
4-E	876.0	35.8	61.0	0.31	0.44	25.9	9.31	180.4
4-F	1031.0	16.3	32.7	0.31	0.38	31.2	3.42	84.8
4-G	814.0	25.3	51.2	0.59	0.64	25.1	7.37	163.9
4-H	768.0	26.7	54.6	0.65	0.64	23.7	7.82	156.9
4-I	591.0	41.3	124.6	1.75	0.89	23.5	22.80	317.0
5-A	637.0	40.1	118.7	2.20	0.89	23.2	13.20	338.0
5-B	611.0	45.6	139.0	7.05	0.82	23.3	23.20	428.0
5-C	707.0	36.5	84.3	1.31	0.87	24.5	13.10	255.0
5-D	651.0	37.2	73.8	1.78	0.77	24.8	10.10	234.0
5-E	775.0	36.6	80.9	1.32	0.70	24.5	9.80	228.0
5-F	594.0	15.1	35.4	0.19	0.29	34.7	3.84	64.1
5-G	808.0	24.5	54.8	0.31	0.48	27.1	6.95	134.2
5-H	753.0	23.6	44.5	0.29	<0.17	30.8	5.71	121.5
5-I	1026.0	22.5	34.0	0.17	0.19	33.7	2.87	69.7
6-A	757.0	22.7	49.2	0.38	0.70	24.1	5.56	164.8
6-B	780.0	25.1	54.3	0.51	0.64	27.2	6.48	168.8
6-C	623.0	13.3	32.2	0.20	0.32	28.7	2.68	88.5
6-D	603.0	32.1	77.8	0.78	0.57	25.6	9.41	237.0

Appendix Table 4.2 (Con't.). Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Manganese (Mn)	Nickel (Ni)	Lead (Pb)	Antimony (Sb)	Selenium (Se)	Silica % (Si)	Tin (Sn)	Zinc (Zn)
6-E	635.0	31.9	78.9	0.71	0.75	25.1	10.10	229.0
6-F	748.0	29.1	60.4	0.68	0.57	24.1	7.74	184.8
6-G	754.0	27.7	54.6	0.60	0.51	24.4	6.54	172.3
6-H	778.0	30.0	49.8	0.50	0.44	25.5	6.31	165.3
6-I	773.0	23.0	33.8	0.31	0.32	28.0	3.57	106.2
7-A	517.0	33.4	89.1	0.56	0.87	24.5	9.59	227.0
7-B	690.0	33.2	80.7	0.59	0.67	24.8	11.00	239.0
7-C	807.0	33.4	71.6	0.49	0.29	24.3	9.20	226.0
8-A	674.0	13.8	34.5	0.13	<0.17	34.3	2.84	65.0
8-B	641.0	38.1	109.4	0.58	0.48	21.7	15.60	212.0
8-C	676.0	38.9	136.2	0.75	0.86	23.0	20.50	240.0
9-A	502.0	36.4	102.5	0.79	0.76	23.7	7.95	240.0
9-B	758.0	31.3	60.3	0.67	0.45	24.9	5.80	187.2
9-C	774.5	36.3	76.5	0.53	0.77	24.2	9.63	247.0
10-A	483.0	23.2	69.0	0.38	0.77	28.3	6.64	154.5
10-B	643.0	36.7	71.2	0.66	0.57	26.0	6.74	198.0
10-C	689.0	24.3	56.1	0.34	0.58	28.8	6.32	156.3
11-A	668.0	35.7	90.2	0.68	0.58	24.0	9.81	245.0
11-B	1371.0	30.7	72.9	0.52	0.58	24.5	9.09	216.0
11-C	723.0	17.5	47.2	0.33	0.29	23.9	5.45	144.3
12-A	588.0	43.1	107.4	0.66	0.86	23.7	15.20	274.0
12-B	689.0	44.9	103.2	0.65	0.77	23.7	14.80	287.0
12-C	810.0	37.5	83.1	0.65	0.67	23.8	13.20	243.0
13-A	280.0	7.1	19.4	< 0.13	0.13	34.8	1.28	24.6
13-B	1138.0	18.9	35.1	0.42	0.25	32.6	4.89	91.9
13-C	853.0	28.7	46.8	1.18	0.38	26.9	6.10	137.4

Appendix Table 4.2 (Con't.). Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Manganese (Mn)	Nickel (Ni)	Lead (Pb)	Antimony (Sb)	Selenium (Se)	Silica % (Si)	Tin (Sn)	Zinc (Zn)
14-A	745.0	22.9	35.1	0.32	0.13	26.6	5.85	115.7
14-B	861.0	30.3	43.1	0.54	0.32	26.2	7.92	145.9
14-C	813.0	21.1	33.7	0.44	0.25	24.0	5.90	115.3
15-A	541.0	13.2	27.1	0.18	<0.11	33.9	3.20	61.4
15-B	876.0	24.9	38.8	0.49	0.32	27.1	5.72	132.3
15-C	935.0	20.6	21.4	0.20	0.13	31.2	2.35	65.6
16-A	713.5	19.3	22.7	0.18	<0.11	33.5	2.56	71.3
16-B	613.0	28.1	32.1	0.52	0.19	29.4	5.13	109.3
16-C	740.0	30.2	32.8	0.27	0.13	29.6	4.59	110.9
17-A	538.0	33.6	41.6	0.39	0.19	30.1	7.56	115.3
17-B	866.0	34.6	64.9	0.82	0.57	23.1	10.90	209.0
17-C	778.0	36.8	68.2	0.97	0.44	24.1	12.50	229.0
17-D	733.0	13.2	24.5	< 0.13	0.13	33.6	2.52	74.6
17-E	731.0	31.6	63.1	0.42	0.32	25.6	9.47	179.3
17-F	1027.0	30.9	58.4	0.33	0.44	24.9	7.70	195.0
17-G	796.0	39.0	80.9	0.58	0.51	23.3	12.20	241.0
17-H	735.0	41.6	88.1	0.80	0.25	23.1	14.30	268.0
17-I	653.0	43.7	131.5	1.24	0.70	22.6	21.00	335.0
18-A	773.0	31.6	57.1	0.35	0.25	29.4	7.99	198.0
18-B	752.0	35.2	71.1	< 0.13	0.26	28.9	12.50	251.0
18-C	636.0	29.5	48.4	0.43	0.32	22.5	7.58	194.0
18-D	719.0	17.5	32.1	< 0.24	0.19	33.5	6.59	113.8
18-E	621.0	13.2	26.3	< 0.13	<0.11	34.5	2.09	87.9
18-F	1185.0	15.0	18.1	< 0.13	<0.11	33.8	1.37	69.2

Appendix Table 4.2 (Con't.). Concentrations of Metallic Elements in LIS Sediments. Aluminum, iron and silica expressed as % dry weight, all others as ug/g dry weight.

Station	Manganese (Mn)	Nickel (Ni)	Lead (Pb)	Antimony (Sb)	Selenium (Se)	Silica % (Si)	Tin (Sn)	Zinc (Zn)
18-G	451.0	9.7	57.2	< 0.13	0.13	35.6	29.70	64.3
18-H	989.0	20.4	37.8	0.18	<0.11	31.7	10.70	147.6
18-I	851.0	17.8	29.7	< 0.13	<0.11	32.0	3.35	115.0
19-A	581.0	47.5	183.7	1.03	1.05	24.0	24.50	313.0
19-B	692.0	43.2	174.6	0.93	0.97	25.2	25.50	282.0
19-C	641.0	44.2	187.4	0.88	0.86	23.3	27.10	291.0
19-D	648.0	46.1	185.1	0.86	0.96	24.7	27.00	298.0
19-E	659.0	42.8	165.0	1.12	0.95	22.9	24.50	272.0
19-F	908.5	40.7	160.3	0.96	0.91	23.7	22.85	265.0
19-G	710.0	39.8	163.7	0.83	0.87	23.4	22.80	253.0
19-H	647.0	41.7	184.4	0.84	1.06	24.0	26.60	276.0
19-I	651.0	44.4	169.1	0.90	0.86	24.6	24.10	310.0
20-A	475.0	44.1	108.1	1.24	0.57	23.1	10.80	182.0
20-B	458.0	42.0	110.0	4.70	0.38	25.4	18.80	219.0
20-C	478.0	46.0	82.5	0.96	0.44	24.4	9.53	157.9
20-D	492.0	42.9	42.2	0.45	0.32	26.5	5.39	121.0
20-E	464.0	31.7	86.8	0.64	0.44	26.2	10.80	135.1
20-F	512.0	38.8	43.8	0.30	0.26	26.0	4.54	113.0
20-G	480.0	26.1	42.1	0.36	0.32	25.6	5.01	103.9
20-H	540.0	15.8	25.7	< 0.13	<0.11	29.8	2.90	67.6
20-I	572.0	16.6	63.6	0.59	0.13	32.7	9.38	85.9
CLIS-A	785.5	33.1	52.1	0.48	0.29	26.5	6.01	147.2
CLIS-B	781.0	35.2	49.5	0.37	0.26	27.8	5.11	141.5
CLIS-C	888.0	30.5	51.5	0.47	0.26	27.3	5.72	148.7

Appendix Table 5. Survey of sediment toxicity in Long Island Sound—acid volatile sulfide (AVS) and simultaneously extracted metal (SEM) in LIS sediment samples. Concentrations on dry weight basis.

Station	Batch #/ Rep#	AVS (uM/g)	SEM (uM/g, except Hg = nM/g)					
			Cadmium (Cd)	Copper (Cu)	Mercury (Hg- nM/g)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
1-A	#1	78.90	0.0120	<0.023	<0.0007	0.111	0.514	2.028
1-C	#1	9.25	0.0148	1.0080	0.0088	0.134	0.705	1.960
1-D	#1	26.73	0.0082	0.2414	0.0012	0.079	0.415	1.342
2-A	#1	61.02	0.0192	<0.030	<0.0009	0.074	0.498	2.194
2-E	#1	51.82	0.0088	0.0409	<0.0005	0.079	0.331	1.503
2-G	#1	35.39	0.0146	0.2592	0.0019	0.095	0.591	2.232
3-A	#1	79.89	0.0108	<0.024	<0.0007	0.116	0.341	1.843
3-C	#1	32.05	0.0131	0.0666	<0.0012	0.135	0.407	2.007
3-F	#1	50.39	0.0100	0.0440	<0.0008	0.097	0.251	1.460
4-A	#1/R1	14.69	0.0080	0.3170	0.0010	0.126	0.303	1.443
4-A	#1/R2	14.69	0.0056	0.0359	<0.0006	0.046	0.133	0.893
4-D	#2/R1	37.97	0.0032	0.0611	<0.0005	0.062	0.174	1.042
4-D	#2/R2	31.07	0.0017	0.0556	<0.0002	0.032	0.081	0.508
4-G	#2	3.71	0.0039	0.4565	0.0020	0.080	0.190	1.195
5-A	#1	100.80	0.0260	0.0539	<0.0011	0.202	0.531	4.129
5-D	#1	39.96	0.0072	0.0307	<0.0004	0.093	0.209	1.922
5-H	#1	16.37	0.0025	0.0560	<0.0003	0.107	0.090	0.640
6-A	#2	59.59	0.0087	0.0534	<0.0007	0.095	0.222	1.874
6-B	#2	21.80	0.0116	0.9755	0.0048	0.119	0.305	2.208
6-F	#3	3.73	0.0025	0.2802	0.0171	0.022	0.224	0.635

Appendix Table 5 (Con't.). Survey of sediment toxicity in Long Island Sound—acid volatile sulfide (AVS) and simultaneously extracted metal (SEM) in LIS sediment samples. Concentrations on dry weight basis.

Station	Batch #/ Rep#	AVS (uM/g)	SEM (uM/g, except Hg = nM/g)					
			Cadmium (Cd)	Copper (Cu)	Mercury (Hg- nM/g)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
7-A	#1	27.41	0.0143	0.6560	0.0019	0.111	0.450	2.361
7-B	#1	18.73	0.0055	0.1856	<0.0005	0.065	0.215	1.034
7-C	#1	40.63	0.0080	0.0388	<0.0008	0.090	0.240	1.406
8-A	#1	2.17	0.0040	0.0653	0.0009	0.013	0.090	0.371
8-B	#1	7.22	0.0154	0.4403	0.0023	0.075	0.463	1.475
8-C	#1	17.12	0.0075	0.2117	0.0028	0.074	0.380	1.194
9-A	#1	65.31	0.0136	<0.021	<0.0006	0.080	0.315	1.754
9-B	#1/R1	17.81	0.0065	0.1228	<0.0008	0.071	0.192	1.215
9-B	#1/R2	17.81	0.0084	0.2188	<0.0006	0.075	0.253	1.662
9-C	#1	29.72	0.0100	0.2496	0.0010	0.118	0.304	2.094
10-A	#2	13.09	0.0029	0.0700	0.0004	0.022	0.103	0.519
10-B	#1	14.95	0.0040	0.1267	0.0014	0.042	0.190	0.749
10-C	#2	4.71	0.0021	0.2818	0.0015	0.063	0.185	0.745
11-A	#2	24.58	<0.0074	<0.039	<0.0011	0.004	<0.001	<0.037
11-B	#2	30.88	0.0094	0.1780	<0.0007	0.102	0.306	0.919
11-C	#1/R1	25.81	0.0039	0.0497	<0.0002	0.035	0.107	0.676
11-C	#1/R2	25.81	0.0073	0.1242	0.0005	0.055	0.170	1.210
12-A	#1	61.84	0.0142	<0.042	0.0020	0.108	0.346	2.152
12-B	#1	46.45	0.0126	0.0608	<0.0011	0.085	0.286	2.018
12-C	#1	62.76	0.0129	0.0954	<0.0008	0.125	0.319	2.174

Appendix Table 5 (Con't.). Survey of sediment toxicity in Long Island Sound—acid volatile sulfide (AVS) and simultaneously extracted metal (SEM) in LIS sediment samples. Concentrations on dry weight basis.

Station	Batch #/ Rep#	AVS (uM/g)	SEM (uM/g, except Hg = nM/g)					
			Cadmium (Cd)	Copper (Cu)	Mercury (Hg- nM/g)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
13-A	#2	5.31	0.0005	0.0164	<0.0002	0.006	0.017	0.083
13-B	#2	3.60	0.0016	0.1756	0.0013	0.038	0.093	0.391
13-C	#2	16.52	0.0016	0.0996	0.0012	0.059	0.149	0.640
14-A	#2	5.63	0.0026	0.1059	0.0010	0.026	0.096	0.469
14-B	#1	6.44	0.0012	0.1233	0.0007	0.038	0.097	0.341
14-C	#1	3.51	0.0023	0.2280	0.0013	0.045	0.143	0.693
15-A	#2	4.18	0.0013	0.0353	<0.0001	0.009	0.030	0.146
15-B	#2	3.88	0.0015	0.1861	0.0011	0.042	0.105	0.529
15-C	#2	1.39	0.0006	0.0881	0.0006	0.027	0.044	0.195
16-A	#1	0.09	0.0013	0.0357	0.0006	0.014	0.028	0.131
16-B	#1	4.01	0.0014	0.0454	0.0003	0.023	0.040	0.222
16-C	#1/R1	6.61	0.0052	0.0448	0.0003	0.043	0.057	0.473
16-C	#1/R2	7.02	0.0029	0.0355	<0.002	0.025	0.044	0.318
17-A	#2	6.94	0.0031	0.1171	<0.0002	0.033	0.065	0.398
17-F	#1	12.48	0.0021	0.2448	0.0010	0.043	0.165	0.990
17-i	#1	83.01	0.0166	0.0471	<0.0011	0.156	0.333	2.152
18-A	#2	0.38	0.0018	0.5608	0.0010	0.055	0.093	0.595
18-B	#1	11.30	0.0029	0.0689	<0.0002	0.063	0.101	0.844
18-D	#2	1.09	0.0010	0.2025	0.0002	0.026	0.051	0.316

Appendix Table 5 (Con't.). Survey of sediment toxicity in Long Island Sound—acid volatile sulfide (AVS) and simultaneously extracted metal (SEM) in LIS sediment samples. Concentrations on dry weight basis.

Station	Batch #/ Rep#	AVS (uM/g)	SEM (uM/g, except Hg = nM/g)					
			Cadmium (Cd)	Copper (Cu)	Mercury (Hg- nM/g)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
19-A	#1	35.05	0.0134	0.2138	0.0028	0.127	0.535	1.921
19-C	#1	16.08	0.0178	0.8066	0.0092	0.157	0.802	2.540
19-F	#1	33.63	0.0086	0.1546	0.0017	0.098	0.420	1.419
20-A	#2	19.99	0.0053	0.4067	0.0047	0.137	0.422	1.392
20-D	#1/R1	0.81	0.0018	0.1207	0.0018	0.074	0.074	0.369
20-D	#1/R2	0.85	0.0029	0.1960	0.0020	0.157	0.119	0.549
20-G	#1	2.06	0.0015	0.1051	0.0016	0.032	0.099	0.402
CLIS-A	#1	1.00	0.0009	0.1690	0.0042	0.067	0.135	0.588
CLIS-B	#1	2.08	0.0013	0.2374	0.0028	0.032	0.168	0.794
CLIS-C	#1	0.96	0.0007	0.1440	0.0031	0.059	0.115	0.486

Appendix Table 6.1. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: polynuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry weight.

Station	Nap	2-M Nap	1-M Nap	biphen	2,6-dMN	Aceny	Acena	TMN	Fluore
1-A	252.74	218.52	111.29	61.46	151.24	437.69	90.39	38.29	104.99
1-C	260.22	215.94	111.48	58.10	143.03	493.80	94.37	41.54	95.24
1-D	387.67	327.97	172.32	87.66	224.77	739.79	143.77	62.50	134.96
2-A	128.68	114.39	51.28	37.31	97.60	147.45	45.55	21.44	68.60
2-E	142.62	126.76	57.09	34.79	83.94	167.97	32.62	18.27	43.73
2-G	183.70	152.75	69.92	41.73	99.45	232.21	43.65	32.04	57.18
3-A	79.48	61.26	30.69	19.12	46.43	114.72	45.93	15.20	62.11
3-C	68.72	54.86	25.35	17.54	43.65	93.45	21.28	8.23	31.28
3-F	92.51	72.66	32.66	22.21	51.26	90.58	25.34	15.42	41.41
4-A	137.96	53.22	26.50	18.48	39.80	116.46	25.73	13.77	49.05
4-D	47.19	25.67	12.94	8.54	16.94	67.18	8.39	5.28	20.06
4-G	41.68	23.65	11.37	7.72	15.45	68.04	6.67	4.19	13.49
5-A	103.80	77.52	39.18	25.86	57.30	187.91	69.72	19.08	97.91
5-D	49.33	35.96	18.04	11.93	27.09	80.38	18.73	6.60	30.58
5-H	18.19	13.33	6.69	4.75	10.22	34.58	5.54	4.68	9.65
6-A	39.72	30.31	17.14	10.19	23.23	97.57	15.32	7.29	24.55
6-B	49.96	34.83	19.16	12.07	31.66	117.18	18.48	12.24	32.52
6-F	10.53	8.23	4.42	2.50	5.94	24.22	2.44	3.11	5.30
7-A	44.38	34.46	16.81	12.53	25.08	56.02	12.90	6.64	23.11
7-B	43.50	34.43	15.90	11.60	23.33	50.18	8.73	4.91	15.61
7-C	50.79	40.48	18.42	12.45	28.55	52.16	9.96	7.23	17.09
8-A	10.52	8.77	5.50	3.27	7.34	13.57	8.25	3.13	12.55
8-B	118.04	100.89	43.80	28.16	65.98	123.93	30.83	17.52	47.27
8-C	176.14	159.76	70.65	46.05	105.93	202.67	41.11	20.79	58.84

Appendix Table 6.1.(Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: poly-nuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry wt.

Station	Nap	2-M Nap	1-M Nap	biphen	2,6-dMN	Aceny	Acena	TMN	Fluore
9-A	41.77	33.24	17.85	11.63	31.61	76.15	17.75	8.13	32.07
9-B	29.98	24.82	12.52	8.52	20.08	25.71	6.00	5.36	12.40
9-C	38.89	32.26	15.54	11.40	26.32	45.04	7.59	5.74	15.95
10-A	24.72	21.10	11.12	8.49	18.46	30.82	13.72	5.01	24.83
10-B	23.12	19.23	9.83	7.33	14.98	30.24	5.81	3.52	10.62
10-C	33.02	28.05	13.28	11.10	22.79	39.09	5.94	4.14	12.48
11-A	52.46	44.52	20.39	14.36	37.36	54.28	10.99	6.71	20.28
11-B	49.16	42.02	19.30	13.33	35.11	32.48	8.91	5.44	17.14
11-C	43.31	33.84	19.35	10.83	25.14	23.52	25.71	6.90	34.90
12-A	71.04	61.47	29.16	20.52	50.45	73.44	20.37	10.16	33.13
12-B	82.03	70.42	33.17	23.12	55.26	99.55	22.56	13.81	37.79
12-C	70.31	57.21	26.30	17.72	47.29	70.76	18.63	10.65	30.85
13-A	3.58	2.50	1.48	1.02	2.27	7.51	0.76	0.69	2.02
13-B	20.02	15.15	8.10	5.42	11.23	44.79	4.55	2.98	8.94
13-C	36.88	26.46	13.72	8.47	18.57	73.26	8.81	6.14	17.01
14-A	21.75	13.05	7.21	4.63	8.75	46.26	3.70	2.73	8.61
14-B	35.19	20.52	10.18	6.77	12.66	36.50	5.34	4.69	12.45
14-C	27.71	16.47	8.11	5.43	11.33	33.59	4.07	3.73	9.79
15-A	10.02	6.18	3.60	2.25	5.02	24.37	4.27	2.79	9.00
15-B	28.92	19.60	10.74	7.00	13.96	48.75	8.53	5.88	16.80
15-C	9.47	6.03	2.98	2.13	4.15	11.70	1.82	2.00	3.77
16-A	15.60	14.66	7.54	4.82	10.42	45.16	11.71	4.36	22.09
16-B	41.21	35.78	19.35	10.82	23.61	85.61	26.72	9.04	43.75
16-C	22.37	21.16	11.03	8.78	17.62	61.61	19.07	7.08	30.68

Appendix Table 6.1. (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: poly-nuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry wt.

Station	Nap	2-M Nap	1-M Nap	biphen	2,6-dMN	Aceny	Acena	TMN	Fluore
17-A	51.27	51.32	33.09	12.13	31.58	45.00	24.33	14.72	35.34
17-F	62.20	47.89	25.61	14.70	32.02	118.07	16.14	12.93	31.84
17-I	303.07	225.96	122.64	84.40	168.02	191.74	241.31	47.12	395.66
18-A	86.02	77.62	43.43	22.94	53.23	216.79	47.77	25.96	81.05
18-B	80.24	65.69	36.26	51.33	53.48	205.24	63.46	25.75	99.98
18-D	35.40	30.05	16.26	8.69	20.22	106.34	14.06	10.34	28.75
19-A	219.29	195.31	85.90	56.34	134.89	229.56	55.63	32.99	88.23
19-C	265.09	230.61	98.63	60.55	137.76	227.83	58.65	33.31	84.16
19-F	411.61	356.59	182.33	95.49	244.17	698.45	147.83	67.89	154.61
20-A	145.15	118.47	66.60	41.44	84.26	247.68	53.65	28.04	105.23
20-D	43.02	30.86	15.31	13.37	26.58	66.49	11.06	9.20	24.60
20-G	39.53	29.22	16.64	11.01	24.21	102.62	11.88	8.10	25.36
CLIS-A	37.15	22.44	11.55	6.96	13.60	67.39	6.43	4.47	12.67
CLIS-B	36.41	23.55	12.31	8.12	15.31	57.27	6.40	5.16	14.54
CLIS-C	34.93	22.71	11.21	7.69	15.03	52.63	6.22	4.88	13.25

Compounds listed are: naphthalene; 2-methyl naphthalene; 1-methyl naphthalene; biphenyl; 2,6-di-methyl naphthalene, acenaphthylene; acenaphthene; 2,3,5-trimethylnaphthalene; and fluorene. Appendix Table 6.2. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: polynuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry weight.

Station	phe	anthr	1-M phe	fluor	pyr	b[a]anth	chry	b[b]fluor	b[k]fluor
1-A	696.90	415.69	160.95	1430.51	1472.92	843.49	890.31	1319.58	833.85
1-C	603.25	451.15	180.78	1110.09	1394.16	985.92	903.39	1187.62	762.66
1-D	835.05	691.28	254.21	1493.30	1744.99	1350.01	1184.41	1709.48	958.94
2-A	482.77	204.21	70.88	1300.52	1138.26	571.45	704.23	916.09	670.81
2-E	290.01	159.41	62.24	636.32	689.32	416.03	469.73	520.52	359.75
2-G	386.84	225.23	96.50	816.99	934.51	591.94	635.45	753.71	421.87
3-A	615.09	186.01	76.23	1468.65	1269.34	716.25	777.41	960.76	605.85
3-C	264.86	96.14	43.17	616.01	580.21	316.03	371.65	398.29	283.61
3-F	343.51	117.23	61.28	842.90	806.85	437.70	530.57	580.22	358.61
4-A	332.00	122.47	44.39	924.08	785.72	420.82	516.81	670.99	374.32
4-D	183.94	56.61	28.35	446.98	425.45	215.59	256.80	306.81	197.08
4-G	121.75	45.45	22.08	284.98	289.06	148.27	190.69	232.56	149.81
5-A	852.45	236.16	87.57	1744.31	1353.48	709.60	679.24	1522.75	848.99
5-D	249.29	78.69	38.11	548.83	492.66	251.29	321.36	332.28	315.84
5-H	106.64	28.22	17.78	269.73	255.41	131.74	158.50	161.15	120.18
6-A	245.65	66.58	41.95	607.23	555.80	270.10	361.46	413.52	308.19
6-B	262.67	85.13	53.00	650.20	579.55	278.25	379.03	436.68	260.18
6-F	54.70	16.85	18.49	145.25	157.53	83.31	103.17	77.45	64.74
7-A	182.60	58.62	29.00	431.80	402.08	195.16	241.30	252.15	188.85
7-B	121.15	41.87	22.46	280.94	271.18	128.31	183.42	193.25	157.41
7-C	137.24	46.62	26.45	320.91	321.56	162.65	218.12	210.62	144.87
8-A	99.05	25.14	17.95	183.98	183.41	94.94	105.82	72.01	61.64
8-B	317.89	153.65	66.01	780.69	820.19	474.75	549.48	535.95	408.55
8-C	371.34	212.22	92.25	833.76	1002.13	572.43	662.75	618.83	516.11

Appendix Table 6.2 (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: poly-nuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry wt.

Station	phe	anthr	1-M phe	fluor	pyr	b[a]anth	chry	b[b]fluor	b[k]fluor
9-A	387.33	90.39	57.71	1156.26	957.41	492.23	672.32	578.40	449.09
9-B	106.62	26.81	22.18	285.19	270.19	127.54	179.11	156.21	125.87
9-C	133.57	39.00	23.49	353.48	329.42	155.65	218.65	209.54	148.94
10-A	233.45	61.40	30.43	703.48	568.27	303.31	386.96	312.20	217.38
10-B	97.41	26.14	16.22	305.92	286.40	129.20	185.75	159.06	110.38
10-C	105.59	28.96	19.43	293.80	273.66	127.57	178.14	150.08	114.23
11-A	148.76	49.70	26.15	389.86	366.03	178.59	250.21	217.06	181.81
11-B	137.84	39.62	24.68	337.39	324.47	161.53	228.64	198.83	148.29
11-C	269.36	76.70	30.85	418.66	381.78	204.90	240.41	180.75	135.82
12-A	298.88	83.91	48.96	784.64	727.89	384.95	492.28	440.85	315.83
12-B	339.06	105.33	55.52	867.81	833.77	437.67	549.74	449.53	379.56
12-C	261.77	79.58	47.54	641.25	626.82	335.00	437.21	394.03	285.95
13-A	26.03	5.27	4.74	61.37	55.74	26.07	36.87	27.08	21.81
13-B	106.95	27.65	21.00	260.95	263.95	137.29	176.89	131.71	108.34
13-C	207.88	56.38	41.09	504.20	508.58	273.29	340.09	283.80	198.02
14-A	105.05	26.47	18.79	285.55	266.70	138.61	174.03	141.20	99.48
14-B	124.82	30.17	22.10	301.84	288.53	140.05	183.41	191.09	158.48
14-C	100.90	24.90	18.71	247.22	239.24	121.63	157.31	145.67	123.40
15-A	120.32	28.29	17.28	298.68	264.34	137.83	172.19	133.95	104.94
15-B	194.59	44.47	32.32	454.71	419.88	216.87	271.21	211.15	191.98
15-C	41.75	9.81	7.54	98.21	94.27	44.62	61.57	60.54	43.84
16-A	187.82	56.26	36.10	435.36	411.30	279.37	330.57	188.74	170.77
16-B	409.22	102.20	65.67	729.21	696.65	416.05	472.44	379.40	306.47
16-C	234.51	57.78	35.14	552.67	504.65	281.22	309.27	279.71	218.74

Appendix Table 6.2 (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: poly-nuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry wt.

Station	phe	anthr	1-M phe	fluor	pyr	b[a]anth	chry	b[b]fluor	b[k]fluor
17-A	325.59	88.26	48.20	652.36	609.49	321.30	379.98	298.46	245.15
17-F	339.64	94.79	75.08	763.75	793.92	443.21	544.39	465.25	355.27
17-I	1917.94	544.38	204.53	4059.05	3031.10	1559.90	1980.34	1416.93	1026.53
18-A	842.09	247.26	173.11	1730.37	1652.30	911.25	1067.24	990.44	613.07
18-B	797.73	229.11	112.83	1825.16	1592.69	789.81	996.70	947.92	710.50
18-D	357.29	90.52	65.22	820.08	791.11	455.98	540.06	422.34	294.87
19-A	555.53	296.21	115.56	1295.00	1314.38	761.11	911.85	860.71	722.08
19-C	529.55	281.52	120.96	1067.58	1280.21	681.24	783.78	851.53	737.43
19-F	1057.93	720.78	362.63	2078.38	2726.90	1917.88	1835.84	1633.64	1360.18
20-A	904.65	302.76	121.59	2427.17	2181.29	1158.17	1506.18	1349.58	966.67
20-D	195.44	58.57	32.39	457.38	437.71	214.89	271.57	249.02	166.61
20-G	274.16	70.37	48.59	622.77	600.52	324.49	391.07	321.99	272.01
CLIS-A	128.46	37.28	26.81	306.72	311.36	167.11	201.80	198.70	137.67
CLIS-B	146.85	35.51	28.85	352.72	355.97	173.66	235.13	215.62	173.08
CLIS-C	137.87	34.23	26.87	330.17	338.22	169.83	224.27	211.61	159.45

Compounds listed are: phenanthrene; anthracene; 1-methyl phenanthrene; fluoranthene; pyrene; benz[a]anthracene; chrysene; benzo[b]fluoranthene; and benzo[k]fluoranthene.

Appendix Table 6.3. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: polynuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry weight.

Station	b[e]pyr	b[a]pyr	pery	indeno-pyr	db[a,h]anth	b[g,h,i]per	tPAH
1-A	871.71	1310.79	304.47	1043.15	170.19	796.41	3700.31
1-C	834.80	1377.11	288.43	1002.94	196.02	735.27	3699.30
1-D	1140.31	1794.83	394.72	1359.83	274.02	993.37	4963.71
2-A	609.20	783.09	234.45	791.50	117.03	595.15	2535.27
2-E	365.78	501.18	127.81	445.40	68.13	343.08	1508.30
2-G	487.24	695.55	165.24	619.91	118.02	455.21	2085.96
3-A	577.23	766.46	207.26	740.44	105.17	514.44	2396.56
3-C	273.23	349.94	100.28	334.12	45.84	214.55	1103.41
3-F	371.19	466.34	119.93	462.37	68.33	375.86	1488.16
4-A	382.58	451.10	144.48	500.82	68.18	390.91	1547.16
4-D	196.32	240.18	74.20	258.09	35.73	202.27	804.52
4-G	152.78	188.99	55.39	186.48	25.76	128.57	609.40
5-A	900.88	1101.70	303.41	1047.16	234.76	861.60	3587.91
5-D	264.31	315.26	84.43	307.99	41.42	270.74	1013.41
5-H	111.88	138.04	40.31	121.22	18.44	111.51	429.89
6-A	275.22	317.27	93.00	298.22	42.78	270.70	1026.49
6-B	275.98	334.09	101.72	286.38	44.51	251.03	1042.68
6-F	60.86	78.44	25.03	61.30	10.69	58.60	236.32
7-A	179.43	213.57	66.19	194.29	26.81	183.45	680.29
7-B	146.71	169.45	49.94	155.02	21.67	141.52	542.79
7-C	151.34	184.53	54.11	170.10	26.78	166.63	586.86
8-A	53.99	70.77	17.69	50.85	9.49	48.52	202.79
8-B	406.33	535.62	144.50	420.65	75.22	404.80	1582.32
8-C	495.30	665.48	195.90	532.50	98.08	513.47	1987.26

Appendix Table 6.3 (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: poly-nuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry wt.

Station	b[e]pyr	b[a]pyr	pery	indeno-pyr	db[a,h]anth	b[g,h,i]per	tPAH
9-A	392.42	470.69	131.89	414.36	62.17	388.23	1471.53
9-B	117.34	136.09	48.08	133.01	20.63	130.03	455.15
9-C	146.37	167.40	58.43	171.50	24.91	167.84	568.61
10-A	200.00	239.46	120.56	200.33	30.51	189.65	790.86
10-B	108.81	122.52	38.17	117.19	17.35	113.20	404.04
10-C	112.42	124.87	47.23	128.22	18.85	125.98	431.59
11-A	165.39	193.18	57.92	184.54	29.15	184.21	630.18
11-B	144.30	173.04	50.43	163.56	25.89	161.33	557.22
11-C	129.05	170.32	47.97	138.10	22.45	133.24	507.89
12-A	315.11	379.99	110.01	337.49	50.62	333.49	1193.22
12-B	339.72	410.65	124.39	364.96	57.69	357.89	1297.41
12-C	287.80	361.75	109.39	312.38	47.62	305.92	1118.94
13-A	21.61	24.66	6.33	19.44	3.14	19.74	75.18
13-B	103.11	125.77	33.78	102.83	16.92	103.09	382.41
13-C	201.96	255.40	69.23	211.03	34.51	205.87	772.13
14-A	96.03	118.03	39.10	103.54	16.63	97.01	373.33
14-B	143.38	172.13	62.02	164.46	24.61	151.10	566.60
14-C	112.73	136.70	47.59	126.82	19.07	119.83	442.91
15-A	93.90	122.01	34.08	100.35	15.82	92.53	366.16
15-B	171.33	216.37	64.00	189.47	30.03	175.12	671.20
15-C	43.67	51.78	18.06	48.43	7.75	46.59	169.69
16-A	141.49	210.73	69.19	146.05	24.44	127.33	591.90
16-B	278.38	398.95	185.53	288.04	47.69	254.99	1198.59
16-C	202.57	271.63	202.16	221.15	34.11	197.36	931.62

Appendix Table 6.3 (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: poly-nuclear aromatic hydrocarbons (PAH). Concentrations expressed as ng/g dry wt.

Station	b[e]pyr	b[a]pyr	pery	indeno-pyr	db[a,h]anth	b[g,h,i]per	tPAH
17-A	217.06	281.97	87.20	222.76	35.46	207.36	844.45
17-F	349.74	463.78	132.21	376.96	66.85	353.28	1389.54
17-I	981.69	1204.63	363.06	988.69	150.64	893.23	3688.71
18-A	633.54	867.63	269.74	705.38	106.63	594.19	2582.92
18-B	658.56	876.70	275.77	793.58	122.22	636.48	2726.83
18-D	295.46	405.39	111.30	305.71	52.27	259.54	1170.13
19-A	688.29	933.51	250.41	744.85	129.12	660.34	2746.18
19-C	683.89	936.66	254.94	740.87	129.00	660.08	2745.36
19-F	1368.70	2261.83	512.90	1415.35	291.11	1233.64	5849.89
20-A	904.89	1107.82	367.10	920.82	146.69	775.33	3447.32
20-D	165.88	195.46	111.72	167.29	28.04	149.64	668.39
20-G	238.73	317.52	103.21	239.64	42.57	202.83	941.67
CLIS-A	134.63	175.11	50.95	173.88	27.08	130.58	561.65
CLIS-B	163.81	198.22	70.09	184.07	27.68	178.49	643.87
CLIS-C	155.20	190.10	65.79	176.83	26.90	154.48	614.82

Compounds listed are: benz[e]pyrene; benz[a]pyrene; perylene; indeno-pyrene; dibenzo[a,h]-anthracene; benzo[g,h,i]perylene; and total PAH.

Appendix Table 7.1. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Chlorinated Pesticides. Concentrations expressed in ng/g dry weight.

Station	HCB	Lindane	Hptchlr	Aldrin	Hptchlrepox	a-Chlor	t-nonachlor	Dieldrin	Endrin
1-A	ND	ND	ND	ND	ND	11.266	10.291	5.067	ND
1-C	ND	ND	ND	ND	ND	2.791	5.270	4.406	ND
1-D	ND	ND	ND	ND	ND	3.282	5.728	5.071	ND
2-A	ND	ND	ND	ND	ND	24.356	18.310	8.164	ND
2-E	ND	ND	ND	ND	ND	3.346	3.937	3.444	ND
2-G	ND	ND	ND	ND	ND	2.713	3.244	3.191	ND
3-A	ND	ND	ND	ND	ND	5.830	6.114	2.649	ND
3-C	ND	ND	ND	ND	ND	3.007	3.259	3.548	ND
3-F	ND	ND	ND	ND	ND	2.964	4.143	2.423	ND
4-A	ND	ND	ND	ND	ND	2.937	2.233	3.029	3.570
4-D	ND	ND	ND	ND	ND	0.724	1.819	1.410	0.728
4-G	0.285	ND	ND	ND	ND	0.790	2.756	1.115	ND
5-A	ND	ND	ND	ND	ND	10.486	11.701	4.322	ND
5-D	ND	ND	ND	ND	ND	1.056	1.714	1.410	ND
5-H	ND	ND	ND	ND	ND	0.362	0.389	ND	ND
6-A	ND	ND	ND	ND	ND	0.634	2.355	16.081	ND
6-B	ND	ND	ND	ND	ND	0.450	1.979	4.338	ND
6-F	ND	ND	ND	ND	ND	0.072	0.325	0.467	ND
7-A	ND	ND	ND	ND	ND	1.345	1.748	1.867	ND
7-B	ND	ND	ND	ND	ND	0.887	1.360	1.669	ND
7-C	15.451	0.969	0.632	ND	ND	1.616	0.987	1.181	ND
8-A	0.718	0.272	0.711	ND	ND	0.110	0.367	0.453	ND
8-B	0.537	0.998	1.111	ND	ND	3.398	3.215	2.432	ND
8-C	33.058	1.071	1.578	ND	ND	1.793	2.443	2.360	ND

Appendix Table 7.1 (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Chlorinated Pesticides. Concentrations expressed in ng/g dry weight.

Station	HCB	Lindane	Hptchlr	Aldrin	Hptchlrepox	a-Chlor	t-nonachlor	Dieldrin	Endrin
9-A	153.134	ND	ND	ND	0.726	2.299	2.732	2.010	ND
9-B	24.543	ND	0.414	ND	ND	0.764	0.965	0.928	ND
9-C	90.105	ND	0.533	ND	ND	ND	0.988	0.980	ND
10-A	23.007	ND	0.482	ND	ND	1.339	1.083	1.233	ND
10-B	27.520	ND	ND	ND	ND	ND	0.304	1.079	ND
10-C	14.606	ND	0.387	ND	ND	0.489	0.807	0.854	ND
11-A	50.132	ND	0.432	ND	ND	1.373	0.970	1.480	ND
11-B	22.304	ND	ND	ND	ND	0.991	0.644	1.016	ND
11-C	ND	ND	ND	ND	ND	0.906	0.527	0.665	ND
12-A	209.248	ND	ND	ND	ND	2.552	1.950	1.345	ND
12-B	93.740	1.374	ND	ND	ND	2.670	2.175	1.631	ND
12-C	105.140	1.097	ND	ND	ND	2.130	1.465	1.403	ND
13-A	4.347	ND	3.877	ND	ND	ND	0.098	0.669	ND
13-B	5.472	ND	0.794	ND	ND	0.024	0.430	1.202	ND
13-C	11.149	ND	0.488	ND	ND	0.055	0.807	0.904	ND
14-A	0.124	ND	0.591	ND	ND	ND	0.525	0.750	ND
14-B	ND	0.524	0.073	ND	ND	0.395	0.500	2.550	ND
14-C	ND	0.427	0.040	ND	ND	0.233	0.612	2.201	ND
15-A	0.106	ND	0.315	ND	ND	0.204	0.511	1.458	ND
15-B	0.283	0.504	0.184	ND	ND	0.249	0.743	3.093	ND
15-C	ND	ND	0.187	ND	ND	0.372	0.072	0.947	ND
16-A	ND	ND	ND	ND	ND	0.314	0.136	0.535	ND
16-B	ND	ND	ND	ND	ND	0.754	0.404	2.061	ND
16-C	ND	ND	ND	ND	ND	0.528	0.289	0.972	ND

Appendix Table 7.1 (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Chlorinated Pesticides. Concentrations expressed in ng/g dry weight.

Station	HCB	Lindane	Hptchlr	Aldrin	Hptchlrepox	a-Chlor	t-nonachlor	Dieldrin	Endrin
17-A	ND	ND	ND	ND	ND	0.446	0.187	0.641	ND
17-F	ND	ND	ND	ND	ND	0.772	ND	2.096	ND
17-I	ND	ND	ND	ND	0.817	1.200	ND	1.854	ND
18-A	ND	ND	ND	ND	ND	10.942	4.391	4.034	ND
18-B	ND	ND	ND	ND	ND	2.468	ND	ND	ND
18-D	ND	ND	ND	ND	ND	1.182	ND	1.660	ND
19-A	ND	ND	ND	ND	ND	5.111	4.151	10.808	ND
19-C	ND	ND	ND	ND	ND	3.632	ND	6.250	ND
19-F	ND	ND	ND	ND	ND	2.809	4.221	3.433	ND
20-A	ND	ND	ND	ND	ND	2.370	ND	6.144	ND
20-D	ND	ND	ND	ND	ND	1.119	ND	1.593	ND
20-G	ND	ND	ND	ND	ND	1.199	ND	2.007	ND
CLIS-A	0.927	ND	0.050	ND	ND	0.270	1.787	1.694	ND
CLIS-B	5.300	0.650	0.260	5.417	ND	0.114	0.701	1.106	ND
CLIS-C	ND	0.672	0.200	ND	ND	0.360	0.599	2.235	ND

Appendix Table 7.2. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Chlorinated Pesticides. Concentrations expressed in ng/g dry weight.

Station	Mirex	tPest	OPDDE	PPDDE	OPDDD	PPDDD	OPDDT	PPDDT	Sum DDT
1-A	ND	0.000	5.023	16.085	1.595	16.315	ND	4.489	43.507
1-C	ND	0.000	ND	9.874	1.005	10.036	ND	2.906	23.821
1-D	ND	0.000	ND	11.425	0.899	11.639	ND	2.146	26.109
2-A	ND	0.000	ND	30.923	2.638	29.582	ND	ND	63.143
2-E	ND	0.000	ND	8.289	0.680	8.039	ND	ND	17.008
2-G	ND	0.000	ND	6.832	0.108	6.807	ND	ND	13.747
3-A	ND	0.000	ND	10.256	0.267	11.698	ND	3.245	25.466
3-C	ND	0.000	0.664	8.792	ND	5.396	ND	2.319	17.171
3-F	ND	0.000	ND	11.947	ND	8.613	ND	ND	20.560
4-A	ND	0.000	3.606	11.651	ND	4.782	15.251	34.035	69.325
4-D	ND	0.000	ND	5.363	ND	1.393	2.589	ND	9.345
4-G	ND	0.000	0.019	5.088	ND	1.261	ND	6.369	12.737
5-A	ND	0.000	ND	19.021	2.119	16.519	ND	2.062	39.721
5-D	ND	0.000	ND	5.385	ND	3.001	ND	0.888	9.274
5-H	ND	0.000	ND	2.163	ND	1.145	0.063	ND	3.371
6-A	ND	0.000	ND	4.361	ND	2.101	ND	0.814	7.276
6-B	ND	0.000	ND	5.847	0.009	3.062	ND	0.657	9.575
6-F	ND	0.000	ND	1.235	ND	ND	ND	0.302	1.537
7-A	ND	0.000	0.488	4.427	ND	2.502	ND	1.811	9.228
7-B	ND	0.000	ND	4.769	ND	2.170	ND	1.251	8.190
7-C	ND	0.000	ND	3.737	0.227	2.908	ND	0.996	7.868
8-A	3.239	3.239	ND	1.105	0.024	1.076	ND	ND	2.205
8-B	26.980	26.980	ND	11.144	1.693	12.112	ND	1.277	26.226
8-C	1.707	1.707	ND	6.228	0.678	6.159	ND	2.250	15.315

Appendix Table 7.2. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Chlorinated Pesticides. Concentrations expressed in ng/g dry weight.

Station	Mirex	tPest	OPDDE	PPDDE	OPDDD	PPDDD	OPDDT	PPDDT	Sum DDT
9-A	ND	0.000	0.771	5.006	0.421	7.111	ND	1.436	14.745
9-B	ND	0.000	0.547	2.690	ND	2.249	ND	0.939	6.425
9-C	ND	0.000	0.836	2.849	ND	2.548	ND	0.732	6.965
10-A	ND	0.000	0.587	3.611	0.407	5.542	ND	ND	10.147
10-B	ND	0.000	0.492	2.599	ND	1.872	ND	ND	4.963
10-C	ND	0.000	0.624	2.692	ND	2.264	ND	0.810	6.390
11-A	ND	0.000	0.889	4.220	0.042	3.033	ND	1.195	9.379
11-B	ND	0.000	0.870	2.619	ND	2.130	ND	ND	5.619
11-C	ND	0.000	0.371	2.539	0.022	2.005	ND	ND	4.937
12-A	ND	0.000	1.849	4.895	ND	4.567	ND	ND	11.311
12-B	ND	0.000	1.226	5.439	0.293	5.204	ND	2.105	14.267
12-C	ND	0.000	1.251	4.521	0.113	3.869	ND	0.967	10.721
13-A	ND	0.000	0.130	0.406	ND	0.369	ND	ND	0.905
13-B	ND	0.000	0.180	1.392	ND	0.802	ND	0.282	2.656
13-C	ND	0.000	ND	2.232	0.212	1.758	ND	0.959	5.161
14-A	ND	0.000	ND	1.602	0.096	0.988	ND	0.901	3.587
14-B	ND	0.000	ND	2.455	0.246	2.151	ND	1.581	6.433
14-C	ND	0.000	ND	2.170	0.141	2.096	ND	0.834	5.241
15-A	ND	0.000	0.197	1.702	0.071	1.623	ND	0.542	4.135
15-B	ND	0.000	ND	2.746	0.181	2.521	ND	1.826	7.274
15-C	ND	0.000	0.206	0.989	ND	ND	ND	ND	1.195
16-A	ND	0.000	ND	1.967	0.953	0.397	ND	0.222	3.539
16-B	ND	0.000	ND	4.286	1.502	0.982	ND	0.782	7.552
16-C	ND	0.000	ND	3.010	0.663	1.197	ND	ND	4.870

Appendix Table 7.2. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Chlorinated Pesticides. Concentrations expressed in ng/g dry weight.

Station	Mirex	tPest	OPDDE	PPDDE	OPDDD	PPDDD	OPDDT	PPDDT	Sum DDT
17-A	ND	0.000	ND	2.210	0.894	8.651	1.100	73.463	86.318
17-F	ND	0.000	ND	4.912	2.346	1.521	1.236	0.584	10.599
17-I	ND	0.000	ND	6.032	3.417	2.051	0.537	ND	12.037
18-A	3.092	3.092	ND	11.609	5.647	6.080	2.582	ND	25.918
18-B	ND	0.000	ND	10.044	4.661	9.030	2.917	ND	26.652
18-D	ND	0.000	ND	5.821	2.944	2.173	ND	ND	10.938
19-A	ND	0.000	ND	22.305	3.078	12.484	ND	ND	37.867
19-C	ND	0.000	2.939	14.478	2.684	10.582	ND	ND	30.683
19-F	ND	0.000	ND	16.193	4.184	12.368	ND	ND	32.745
20-A	ND	0.000	ND	12.496	4.543	4.827	ND	ND	21.866
20-D	ND	0.000	ND	3.204	1.138	1.419	ND	ND	5.761
20-G	ND	0.000	ND	4.569	1.374	2.588	ND	ND	8.531
CLIS-A	ND	0.000	ND	4.188	ND	ND	ND	2.568	6.756
CLIS-B	ND	0.000	ND	2.500	0.001	1.252	ND	1.278	5.031
CLIS-C	ND	0.000	ND	2.669	0.137	2.396	ND	0.944	6.146

Appendix Table 8.1. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Polychlorinated Biphenyls (PCBs). Concentrations expressed in ng/g dry weight.

Station	2(08)	3(18)	3(28)	4(44)	4(52)	4(66)	5(101)	4(77)	5(118)	6(153)	5(105)
1-A	5.646	2.418	8.781	2.321	7.613	8.558	14.889	ND	10.660	18.079	2.732
1-C	5.922	2.075	5.300	2.726	4.645	8.012	11.735	ND	6.756	13.047	2.115
1-D	9.630	3.927	14.335	4.712	8.393	9.613	13.480	ND	8.386	16.501	2.215
2-A	ND	1.634	6.126	5.386	9.824	8.681	33.749	ND	27.724	35.375	9.286
2-E	ND	0.435	4.869	1.854	3.492	5.630	11.898	ND	7.357	11.581	1.658
2-G	ND	ND	4.317	2.278	6.949	4.779	10.217	ND	6.904	10.760	1.612
3-A	ND	ND	0.412	0.366	3.934	2.573	17.056	ND	9.882	16.053	2.037
3-C	ND	0.095	0.394	0.797	1.708	3.322	9.635	ND	5.963	8.473	0.395
3-F	ND	ND	0.783	0.650	2.606	4.750	11.788	ND	8.281	15.163	1.251
4-A	ND	ND	2.703	3.492	4.708	7.271	11.871	ND	7.283	13.781	1.538
4-D	ND	ND	0.761	0.722	1.054	3.076	5.577	ND	3.250	5.253	0.012
4-G	ND	ND	0.270	0.537	ND	2.461	6.090	ND	2.716	5.054	0.185
5-A	ND	ND	ND	ND	5.115	5.210	23.526	ND	15.862	28.928	3.782
5-D	ND	ND	ND	ND	1.061	1.923	6.737	ND	4.269	6.454	0.387
5-H	ND	ND	ND	0.760	2.959	1.971	6.655	ND	4.633	6.821	1.251
6-A	ND	5.539	0.331	ND	1.060	2.619	7.295	ND	2.913	4.392	0.250
6-B	ND	ND	ND	0.126	0.398	2.186	8.124	ND	2.809	5.257	0.181
6-F	ND	ND	ND	ND	ND	0.291	1.637	ND	0.253	1.208	ND
7-A	ND	ND	ND	ND	ND	0.451	5.491	ND	1.208	2.271	ND
7-B	ND	ND	ND	ND	ND	1.243	5.111	ND	2.065	4.134	0.113
7-C	7.045	0.247	1.112	0.588	1.629	1.945	3.817	2.607	2.865	7.326	0.603
8-A	0.443	0.052	0.485	0.317	0.759	0.735	1.065	ND	0.647	2.295	0.195
8-B	3.215	2.591	7.746	4.469	9.682	7.477	10.580	ND	8.371	13.432	ND
8-C	6.235	2.160	10.159	2.023	8.533	5.008	7.650	ND	5.972	11.456	1.732

Appendix Table 8.1 (Con't). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Polychlorinated Biphenyls (PCBs). Concentrations expressed in ng/g dry weight.

Station	2(08)	3(18)	3(28)	4(44)	4(52)	4(66)	5(101)	4(77)	5(118)	6(153)	5(105)
9-A	13.923	ND	ND	ND	1.681	0.324	3.387	ND	1.284	7.262	ND
9-B	5.094	ND	0.446	ND	0.435	1.415	3.435	ND	1.691	5.271	0.179
9-C	9.061	ND	ND	ND	ND	1.265	2.192	ND	1.513	7.066	ND
10-A	4.828	ND	ND	ND	0.378	1.504	2.595	ND	1.462	5.087	0.569
10-B	3.912	ND	ND	ND	ND	0.511	1.480	ND	0.577	4.400	ND
10-C	4.335	ND	ND	ND	0.324	1.225	3.752	ND	1.489	5.316	0.205
11-A	7.699	ND	0.773	0.350	0.664	1.595	3.564	ND	2.854	7.831	0.604
11-B	8.167	ND	0.322	ND	0.387	1.050	2.764	ND	2.282	6.048	0.570
11-C	2.274	ND	0.159	ND	0.051	1.458	2.191	ND	1.627	4.959	0.258
12-A	16.650	ND	3.469	0.440	4.777	1.112	4.860	ND	3.916	10.087	0.620
12-B	9.568	0.071	2.773	0.306	1.338	2.271	5.448	ND	4.101	9.120	0.902
12-C	12.464	ND	2.503	0.518	1.784	2.669	6.275	ND	5.504	10.130	1.509
13-A	0.504	ND	ND	0.116	0.820	0.188	1.276	ND	0.824	2.225	0.171
13-B	2.648	ND	0.312	0.059	0.406	0.525	1.661	ND	0.453	2.936	ND
13-C	3.775	ND	0.878	0.230	1.157	1.198	2.715	ND	1.077	4.671	0.211
14-A	0.767	0.148	0.142	ND	0.290	0.692	1.448	ND	0.693	2.745	0.010
14-B	4.403	1.013	0.938	0.117	0.111	1.558	3.277	ND	1.145	3.411	0.281
14-C	3.308	0.907	1.134	ND	ND	0.696	2.863	ND	0.698	2.843	0.578
15-A	0.928	ND	0.110	0.087	0.119	0.299	2.405	ND	0.488	1.906	0.219
15-B	2.606	1.268	0.575	0.059	ND	1.258	3.456	ND	1.214	3.404	0.348
15-C	0.954	0.831	0.088	ND	0.197	0.190	0.652	ND	0.187	0.438	0.015
16-A	1.184	0.535	0.847	0.175	0.905	0.871	1.787	ND	0.221	0.816	0.124
16-B	2.444	0.738	1.632	0.989	1.540	2.575	5.242	ND	1.523	3.215	0.449
16-C	2.774	3.976	7.860	3.647	6.449	6.406	5.105	ND	2.630	4.678	0.777

Appendix Table 8.1. (Con't). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Poly-chlorinated Biphenyls (PCBs). Concentrations expressed in ng/g dry weight.

Station	2(08)	3(18)	3(28)	4(44)	4(52)	4(66)	5(101)	4(77)	5(118)	6(153)	5(105)
17-A	ND	6.059	10.747	3.623	7.217	6.548	5.202	ND	3.670	3.646	1.232
17-F	ND	ND	0.987	1.365	2.982	3.152	5.894	ND	2.571	4.142	0.612
17-I	ND	6.535	13.817	5.800	18.376	13.165	12.834	ND	8.101	15.389	1.729
18-A	ND	ND	1.150	2.419	3.381	4.891	18.376	ND	2.466	9.623	1.041
18-B	9.189	8.210	7.526	13.757	18.501	24.729	26.017	ND	10.201	30.807	3.856
18-D	ND	ND	1.007	0.995	1.342	1.806	7.497	ND	1.177	3.621	0.598
19-A	ND	3.824	8.289	6.578	9.124	21.838	29.718	ND	17.184	31.179	5.633
19-C	ND	2.939	8.323	5.326	7.119	22.872	25.692	ND	12.915	28.404	3.954
19-F	ND	2.553	6.567	5.184	7.119	23.702	20.962	ND	10.045	24.522	3.036
20-A	14.419	6.705	9.367	8.798	17.152	23.285	27.316	ND	12.816	21.767	3.291
20-D	9.201	4.777	8.605	4.629	5.310	10.886	7.054	ND	3.767	4.381	1.221
20-G	5.523	0.937	3.522	3.307	5.849	8.947	11.688	ND	6.503	10.040	1.330
CLIS-A	1.632	ND	0.458	1.631	ND	1.788	4.791	ND	1.527	2.682	ND
CLIS-B	3.760	0.320	1.002	0.386	0.654	1.374	2.218	ND	1.151	5.312	0.027
CLIS-C	ND	0.009	1.458	ND	0.235	1.758	3.910	ND	1.342	4.080	0.324

Appendix Table 8.2. Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Polychlorinated Biphenyls (PCBs). Concentrations expressed in ng/g dry weight.

Station	6(138)	5(126)	7(187)	6(128)	7(180)	7(170)	8(195)	9(206)	10(209)	Sum PCB
1-A	14.675	ND	4.134	ND	7.982	2.415	0.507	0.651	ND	30.364
1-C	11.411	ND	3.091	ND	5.984	1.666	0.241	ND	2.541	24.934
1-D	12.752	9.306	3.618	13.955	7.994	2.217	0.268	2.125	ND	52.235
2-A	29.511	ND	3.831	ND	7.365	3.722	ND	ND	ND	44.429
2-E	10.967	ND	2.207	ND	4.795	1.893	ND	ND	ND	19.862
2-G	7.837	ND	2.089	ND	4.404	1.674	ND	ND	ND	16.004
3-A	12.958	ND	1.736	ND	4.229	2.732	ND	ND	ND	21.655
3-C	6.932	ND	1.401	7.243	2.665	0.524	ND	ND	ND	18.765
3-F	11.732	ND	3.254	3.242	3.984	2.005	ND	ND	ND	24.217
4-A	10.008	ND	4.105	ND	5.004	3.187	ND	ND	ND	22.304
4-D	4.060	ND	1.287	ND	2.036	1.276	ND	ND	ND	8.659
4-G	3.189	1.229	2.272	0.102	1.715	ND	ND	ND	ND	8.507
5-A	23.092	ND	6.425	6.088	12.558	8.348	ND	ND	ND	56.511
5-D	4.364	ND	0.794	2.635	2.348	ND	ND	ND	ND	10.141
5-H	6.093	ND	0.172	0.903	1.042	0.729	ND	ND	ND	8.939
6-A	2.956	ND	0.487	0.843	0.750	1.177	ND	ND	ND	6.213
6-B	3.656	ND	0.852	ND	1.117	1.118	ND	ND	ND	6.743
6-F	0.546	ND	ND	ND	ND	ND	ND	ND	ND	0.546
7-A	1.473	ND	ND	ND	ND	ND	ND	ND	ND	1.473
7-B	0.852	ND	ND	ND	0.140	ND	ND	ND	ND	0.992
7-C	3.937	ND	1.355	3.923	1.514	6.494	0.016	ND	ND	17.239
8-A	1.152	ND	0.265	0.252	0.463	0.219	ND	ND	ND	2.351
8-B	11.746	ND	4.273	4.223	6.182	3.170	0.865	1.050	ND	31.509
8-C	8.834	ND	2.828	4.058	4.615	6.311	0.307	0.411	ND	27.364

Appendix Table 8.2 (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Polychlorinated Biphenyls (PCBs). Concentrations expressed in ng/g dry wt.

Station	6(138)	5(126)	7(187)	6(128)	7(180)	7(170)	8(195)	9(206)	10(209)	Sum PCB
9-A	2.344	ND	0.024	3.015	0.373	5.264	ND	ND	ND	11.02
9-B	2.162	ND	0.644	2.157	0.594	0.292	ND	ND	ND	5.849
9-C	2.927	ND	0.187	6.013	0.468	0.357	ND	ND	ND	9.952
10-A	1.847	ND	0.226	2.443	0.378	0.402	ND	ND	ND	5.296
10-B	1.047	ND	ND	1.293	0.008	ND	ND	ND	ND	2.348
10-C	ND	ND	0.494	2.152	0.393	ND	ND	ND	ND	3.039
11-A	ND	ND	1.180	4.504	1.128	0.849	ND	ND	ND	7.661
11-B	2.996	ND	0.683	2.715	0.709	0.586	ND	ND	ND	7.689
11-C	2.839	ND	0.832	2.110	0.960	0.338	ND	ND	ND	7.079
12-A	5.467	ND	0.467	8.071	0.898	0.758	ND	ND	ND	15.661
12-B	6.521	ND	1.363	9.414	1.685	1.121	ND	ND	ND	20.104
12-C	8.620	ND	1.344	4.482	2.341	1.563	ND	0.047	ND	18.397
13-A	0.994	ND	ND	0.105	0.092	ND	ND	ND	ND	1.191
13-B	0.918	ND	0.534	0.947	0.567	0.365	ND	ND	ND	3.331
13-C	1.916	ND	1.265	1.787	1.337	0.597	0.102	0.679	ND	7.683
14-A	1.032	ND	0.681	0.638	1.039	ND	ND	0.138	ND	3.528
14-B	1.662	ND	0.784	1.111	1.007	0.773	1.560	1.817	ND	8.714
14-C	1.004	ND	0.483	1.798	0.705	0.698	1.372	1.567	ND	7.627
15-A	0.699	ND	0.063	0.892	0.225	0.442	0.979	1.031	ND	4.331
15-B	1.886	ND	0.974	1.388	0.932	0.794	1.564	1.793	ND	9.331
15-C	0.525	ND	0.210	0.470	0.176	0.189	ND	ND	ND	1.57
16-A	0.821	ND	0.210	ND	1.055	0.485	ND	ND	ND	2.571
16-B	4.327	ND	0.729	2.641	1.101	0.967	ND	ND	ND	9.765
16-C	3.829	ND	1.037	0.983	1.670	0.801	ND	ND	ND	8.32

Appendix Table 8.2 (Con't.). Survey of sediment toxicity in Long Island Sound—National Status and Trends organics: Polychlorinated Biphenyls (PCBs). Concentrations expressed in ng/g dry wt.

Station	6(138)	5(126)	7(187)	6(128)	7(180)	7(170)	8(195)	9(206)	10(209)	Sum PCB
17-A	3.051	ND	0.809	0.742	0.976	0.494	ND	ND	ND	6.072
17-F	ND	ND	1.577	1.207	1.557	ND	ND	ND	ND	4.341
17-I	13.352	ND	2.281	2.109	2.404	ND	ND	ND	ND	20.146
18-A	14.230	ND	4.746	ND	5.036	ND	ND	ND	ND	24.012
18-B	8.446	ND	9.158	5.051	11.211	ND	ND	ND	ND	33.866
18-D	2.311	ND	2.054	3.064	2.183	ND	ND	ND	ND	9.612
19-A	26.823	ND	5.561	7.207	5.941	ND	ND	ND	ND	45.532
19-C	24.486	ND	4.097	5.956	4.841	ND	ND	ND	ND	39.380
19-F	ND	ND	3.557	16.392	4.597	ND	ND	ND	ND	24.546
20-A	27.174	ND	ND	71.006	4.838	ND	ND	ND	ND	103.018
20-D	ND	ND	ND	ND	1.651	ND	ND	ND	ND	1.651
20-G	8.447	ND	ND	22.176	1.912	ND	ND	ND	ND	32.535
CLIS-A	2.136	ND	0.847	ND	0.787	0.043	ND	0.055	0.421	4.289
CLIS-B	2.271	ND	1.143	0.898	1.221	0.591	0.022	ND	ND	6.146
CLIS-C	2.037	ND	0.870	1.205	1.270	0.790	1.815	1.977	2.177	12.141