2002 Boston Harbor benthic monitoring report

Massachusetts Water Resources Authority

Environmental Quality Department
Report ENQUAD 2004-02

Citation:

Maciolek, NJ, RJ Diaz, DT Dahlen, CD Hunt, and IP Williams. 2004. **2002 Boston Harbor Benthic Monitoring Report**. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2004-02. 96 pages plus appendices.

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Submitted to

Massachusetts Water Resources Authority
Environmental Quality Department
100 First Avenue
Charleston Navy Yard
Boston, MA 02129
(617) 242-6000

prepared by

Nancy J. Maciolek[1]
Robert J. Diaz[2]
Deirdre Dahlen[3]
Carlton D. Hunt[3]
Isabelle P. Williams[1]

[1]ENSR Marine & Coastal Center
89 Water Street
Woods Hole, MA 02543

[2]Diaz and Daughters
6198 Driftwood Lane
Ware Neck, VA 23178

[3]Battelle
397 Washington Street
Duxbury, MA 02332

May 15, 2004
Report No. 2004-02

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EXECUTIVE SUMMARY

The 2002 sampling program in Boston Harbor was similar to programs of the last several years (Kropp *et al.* 2000b). A sediment profiling camera was used to document conditions in a wide array of habitats throughout the harbor. The camera provides a view of surficial sediments, and images can be analyzed for a number of parameters, including the apparent redox potential discontinuity. Eight stations in the harbor were sampled for infaunal benthos, which is considered an integrator of environmental conditions. Ancillary parameters including sediment grain size, total organic carbon, and *Clostridium perfringens* were measured at each of the eight stations sampled for infaunal benthos. These several types of samples contribute to an overall view of the environmental status of the harbor, and its recovery from the deposition of sewage sludge and effluents.

Sediment Profile Images

2002 vs. 2001—While conditions at almost all harbor SPI stations for 2002 reflected the strong influence of biological processes in structuring surface sediments with tubes and other biogenic structures, there was a reduction in the overall level of predominance in biological processes compared with the previous year**.** In 2001, the sediment surface at 53% of the stations appeared to be dominated by biogenic structures such as tubes, feeding pits, and defecation mounds; in 2002 this declined to 16%. Physical processes, as indicated by bedforms, coarse-grained sediment, or soft deep-penetration sediments, increased in predominance from 26% of stations in 2001 to 41% in 2002. No station that was classified with either physical or a combination of biological and physical processes structuring surface sediments in 2001 was classified as biologically dominated in 2002.

The areal distribution of *Ampelisca* spp. tube mats contracted in 2002 to 22% of the stations from the 50% reported for 2001. In comparison, the high was 65% in 1995 and the low was 18% in 1990. However, the total number of stations with *Ampelisca* spp. tubes at any density, from only a few to mat densities, increased in 2002 relative to the last three years. From 2001 to 2002, 18 stations lost tube mats and two stations gained mats; mats were present in both years at 11 stations. The low occurrence of epifaunal organisms noted in 2001 relative to 2000 continued into 2002. Also, large infauna were more prevalent in 2001 relative to 2002 despite there being significantly more infauna per image in 2002. The infauna in 2002 appeared to be smaller and likely pioneering Stage I individuals.

The two principle parameters dependent on biogenic activity, RPD and OSI, were both significantly lower in 2002 relative to 2001. Benthic habitat quality, as measured by the OSI, decreased at most stations in 2002 with the mean decrease being 1.0±0.34 (mean±SE). The principal reason for the decline in the OSI was the corresponding decrease in the depth of the apparent color RPD layer in 2002 relative to 2001 (1.6±0.24 cm). Station T04 continued to have the poorest habitat quality.

Long-term Trends—Over the last 11 years, benthic habitat quality in Boston Harbor as measured by sediment profile imaging has not changed appreciably. From 1992 to 2002, the two basic measures of benthic habitat quality, the Organism Sediment Index (OSI) of Rhoads and Germano (1986) and the depth of the apparent color RPD layer, oscillated about the long-term mean with no yearly mean being more than 17% and 45% from the grand mean, for OSI and RPD respectively. Using the OSI as a surrogate for habitat quality, no station has exhibited a monotonic long-term trend, either improving or declining. However, six stations consistently have had OSI values ≥6 (R11, R12, R28, R29, R45, and R46).

Sediment Properties

Grain size—There were no substantial changes to the spatial and temporal characteristics of sediment grain size in 2002 from previous years (1991–2001). Further, patterns in sediment composition between April and August surveys were similar across all common sampling years. In general, grain size and TOC were strongly correlated across all sampling years, indicating that the relationship between grain size and TOC did not change over time.

TOC—The spatial and temporal distribution of TOC concentrations in 2002 was not substantially different from earlier years (1991–2001). Since 1999, however, concentrations of TOC measured during August surveys have decreased at most traditional stations compared with 1991–1998 levels, although the decreases are small and effects on the biological community may be subtle. The variability among the TOC data has decreased on a harbor-wide basis since 1999, likely due to the cessation of sludge disposal in 1991 and subsequent improvements in sewage treatment.

An evaluation of flux and traditional harbor TOC results did suggest a seasonal peak in TOC in May, indicative of inputs to the system from a winter/spring bloom, or an imbalance in production versus metabolism of organic carbon in the system over the annual cycle. Seasonal TOC decreased from July through October, likely reflecting TOC consumption by bacteria and infauna.

Clostridium perfringens—The abundance of *C. perfringens* has decreased on a harbor-wide basis since 1999, and the system appears to be more stable as evidenced by decreased variability among the data. Major facility improvements implemented to improve conditions in Boston Harbor likely contributed to the reduced abundance and temporal variability observed in the system. These findings demonstrate that *C. perfringens* continues to serve as a good indicator of the response to effluent discharge.

The correspondence between *C. perfringens* and bulk sediment properties was stronger after 1998, suggesting that the factors that influence the variability (percent fines, TOC) are more closely coupled after implementation of facility improvements. In addition, the strength of the correspondence between *C. perfringens* and bulk sediment properties is similar between April and August. This suggests that the system is becoming more coherent in its overall response, indicating that the processes that regulate carbon and *C. perfringens* are more similar.

Infaunal Communities

In 2002, the benthic infauna included 157 species, of which 123 occurred in the spring (April) samples, and 123 (a slightly different assortment) occurred in the summer (August) samples. For the period 1991–2002, a total of 276 valid species has been recorded; 117 of these have five or fewer occurrences, including 54 with single occurrences. In addition, 87 taxa that include juveniles, damaged, or otherwise indeterminable animals were also recorded. Finally, 26 taxa that are either parasitic, epifaunal, or otherwise not part of the infaunal benthos and therefore excluded from any analyses, were present in the samples. Of the 276 species recorded in Boston Harbor, 193 also occur in the HOM Massachusetts Bay samples.

The 2002 benthic community parameters were similar to the results from 2001: densities were highest at stations T03 and T06 in both April and August, and lowest at T02 in April and T04 in August. The number of species per sample, diversity as measured by log-series *alpha* and the Shannon index, and Pielou's evenness was lowest at T04 and highest at T08 in both April and August.

Dominant species at each of the eight stations were essentially similar to those seen in previous years, with only one or two exceptions. The spionid *Prionospio steenstrupi*, which was especially abundant in Massachusetts Bay in 2002, but not a dominant at any Boston Harbor station in recent years, was among the most numerous species at six of the eight stations in April, and at all eight stations in August. Since the beginning of monitoring in 1991, 4594 P. steenstrupi have been recorded from the eight harbor traditional grab stations: 43% of these were recorded in 2002. The community at T04 remains depauperate compared with the infauna at the other seven stations, but in 2002 the species composition at T04 was very different from that seen in 2000 or 2001, with the oligochaete *Paranais litoralis* the numerical dominant in 2002.

Results for the period 1991–2002 were compared with the results of the earliest studies of the benthic communities of Boston Harbor (1978, 1979, 1982). Since the discharge of sludge into the harbor was ended in 1991, and all effluent discharge from Nut Island was discontinued and full secondary treatment of the effluent was implemented in 1998, the most dramatic changes in benthic communities have been at T01, near the Deer Island flats, and T02 near Logan Airport. Both of these stations have increased in diversity and other benthic community parameters. Species composition has changed, especially at T01, where densities of *Streblospio benedicti*, usually considered indicative of stressed environments, have declined in recent years, and densities of *Aricidea catherinae*, a very common polychaete found both elsewhere in the harbor and offshore in Massachusetts Bay, have increased.

Although Station T05A does not appear to have changed significantly in terms of numerically dominant species, it is noteworthy that offshore species such as *Scolelepis tridentata* and *Polydora* sp. 1 have occurred there in the last year or two, although such occurrences are usually only of a single individual.

Many of the patterns in benthic community structure described for 1978–1982 have continued throughout the period 1991–2002 at stations in the southern portion of the harbor. Those stations that appeared relatively diverse according to the several parameters measured prior to the cessation of sludge and effluent discharge have changed little in those parameters in the years since the discharges were diverted. Stations T06, T07, and T08 have consistently had the highest species richness and diversities, and the dominant species have remained similar.

Similarity and principal components analysis (PCA) of the 1991–2002 dataset indicated both spatial and seasonal elements. Each of the eight stations has a specific signature, with T04 being the most dissimilar to all of the other stations. Samples from stations T03 and T06, both dominated by amphipod species, tend to intermix, as do some samples form T01 and T02. These analyses reveal that samples from T01 from the years 2000–2002 are significantly different from samples taken at that station in earlier years. This result is one line of evidence that some locations in the harbor are responding to pollution abatement, and increasing in diversity and species richness. Another line of evidence is that when all Boston Harbor stations are considered together, the numbers of species per sample, as well as the computed parameter log-series *alpha*, have nearly doubled over the period 1991–2002.

1.0 INTRODUCTION

1.1 Program Background

1.1.1 History of Discharges to Boston Harbor

Boston Harbor has had a long history of anthropogenic impacts dating back at least to colonial times (Loud 1923). In addition to the damming of rivers and the filling of salt marshes and shallow embayments to create the present footprint of the city, the direct discharge of waste products has had a profound impact on the composition of the biological communities in the harbor. Prior to the 1950s, raw sewage was discharged into Boston Harbor primarily from three locations: Moon Island, Nut Island, and Deer Island. In 1952, the Nut Island treatment plant became operational and began treating sewage from the southern part of Boston's metropolitan area. The Deer Island treatment plant was completed in 1968, thus providing treatment for sewage from the northern part of the area. (The third location, Moon Island, was relegated to emergency status at that time and not used routinely thereafter.) The effluent was discharged continuously from both plants; an annual average of 120 million gallons per day (MGD) from Nut Island and 240 MGD from Deer Island. Storm events caused up to 3.8 billion gallons per year (BGY) of additional material to be occasionally discharged to the harbor through the system of combined sewer overflows (CSOs) (Rex *et. al* 2002).

Sludge, which was separated from the effluent, was digested anaerobically prior to discharge. Digested sludge from Nut Island was pumped across Quincy Bay and discharged through an outfall near Long Island on the southeastern side of Presidents Roads. Sludge from Deer Island was discharged through that plant’s effluent outfalls on the northern side of Presidents Roads. Sludge discharges were timed to coincide with the outgoing tide, under the assumption that the tide would carry the discharges out of the harbor and away offshore. Unfortunately, studies have shown that the material from Nut Island often was trapped near the tip of Long Island and carried back into the harbor on incoming tides (McDowell *et al*. 1991).

In 1972, the Federal Clean Water Act (CWA) mandated secondary treatment for all sewage discharges to coastal waters, but an amendment allowed communities to apply for waivers from this requirement. The metropolitan Boston area’s application for such a waiver was denied by the US Environmental Protection Agency (EPA), partly on the basis of the observed degradation of the benthic communities in Boston Harbor. In 1985, in response to both the EPA mandate to institute secondary treatment and a Federal Court order to improve the condition of Boston Harbor, the Massachusetts Water Resources Authority (MWRA) was created. The MWRA instituted a multifaceted approach to upgrading the sewage treatment system, including an upgrade in the treatment facility itself and construction of a new outfall pipe to carry the treated effluent to a diffuser system in Massachusetts Bay located 9.5 mi offshore in deep water.

In 1989, discharge of more than 10,000 gallons per day (GPD) of floatable pollutants comprising grease, oil, and plastics from the Deer Island and Nut Island treatment plants was ended. Sludge discharge ceased in December 1991, marking the end of one of the most significant inputs of pollutants to Boston Harbor. In 1995, a new primary treatment plant at Deer Island was completed, increasing the system's overall capacity and the effectiveness of the treatment. In August 1997, the first phase of secondary treatment was completed, increasing the level of solids removal to 80%. For the first time, the MWRA's discharge met the requirements of the CWA (Rex *et. al* 2002).

In July 1998, a new screening facility at Nut Island became operational, with sand, gravel, and large objects being removed from the wastewater flow prior to transport via tunnel to Deer Island for further processing. In October 1998, the old Nut Island plant was officially decommissioned, ending more than 100 years of wastewater discharges to the shallow waters of Quincy Bay. By 2000, the average effluent solids loading to the Harbor had decreased to less than 35 tons per day (TPD), reduced from the 138 TPD discharged through the 1980s. On September 6, 2000, all wastewater discharges were diverted to the new outfall in Massachusetts Bay, and in early 2001, the final battery of secondary treatment became operational.

Ongoing MWRA pollution abatement projects for Boston Harbor involve reducing the number and discharge volumes from Combined Sewer Overflows (CSOs). In 1988, 88 CSOs discharged a total of about 3.3 billion gallons per year (BGY). By 1998, 23 CSOs had been closed, and pumping improvements reduced discharges to about 1 BGY, of which about 58% is screened and disinfected. By 2008, ongoing projects will reduce the number of CSO outfalls to fewer than 50, with an estimated discharge of 0.4 BGY, of which 95% will be treated by screening and disinfection (Rex *et. al* 2002).

1.1.2 Benthic Studies in Boston Harbor

The first extensive studies of the infaunal benthos of Boston Harbor were conducted in the summers of 1978, 1979, and 1982 in support of the secondary treatment waiver application (Maciolek 1978, 1980; McGrath *et al.* 1982). These studies documented spatial and temporal variability in infaunal communities in Boston Harbor prior to any pollution abatement projects, and informed the design of the current monitoring program.

As MWRA's long-term sediment monitoring was being developed, reconnaissance surveys were carried out using sediment profile imaging in 1989 and 1990 (SAIC 1990). This technique provides information on the depth of the apparent redox potential discontinuity (RPD), an estimation of sediment grain-size composition, the successional stage of the infauna, and the presence of any biogenic features such as burrows and tubes (Rhoads and Germano 1982). The sediment profile stations provided the means to assess benthic conditions over most of the outer Boston Harbor and Dorchester, Quincy, Hingham, and Hull Bays.

Quantitative infaunal sampling was initiated in 1991and was intended to characterize the infauna of Boston Harbor so that changes following the various phases of the Boston Harbor Project (*e.g.*, sludge abatement) could be documented. Eight stations (one was later relocated) were positioned near the major effluent and sludge discharges and in key reference locations. Benthic infaunal communities and correlated sediment parameters were first sampled in September 1991, approximately three months prior to the cessation of sludge discharge. Post-abatement surveys were conducted in April/May and August 1992 to 2002. Reconnaissance surveys at 25–50 additional stations using either or both sediment profile imaging and rapid partial grab analyses have continued annually since 1991, allowing researchers to put the results of the quantitative sampling in the context of Boston Harbor sediments as a whole. Reports to the MWRA on the results of these surveys have been prepared and can be requested from the MWRA through their website (http://www.mwra.state.ma.us).

Results from the 2002 harbor benthic surveys are presented in this report and compared with results from previous years. Recent reports (Kropp *et al*. 2002a, b) have suggested that the infaunal community is responding to some degree to changes in the discharges to the harbor. The occurrence and spread of *Ampelisca abdita* tube mats, and the increase in species numbers and diversity at some of the stations are considered especially important.

1.2 Report Overview

The Boston Harbor benthic monitoring program includes three components: sediment profile imaging (SPI), sediment geochemistry, and benthic infaunal community analysis. The sampling design and field methods are presented in Section 2. Sediment images were collected in August 2002 at 60 stations; these images are evaluated in Section 3. Sediment geochemistry studies, based on sediment grab samples taken at eight stations in April and August, consist of grain-size analysis, total organic carbon (TOC) content determination, and quantification of the sewage tracer, *Clostridium perfringens*. These analytical results are presented in Section 4. Results of the analyses of metals, organics, *Enterococcus*, and fecal coliform samples taken in August 2002 at the traditional stations will be presented in the CSO report and are not included here (Lefkowitz, *in preparation*). The benthic communities were sampled at eight stations in both April and August 2002; the results are presented in Section 5. The raw data generated for all of these components are available from the MWRA; summaries are included in the appendices to this report.

2.0 2002 HARBOR FIELD OPERATIONS

by Isabelle P. Williams

2.1 Sampling Design

The station array provides spatial coverage of the major bays that make up Boston Harbor (Figure 2-1). The eight stations designated as "traditional" are those that are sampled for benthic infauna, followed by a full taxonomic analysis of the organisms in each sample. These station locations were selected after consideration of previous sampling programs in the harbor (*e.g.*, those conducted for the 301(h) waiver application) and consideration of water circulation patterns and other inputs to the harbor (*e.g.*, combined sewer overflow). The 52 stations designated as "reconnaissance" are those at which only sediment profile images (SPI) are taken.

2.1.1 Sediment Profile Images

The Boston Harbor SPI survey was conducted in August 2002 at the eight traditional stations and the 52 reconnaissance stations (Figure 2-1). The SPI data supplement the infaunal data to provide a large-scale picture of benthic conditions in the harbor. Sediment profile imagery, whether using 35-mm film as in past years or digital technology as in 2002, permits a faster evaluation of the benthos than can be made by traditional infaunal analyses. This qualitative evaluation can be integrated with the quantitative results from the infaunal and sediment chemistry analyses. The target locations for the SPI stations are listed in Table 2-1. Specific locations of all sediment profile images collected in 2002 are listed in Appendix A (Table A1).

2.1.2 Sediment Samples

In 2002, the Boston Harbor benthic infaunal surveys were conducted in April and August. Two April stations were re-sampled in May because a sorting lab error rendered one infaunal replicate each from T01 and T03 unusable. Benthic infaunal and sediment chemistry samples were collected from the eight traditional stations (Figure 2-1). The target locations for these stations are listed in Table 2-1. The actual station coordinates for each biology and chemistry grab sample, along with a brief description of each sample, is given in Appendix A (Tables A2 and A3).

The Combined Sewer Overflow (CSO) Survey, which is designed to provide information on improvements in sediment quality in Boston Harbor after CSO upgrades, was conducted in conjunction with the 2002 harbor survey so that samples for sediment chemistry and infauna would be collected on the same day (CSO Sediment Synthesis Report, Lefkowitz, *in preparation*).

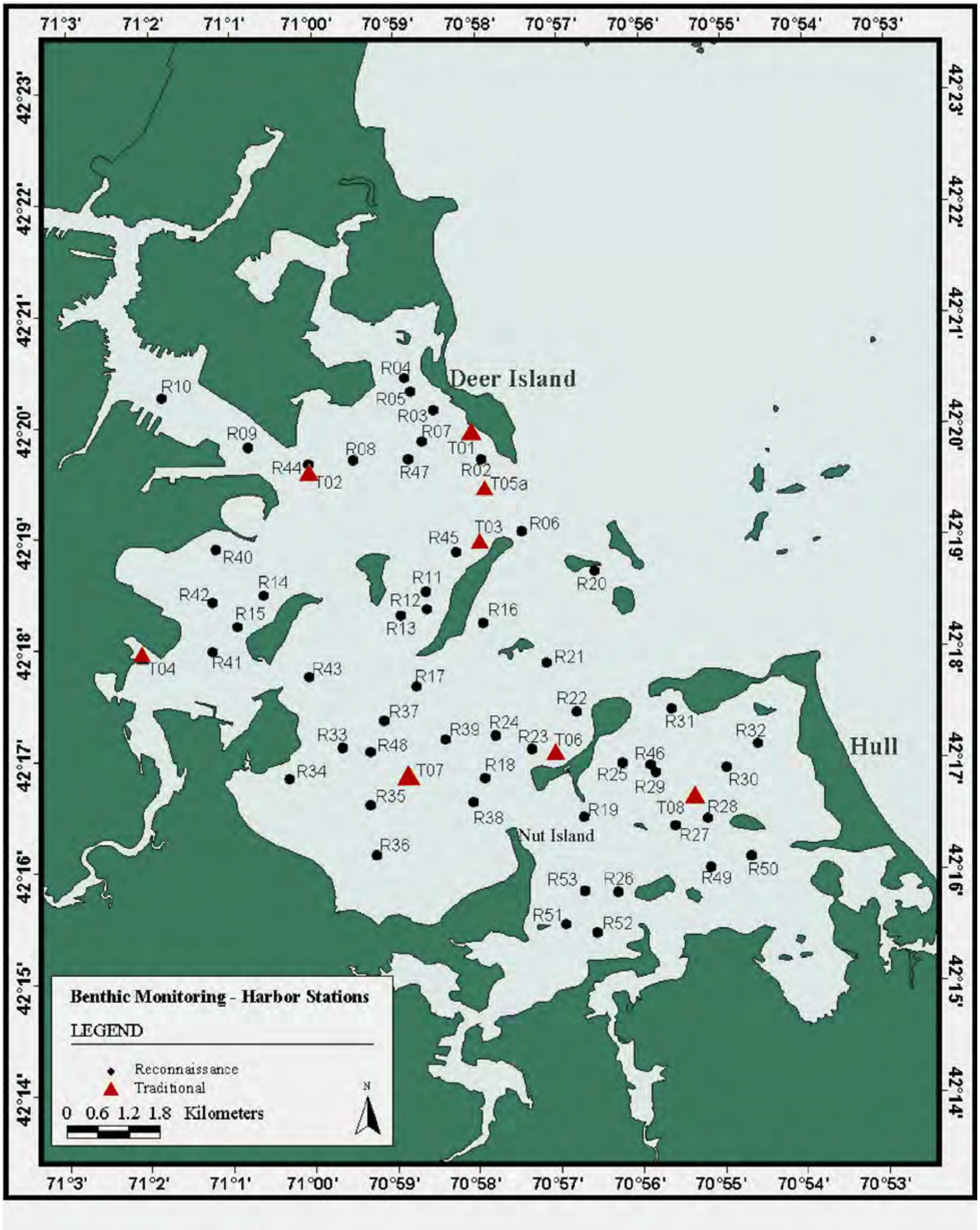


Figure 2-1. Locations of Boston Harbor grab and SPI stations sampled in 2002.
Triangles show traditional stations sampled by grab in April and August and by SPI in August. Circles indicate reconnaissance SPI stations sampled in August.

Table 2-1. Target locations for Boston Harbor grab and SPI stations.

Station	Latitude	Longitude	Depth (m)
Traditional Stations			
T01	42E20.95NN	70E57.81NW	4.9
T02	42E20.57NN	71E00.12NW	6.8
T03	42E19.81NN	70E57.72NW	8.7
T04	42E18.60NN	71E02.49NW	3.2
T05A	42E20.38NN	70E57.64NW	17.5
T06	42E17.61NN	70E56.66NW	6.6
T07	42E17.36NN	70E58.71NW	5.9
T08	42E17.12NN	70E54.75NW	11.3
Reconnaissance Stations			
R02	42E20.66NN	70E57.69NW	13.8
R03	42E21.18NN	70E58.37NW	4.5
R04	42E21.52NN	70E58.78NW	7.2
R05	42E21.38NN	70E58.68NW	5.7
R06	42E19.91NN	70E57.12NW	10.9
R07	42E20.85NN	70E58.53NW	5.6
R08	42E20.66NN	70E59.50NW	2.6
R09	42E20.80NN	71E00.98NW	11.6
R10	42E21.32NN	71E02.20NW	12.8
R11	42E19.28NN	70E58.48NW	7.3
R12	42E19.10NN	70E58.47NW	6.1
R13	42E19.03NN	70E58.84NW	6.7
R14	42E19.25NN	71E00.77NW	10.0
R15	42E18.92NN	71E01.15NW	3.2
R16	42E18.95NN	70E57.68NW	8.0
R17	42E18.29NN	70E58.63NW	8.1
R18	42E17.33NN	70E57.67NW	8.0
R19	42E16.92NN	70E56.27NW	9.2
R20	42E19.49NN	70E56.10NW	11.2
R21	42E18.53NN	70E56.78NW	8.7
R22	42E18.02NN	70E56.37NW	9.4
R23	42E17.63NN	70E57.00NW	10.8

Table 2-1 (continued)

Station	Latitude	Longitude	Depth (m)
R24	42E17.78NN	70E57.51NW	7.4
R25	42E17.48NN	70E55.72NW	7.3
R26	42E16.13NN	70E55.80NW	7
R27	42E16.83NN	70E54.98NW	6
R28	42E16.90NN	70E54.52NW	7
R29	42E17.38NN	70E55.25NW	11
R30	42E17.43NN	70E54.25NW	5
R31	42E18.05NN	70E55.03NW	10
R32	42E17.68NN	70E53.82NW	5
R33	42E17.65NN	70E59.67NW	5
R34	42E17.33NN	71E00.42NW	4
R35	42E17.05NN	70E59.28NW	6
R36	42E16.53NN	70E59.20NW	5
R37	42E17.93NN	70E59.08NW	6
R38	42E17.08NN	70E57.83NW	7
R39	42E17.73NN	70E58.22NW	8
R40	42E19.73NN	71E01.45NW	2
R41	42E18.67NN	71E01.50NW	4
R42	42E19.18NN	71E01.50NW	2
R43	42E18.40NN	71E00.13NW	3
R44	42E20.62NN	71E00.13NW	9.3
R45	42E19.70NN	70E58.05NW	6.8
R46	42E17.46NN	70E55.33NW	10.5
R47	42E20.67NN	70E58.72NW	6.5
R48	42E17.61NN	70E59.27NW	5.9
R49	42E16.39NN	70E54.49NW	6.1
R50	42E16.50NN	70E53.92NW	6.1
R51	42E15.80NN	70E56.53 NW	5.3
R52	42E15.71NN	70E56.09NW	5.2
R53	42E16.15NN	70E56.27NW	6

2.2 Field Program Results

2.2.1 Survey Dates and Samples Collected

A summary of the samples collected on Boston Harbor surveys conducted in 2002 is presented in Table 2-2.

Table 2-2. Survey dates and numbers of samples collected on Boston Harbor benthic surveys in 2002.

Survey Type	Survey ID	2002 Date(s)	Samples Collected								
			Inf	TOC	GS	Cp	Ent	Fc	O	M	SPI
SPI	HR021	26–28 August									241
Benthic	HT021	25 April 21 May	24 2	8	8	8					
Benthic	HT022	8 August	24	24	24	24	24	24	24	24	

Key: Inf: Infauna, TOC: total organic carbon, GS: grain size, Cp: *Clostridium perfringens*, Ent: *Enterococcus*, Fc: fecal coliform, O: organics; M: metals; SPI: individual sediment profile images.

2.2.2 Vessel and Navigation

The 2002 Boston Harbor benthic surveys were conducted from Battelle's research vessel, the R/V *Aquamonitor*. Vessel positioning was accomplished with the Battelle Oceans Sampling Systems (BOSS) navigation system. BOSS consists of a Northstar differential global positioning system (DGPS) interfaced to an on-board computer. Data were recorded and reduced by NAVSAM© data acquisition software. The GPS receiver has six dedicated channels and is capable of locking onto six satellites at once. The system was calibrated with coordinates obtained from NOAA navigation charts at the beginning and end of each survey day.

At each sampling station, the vessel was positioned as close to target coordinates as possible. The NAVSAM© navigation and sampling software collected and stored navigation data, time, and station depth every 2 seconds throughout the sampling event, and assigned a unique designation to each sample when the sampling instrument hit the bottom. The display on the BOSS computer screen was set to show a radius of 30 m around the target station coordinates (six 5-m rings) for all harbor benthic surveys. A station radius of up to 30 m is considered acceptable for benthic sampling in Boston Harbor.

2.2.3 Sediment Profile Imagery (SPI)

Dr. Robert Diaz was the Senior Scientist for the Boston Harbor SPI (HR021) survey that was conducted on 26, 27, and 28 August 2002. Three replicate Sediment Profile Images (SPI) were successfully collected at 52 long-term reconnaissance (R) and eight traditional (T) stations. The sediment profile images were collected using a modified Hulcher sediment profile camera with a Minolta Dimage 7i, 5.2-megapixal digital camera and strobe in a stainless steel housing and a 45^{o}-angle prism with a 16.5-cm by 23-cm Plexiglas faceplate. The camera and prism are attached to an aluminum frame with a hydraulic arm to slowly lower the prism and camera into the sediment. The digital camera recorded to a 1-gigabyte IBM microdrive and was used in place of the 35-mm film camera with attached video camera that was described in the QWAPP for this project (Williams *et al*., 2002). The microdrive could accommodate about 420 JPEG compressed images and reached capacity after 13–16 stations. On retrieval of the microdrive, images were transferred to a computer for preliminary evaluation of image quality and benthic habitat conditions while still conducting field operations. The use of digital technology allowed for field review of all images and implementation of corrective action if images from any station were disturbed or of poor quality. More detail on sediment profile camera operation can be found in Rhoads and Cande (1971).

At each station, four replicates were collected even though only three replicates were required. This was done to save resampling time, because the replicate failure rate from physical disturbance of the surface sediments by the camera frame landing on the bottom or movement of the vessel dragging the camera frame is about 15–20%. If one of the four replicates were disturbed, it would be eliminated. If all four replicates were good, the first three would be processed. While on the bottom, the digital profile camera took a photograph about every 1.5 s. Every replicate was marked as an event on the NAVSAM© system, and the date, time, station, water depth, photo number, and estimated prism penetration were recorded in a field log.

2.2.4 Grab Sampling

In April (HT021), August (HT022), and the resampling in May, a 0.04-m^2 Ted Young-modified Van Veen grab sampler was used to collect replicate samples at each station for infaunal analysis, and, in April, one sample at each station for analysis of TOC, *C. perfringens*, and sediment grain size. In August, a 0.10-m^2 Kynar-coated Young-modified Van Veen grab was used to collect three replicate samples for analysis of sedimentary parameters (metals, organics, TOC, *C. perfringens*, *Enterococcus*, fecal coliform, and sediment grain size).

Infaunal samples were sieved onboard with filtered seawater over a 300-μm-mesh sieve and fixed in 10% buffered formalin. For chemistry samples, the top 2 cm of the sediment in the grab was removed with a Kynar-coated scoop and homogenized in a clean glass bowl before being distributed to appropriate storage containers. The TOC, metals, and organics samples were frozen, whereas the *C. perfringens*, *Enterococcus*, fecal coliform, and grain-size samples were placed on ice in coolers.

3.0 2002 HARBOR SEDIMENT PROFILE IMAGING

by Robert J. Diaz

3.1 Introduction

The current sediment profile image (SPI) monitoring strategy was established in 1993. This strategy includes summer sampling at a series of 52 reconnaissance (R) and eight traditional (T) stations, with stations located based on data collected in 1990–1992 (SAIC 1992, Blake *et al.* 1993). Infaunal data were also collected at the traditional stations (see section 5). The objective of the SPI sampling was to determine the general condition of benthic habitats within the harbor and track long-term changes in benthic habitat quality.

3.2 Materials and Methods

3.2.1 Image Analysis

Steps in the computer analysis of each image were standardized and followed the basic procedures in Viles and Diaz (1991). Data from each image were sequentially saved to a spreadsheet file for later analysis. Details of how these data were obtained can be found in Diaz and Schaffner (1988), Rhoads and Germano (1986), and Williams *et al*. (2002).

3.2.2 Data Reduction and Statistics

Penetration at stations R19, R23, and T08 for all three replicates was insufficient for estimating the apparent color RPD layer depth and also the organism sediment index (OSI). These three stations were not included in any comparison involving RPD or OSI. At station R08 only one of three replicate images had sufficient penetration to allow for estimation of RPD layer depth, so for any calculation that used the mean station RPD layer depth or OSI the single replicate value was used. Stations that had two of three replicates in the calculation of mean RPD were R15, T05A, and T07. All other stations had three measured RPD layer depths.

Analysis of variance or Student's t-test for paired data were used to test for differences between and within areas for quantitative parameters. Normality was checked with the Shapiro-Wilk test and homogeneity of variance with Bartlett's test. If variance was not homogeneous, Welch analysis of variance, which allows standard deviations to be unequal, was used in testing means (Zar 1999).

3.3 Results

Copies of 2002 Harbor SPI images and replicate data are contained in the CD-ROM Appendix B. Table 3-1 contains a station summary of SPI data for 2002.

3.3.1 Physical Processes and Sediments

The predominant sediment type throughout the study area appeared to be silt with a significant fine-sand component. In 2002, the three sediment categories of silty-fine-sand (SIFS, modal Phi 6 to 5), fine-sandy-silt (FSSI, modal Phi 5 to 4), and fine-sand-silt-clay (FISICL, modal Phi 5.5 to 4.5) occurred at 62% (37 of 60) of the stations (Table 3-1). This represents a slight shift in grain-size from 2001 when 50% of the stations appeared to be silty mud (SICL or SI, modal Phi 8 to 6) and 36% either silty-fine-sand or fine-sandy-silt. In 2002, silty-clay and silt occurred at 27% of the stations. The remaining 12% of the stations (7 of 60) ranged from sands (R08, R23, R53, T05A, and T08) to gravel and pebbles (R06 and R19). None of the stations appeared to have layered sediments. Pure sands and coarser sediments, indicative of high kinetic energy bottoms tended to occur toward the Outer Harbor. Bedforms were observed at all five sand stations (Table 3-1).

The broad range of sedimentary habitats within the harbor was also reflected in the average station prism penetration, which ranged from 1.6 cm at medium-sand-gravel station R19 in Hingham Bay to 22.8 cm at silty-clay station R02 off Deer Island. Prism penetration was significantly lower at stations with coarser sediments that were sand, gravel, or pebble (2.8±1.1 cm, mean±SE, N = 7) than at either silty-sand stations (9.8±0.5 cm, N = 37) or at silty stations (16.9±0.7 cm, N = 16).

The bed roughness or surface relief was the same magnitude at stations that appeared to be dominated by physical or biological processes (Table 3-1). Surface relief was 1.2±0.12 cm (mean±SE) at physically dominated stations; 1.2±0.18 cm at biologically dominated stations; and 0.9±0.09 cm at stations that appeared to be intermediate. In physically dominated habitats with coarse sediments, surface relief was due to sediment grain size (gravel, pebble, or cobble) and bedforms, and in silty sediments was related to irregularities in the surface. In biologically dominated habitats, surface relief was typically biogenic structures produced by benthic organisms. *Ampelisca* spp. tube mats were the primary relief-creating biogenic features, followed by what appeared to be feeding pits or mounds.

Table 3-1. Summary of sediment profile image data for Boston Harbor, August 2002.

STA	Pen (cm)	Max RPD (cm)	RPD (cm)	Infauna (#/image)	Burrows (#/image)	Oxic Voids (#/image)	Anaerobic Voids (#/image)	Gas Voids (#/image)	OSI	Modal Grain Size	Surface Process	*Ampelisca* Tubes	Worm Tubes	Succ. Stage	Bed-forms
R02	22.8	6.6	2.2	3.0	4.7	0.0	4.7	1.0	4.7	SICL	BIO	MAT	NONE	II	-
R03	12.2	8.6	2.4	7.0	4.7	4.0	0.3	0.0	8.0	SIFS	BIO/PHY	SOME	SOME	II-III	-
R04	17.9	6.3	1.4	2.7	6.3	2.3	0.7	2.0	3.7	SI	BIO/PHY	NONE	FEW	I-II	-
R05	17.5	7.8	1.8	4.3	10.3	3.0	2.3	0.0	5.7	SI	BIO/PHY	SOME	SOME	II	-
R06	3.0	3.0	2.2	0.0	0.0	0.0	0.0	0.0	4.3	FSMSG RPB	PHY	NONE	SOME	I	-
R07	20.6	10.7	4.2	5.3	4.7	2.3	2.3	0.0	9.0	SICL	BIO/PHY	MAT	SOME	II-III	-
R08	2.4	3.7	2.2	0.0	0.0	0.0	0.0	0.0	5.0	FS	PHY	NONE	FEW	I	+
R09	10.9	3.3	1.4	2.3	3.3	0.3	1.0	0.0	4.0	SIFS	PHY	SOME	SOME	I-II	-
R10	18.2	2.7	1.1	1.0	2.0	1.0	1.3	0.0	3.7	SICL	PHY	NONE	FEW	I-II	-
R11	15.2	9.7	2.8	6.7	8.7	1.7	2.0	0.7	7.3	SIFS	BIO	MAT	SOME	II-III	-
R12	14.3	6.6	1.9	2.0	5.7	2.0	0.3	0.0	7.0	SIFS	BIO	MAT	FEW	II-III	-
R13	6.7	5.0	1.7	0.0	1.7	0.7	0.0	0.0	4.3	FSSICL	PHY	NONE	NONE	I-II	-
R14	5.3	3.6	2.1	0.7	2.0	0.3	0.0	0.0	4.3	FSSI	PHY	NONE	SOME	I	-
R15	6.0	6.2	1.1	0.3	0.7	0.0	0.0	0.0	3.0	SIFS	PHY	NONE	MANY	I	-
R16	9.0	6.2	1.7	0.7	0.7	0.0	0.0	0.0	3.7	SIFS	PHY	NONE	MANY	I	-
R17	15.3	9.6	3.2	6.0	6.3	7.3	0.7	0.0	8.7	SICL	BIO/PHY	SOME	SOME	II-III	-
R18	12.9	8.7	1.3	4.3	3.7	2.7	1.7	0.0	6.0	SIFS	BIO/PHY	SOME	SOME	II-III	-
R19	1.6		>1.6	0.0	0.0	0.0	0.0	0.0		MSGR	PHY	NONE	SOME	I	-
R20	13.1	6.7	1.6	4.0	5.3	1.3	0.7	0.0	6.3	SIFS	BIO/PHY	MAT	FEW	II-III	-
R21	8.1	5.8	>1.4	5.3	9.0	0.3	0.0	0.0	6.7	SIFS	BIO	MAT	FEW	II-III	-
R22	7.8	6.2	1.5	3.0	8.3	0.3	0.0	0.0	6.3	SIFS	BIO/PHY	MANY	FEW	II-III	-
R23	2.3		>2.3	0.0	0.0	0.0	0.0	0.0		FSMS	PHY	MANY	SOME	I-II	+
R24	8.5	5.7	1.5	5.3	5.0	1.0	0.0	0.0	5.7	SIFS	BIO	MANY	SOME	II-III	-
R25	13.7	2.7	1.0	2.3	3.0	2.0	0.0	0.0	6.0	SI	BIO/PHY	NONE	MANY	II-III	-

Table 3-1. Summary of sediment profile image data for Boston Harbor, August 2002.

STA	Pen (cm)	Max RPD (cm)	RPD (cm)	Infauna (#/image)	Burrows (#/image)	Oxic Voids (#/image)	Anaerobic Voids (#/image)	Gas Voids (#/image)	OSI	Modal Grain Size	Surface Process	*Ampelisca* Tubes	Worm Tubes	Succ. Stage	Bed-forms
R26	18.4	2.1	1.4	3.0	3.7	3.0	0.3	0.0	6.3	SICL	PHY	NONE	SOME	II-III	-
R27	10.9	2.9	1.4	1.3	7.0	1.7	0.0	0.0	6.3	SIFS	BIO/PHY	FEW	SOME	II-III	-
R28	7.4	3.4	1.9	4.0	3.3	1.0	0.0	0.0	6.3	SIFS	BIO/PHY	MANY	FEW	II-III	-
R29	12.2	4.7	1.6	2.3	7.0	1.3	0.3	0.0	6.7	SIFS	BIO	MAT	SOME	II-III	-
R30	7.6	4.2	1.8	3.3	7.7	0.3	0.0	0.0	4.7	SIFS	BIO/PHY	SOME	MANY	I-II	-
R31	9.2	6.9	2.6	5.0	7.3	0.0	0.0	0.0	8.0	SIFS	BIO	MAT	NONE	II-III	-
R32	9.6	4.7	1.8	2.7	4.0	0.7	0.0	0.0	5.0	SIFS	BIO/PHY	NONE	MANY	I-II	-
R33	10.6	4.2	1.3	2.0	3.3	0.7	0.7	0.0	3.3	SIFS	PHY	FEW	FEW	I	-
R34	14.0	6.7	1.3	1.3	5.7	1.3	0.3	0.0	5.3	SIFS	BIO/PHY	NONE	SOME	I-II	-
R35	13.3	3.6	1.1	1.7	4.7	1.3	0.3	0.0	5.3	SIFS	BIO/PHY	NONE	SOME	II-III	-
R36	4.2	2.8	1.1	1.3	2.7	0.7	0.0	0.0	4.0	FSSI	PHY	NONE	SOME	I-II	-
R37	10.1	4.3	1.9	2.0	4.7	2.0	0.0	0.0	6.7	SIFS	BIO/PHY	SOME	SOME	II-III	-
R38	11.1	8.6	4.4	6.0	6.0	6.3	0.0	0.0	9.0	SIFS	BIO/PHY	MANY	SOME	II-III	-
R39	12.2	9.0	3.0	9.7	6.7	4.3	0.0	0.0	8.7	SIFS	BIO/PHY	MAT	SOME	II-III	-
R40	9.3	2.8	1.1	5.7	6.3	3.0	0.0	0.0	6.0	SIFS	PHY	MANY	SOME	II-III	-
R41	9.7	4.8	1.9	2.7	5.3	1.3	0.0	0.0	7.0	SIFS	BIO/PHY	MAT	SOME	II-III	-
R42	6.1	2.9	1.3	0.7	5.7	1.0	0.0	0.0	4.0	SIFS	PHY	FEW	FEW	I-II	-
R43	14.8	2.4	1.2	0.7	3.7	0.0	1.0	0.0	3.0	SICL	PHY	NONE	NONE	I	-
R44	20.1	4.0	1.7	0.7	7.7	2.0	1.3	0.0	6.3	SICL	PHY	SOME	SOME	II-III	-
R45	11.6	7.3	3.2	5.7	11.7	1.0	0.3	0.0	8.3	SI	BIO	MAT	FEW	II-III	-
R46	12.7	4.9	1.8	3.7	8.0	2.3	0.3	0.0	7.0	SI	BIO/PHY	SOME	FEW	II-III	-
R47	18.0	6.9	1.9	7.3	9.0	4.0	1.0	0.0	7.0	SICL	BIO/PHY	MAT	FEW	II-III	-
R48	10.3	6.7	1.7	0.7	3.0	1.3	0.0	0.0	7.0	SIFS	BIO/PHY	SOME	NONE	II-III	-
R49	9.7	4.8	1.3	1.7	3.0	1.7	0.0	1.0	5.7	SIFS	BIO/PHY	FEW	SOME	II-III	-

Table 3-1. Summary of sediment profile image data for Boston Harbor, August 2002.

STA	Pen (cm)	Max RPD (cm)	RPD (cm)	Infauna (#/image)	Burrows (#/image)	Oxic Voids (#/image)	Anaerobic Voids (#/image)	Gas Voids (#/image)	OSI	Modal Grain Size	Surface Process	*Ampelisca* Tubes	Worm Tubes	Succ. Stage	Bed-forms
R50	7.4	3.2	1.8	3.3	6.0	0.3	0.0	0.0	4.7	FSSI	BIO/PHY	SOME	SOME	I-II	-
R51	6.5	5.0	2.3	1.0	6.7	3.0	0.0	0.0	5.7	FSSI	BIO/PHY	NONE	FEW	I-II	-
R52	7.2	2.8	1.5	1.0	5.7	0.0	0.0	0.0	3.7	FSSI	BIO/PHY	NONE	FEW	I	-
R53	5.8	5.3	3.1	1.0	5.0	0.0	0.0	0.0	5.0	FS	PHY	FEW	MANY	I	+
T01	9.1	8.0	2.5	2.3	3.3	4.0	0.0	0.0	8.0	FSSI	PHY	FEW	SOME	II-III	-
T02	16.1	5.5	1.4	2.3	6.3	3.0	1.3	0.0	6.3	SI	PHY	NONE	MANY	II-III	-
T03	11.6	4.8	1.8	4.3	7.3	4.3	0.3	0.0	6.7	SI	BIO	MAT	NONE	II-III	-
T04	21.4	3.4	0.9	0.0	2.3	0.0	2.0	7.7	1.0	SICL	PHY	NONE	NONE	I	-
T05A	3.3	3.3	2.2	0.3	0.7	0.0	0.0	0.0	4.5	FSMSSI	PHY	NONE	SOME	I	+
T06	8.2	3.6	1.3	3.3	5.7	2.3	0.0	0.0	6.3	SIFS	BIO/PHY	MANY	SOME	II-III	-
T07	14.8	2.2	1.0	0.0	1.0	0.0	0.0	0.0	3.0	SIFS	PHY	NONE	NONE	I	-
T08	1.9		>1.9	0.0	0.0	0.0	0.0	0.0		FSMS	PHY	SOME	MANY	I-II	+

Partial Key: Pen = Penetration, RPD = redox potential discontinuity; OSI = Organism Sediment Index; Succ Stage = Successional Stage.

3.3.2 Apparent Color RPD Layer Depth

The grand mean depth of the apparent color redox potential discontinuity (RPD) layer for 2002 was 1.9±0.8 (±SD) cm (Table 3-1). In 2001, the grand mean was 3.4±2.1 cm. The shallowest RPD layer was 0.9 cm at station T04 and deepest was 4.4 cm at station R38 (Table 3-1). Stations with shallower RPD layer depths tended to be closest to the shore along the mainland and furthest from the mouth of the harbor. Shallower RPD values (<1.5 cm) were associated with what appeared to be organically enriched dark-gray silty sediments without much indication of bioturbation—for example, stations R33 in outer Quincy Bay and T04 in Dorchester Bay. Physical processes or a combination of physical and biological processes dominated surface sediments at these shallower RPD layer stations. Benthic community structure at station T04 consistently showed the signs of being the most stressed of all harbor stations (see Section 5). Organic content of sediment at T04 was also highest of all stations (see Section 4). Organic loading and periodic low dissolved oxygen likely prevent deep bioturbating fauna, resulting in a shallow RPD layer depth at T04. The six stations with deeper RPD layer depths (>3.0 cm) also consisted of silty sediments but tended to be close to the mouth of the harbor and away from the mainland (R07, R17, R38, R39, R45, and R53). Surface sediments at these deeper-RPD-layer stations were dominated by a combination of physical and biological processes and characterized by a high degree of bioturbation. For example, stations R07, R39, and R45 had dense *Ampelisca* spp. tube mats (defined as more than 50 tubes in one image) and other evidence of well-developed infaunal communities (Table 3-1).

Ampelisca spp. were the primary biogenic structure builders responsible for deepening RPD layer depths. They occurred at 38 stations (63%) in sandy to silty sediments and formed tube mats in at least one replicate image at 13 stations (22%) across a broad band from the outer harbor to the western ends of Deer Island Flats, Long Island, Peddocks Island, and Hull Bay. Where *Ampelisca* spp. tube mats occurred, mean RPD depths were significantly deeper (2.3±0.19 cm, mean±SE) than at stations without *Ampelisca* spp. (1.5±0.15 cm), but RPD layer depths at stations with *Ampelisca* spp. at less than tube mat densities were not different (1.9±0.15 cm) from either stations with mats or from stations without *Ampelisca* spp. (ANOVA, $p = 0.010$). This indicated that the overall level of bioturbation in 2002 may have been lower than in 2001 when there were significantly deeper RPD layers at stations with *Ampelisca* spp. (both mat and non-mat densities). While the percentage of stations with mat densities declined in 2002, *Ampelisca* spp. populations in the harbor expanded station coverage slightly relative to 2001. The presence of *Ampelisca* spp. at 63% of stations in 2002 is higher than the recent low of 52% in 2000, but lower than the 96% of station coverage in 1996 (Figure 3-1). Overall, the *Ampelisca* spp. tube mats continued to trend downward, but the presence of *Ampelisca* spp. may be trending upward.

Subsurface biogenic activity in the form of infaunal burrows convoluted and extended the depth of the RPD layer at most stations with *Ampelisca* spp. mats below the depth of the mean RPD layer. The maximum extent of oxic sediments was 10.6 cm at R07 on Deer Island Flats. These deep oxic sediments were evidence that a large, deep-burrowing infaunal assemblage was present.

3.3.3 Biogenic Activity

The sediment surface at 15% (9 of 60) of the stations was dominated by biological processes as evidenced by the widespread biogenic activity associated with successional Stage II and III fauna (Table 3-1). Evidence that a combination of biological and physical processes was active in structuring bed roughness occurred at 45% (27 of 60) of the stations. Physical processes dominated at 40% (24 of 60) of the stations. Tubes and feeding structures were the predominant biogenic features.

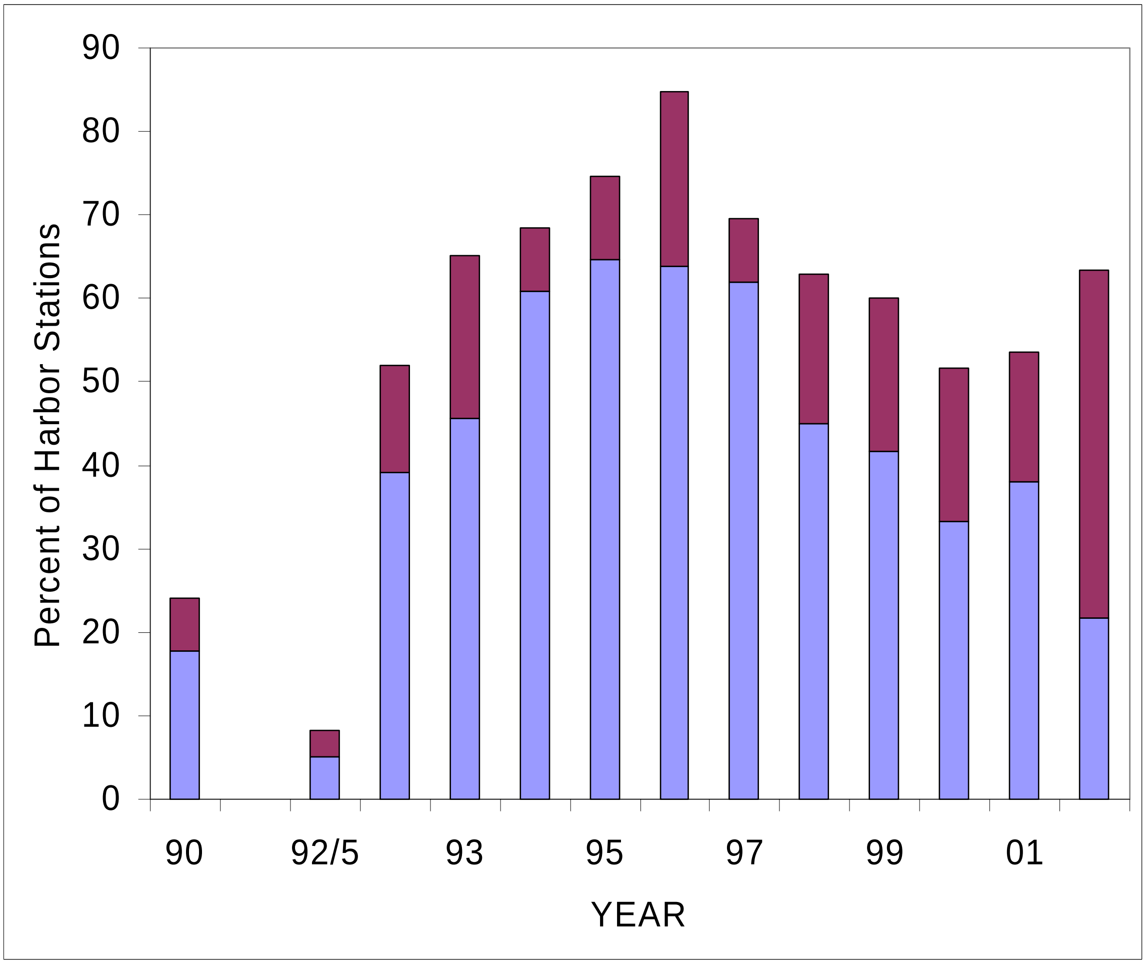


Figure 3-1. Histogram showing the percentage of stations with *Ampelisca* spp. tube mats (bottom portion of bar) and the total percentage of stations with *Ampelisca* spp. tubes.

Subsurface biogenic structures and activities were also highest at stations where biological processes dominated surface features. For example, the number of infaunal organisms per image was significantly higher at stations with *Ampelisca* spp., both tube mats (4.8±0.49 infauna/image, mean±SE) and non-mat densities (3.0±0.35 infauna/image), than at stations without *Ampelisca* spp. (1.0±0.38 infauna/image) (Welsh ANOVA, p = <0.0001). The highest number of infauna was seen at station R39 on the outer edge of Quincy Bay with a mean of 9.7 infauna/image. Similar patterns of higher mean values at biologically dominated stations were observed for number of burrows, oxic voids, and anaerobic voids per image.

The distribution of subsurface biogenic features (burrow structures, infaunal organisms, water- and gas-filled voids) was sediment related and tended to mirror patterns seen for surface biogenic features as shown above. Burrows were observed at 92% of all stations with a grand mean of 4.7±2.8 burrows/image (±SD). Infauna occurred at 87% of all stations (2.7±2.2 infaunal/image) and was more abundant in finer sediments than in coarser sediments. Gas-filled voids, indicative of high rates of organic loading to the sediments, occurred at five stations (R02, R04, R11, R49, and T04). Water-filled voids occurred at 80% of all stations with a distribution pattern similar to burrows and infauna (Table 3-1). Water-filled voids are biogenic structures typically created by larger infauna. Seventy-five percent of all voids were oxic voids, apparently filled with oxidized sediment indicating current or recent infaunal activity; and 25% were anaerobic voids, apparently relic voids from previous infaunal activity or created by some physical processes such as sediment cracking during profiling of the sediment.

3.3.4 Successional Stage and Organism Sediment Index

The apparent modal successional stage indicated that the infaunal communities in the harbor area ranged from pioneering Stage I to equilibrium Stage III. The high degree of biogenic sediment reworking observed at many stations was consistent with both intermediate Stage II (observed at 78% of stations) and equilibrium Stage III communities (53%). Evidence of Stage I communities occurred at 43% of the stations with 50% of these stations having only signs of Stage I and the other 50% signs of both Stage I and II communities. Stations R43 southeast of Thompson Island and T04 in inner Dorchester Bay, both with a Stage I designation, also had the poorest infaunal community structure of all stations (see section 5).

The range of the Organism Sediment Index (OSI) from 1.0 to 9.0 at harbor stations indicated a wide range of environmental conditions affecting infaunal community development. Lowest values occurred at fine-sediment stations that had little evidence of infaunal activity, for example stations R43 and T04 (Table 3-1). The highest OSI values were also at fine-sediment stations, but at those with high levels of infaunal activity, for example stations R07 and R38. About half of the harbor stations (48%) had OSI values <6, which indicated communities that were under some form of moderate stress, possibly related to organic loading or physical disturbance of the benthic habitat (Rhoads and Germano 1986). Most of these lower OSI stations were located in the inner bays and away from the harbor mouth. Higher OSI stations occurred in a broad band that arced through the mid harbor running from Deer Island to Hull Bay, basically following the distribution of *Ampelisca* spp. tube mats. The source of stress to the benthos at both types of harbor stations (traditional and reconnaissance) is most likely a combination of physical processes such as hydrodynamics and sediment transport at coarse-sediment stations (for example, station R06) and high rates of sediment accumulation and organic enrichment at muddy stations (for example, station T04).

3.4 Discussion

3.4.1 Comparison of 2002 and 2001 results.

While conditions at almost all harbor SPI stations for 2002 reflected the strong influence of biological processes in structuring surface sediments with tubes and other biogenic structures, there was a reduction in the overall level of predominance in biological processes. In 2001, the sediment surface at 53% of the stations appeared to be dominated by biogenic structures such as tubes, feeding pits, and defecation mounds; in 2002 this declined to 16% (Table 3-2). Physical processes, as indicated by bedforms, coarse-grained sediment, or soft deep-penetration sediments, increased in predominance from 26% of stations in 2001 to 41% in 2002. No station that was classified with either physical or a combination of biological and physical processes structuring surface sediments in 2001 was classified as biologically dominated in 2002.

Table 3-2. Summary of change from 2001 to 2002 in processes structuring surface sediments at Boston Harbor stations. Values are percent of stations (number of stations in parentheses). Stations R34 and R35 were not included because no useable images were obtained there in 2001.

		2002			
		Biological	**Bio/Phy**	**Physical**	**Total**
2001	**Biological**	16 (9)	24 (14)	14 (8)	53 (31)
	Bio/Phy	0	14 (8)	7 (4)	21 (12)
	Physical	0	5 (3)	21 (12)	26 (15)
	Total	16 (9)	43 (25)	41 (24)	

The areal distribution of *Ampelisca* spp. tube mats contracted in 2002 to 22% of the stations. Relative to previous years, the high was 65% in 1995 and the low was 18% in 1990. But the total number of stations with *Ampelisca* spp. tubes at any density, from a few tubes to mat densities, increased in 2002 relative to the last three years (Figure 3-1). From 2001 to 2002, 18 stations lost tube mats and two stations gained mats. Mats were present in both years at 11 stations (Table 3-3).

Table 3-3. Presence of *Ampelisca* spp. tubes at a given station in 2001 and 2002, cross-classified by density category. Values are number of stations (percent in parentheses). For example, 11 stations did not have *Ampelisca* spp. tubes in either 2001 or 2002. The total number of stations classified was 57. In 2001, no useable images were obtained at Stations R34 and R35, and R36 was disturbed.

		2002			
		None	**Few to Many**	**Mat**	**Total**
2001	**None**	11 (19)	8 (14)	0	19 (33)
	Few to Many	3 (5)	4 (7)	2 (4)	9 (16)
	Mat	5 (9)	13 (23)	11 (19)	29 (51)
	Total	19 (33)	25 (44)	13 (23)	

The overall level of biogenic activity appeared to be lower in 2002 relative to 2001. The low occurrence of epifaunal organisms noted in 2001 relative to 2000 continued into 2002 and large infauna were more prevalent in the 2001 relative to 2002 despite there being significantly more infauna per image in 2002. The infauna in 2002 appeared to be smaller and likely pioneering Stage I individuals. The two principle parameters dependent on biogenic activity, RPD and OSI, were both significantly lower in 2002 relative to 2001 (Table 3-4).

Table 3- 4. Comparison of quantitative biogenic activity parameters between 2001 and 2002. Only stations with data for both years were included in the analysis, which used Student's t-test for paired data. Excluded stations were R34, R35, and R36.

Parameter	Year	Mean Difference	Alpha probability
Infauna (#/image)	2001 < 2002		
	1.2 < 2.7	1.6±0.24	<0.0001
Burrows (#/image)	2001 < 2002		
	3.9 < 4.7	0.8±0.36	0.024
Oxic Voids (#/image)	2001 = 2002		
	1.8 = 1.5		0.427
RPD (cm)	2001 > 2002		
	3.4 > 1.9	1.6±0.28	<0.0001
OSI	2001 > 2002		
	6.8 > 5.8	1.0±0.34	0.027

Benthic habitat quality, as measured by the OSI, decreased at most stations in 2002 with the mean decrease being 1.0±0.34 (mean±SE). The principal reason for the decline in the OSI was the corresponding decrease in the depth of the apparent color RPD layer in 2002 relative to 2001 (1.6±0.24 cm). Station T04 continued to have the poorest habitat quality and community structure (see section 5) in 2002, with gas voids, an apparent color RPD layer of 0.9 cm, and OSI of 1.0.

3.4.2 Long-term

Over the last 11 years, benthic habitat quality as measured by sediment profile imaging did not appear to change appreciably. Major disturbance events in 1991, including the severe storm that affected the entire region in October and the abatement in December of sewage sludge discharge from near Long Island (Blake *et al.* 1998), which took place prior to the current SPI sampling design may have set the stage for current patterns in benthic habitat quality. Interestingly, stations with poorest habitat quality in 1989/90 (Blake *et al.* 1993) continued to have poor quality habitat in 2002. For example, stations T04 and R43, both in Dorchester Bay, had long-term average OSI values <3 (Table 3-5). A general impression of benthic habitat conditions at the eight traditional stations from 1991 to 2002 can be seen in Figures 3-2a to 3-2c.

From 1992 to 2002, the two basic measures of benthic habitat quality, the Organism Sediment Index (OSI) of Rhoads and Germano (1986) and the depth of the apparent color RPD layer oscillated about the long-term mean with no yearly mean being more than 17% and 45% from the grand mean, for OSI and RPD respectively (Figures 3-3 and 3-4). The largest decline in OSI from the long-term mean was 17% in 1999 and the largest increase was 16% in 2001. The grand mean OSI was 5.8±2.8 (mean±SD). The 2002 mean OSI was very close to the long-term mean (Figure 3-3). For the RPD, the largest decline of 25% occurred in 1994 and the largest increase of 45% in 2001. The grand mean RPD layer depth was 2.3±1.64 cm. In 2002, the mean RPD was below the grand mean (Figure 3-4).

Variation in the annual mean OSI and RPD was associated with changes in the apparent successional stage of the infauna, with much of the benthic habitat quality determined by the spatial distribution of Stage I and Stage II seres (Blake *et al* 1998). The long-term predominance of pioneering successional Stage I seres at most inner harbor stations tended to reduce yearly averages in OSI and RPD, whereas the predominance of intermediate Stage II to equilibrium Stage III seres at most outer harbor stations tended to increase these parameters. The tube-building amphipods in the genus *Ampelisca*, associated with the intermediate successional stage (Stage II) and good benthic habitat quality, were key to following temporal change in benthic habitat quality. Data from grab samples indicated that *Ampelisca* spp. tube mats were not broadly distributed in Boston Harbor prior to 1993 (Figure 3-1). In 1992 there was about a doubling of stations with *Ampelisca* spp. tube mats from <20% to about 40%. From 1993 to 1995 the spatial distribution of tube mats increased to >60% of stations and remained at >60% until 1998 when the distribution of tube mats started to contract and dropped to <40% by 2000 and has remained <40% through 2002.

Overall, general benthic habitat quality at the R and T stations was similar from August 1992 to 2002 with minor variation from year to year (Blake *et al.* 1998; Kropp *et al.* 2000, 2001, 2002; this report). Using the OSI as a surrogate for habitat quality, none of the stations exhibited monotonic long-term trends, either improving or declining (Table 3-1). However, there were six stations that consistently had OSI values ≥6 (R11, R12, R28, R29, R45, and R46), the break point for stressed/not stressed habitat conditions (Rhoads and Germano 1986), and five stations with consistently <6 OSI values (R06, R10, R36, R43, and T04). Station T04 located in inner Dorchester Bay consistently had low OSI values with three years of negative values, indicative of a highly stressed habitat, likely from organic loading. Stations R11, R12, R45, and T03 along the western side of Long Island had consistently good habitat quality, and had the highest overall averages. Station T03, located <1.4 km from the Deer Island treatment plant which discharged combined sludge and effluent until September 2000, had the fourth highest long-term average OSI index (8.5) of all monitoring stations (Table 3-5).

Table 3-5. Summary of Organism Sediment Index (OSI) by year.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Mean
T04	2.6	2.0	-4.3	-5.3		2.0	-5.3	2.0	1.3	2.7	1.0	-0.1
R43	3.3	2.3	2.5	4.7	2.0	2.7	2.0	2.0	2.0	2.5	3.0	2.6
R36				3.7		2.3	3.0	2.0	4.3		4.0	3.2
R33	5.3	2.7	0.7	7.0	4.0	2.7	2.3	3.0	3.0	3.0	3.3	3.4
R35	7.4	2.7	-0.7	5.0	5.0	2.7	2.7	3.7	3.0		5.3	3.7
R34	7.0	3.0	-1.0	6.7	5.7	3.3	2.3	2.7	2.3		5.3	3.7
R52	8.0			2.0	4.0		3.5	3.0	3.0	3.0	3.7	3.8
R10		2.0	3.0	3.3	4.0	5.0	5.3	4.3	3.7	3.7	3.7	3.8
T07	2.0	2.7	3.7	7.5	4.3	3.0	2.7	4.0	3.7	5.7	3.0	3.8
R49	3.5			3.0	7.7	1.0	3.0	3.3	2.3	5.3	5.7	3.9
R53	6.0			3.0	5.3		2.5	2.0	3.7	4.0	5.0	3.9
R51	7.0			2.7	4.7		3.0	3.3	2.3	3.3	5.7	4.0
R06		6.0	4.0	3.3				2.3	3.3	5.0	4.3	4.0
R42	5.0	4.7		6.0	3.0		3.7	2.3	5.0	3.0	4.0	4.1
R37	5.7	2.7	4.3	7.0	3.0	3.3	4.0	2.3	3.7	3.0	6.7	4.2
R08					8.0	4.5	3.5	3.7	2.7	3.0	5.0	4.3
T01	3.0	5.3	4.0	5.0	4.3	4.0	3.7	2.3	3.7	4.7	8.0	4.4
R19	7.0	5.7	4.0	4.0	6.0		3.0	2.0	3.0	4.7		4.4
R15	8.7	3.0	2.3	11.0	5.0		3.0	2.0	3.0	3.5	3.0	4.5
R48				5.0	5.7		3.0	2.3	4.0	4.7	7.0	4.5
R04		2.7	4.3	7.0	5.0	3.0	4.7	2.3	2.7	10.0	3.7	4.5
T02	3.0		5.7	6.7	5.0	4.3	3.7	3.0	3.0	5.0	6.3	4.6
R32	6.0	4.0	6.3	5.0	5.3	2.7	3.7	3.0	4.0	6.0	5.0	4.6
T05A				6.7	4.3	5.5	4.3	2.3	3.0	7.0	4.5	4.7
R44				7.0	3.3	2.7	5.7	3.3	3.0	7.3	6.3	4.8
R26	7.7	5.0	9.3	4.3	5.7		3.0	3.3	3.3	3.3	6.3	5.1
R41	6.3	2.3	5.3	11.0	6.0	5.0	4.7	2.3	3.3	3.7	7.0	5.2
R40	6.0	3.5	4.0	10.7	8.0		2.7	3.3	4.7	4.0	6.0	5.3
R05	7.7	4.0	6.0	7.0	5.7		5.7	3.0	3.7	5.7	5.7	5.4
T08	7.0	7.0	4.5	8.0			3.7	2.7	4.7	6.0		5.4
R09		5.3	5.0	2.7	7.3	6.3	4.7	8.0	3.7	7.7	4.0	5.5
R13	6.8	5.3	10.0	6.7	5.0		2.7	2.0	2.3	10.0	4.3	5.5
R14	5.7	5.3	4.7	7.0	5.0	11.0	5.3	2.3	3.3	9.0	4.3	5.7
R17	6.0	4.3	5.3	8.0	3.0	4.7	4.3	8.7	6.3	4.7	8.7	5.8
R02	6.7	3.0	5.7	2.0	4.7	9.3	5.7	5.7	7.0	10.0	4.7	5.9
R16		8.0	2.5	6.3	9.0	8.0	4.0	5.7	5.3	8.7	3.7	6.1
R23		9.0	6.7	6.0	8.0		3.0		5.3	5.3		6.2
R50	8.0			7.3	11.0	5.7	7.7	2.7	5.0	5.3	4.7	6.4
R30	8.0	5.7	7.3	6.3	6.7	5.7	8.3	6.3	5.7	6.0	4.7	6.4
R03		3.7	6.7	7.7	8.0	8.3	6.7	3.3	4.0	9.0	8.0	6.5

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Mean
R25	7.3	7.7	4.3	5.3	9.0	8.7	10.0	8.0	3.3	8.0	6.0	7.1
T06	6.7	9.3	5.0	6.3	5.7	7.7	7.7	7.7	6.3	9.0	6.3	7.1
R22		9.0	5.7	7.3	4.3	10.3	7.7	4.5	6.0	10.0	6.3	7.1
R27	9.0	4.3	7.0	6.3	8.0	6.0	10.3	6.3	6.7	8.7	6.3	7.2
R39	8.3	6.7	8.7	7.0	6.3	6.3	9.0	3.7	5.3	10.0	8.7	7.3
R38	7.7	5.3	4.7	8.7	6.3	9.7	6.7	9.0	4.7	9.7	9.0	7.4
R07		2.7	6.0	7.3	8.3	10.7	6.7	9.3	9.3	10.0	9.0	7.9
R47	4.7			8.7	7.0	10.3	9.3	9.0	10.0	5.5	7.0	7.9
R20		9.3	5.5	11.0	7.3	10.3	4.0	9.0	7.7	10.0	6.3	8.0
R18		9.0	5.7	8.3	7.7	9.7	10.7	9.0	5.3	9.0	6.0	8.0
R29	7.3	8.0	8.7	8.0	10.3	6.7	10.0	7.0	7.3	8.7	6.7	8.1
R24	8.0	9.0	5.0	9.0	9.7		7.3	9.7	8.0	10.0	5.7	8.1
R21		9.0	8.0	9.0	7.3	10.0	9.3	5.7	8.0	8.7	6.7	8.2
R28	9.0	6.3	10.0	6.7	9.7	7.3	9.7	8.3	7.3	10.0	6.3	8.2
R46				8.0	10.3	7.7	9.0	6.3	7.7	10.0	7.0	8.2
R31	5.3	10.3	8.0	7.3	8.7	9.0	9.0	8.7	6.7	10.0	8.0	8.3
T03	8.3	11.0	5.5	9.7	9.7	10.3	5.7	8.3	9.0	9.0	6.7	8.5
R45	9.0			9.7	9.7	9.7	7.7	7.7	8.3	10.0	8.3	8.9
R11		8.7	9.0	11.0	8.3	9.7	9.7	9.0	8.3	8.3	7.3	8.9
R12		6.7	10.0	10.3	8.0	10.0	11.0	9.0	9.3	9.0	7.0	9.0
N	40	46	46	59	56	45	59	59	60	57	57	
Mean	6.4	5.5	5.2	6.5	6.4	6.4	5.4	4.8	4.9	6.7	5.7	
SE	0.30	0.38	0.43	0.37	0.29	0.45	0.39	0.35	0.28	0.35	0.23	
Median	6.9	5.3	5.3	7.0	6.0	6.3	4.7	3.3	4.0	6.0	6.0	
Min	2.0	2.0	-4.3	-5.3	2.0	1.0	-5.3	2.0	1.3	2.5	1.0	
Max	9.0	11.0	10.0	11.0	11.0	11.0	11.0	9.7	10.0	10.0	9.0	

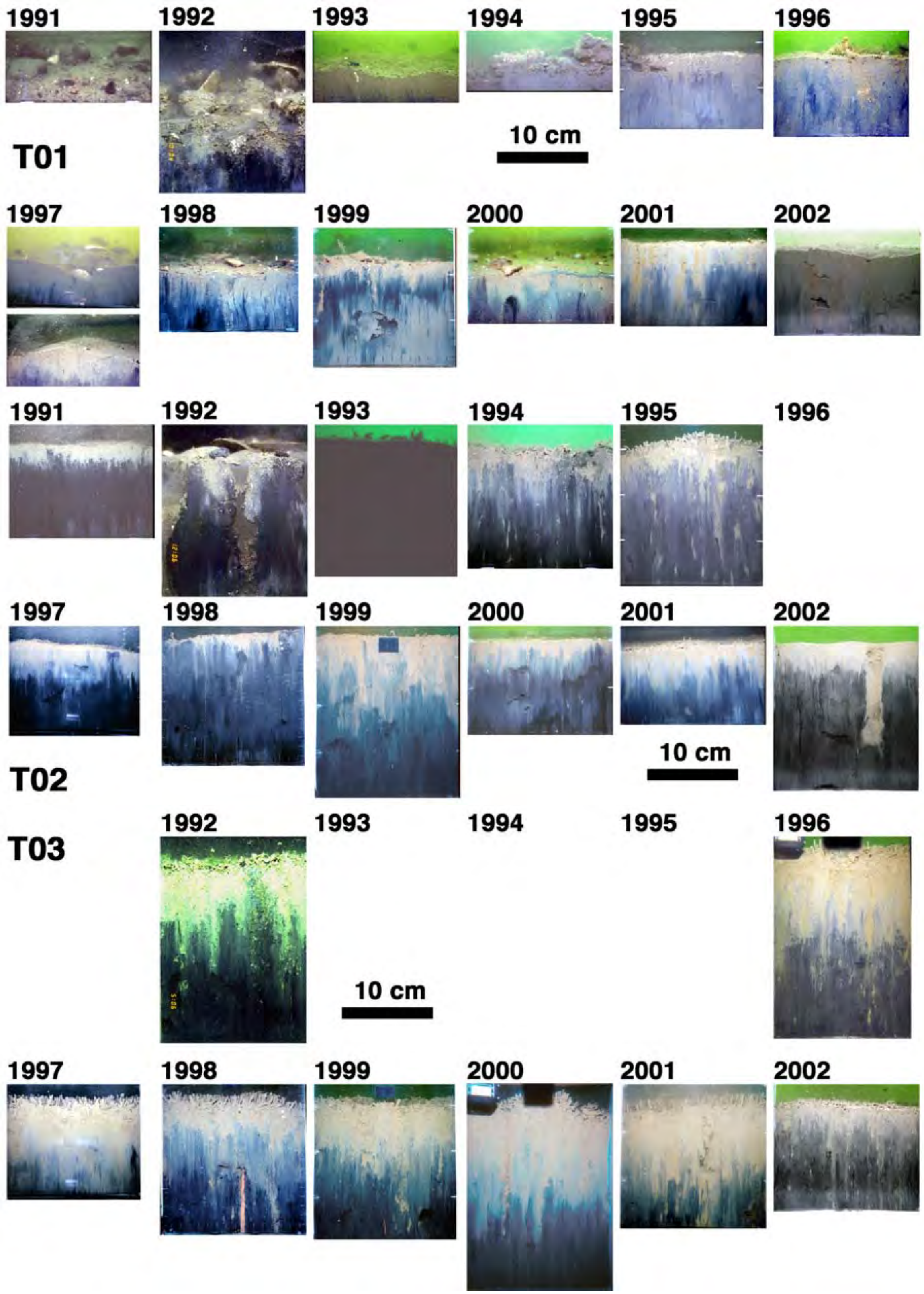


Figure 3-2A. Representative SPI from T01, T02, and T03. Images are digitally enhanced.

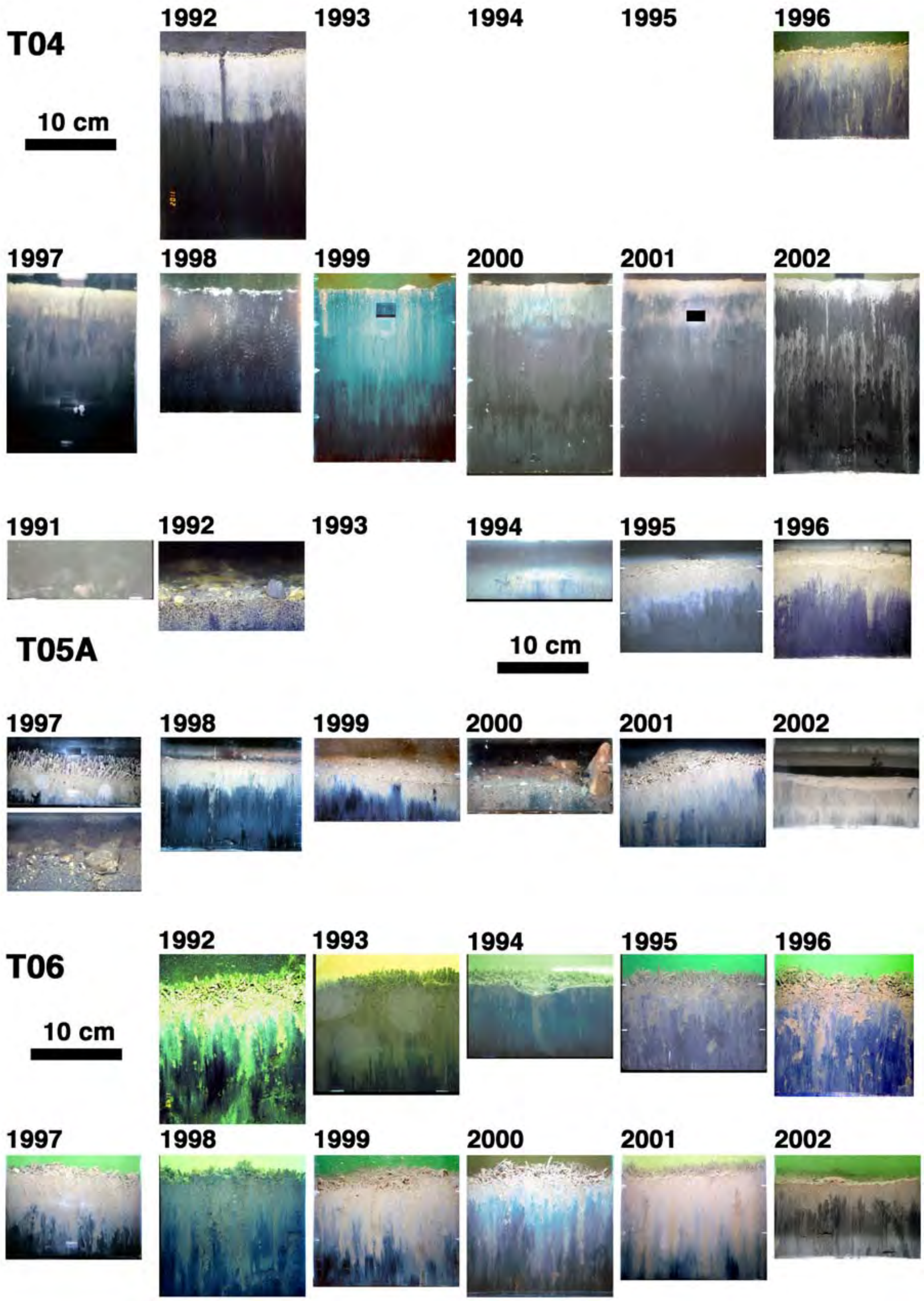


Figure 3-2B. Representative SPI from T04, T05A, and T06. Images are digitally enhanced.

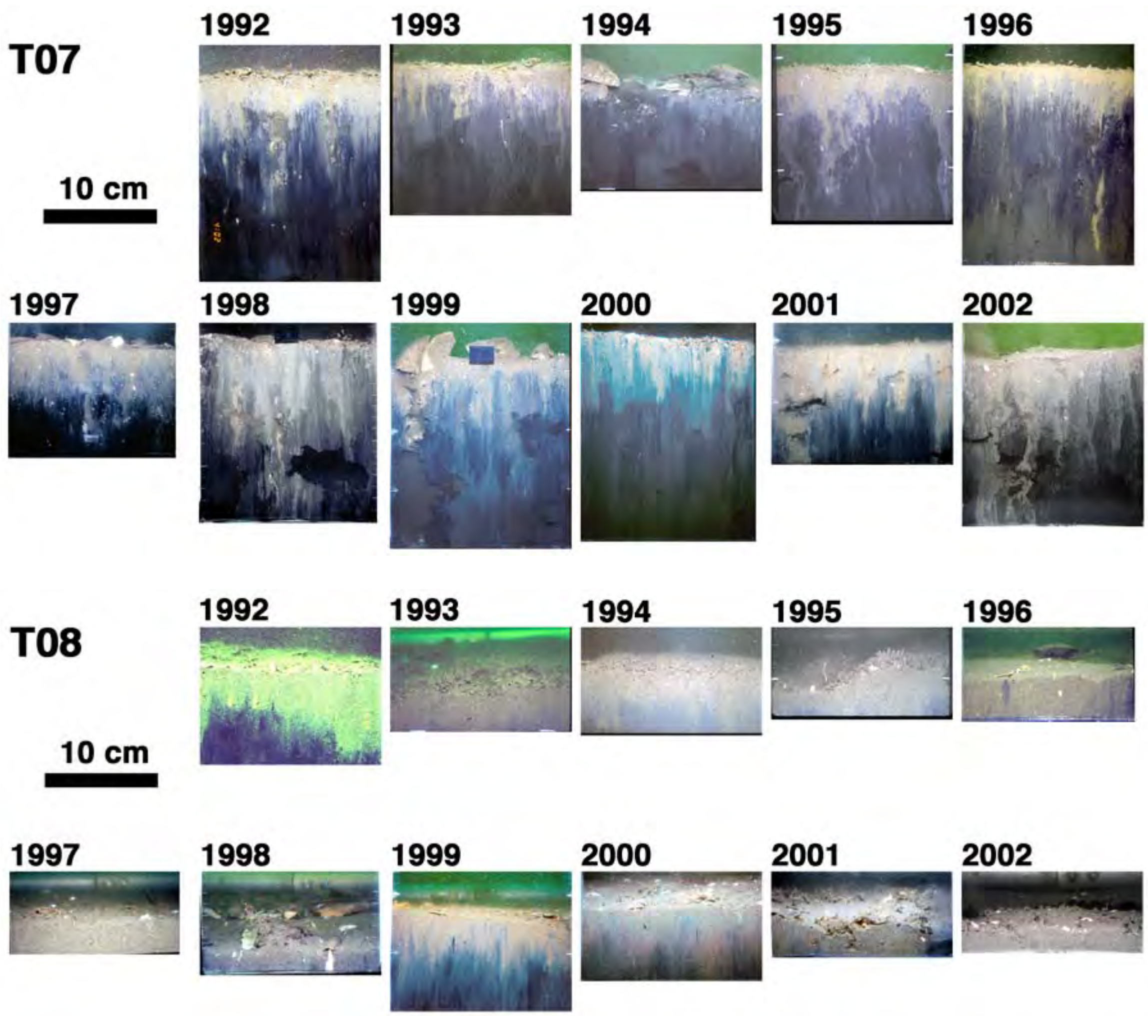


Figure 3-2C. Representative SPI from T07 and T08. Images are digitally enhanced.

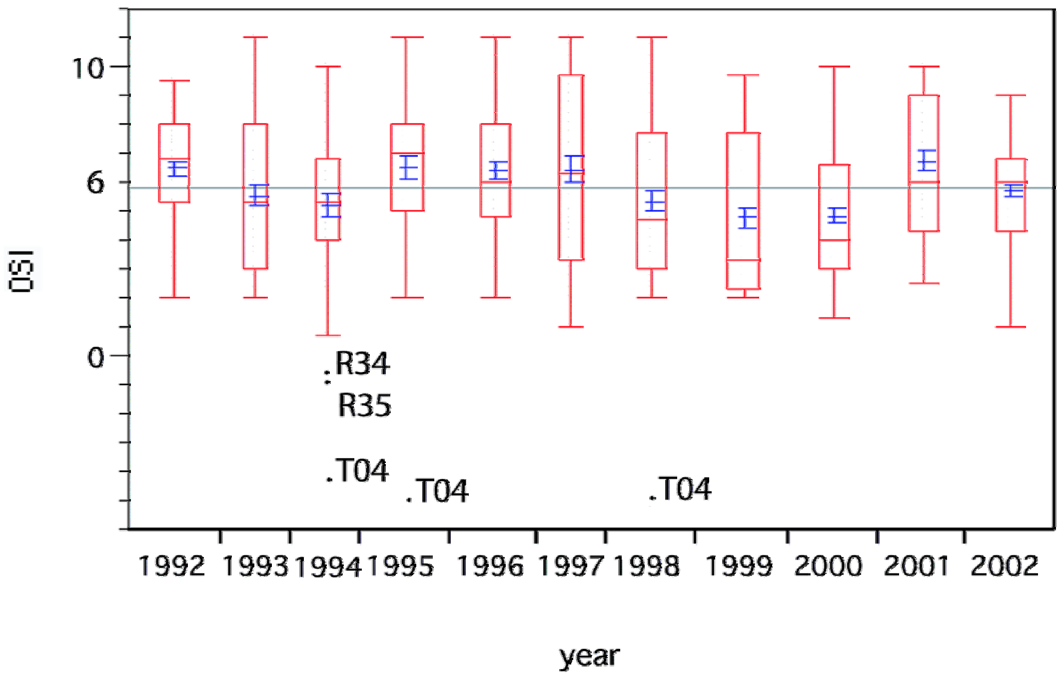


Figure 3-3. Organism Sediment Index (OSI) summarized by year for all harbor stations. Box is interquartile range (IR), bar is median, whiskers are 2IR or data range, and smaller bar within the box is mean and standard error. Outliers (2IR) are labeled. Horizontal line is grand mean for all years.

Outliers:	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
				R15	T03						
				R20	R28						
				R18	R45						
				R21	R50						
			R12	T03	R46			R17	R12		
			R11	R45	R24			R12	R11		R38
		R21	R13	R11	R29		R11	R20	TO3		R07

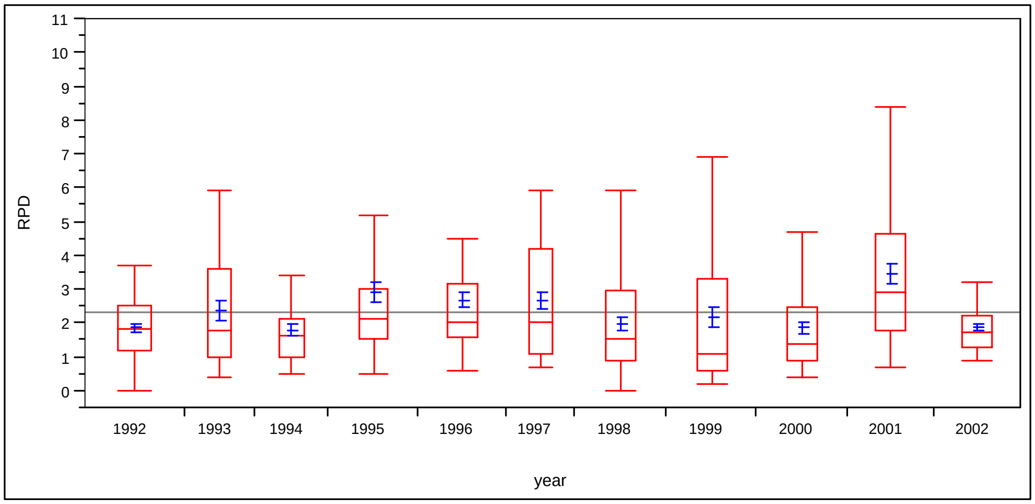


Figure 3-4. Apparent color RPD layer depth (cm) summarized by year for all harbor stations. Box is interquartile range (IR), bar is median, whiskers are 2IR or data range, and smaller bar within the box is mean and standard error. Horizontal line is grand mean for all years. Outlier stations (2IR) are shown above the figure and were all above the grand mean.

4.0 2002 SEDIMENT PROPERTIES

by Deirdre T. Dahlen and Carlton D. Hunt

4.1 Methods

4.1.1 Laboratory Analyses for Ancillary Measurements

Laboratory procedures followed those outlined in the Benthic Monitoring CW/QAPP (Williams *et al.* 2002). Summaries of the procedures are provided below.

Grain Size—Samples were analyzed for grain size by following the sequence of wet and dry sieving methodologies of Folk (1974). Data were presented in weight percent by size class. In addition, the gravel:sand:silt:clay ratio and a numerical approximation of mean particle size and sorting (standard deviation) were calculated. Grain size determinations were made by GeoPlan Associates.

Total Organic Carbon (TOC)—Samples were analyzed for TOC by using a coulometric carbon analyzer following SOP AMS-2201 (formerly AMS-TOC94)[1]. Data were presented on a percent dry weight basis. TOC determinations were performed by Applied Marine Sciences, Inc.

***Clostridium perfringens*—**Sediment extraction methods for determination of *C. perfringens* spores followed those developed by Emerson and Cabelli (1982), as modified by Saad (1992). Data are reported as colony-forming units (cfu) per gram dry weight of sediment. This analysis was performed by MTH Environmental Associates.

4.1.2 Statistical Analyses and Data Treatments

Statistical Analysis—Microsoft Excel® and JMP® were used to perform correlation analyses on sediment grain size, TOC, and *C. perfringens* data to examine the relationships among parameters. Probability values were taken from Rohlf and Sokal (1969).

Data Treatments— In the discussion of sediment grain size, TOC and *C. perfringens* data, numerous terms are used to describe the data. See Appendix C1 for a list of the terms referenced in this report. Appendix C1 also summarizes data analyses (e.g., correlations) and evaluations (*e.g.*, histogram plots) performed on the data to assess temporal and spatial trends over time.

4.2 Results and Discussion

Bulk sediment results for all Traditional station samples collected in the April and August surveys were evaluated separately to examine spatial and temporal characteristics. All sediment results discussed here are station mean values expressed as dry weight.

[1] SOPs AMS-2201 and AMS-TOC94 are comparable to EPA Method 9060, as modified by the NIST Benthic Surveillance Program. The change in SOP numbers from AMS-TOC94 to AMS-2201 simply represents a change in the numbering system, not a change in procedure.

4.2.1 Grain Size 1991–2002

With few exceptions, patterns in sediment composition in 2002 were within the ranges observed in previous years. Further, sediment type did not vary substantially at Traditional stations between April and August sampling periods. Grain-size composition for representative Traditional Harbor stations T01, T02, and T05A, sampled in August (1991–2002) are shown in Figure 4-1; complete data are provided in Appendix C2. T01, T02, and T05A represent those stations where the infaunal communities have changed the most since the abatement of sludge and effluent discharges to the harbor (see Chapter 5, this report).

April—Patterns in sediment composition at all Traditional stations in 2002 were within the ranges observed for previous years except that T01 was comprised of slightly finer-grained sediment compared to earlier years (1993–2001; Appendix C2, Figure C2-1). Patterns in sediment composition were consistent at some stations and more variable at others (Appendix C2). Coarse-grained sediment was generally found at stations T01 and T05A, located in the northern parts of the harbor near Deer Island, and T08 located further south near Hull. Sediment found at stations T02, T03, T06, and T07 had more variable grain-size composition over time, ranging from sandy to silty sediment. Sediment found at T04 was siltier (69% to 97% fines) relative to all other sampling locations within the harbor, likely because T04 is located near an area of combined sewer overflow (CSO) discharge and is in an area of sediment focus/carbon deposition for the harbor (Lefkovitz et al. 1999).

August—Patterns in sediment composition in 2002 at all Traditional stations were not substantially different from previous years except that T06 was comprised of slightly coarser-grained sediment compared to earlier years (1991–2001; Appendix C2, Figure C2-6). Patterns in sediment composition were consistent at some stations and variable at others (representative stations shown in Figure 4-1; all data in Appendix C2). As was observed during the April surveys, stations T01, T05A, and T08 were generally comprised of coarse-grained sediment. Sediment from T02, T03, T06, and T07 had more variable grain-size composition over time, ranging from sandy to silty sediment. Consistent with April findings, sediment from T04 was siltier (68% to 97% fines) than sediment from other Traditional harbor locations.

Comparison of April and August Surveys—Sediment composition at Traditional locations was generally consistent between April and August sampling events (Appendix C2). For example, coarse-grained sediment was found at T01, T05A, and T08 during both April and August sampling periods. While the overall sediment type did not change between April and August surveys, the degree to which sediment composition varied over time was higher at selected stations in April compared to August surveys. For example, sediment found at T02, T07, and T08 had more variable grain-size composition during April surveys compared to August (Appendix C2, Figures C2-2, C2-7, and C2-8). In contrast, patterns in sediment composition at station T01 in April were less variable over time relative to August surveys (Appendix C2, Figure C2-1). Stations T03, T04, T05A, and T06 generally showed equally variable patterns in sediment composition over time during April and August surveys (Appendix C2).

4.2.2 Total Organic Carbon 1991–2002

Concentrations of TOC at most Traditional stations in 2002 fell within the range of values measured during previous years (Figure 4-2, detailed line charts for each station are included in Appendix C2). Since 1999, however, concentrations of TOC measured during August surveys have decreased at most Traditional stations compared to 1991–1998 levels, although the decreases are small and effects on the biological community may be subtle as a result. The variability among the TOC data has decreased on

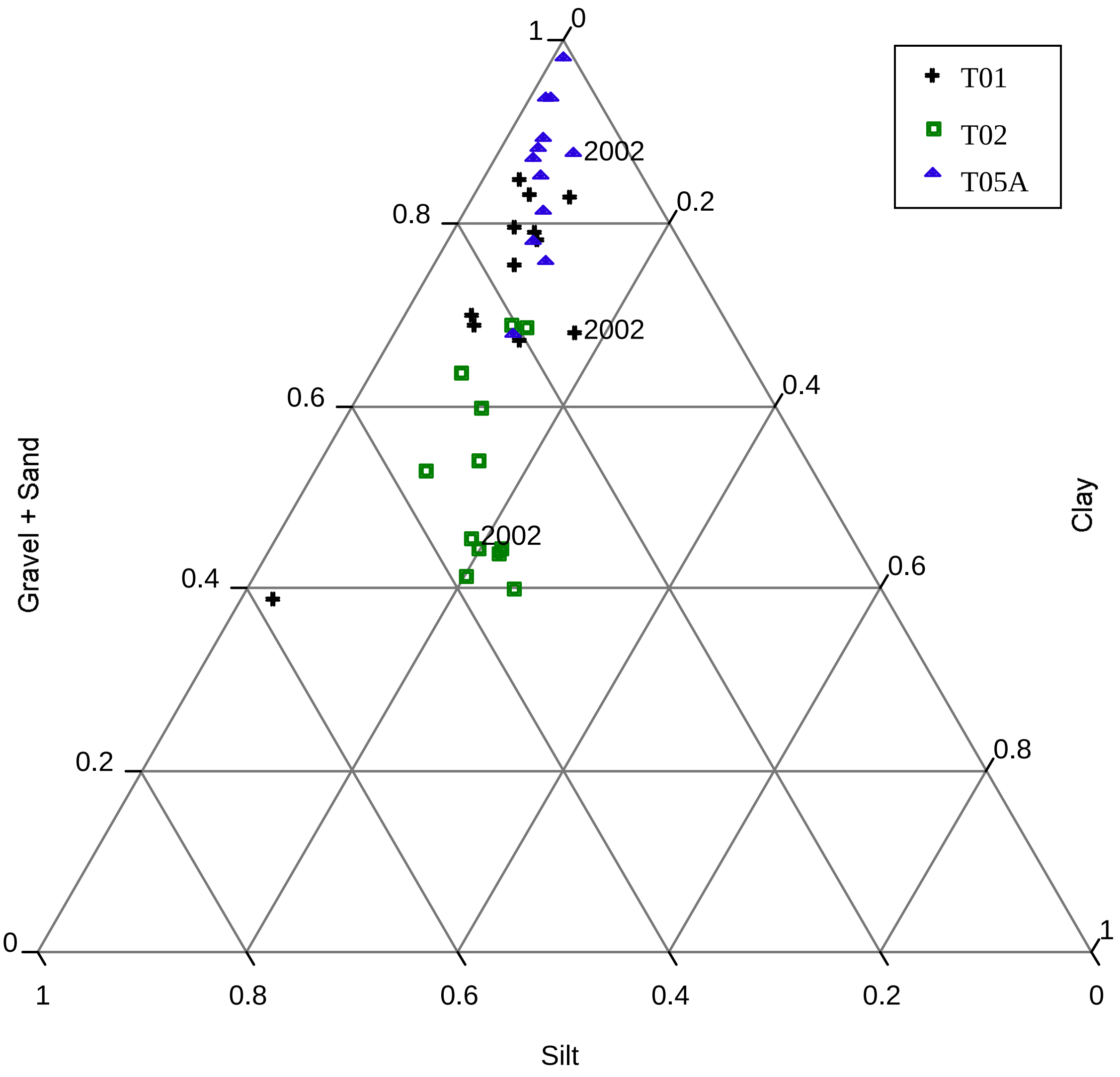


Figure 4-1. Grain-size composition of sediment collected at representative traditional stations in September 1991 and August 1992–2002. Stations depicted here correspond to locations where the infaunal communities have changed the most since the abatement of sludge and effluent discharges to the harbor (YR2002 data are labeled).

a harbor-wide basis since 1999, likely due to the cessation of sludge disposal in 1991 and subsequent improvements in sewage treatment[2].

Sediment from station T04 had the highest concentrations of TOC across all years, followed by T03, T07, and T06, in that order. In contrast, the lowest concentrations of TOC were found in sediment from T05A and T08. Concentrations of TOC were consistent over time at some stations, and more variable at others (Figure 4-2, Appendix C3).

April—Concentrations of TOC found in sediment from T03 and T07 were more consistent over time compared to other stations, with coefficient of variation (CV) less than 13% among TOC values from 1993 to 2002 (Figure 4-2a, Appendix C3). Concentrations of TOC found in sediment from T01, T02, T04, and T06 were moderately variable (CVs ranged from 21% to 26%) over time (Appendix C3). Sediment from T05A and T08 had among the lowest concentrations of TOC (frequently <1%), and as a result were also more variable over time (CVs greater than 40%, Appendix C3). Sediment from station T04 consistently had the highest concentrations of TOC over time (Figure 4-2a). This is consistent with the grain-size data, which showed that sediment from T04 contained more fine-grained material compared to other sampling locations throughout the harbor.

August—Concentrations of TOC at stations T01 and T06 decreased slightly in 2002 compared to 1991–2001 values; however the decrease was small and effects on the biological community may be subtle (Figure 4-2b, Appendix C4).

Concentrations of TOC found in sediment from T02, T03, and T07 were more consistent over time compared to other stations (CVs less than 14%, Appendix C4). T01, T04, and T06 were more variable, with CVs ranging from 29% to 36% among TOC concentrations from 1991 to 2002 (Appendix C4). Consistent with the April TOC findings, concentrations of TOC were generally lower in sediment from stations T05A and T08, resulting in greater variability among TOC concentrations over time at those stations (CVs greater than 39%, Appendix C4).

Sediment from station T04 had the highest levels of TOC over time, peaking in 1998 with the highest measured value (8.86% TOC) among all sampling years. The unusually high TOC content observed at T04 in 1998 (Figure 4-2b) likely resulted from localized inputs from a major storm event that occurred in June 1998 (Lefkovitz *et al*. 1999). Concentrations of TOC at station T04 decreased in 1999 indicating that the system had returned to previous conditions (Figure 4-2b), possibly due to the rapid sedimentation rate (approximately 4 cm/year) observed at the site by Gallagher *et al.* (1992) and Wallace *et al.* (1991).

Comparison of April and August Surveys—At low temperatures, organic carbon is expected to build up in the sediment, whereas at higher temperatures TOC is degraded more rapidly, lowering concentrations (Blake *et al*. 1998). Thus, TOC is generally expected to be higher in April than in August. Findings presented in Kropp *et al.* (2002a) for the 2001 harbor data did not support this, in that TOC concentrations on a harbor-wide basis were not substantially different between April and August. Results from 2002 were no different. Approximately 30% of the stations sampled from 1993 to 2002 had similar TOC concentrations between April and August (*i.e.*, relative percent difference (R%D) within 10%), and the remaining stations showed an almost even distribution where approximately half the time April TOC values were higher and the other half August values were higher.

To further evaluate trends between April and August TOC concentrations, station mean data by year were compared to the one-to-one correlation expected if no processes were operating to modify the TOC

[2] Primary treatment in 1995, secondary treatment in 1997, and diversion of Nut Island influent to Deer Island in 1998.

between April and August (Figure 4-3). TOC data from station T04 in 1998 were excluded from the correlation analysis because of the suspected localized influence from a June 1998 storm event. Indeed, TOC concentrations at T04 are clearly higher relative to values measured at other stations (Figure 4-3), and, as a result, skew the correlation analysis resulting in a smaller slope value ($y = 0.68x + 0.61$) than had T04 data from all years been excluded ($y = 0.85x + 0.32$). These data suggest that TOC loss occurs on a harbor-wide basis, but losses at T04 are greater than in other parts of the harbor (slope equals 0.68 vs. 0.85), likely because T04 is located in a shallow, warm area with highly enriched TOC concentrations. If there is a trend of higher TOC concentrations in April compared with August values, then the trend is subtle and within the noise of the data.

Seasonal TOC Evaluation— Kropp *et al.* (2002a) evaluated TOC data from the Benthic Nutrient Flux (Tucker *et al.* 2003) and Traditional Harbor programs to determine if there was a seasonal peak in TOC levels in the Harbor[3]. TOC results from 2002 continued to support the findings presented in Kropp *et al.* (2002a). That is, an evaluation of the distributions of individual flux and traditional harbor TOC results for all years within a given sampling month, and mean TOC results within a given sampling month and year did not conclusively show a seasonal peak in harbor TOC values (Appendix C-5). An evaluation of monthly, grand mean flux, and traditional harbor TOC results, however, did suggest a seasonal TOC cycle, with a build-up in carbon content in the sediment in early spring, an apparent peak in May, followed by decreasing carbon content from July through October (Figure 4-4). Seasonal changes in TOC were small (<0.4%), and effects on the biological community may be subtle as a result.

A potential cause of the seasonal peak in the carbon content of the sediments in May is carbon input to the system from winter/spring blooms (Figure 4-4), although over the baseline period the harbor did not have a distinctive nor consistent spring bloom (*i.e.*, productivity) (Libby *et al.*, 2003). An alternative cause is an imbalance in production versus metabolism of organic carbon (slower metabolism in the winter, higher metabolism in the summer) in the system over the annual cycle. Regardless of the cause, the apparent reduction in carbon content of the sediments in the late summer and early fall months likely reflects TOC consumption by bacteria and infauna (Figure 4-4). Results also showed that carbon content at Traditional Harbor stations was fairly similar between April and August surveys (Figure 4-4), supporting the evaluation above. Evidently, the seasonal peak in carbon content in the system cannot be measured from the Traditional Harbor surveys given that the apparent peak does not occur until May and the Traditional Harbor surveys occur only in April and August.

It is also important to note that the seasonal productivity cycle appears to be changing at the mouth of Boston Harbor, from the pattern of summertime blooms seen over the baseline period to winter/spring peaks seen following diversion of treated effluent discharge from the harbor to the Massachusetts Bay outfall (Libby *et al.*, 2003). The switch from a summertime dominated bloom to winter/spring peaks may influence future seasonal TOC results.

[3] The evaluation was limited to those stations that represented similar geographic regions of the harbor, *i.e.*, BH02 and BH03 from the Flux Program and T02 and T03 from the Traditional Harbor program. As a result, the evaluation does not represent the entire harbor system, rather only some of the northern areas. Also, the location of BH03 has varied slightly, and from 1995 to 1997 was sampled as BH03A, a station located about 200 m west of BH03. However, according to Tucker (2001), these two stations (BH03 and BH03A) are comparable for the purpose of discussing long-term trends.

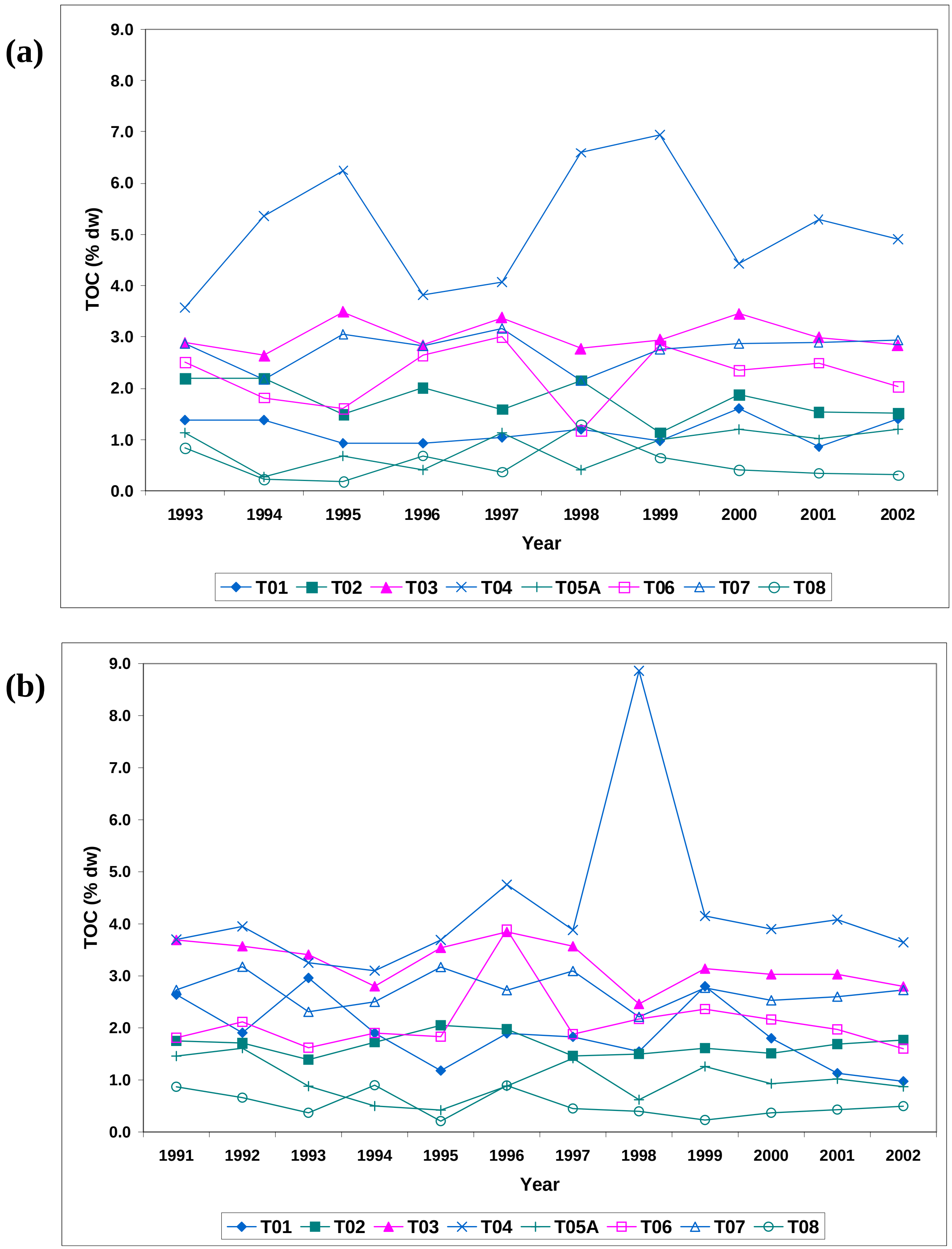


Figure 4-2. Total organic carbon content in sediment collected at Traditional stations in April 1993–2002 (a) and September 1991 and August 1992–2002 (b).

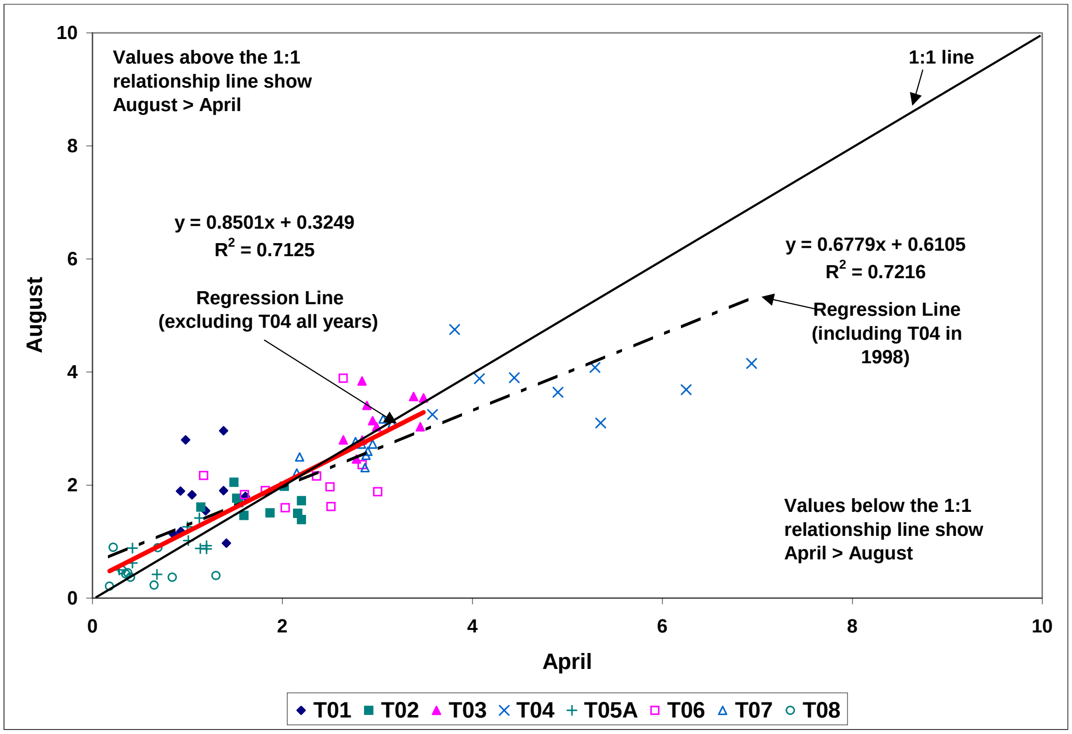


Figure 4-3. A seasonal comparison of April and August total organic carbon content in sediment collected from Traditional stations from 1993 to 2002.

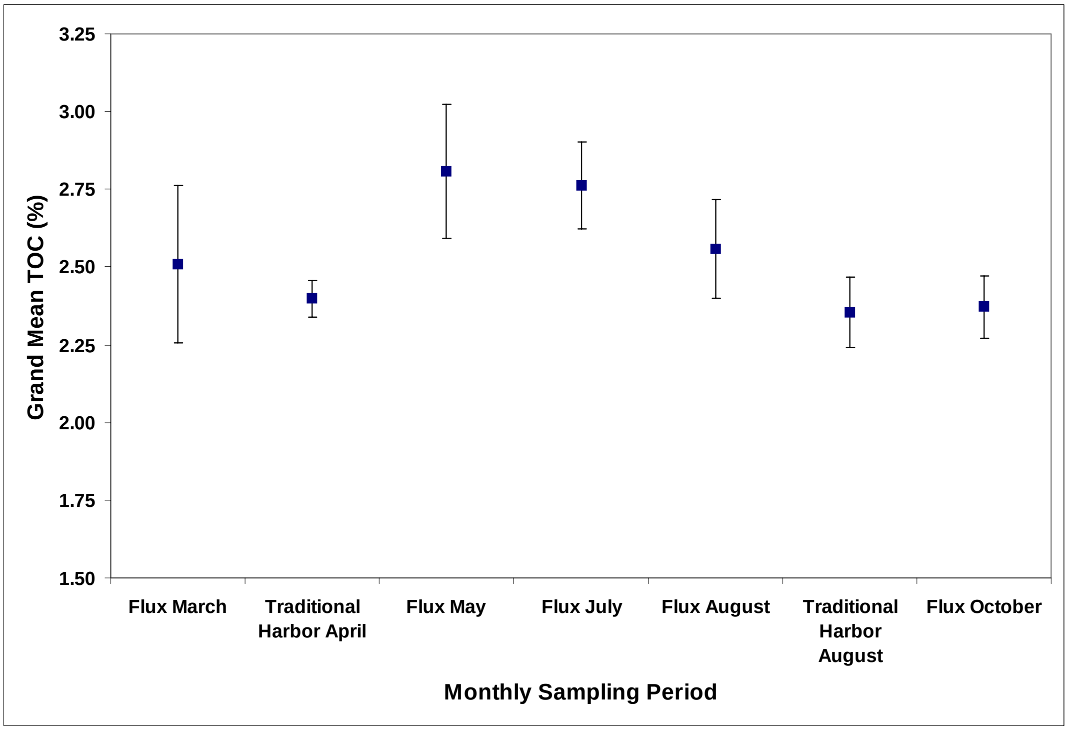


Figure 4-4. Comparison of monthly grand mean TOC results from the flux program (BH02, BH03, and BH03A only) to Traditional Harbor April and August (T02, T03 only), by sampling period (1993–2002). Error bars represent the standard error around the mean.

4.2.3 *Clostridium perfringens* 1991–2002

The abundance of *C. perfringens* has decreased on a harbor-wide basis since 1999, and the system appears to be more stable as evidenced by decreased variability among the data (Figure 4-5; detailed line charts for each station are included in Appendix C2). Major facility improvements implemented to clean-up Boston Harbor (*e.g.,* secondary treatment coming on-line in August 1997 and the cessation of Nut Island discharges in July 1998) likely contributed to the reduced abundance and temporal variability observed in the system.

Abundance of *C. perfringens* in 2002 fell within the range of values measured during previous years at all stations except T04 (April only), T05A, and T06, where concentrations decreased, albeit by a relatively small amount (Figure 4-5; Appendices C3 and C4). Notably, stations T05A and T06 are located near areas where effluent discharge has been discontinued.

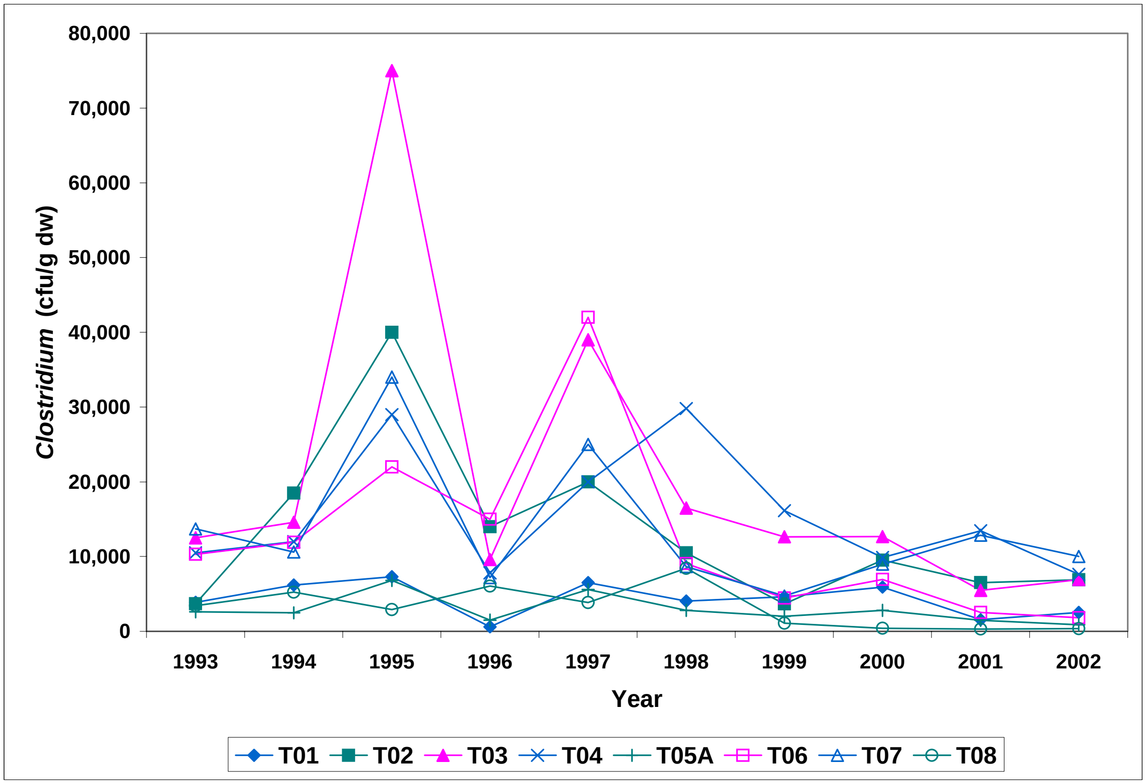
April—Stations T01, T05A, and T08 generally had the lowest *C. perfringens* concentrations (< 8,500 cfu/g dw) relative to other Traditional stations (Figure 4-5a, Appendix C3). In contrast, stations sampled in 1995 generally had the highest *C. perfringens* concentrations relative to all other sampling years (Figure 4-5a, Appendix C3). *C. perfringens* concentrations in April 1996 appear unusually low at all stations except T08 (Figure 4-5a, Appendix C2).

August—With few exceptions (*i.e.,* T01 in 1991; T05A in 1991 and 1992), stations T01, T05A, and T08 had lower *C. perfringens* concentrations (< 10,000 cfu) across all years relative to other Traditional stations (Figure 4-5b; Appendix C4). In contrast, stations sampled in 1991 and 1996 had the highest *C. perfringens* concentrations relative to all other sampling years (Figure 4-5b). *C. perfringens* concentrations were high at station T03 in 1991, decreased to less than 1,000 cfu in 1992, increased again in 1993 remaining somewhat consistent until 1997 (20,000 to 30,000 cfu), then decreased again in 1998 and remained fairly stable and low through 2002 (Figure 4-5b). While *C. perfringens* concentrations at T03 in 1991 were high relative to other Traditional stations, the concentrations are not unusually high considering that sludge discharges were ongoing at that time (personal communication, Ken Keay, MWRA).

Comparison of April and August Surveys—April and August station mean values (raw and normalized to percent fines, percent clay, and TOC) were determined for each sampling year and season. A scatter plot depicting April (x-axis) and August (y-axis) *C. perfringens* concentrations was prepared to evaluate seasonal trends for common sampling years from 1993 to 2002 (Figure 4-6a). With the exception of some stations in 1993 (*i.e.,* T01, T02, T03, T06) and all stations in 1996, *C. perfringens* concentrations were consistently higher at most Traditional stations in April relative to August values, as evidenced by a slope value of less than one from the regression analysis (Figure 4-6a). As previously noted, *C. perfringens* concentrations in April 1996 appear unusually low at all stations except T08.

To remove variability associated with changes in grain size and TOC, *C. perfringens* concentrations were normalized to percent fines, clay, and TOC. Normalization did not improve the correspondence. In fact the correspondence was degraded, suggesting that grain size and TOC factors had less influence on *C. perfringens* concentrations, at least prior to facility improvements (pre-1998) implemented to clean up the harbor (representative correlations using data normalized to percent fines and TOC shown in Figures 4-6b and 4-6c, respectively).

(a)



(b)

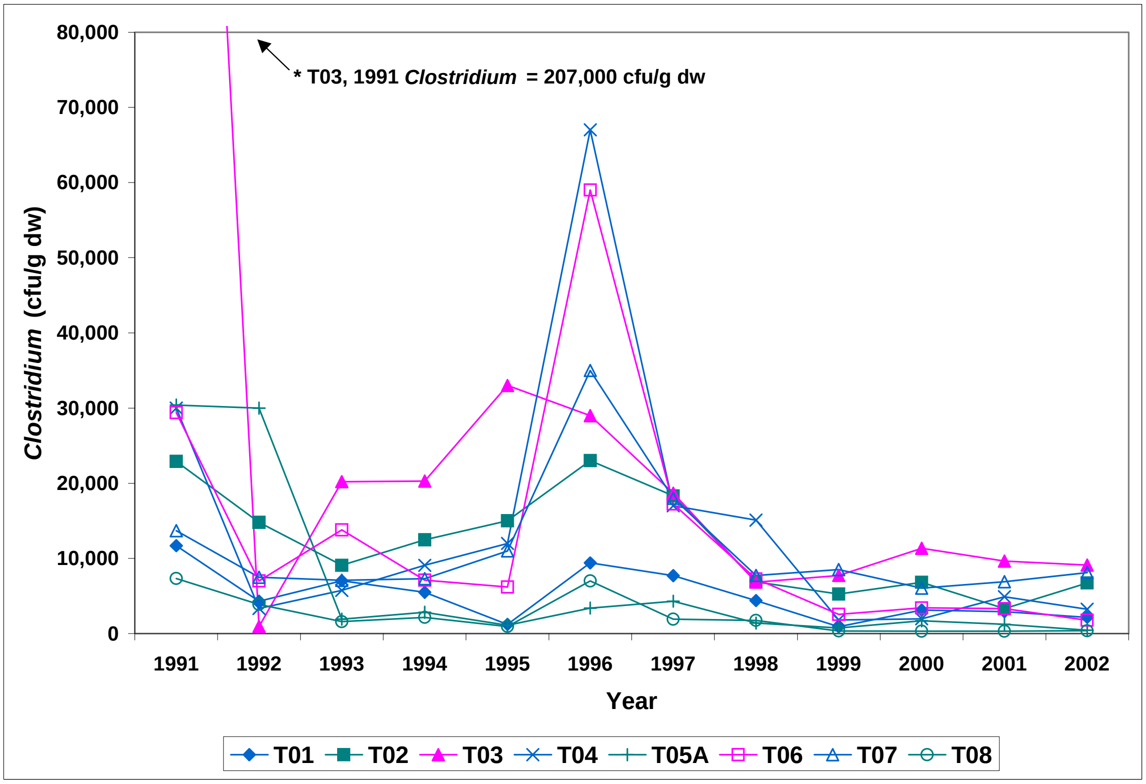


Figure 4-5. ***Clostridium perfringens*** **concentrations in sediment collected at Traditional stations in April 1993–2002(a) and September 1991 and August 1992–2002 (b).**

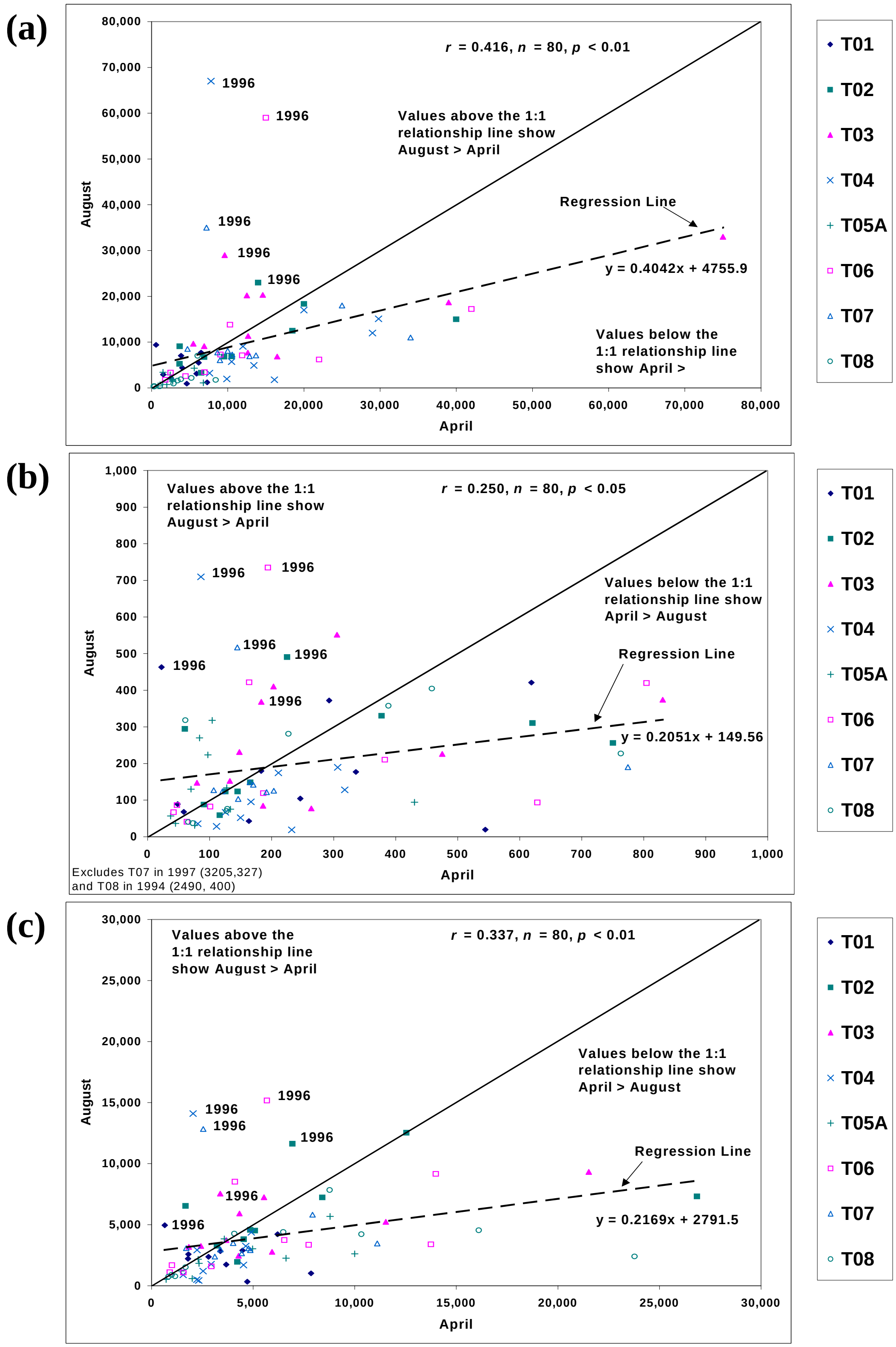


Figure 4-6. Comparison of April and August station mean values for *Clostridium perfringens* from 1993 to 2002. (a) non-normalized data; (b) normalized to percent fines; and (c) normalized to TOC.

4.2.4 Correspondence within Ancillary Measurements

Station mean values from all April and August surveys (Appendices C3 and C4) were included in the correlation analysis to evaluate the correspondence within bulk sediment properties and against *C. perfringens* over time (1991–2002). Consistent with the 2001 harbor data (Kropp *et al*, 2002a), the correlation analysis was performed using data from two sampling periods: pre-1998 and post-1998. 1998 was chosen as the cut-off because it represented the first full year after implementation of facility improvements (*i.e.,* secondary treatment and cessation of discharge from Nut Island). Data from September 1991 were excluded because 1991 represented a period of sludge discharge to the Harbor. T04 was also excluded from the correlation analysis given that this station represents an area with highly localized source(s) (*e.g.*, CSO) compared to other Traditional stations. Grain size results for T07 and T08 in 1997 were also excluded because these data are anomalous compared to the corresponding TOC and *C. perfringens* data, suggesting that the grain-size samples may have been switched.

Results from the correlation analysis were consistent with findings presented for the 2001 harbor data (Kropp *et al.* 2002a). Grain size remained strongly correlated to TOC during both sampling periods (pre-1998 and 1998-2002), indicating that the relationship between grain size (percent fines) and TOC did not change much over time (Table 4-1). In contrast, the correspondence between *C. perfringens* and bulk sediment properties (percent fines, TOC) was stronger after 1998 compared to earlier years (Table 4-1, Figures 4-7 and 4-8). This suggests that the factors (*i.e.,* percent fines, TOC) that influence *Clostridium* variability are more closely coupled to *C. perfringens* after implementation of facility improvements. The high *C. perfringens* concentrations observed during 1995 and 1997 (see Section 4.2.3) are also evident in the correlation analysis (Figure 4-7 b,c).

The correlation analysis also showed that the strength of the correspondence between *C. perfringens* and bulk sediment properties was similar (R%D between r values <10%) between April and August surveys (Table 4-1). This suggests that the system is more coherent in response, indicating that the processes that regulate carbon and *C. perfringens* are more similar.

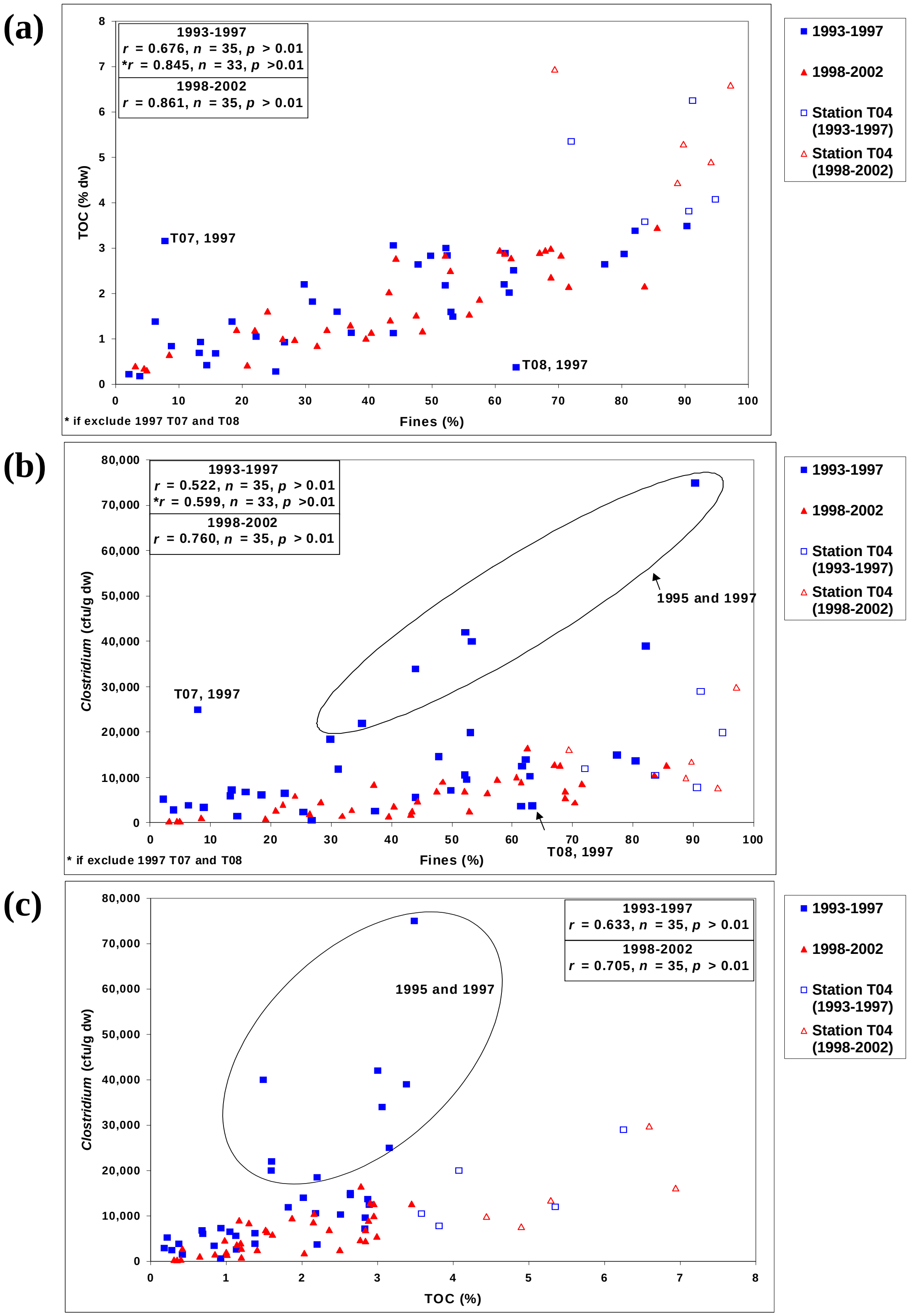


Figure 4-7. Correspondence among grain size, TOC and *Clostridium perfringens* at Traditional Stations during April Surveys, 1993–2002. (a) percent fines by TOC; (b) *Clostridium perfringens* by percent fines; (c) *Clostridium perfringens* by TOC.

(a)
(b)
(c)

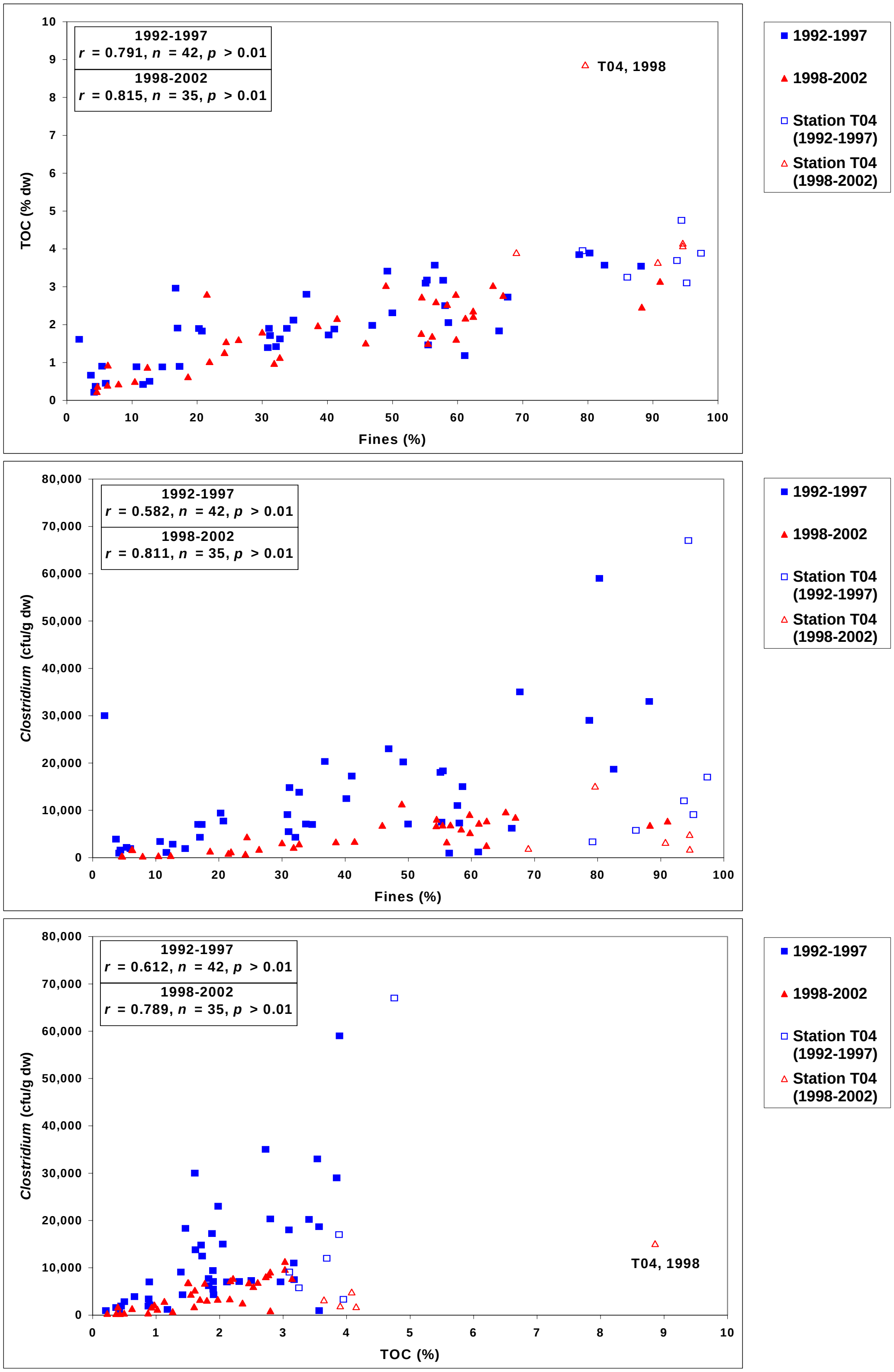


Figure 4-8. Correspondence among grain size, TOC, and *Clostridium perfringens* at Traditional Stations during August Surveys, 1992–2002. (a) percent fines by TOC; (b) *Clostridium perfringens* by percent fines; (c) *Clostridium perfringens* by TOC.

Table 4-1. Correspondence within bulk sediment properties and against *Clostridium perfringens* for April and August surveys, excluding Traditional station T04.

Sampling Period	TOC by Fines		*Clostridium perfringens* by Fines		*Clostridium perfringens* by TOC		
	r	***p***	***r***	***p***	***r***	***p***	***n***
April Surveys							
1993–2002 [a]	0.849	<0.01	0.485	<0.01	0.526	<0.01	68
1993–1997[a]	0.845	<0.01	0.599	<0.01	0.622	<0.01	33
1998–2002	0.861	<0.01	0.760	<0.01	0.705	<0.01	35
August Surveys							
1992–2002	0.785	<0.01	0.483	<0.01	0.582	<0.01	77
1992–1997	0.791	<0.01	0.582	<0.01	0.612	<0.01	42
1998–2002	0.815	<0.01	0.811	<0.01	0.789	<0.01	35

[a] Grain size data for stations T07 and T08 in April 1997 are “anomalous”; results excluded from the correlation analysis.

4.3 Conclusions

Grain size: There were no substantial changes to the spatial and temporal characteristics of sediment grain size in 2002 from previous years (1991–2001). Further, patterns in sediment composition between April and August surveys were similar across all common sampling years. In general, grain size and TOC were strongly correlated across all sampling years, indicating that the relationship between grain size and TOC did not change over time.

TOC: The spatial and temporal distribution of TOC concentrations in 2002 was not substantially different from earlier years (1991–2001). Since 1999, however, concentrations of TOC measured during August surveys have decreased at most traditional stations compared to 1991–1998 levels, although the decreases are small and effects on the biological community may be subtle as a result. The variability among the TOC data has decreased on a harbor-wide basis since 1999, likely due to the cessation of sludge disposal in 1991 and subsequent improvements in sewage treatment.

An evaluation of flux and traditional harbor TOC results did suggest a seasonal peak in TOC in May, indicative of inputs to the system from a winter/spring bloom or an imbalance in production versus metabolism of organic carbon in the system over the annual cycle. Seasonal TOC decreased from July through October, likely reflecting TOC consumption by bacteria and infauna.

Clostridium**:** The abundance of *Clostridium perfringens* has decreased on a harbor-wide basis since 1999, and the system appears to be more stable as evidenced by decreased variability among the data. Major facility improvements implemented to clean up Boston Harbor likely contributed to the reduced abundance and temporal variability observed in the system. These findings demonstrate that *C. perfringens* continues to serve as a good indicator of the response in sediment from effluent discharge.

The correspondence between *C. perfringens* and bulk sediment properties was stronger after 1998, suggesting that the factors that influence the variability (percent fines, TOC) are more closely coupled after implementation of facility improvements. In addition, the strength of the correspondence between *C. perfringens* and bulk sediment properties is similar between April and August surveys (T04 excluded from correlation). This suggests that the system is becoming more coherent in its overall response, indicating that the processes that regulate carbon and *C. perfringens* are more similar.

5.0 2002 SOFT-BOTTOM INFAUNAL COMMUNITIES

by Nancy J. Maciolek

5.1 Introduction

Eight stations in Boston Harbor were sampled in April and August 2002 for soft-bottom benthic infauna. These stations are termed “traditional” because a full taxonomic analysis of the benthic infauna is performed, rather than a cursory or rapid analysis. With the exception of station T04, the sites sampled since 1991 generally correspond to stations sampled in 1978, 1979, and/or 1982 for the 301(h) and outfall siting programs. Methods used in those earlier studies were different in terms of the size of sample taken and the mesh size of the screens used to process the samples, but those earlier samples do provide some historical benchmark against which to measure the response of harbor communities to relief from the input of sewage sludge and wastewater.

5.2 Methods

5.2.1 Laboratory Analyses

Samples were preserved with formalin in the field, and in the laboratory, were rinsed with fresh water over 300-μm-mesh screens and transferred to 70–80% ethanol for sorting and storage. To facilitate the sorting process, all samples were stained in a saturated, alcoholic solution of Rose Bengal at least overnight, but no longer than 48 h. After rinsing with clean alcohol, all organisms, including anterior fragments, were removed and sorted to major taxonomic categories such as polychaetes, arthropods, and mollusks. After samples were sorted, the organisms were identified to the lowest practical taxonomic category, usually species.

Voucher specimens of each species were kept as part of the MWRA reference collection. During the past contract year, taxonomists from Cove Corporation, who had been entirely responsible for the last several years of identifications, worked closely with the ENSR taxonomists, most of whom had also participated in the early years of the program. Coordination of identifications between the two laboratory groups and discussion of difficult identifications facilitates the generation of a consistent dataset.

As noted in Section 2 of this report, an error in the sorting lab rendered two of the samples collected in April 2002—one infaunal replicate each from T01 and T03—unusable. The two stations were re-sampled in May in order to have the requisite number of samples from each station. Although the time difference in collection of the samples suggests that results should be viewed with caution, the evaluations reported below suggest that the April and May samples were comparable.

5.2.2 Preliminary Data Treatment

Prior to performing any of the analyses of the 2002 and 1991–2002 MWRA datasets, several modifications were made to the database. These were generally similar to those performed in previous years as given in the standard operating procedure (SOP) for this project (Williams *et al.*, 2000) and are summarized in Appendix D1. Calculations of abundance included all infaunal taxa occurring in each sample, whether identified to species level or not, but did not include epifaunal or colonial organisms. Calculations based on species (number of species, dominance, diversity, evenness, cluster and principle components analysis) included only those taxa identified to species level, or those treated as such. For report purposes, *Ampelisca abdita* and *A. vadorum* have been combined with *Ampelisca* spp. in previous years, similarly, *Pholoe minuta* and *P. tecta* have been combined with *Pholoe* spp. The species have been distinguished since 1995 and merging them results in the loss of considerable information. Initial analysis of the 2002 data was conducted with and without these merges, in order to determine the effect of these merges.

Earlier data based on samples collected in 1978, 1979, and 1982 as part of the 301(h) waiver application process were re-assessed for this report. Data for the stations that correspond to the current traditional stations were extracted from the larger data base: eight stations were used, including two representing T02, none for T04, and one for each of the remaining stations. Where possible, species names were updated to reflect those used in the current program. Samples from 1978 and 1979 were taken with a slightly larger grab (0.05-m^2 Ponar) and sieved through a larger mesh (0.5 mm) than is used in the current monitoring program, probably resulting in fewer organisms, and possibly fewer species, extracted from each sample than would be the case if finer-mesh screens had been used. Similarly, samples from 1982 were taken with an 0.1-m^2 Van Veen grab and sieved through 0.5-mm mesh. Because the sample size and handling methods for these samples differed from those used in the current monitoring program, only basic benthic community parameters were calculated (see below) and only general comparisons will be made.

5.2.3 Statistical Analysis

Initial inspection of the benthic data included production of summaries of species densities by sample, tables of species dominance, and lists of numbers of species and numbers of individuals per sample. Data were inspected for any obvious faunal shifts or species changes between stations. Following these preliminary inspections of the data, a series of community parameters was calculated along with multivariate statistics to assess community patterns and structure.

The multivariate programs are included in COMPAH96, originally written by Dr. Donald Boesch and now available from Dr. Eugene D. Gallagher (http://www.es.umb.edu/edgwebp.htm). Patterns in benthic communities were analyzed by cluster analysis using CNESS (chord-normalized expected species shared), which was developed by Gallagher and is related to Grassle and Smith's (1976) NESS (normalized expected species shared). CNESS and NESS include several indices that can be made more or less sensitive to rare species in the community and as such are more versatile than other similarity measures such as Bray-Curtis similarity, which is influenced by dominant species. Differences between CNESS and NESS are detailed in Trueblood *et al*. (1994). Both NESS and CNESS are calculated from the expected species shared (ESS) between two random draws of *m* individuals from two samples. For this project, the optimal value of *m* was determined through use of a program written by ED Gallagher (*findcnm*), and was set at 15 for the 2002 database. Because one replicate from T04 had only 12 individuals, *m* was set at 12 for stations considered individually and for the 1991–2002 database (replicates separate); for the analysis of replicates combined, *m* was set at 20. Results of these analyses were inspected for patterns among and between the different seasons.

Using MATLAB as an operating platform and additional programs written by Dr. Gallagher, several diversity indices were calculated, including Shannon's H′ (base 2), Pielou's evenness values J′, and Fisher's log-series *alpha*. May (1975) demonstrated that Sanders-Hurlbert rarefaction curves, which have been used in previous reports to evaluate diversity in samples of different sizes, are often identical to those produced under the assumption that the distribution of individuals among species follows a log-series distribution. Hubble (2001) considers *alpha* the fundamental biodiversity parameter.

Principal Components Analysis of Hypergeometric probabilities (PCA-H) was also applied to the benthic data. PCA-H is an ordination method for visualizing CNESS distances among samples (see Trueblood *et al.*, 1994 for details). The PCA-H method produces a metric scaling of the samples in multi-dimensional space, as well as two types of plots based on Gabriel (1971). The Gabriel covariance biplot shows the association among species. The Euclidean distance biplot provides a two-dimensional projection of the major sources of CNESS variation. The species that contribute to the CNESS variation can be determined using matrix methods adapted from Greenacre's correspondence analysis (Greenacre, 1984). These species are plotted as vectors in the Euclidean distance biplot.

5.3 Results

5.3.1 Species Composition of 2002 Samples and 1991–2002 Summary

During this past contract year, taxonomists from both contract teams that have worked on the MWRA HOM programs had the opportunity to work together and discuss identifications that had been established and sometimes questioned over the past several years. These discussions resulted in only one or two reidentifications for the Boston Harbor data. Appendix D1 contains detailed information on how various taxa were treated prior to statistical analysis. A list of all species used in the analysis of the samples collected in the Boston Harbor Monitoring Program (1991–2002) is included in Appendix D2.

In 2002, the benthic infauna included 157 species, of which 123 occurred in the spring (April) samples, and 123 (a slightly different assortment) occurred in the summer (August) samples. Ten species (plus one generic-level and one family-level taxon) were recorded for the first time in 2002. These 10 new species included 6 polychaetes, 2 amphipods, 1 nemertean, and 1 crab. Seven species were represented by a single individual (all except the amphipod *Stenothoe* sp. 1, which was represented by two individuals at one station, and the two newly recorded species of *Tharyx*, *T.* sp. A and *T.* sp. B, which each occurred at several stations). New species were found at all of the eight harbor stations, with the most (four species) found at Station T08. One of the newly recorded species was a shell-boring polychaete, *Dodecaceria concharum*, and therefore was not included in the analyses. One of the newly recorded polychaetes, *Scolelepis tridentata*, represents a significant range extension for this species, and is discussed in the section on station T05A.

For the period 1991–2002, a total of 276 valid species have been recorded; 117 of these have 5 or fewer occurrences, including 54 with single occurrences. In addition, 87 taxa that include juveniles, damaged, or otherwise indeterminable animals were also recorded. Finally, 26 taxa that are either parasitic, epifaunal, or otherwise not part of the infaunal benthos and therefore excluded from any analyses, were present in the samples. As detailed in previous reports (*e.g.*, Blake *et al.* 1998, Kropp *et al.* 2002a), annelids are the most abundant infaunal taxon, usually accounting for 50% or more of the organisms collected, followed by amphipod crustaceans and molluscs. Of the species recorded in Boston Harbor, 193 also occur in the HOM Massachusetts Bay samples.

5.3.2 Benthic Community Analysis for 2002

Density, Species Richness, Diversity, and Evenness—Community parameters for the grab samples collected in 2002 at the eight harbor stations are shown in Table 5-1. These calculations are presented both with and without merging the *Ampelisca* species (*A. abdita*, *A. vadorum*, and *A.* spp.) or the *Pholoe* species (*P. minuta*, *P. tecta*, and *P.* spp.) into one taxon per genus in order to investigate whether these mergers significantly impact the results. *Ampelisca* were not identified to species until 1995, and these taxa have always been merged for report purposes (Blake *et al*. 1998, Kropp *et al*. 2002b, *inter alia*). Similarly, the two species of *Pholoe* present in the harbor were not differentiated until 1995 and also have been merged for earlier analyses. The current results show that the differences in the data treatments do not produce significantly different results in the parameters of interest. Even at those stations where *Ampelisca* is most important (T01, T03, T06, and T08), and where the calculated parameters, especially log-series *alpha* differed the most, the differences were not enough to change the overall patterns seen in the data. Therefore, the remaining analyses and discussions pertain to the dataset with *Ampelisca* species combined to *Ampelisca* spp. and *Pholoe* categories combined to *Pholoe minuta*. These merges reduced the number of species analyzed to 155 for the 2002 data and 274 for the 1991–2002 dataset. Also, because the two replicates collected in May had density and abundance values comparable to the April replicates, these samples were included in the remaining analyses.

Table 5-1. Benthic community parameters for samples taken at Boston Harbor Traditional stations in 2002 . Values are presented for *Ampelisca* and *Pholoe* taxa kept separate or merged within each genus.

			***Ampelisca* and *Pholoe* categories kept separate.**					***Ampelisca* and *Pholoe* categories merged as in previous HOM reports.**				
Time	**Sta**	**Sum All Taxa**	**Sum Good Species only**	**No. Taxa**	**H′**	**J′**	**Log-Series *Alpha***	**Sum Good Species only**	**No. Taxa**	**H′**	**J′**	**Log-Series *Alpha***
April	T01	585	563	36	3.77	0.73	8.57	563	35	3.76	0.73	8.26
May	T01	946	904	34	3.98	0.78	6.98	904	34	3.98	0.78	6.98
April	T01	1302	1280	37	2.21	0.42	7.12	1281	37	2.22	0.43	7.12
August	T01	1436	1250	51	3.66	0.65	10.69	1250	50	3.66	0.65	10.43
August	T01	538	470	33	3.69	0.73	8.09	470	32	3.68	0.74	7.77
August	T01	1102	968	45	4.18	0.76	9.77	968	45	4.18	0.76	9.77
April	T02	696	659	23	2.47	0.55	4.63	659	23	2.47	0.55	4.63
April	T02	1052	1012	34	2.41	0.47	6.78	1012	34	2.41	0.47	6.78
April	T02	866	770	34	3.14	0.62	7.28	770	34	3.14	0.62	7.28
August	T02	748	747	33	3.36	0.67	7.07	747	33	3.36	0.67	7.07
August	T02	1014	1005	31	3.27	0.66	6.06	1005	31	3.27	0.66	6.06
August	T02	1857	1847	37	3.07	0.59	6.55	1847	37	3.07	0.59	6.55
May	T03	2891	2826	35	2.41	0.47	5.63	2826	35	2.41	0.47	5.63
April	T03	3408	3241	33	2.41	0.48	5.11	3241	33	2.41	0.48	5.11
April	T03	5977	5375	41	2.78	0.52	6.04	5406	41	2.79	0.52	6.03
August	T03	5501	5494	42	2.87	0.53	6.19	5494	41	2.86	0.53	6.01
August	T03	6039	6028	44	2.78	0.51	6.43	6031	43	2.78	0.51	6.26
August	T03	5486	5475	43	2.78	0.51	6.36	5475	42	2.78	0.51	6.19
April	T04	146	139	12	2.43	0.68	3.15	139	12	2.43	0.68	3.15
April	T04	999	991	11	0.98	0.28	1.73	991	11	0.98	0.28	1.73
April	T04	1971	1952	13	0.99	0.27	1.87	1952	13	0.99	0.27	1.87
August	T04	515	510	12	1.09	0.30	2.20	510	12	1.09	0.30	2.20
August	T04	187	181	8	0.97	0.32	1.71	181	8	0.97	0.32	1.71
August	T04	356	346	9	1.11	0.35	1.69	346	9	1.11	0.35	1.69
April	T05A	1323	1010	42	3.91	0.73	8.85	1010	42	3.91	0.73	8.85
April	T05A	1356	1044	49	4.07	0.72	10.67	1044	49	4.07	0.72	10.67
April	T05A	1649	1231	46	3.94	0.71	9.43	1231	46	3.94	0.71	9.43
August	T05A	693	684	43	4.17	0.77	10.19	684	43	4.17	0.77	10.19
August	T05A	1294	1284	40	3.87	0.73	7.84	1284	40	3.87	0.73	7.84
August	T05A	1053	1036	41	4.09	0.76	8.53	1036	41	4.09	0.76	8.53

Table 5-1. continued.

			***Ampelisca* and *Pholoe* species are kept separate.**					***Ampelisca* and *Pholoe* species are merged as in previous reports.**				
Time	**Sta**	**Sum All Taxa**	**Sum Good Species only**	**No. Taxa**	**H′**	**J′**	**Log-Series *Alpha***	**Sum Good Species only**	**No. Taxa**	**H′**	**J′**	**Log-Series *Alpha***
April	T06	3607	3555	31	2.32	0.47	4.67	3555	30	2.28	0.46	4.49
April	T06	2114	2073	32	2.78	0.56	5.37	2073	31	2.72	0.55	5.17
April	T06	3108	3087	31	2.40	0.49	4.79	3087	30	2.35	0.48	4.61
August	T06	3722	3722	38	2.81	0.54	5.89	3722	37	2.70	0.52	5.71
August	T06	3802	3797	36	2.36	0.46	5.51	3798	35	2.32	0.45	5.33
August	T06	2898	2894	37	2.52	0.48	5.98	2894	36	2.47	0.48	5.79
April	T07	1114	1088	37	2.25	0.43	7.40	1088	37	2.25	0.43	7.40
April	T07	859	850	30	2.22	0.45	6.06	850	30	2.22	0.45	6.06
April	T07	1410	1386	30	1.79	0.37	5.40	1386	30	1.79	0.37	5.40
August	T07	1177	1138	31	2.58	0.52	5.88	1138	31	2.58	0.52	5.88
August	T07	1682	1666	35	2.52	0.49	6.26	1666	35	2.52	0.49	6.26
August	T07	1468	1387	35	2.55	0.50	6.53	1387	35	2.55	0.50	6.53
April	T08	1123	1057	57	4.09	0.70	12.90	1057	56	4.07	0.70	12.61
April	T08	1222	1148	58	4.19	0.71	12.89	1148	58	4.19	0.71	12.89
April	T08	786	740	49	3.99	0.71	11.79	740	48	3.98	0.71	11.48
August	T08	790	785	47	3.70	0.67	10.97	785	46	3.65	0.66	10.67
August	T08	1708	1684	58	3.50	0.60	11.64	1685	57	3.42	0.59	11.39
August	T08	903	884	47	3.43	0.62	10.60	884	46	3.40	0.62	10.31

Density— Densities were highest at stations T03 and T06 in both April and August 2002 (Table 5-1, Figure 5-1). Mean densities in April 2002 ranged from 871 organisms per sample at T02 to 4092 per sample at T03. In August, mean densities of organisms per sample ranged from a low of 353 at T04 to a high of 5675 at T03. Variability among replicates was higher in April than in August, as evidenced by the larger standard errors in April (Figure 5-1). These results are generally comparable to results from previous years: T03 and T06 often exhibit the highest infaunal abundances, while T04 usually has the lowest (Blake *et al*. 1998, Kropp *et al*. 2002b).

Species Richness —The number of species per sample was lowest at T04 in both April and August, ranging from 11 to 13 (mean value of 12.0) in April and 8 to 12 (mean value of 9.7) in August (Table 5-1, Figure 5-1). Station T08 had the greatest number of species in both sampling seasons, with a range of 48 to 58 (mean of 54.0) species in April and 46 to 57 (mean of 49.7) in August (Figure 5-1). Single replicates at T01 and T05A had similarly high values: 50 at T01 in August and 46 and 49 at T05A in April, but the mean values fell below those for T08. This pattern is similar to that seen in previous years, with T04 having the fewest species, and T08, T01, and T05A having the most (Blake *et al*. 1998, Kropp *et al*. 2002b).

Diversity —Mean Shannon diversity was lowest at T04 in both months (1.47 and 1.06 in April and August, respectively) and highest at T08 (4.08 in April) and T05A (4.04 in August). Mean Shannon diversity at stations T02, T03, T06, and T07 were generally comparable and intermediate, ranging from 2.09 to 2.67 in April and from 2.50 to 3.23 in August (Figure 5-1). Diversity as measured by Fisher's log-series *alpha* mirrored the pattern seen with the Shannon index: the lowest mean values in both April and August were recorded at T04 and the highest at T08, with T05A second highest in both months (Table 5-1, Figure 5-1). In 2001, these stations had similar patterns: T04 with the lowest H′ and *alpha* in both spring and summer, and T01, T05A, and T8 with the highest H′ or *alpha* in one season or another (Kropp *et al*. 2002b).

Evenness —The pattern of evenness at the Boston Harbor stations in 2002 followed the patterns discussed above for other parameters. Station T04, with the lowest densities, number of species, and diversity, also had the lowest evenness or distribution of organisms over the few species present (Table 5-1, Figure 5-1). This station is dominated by very few species: an oligochaete in the April collections and a spionid polychaete in the August collections. Similarly, stations T05A and T08 had the highest evenness values in April and August, respectively, with mean values greater than 0.7. Variability in evenness was highest in April, at stations T01 and T04 (Figure 5-1). Evenness values at specific stations have been inconsistent among years; for example, in 2001 the lowest values were seen at T07 in the spring and T05A in the summer, and the highest values were at T01 and T02 in the spring and T08 in the summer (Kropp *et al*. 2002b).

The results of the sediment image profiling (see Chapter 3, this report) generally correspond well with the results from the grab samples. T04 in Dorchester Bay consistently has had the lowest OSI; T03 and T06 often have the highest. In 2002, T01 had an unusually high OSI, reflecting the high diversity seen at this station in August.

Dominant Species —The numerically dominant species at each harbor station in April and August 2002 are listed in Appendix D3. Dominant species at each of the eight stations were essentially similar to those seen in previous years, with only one or two exceptions. The spionid *Prionospio steenstrupi*, which was especially abundant in Massachusetts Bay in 2002 (Maciolek *et al.* 2003), but not a dominant at any Boston Harbor station in recent years, was among the most numerous species at six of the eight stations in April, and at all eight stations in August. Since the beginning of monitoring in 1991, 4594 *P. steenstrupi* have been recorded from the eight harbor traditional grab stations: 43% of these were recorded in 2002. The percent of the infauna represented by *P. steenstrupi* in 2002 ranged from 0.1% at T04 in August to 10.1 % at T02 in August.

The community at T04 remains depauperate compared with the infauna at the other seven stations, but in 2002 the species composition at T04 was very different from that seen in 2000 or 2001. In spring 2000 and 2001, *Capitella capitata* complex was the most abundant taxon, accounting for 47.6% in 2000 and 18.1% in 2001, whereas in spring 2002, the community was strongly dominated (81%) by an oligochaete, *Paranais litoralis*, with *Capitella* accounting for only 2.8% of the fauna. In August 2002, the community was dominated by *Streblospio benedicti* (79%), similar to previous summers, but of the remaining 14 species, only two had been present in 2000 and 2001 at this station (Appendix D3).

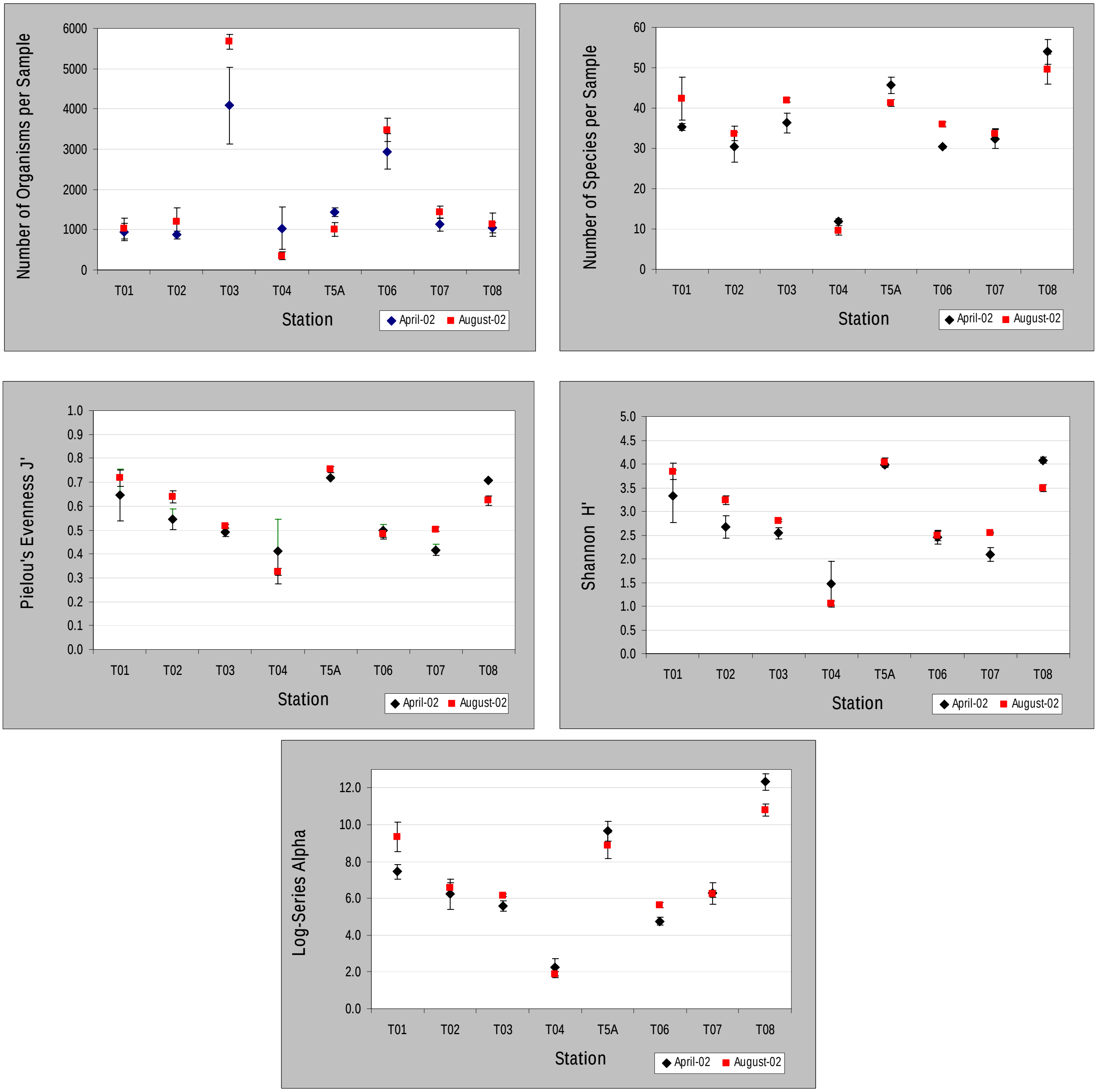
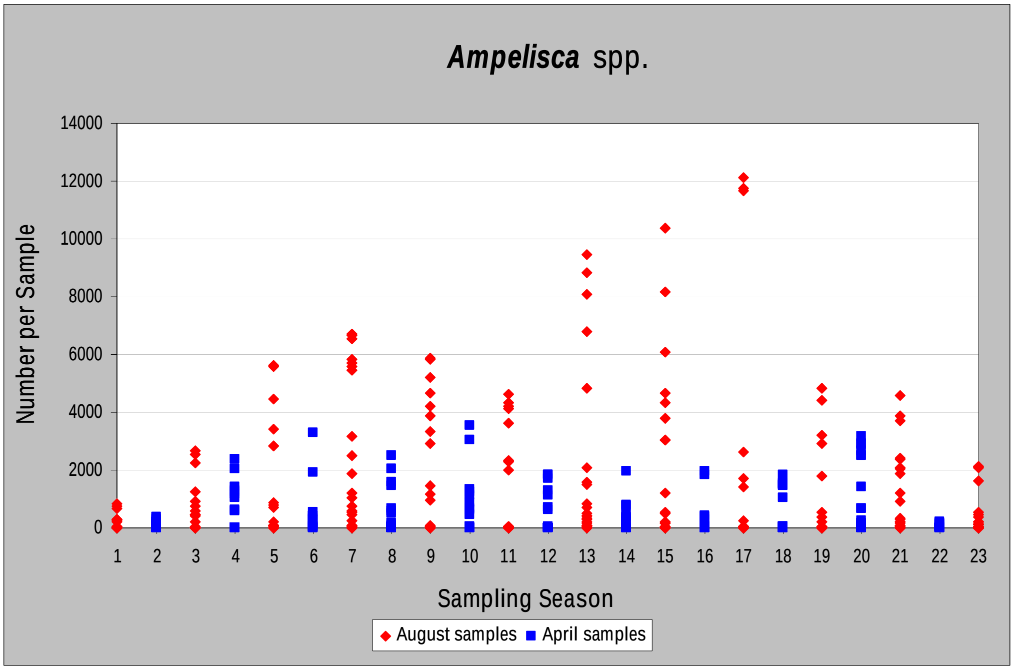
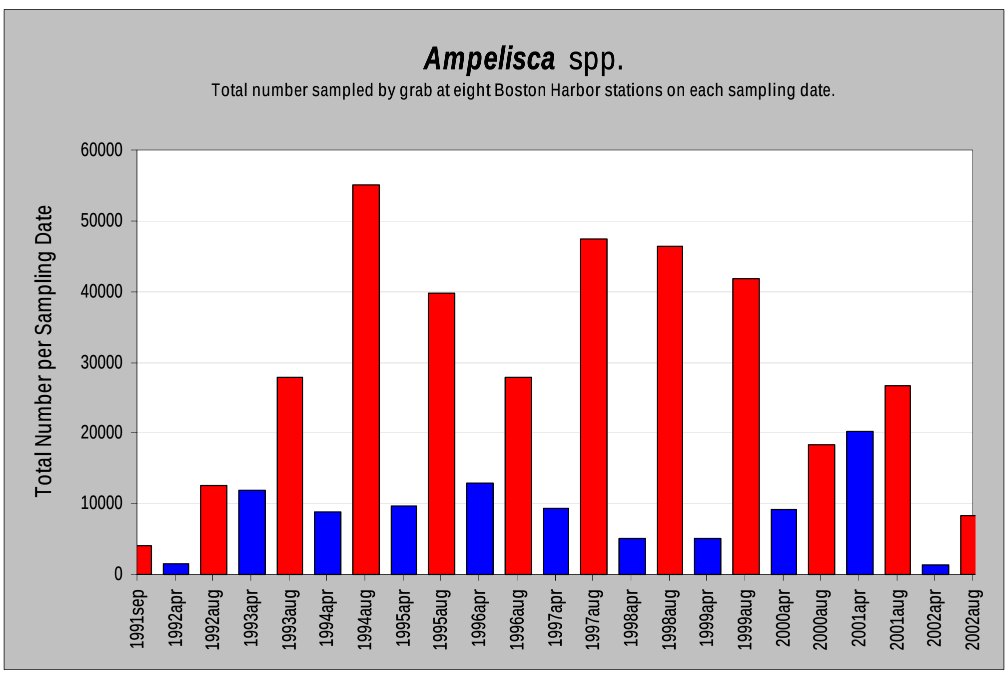


Figure 5-1. Mean ±SE of five benthic infaunal community parameters for the eight Boston Harbor traditional stations sampled by grab in 2002.

Ampelisca. The amphipod species *Ampelisca abdita* has been considered a key organism in following the status of the infaunal community of Boston Harbor, partly because members of this genus are considered (by some) indicative of clean environments. The increase in numbers of *Ampelisca* and the spread and constriction of tube mats (*i.e*., extremely high densities) has been followed in several reports (*e.g.*, Hilbig *et al*. 1996). Observations made on the grab samples as they were collected in 2002 in the field included, in April, amphipod tube mats at T06 and amphipod tubes at T01, T02, T03,and T05A; and, in August, amphipod tube mats at T03 and T06, and amphipod tubes at T01, T02, T05A, and T08. However, the only station at which *Ampelisca* spp. was the numerical dominant was at T03 (34.4%) in August. At T06 it was no more than the fourth most abundant taxon, ranging from 5.5 to 9.3% of the fauna in April and August 2002, respectively. At the remaining stations, *Ampelisca* ranged from 1.9% (T01) to 7.5% (T08) in April, and from 1.1% (T07) to 19.2% (T02); it was completely absent from T04 in both seasons, and only eight specimens (0.2%) were found at T07 in April. In contrast, in both April and August 2001, *Ampelisca* occurred in much higher densities and was a numerical dominant at several stations, including ranking first at T03, T06, and T07 in April, and T03, T05A, and T06 in August (Kropp *et al.* 2002b). Overall, the numbers of *Ampelisca* from grab samples taken at the eight traditional harbor stations are much lower in recent years compared with the high densities recorded in 1997–1999 or the earlier high densities seen in 1994–1995 (Figure 5-2). The highest densities per sample were seen in August 1999 at T03. In contrast to results from the grab samples, the results from SPI, which covered a greater number of stations throughout the harbor (Chapter 3, this report), suggest that areas of amphipod mats declined in 2002 compared with 2001, but the number of stations where *Ampelisca* was found in any density may be increasing.



(A)



(B)

Figure 5-2. (A) Abundance of *Ampelisca* per 0.04-m^2 sample for all eight stations and all seasonal collections made at the Boston Harbor traditional stations starting in September 1991. (B) Total *Ampelisca* spp. collected at the eight traditional Boston Harbor grab stations on each sampling date. April data represent overwintered population; August data represent the new summer generation (see Discussion).

5.3.3 Multivariate Community Analysis of the 2002 Data

Similarity Analysis with CNESS—Clustering the 48 Boston Harbor 2002 samples resulted in a clear pattern of seven station groups: six clusters each corresponded to one of six stations, and one cluster comprised samples from T03 and T06 (Figure 5-3). There is also a strong but secondary element of seasonality in these results, with the April samples clearly separating from the August samples within each station. The two samples that were recollected in May are designated as T01 sample 2 and T03 sample 1, and can be seen to be highly similar to one of the two other samples from their respective stations, while in both cases the third sample from each station is highly dissimilar to the other two. On a larger scale, this figure shows four major groups of stations:

(1) T01, in the northern part of the harbor near Deer Island Flats;

(2) T02/T03/T06/T07, all central harbor stations (*i.e*., neither close to shore nor directly near the outer entrances to the harbor) in both the northern and southern sections of the harbor;

(3) T05A and T08, in Presidents' Roads and Hingham Bay; and

(4) T04 in Dorchester Bay, which is the most distinct station and has an extremely low similarity to the other harbor stations.

This pattern of station associations generally corresponds to the varying sediment types within the harbor, which have remained generally consistent over the monitoring period (see Chapter 4, this report). The coarsest sediments, and also those with the lowest TOC content, are seen at T01, T05A, and T08. T04 has the siltiest sediments, and also the highest TOC. The remaining stations—T02, T03, T06, and T07—range from sandy to silty, and have been more variable over time.

Analyses of samples from 2001 summed at each station (Kropp *et al.* 2002b) also indicated an element of within-station seasonality similar to that presented here. The 2001 samples also had a comparable (but not identical) pattern of station associations, especially for T04, which was highly dissimilar to the remaining stations; T03 and T06, which were highly similar in both seasons; and T08, with both seasons being highly similar to the April sample from T05A.

PCA-H Analysis— The metric scaling of the 2002 samples on the first two PCA-H axes, which accounted for 46% of the CNESS variation in the communities, is shown in Figure 5-4A. The separation of the April and August samples from T04 is evident on these two axes, whereas the samples from T01 and T05A appear closer together than might be expected from the cluster dendrogram (Figure 5-3). However, only two axes of this multidimensional scaling are presented here, and the CNESS distances between the April and August samples from T01 and T5A are likely reflected on one of the several other axes.

The PCA-H analysis indicated which species of the 155 in the analysis were responsible for the metric scaling of the samples. With CNESS (m=15), seven species contributed at least 5% to the total CNESS variation on PCA-H axes 1 and 2, 13 species contributed 2% or more of the variation (Table 5-2). The Gabriel Euclidean distance biplot (Figure 5-4B) shows the 13 important species superimposed over the metric scaling of the stations. Oligochaetes appear to be especially important in structuring the harbor benthic communities in 2002: *Paranais litoralis*, along with the polychaete *Streblospio benedicti* and to a lesser extent the oligochaete *Tubificoides* sp. 2, distinguishes T04 from the other stations. The oligochaetes *Tubificoides apectinatus* and *T*. nr. *pseudogaster* are important at T02, T03, T06, and T07. The polychaete *Spiophanes bombyx*, typically found in sandy environments from shallow to continental shelf depths, is the species responsible for differentiating T05A and T08 from the remaining stations.

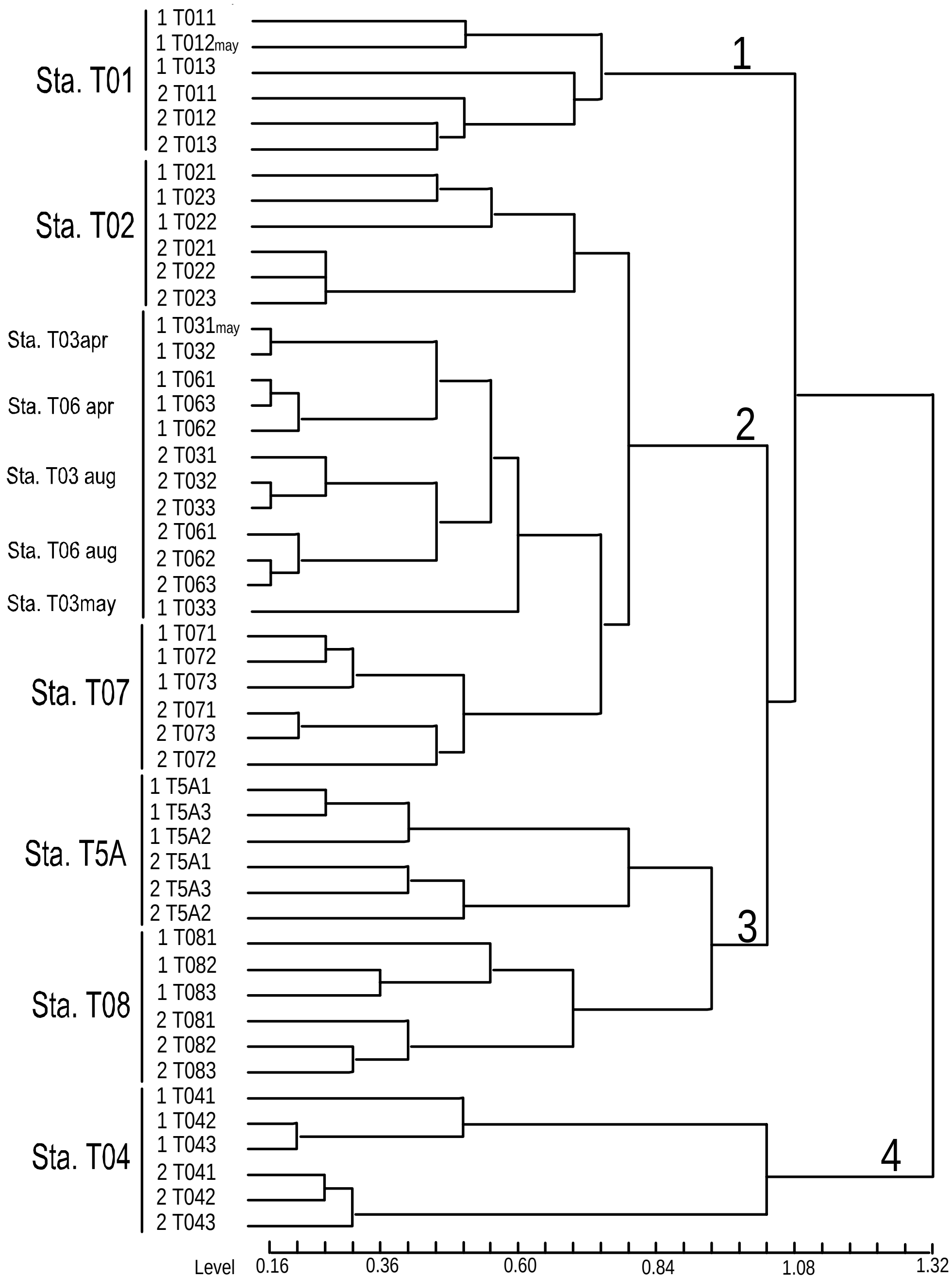


Figure 5-3. Cluster dendrogram of the 48 samples collected at the eight Boston Harbor traditional stations in 2002. CNESS with *m* set at 15. Seasons are indicated by a "1" (April) or "2" (August) in front of the station-replicate number. Large numbers to the right indicate cluster groups described in the text.

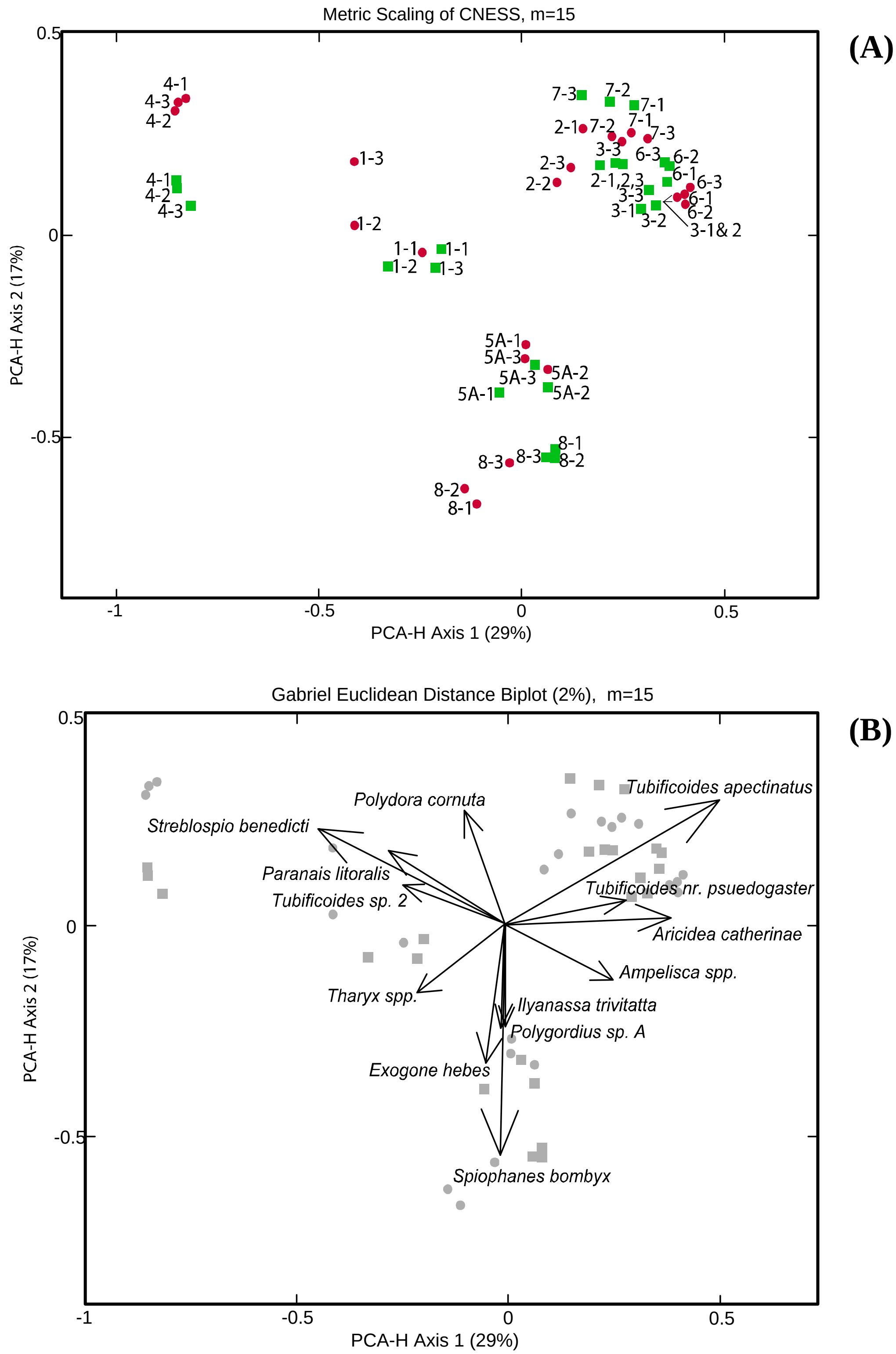


Figure 5-4. Metric scaling (A) and Gabriel Euclidean distance biplot (B) of the 2002 Boston Harbor samples. CNESS *m* was set at 15. Circles represent April samples and squares represent August samples. Labels indicate station and replicate (A) and species that account for at least 2% of the variation (B).

Table 5-2. Contribution to PCA-H axes 1 and 2 of the 13 species accounting for at least 2% of the community variation at the 2002 Boston Harbor stations. (see the Euclidean Distance Biplot, Figure 5-4B.)

PCA-H Rank	Species	Contr.	Total Contr.	Axis 1	Axis 2
1	*Tubificoides apectinatus*	19	19	25	8
2	*Streblospio benedicti*	14	33	20	5
3	*Spiophanes bombyx*	11	44	0	30
4	*Aricidea catherinae*	10	54	15	0
5	*Paranais litoralis*	6	60	8	3
6	*Tubificoides* nr. *pseudogaster*	5	65	8	0
7	*Ampelisca* spp.	5	70	7	2
8	*Exogone hebes*	4	74	0	11
9	*Tubificoides* sp. 2	4	78	6	1
10	*Tharyx* spp.	4	82	4	3
11	*Polydora cornuta*	3	85	1	7
12	*Polygordius* sp. A	2	88	0	6
13	*Ilyanassa trivittata*	2	90	0	6

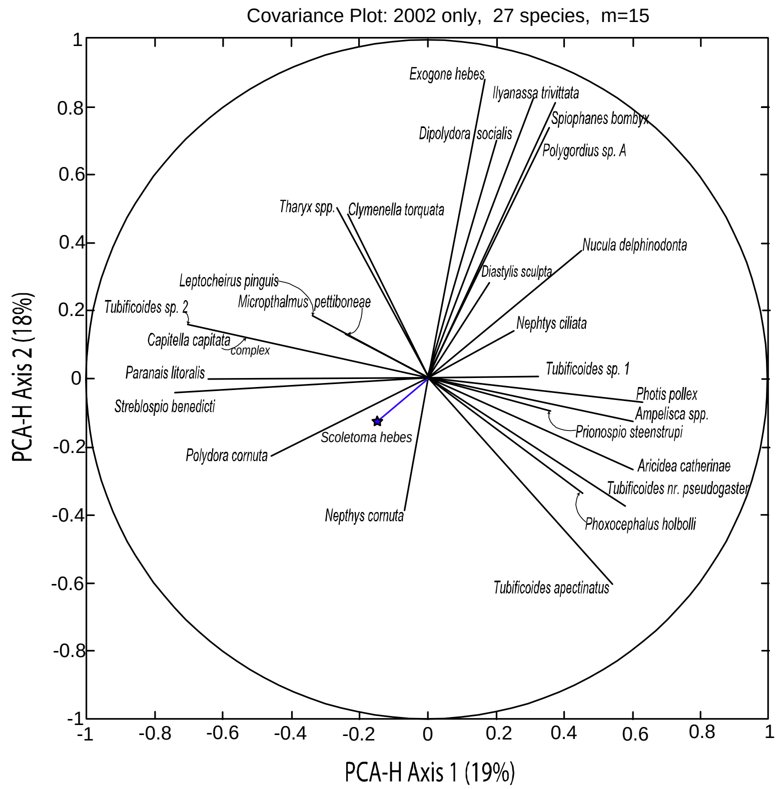
With CNESS (*m*=15), 27 species accounted for 95% of the variation in Boston Harbor community structure and contributed at least 1% to the PCAH axes. A covariance analysis of these 27 species (Table 5-3, Figure 5-5) and of all 155 taxa in the 2002 samples (Appendix D4, Figure D-1) were prepared, as was a CNESS cluster diagram for the 27 species (Figure 5-6). Three major species assemblages are evident in both the covariance plot (based on the angles between the species) (Figure 5-5) and the cluster analysis (based on the similarity levels indicated in the diagram) (Figure 5-6). Reading the covariance diagram (Figure 5-5) counterclockwise (from the 5PM position) , the first assemblage includes eight species: *Tubificoides apectinatus*, *Phoxocephalus holbolli*, *T.* nr. *pseudogaster, Aricidea catherinae*, *Prionospio steenstrupi*, *Ampelisca* spp., *Photis pollex, and Tubificoides* sp.1. The second assemblage includes species mostly associated with sandier (coarser) sediments: *Diastylis sculpta*, *Polygordius* sp. A, *Spiophanes bombyx*, *Ilyanassa trivittata*, *Dipolydora socialis*, and *Exogone hebes*. Intermediate between these two assemblages are *Nephtys ciliata* and *Nucula delphinodonta*. The third assemblage includes species associated with fine-grained sediments and/or stressed habitats, including *Leptocheirus pinguis*, *Micropthalmus pettiboneae*, *Tubificoides* sp. 2, *Capitella capitata* complex, *Paranais litoralis*, *Streblospio benedicti*, and *Polydora cornuta*. A grouping of *Tharyx* spp. and *Clymenella torquata* is seen intermediate to assemblages two and three, and *Nephtys cornuta* is seen between assemblages 3 and 1, with a negative correlation to assemblage 2. *Scoletoma hebes*, marked by a solid star in Figure 5-5, is the only one of the 27 species not important on axes 1 and 2, but has a larger contribution to axes 4 and 5 (see Table 5-3); however, it appears to have some association with *N. cornuta*.

The cluster analysis of 27 species (Figure 5-6) also produced three groupings, essentially similar in composition to the three groups elucidated by the covariance plot. The differences between the two analyses include *Nephtys cornuta* and *Scoletoma hebes* being strongly associated with group 1; *Nephtys ciliata* and *Nucula delphinodonta* being strongly associated with group 2; and *Tharyx* spp. and *Clymenella torquata* being strongly associated with group 3, rather than these species appearing intermediate between the covariance plot species groups.

Table 5-3. The total, cumulative, and relative contributions (%) of the 27 of 155 species in the 2002 data that contribute at least 1% to the PCA-H axes in the covariance plot (see Figure 5-5).

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6	Axis 7
1	*Tubificoides apectinatus*	11	11	25	8	17	3	0	1	3
2	*Streblospio benedicti*	9	20	20	5	7	5	0	1	8
3	*Tubificoides* nr. *pseudogaster*	6	26	8	0	3	17	6	18	3
4	*Aricidea catherinae*	6	33	15	0	4	7	3	0	6
5	*Ampelisca* spp.	6	39	7	2	5	14	21	0	4
6	*Spiophanes bombyx*	6	45	0	30	0	0	0	3	1
7	*Paranais litoralis*	6	51	8	3	1	5	5	27	5
8	*Polydora cornuta*	6	56	1	7	21	1	1	0	17
9	*Tharyx* spp.	5	61	4	3	13	5	3	13	1
10	*Tubificoides* sp. 2	5	66	6	1	5	7	2	15	0
11	*Nephtys cornuta*	3	69	1	3	0	4	13	7	4
12	*Scoletoma hebes*	3	72	0	1	1	9	8	1	5
13	*Exogone hebes*	3	75	0	11	1	2	1	0	3
14	*Prionospio steenstrupi*	2	77	1	0	0	0	17	0	3
15	*Polygordius* sp. A	2	79	0	6	1	1	1	1	0
16	*Dipolydora socialis*	2	80	0	5	0	1	2	0	3
17	*Leptocheirus pinguis*	2	82	0	0	5	3	0	0	0
18	*Tubificoides* sp. 1	2	84	0	0	2	0	2	1	4
19	*Nucula delphinodonta*	1	86	0	3	1	3	1	0	5
20	*Ilyanassa trivittata*	1	87	0	6	0	1	0	0	1
21	*Photis pollex*	1	88	1	0	1	1	1	2	4
22	*Capitella capitata complex*	1	90	1	0	0	0	1	4	2
23	*Nephtys ciliata*	1	91	0	0	0	0	7	1	3
24	*Clymenella torquata*	1	92	0	1	5	1	0	0	0
25	*Diastylis sculpta*	1	93	0	1	1	0	1	0	6
26	*Micropthalmus pettiboneae*	1	94	0	0	1	3	1	0	0
27	*Phoxocephalus holbolli*	1	95	0	0	0	2	1	1	0

Figure 5-5. Covariance of the 27 species in 2002 Boston Harbor samples that contribute at least 1% to PCA-H axes 1 and 2. One species, *Scoletoma hebes*, (indicated by a small star on its vector line) was actually more important on an axis not represented in this diagram, but is included here so that all 27 species are represented.



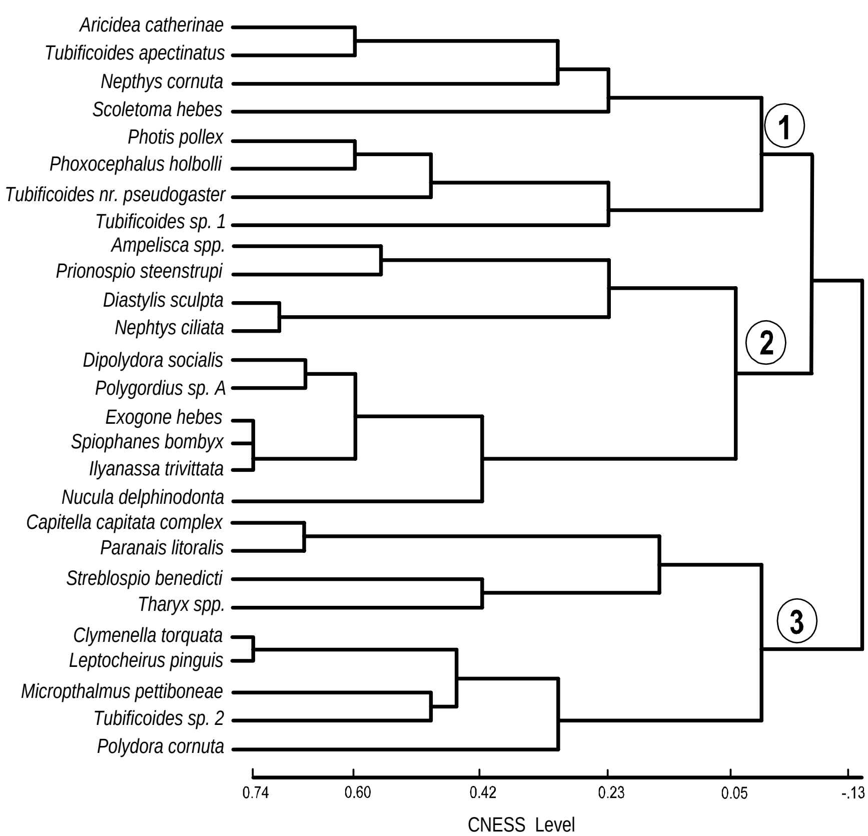


Figure 5-6. Cluster dendrogram of 27 species determined through PCA-H analysis to be the most important in affecting the metric scaling of CNESS distances. See text for discussion of species groups.

5.3.4 Benthic Community Analysis for Long-term Monitoring (1991-2002)

Long-term patterns in density, species richness, diversity, evenness, and dominance will first be considered for each station separately, and in the next section, for all stations together.

T01, Deer Island Flats

This station was first sampled in 1978 (as Station T4N) (Blake and Maciolek, unpublished manuscript). Located to the west of the Deer Island Flats in the northern part of the harbor, near the original site of effluent discharge, this general area was described in 1978 as having a deep flocculent layer near the bottom with much debris from the sewage outfall (J Williams, pers. com. to NJ Maciolek, Battelle, 1978).

In the two 1978 samples, which were taken with a 0.05-m^2 grab and sieved through 0.5-mm-mesh screens, 31 valid infaunal taxa were reported from replicate 1, and 27 taxa from replicate 2, for a total of 39 taxa from this station (these numbers might have been higher if oligochaetes had been identified to species). The samples were dominated by oligochaetes, and each replicate contained 100–200 predatory polychaetes *Pholoe minuta* and *Eteone longa*. The spionids *Polydora cornuta* and *Streblospio benedicti* were also numerous in each sample, as was a species of cirratulid (*Chaetozone*), which was also represented by nearly 1000 juveniles in one of the replicates. Several species of amphipod crustaceans were present, including *Ampelisca abdita*, *Photis pollex*, *Unciola irrorata*, and *Leptocheirus pinguis*, although their numbers were very low, ranging from 1 to 57 per sample.

Samples taken from September 1991 through August 2002 show a similar species composition, with about 80% (allowing for minor discrepancies in identifications) of the species that were present in 1978 occurring during this period. A total of 142 species have been recorded in the 69 0.04-m^2 samples, with an average of 34 taxa per sample. Fifty-five species are represented by five or fewer individuals, and 23 of these are singletons. Two species of oligochaetes, *Tubificoides* nr. *pseudogaster* and *Tubificoides* sp. 2, along with *Polydora cornuta*, often dominate the fauna. *Pholoe minuta* and *Eteone longa* are routinely found, although neither species occurs in numbers large enough to be numerically dominant.

Five community parameters are plotted in Figure 5-7. The early years of monitoring were marked by large fluctuations in abundances, with high densities in the August samples and low densities in the spring samples. These fluctuations were primarily due to large numbers of *Polydora cornuta* and *Clymenella torquata* (a head-down deposit feeder) that settled in August but had migrated or died off by the following spring. Since 1998, however, these fluctuations have been much reduced. A small peak in August 2001 was due to the amphipod *Leptocheirus pinguis*: nearly 58% of all individuals of this species found at Station T01 were recorded from one replicate sample collected in August 2001. Another contributor to the August 2001 peak in densities was *C. torquata*, which had been largely absent from this station in 1999 and 2000.

Other parameters, including species richness, Shannon diversity, and Pielou's evenness, also appear to be fluctuating less between spring and summer than they were in the early 1990s. Shannon diversity measured in the two 1978 samples was 2.9 and 2.3, respectively; these values are comparable to those seen in the early 1990s at this station. Beginning in August 1998, the mean H' has consistently been above 3.0, and reached a high of 3.8 in August 2002. Diversity as measured by log-series *alpha* has remained more variable than Shannon diversity, but also appears to have increased during the last few years of sampling. Community evenness (Pielou's J') was 0.6 and 0.5 for the two 1978 samples; as with H', these values are comparable to those seen in samples taken in the early 1990s. Beginning in spring 1999, mean J' values have consistently been 0.6 or higher, reaching a value of 0.72 in August 2002.

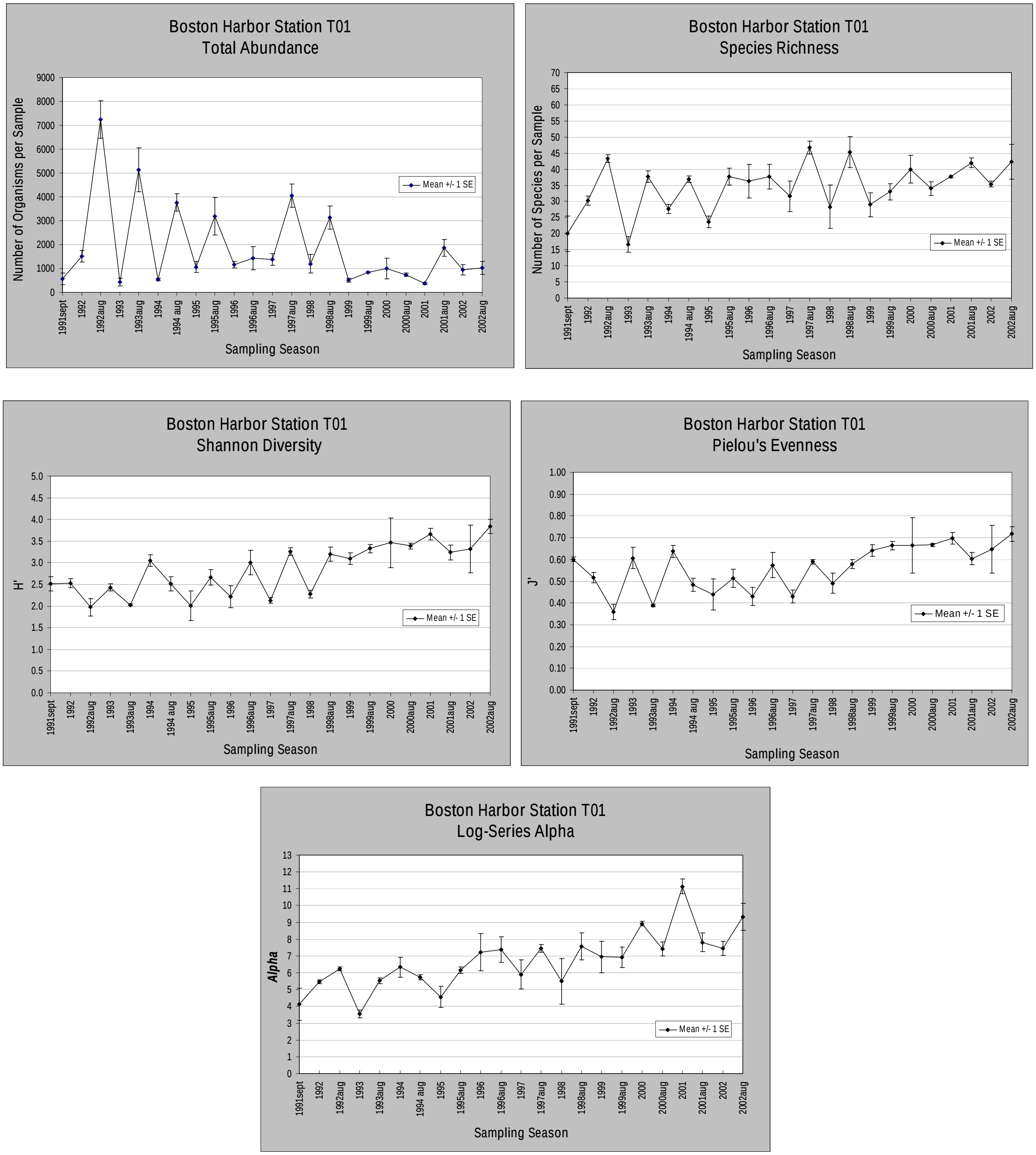


Figure 5-7. Benthic community parameters at Boston Harbor station T01 for the period September 1991 through August 2002.

PCA-H analysis of the 69 T01 samples showed a clear dichotomy between spring and summer samples in the early 1990s (Figure 5-8A), due to the large *Polydora* sets mentioned above (Figure 5-8B), and also between samples from the 1990s and those taken in 2000–2002 (Figure 5-8A). The contribution of individual species to the Gabriel Euclidean distance PCA-H axes is given in Appendix D4, Table D4-1. The higher densities of *Aricidea catherinae* and *Tharyx* spp., and the replacement of *Tubificoides* nr. *pseudogaster* by *Tubificoides* sp. 2 in some or all samples collected since 2000, partly account for the separation of the later samples from the earlier ones. In addition, *Streblospio benedicti* has been present in much lower densities since 1998.

(A)

(B)

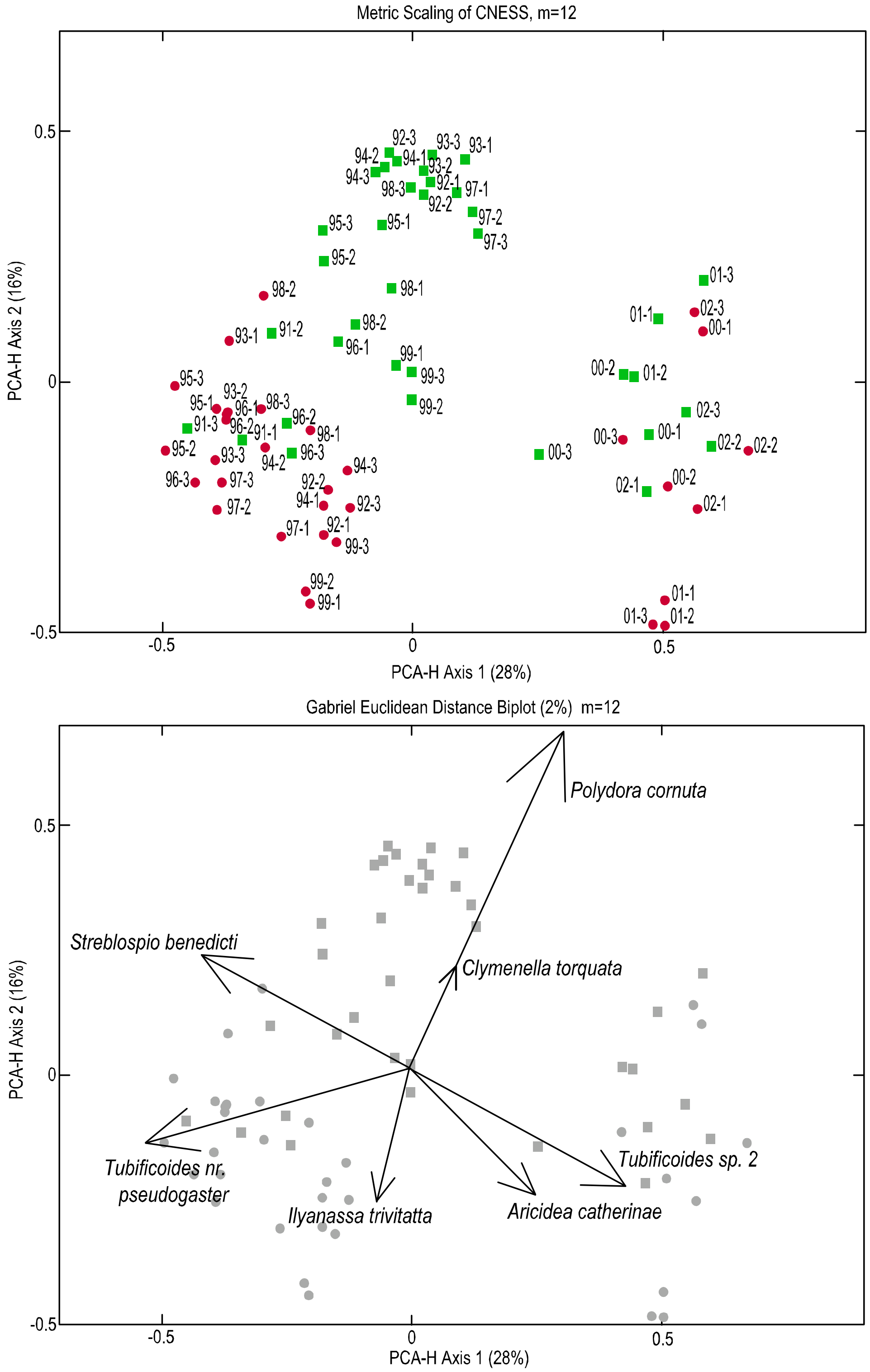


Figure 5-8. Metric scaling (A) and Gabriel Euclidean distance biplot (B) for Boston Harbor station T01, 1991–2002. Squares represent summer (August or September) samples and circles represent April samples. Labels are year and replicate (A) and species that account for more than 2% of the variation (B).

T02, Governor's Island Flats

This station, located in the Inner Harbor near the entrance to the Boston South Channel, was first sampled in 1979 (as station DW) and 1982 (as station CI) (Blake and Maciolek, unpublished manuscript). The two 0.05-m^2 1979 samples contained 13 and 17 taxa, respectively, and were dominated by *Polydora cornuta*. Additional abundant species included *Eteone longa* and *Capitella capitata* complex; the remaining species were represented by only a few individuals per sample. In 1982, although the sample size was nearly twice as large as the 1979 samples (the effective sample size was 0.085 m^2 after a core was removed for sediment grain size analysis), the fauna appeared much more depauperate. Two of the three replicates had only three species per sample, while the third sample had 12 taxa. All three samples were almost completely composed of *Capitella* and *P. cornuta*, although the sample with 12 species also had *E. longa* and *P. aggregata* in relatively high numbers.

Samples taken from September 1991 through August 2002 at T02 include 18 or 19 of the 25 taxa recorded in 1979 and 1982 (combined). A total of 143 species have been recorded in the 69 0.04-m^2 samples, with an average of 29 taxa per sample (samples taken in September 1991 had only 5–7 taxa per sample). Fifty-nine species are represented by five or fewer individuals, and 25 of these are singletons. Species that dominated the benthic infauna in the early 1990s included *Streblospio benedicti, Polydora cornuta*, *Tharyx* spp., and *Tubificoides* nr. *pseudogaster*. In the past several years (1998–2002), *Tubificoides apectinatus* has replaced *T.* nr. *pseudogaster*, and other species not previously resident in large numbers, including *Aricidea catherinae, Nephtys cornuta*, and *Micropthalmus pettiboneae*, have come to dominate the fauna. Ampeliscid amphipods have been numerous at times, most noticeably in the summer collections of 1994 and 1995.

Five community parameters are plotted in Figure 5-9. Mean abundances per sample have been comparable throughout the monitoring period, with the notable exception of the summer samples in 1994 and 1995. The high densities recorded in those samples were due to large numbers of *Ampelisca* spp., *P. cornuta*, and *S. benedicti*. Densities of *Ampelisca* and *S. benedicti* have not again reached such densities in the eight years of additional monitoring.

Seasonal fluctuations in species richness and log-series *alpha* are most noticeable in the early 1990s; values after 1998 appear more stable, with a suggestion of a trend toward higher values in the 2000s (Figure 5-9). Trends in Shannon diversity are more difficult to discern; although no seasonal trend is apparent, the values in the later years of monitoring are clearly higher than in the first two sampling periods (9/91 and 4/92). Those first two values (mean H′ =1.5 for each sampling period) are comparable to the values calculated for the 1979 and 1982 samples: in 1979, H′ was 1.3 and 1.6 for each sample, respectively, and in 1982 H′ was 0.9, 1.0, and 1.9 for the three replicates, respectively. Evenness values associated with both 1979 samples was 0.4, reflecting a high dominance by *P. cornuta*; in 1982, evenness was somewhat higher at 0.5–0.6, although this is misleading because the samples were so depauperate.

PCA-H analysis of the 69 T02 samples showed a clear separation of spring and summer samples along PCA-H axis 2 for the period 1993–2002 (Figure 5-10). Samples taken in 1997, 1999, and 2000–2002 in both seasons separate along Axis 1, due to the presence of *Aricidea catherinae, Nephtys cornuta*, and the two oligochaetes *Tubificoides* sp. 2 and *T. apectinatus*. The contribution of individual species to the Gabriel Euclidean distance PCA-H axes is given in Appendix D4, Table D4-2.

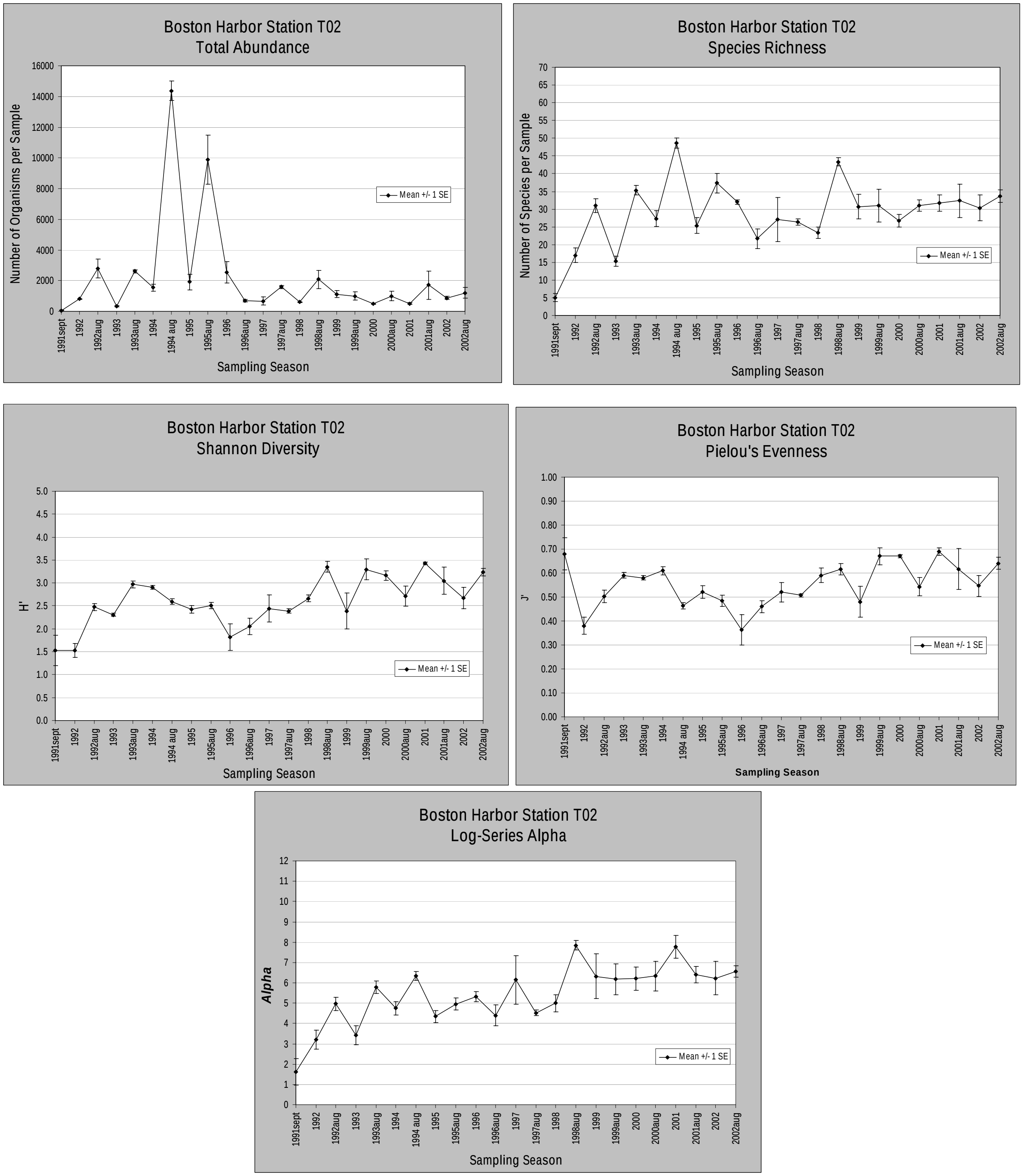


Figure 5-9. Benthic community parameters at Boston Harbor station T02 for the period September 1991 through August 2002.

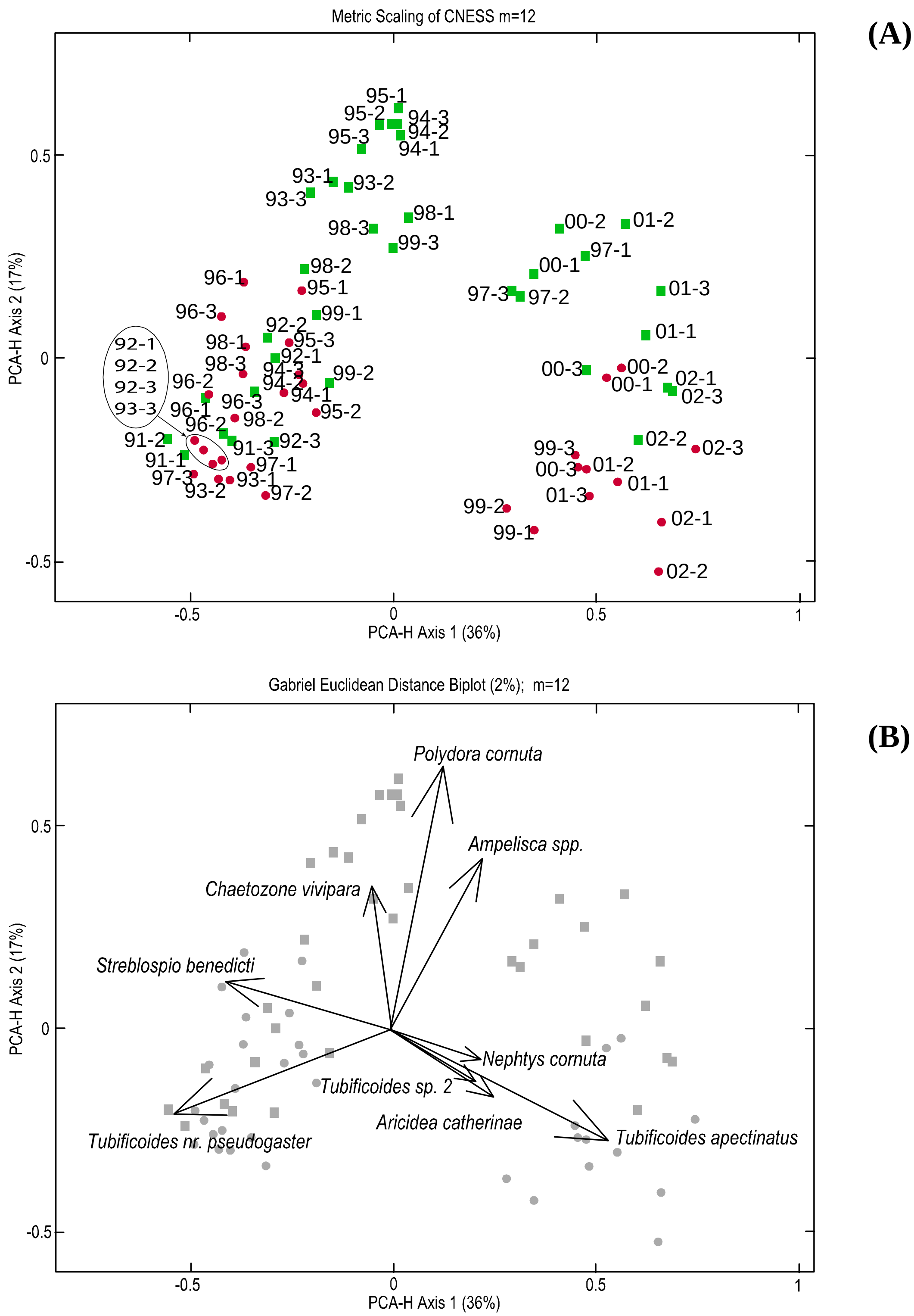


Figure 5-10. Metric scaling (A) and Gabriel Euclidean distance biplot (B) for Boston Harbor station T02, 1991-2002. Squares represent summer (August or September) samples and circles represent April samples. Labels are year and replicate (A) and species that account for more than 2% of the variation (B).

T03, Long Island

Two replicate 0.05-m^2 samples from Station T7N (about 1500 m from T03) were analyzed for infauna in 1978 (Blake and Maciolek, unpublished manuscript). One replicate contained 180 organisms in 13 taxa and the other contained 728 organisms in 31 taxa. Oligochaeta, which were not identified to species, were the numerical dominant in both samples; secondary dominants included *Pholoe minuta* and *Eteone longa*. One sample had five ampeliscid amphipods; the other sample had none.

The 68 samples[1] taken from September 1991 through August 2002 at T03 included at least 29 of the 38 infaunal taxa recorded in 1978 (eliminating differences in identification may increase the number of shared species). A total of 156 species have been recorded in the 68 0.04-m^2 samples taken at this station, with a range of 21 to 59 and an average of 38 taxa per sample. Sixty-nine species are represented by five or fewer individuals, and 35 of these are singletons.

Five community parameters are plotted in Figure 5-11. Mean abundances per sample have fluctuated seasonally, with high densities in the summer samples, especially in 1997, 1998, and 1999, often with corresponding low evenness values. The large densities recorded in those samples were due to large numbers of amphipods, either *Ampelisca* spp. (*e.g*., 1998–99), *C. bonelli* (*e.g*., 1997), or *Phoxocephalus holbolli* (*e.g*., 1997), and the polychaete *Polydora cornuta*.

Ampelisca has been important in the recent collections from T03, with peak densities in the August samples collected in 1994, 1998, and 1999 (mean densities of 6269, 8222, and 11,853 individuals per sample, respectively). At other times, densities have ranged from 35 to 4837 in summer (mean 1379 ±1387 SD) and from 15 to 2894 in the spring (mean 931± 837+/- SD). In addition to *Ampelisca*, other amphipods, including *Crassicorophium bonelli*, *Leptocheirus pinguis* (1995–1999), *Unciola irrorata*, and *Photis pollex* have also been dominant during summer months. As seen for station T02, *Tubificoides apectinatus* has joined or replaced *T.* nr. *pseudogaster* as a dominant in the past few years (2000–2002), and other species not previously resident in large numbers have come to dominate the fauna, including *Aricidea catherinae*, which is very common at several other harbor stations and also in the offshore samples collected in Massachusetts Bay (Maciolek *et al*. 2003).

Shannon diversity for the two 1978 samples was 2.2 for each, with associated evenness indices of 0.4 and 0.6. The summer samples taken in 1991, 1994, 1998, and 1999 had mean H′ values equal to or lower than these values (1.7, 1.8, 2.3, 1.7, respectively) (Figure 5-11). Mean diversity in all other sampling seasons was 2.5 or higher, with the highest value of 3.2 in August 2000. Diversity as measured by log-series *alpha* has been the most stable parameter at T03: after increasing through August 1992, and a small increase in August 1998, it has not evidenced the fluctuations seen in Shannon diversity or the other parameters. The lowest evenness value (0.3) was for the summer 1999 samples, which had the second highest species richness (48 taxa) recorded at this station. Species richness appears to have essentially doubled between 1991 and 1994, increasing from a mean of 23 to a mean of 42 species per sample, and has continued to remain high over the past several years. It should again be noted, however, that one of the samples collected in 1978 had 31 infaunal taxa, suggesting that the increase may not be as large as would appear from the 1991–2002 data alone.

PCA-H analysis of the 68 T03 samples showed a clear separation of the majority of summer samples from the spring samples along axis 1. The September 1991 samples, as at other stations, appear close in position to the spring 1992 samples, rather than to other late summer (August) samples. The separation of samples is driven primarily by the higher densities of *Ampelisca* spp. and *Polydora cornuta* in summer (Figure 5-12 B). The contribution of individual species to the Gabriel Euclidean distance PCA-H axes is given in Appendix D4, Table D4-3.

[1] In 2000, one replicate from T03 was lost in transit, resulting in 68 rather than 69 samples for this station.

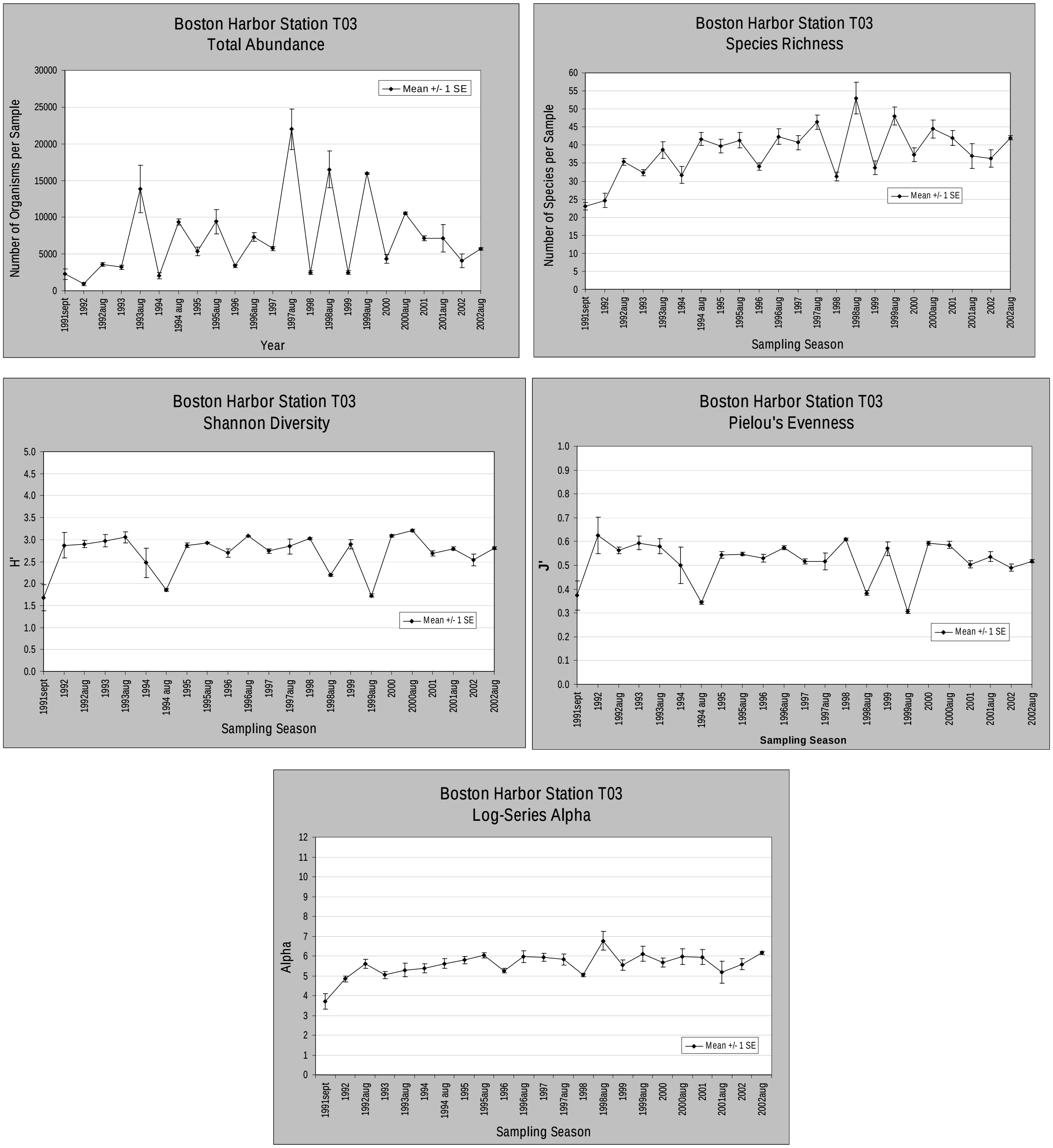
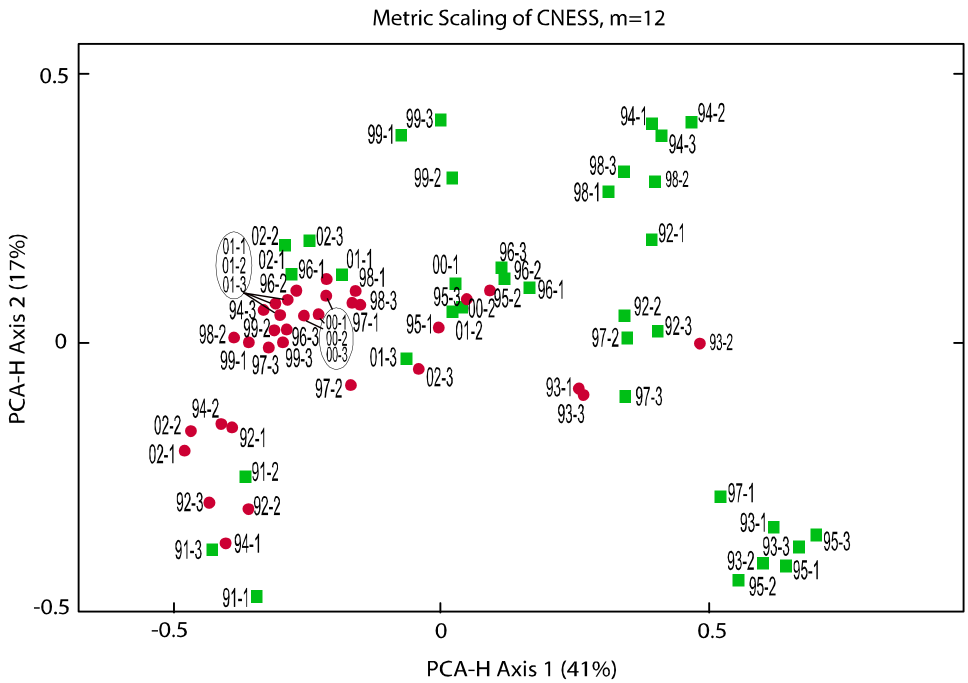


Figure 5-11. Benthic community parameters at Boston Harbor station T03 for the period September 1991 through August 2002.

(A)



(B)

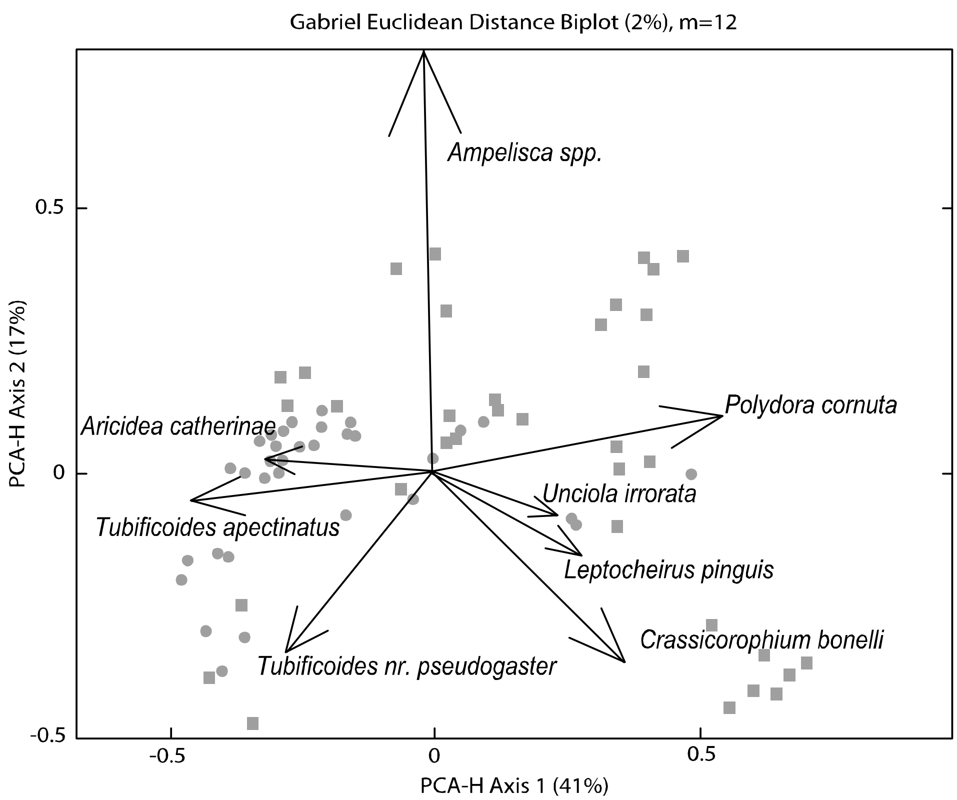


Figure 5-12. Metric scaling (A) and Gabriel Euclidean distance biplot (B) for Boston Harbor station T03, 1991-2002. Squares represent summer (August or September) samples and circles represent April samples. Labels are year and replicate (A) and species that account for more than 2% of the variation (B).

Station T04, Dorchester Bay

This station was not sampled during the early studies in Boston Harbor, but was included in the monitoring program as a degraded station. Studies (Gallagher and Grassle 1989, Gallagher *et al* 1992) indicated that the site was heavily impacted by both local sources and by focused deposition of effluent and sludge particulates transported from distant outfalls, and was unlikely to show rapid improvement.

The benthic infauna at this station has comprised many fewer species than at the other harbor stations: 76 infaunal species have been recorded from the 68 samples[2] analyzed during the period 1991–2002, with an average of eight species per sample. The August samples typically have more taxa than the spring samples, but the overall range is 2 to 19 taxa per sample. Of these 76 taxa, 40 have five or fewer occurrences and 17 are singletons. Many of the collections in the early 1990s were dominated by *Streblospio benedicti*, and occasionally by *Capitella capitata* complex (*e.g*., April 1994) More recently, the numerical dominant has been inconsistent among sampling seasons and years, with *Capitella* (August 1998), *Polydora cornuta* (April 1997, April 2000), or, as in April 2002, the oligochaete *Paranais litoralis* being the numerical dominant (Blake *et al*. 1998, Kropp *et al.* 2002a, Appendix D3). In 1999 and 2001, abundances and species richness were extremely low in both seasons, but either *Capitella* or *S. benedicti* were present in the samples.

Five community parameters are plotted in Figure 5-13. While species richness has remained steadily low during all sampling seasons, total abundance, Shannon diversity, and evenness have exhibited wide fluctuations both within a sampling season and between seasons and/or years. The highest mean abundance (3885 ± 1011organisms per sample) was recorded in 1998. In each of those samples, *Capitella* accounted for over 99% of the organisms, therefore Shannon and log-series *alpha* diversities, as well as evenness, were notably low for that sampling date. The benthic community at T04 continues to remain unstable, with no real patterns either within a sampling date (*i.e.*, large SE around parameter means) or between years (*e.g*., dominant species change from year to year).

PCA-H analysis of the 68 T04 samples showed the separation of samples according to both season and the major dominant organisms seen in the samples Figure 5-14 A,B). For example, the high density of *Capitella* in summer 1998 as well as spring 1994 resulted in those samples separating along both PCA-H axes 1 and 2 (Figure 5-14). The recent spring 2002 samples, with the newly dominant species *P. litoralis*, as well as the majority of spring samples from other years, also separate along both axes, while the majority of summer samples have a negative loading on axis one and spread only slightly along axis 2. The contribution of individual species to the Gabriel Euclidean distance PCA-H axes is given in Appendix D4, Table D4-4.

T05 and T05A, President's Roads

Station T05, located off the tip of Long Island near the Nut Island discharge, was sampled only twice, in September 1991 and August 1992. Due to difficulty in sampling the coarse sediments of this station in April 1992, an alternate location farther out in the channel was selected and sampled (Kropp and Diaz 1995). Starting in April 1993, this alternate station was sampled routinely under the designation T05A. The data points from the original station, T05, are included in the graphs presented below, but the reader should be aware that the station location and sediment type of those samples differs from all of the remaining ones.

[2] In 1995, replicates 1 and 3 from T04 were combined in error.

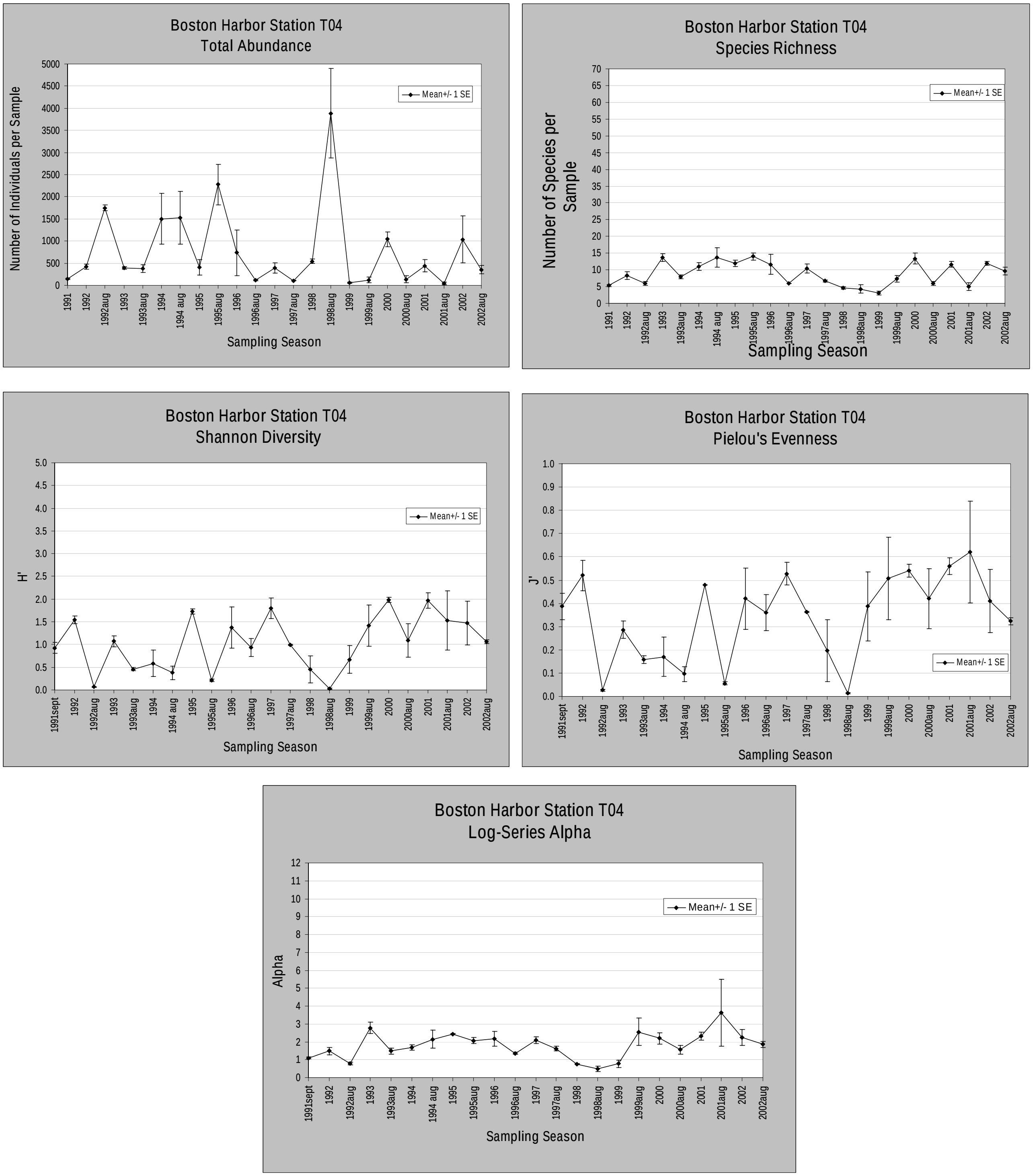


Figure 5-13. Benthic community parameters at Boston Harbor station T04 for the period September 1991 through August 2002.

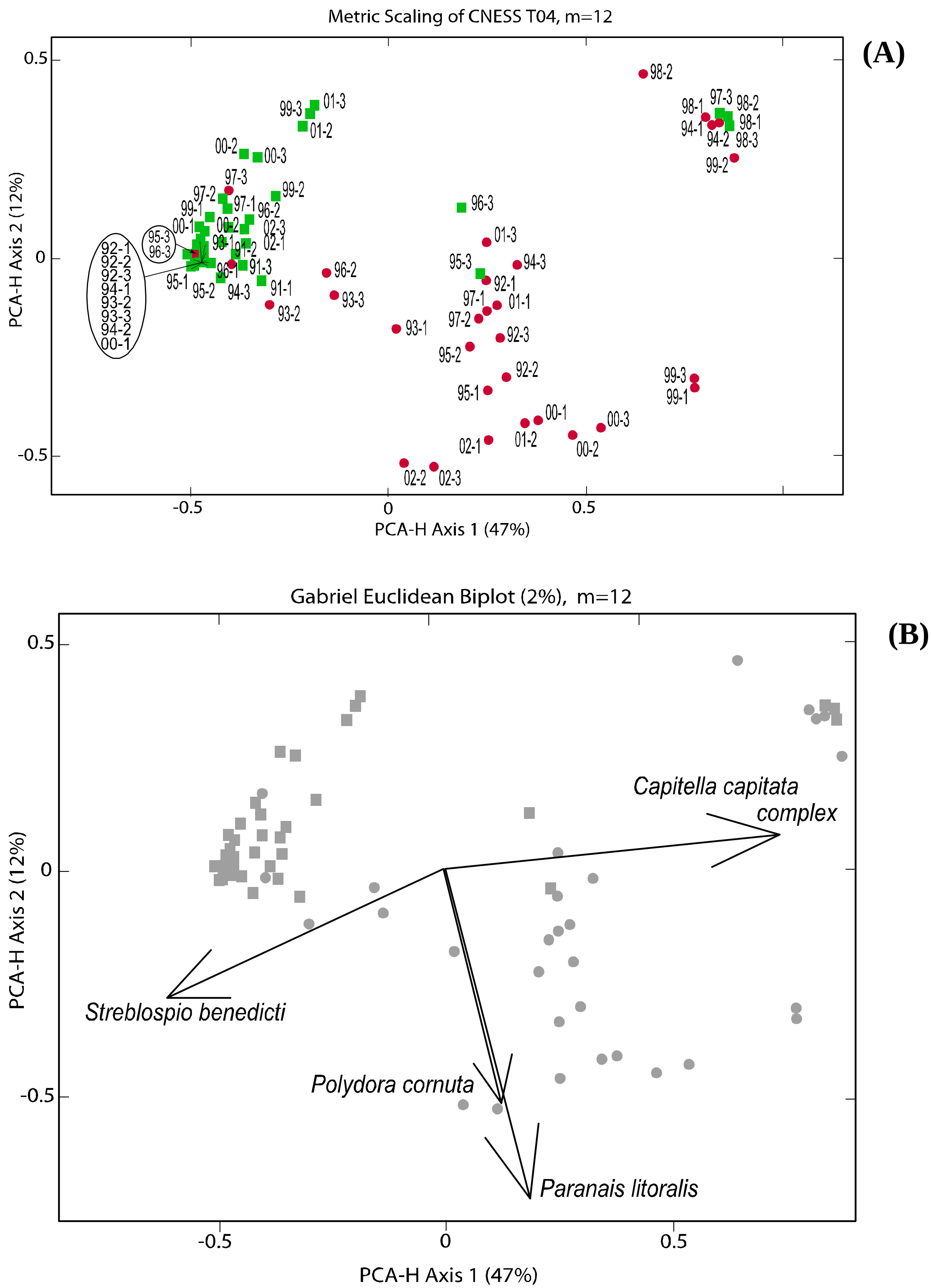


Figure 5-14. Metric scaling (A) and Gabriel Euclidean distance biplot (B) for Boston Harbor station T04, 1991-2002. Squares represent summer (August or September) samples and circles represent April samples. Labels are year and replicate (A) and species that account for more than 2% of the variation (B).

Two samples from T4M, a 1978 station corresponding in location to T05A (Blake and Maciolek, unpublished manuscript) had 11 and 9 taxa, and 76 and 193 organisms, respectively. The first sample comprised >50% oligochaetes, and also contained fauna typical of sandy sediments (*Eteone longa*, *Pectinaria gouldi, Edotia* spp.) and the amphipods *Ampelisca abdita* and *Phoxocephalus holbolli*. The second sample comprised about 44% oligochaetes and 28% *Diastylis sculpta* (a cumacean), as well as taxa mentioned for the first sample. Shannon diversity for both samples was 2.3, with evenness values of 0.7. The two sets of samples from T05 in September 1991 and August 1993 had similar or lower mean values of abundance, Shannon diversity, and evenness than the 1978 samples. The 1991 samples also had very low species richness (mean of 8±0.6 SE taxa per sample), but the August 1992 samples showed a very high richness of 39±1.4 species per sample.

Between September 1991 and August 2002, 156 species have been recorded at T05/5A; of these, 49 have five or fewer occurrences, and 22 are singletons. Five of the rare species occurred only at T05. At T05A, the mean number of taxa ranged from 14.7 in 1995 to 56.7 in 1997, with an average of 34 species per sample.

Species that dominated the benthic infauna in the early to mid-1990s included *Polydora cornuta*, *Ampelisca* spp., *Tharyx* spp., *Edotia triloba*, *Unciola irrorata*, and occasionally *Capitella capitata* complex, *Tubificoides* nr. *pseudogaster*, and *T. apectinatus*. Many of these species have continued to be important components of the benthic community along with *Ilyanassa trivittata*, *Aricidea catherinae*, and *Spiophanes bombyx*. In years when *Ampelisca* or *Polydora cornuta* do not overwhelm the fauna, one of these taxa may be the dominant, as in 2002 when *T. apectinatus* was the numerical dominant in both spring and summer samples (Appendix D3).

Some of the singleton or rare species found at T05A represent new distribution records. For example, *Scolelepis tridentata*, originally described in 1914 from the coast of Ireland, was not recorded from this coast until recent collections from Georges Bank (NOAA, Fishery Exclusion Project, 1998 samples, Maciolek unpublished data). A single specimen was found at T05A in August 2002, and several additional specimens were found at the nearfield Massachusetts Bay stations in spring 2003 (Maciolek *et al*. 2003). Similarly, three specimens of an unusual, undescribed species of *Polydora* were found at T05A in the August 2002 samples, and several hundred were found in 2003 at one of the nearfield stations (MWRA HOM 4 unpublished data). T05A thus appears open to incursions of species from offshore waters, most likely brought in by tidal currents.

Benthic community parameters for samples from T05A have shown wide, primarily seasonal fluctuations (Figure 5-15). Mean total densities showed peaks in August collections in 1994, 1995, 1997, 1998, and 2001. Summer peak densities were due to high numbers of *Polydora cornuta* and/or *Ampelisca* spp.—sometimes *Polydora* densities would be high and *Ampelisca* low (1998); sometimes the reverse (2001), and sometimes both have been present in equally high densities (1995, 1997). The 1997 peak was especially pronounced, with mean densities of 21,300±225 organisms per sample, more than four times earlier peak densities. In 1993, 2000, and 2002, the mean August densities were the same or slightly lower than the spring densities recorded in that same year.

PCA-H analysis of the six T05 and 63 T05A samples for the period 1995–2002 (Figure 5-16A,B) showed the samples from T05 (fall 1991 and summer 1992) with negative loadings on both axis 1 and 2: these six samples, along with the three spring 1992 samples from T05A, contained the majority of the *Capitella* collected at either station. *Polydora cornuta* and *Ampelisca* spp., along with *Unciola irrorata*, characterize the summer samples with positive loadings on axis 1. The remaining samples, with spring and summer samples from all years separated slightly along both axes 1and 2, reflect the years in which *Tubificoides apectinatus* and *Aricidea catherinae* dominate the samples (Figure 5-16). The contribution of individual species to the Gabriel Euclidean distance PCA-H axes is given in Appendix D4, Table D4-5.

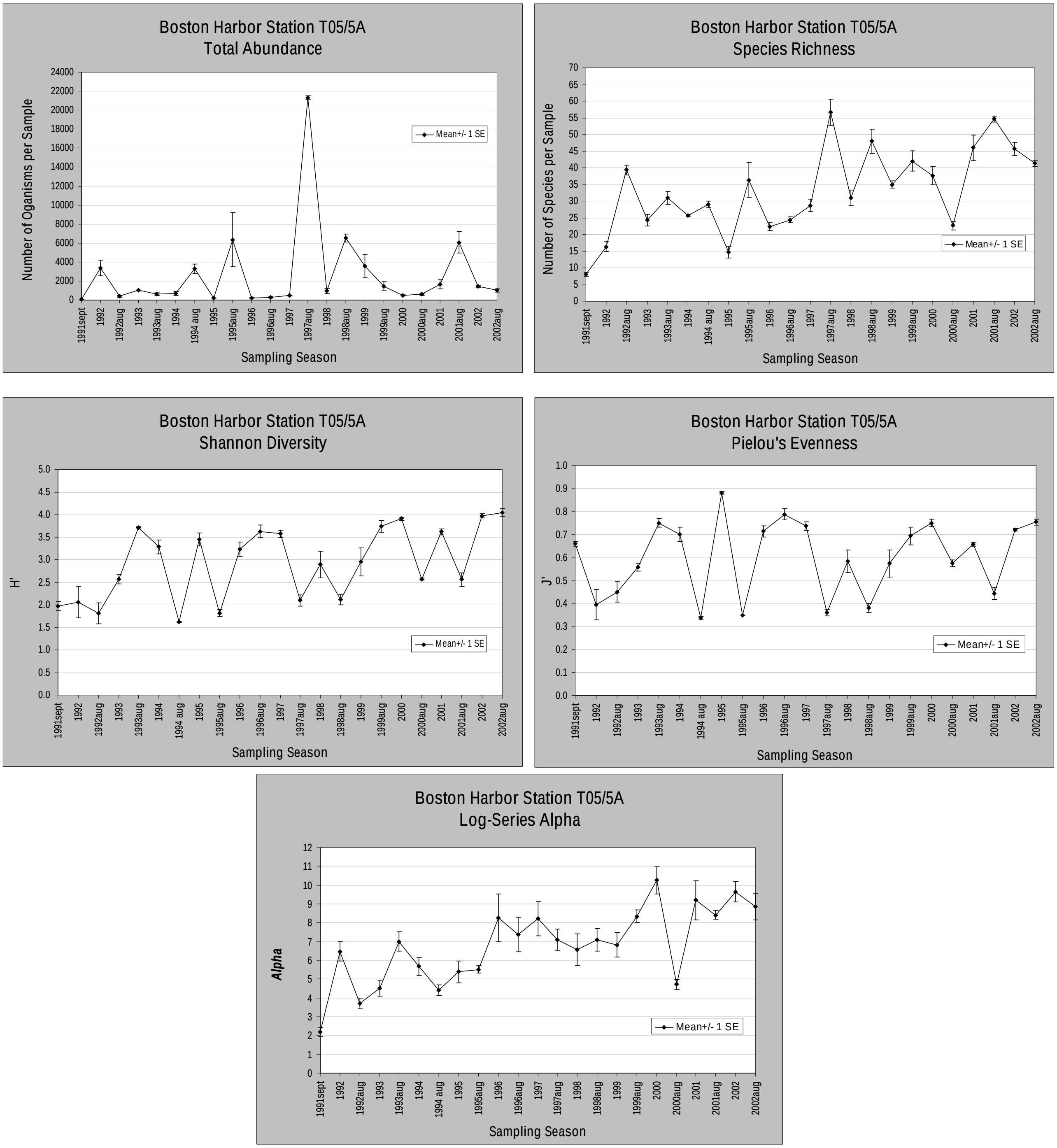


Figure 5-15. Benthic community parameters at Boston Harbor station T05 and T05A for the period September 1991 through August 2002.

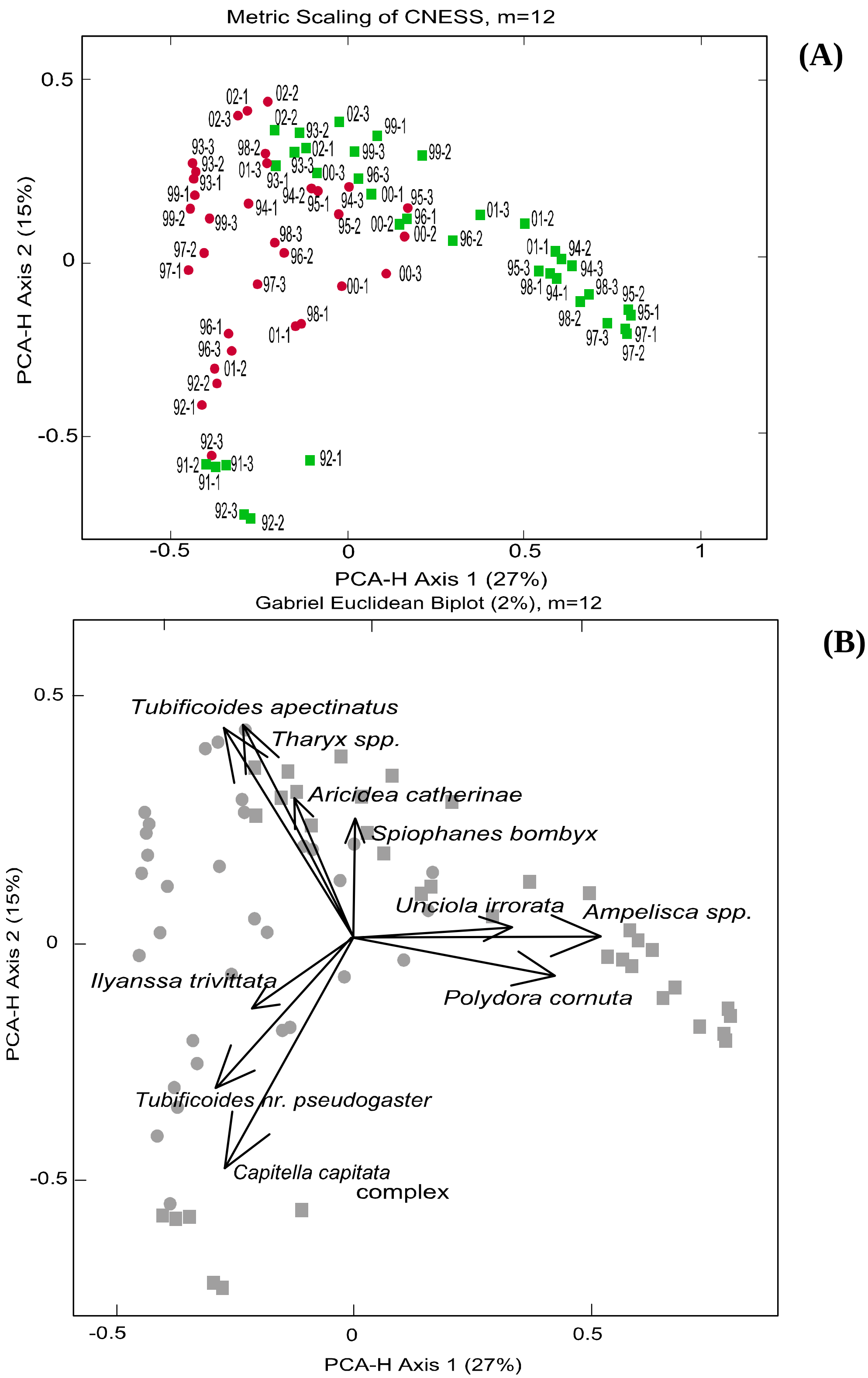


Figure 5-16. Metric scaling (A) and Gabriel Euclidean distance biplot (B) for Boston Harbor stations T05 and T05A, 1991-2002. Squares represent summer (August or September) samples and circles represent April samples. Labels are year and replicate (A) and species that account for more than 2% of the variation (B).

T06, Peddocks Island

This station in the southern part of Boston Harbor was first sampled in 1979 as station NI (Blake and Maciolek, unpublished manuscript). The three samples contained 36, 38, and 30 infaunal taxa, respectively, with total densities per 0.04-m^2 sample of 2422, 3018, and 1336 organisms, respectively. A diverse amphipod fauna characterized this station, with numerical dominants including *Ampelisca abdita*, *Leptocheirus pinguis*, *Orchomenella minuta*, and *Unciola irrorata*. Additional amphipod species were present in the samples, along with oligochaetes, *Capitella*, and *Mediomastus*. Shannon diversity values were 3.7, 3.4, and 4.0, respectively, and evenness values were 0.7, 0.6, and 0.8, respectively.

Samples taken from September 1991 through August 2002 at T06 include the majority of the 47 taxa recorded in 1979. A total of 138 species have been recorded from the 69 samples taken at T06; of these, 61 are represented by five or fewer individuals, and 38 are singletons. The number of species per sample has ranged from 22 (September 1991 and April 1998) to 47 (August 1999), with a mean of 35.0±0.8 SE, which coincidentally is very close to the mean number of species per sample in August 2002. The species composition of the T06 samples has remained fairly consistent throughout the years of the monitoring program. Amphipod species in particular have been diverse and numerically dominant at this station.

Five community parameters are plotted in Figure 5-17. Mean abundances per sample have fluctuated more-or-less seasonally throughout the monitoring period, with a particularly high density in the 1993 summer samples. Those samples were dominated by several species of amphipods, including *Ampelisca* spp., *Crassicorophium bonelli*, and the polychaete *Polydora cornuta*. In addition, the amphipods *Phoxocephalus holbolli* and *Leptocheirus pinguis* and the polychaete *Aricidea catherinae* occurred in large numbers. Seasonal fluctuations or trends in species richness, evenness, and the diversity measures H′ and log-series *alpha* are not obvious. Shannon diversity as measured for the 1991–2002 samples is lower than the diversity of the 1979 samples, with the lowest mean value being 2.01 in April 1996; the highest, 3.29 in August 2001; and the mean 2.55.

PCA-H and cluster analysis of the 69 T06 samples suggested two outlier groups: August 1993 and April 1998, which are clearly seen in the metric scaling diagram of PCA-H axes 1 and 2 (Figure 5-18A). These samples were characterized by either very low (1998) or very high (1993) abundances. The April 2002 samples also had low abundances, and appear as a trio of point with negative loadings on axis 1 (Figure 5-18A). The cluster diagram for T06 (not shown) indicated that all six 2002 replicates formed a subcluster within a larger group of samples; this grouping is seen more clearly on axis 3 of the PCA-H diagram (not shown).

There is also a suggestion of seasonal separation of the samples, with a large number of summer samples strongly influenced by *Polydora cornuta* (Figure 5-18B). April samples and the remaining August samples are influenced by abundances of the several amphipod species common at this station (samples with positive loadings on axis 1), as well as *Aricidea catherinae* and the two species of oligochaetes *Tubificoides* nr. *pseudogaster* and *T. apectinatus* (negative loadings on axis 1). The contribution of individual species to the Gabriel Euclidean distance PCA-H axes is given in Appendix D4, Table D4-6.

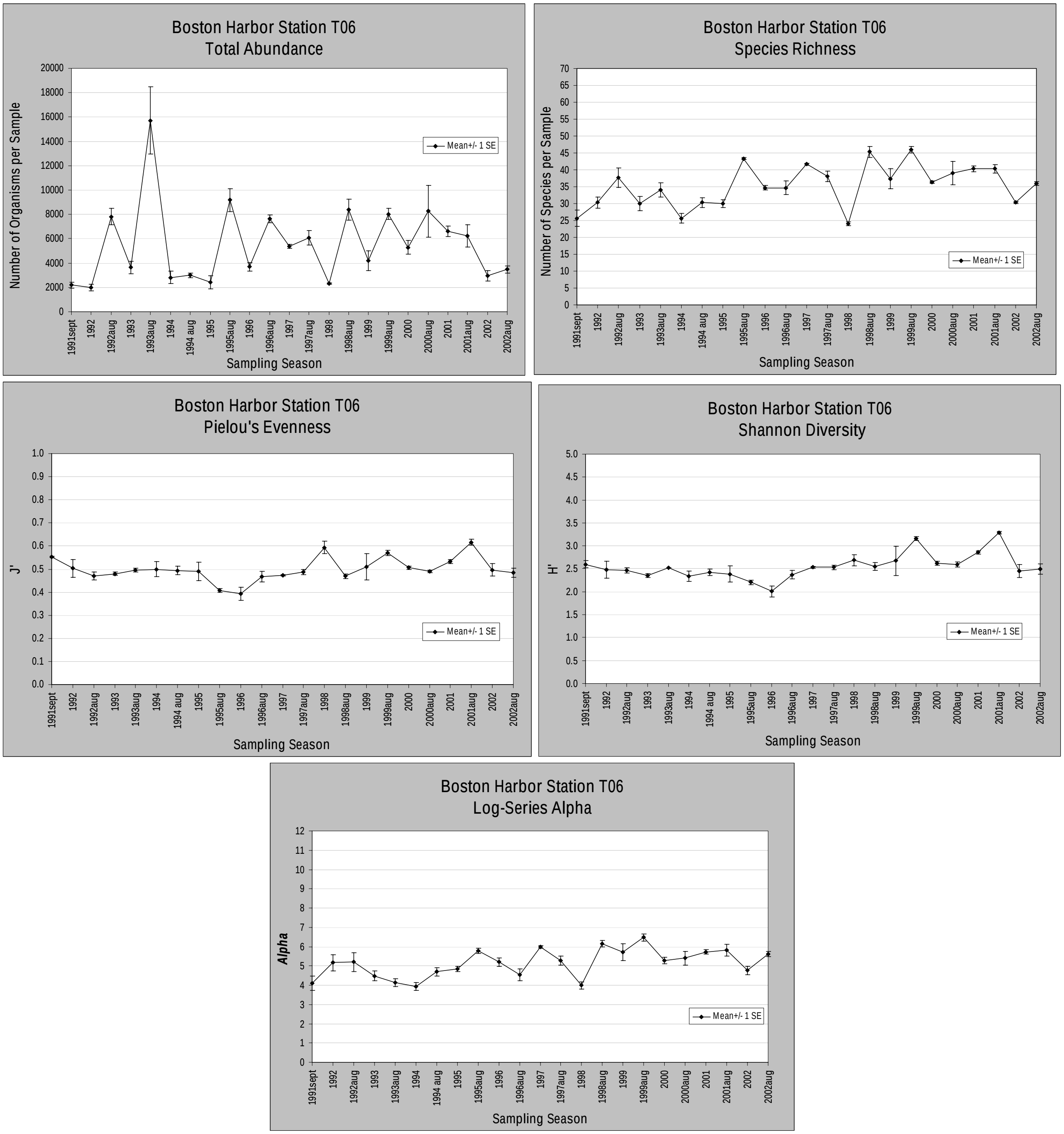
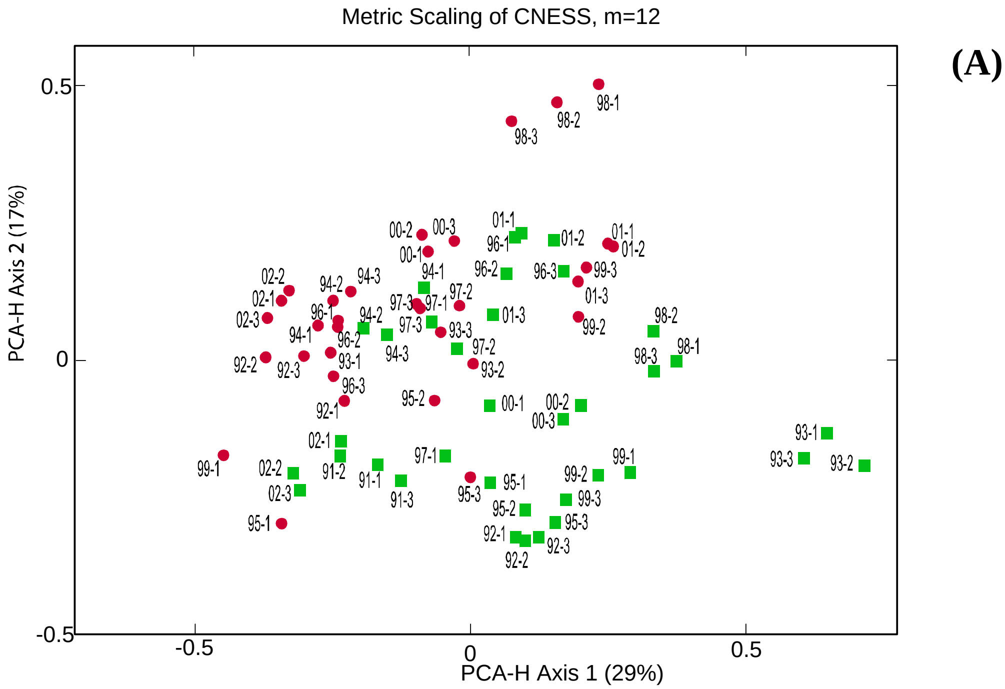


Figure 5-17. Benthic community parameters at Boston Harbor station T06 for the period September 1991 through August 2002.



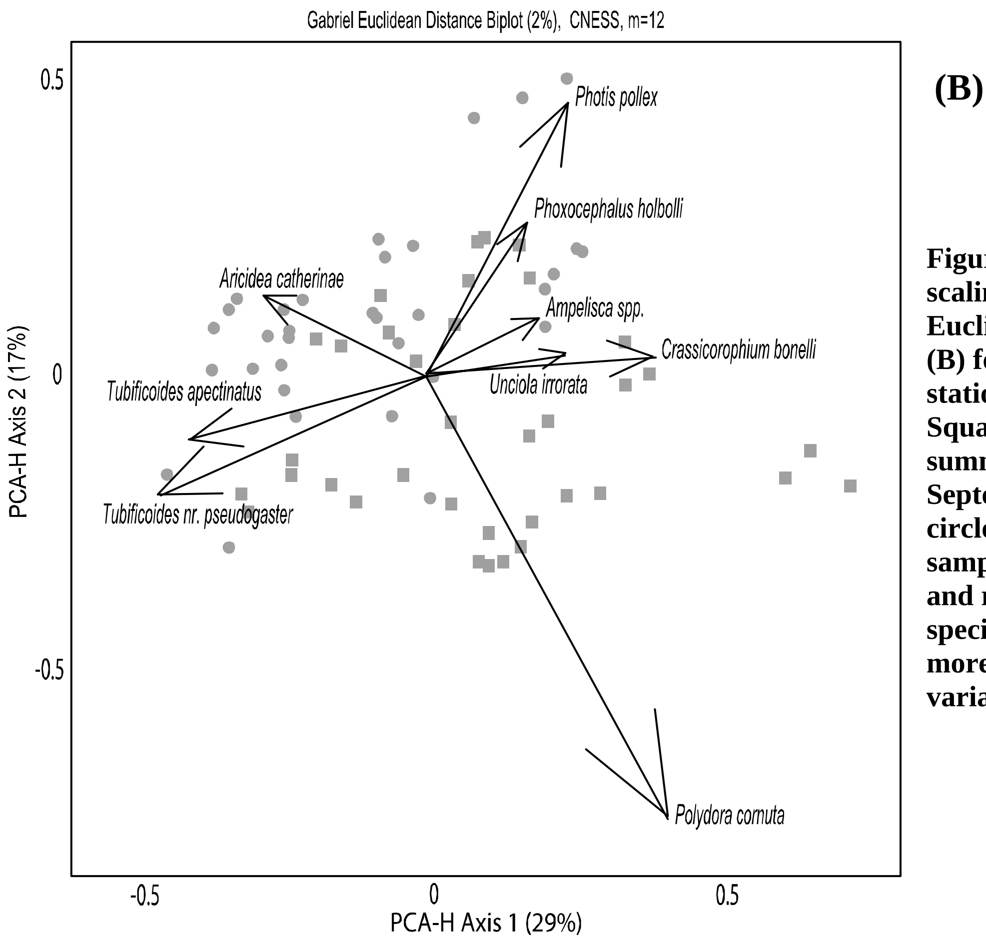


Figure 5-18. Metric scaling (A) and Gabriel Euclidean distance biplot (B) for Boston Harbor station T06, 1991-2002. Squares represent summer (August or September) samples and circles represent April samples. Labels are year and replicate (A) and species that account for more than 2% of the variation (B).

T07, Quincy Bay

This station is located in the southern central part of Boston Harbor. It was not sampled during the waiver studies—the closest station, NIC, was nearly 2 km distant. Samples taken from September 1991 through August 2002 at T07 comprised a total of 121 species in the 69 0.04-m^2 samples, with a range of 13 to 41 and an average of 25 taxa per sample. Sixty species are represented by five or fewer individuals, and 25 of these are singletons. The dominant species at T07 have remained fairly constant throughout the 1990s, with *Aricidea catherinae*, the oligochaetes *Tubificoides apectinatus* and *T. nr. pseudogaster*, and ampeliscid amphipods being the most numerous. *Streblospio benedicti* is a common spionid, and species of *Polydora* are numerous, along with *Tharyx* spp. Syllid polychaetes have been very rare in the 1991–2002 samples: only 39 specimens of syllids were recorded in the 69 samples. The hesionid *Micropthalmus pettiboneae* and the lumbrinerid *Scoletoma hebes* are common and often among the numerical dominants, as they were in both April and August 2002. In recent years (2000–2002), the polychaete *Nephtys cornuta* and the oligochaete *Tubificoides apectinatus* have increased in abundance compared with the early 1990s.

Five community parameters are plotted in Figure 5-19. Seasonal peaks in abundance were most pronounced during the early 1990s, with particularly high abundances occurring in 1995 due to *Polydora cornuta*, *Ampelisca* spp., and *A. catherinae*. The summer samples taken in 1996 and 1999 had very low abundances, and were exceptions to the pattern seen in all other years, in which summer densities were always higher than spring densities. However, the April 2001 samples had abundances higher than those recorded the previous August; otherwise all spring samples had fewer or equal numbers of organisms compared with the previous or following summers.

Shannon diversity was fairly steady at a mean of 2.6 (range 2.3–2.9) through August 1997. The mean diversity for the period 1998–2002 was also 2.6, but the range of diversities was wider (2.1 in April 2002 to 3.2 in August 1998). The three collections made between August 1998 and August 1999 have the three highest diversities at this station, and collections made after 2001 have among the lowest. Evenness values also appeared to be steady in the early 1990s (mean 0.6, range 0.47 to 0.69 through August 1999) but have declined since 2000 (mean 0.50, range 0.42 to 0.59) (Figure 5-19). Diversity as measured by log-series *alpha* and species richness, however, both appear to have increased from the early 1990s through 2002 (Figure 5-19).

PCA-H analysis of the 69 T07 samples indicated seasonality, but this is not seen clearly in the metric scaling diagram (Figure 5-20A) because only the first two PCA-H axes are presented. The majority of samples with a negative loading on axis 1 are summer samples from 1992–1995; these samples are the most dissimilar to all the others. Samples with a negative loading on axis 2 include a mixture of April and August samples from 1993 and 1996–1998. *Polydora cornuta* and *Ampelisca* spp. contribute to the separation of the summer samples (Figure 5-20B).

Samples from 2002 are positioned to the right of the diagram (Figure 5-20A) (*i.e.*, with positive loadings on both axis 1 and axis 2), with some separation from the other samples, but with strong affinities for samples taken in 1999–2001. The April 2002 replicates are most clearly separated from the other samples, whereas the August 2002 samples do not appear as distinct; however, the six 2002 samples formed a subcluster in the dendrogram generated for the similarity analysis (not shown).

The contribution of individual species to the Gabriel Euclidean distance PCA-H axes is given in Appendix D4, Table D4-7.

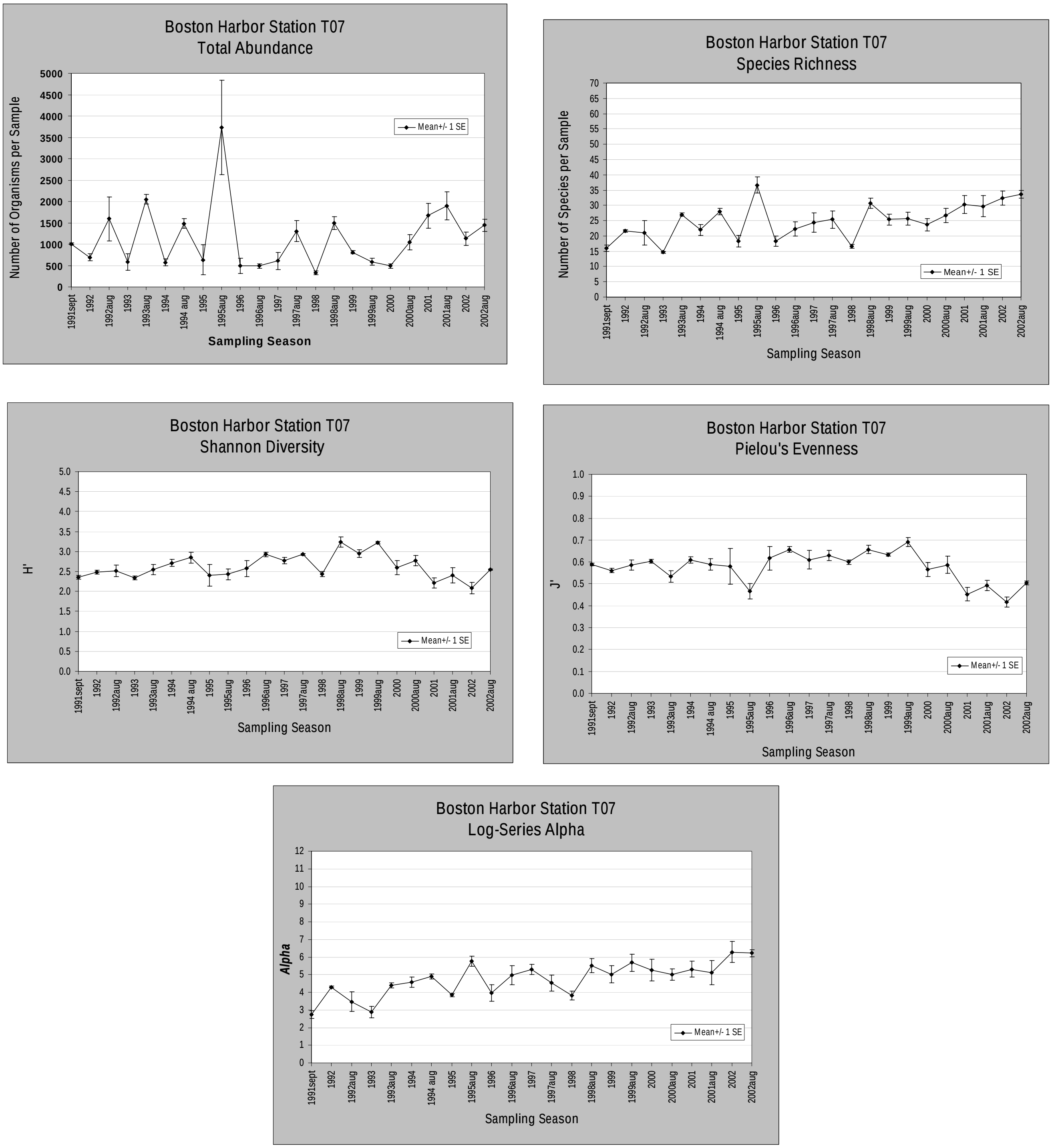
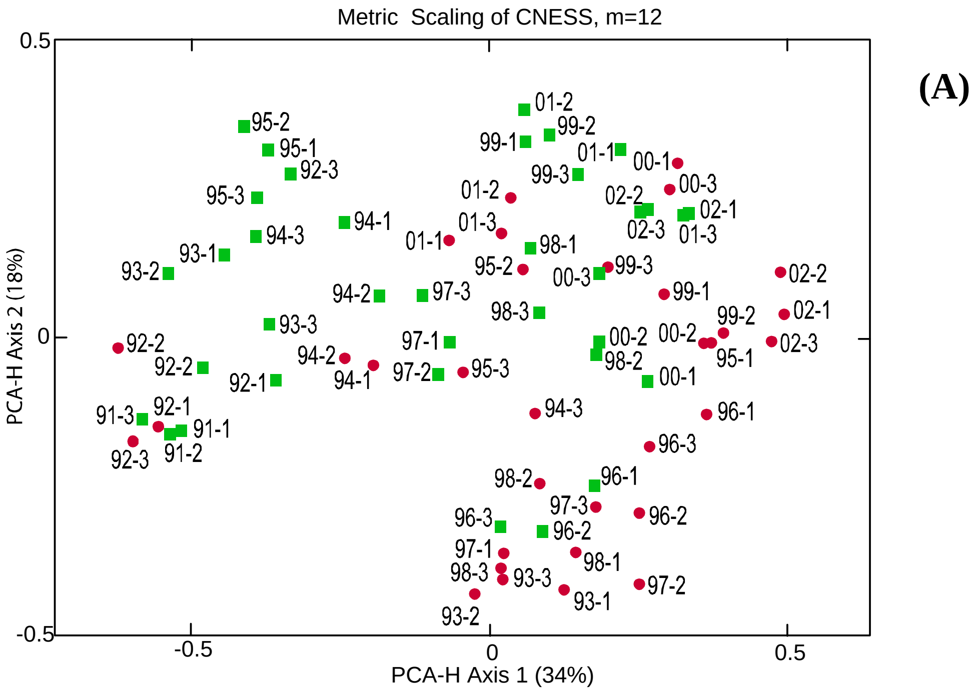


Figure 5-19. Benthic community parameters at Boston Harbor station T07 for the period September 1991 through August 2002.



(B)

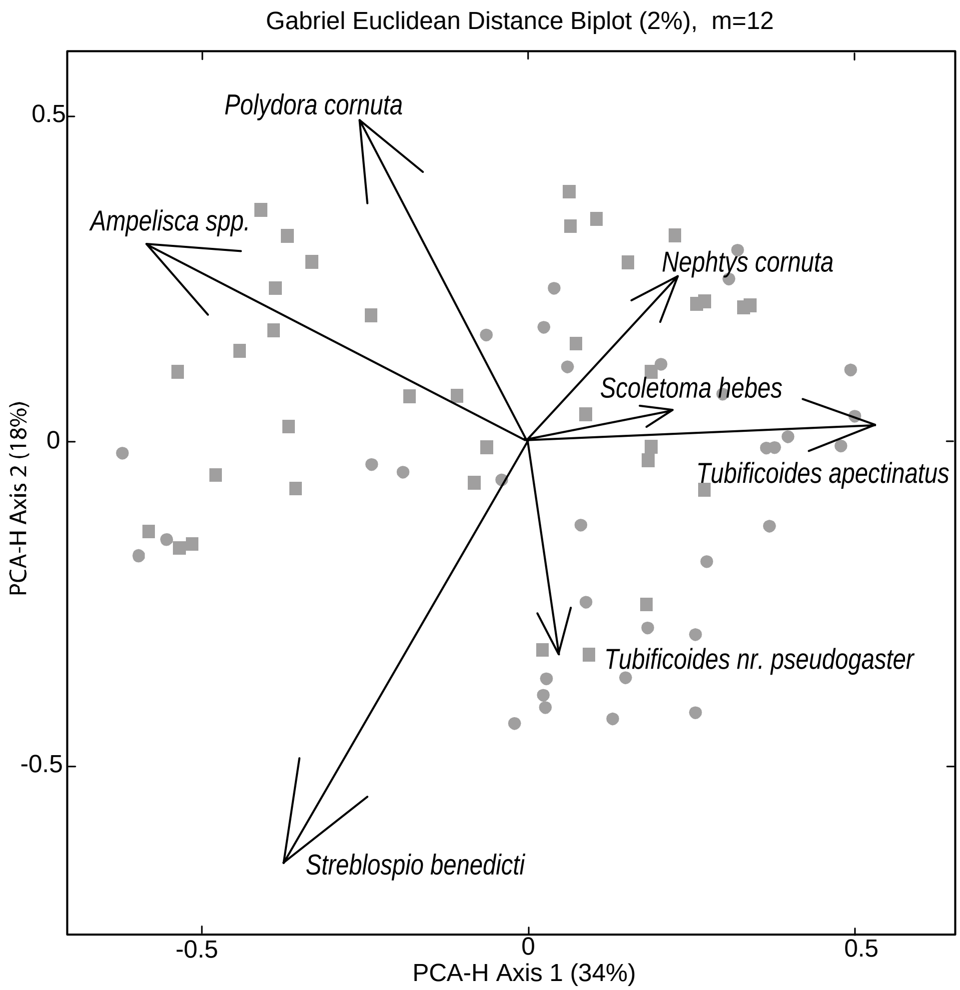


Figure 5-20. Metric scaling (A) and Gabriel Euclidean distance biplot (B) for Boston Harbor station T07, 1991–2002. Squares represent summer (August or September) samples and circles represent April samples. Labels are year and replicate (A) and species that account for more than 2% of the variation (B).

T08, Hingham Bay

This station is located in the southern part of Boston Harbor, in the center of Hingham Bay. It was first sampled in 1982 as Station CH (Blake and Maciolek, unpublished manuscript): four samples were taken with a 0.1-m^2 Van Veen grab. A total of 71 taxa were reported from these samples, with each sample having 30, 32, 31, and 39 species, respectively. The samples were dominated by oligochaetes (not identified to species), several species of amphipods, *Aricidea catherinae*, *Polydora quadrilobata*, and *Cirriformia grandis*. As seen at T07, the common ampeliscid amphipod was *Ampelisca vadorum*; other common amphipod species included *Leptocheirus pinguis*, *Orchomenella minuta*, and *Phoxocephalus holbolli*. Shannon diversity for these four samples was 3.3, 3.7, 3.6, and 3.6, respectively; the evenness value for samples 1 and 4 was 0.6; for samples 2 and 3, evenness was 0.7.

Samples taken from September 1991 through August 2002 at T08 include the majority of the 71 taxa recorded in 1982 (allowing for differences in some species identifications). A total of 188 species have been recorded in the 69 0.04-m^2 samples, with a range of 15 to 48 and a mean of 28 taxa per sample. Eighty-six species are represented by five or fewer individuals, and 47 of these are singletons.

The dominant species at T08 remained fairly constant through the early 1990s, with *Ampelisca* spp. and *A. catherinae* as the numerical dominants. The abundances of both taxa in samples taken in 1999–2002 has declined, although both remain among the highest numerical dominants. For example, *A. catherinae* had a mean abundance of 177 organisms per sample, and accounted for 18% of the fauna in April 2002 versus a mean of 917 (34%) in 1997 and 835 (27%) in 1998 (this report, Kropp *et al.* 2000b). The two common oligochaete species, *Tubificoides* nr. *pseudogaster* and *T. apectinatus*, were common in 1996–1998, but abundances of both have fallen in recent years. Another species common in the early 1990s, *Exogone hebes,* has also declined. Conversely, *Spiophanes bombyx*, which was rare in the 1982 samples, has increased considerably in density and was the numerical dominant in several seasons, including August 2002. *Polygordius* sp. A has shown a pattern of increase similar to that of *S. bombyx*. Species that have had variable patterns of abundance, with periodic peaks followed by declines, include several mollusc species, such as the bivalves *Nucula delphinodonta* and *Tellina agilis*, and the gastropod *Ilyanassa trivittata*.

Five community parameters are plotted in Figure 5-21. Seasonal peaks in abundance were most pronounced in spring 1996 and the summers of 1997 and 1998: these were the years in which the two species of *Tubificoides*, *A. catherinae*, and *Ampelisca* spp. reached peak abundances. Mean abundances have been significantly lower in the years since the summer 1998 peak, and variability around the mean has also been much reduced (Figure 5-21). Species richness in samples from T08 has been variable, with no discernable pattern of seasonality. Although the species composition of samples may have changed slightly over the intervening years, the number of species per sample has remained similar, with a mean in September 1991of 44, and in August 2002 of 50. Similarly, Shannon diversity and evenness, while showing increases and decreases throughout the sampling period, are essentially the same in 2002 as they were in 1991, with an H′ of around 3.4 and J′ of 0.6; these values are similar to those obtained for the 1982 samples. Diversity as measured by log-series *alpha* did not change significantly during the period 1991–1999, but appears to have increased since then, reaching a high mean value of 12.3 in April 2002. This increase echoes increases in H′ and J′ during the same period, however, so it remains to be determined if this pattern is meaningful.

PCA-H analysis of the 69 samples showed the most dissimilar group to be those samples with negative loadings on axis 1 and positive loadings on axis 2; these samples were not particularly distinguished in any way by total abundance or diversity values, but had high abundances of the two *Tubificoides* species, as well as the other species common at this station (Figure 5-22A,B). The contribution of individual species to the Gabriel Euclidean distance PCA-H axes is given in Appendix D4, Table D4-8.

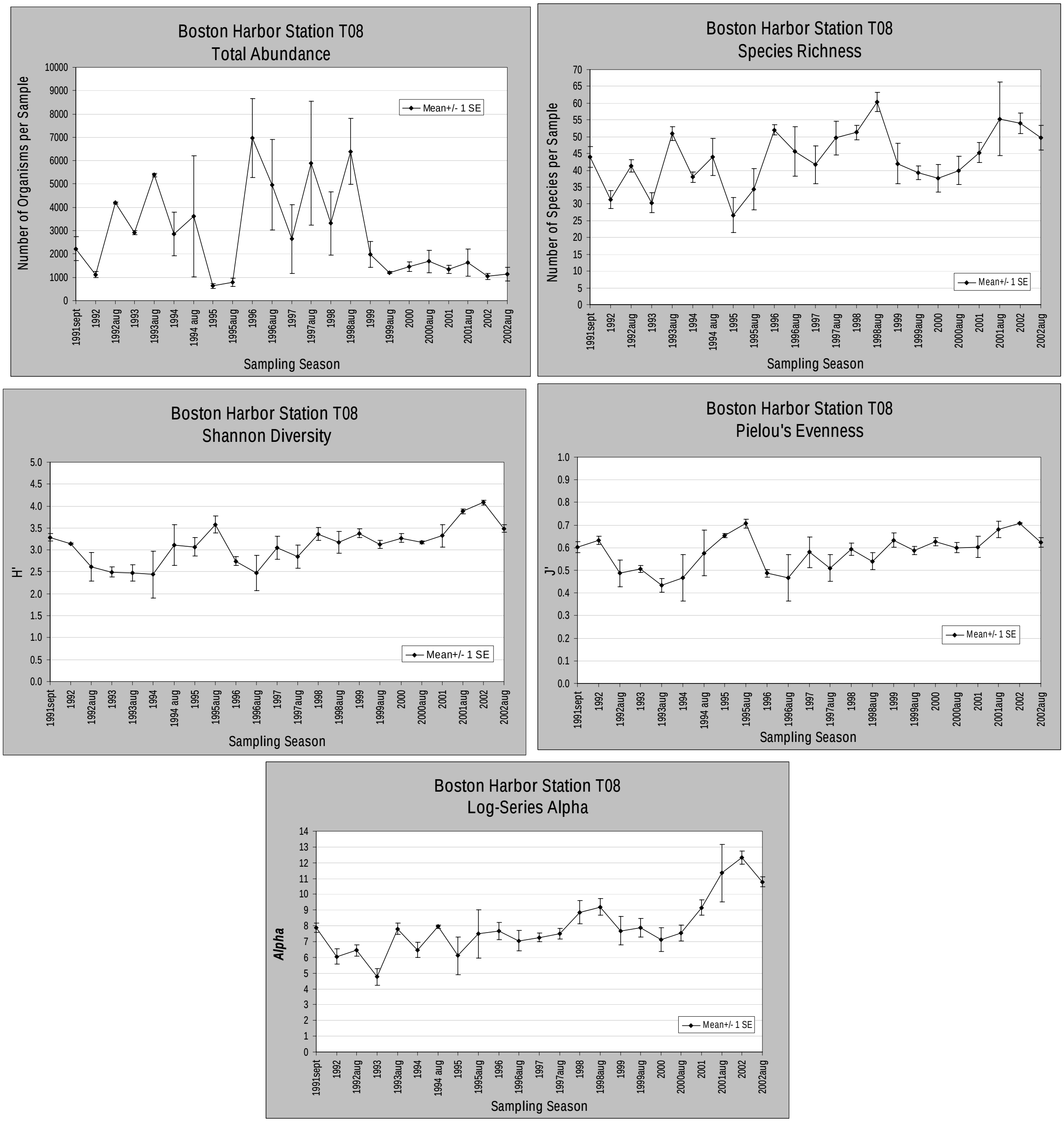


Figure 5-21. Benthic community parameters at Boston Harbor station T08 for the period September 1991 through August 2002.

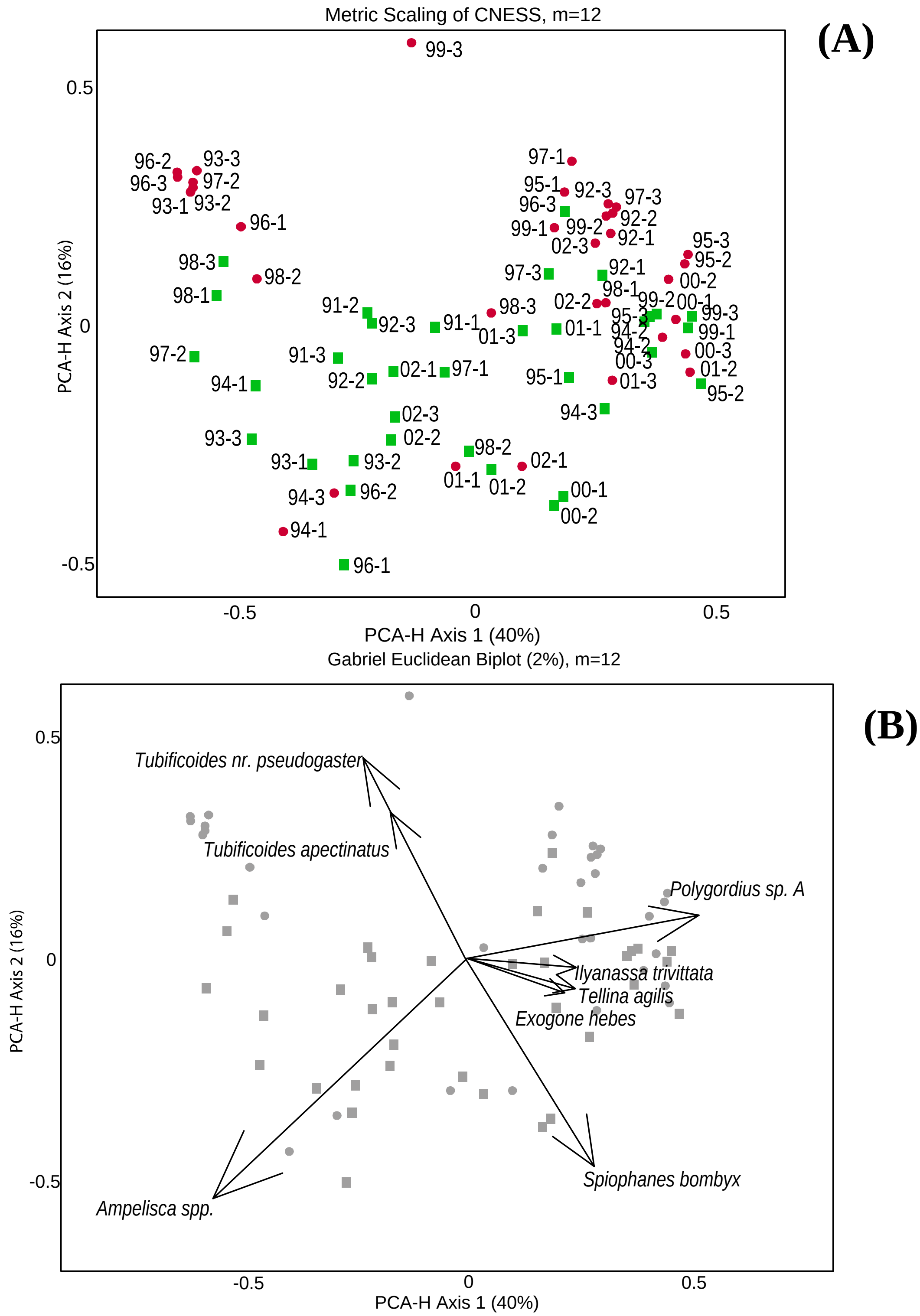


Figure 5-22. Metric scaling (A) and Gabriel Euclidean distance biplot (B) for Boston Harbor station T08, 1991-2002. Squares represent summer (August or September) samples and circles represent April samples. Labels are year and replicate (A) and species that account for more than 2% of the variation (B).

5.3.5 Multivariate Analysis for Long-term Trends in Similarity Among Stations

The full 1991–2002 data set of 550 samples and 274 species was analyzed by PCA-H to investigate the relationships among samples and stations from successive sampling dates. Figure 5-23 shows the relationship of all 550 samples on PCA-H axes 1 and 2, which explained 34% of the total CNESS variation. Not all samples could be distinguished on the printout, but a sufficient number could be identified to indicate that, as seen for the analysis of 2002 data only, CNESS distances among samples tend to distinguish stations within the multidimensional space. For example, samples from T04 are seen on the left center of the diagram, and samples from T08 are in the upper right corner. Table 5-4 shows the species that are important in causing the distribution of samples on seven axes in PCA-H space. The Gabriel Euclidean distance biplot for this data set (axes 1 and 2 only) is shown in Figure 5-24.

Table 5-4. Important species, and their relative and cumulative and contributions to PCA-H axes 1–7.

Rank	Species	% Contr.	Cum. Contr.	Ax.1	Ax.2	Ax.3	Ax.4	Ax.5	Ax.6	Ax.7
1	*Streblospio benedicti*	13	13	42	4	6	4	24	0	0
2	*Ampelisca* spp.	9	22	21	17	3	0	16	4	10
3	*Tubificoides* nr. *pseudogaster*	8	30	1	7	24	46	2	4	2
4	*Polydora cornuta*	7	38	0	20	18	5	13	18	7
5	*Aricidea catherinae*	7	45	16	2	7	5	3	1	26
6	*Tubificoides apectinatus*	7	52	7	0	21	21	10	1	2
7	*Capitella capitata* complex	5	57	4	3	3	1	14	36	2
8	*Tharyx* spp.	4	61	0	1	3	1	4	10	30
9	*Spiophanes bombyx*	3	65	1	12	4	1	3	4	0
10	*Polygordius* sp. A	3	67	0	10	2	1	2	2	0
11	*Ilyanassa trivittata*	2	70	0	5	0	2	0	1	3
12	*Micropthalmus pettiboneae*	2	72	0	0	1	0	1	5	1
13	*Leptocheirus pinguis*	2	74	1	1	1	0	0	0	0
14	*Tubificoides* sp. 2	2	75	0	0	0	1	0	1	0
15	*Paranais litoralis*	2	77	1	0	1	0	1	1	2
16	*Phoxocephalus holbolli*	2	79	2	2	0	1	0	1	0
17	*Nephtys cornuta*	2	80	0	0	1	7	0	0	0
18	*Nucula delphinodonta*	1	82	1	2	0	0	3	0	1
19	*Tellina agilis*	1	83	0	4	1	0	0	1	1
20	*Crassicorophium bonelli*	1	85	0	1	1	0	0	0	0
21	*Chaetozone vivapara*	1	86	0	0	0	0	0	1	2
22	*Exogone hebes*	1	87	0	4	1	0	1	2	1
23	*Photis pollex*	1	89	1	1	0	1	0	0	2
24	*Unciola irrorata*	1	90	1	0	3	0	0	0	1
25	*Dipolydora socialis*	1	91	0	1	0	0	0	1	0
26	*Turbellaria* spp.	1	91	0	0	0	0	0	0	0
27	*Clymenella torquata*	1	92	0	0	0	0	0	1	0
28	*Tubificoides benedeni*	1	93	0	0	0	0	1	0	1
29	*Edotia triloba*	1	93	0	0	0	0	0	0	2
30	*Scoletoma hebes*	1	94	0	0	0	0	0	0	1

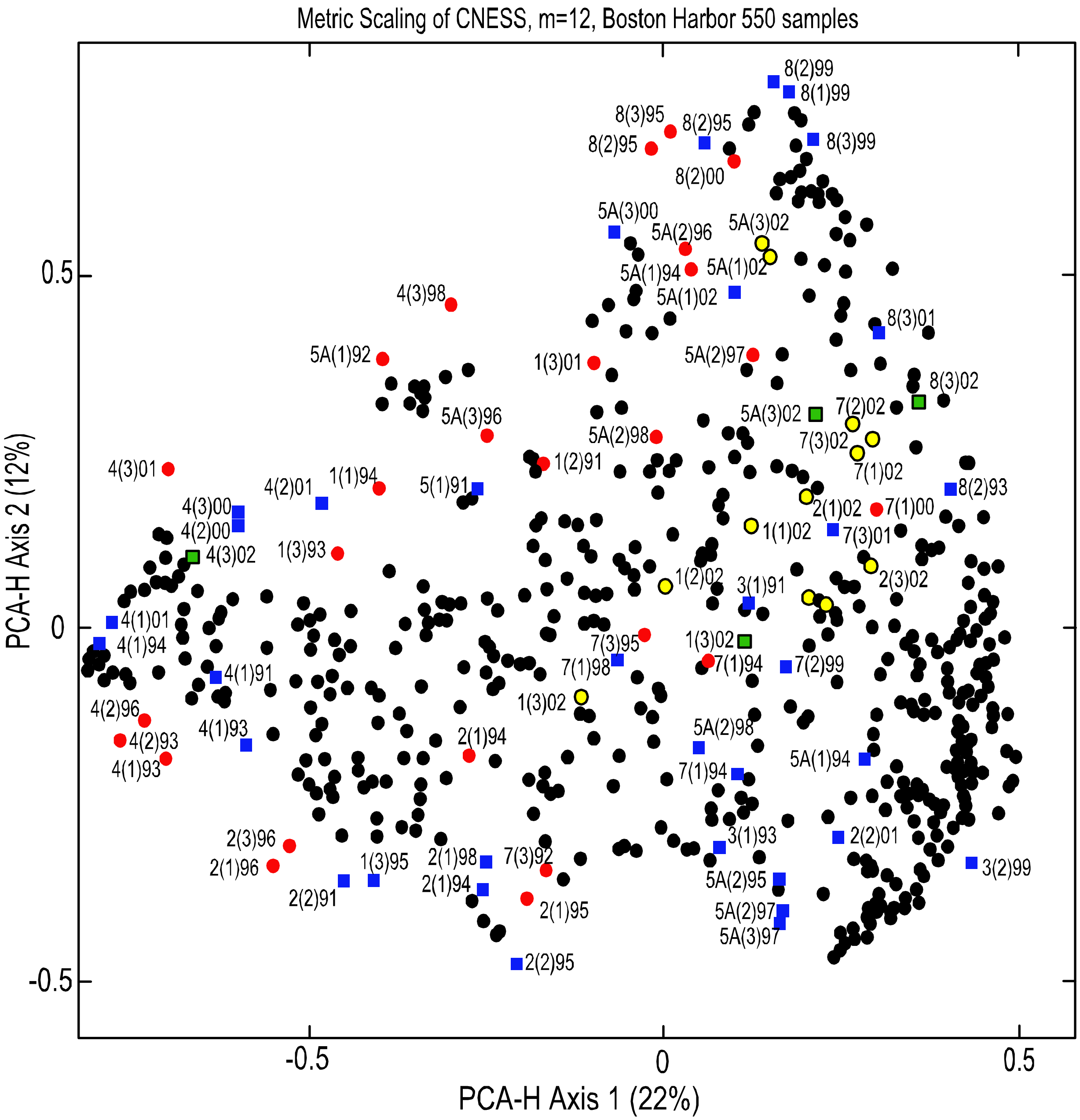


Figure 5-23. Metric scaling of all 550 samples taken in Boston Harbor from September 1991 through August 2002. Selected samples are plotted as colored circles (red for Spring 1991–2001, yellow for Spring 2002) or colored squares (blue for Summer 1991–2001, green for Summer 2002); remaining samples are plotted as black circles. Labels are station (replicate) year.

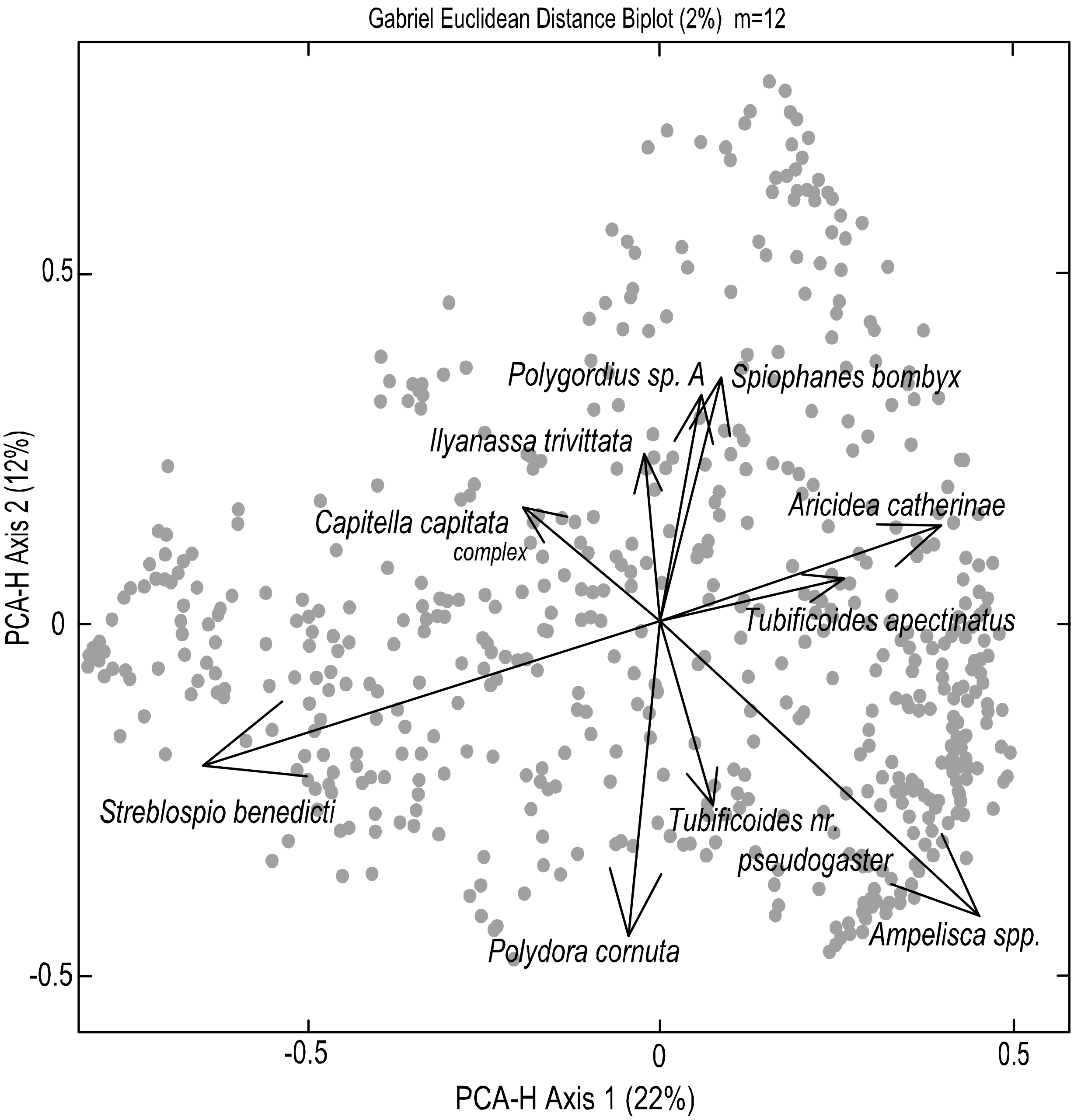


Figure 5-24. Gabriel Euclidean distance biplot of all 550 Boston Harbor samples, showing the ten species that account for at least 2% of the plot variation on PCA-H axes 1 and 2.

A series of cluster analyses of this data set was carried out with replicates pooled at each station (184 “samples”, 274 taxa), with all stations pooled for each season (23 “samples”, 274 taxa), summer “samples” only, with all replicates pooled within a year (12 “samples”, 234 taxa), and spring samples only, with all replicates pooled within a year (11 “samples”, 216 taxa). The most informative analysis, and one comparable to that presented by Diaz and Kropp (Figure 5-11 in Kropp *et al.* 2002b), is the one with 184 samples, representing replicates pooled at each station. In the earlier analysis, taxa with >16 occurrences and >1000 total abundance were used; in the present analysis, all taxa were used irrespective of total abundances. CNESS was used as the dissimilarity index in both cases, and because this algorithm is sensitive to rare species, leaving all taxa in the analysis takes greater advantage of the CNESS capabilities than dropping those species which may be considered rare.

Even with this difference, the results were exceedingly similar. Diaz and Kropp (Table 5-4 and Figure 5-11 in Kropp *et al.* 2002b) show ten station groups with many stations showing a high degree of within-station similarity. Essentially the same groups were seen, clustering at the same level in the 1991–2002 analysis (Figure 5-25) as in the 1991–2001 analysis. The most interesting point from this figure, however, is that samples from T01 for 2002 cluster with samples from that station for 2000 and 2001, and are very dissimilar to earlier samples from this station. Taken together with the increased diversity and changing species composition at this station, as well as the very high OSI seen here in 2002 (Chapter 3, this report), it would seem that conditions at this station are improving relative to the condition in the late 1970s and early 1990s.

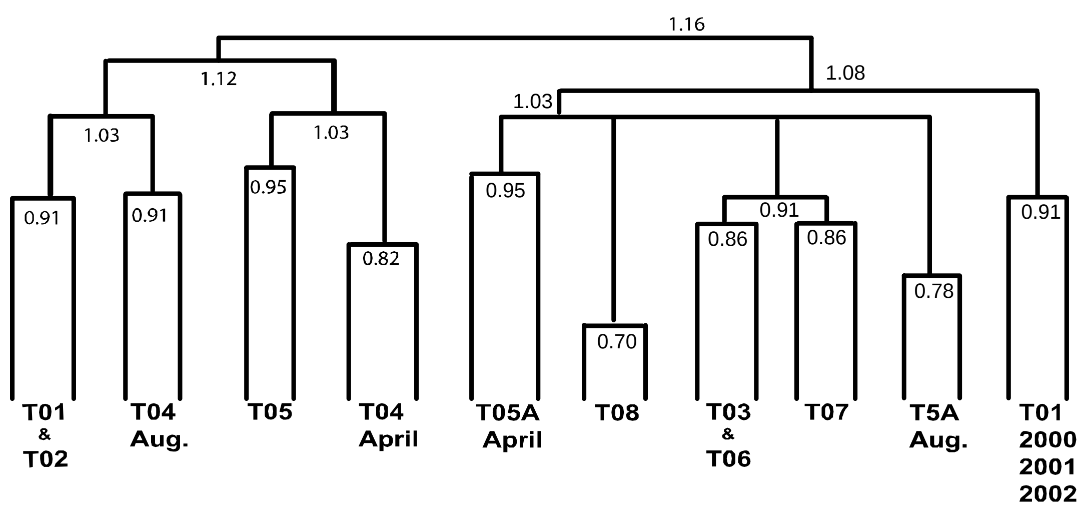


Figure 5-25. Station dendrogram for Boston Harbor 1991-2002 infauna. The similarity levels for each cluster are indicated on the diagram: the lower the number, the more similar the stations. Replicates summed at each station, CNESS *m* = 20 and group average sorting were used. 274 taxa and 184 samples were included.

5.4 Discussion

5.4.1 Long-term Changes in the Infaunal Communities

The results of the earliest studies of the benthic communities of Boston Harbor (1978, 1979, 1982) indicated distinct groupings of stations that corresponded to (1) a progression from higher saline oceanic conditions in the outer harbor to estuarine conditions in the inner harbor and (2) known areas of pollution (Blake and Maciolek, unpublished manuscript). The 1978 data suggested a pattern of change from the outer to the central portions of the harbor. A distinct outer harbor assemblage that included species with close affinities to faunal communities in Massachusetts Bay changed in the middle of the harbor to one that included estuarine species and elements of so-called pollution indicators or stress-tolerant taxa. Species diversity values for 1978 indicated a richer infaunal component in the outer rather than in the middle of the harbor. All stations in the outer harbor assemblage had more species and higher species diversity values regardless of the analytical technique. Stations having high infaunal densities were found throughout the station array, but opportunistic species were found only at the stations in the middle of the harbor.

The 1979 and 1982 data clearly indicated an obvious north/south pattern in the communities, with stations near the northern Deer Island outfall being distinctly different from those near Nut Island in Hingham Bay in the southern part of the harbor. As seen in the 1978 data, the southern region of the harbor shared more species with Massachusetts Bay than with other areas of the harbor, suggesting a link between Boston Harbor and Massachusetts Bay. Stations in the inner harbor differed from these outer harbor communities. In 1979, the high faunal densities were due largely to dense populations of amphipods that were not as important in 1978 or 1982. In 1982, very low infaunal densities were recorded for stations in the deeper channels off the Deer Island outfall. Diversities, however, were high, suggesting that the tidal exchange through Presidents Road and Broad Sound was sufficient to maintain benthic assemblages that were only moderately stressed despite their proximity to the sewage and sludge outfalls. In contrast, shallow sites to the east and west of the outfall had low diversities and high densities of opportunistic stress-tolerant species.

Discharge of sludge into the harbor was ended in 1991 and, in 1998, all effluent discharge from Nut Island was discontinued and full secondary treatment of the effluent was implemented. Since that time, the most dramatic changes in benthic communities have been at T01, near the Deer Island flats, and T02 near Logan Airport. Both of these stations have increased in diversity and other measures of benthic community status. Species composition has changed, especially at T01, where densities of *Streblospio benedicti*, usually considered indicative of stressed environments, have declined in recent years, and densities of *Aricidea catherinae*, a very common polychaete found both elsewhere in the harbor and offshore in Massachusetts Bay, have increased. The presence of particular benthic species is often related to the grain-size composition of the sediment. Mean percent fines (silt-plus-clay fraction) have increased slightly at T01 in the past few years (see Chapter 4, this report), but this change does not appear to be of sufficient magnitude in itself to have resulted in the changes seen in the structure of the benthic community. In some areas, an increase in fines might be expected to favor rather than inhibit the maintenance of the *Streblospio* population (JA Blake, pers comm to NJ Maciolek).

Stations T03 and especially T05A have evidenced wide fluctuations in community parameters, often due to the seasonal presence of large numbers of amphipod species or the polychaete *Polydora cornuta*. Although these stations do not appear to have changed significantly in terms of numerically dominant species, it is noteworthy that offshore species such as *Scolelepis tridentata* and *Polydora* sp. 1 have occurred at T05A in the last year or two, although such occurrences are usually only of a single individual.

Many of the patterns in benthic community structure described above for 1978–1982 have continued throughout the period 1991–2002 at stations in the southern portion of the harbor. Those stations that appeared diverse according to the several parameters measured prior to the cessation of sludge and effluent discharge have changed little in those parameters in the years since the discharges were diverted. Stations T06, T07, and T08 have consistently had the highest species richness and diversities, and the dominant species have remained similar, although at T07 *Nephtys cornuta* and *Tubificoides apectinatus* have increased in recent years.

5.4.2 *Ampelisca*

Recovery of areas degraded by the long-term disposal of sludge and effluents may involve a transitional stage of undetermined length before an equilibrium community is established. This intermediate stage involves the appearance of a diverse assemblage of tube-dwelling amphipods, molluscs, and polychaetes. The periodic explosion and decline of amphipod populations dominated by *Ampelisca* spp. would suggest that infaunal succession patterns are being held in the Stage I and II seres as defined by Rhoads and Germano (1986). Two species of *Ampelisca* are found in Boston Harbor: *A. abdita* and *A. vadorum*, but are combined with juveniles and otherwise unidentifiable individuals to the taxon *Ampelisca* spp. for report purposes. Early populations of *A. vadorum* recorded in the 1978–1982 studies have largely been replaced by *A. abdita*, which has accounted for nearly 97% of the *Ampelisca* identified since 1995. The two species often co-occur at T06 and T08.

Mills (1967) studied the biology of *Ampelisca abdita* in Barnstable Harbor, Cape Cod, and compared it with that of *A. vadorum* from Long Island Sound. *A. abdita* is associated with fine sand to muddy substrates, and *A. vadorum* with coarse sand (Mills 1967). The animals collected in April represent an over-wintering generation Mills (1967); breeding starts when water temperatures reach 8°C, which is probably late April to early May. Young produced by this overwintering generation attain breeding size in June or July and over the course of the next few months produce the next over-wintering generation. Adults swim freely in the water column to mate, and the ovigerous females will settle into previously unoccupied areas to release their young, causing a physical shift in the location of the population from areas of old, silted-in tubes to unmodified sediments. The adults do not survive beyond breeding, but the juveniles quickly begin building tubes (Mills 1967). Establishment of a population and expansion within a suitable area results in modification of the environment. The amphipod tubes trap sediment and detritus and result in a much more complex habitat than was previously available, allowing other species to colonize the area. Ultimately, the *Ampelisca* may leave the area, either through the reproductive behavior noted above or unavailability of the preferred clean fine-sand substrate (Mills 1969). The storm in late October 1991 that scoured bottom areas of Massachusetts Bay and Boston Harbor likely caused the disappearance of the *Ampelisca* mats that had been seen in sediment profiling surveys in previous years (SAIC 1992), with the resultant low densities in spring 1992 (see Figure 5-2). However, this storm action also probably provided clean uncolonized areas of suitable substrate for *Ampelisca* to become reestablished, after which large populations were able to develop.

5.4.3 Changes in Species Richness

One line of evidence that the benthic communities in Boston Harbor are responding to the elimination of pollutants from the former sewage discharge(s), particularly since 1998, is the increase in species richness; that is, the absolute number of taxa found in each sample. Over the period 1991–2002, the sample size, mesh size of the sieves, and method of processing the samples were consistent, allowing direct comparison of these samples. Although there was some turnover in the taxonomists dealing with specific faunal groups, a recent review of the data suggests that any discrepancies in faunal identifications most likely pertain only to a few rare species. During the monitoring period, the overall species richness in the harbor increased approximately 1.5 times (Figure 5-26, left). Similarly, Fisher's log-series *alpha*, a computed measure of species richness, also increased dramatically, especially for the summer samples (Figure 5-26, right). As seen in Figure 5-27, these increases were not equivalent at all stations: species richness at T04 has not particularly increased over the past decade, whereas at T08 the number of species recorded in each summer sample has nearly doubled. A similar increase is seen in spring samples from T01. The statistical significance of these findings, including the seasonal and annual fluctuations in these measures at each station and over the entire harbor, will be evaluated further in future reports.

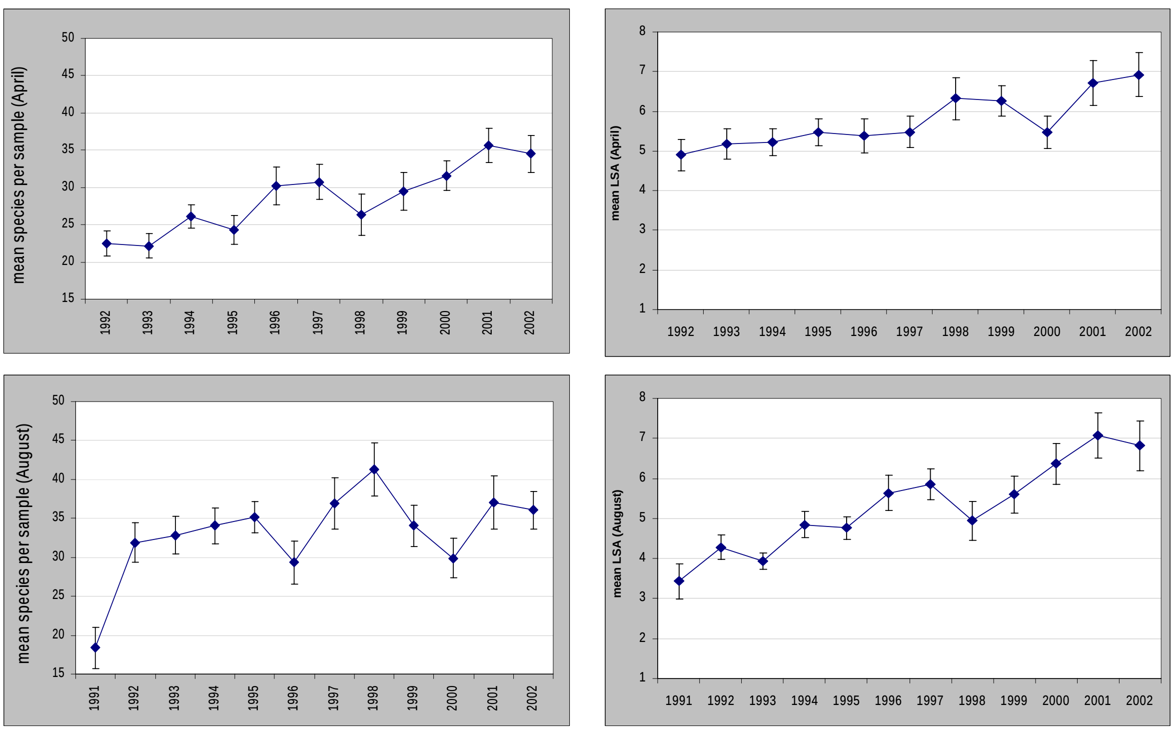


Figure 5-26. Species richness (left) and log-series *alpha* (right) (mean ± 1 SE) in Boston Harbor, with all eight stations pooled for each sampling event from 1991 through 2002. Top: Spring (April) samples; Bottom: Summer (August or September samples.)

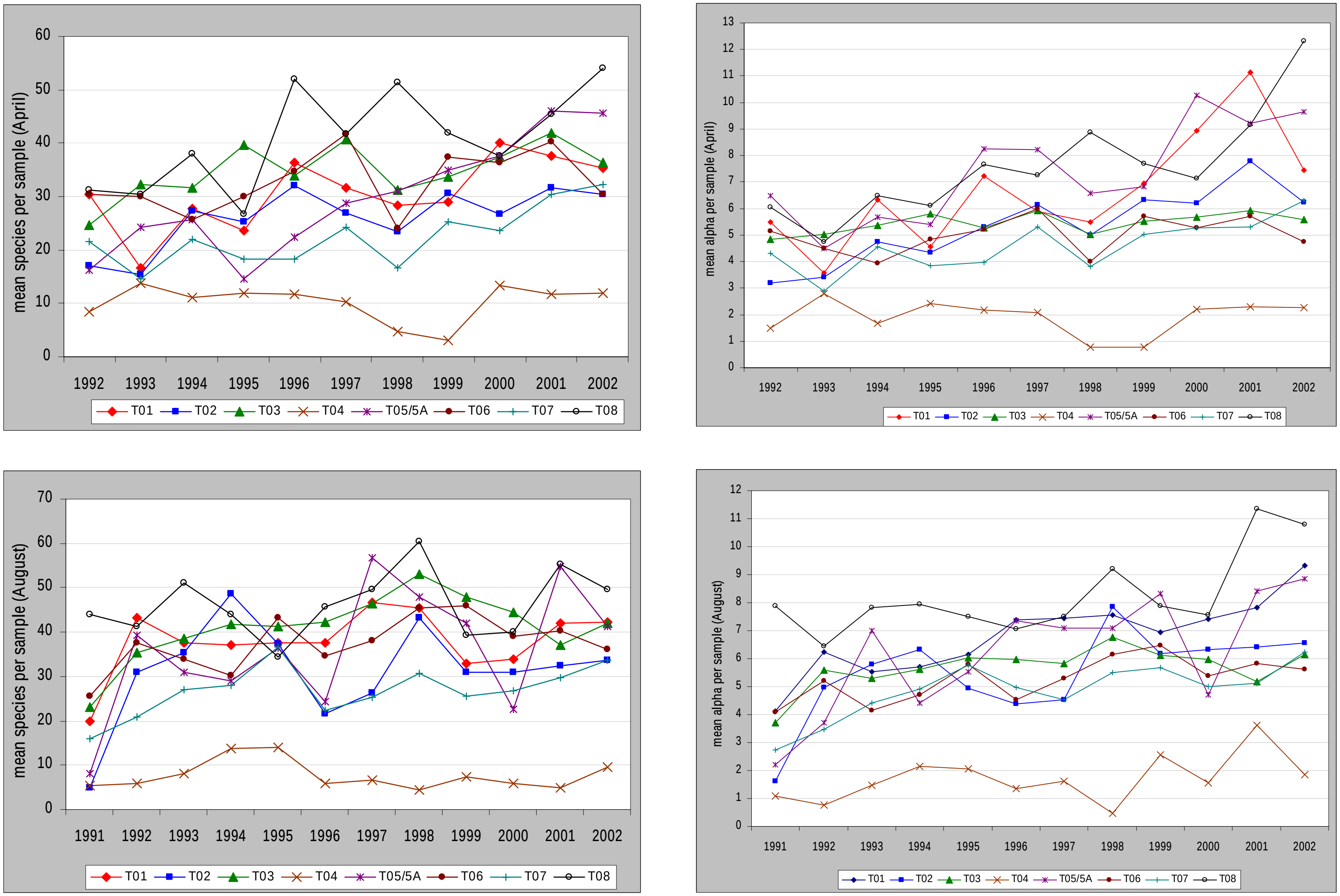


Figure 5-27. Species richness (left) and Fisher's log-series *alpha* (right) (mean ± 1 SE) at individual Boston Harbor stations, with samples at each station averaged for each sampling event from 1991 through 2002. Top: Spring (April); Bottom: Summer (August or September).

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APPENDIX A

Station Data

Sediment Profile Images (HR021)

April/ May Benthic Grab Samples (HT021)

August Benthic Grab Samples (HT022)

Table A-1. Station data for individual sediment profile images collected in August 2002 (HR021).

SPI Station ID	SPI Sample ID	Date/Time (EDT)	Replicate analyzed*	Longitude (W)	Latitude (N)	Depth (m)
R02	HR0210DC	8/26/02 15:06	1*	-70.961502	42.344349	14.1
	HR0210DD	8/26/02 15:07	2*	-70.961487	42.344368	14.1
	HR0210DE	8/26/02 15:09	3*	-70.961502	42.344334	14.1
	HR0210DF	8/26/02 15:10	4	-70.961517	42.344318	14.2
R03	HR0210FA	8/26/02 15:41	1*	-70.972900	42.353050	5.8
	HR0210FB	8/26/02 15:41	2*	-70.972900	42.353050	5.8
	HR0210FC	8/26/02 15:42	3*	-70.972900	42.353065	5.8
	HR0210FD	8/26/02 15:43	4	-70.972900	42.353065	5.8
R04	HR021108	8/26/02 15:54	1*	-70.979469	42.358616	7.7
	HR021109	8/26/02 15:55	2*	-70.979485	42.358650	8.0
	HR02110A	8/26/02 15:56	3*	-70.979515	42.358685	8.0
	HR02110B	8/26/02 15:57	4	-70.979568	42.358715	7.7
R05	HR021101	8/26/02 15:48	1*	-70.978119	42.356400	6.5
	HR021102	8/26/02 15:49	2*	-70.978119	42.356400	6.4
	HR021103	8/26/02 15:49	3*	-70.978165	42.356415	6.4
	HR021104	8/26/02 15:51	4	-70.978233	42.356434	6.5
R06	HR0210CE	8/26/02 14:44	1*	-70.951851	42.331718	7.7
	HR0210CF	8/26/02 14:45	2*	-70.951950	42.331699	7.3
	HR0210D0	8/26/02 14:47	3*	-70.952103	42.331665	7.0
	HR0210D1	8/26/02 14:48	4	-70.952263	42.331665	7.1
R07	HR0210F1	8/26/02 15:31	1*	-70.975487	42.347450	7.1
	HR0210F2	8/26/02 15:32	2*	-70.975433	42.347500	7.1
	HR0210F3	8/26/02 15:33	3*	-70.975380	42.347515	7.1
	HR0210F4	8/26/02 15:34	4	-70.975334	42.347515	7.0
R08	HR021111	8/26/02 16:09	1*	-70.991600	42.344398	3.8
	HR021112	8/26/02 16:11	2*	-70.991570	42.344467	3.8
	HR021113	8/26/02 16:12	3	-70.991547	42.344482	3.7
	HR021114	8/26/02 16:12	4*	-70.991531	42.344517	3.8
R09	HR021126	8/26/02 16:38	1*	-71.016380	42.346699	12.6
	HR021127	8/26/02 16:40	2*	-71.016281	42.346649	12.5
	HR021128	8/26/02 16:42	3*	-71.016151	42.346615	12.0
	HR021129	8/26/02 16:43	4	-71.015999	42.346600	12.6
R10	HR02112D	8/26/02 17:00	1	-71.036835	42.355148	13.5
	HR02112E	8/26/02 17:02	2*	-71.036751	42.355133	13.6
	HR02112F	8/26/02 17:03	3*	-71.036598	42.355148	13.6
	HR021130	8/26/02 17:05	4*	-71.036469	42.355167	13.5
R11	HR021179	8/27/02 10:36	1*	-70.974648	42.321350	6.2
	HR02117A	8/27/02 10:37	2*	-70.974716	42.321350	5.7
	HR02117B	8/27/02 10:38	3	-70.974785	42.321365	5.6
	HR02117C	8/27/02 10:39	4*	-70.974831	42.321384	5.5
R12	HR021180	8/27/02 10:44	1	-70.974586	42.318466	4.9
	HR021181	8/27/02 10:45	2*	-70.974632	42.318481	4.9
	HR021182	8/27/02 10:45	3*	-70.974648	42.318501	5.0
	HR021183	8/27/02 10:46	4*	-70.974686	42.318516	4.9
R13	HR021187	8/27/02 10:57	1*	-70.980598	42.317200	4.6
	HR021188	8/27/02 10:58	2*	-70.980598	42.317215	5.0
	HR021189	8/27/02 10:59	3*	-70.980598	42.317234	5.0
	HR02118A	8/27/02 10:59	4	-70.980598	42.317249	5.0

SPI Station ID	SPI Sample ID	Date/Time (EDT)	Replicate analyzed*	Longitude (W)	Latitude (N)	Depth (m)
R14	HR0211B0	8/27/02 11:31	1	-71.012680	42.320766	7.1
	HR0211B1	8/27/02 11:31	2*	-71.012634	42.320766	7.1
	HR0211B2	8/27/02 11:32	3*	-71.012619	42.320751	7.1
	HR0211B3	8/27/02 11:33	4*	-71.012581	42.320751	7.2
R15	HR0211B7	8/27/02 11:40	1*	-71.019302	42.315300	3.5
	HR0211B8	8/27/02 11:41	2	-71.019333	42.315334	3.8
	HR0211B9	8/27/02 11:41	3*	-71.019348	42.315365	3.9
	HR0211BA	8/27/02 11:42	4*	-71.019386	42.315384	3.9
R16	HR02121F	8/27/02 14:48	1*	-70.961280	42.315900	8.6
	HR021220	8/27/02 14:49	2*	-70.961197	42.315933	8.7
	HR021221	8/27/02 14:50	3	-70.961136	42.315968	8.6
	HR021222	8/27/02 14:51	4*	-70.961136	42.316002	8.5
R17	HR0211DC	8/27/02 13:00	1*	-70.977417	42.304867	7.0
	HR0211DD	8/27/02 13:01	2	-70.977486	42.304901	7.0
	HR0211DE	8/27/02 13:02	3*	-70.977516	42.304882	7.3
	HR0211DF	8/27/02 13:03	4*	-70.977501	42.304798	6.5
R18	HR021253	8/27/02 15:59	1*	-70.961197	42.288666	9.5
	HR021254	8/27/02 16:00	2*	-70.961266	42.288685	9.1
	HR021255	8/27/02 16:01	3*	-70.961334	42.288685	9.1
	HR021256	8/27/02 16:02	4	-70.961449	42.288700	8.9
R19	HR021137	8/27/02 7:46	1*	-70.937653	42.282082	8.4
	HR021138	8/27/02 7:47	2*	-70.937614	42.282101	8.3
	HR021139	8/27/02 7:48	3*	-70.937614	42.282101	8.4
	HR02113A	8/27/02 7:49	4	-70.937599	42.282101	8.4
R20	HR021228	8/27/02 15:02	1*	-70.935036	42.324833	10.5
	HR021229	8/27/02 15:03	2*	-70.935020	42.324848	10.6
	HR02122B	8/27/02 15:05	3	-70.935081	42.324848	10.6
	HR02122C	8/27/02 15:06	4*	-70.935120	42.324848	10.4
R21	HR021230	8/27/02 15:16	1*	-70.946098	42.308968	8.7
	HR021231	8/27/02 15:17	2*	-70.946068	42.308918	8.5
	HR021232	8/27/02 15:18	3	-70.946068	42.308899	8.5
	HR021233	8/27/02 15:19	4*	-70.946083	42.308884	8.5
R22	HR021237	8/27/02 15:25	1*	-70.939400	42.300301	10.1
	HR021238	8/27/02 15:26	2*	-70.939400	42.300335	10.2
	HR021239	8/27/02 15:27	3*	-70.939453	42.300385	10.0
	HR02123A	8/27/02 15:29	4	-70.939499	42.300434	10.2
R23	HR021245	8/27/02 15:41	1*	-70.950165	42.293865	11.2
	HR021246	8/27/02 15:42	2*	-70.950203	42.293900	11.3
	HR021247	8/27/02 15:43	3	-70.950249	42.293949	11.4
	HR021248	8/27/02 15:45	4*	-70.950302	42.293999	11.5
R24	HR02124C	8/27/02 15:51	1*	-70.958519	42.296417	8.5
	HR02124D	8/27/02 15:52	2*	-70.958519	42.296417	8.3
	HR02124E	8/27/02 15:53	3*	-70.958534	42.296398	8.1
	HR02124F	8/27/02 15:53	4	-70.958580	42.296383	8.0
R25	HR02113E	8/27/02 7:56	1*	-70.928635	42.291367	4.9
	HR02113F	8/27/02 7:57	2*	-70.928619	42.291382	5.0
	HR021140	8/27/02 7:58	3*	-70.928619	42.291401	4.9
	HR021141	8/27/02 7:58	4	-70.928581	42.291416	4.9
R26	HR02101D	8/26/02 7:41	1*	-70.929890	42.268820	5.8
	HR02101E	8/26/02 7:42	2	-70.929830	42.268820	5.8

SPI Station ID	SPI Sample ID	Date/Time (EDT)	Replicate analyzed*	Longitude (W)	Latitude (N)	Depth (m)
	HR02101F	8/26/02 7:43	3*	-70.929800	42.268820	5.8
	HR021020	8/26/02 7:43	4*	-70.929750	42.268820	5.8
R27	HR021291	8/28/02 8:39	1	-70.916214	42.280468	3.6
	HR021292	8/28/02 8:39	2*	-70.916214	42.280499	3.7
	HR021293	8/28/02 8:40	3*	-70.916130	42.280518	3.4
	HR021294	8/28/02 8:41	4*	-70.916130	42.280518	3.4
R28	HR021274	8/28/02 7:57	1*	-70.908653	42.281734	8.2
	HR021275	8/28/02 7:58	2*	-70.908630	42.281765	8.2
	HR021276	8/28/02 7:58	3*	-70.908615	42.281799	8.3
	HR021277	8/28/02 7:59	4	-70.908615	42.281868	8.3
R29	HR021145	8/27/02 8:04	1	-70.920967	42.289799	7.8
	HR021146	8/27/02 8:05	2*	-70.920967	42.289799	7.8
	HR021147	8/27/02 8:06	3*	-70.920967	42.289818	7.8
	HR021148	8/27/02 8:07	4*	-70.920967	42.289818	7.8
R30	HR02127B	8/28/02 8:07	1	-70.904213	42.290482	3.0
	HR02127C	8/28/02 8:08	2*	-70.904182	42.290501	2.9
	HR02127D	8/28/02 8:09	3*	-70.904167	42.290501	2.9
	HR02127E	8/28/02 8:09	4*	-70.904167	42.290501	2.9
R31	HR021153	8/27/02 8:20	1*	-70.917183	42.300850	8.9
	HR021154	8/27/02 8:21	2*	-70.917168	42.300884	8.8
	HR021155	8/27/02 8:22	3*	-70.917152	42.300884	8.8
	HR021156	8/27/02 8:23	4	-70.917137	42.300884	8.9
R32	HR021282	8/28/02 8:17	1*	-70.897003	42.294701	3.0
	HR021283	8/28/02 8:17	2	-70.896980	42.294701	3.0
	HR021284	8/28/02 8:18	3*	-70.896965	42.294701	3.0
	HR021285	8/28/02 8:19	4*	-70.896950	42.294682	3.0
R33	HR0211F1	8/27/02 13:26	1*	-70.994614	42.294182	4.4
	HR0211F2	8/27/02 13:26	2*	-70.994614	42.294182	4.4
	HR0211F3	8/27/02 13:43	3*	-70.994514	42.294266	4.6
	HR0211F4	8/27/02 13:44	4	-70.994499	42.294300	4.6
	HR0211F5	8/27/02 13:44	5	-70.994484	42.294300	3.4
R34	HR0211FA	8/27/02 13:56	2*	-71.007050	42.288834	3.8
	HR0211FB	8/27/02 13:57	3*	-71.007034	42.288849	3.8
	HR0211FC	8/27/02 13:58	4*	-71.007034	42.288849	3.8
	HR0211FF	8/27/02 13:59	5	-71.006866	42.288883	3.9
R35	HR02120A	8/27/02 14:18	1	-70.987984	42.284382	5.0
	HR02120B	8/27/02 14:19	2*	-70.987930	42.284382	5.0
	HR02120C	8/27/02 14:20	3*	-70.987900	42.284401	5.1
	HR02120D	8/27/02 14:21	4*	-70.987900	42.284416	5.1
R36	HR021203	8/27/02 14:10	1	-70.986580	42.275684	4.4
	HR021204	8/27/02 14:11	2*	-70.986534	42.275700	4.4
	HR021205	8/27/02 14:12	3*	-70.986534	42.275700	4.4
	HR021206	8/27/02 14:12	4*	-70.986504	42.275700	4.4
R37	HR0211E3	8/27/02 13:08	1*	-70.984581	42.298733	5.4
	HR0211E4	8/27/02 13:10	2*	-70.984787	42.298752	5.4
	HR0211E5	8/27/02 13:11	3*	-70.984787	42.298752	5.4
	HR0211E6	8/27/02 13:11	4	-70.984802	42.298733	5.4
R38	HR02125A	8/27/02 16:07	1*	-70.963715	42.284634	6.6
	HR02125B	8/27/02 16:08	2	-70.963730	42.284634	6.5
	HR02125C	8/27/02 16:09	3*	-70.963730	42.284649	6.5

SPI Station ID	SPI Sample ID	Date/Time (EDT)	Replicate analyzed*	Longitude (W)	Latitude (N)	Depth (m)
	HR02125D	8/27/02 16:10	4*	-70.963715	42.284649	6.5
R39	HR021218	8/27/02 14:37	1*	-70.970337	42.295601	7.5
	HR021219	8/27/02 14:37	2*	-70.970314	42.295635	7.9
	HR02121A	8/27/02 14:38	3	-70.970299	42.295650	7.9
	HR02121B	8/27/02 14:39	4*	-70.970284	42.295685	7.8
R40	HR02118E	8/27/02 11:19	1*	-71.024170	42.328968	3.5
	HR02118F	8/27/02 11:20	2*	-71.024147	42.328983	3.4
	HR021190	8/27/02 11:20	3*	-71.024147	42.328968	3.3
	HR021191	8/27/02 11:21	4	-71.024132	42.328968	3.5
R41	HR0211C5	8/27/02 11:59	1*	-71.024948	42.311134	4.8
	HR0211C6	8/27/02 12:00	2*	-71.024986	42.311134	4.8
	HR0211C7	8/27/02 12:00	3*	-71.025017	42.311115	4.7
	HR0211C8	8/27/02 12:01	4	-71.025047	42.311085	4.8
R42	HR0211BE	8/27/02 11:49	1*	-71.025032	42.319435	3.0
	HR0211BF	8/27/02 11:50	2*	-71.025070	42.319466	2.8
	HR0211C0	8/27/02 11:50	3*	-71.025116	42.319500	2.9
	HR0211C1	8/27/02 11:51	4	-71.025131	42.319515	2.9
R43	HR0211D5	8/27/02 12:45	1	-71.001930	42.306667	4.1
	HR0211D6	8/27/02 12:46	2*	-71.001953	42.306667	4.0
	HR0211D7	8/27/02 12:47	3*	-71.001999	42.306648	4.1
	HR0211D8	8/27/02 12:48	4*	-71.002014	42.306648	4.1
R44	HR02111F	8/26/02 16:28	1*	-71.002151	42.343666	10.6
	HR021120	8/26/02 16:29	2*	-71.002068	42.343700	10.7
	HR021121	8/26/02 16:31	3*	-71.001968	42.343750	10.5
	HR021122	8/26/02 16:32	4	-71.001884	42.343784	10.5
R45	HR021172	8/27/02 10:27	1*	-70.967499	42.328384	6.7
	HR021173	8/27/02 10:28	2*	-70.967468	42.328365	6.8
	HR021174	8/27/02 10:29	3*	-70.967430	42.328335	6.8
	HR021175	8/27/02 10:30	4	-70.967430	42.328300	6.7
R46	HR02114C	8/27/02 8:11	1	-70.922150	42.290966	7.5
	HR02114D	8/27/02 8:12	2*	-70.922150	42.290966	7.5
	HR02114E	8/27/02 8:12	3*	-70.922134	42.290985	7.5
	HR02114F	8/27/02 8:13	4*	-70.922134	42.290966	7.5
R47	HR0210EA	8/26/02 15:24	1*	-70.978920	42.344582	6.5
	HR0210EB	8/26/02 15:25	2*	-70.978920	42.344601	6.5
	HR0210EC	8/26/02 15:26	3	-70.978836	42.344685	6.5
	HR0210ED	8/26/02 15:27	4*	-70.978783	42.344700	6.5
R48	HR0211EA	8/27/02 13:17	1*	-70.987930	42.293499	4.9
	HR0211EB	8/27/02 13:18	2	-70.987953	42.293518	5.0
	HR0211EC	8/27/02 13:19	3*	-70.987968	42.293533	5.0
	HR0211ED	8/27/02 13:20	4*	-70.987984	42.293533	5.0
R49	HR021266	8/28/02 7:35	1*	-70.908134	42.273216	5.8
	HR021267	8/28/02 7:37	2*	-70.908203	42.273132	5.7
	HR021268	8/28/02 7:37	3	-70.908165	42.273132	5.8
	HR021269	8/28/02 7:38	4*	-70.908150	42.273151	5.9
R50	HR02126D	8/28/02 7:47	1	-70.898781	42.275150	6.2
	HR02126E	8/28/02 7:48	2*	-70.898804	42.275185	6.3
	HR02126F	8/28/02 7:48	3*	-70.898804	42.275200	6.4
	HR021270	8/28/02 7:49	4*	-70.898781	42.275215	6.4

SPI Station ID	SPI Sample ID	Date/Time (EDT)	Replicate analyzed*	Longitude (W)	Latitude (N)	Depth (m)
R51	HR02129F	8/28/02 9:08	1	-70.942116	42.263485	2.4
	HR0212A0	8/28/02 9:08	2*	-70.942146	42.263500	2.4
	HR0212A1	8/28/02 9:09	3*	-70.942184	42.263515	2.4
	HR0212A2	8/28/02 9:09	4*	-70.942200	42.263515	2.4
R52	HR0212A9	8/28/02 9:44	1*	-70.934753	42.261883	2.1
	HR0212AA	8/28/02 9:45	2*	-70.934715	42.261902	2.1
	HR0212AB	8/28/02 9:45	3	-70.934700	42.261917	2.2
	HR0212AC	8/28/02 9:46	4*	-70.934700	42.261917	2.2
R53	HR021298	8/28/02 8:55	1	-70.938019	42.269184	2.9
	HR021299	8/28/02 8:55	2*	-70.938019	42.269165	3.0
	HR02129A	8/28/02 8:56	3*	-70.938049	42.269150	2.9
	HR02129B	8/28/02 8:57	4*	-70.938065	42.269135	2.8
T1	HR0210E3	8/26/02 15:15	1*	-70.963654	42.349068	5.7
	HR0210E4	8/26/02 15:15	2*	-70.963600	42.349098	5.7
	HR0210E5	8/26/02 15:16	3	-70.963531	42.349117	5.6
	HR0210E6	8/26/02 15:17	4*	-70.963486	42.349098	5.6
T2	HR021118	8/26/02 16:19	1*	-71.002113	42.342815	7.5
	HR021119	8/26/02 16:20	2*	-71.002098	42.342785	7.9
	HR02111A	8/26/02 16:21	3	-71.002083	42.342766	8.1
	HR02111B	8/26/02 16:22	4*	-71.002037	42.342785	7.8
T3	HR02116B	8/27/02 10:20	1	-70.962166	42.330166	7.3
	HR02116C	8/27/02 10:21	2*	-70.962181	42.330235	7.5
	HR02116D	8/27/02 10:22	3*	-70.962219	42.330250	7.4
	HR02116E	8/27/02 10:22	4*	-70.962219	42.330265	7.4
T4	HR0211CC	8/27/02 12:13	1*	-71.041580	42.310032	2.4
	HR0211CD	8/27/02 12:13	2*	-71.041603	42.310066	2.4
	HR0211CE	8/27/02 12:14	3*	-71.041618	42.310081	2.4
	HR0211CF	8/27/02 12:15	4	-71.041649	42.310135	2.4
T5A	HR0210D5	8/26/02 14:56	1*	-70.960381	42.339668	17.5
	HR0210D6	8/26/02 14:58	2*	-70.960335	42.339668	17.2
	HR0210D7	8/26/02 14:59	3*	-70.960350	42.339668	16.6
	HR0210D8	8/26/02 15:00	4	-70.960403	42.339634	17.6
T6	HR02123E	8/27/02 15:34	1	-70.944267	42.293415	6.1
	HR02123F	8/27/02 15:35	2*	-70.944252	42.293400	6.0
	HR021240	8/27/02 15:36	3*	-70.944237	42.293400	6.0
	HR021241	8/27/02 15:37	4*	-70.944214	42.293385	6.0
T7	HR021211	8/27/02 14:27	1*	-70.978317	42.289368	6.8
	HR021212	8/27/02 14:28	2*	-70.978249	42.289383	6.8
	HR021213	8/27/02 14:29	3	-70.978233	42.289417	6.9
	HR021214	8/27/02 14:29	4*	-70.978218	42.289452	6.8
T8	HR021289	8/28/02 8:30	1*	-70.912498	42.285316	10.6
	HR02128A	8/28/02 8:31	2*	-70.912468	42.285366	10.7
	HR02128B	8/28/02 8:32	3	-70.912430	42.285400	10.8
	HR02128C	8/28/02 8:33	4*	-70.912399	42.285450	10.9

Table A-2. Station data and field observations for individual infauna and chemistry soft-bottom grab samples collected in April/May 2002 (HT021).

Station ID	Sample ID	Date/Time (EDT)	Sample Type	Longitude (W)	Latitude (N)	RPD Depth (cm)	Sediment Texture	Fauna and Miscellaneous Observations
T07	HT021002	4/25/02 8:25	Biol	-70.978683	42.289333	1.3	silty sand/silt	Hermit crab, amphipods
	HT021003	4/25/02 8:38	Biol	-70.978615	42.289318	1.5	silty sand/silt	Snails
	HT021005	4/25/02 8:52	Biol	-70.978584	42.289299	1.5	silty sand/silt	Shell hash
	HT021006	4/25/02 9:01	Chem	-70.978470	42.289284	2.0	silty sand/silt	Brown algae, shell hash
T06	HT02100D	4/25/02 9:32	Biol	-70.944382	42.293449	2.5	sandy silt	Amphipod mat
	HT02100E	4/25/02 9:43	Biol	-70.944420	42.293499	2.5	sandy silt	Amphipod mat
	HT02100F	4/25/02 9:51	Biol	-70.944397	42.293449	2.5	sandy silt	Amphipod mat, snail
	HT021014	4/25/02 10:11	Chem	-70.944397	42.293468	2.0	sandy silt	Amphipod mat, snails
T04	HT02101B	4/25/02 11:00	Biol	-71.041435	42.310001	0.1	silt	None, sulfur odor
	HT02101D	4/25/02 11:13	Biol	-71.041565	42.310017	0.2	silt	None, bacterial mat, sulfur odor
	HT02101E	4/25/02 11:19	Biol	-71.041649	42.310066	0.2	silt	None, bacterial mat, sulfur odor
	HT021022	4/25/02 11:29	Chem	-71.041580	42.310051	0.2	silt	None, bacterial mat, sulfur odor
T02	HT021026	4/25/02 11:57	Biol	-71.001999	42.342850	0.2	sandy silt	Small bacterial mat
	HT021027	4/25/02 12:04	Biol	-71.001816	42.342934	0.3	sandy silt	Brown algae, snail
	HT021028	4/25/02 12:12	Biol	-71.001999	42.342834	0.4	sandy silt	Amphi- and poly-tubes, snails
	HT021029	4/25/02 12:20	Chem	-71.001953	42.342899	0.3	sandy silt	Amphipod tubes
T03	HT02102C	4/25/02 13:11	Biol	-70.962010	42.330280	0.5	sandy silt	Amphipod tubes, tunicates, snails
	HT02102D	4/25/02 13:19	Biol	-70.962050	42.330180	0.2	sandy silt	Amphipod tubes, tunicates, snails, worms
	HT02102E	4/25/02 13:27	Biol	-70.962040	42.330280	0.3	sandy silt	Amphipod tubes, tunicates, snails, stones
	HT021030	4/25/02 13:33	Chem	-70.961937	42.330235	0.4	sandy silt	Amphipod tubes, tunicates, snails, stones
	HT02105C	5/21/02 13:21	Biol	-70.962036	42.330185	1.2	silt	Snail
T05A	HT021035	4/25/02 14:00	Biol	-70.960686	42.339668	1.0	silty sand	Hermit crabs, worm tubes
	HT021036	4/25/02 14:08	Biol	-70.960617	42.339718	0.8	silty sand	Amphi- and poly-;tubes, snails
	HT021037	4/25/02 14:16	Biol	-70.960732	42.339600	0.5	silty sand	Amphi- and poly- tubes, snails
	HT021038	4/25/02 14:28	Chem	-70.960587	42.339733	0.5	silty sand	Amphi- and poly- tubes
T01	HT02103C	4/25/02 14:44	Biol	-70.963470	42.349098	1.0	silt	Amphipods, polychaete tubes, snails
	HT02103E	4/25/02 14:55	Biol	-70.963501	42.349133	1.5	silt	Amphipods, polychaete tubes, snails
	HT02103F	4/25/02 15:01	Biol	-70.963448	42.349098	1.3	silt	Bacterial mat, amphi- and poly- tubes, shrimp, snails
	HT021040	4/25/02 15:08	Chem	-70.963531	42.349117	1.5	silt	Bacterial mat, amphi- and poly- tubes, snails
	HT021053	5/22/02 13:01	Biol	-70.963600	42.349217	1.0	sandy silt	Hermit crabs, shell hash
T08	HT021043	4/25/02 15:47	Biol	-70.912636	42.285416	1.0	sandy silt	Snails, worm tubes
	HT021044	4/25/02 15:53	Biol	-70.912598	42.285435	1.5	silty sand	Snails, worm tubes
	HT021045	4/25/02 15:58	Biol	-70.912613	42.285385	1.0	silty sand	Tunicates, worm tubes
	HT021047	4/25/02 16:07	Chem	-70.912415	42.285301	1.0	silty sand	Snails, worm tubes

Table A-3. Station data and field observations for individual infauna and chemistry soft-bottom grab samples collected in August 2002 (HT022).

Station ID	Sample ID	Date/Time (EDT)	Sample Type	Longitude (W)	Latitude (N)	RPD Depth (cm)	Sediment Texture	Fauna and Miscellaneous Observations
T07	HT02209F	8/8/02 7:54	Biol	-70.978630	42.289318	0.2	sandy silt	Shell hash, no animals
	HT0220A0	8/8/02 7:57	Chem	-70.978516	42.289368	0.2	silt	Snails, worm tubes, shells
	HT0220A1	8/8/02 8:02	Biol	-70.978470	42.289398	0.3	sandy silt	Hermit crab, shell hash
	HT0220A4	8/8/02 8:08	Biol	-70.978516	42.289398	0.3	sandy silt	Hermit crabs, worm tubes
	HT0220A5	8/8/02 8:11	Chem	-70.978516	42.289368	0.8	sandy silt	Snails, worm tubes, shells
	HT0220AA	8/8/02 8:22	Chem	-70.978500	42.289383	0.3	sandy silt	Shells, shell hash
T04	HT0220B9	8/8/02 8:57	Biol	-71.041565	42.310001	0.3	silt	Hermit crabs
	HT0220BA	8/8/02 8:58	Chem	-71.041634	42.310032	0.1	very silty	Hermit crabs, snail, shrimp
	HT0220BB	8/8/02 9:02	Biol	-71.041519	42.310051	0.1	silt	Strong sulfur odor
	HT0220BE	8/8/02 9:06	Biol	-71.041519	42.310101	0.1	silt	No animals
	HT0220BF	8/8/02 9:08	Chem	-71.041534	42.310017	0.1	silt	Hermit crabs
	HT0220C2	8/8/02 9:17	Chem	-71.041534	42.309967	0.1	silt	Shrimp, organic matter
T02	HT0220C9	8/8/02 9:49	Biol	-71.002083	42.342815	0.2	silt	Hermit crab, tubes
	HT0220CA	8/8/02 9:51	Chem	-71.002052	42.342865	0.3	sandy silt	Amphi- tubes, snail, crab
	HT0220CB	8/8/02 9:54	Biol	-71.002083	42.342884	0.2	silt	Hermit crab, fecal pellets
	HT0220CD	8/8/02 10:04	Chem	-71.002037	42.342850	0.1	sandy silt	Snail, crab, shrimp, shells
	HT0220CF	8/8/02 10:12	Biol	-71.002052	42.342884	0.2	silt	Amphi- tubes, hermit crab
	HT0220D0	8/8/02 10:17	Chem	-71.002068	42.342815	0.2	sandy silt	Amphi-tubes, shell hash
T01	HT0220D5	8/8/02 10:35	Chem	-70.963547	42.349098	1.2	silty sand	Hermit crab, algae, snails
	HT0220D7	8/8/02 10:40	Biol	-70.963501	42.349152	0.2	silty sand	Snail, algae
	HT0220D8	8/8/02 10:44	Chem	-70.963501	42.349152	1.0	silty sand	Hermit crab, algae, snails
	HT0220D9	8/8/02 10:46	Biol	-70.963501	42.349152	0.1	sandy/silt	Shrimp, sulfur odor
	HT0220DA	8/8/02 10:52	Biol	-70.963516	42.349098	0.3	sandy/silt	Crab, tubes, kelp
	HT0220DB	8/8/02 10:55	Chem	-70.963333	42.349201	2.0	silty sand	Amphipod tubes, snails
T05A	HT0220E3	8/8/02 11:26	Biol	-70.960785	42.339615	0.3	silty sand	Worm tubes, snails
	HT0220E5	8/8/02 11:35	Chem	-70.960701	42.339584	0.3	sand	Worm tubes
	HT0220E6	8/8/02 11:39	Biol	-70.960648	42.339684	0.3	silty sand	Worm tubes, snails
	HT0220E7	8/8/02 11:48	Chem	-70.960670	42.339699	0.5	sand	Tubes, snails, shell hash
	HT0220E8	8/8/02 11:52	Biol	-70.960701	42.339718	0.3	silty sand	Crabs, amphipods
	HT0220E9	8/8/02 11:59	Chem	-70.960747	42.339615	0.8	sand	Worm tubes, snails
T03	HT0220F0	8/8/02 12:45	Chem	-70.961998	42.330250	1.0	sandy silt	Amphipod mat, shell hash
	HT0220F1	8/8/02 12:47	Biol	-70.961853	42.330250	1.4	silt	Amphipod tube mat, crab
	HT0220F3	8/8/02 12:55	Chem	-70.961967	42.330299	1.1	sandy silt	Amphipod tube mat, shell hash, snail
	HT0220F4	8/8/02 12:58	Biol	-70.961967	42.330299	1.2	silt	Amphipod tube mat, snail
	HT0220F5	8/8/02 13:03	Biol	-70.961998	42.330235	0.8	silt	Amphi- tube mat, hermit crab, snails
	HT0220F6	8/8/02 13:08	Chem	-70.961884	42.330215	0.5	sandy silt	Amphipod tube mat, snails
T06	HT0220FB	8/8/02 13:31	Chem	-70.944214	42.293568	0.6	sandy silt	Amphi-tubes, hermit crabs, snails, shell hash
	HT0220FD	8/8/02 13:36	Biol	-70.944115	42.293583	0.5	sandy silt	Amphi-tubes, shrimp, worm
	HT0220FE	8/8/02 13:43	Biol	-70.944168	42.293617	0.3	sandy silt	Amphi- and poly-tubes, shrimp, crab
	HT0220FF	8/8/02 13:47	Chem	-70.944199	42.293533	1.8	sandy silt	Amphi- tube mat, hermit crabs, snails, shell hash
	HT022100	8/8/02 13:49	Biol	-70.944183	42.293518	0.2	sandy silt	Amphipod tube mat
	HT022101	8/8/02 13:59	Chem	-70.944069	42.293518	0.8	sandy silt	Amphi-tube mat, shrimp, crab, shell hash
T08	HT022107	8/8/02 14:20	Chem	-70.912804	42.285267	1.9	sand	Amphi-tubes, snails, shells
	HT022109	8/8/02 14:26	Biol	-70.912468	42.285198	0.5	silty sand	Amphi- and worm tubes, snails, hermit crabs
	HT02210B	8/8/02 14:38	Biol	-70.912537	42.285316	0.6	silty sand	Amphi- and worm tubes, snails, shell hash
	HT02210C	8/8/02 14:43	Chem	-70.912483	42.285332	1.0	sand	Amphi-tubes, crab, snails, shells
	HT02210D	8/8/02 14:47	Biol	-70.912552	42.285301	1.0	silty sand	Amphi- and worm tubes, shell hash
	HT022112	8/8/02 14:55	Chem	-70.912537	42.285301	1.9	sand	Amphi- and worm tubes, snails, shell hash

APPENDIX B

Sediment Profile Images (HR021)

(*see enclosed CD*)

APPENDIX C1

Chemistry Terminology

In the discussion of bulk sediment data, the following terms are used.

- Percent Fines—sum of percent silt and clay.
- Numerical approximate mean phi (hereafter referred to as mean phi)—calculated by weighting each class fraction measured and summing the weighted fractions as described in Kropp *et al* (2002b).

Mean parameter (*e.g.,* sand) values were determined for two categories:

- Station Mean—average of all station replicates. Laboratory replicates were first averaged to determine a single value for a given replicate prior to calculation of station means. Single grab samples were generally collected at all Traditional stations during most sampling years and seasons, but replicate grabs were also collected during some sampling years (*e.g.,* August 1994 and 1997). Station means were determined for each parameter within a given sampling year and season (*i.e.,* April, August) to assess the spatial and temporal distribution in bulk sediment properties and *C. perfringens* from 1991 to 2002.
- Grand Station Mean—average of all years, by station and season. Grand station means were determined for each parameter over all sampling years and season to assess variability in the spatial and temporal distribution in bulk sediment properties and *C. perfringens* from 1991 to 2002.
- Grand Mean—average of yearly mean values, by sampling period. Grand means were determined for Flux and Traditional Harbor TOC over all sampling years (1993-2002) to assess if there was a characteristic seasonal “peak” in TOC content.

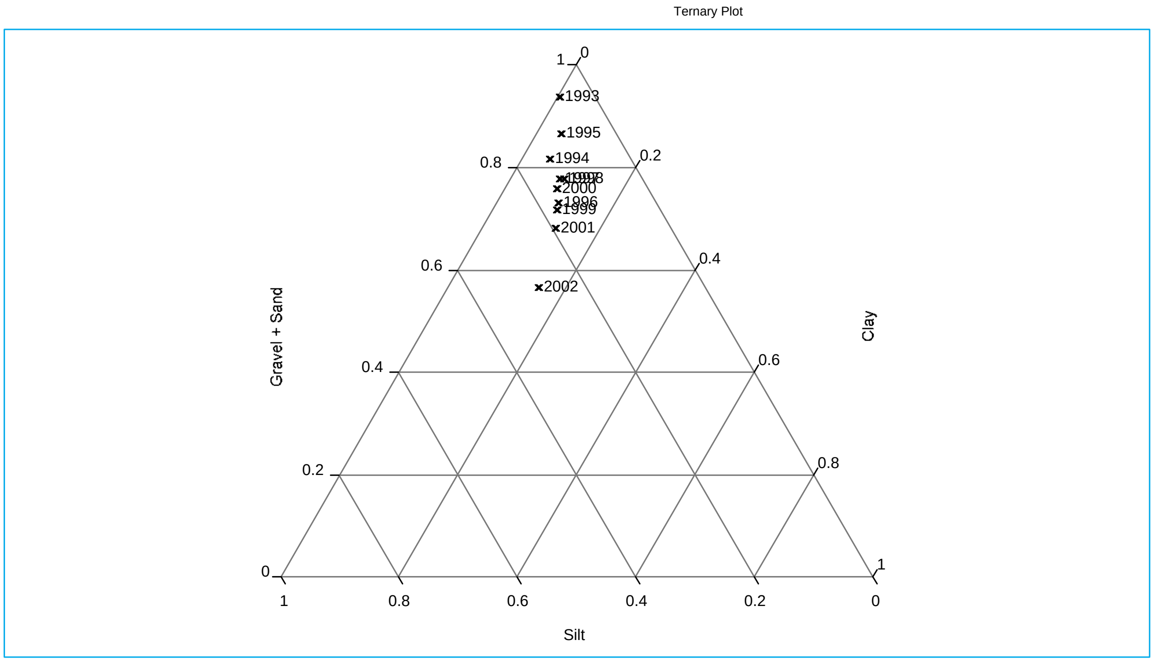
The spatial and temporal distributions of sediment grain size were evaluated by using ternary plots to visually display the distribution of gravel plus sand, silt and clay in sediment collected from Traditional stations from 1991 to 2002.

Results for TOC and *C. perfringens* analyses were compared from all Traditional stations by using line charts to evaluate if the spatial and temporal distributions in 2002 were substantially different from those for previous years.

Seasonal TOC data collected from the Benthic Flux program (BH02, BH03, and BH03A (1995-1997) only) from 1993 to 2002 were evaluated with the Harbor TOC data (stations T02 and T03 only) to explore if there was a characteristic seasonal “peak” in Harbor TOC levels that more or less corresponded to the faunal sampling events. Benthic Flux results from February were excluded from the analysis since these data were only available from a single sampling event in 1993.

APPENDIX C2

Supporting Ternary Plots Showing Grain Size Composition and Line Charts Showing TOC and *Clostridium perfringens* Results, by Station and Season, Across All Years



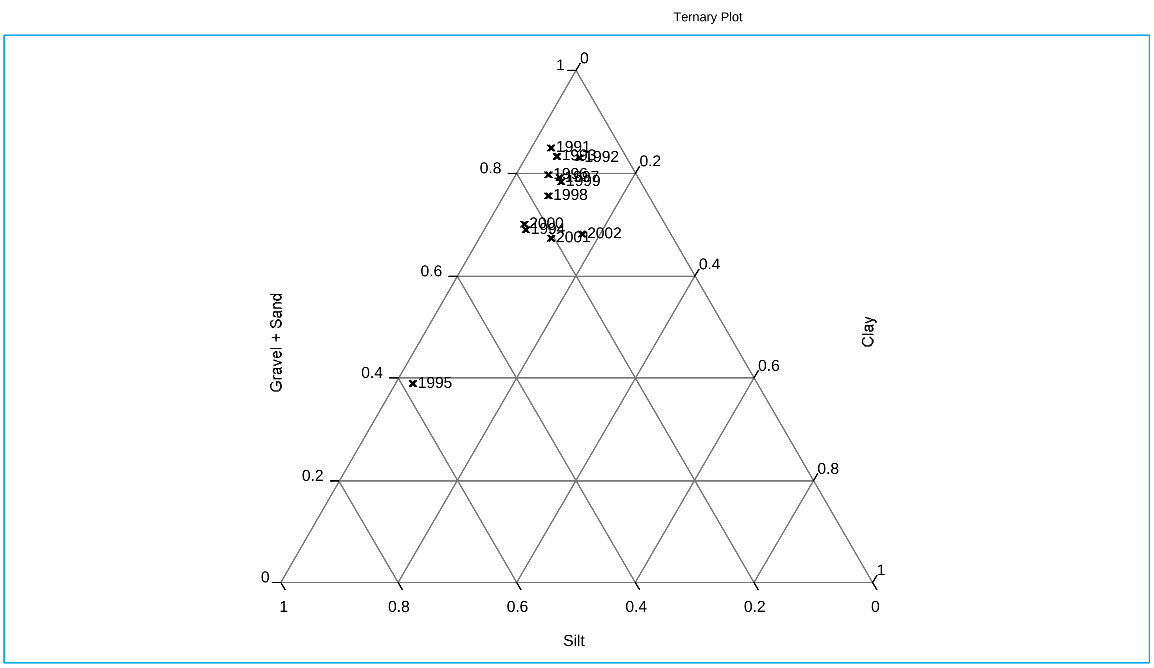
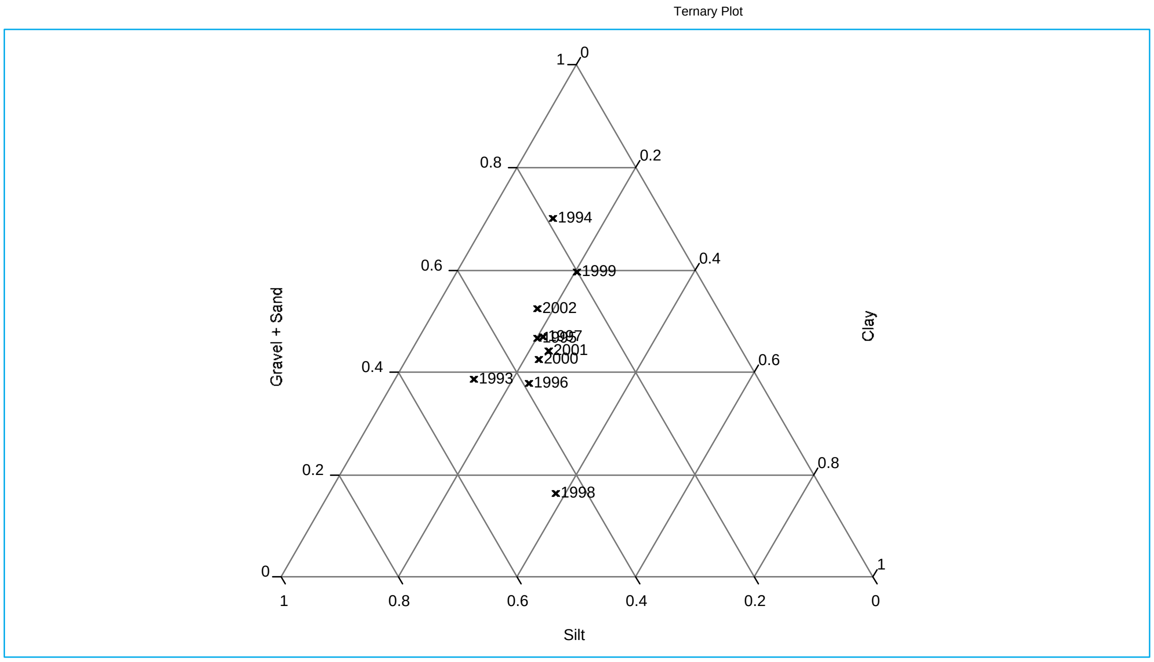


Figure C2-1. Grain size composition from sediments collected at Traditional station T01 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom).



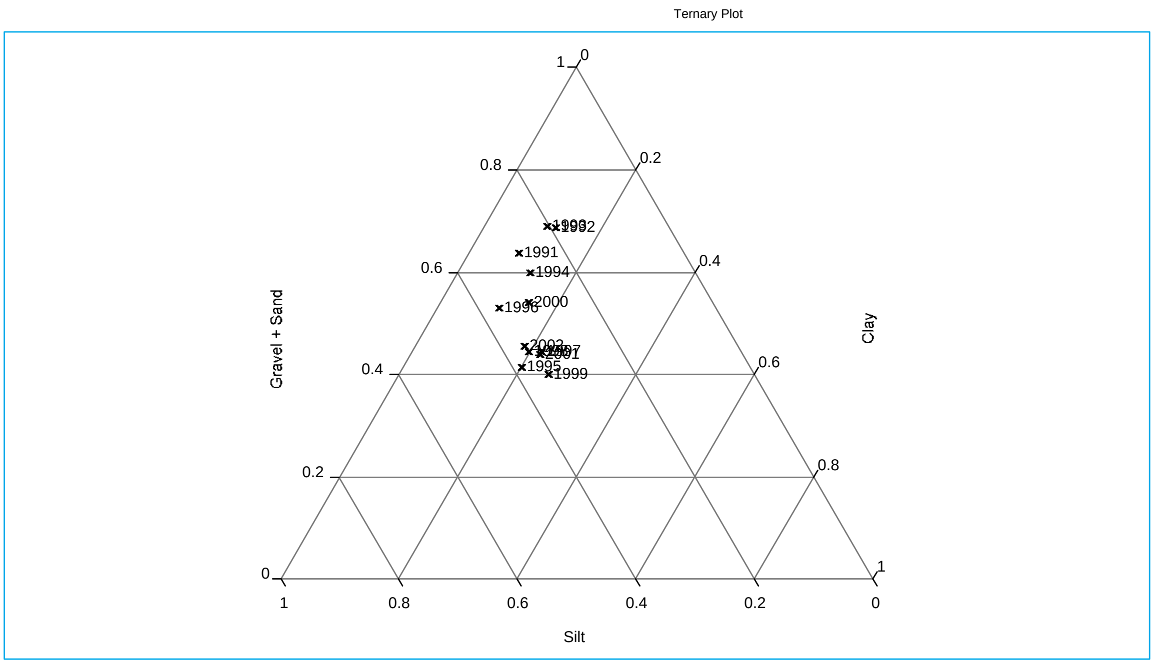
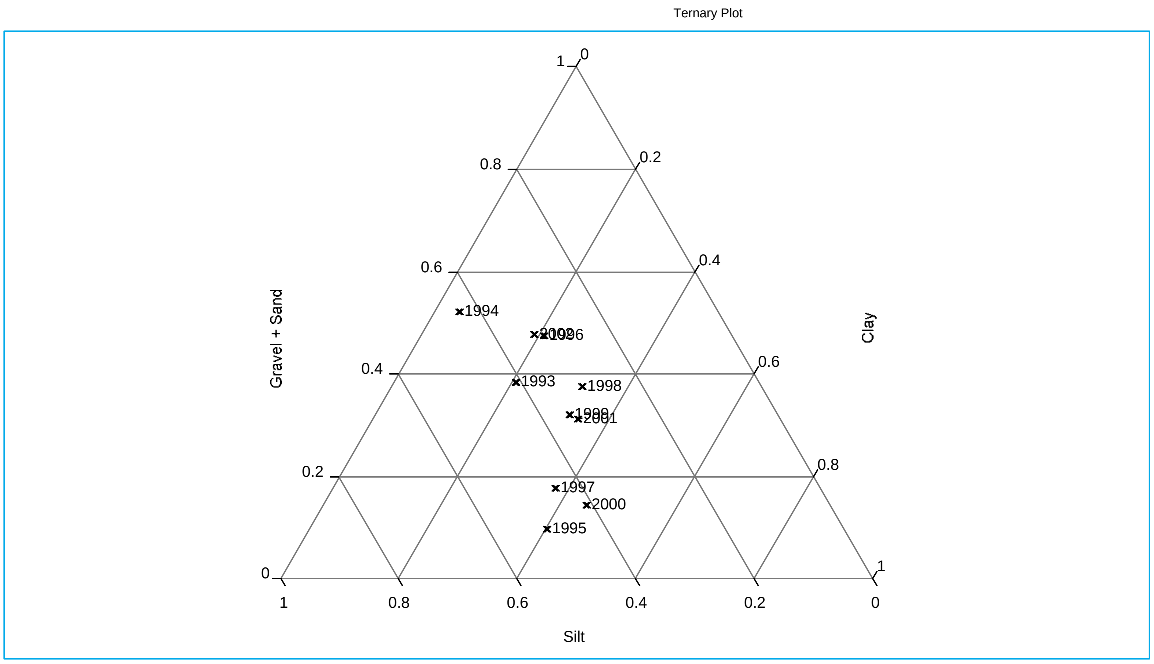


Figure C2-2. Grain size composition from sediments collected at Traditional station T02 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom).



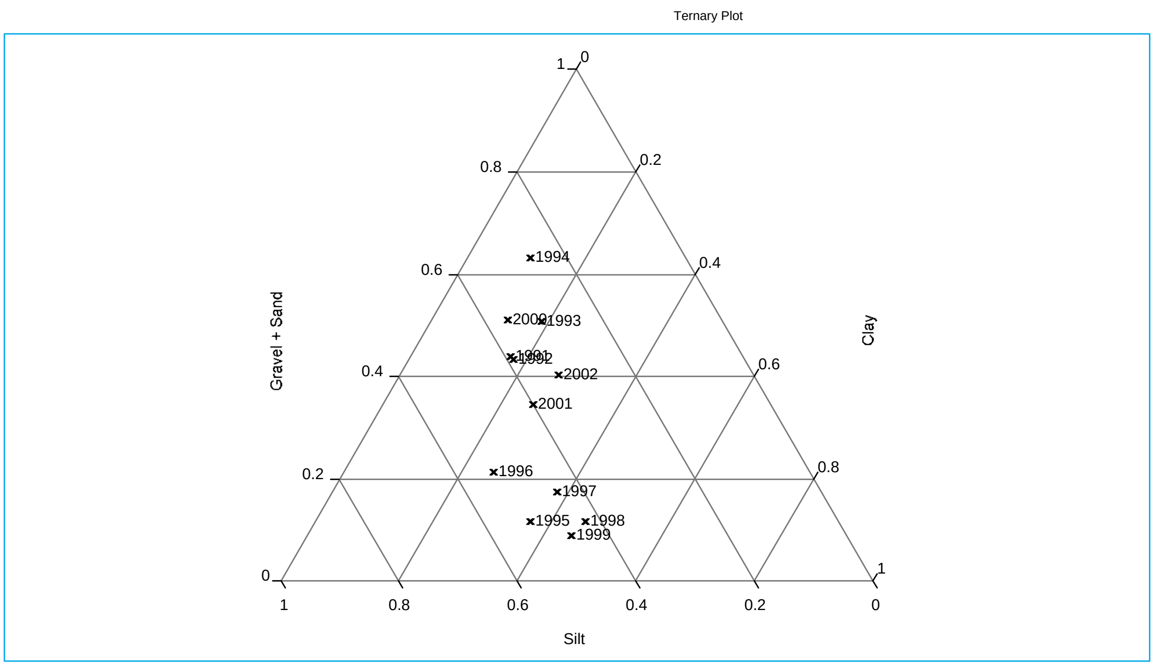
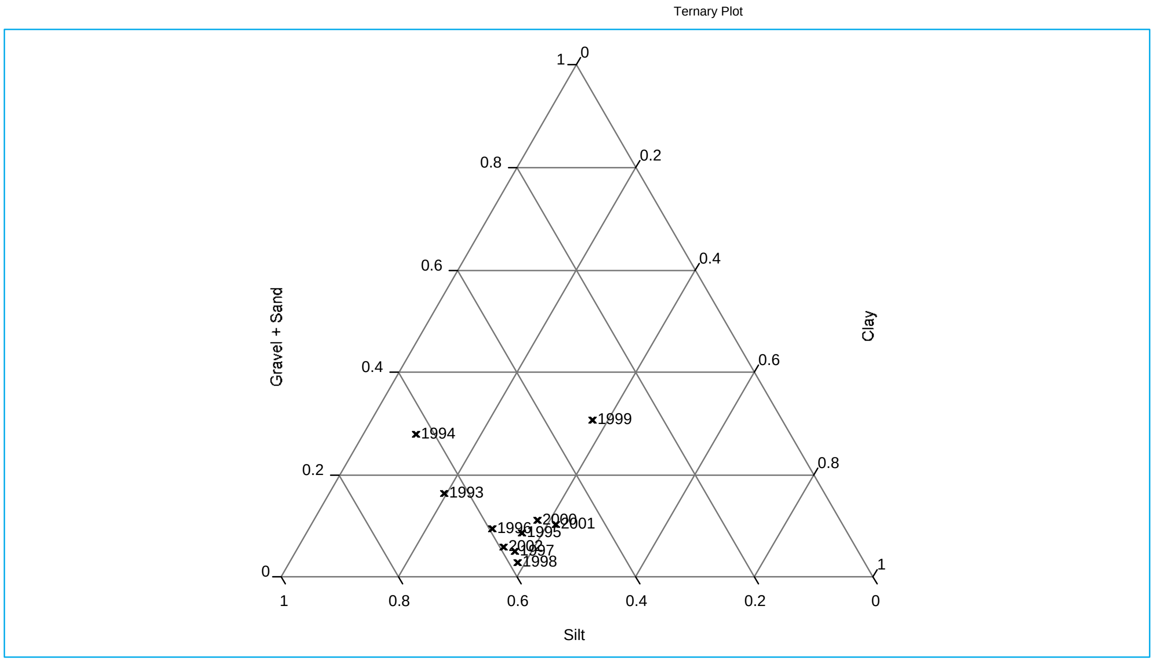


Figure C2-3. Grain size composition from sediments collected at Traditional station T03 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom).



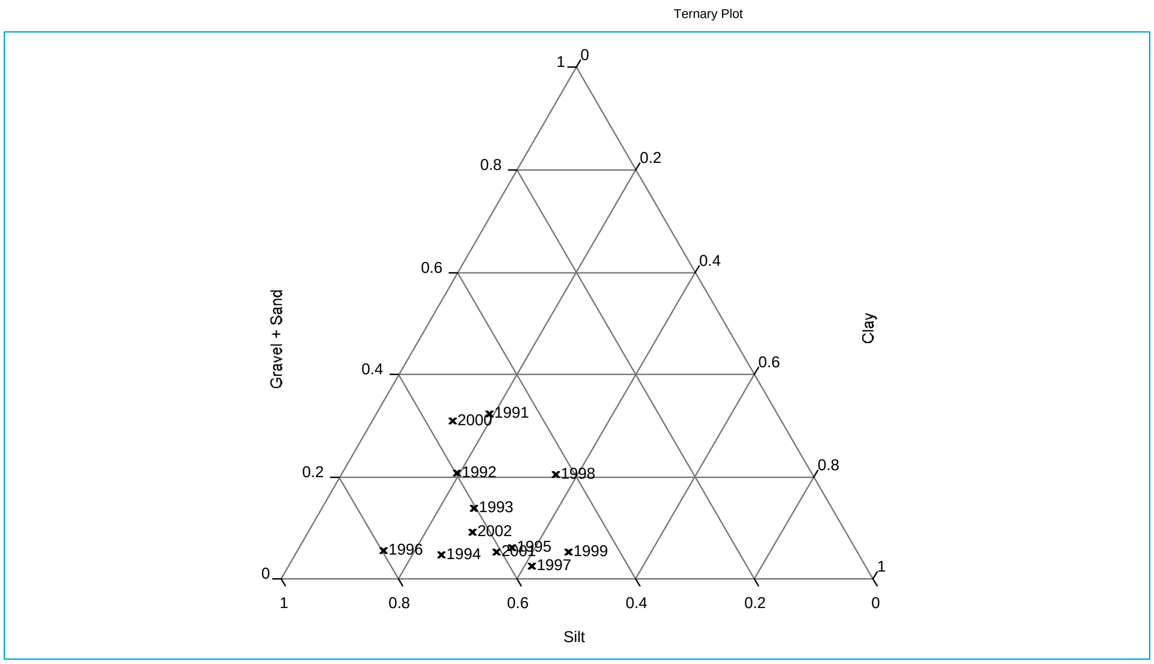
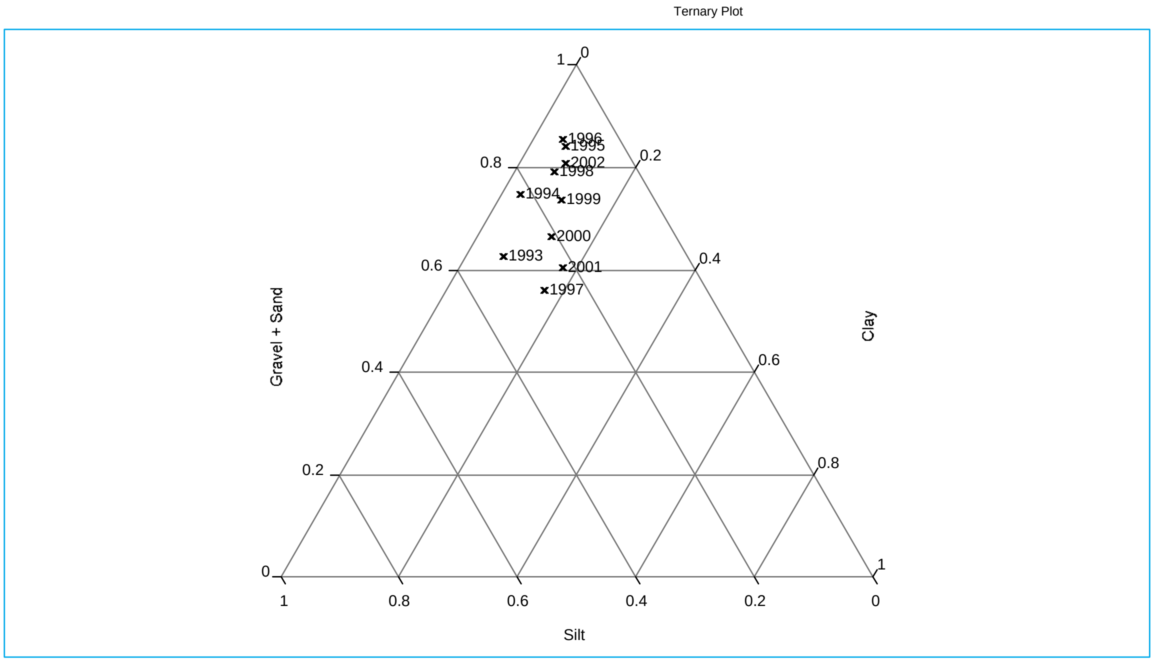


Figure C2-4. Grain size composition from sediments collected at Traditional station T04 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom).



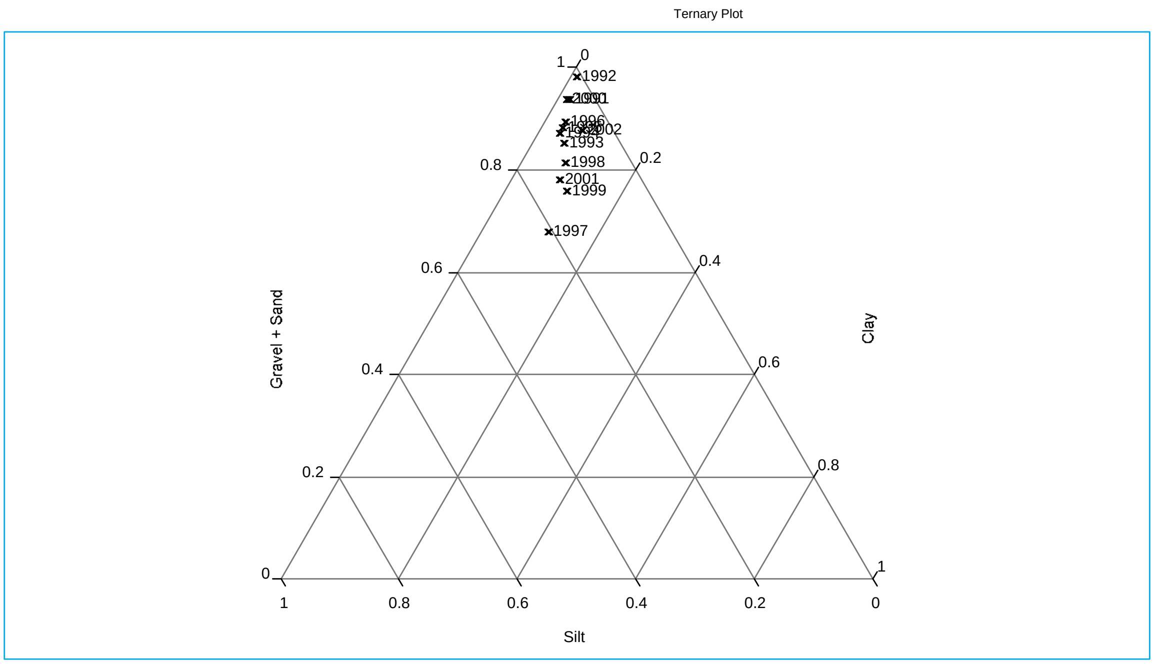
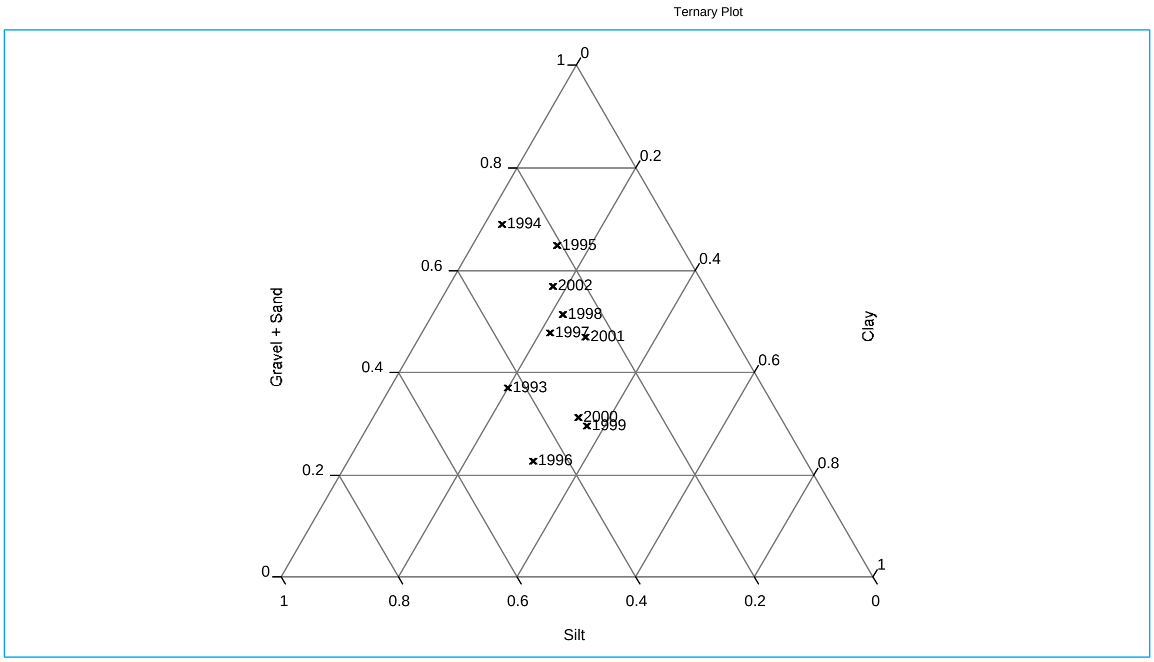


Figure C2-5. Grain size composition from sediments collected at Traditional station T05A in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom).



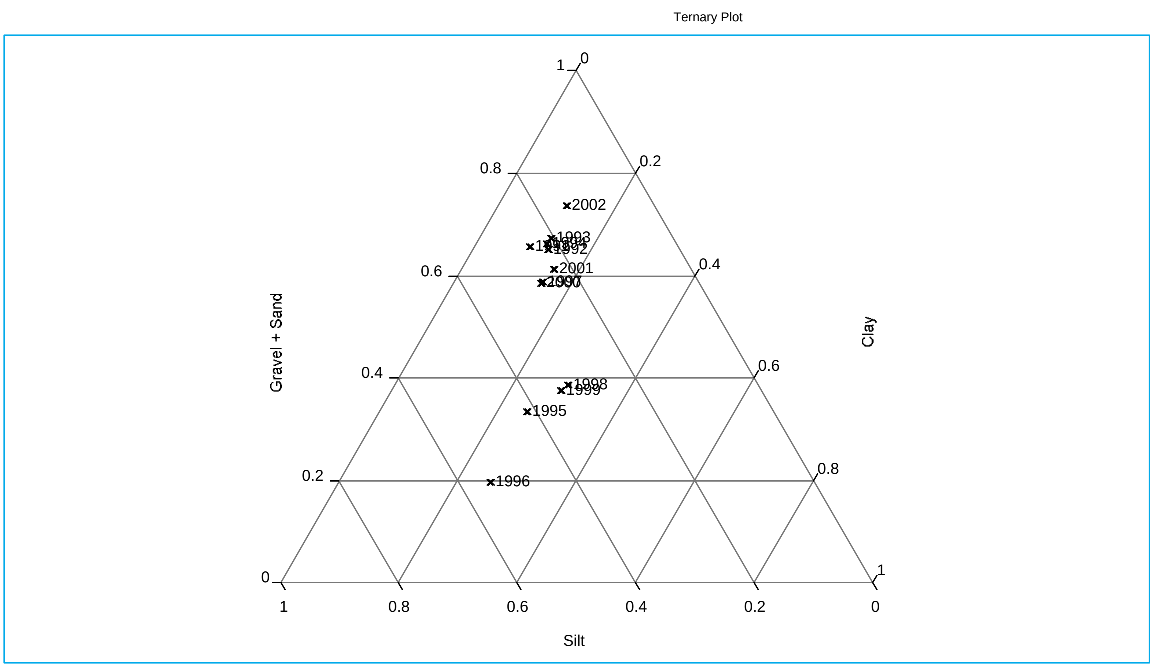
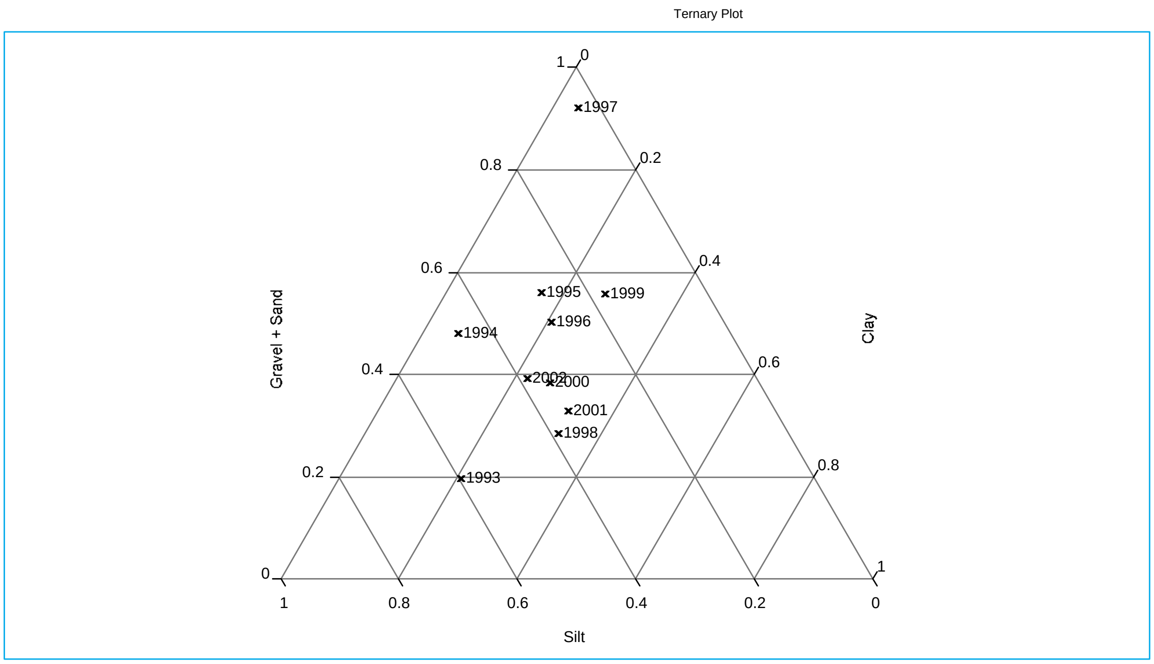


Figure C2-6. Grain size composition from sediments collected at Traditional station T06 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom).



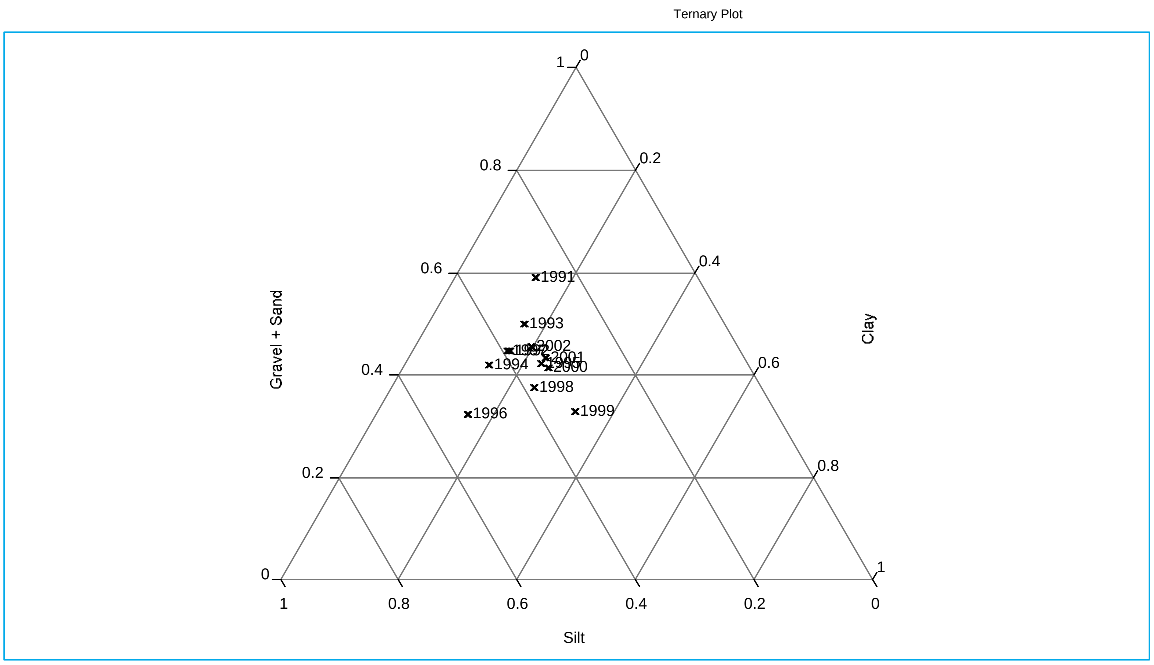
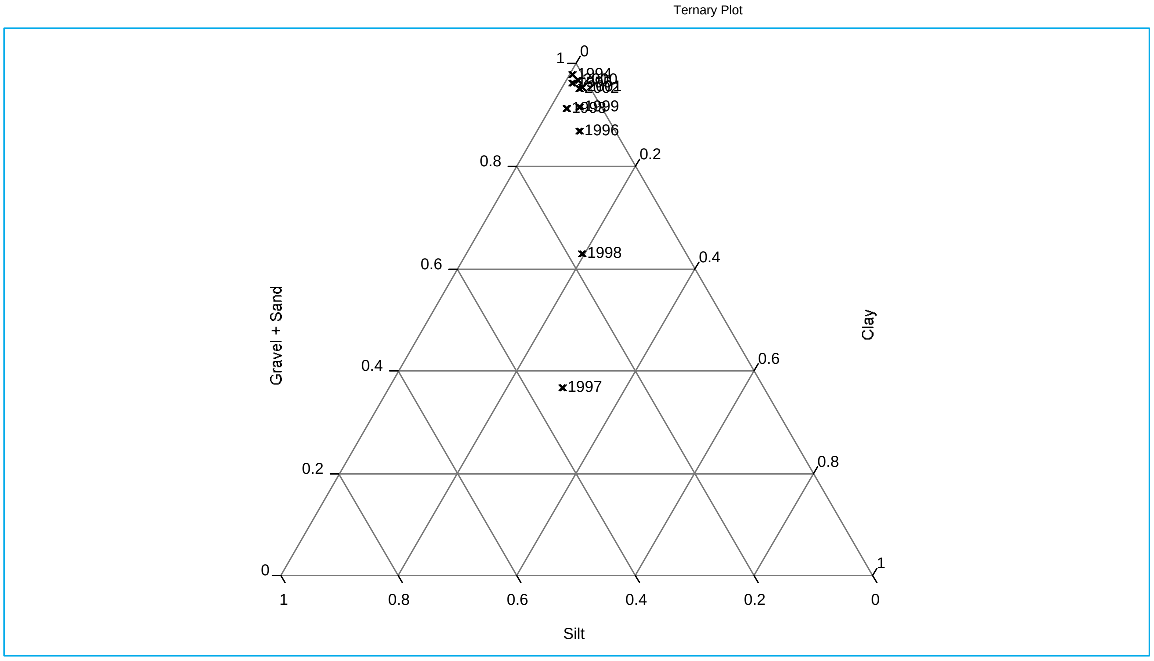


Figure C2-7. Grain size composition from sediments collected at Traditional station T07 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom).



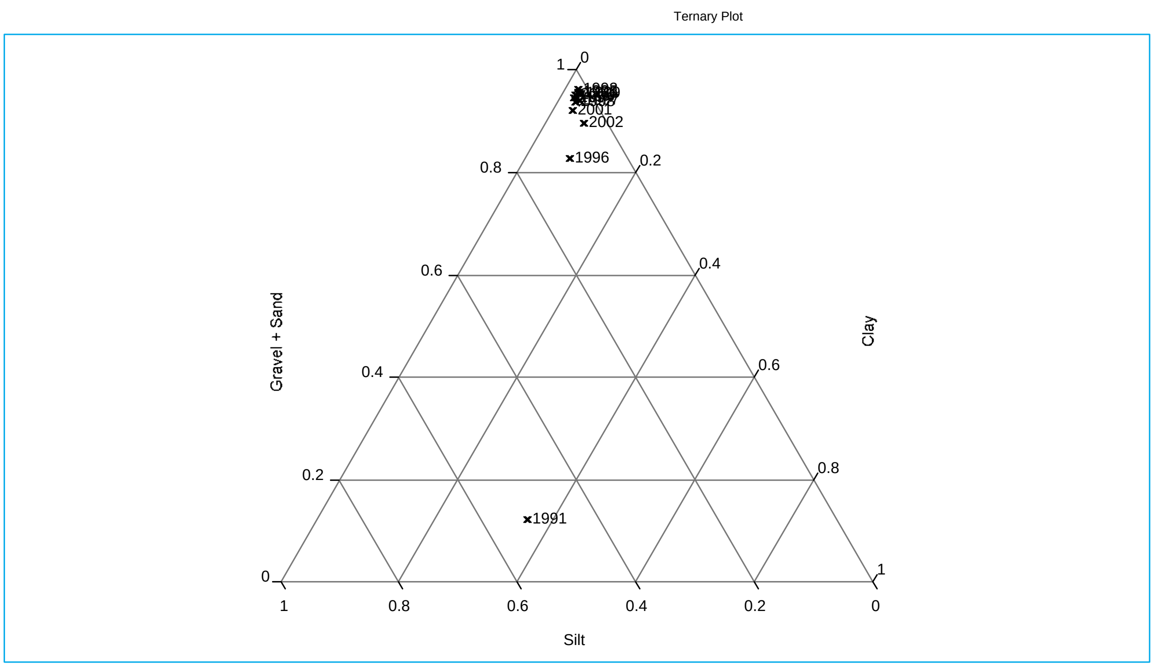


Figure C2-8. Grain size composition from sediments collected at Traditional station T08 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom).

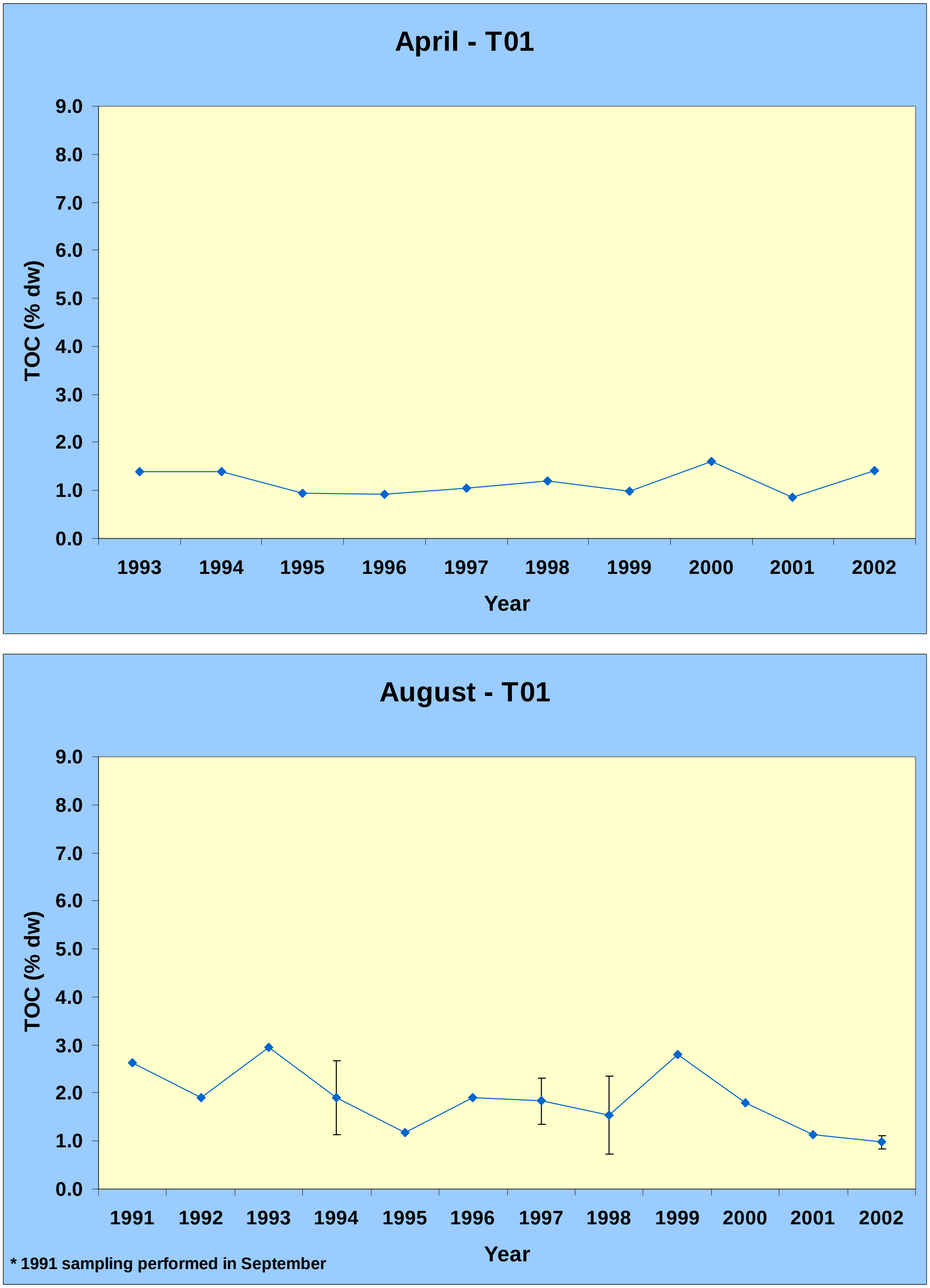
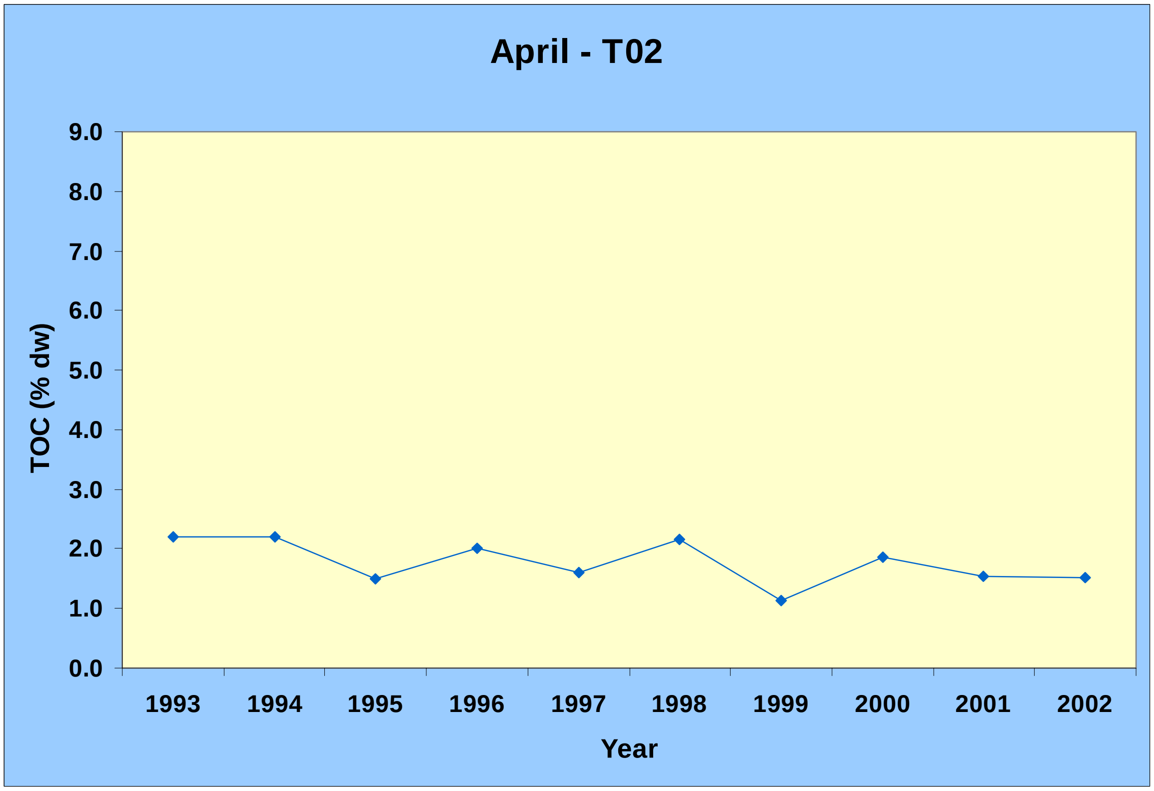


Figure C2-9. Total organic carbon content in sediments collected at Traditional station T01 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



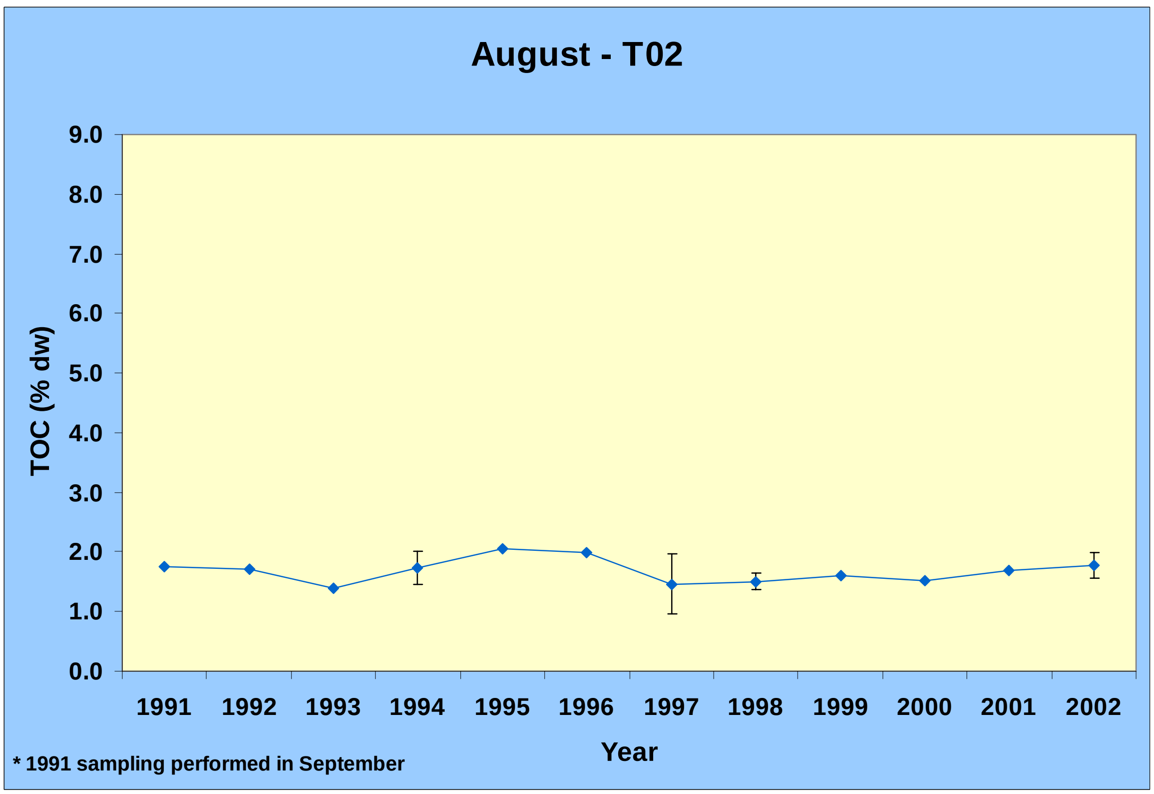
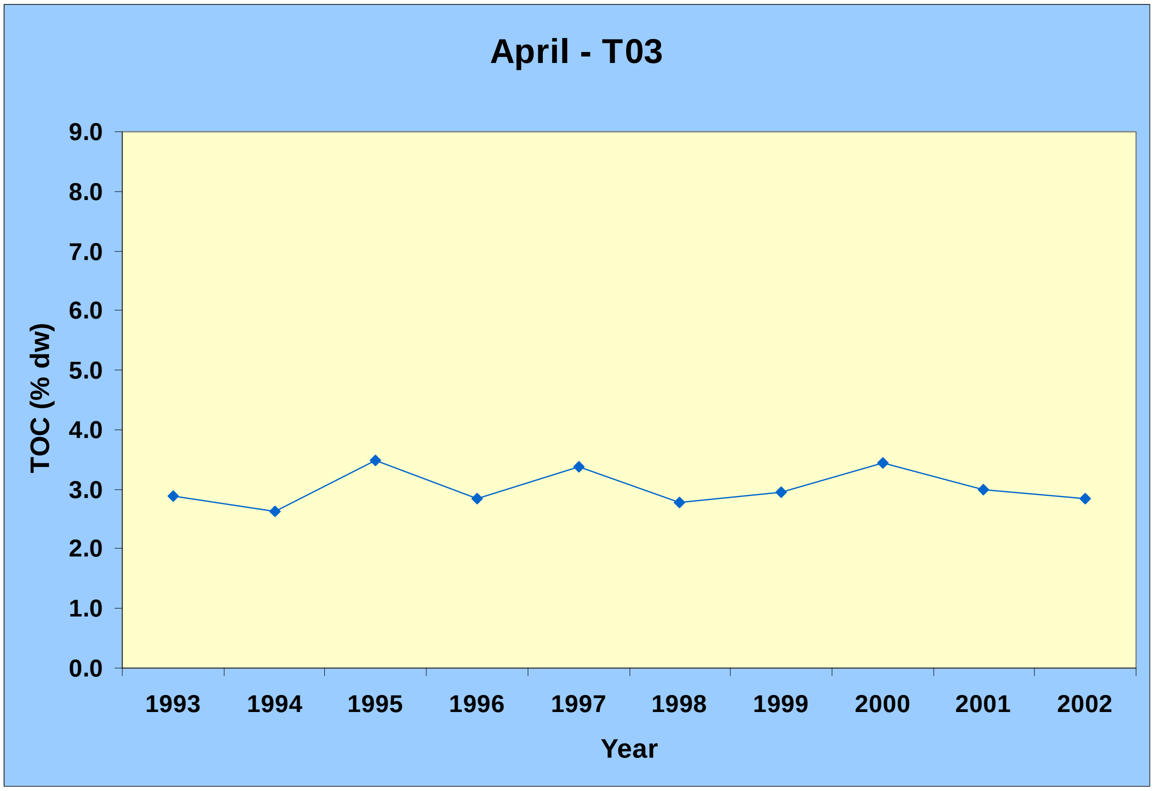


Figure C2-10. Total organic carbon content in sediments collected at Traditional station T02 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



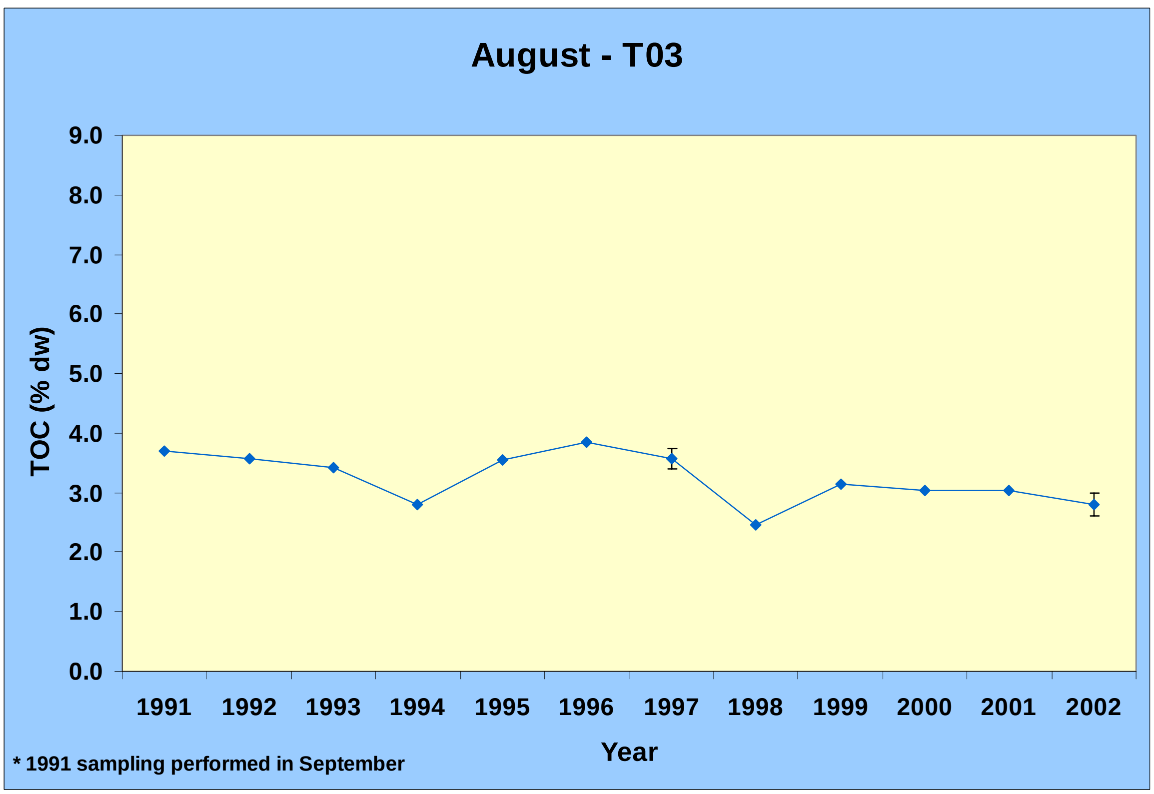
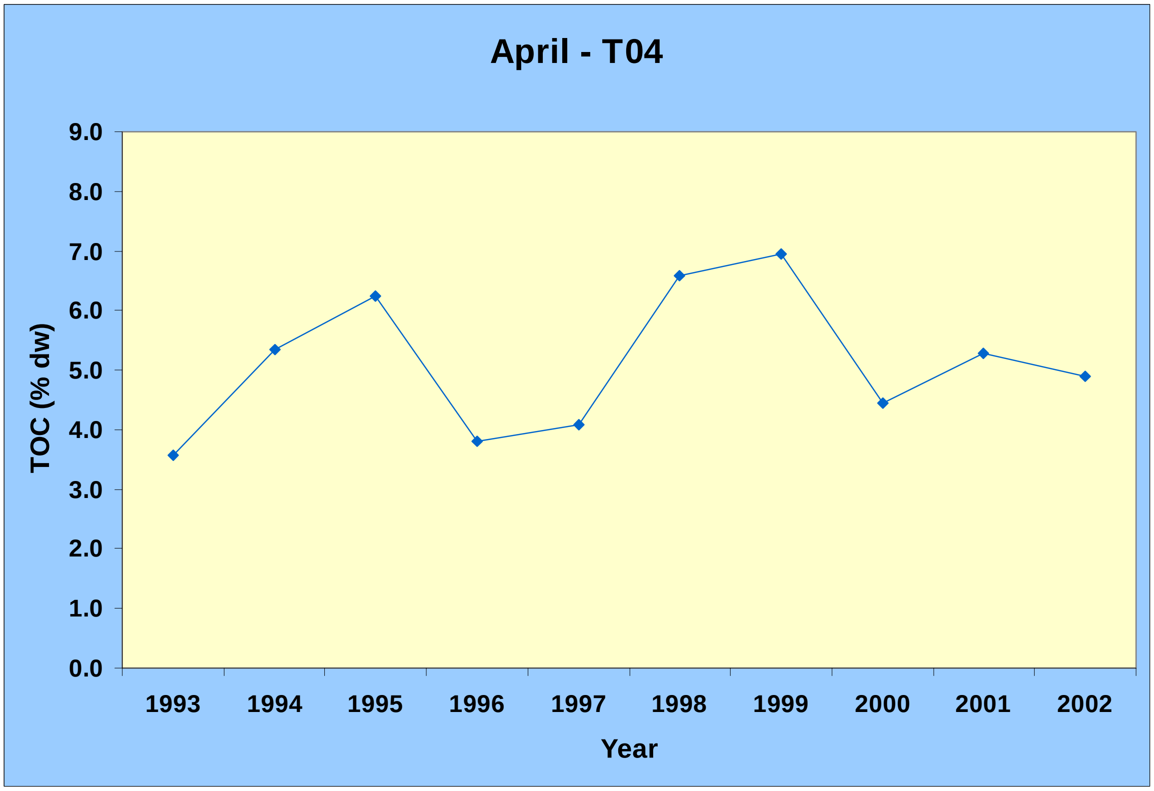


Figure C2-11. Total organic carbon content in sediments collected at Traditional station T03 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



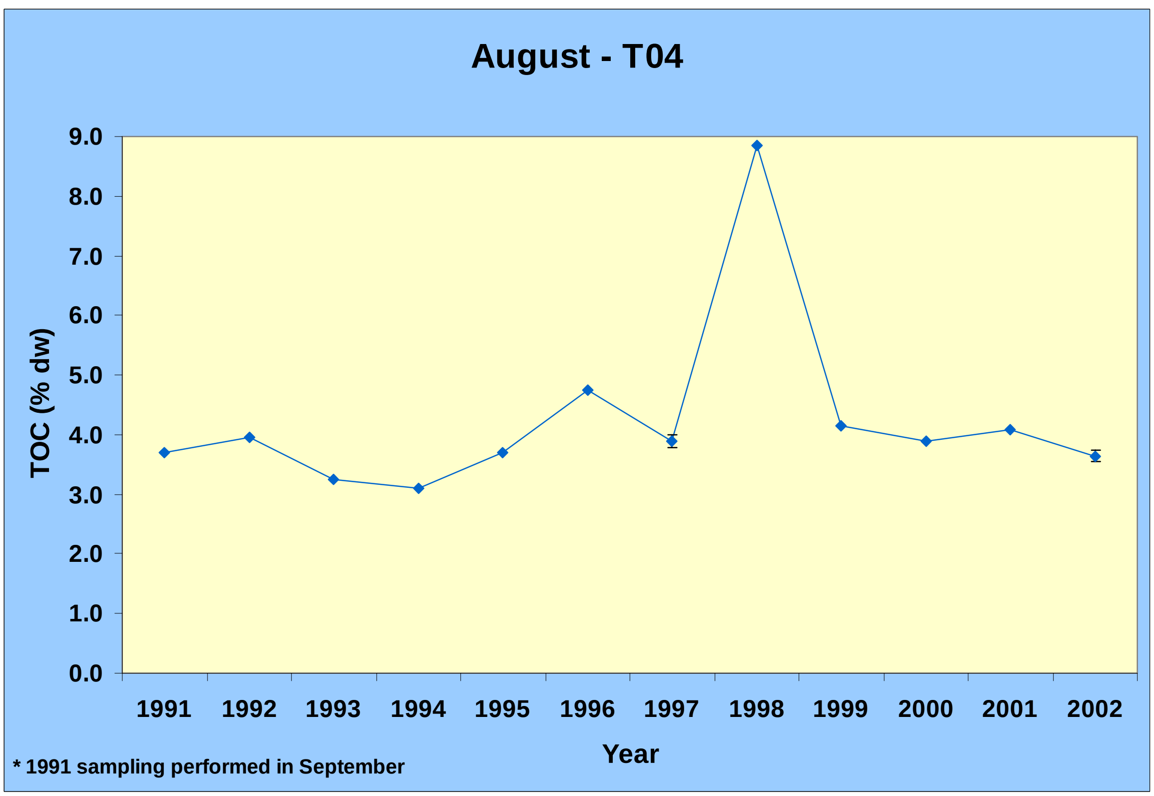
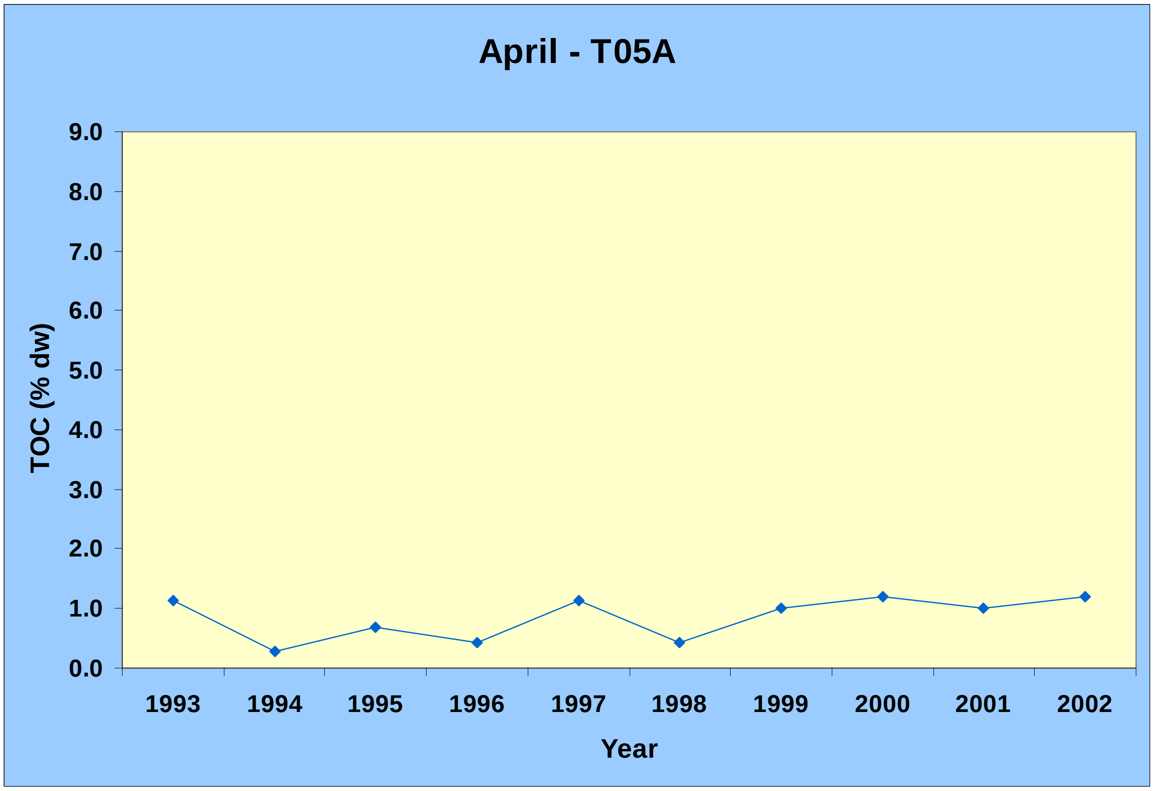


Figure C2-12. Total organic carbon content in sediments collected at Traditional station T04 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



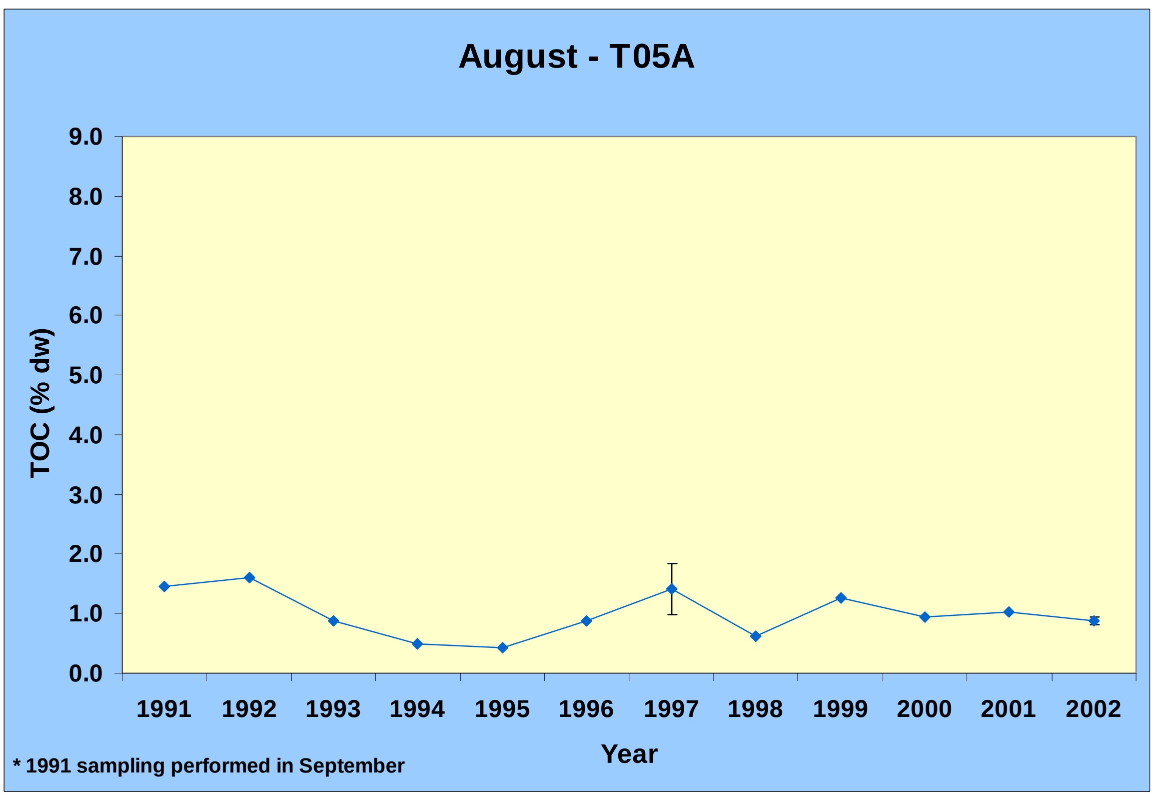


Figure C2-13. Total organic carbon content in sediments collected at Traditional station T05A in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.

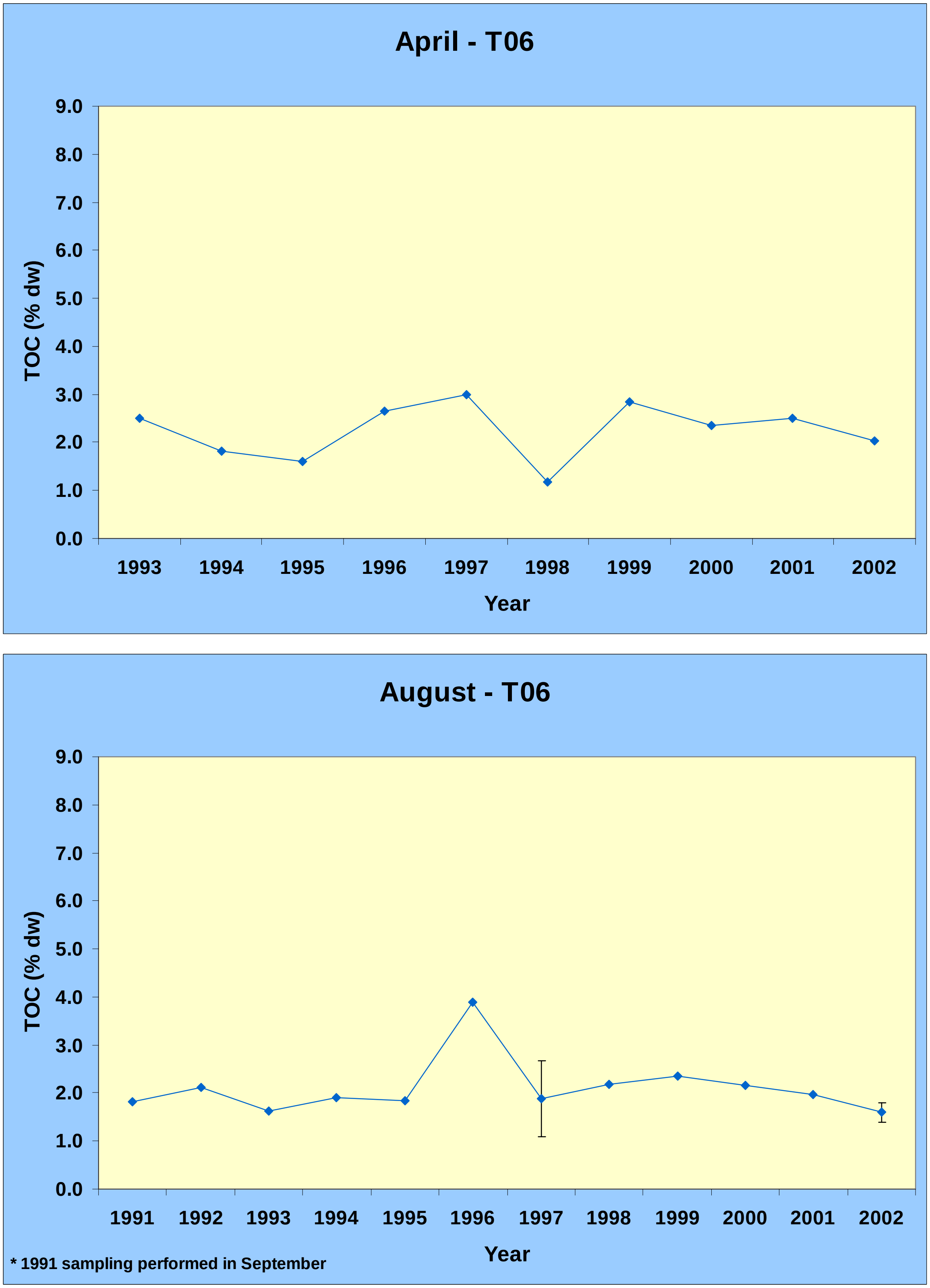
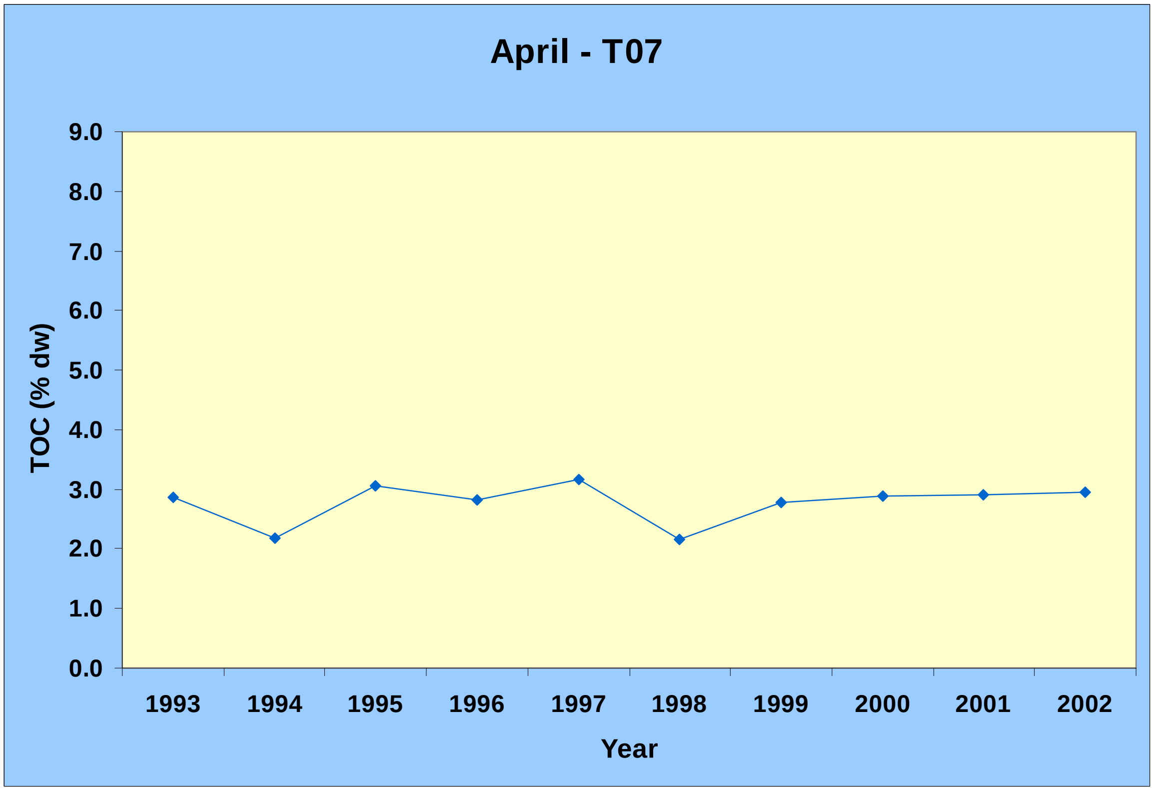


Figure C2-14. Total organic carbon content in sediments collected at Traditional station T06 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



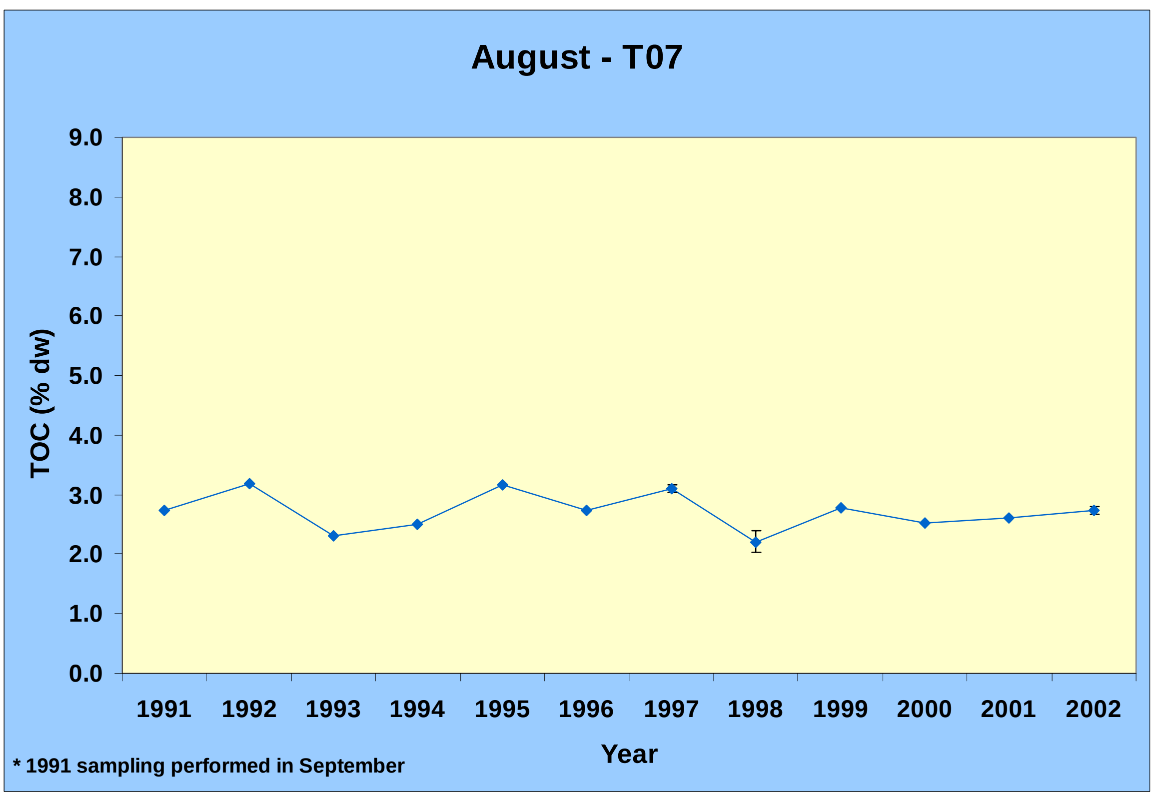
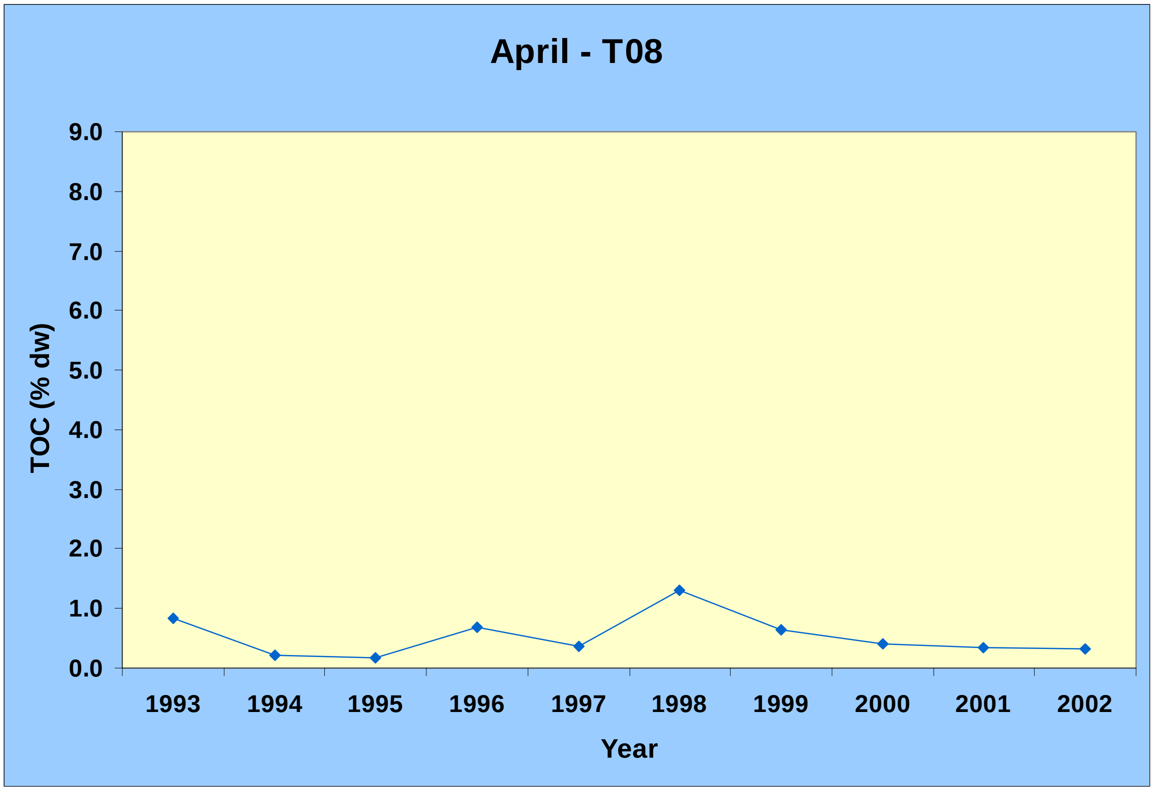


Figure C2-15. Total organic carbon content in sediments collected at Traditional station T07 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



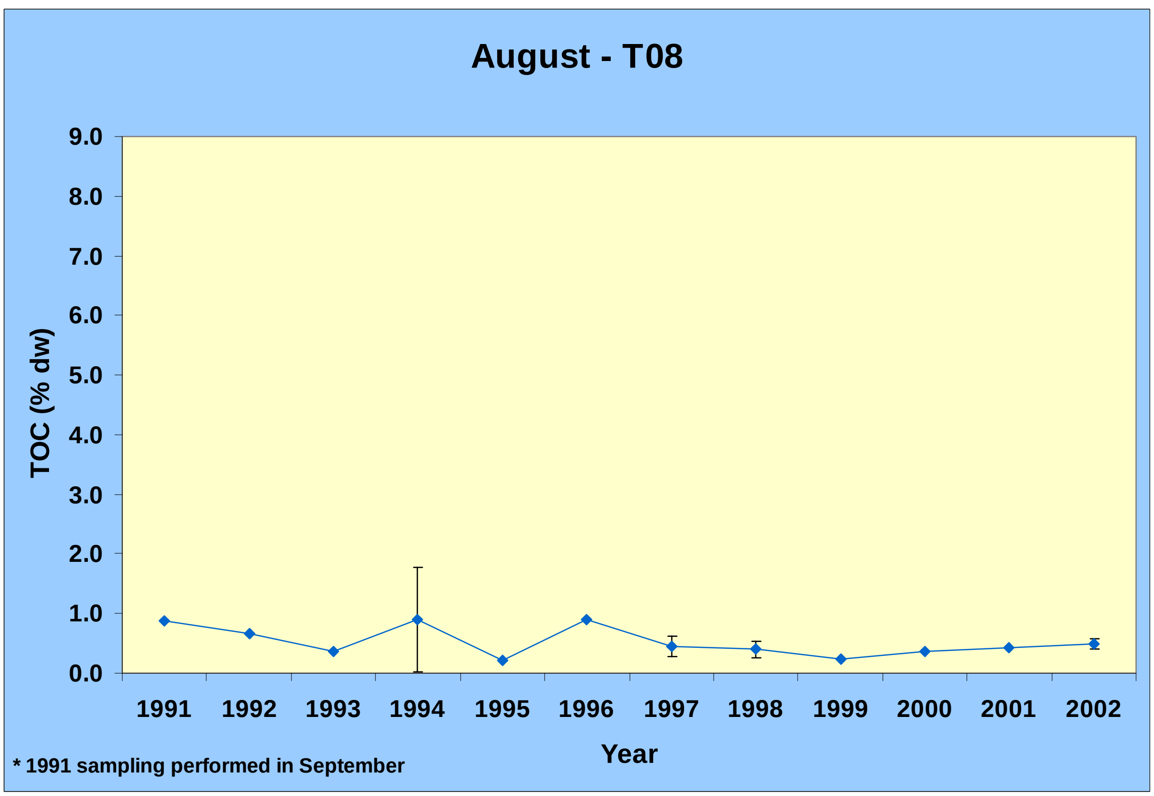
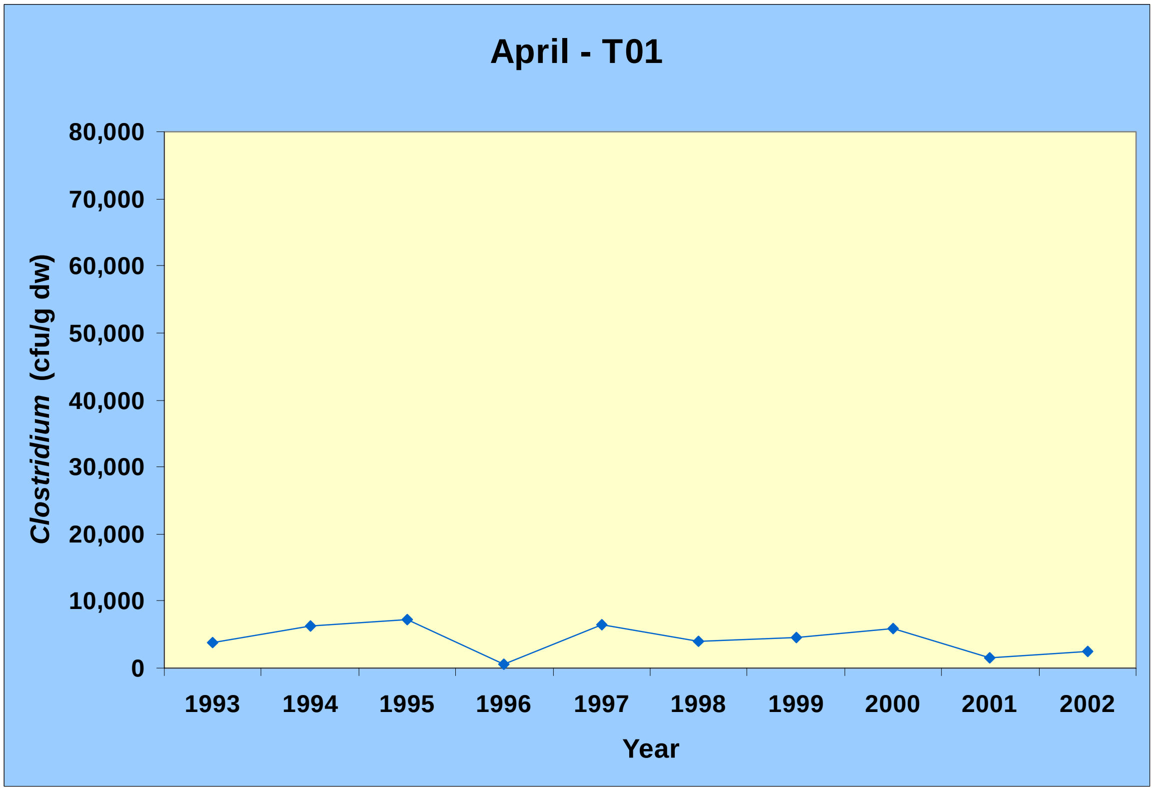


Figure C2-16. Total organic carbon content in sediments collected at Traditional station T08 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



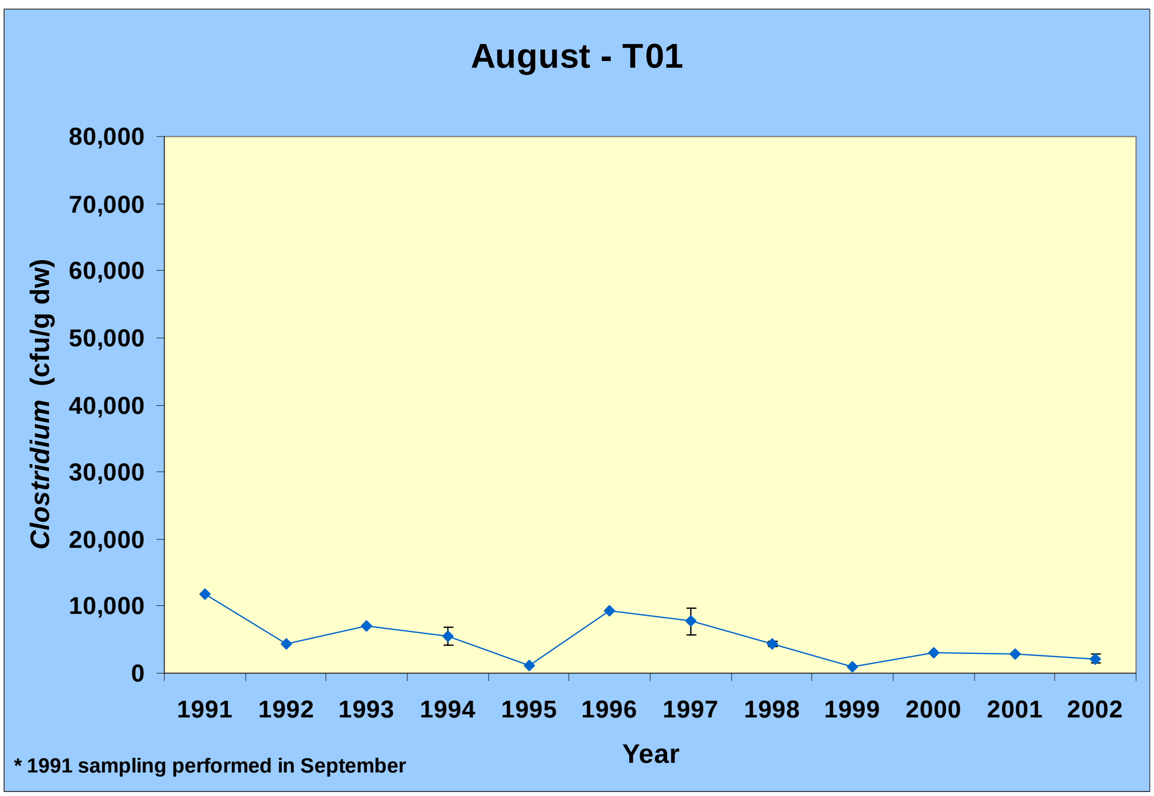
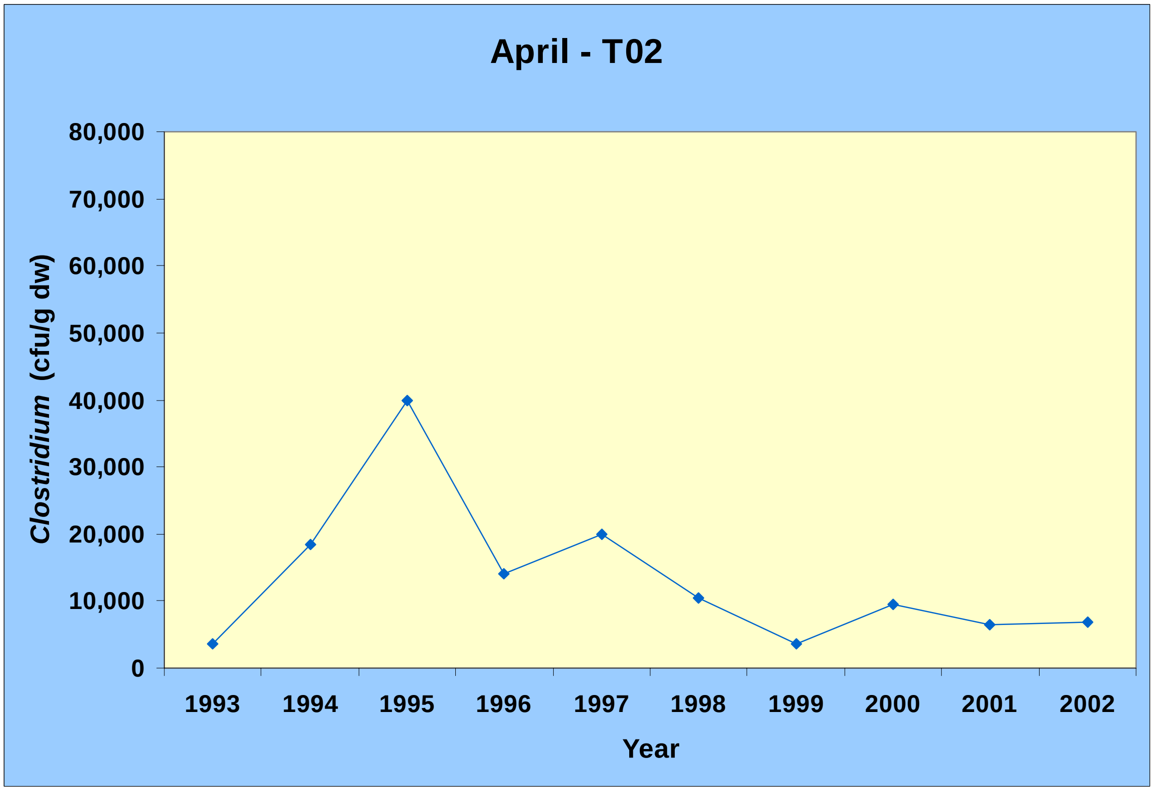


Figure C2-17. *Clostridium perfringens* concentrations in sediments collected at Traditional station T01 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



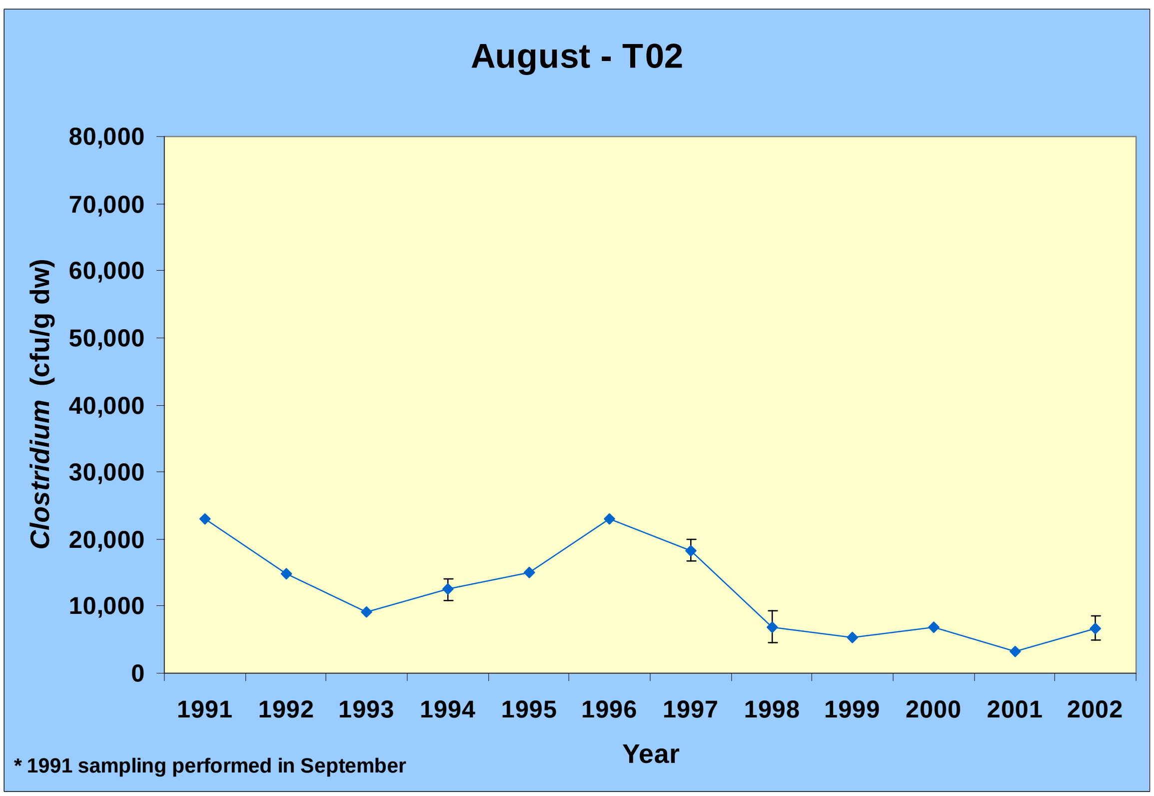


Figure C2-18. *Clostridium perfringens* concentrations in sediments collected at Traditional station T02 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.

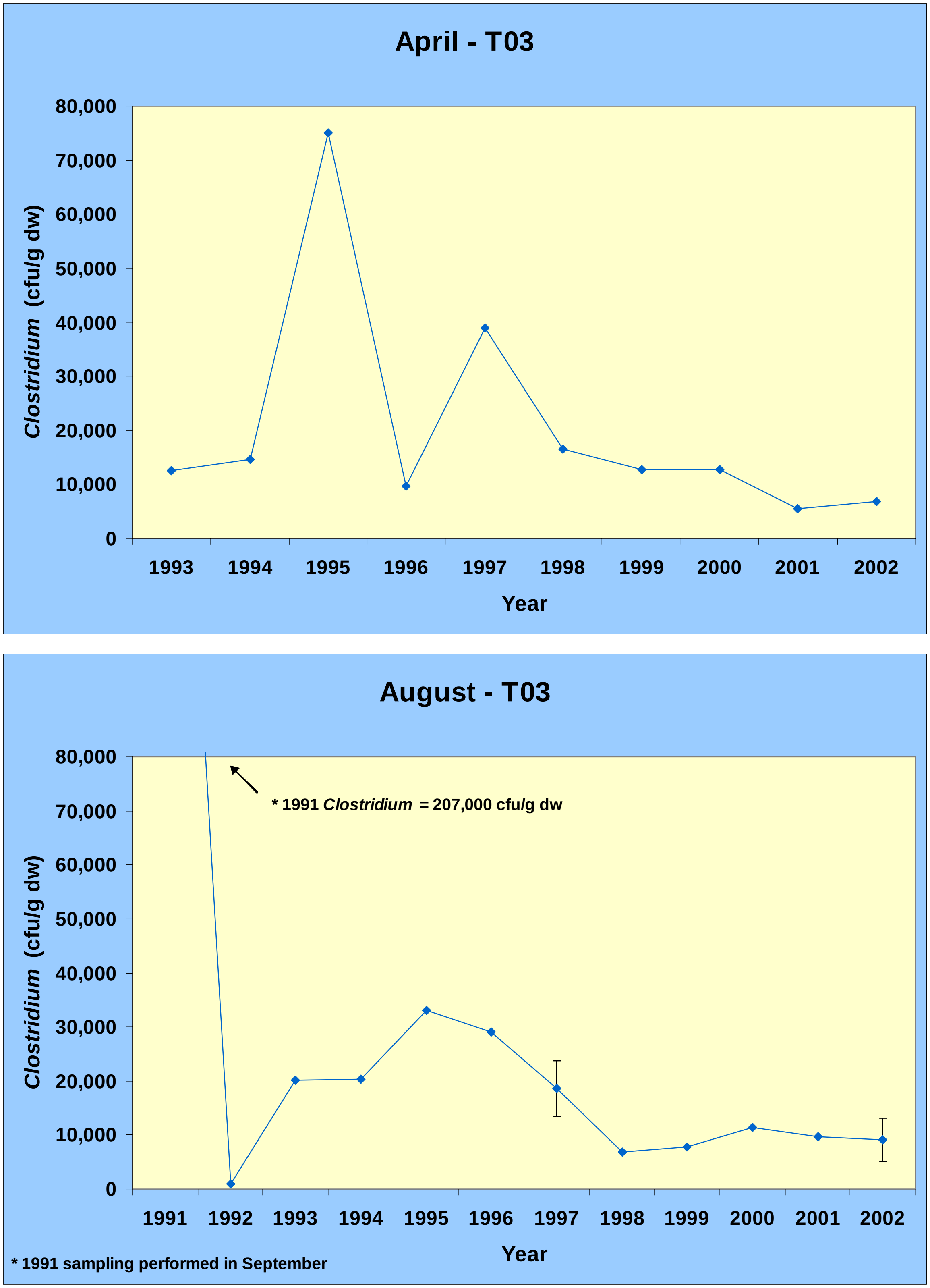
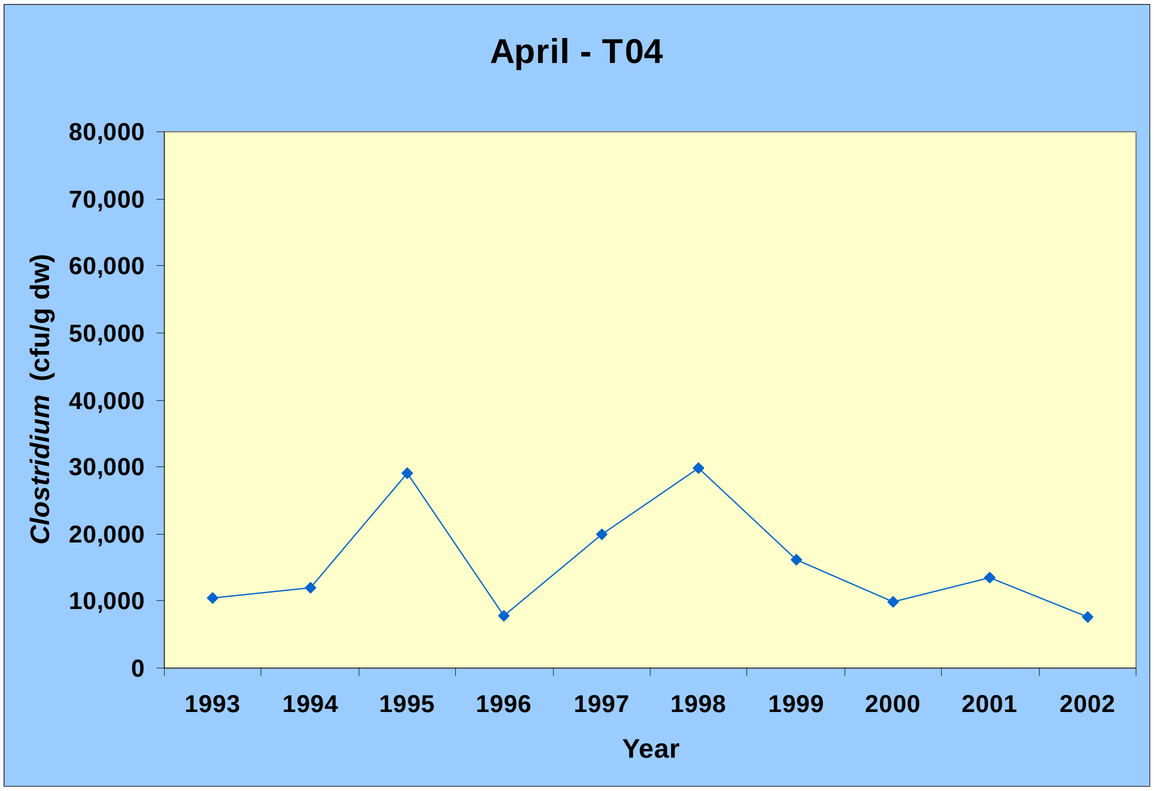


Figure C2-19. ***Clostridium perfringens*** **concentrations in sediments collected at Traditional station T03 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.**



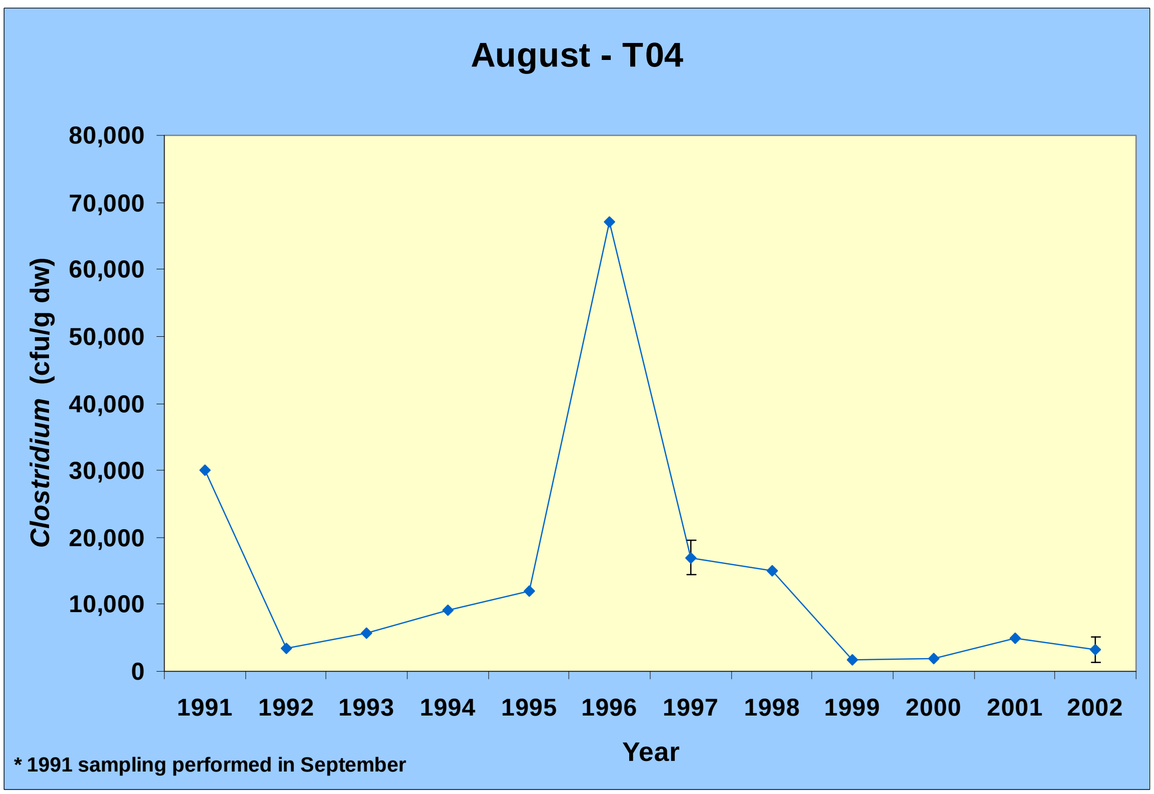
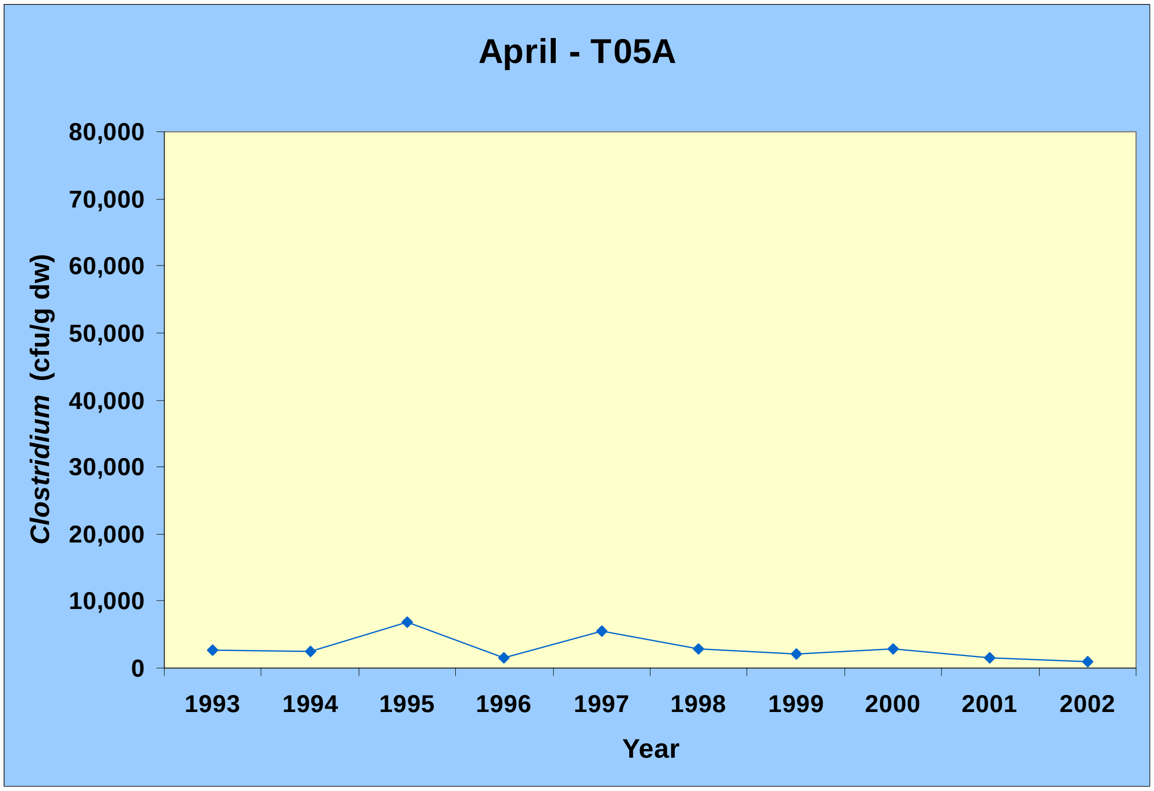


Figure C2-20. *Clostridium perfringens* concentrations in sediments collected at Traditional station T04 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



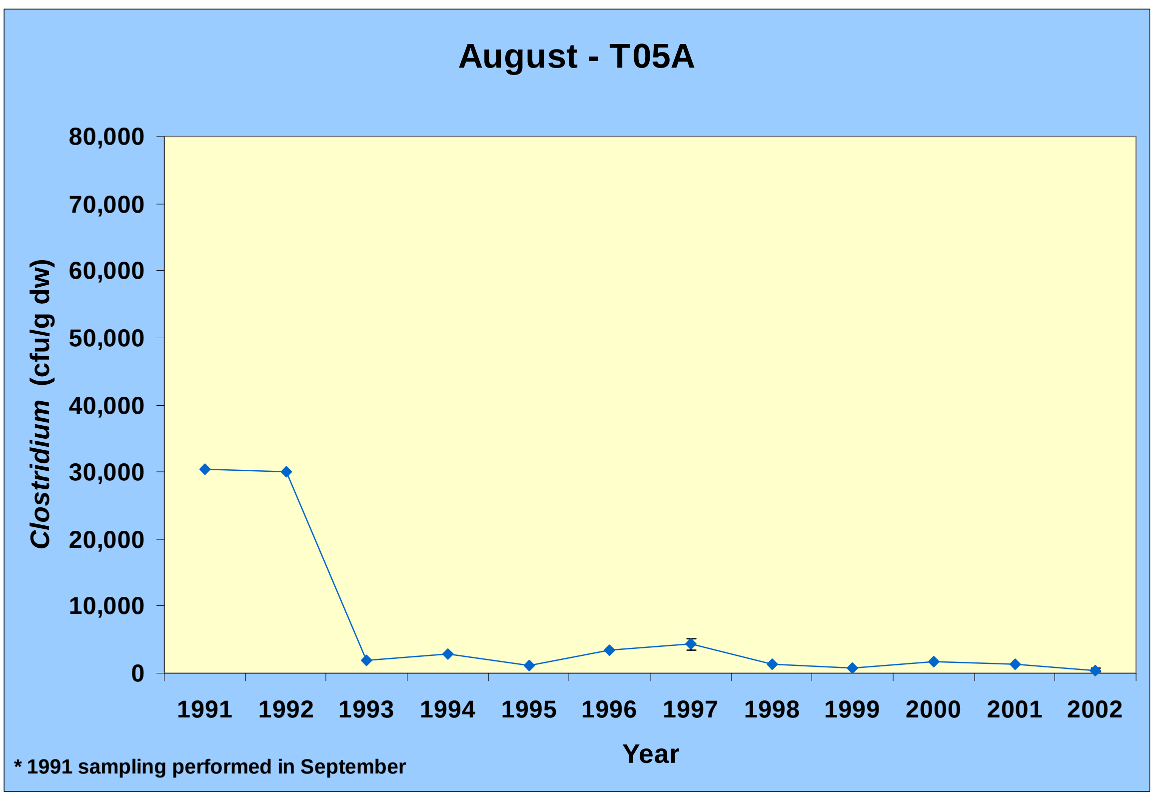
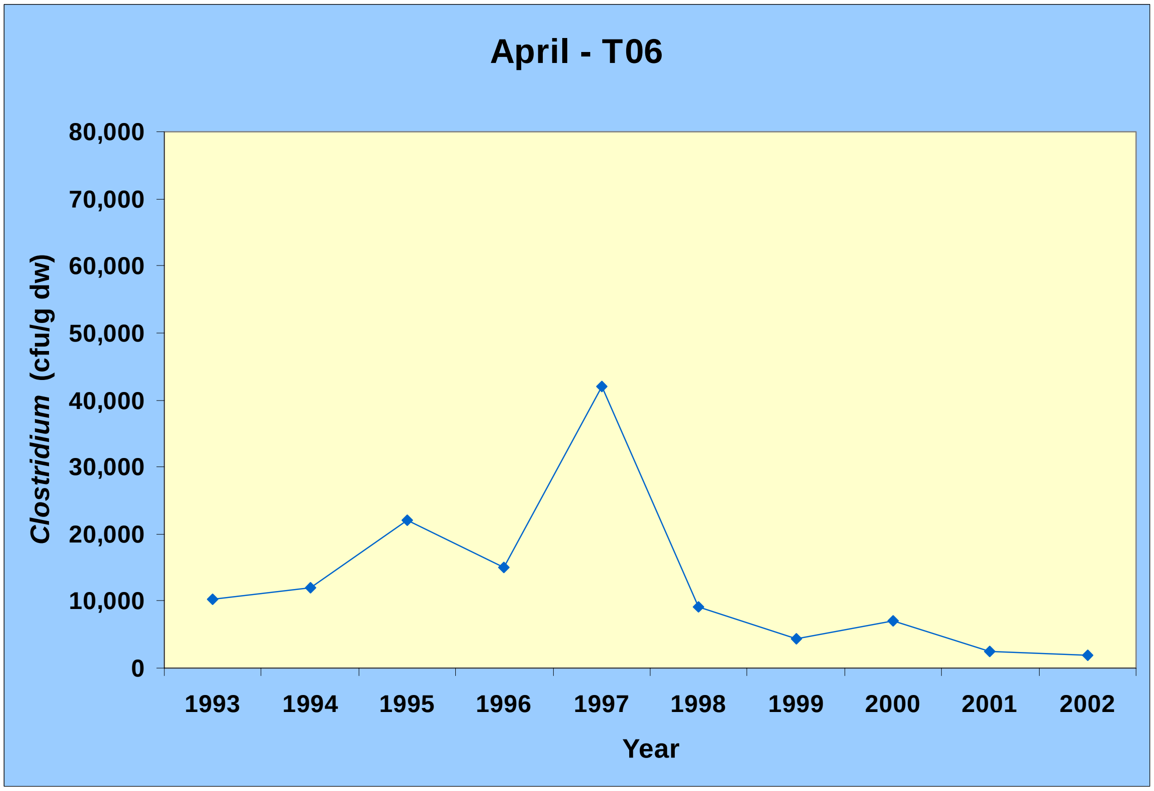


Figure C2-21. *Clostridium perfringens* concentrations in sediments collected at Traditional station T05A in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.



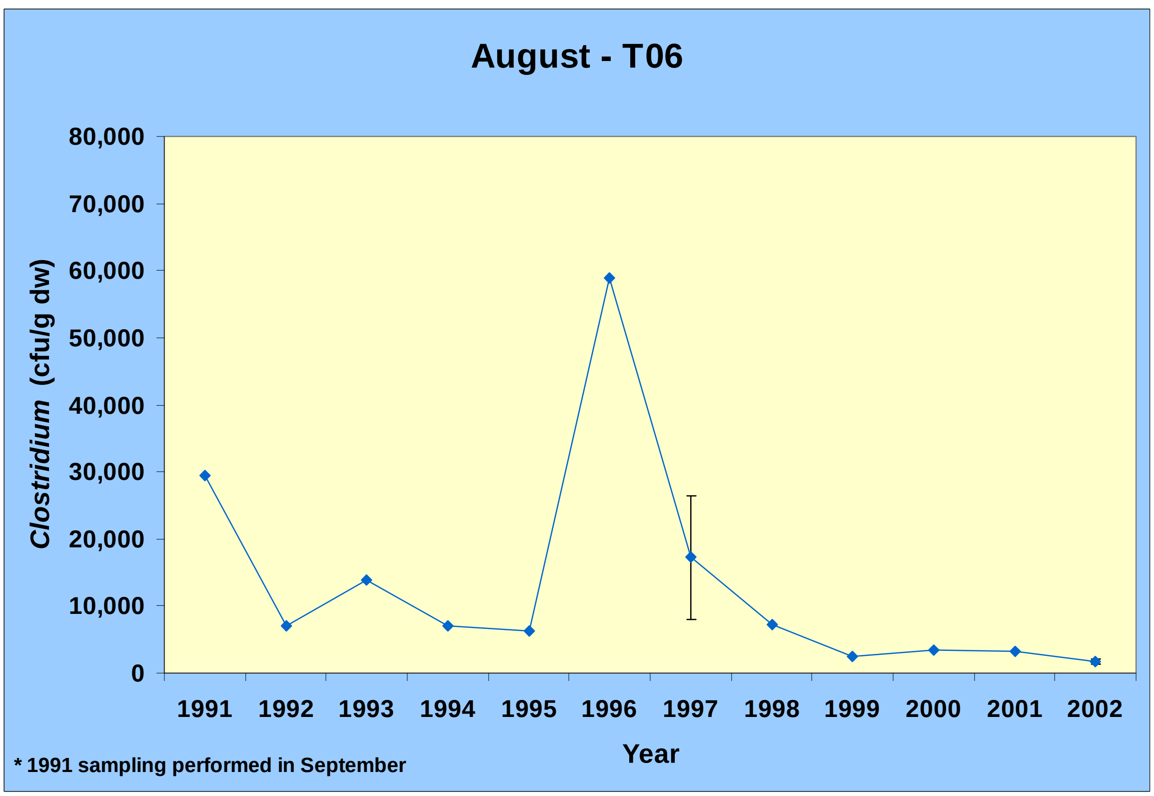
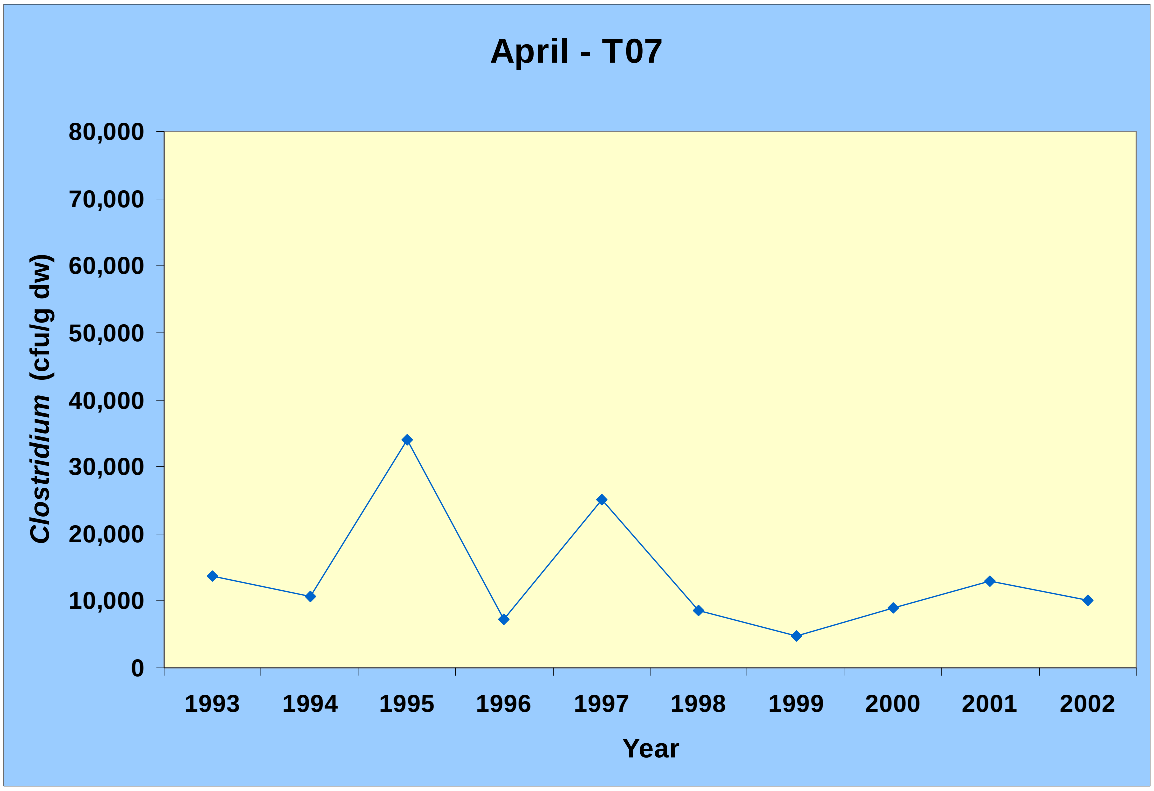


Figure C2-22. ***Clostridium perfringens*** **concentrations in sediments collected at Traditional station T06 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.**



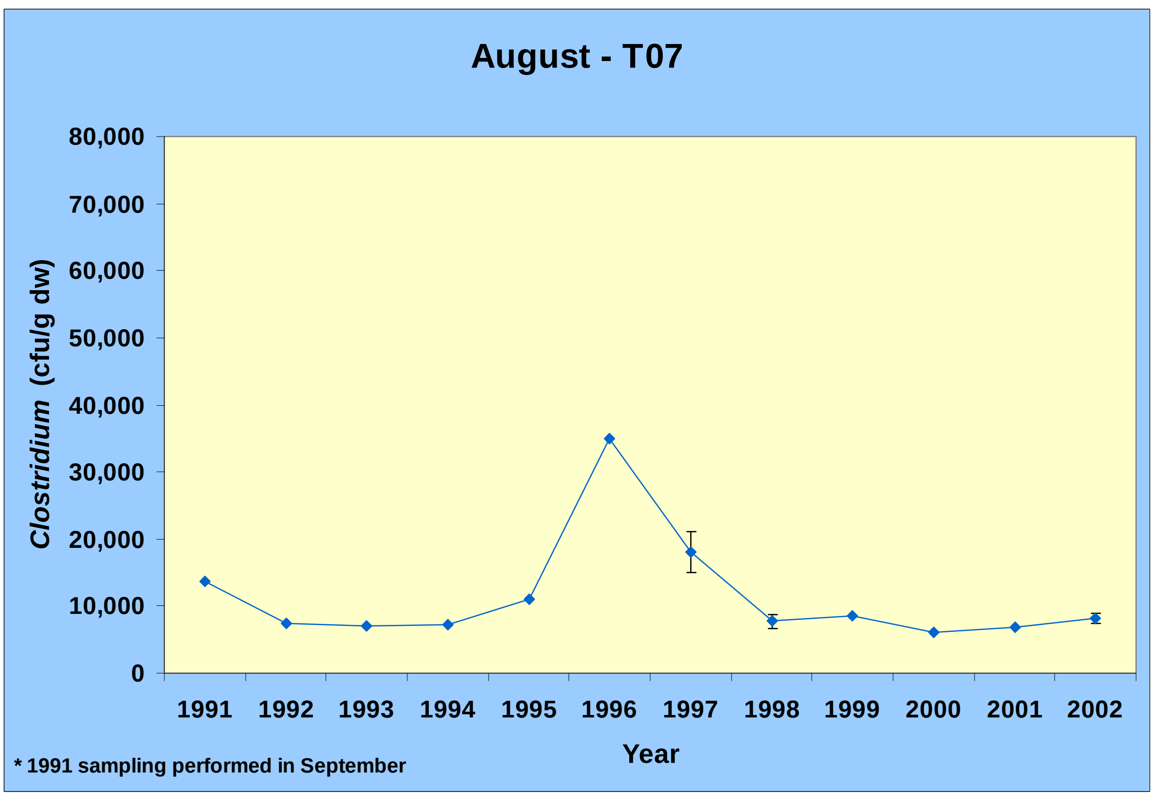
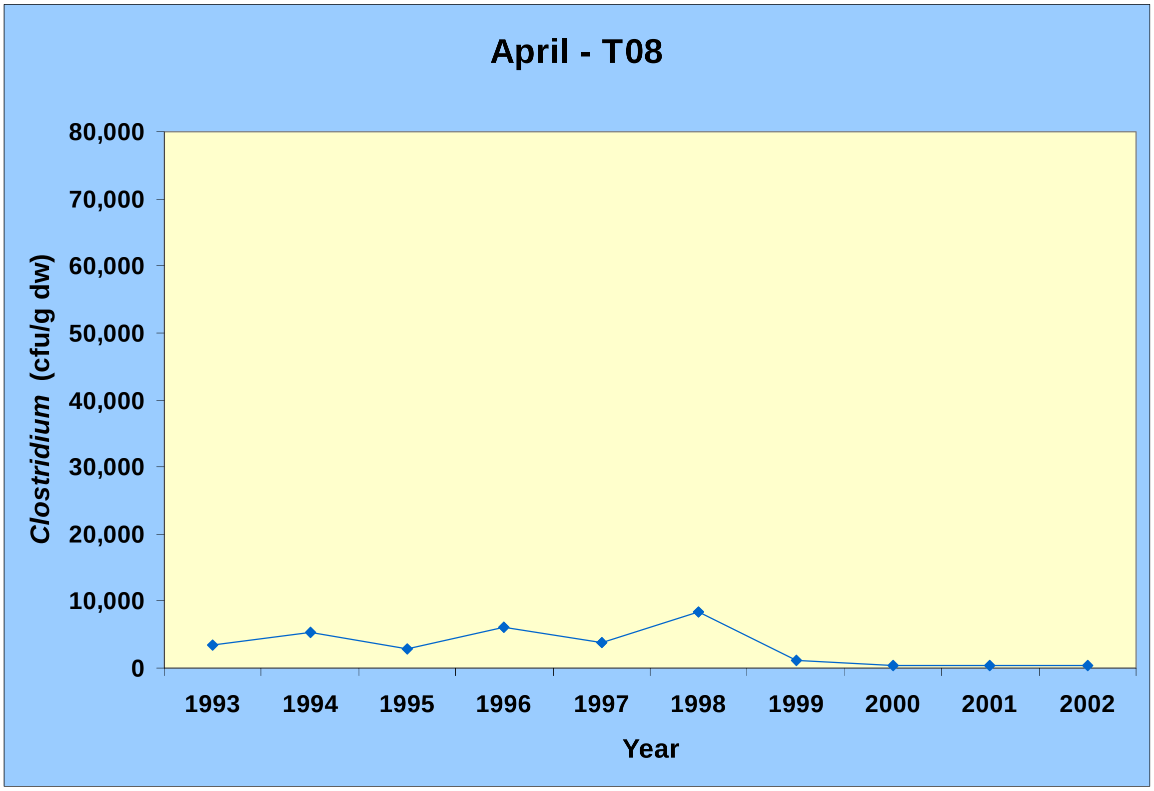


Figure C2-23. ***Clostridium perfringens*** **concentrations in sediments collected at Traditional station T07 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.**



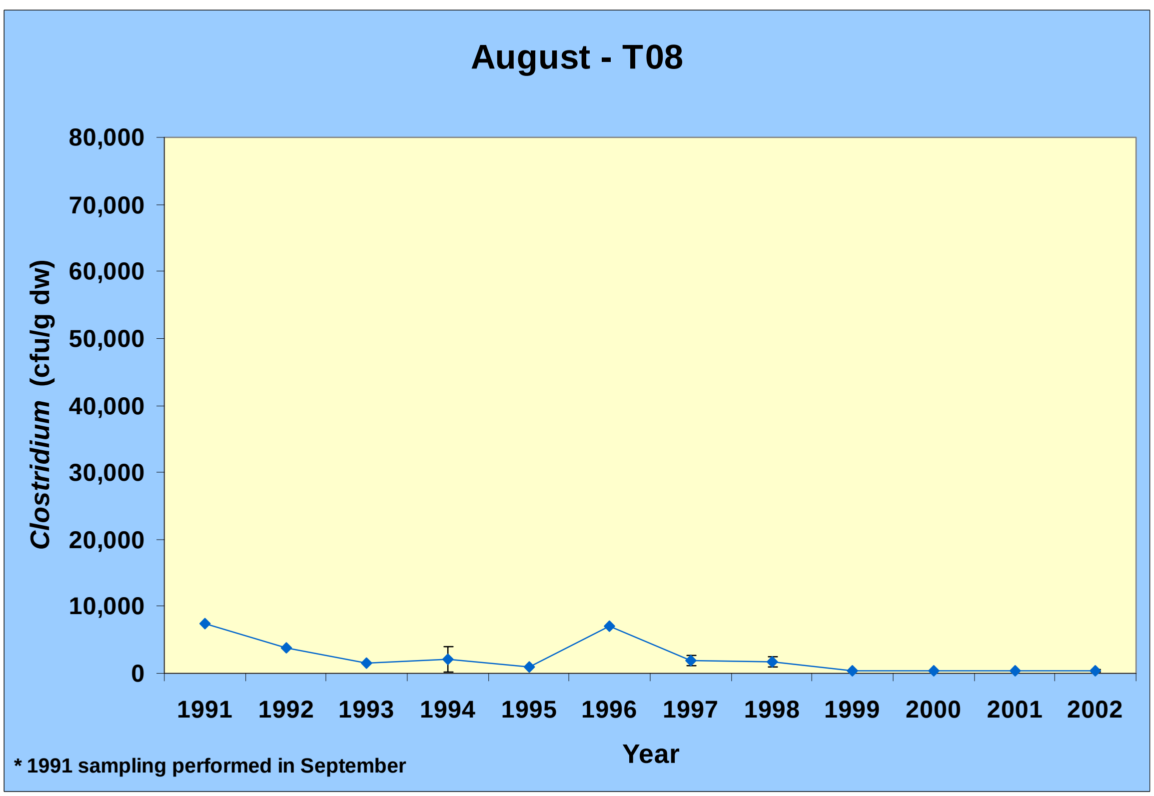


Figure C2-24. *Clostridium perfringens* concentrations in sediments collected at Traditional station T08 in April 1993–2002 (top) and September 1991 and August 1992–2002 (bottom). Error bars represent standard deviation of replicate analyses.

APPENDIX C3

Grain size, TOC, and *Clostridium perfringens* Data from Sediments Collected at Traditional Stations in April 1993–2002.

(Results reported on dry-weight basis to three significant figures.)

Table C3-1. Grain size, TOC, *Clostridium perfringens* data from sediments collected at Traditional stations from April 1993 to 2002.

Parameter	Year	T01	T02	T03	T04	T05A	T06	T07	T08
Gravel (pct)	1993	3.17	0	0	0	0.404	0	0	11.4
	1994	3.7	0.7	0.2	0	0.4	5.4	8.9	5
	1995	18.1	1.5	0	0	0.2	3.9	19.5	2.9
	1996	1.8	0.7	12.8	0	0.3	0.3	23.2	0.2
	1997	9	0.9	0	0.3	0	0	1.4	4.3
	1998	3.9	0	2.6	0	0.1	0.1	5.7	0.2
	1999	3.9	3.6	1.5	0	0.6	0.8	28.2	0.4
	2000	10.7	2.9	0.2	4.1	0	0	9.2	0.3
	2001	0.185	0.034	0	4.51	0.109	1.4	4.55	2.55
	2002	0.6	0.1	1.3	0	0.5	0.9	8.7	0.37
Grand Station Mean		5.51	1.04	1.86	0.891	0.261	1.28	10.9	2.77
Stdev		5.56	1.27	3.94	1.8	0.211	1.87	9.5	3.55
CV		101	122	212	203	80.9	146	86.9	128
Sand (pct)	1993	90.5	38.6	38.4	16.4	62.4	37.1	19.6	79.8
	1994	77.8	69.6	52	28	74.3	63.5	39.1	92.9
	1995	68.5	45.2	9.7	8.8	84	61.1	36.7	93.3
	1996	71.4	37.1	34.8	9.5	85.3	22.4	27	86.6
	1997	68.7	46.1	17.9	4.9	56	47.8	90.9	32.4
	1998	74	16.4	34.9	2.8	79.1	51.4	22.7	62.6
	1999	67.8	56.1	30.6	30.6	73	28.8	27.5	91.1
	2000	65.3	39.5	14.2	7.2	66.6	31.2	29.3	96.6
	2001	68	44.1	31.2	5.75	60.3	45.7	28.4	93
	2002	56	52.4	46.6	5.9	80.4	55.9	30.5	94.7
Grand Station Mean		70.8	44.5	31	12	72.1	44.5	35.2	82.3
Stdev		8.98	13.9	13.7	9.84	10.3	14.1	20.4	20.2
CV		12.7	31.2	44	82.1	14.3	31.7	58	24.6
Gravel + Sand (pct)	1993	93.7	38.6	38.4	16.4	62.8	37.1	19.6	91.2
	1994	81.5	70.3	52.2	28	74.7	68.9	48	97.9
	1995	86.6	46.7	9.7	8.8	84.2	65	56.2	96.2
	1996	73.2	37.8	47.6	9.5	85.6	22.7	50.2	86.8
	1997	77.7	47	17.9	5.2	56	47.8	92.3	36.7
	1998	77.9	16.4	37.5	2.8	79.2	51.5	28.4	62.8
	1999	71.7	59.7	32.1	30.6	73.6	29.6	55.7	91.5
	2000	76	42.4	14.4	11.3	66.6	31.2	38.5	96.9
	2001	68.2	44.1	31.2	10.3	60.5	47.1	33	95.5
	2002	56.6	52.5	47.9	5.9	80.9	56.8	39.2	95
Grand Station Mean		76.3	45.5	32.9	12.9	72.4	45.8	46.1	85.1
Stdev		10.1	14.3	14.8	9.44	10.4	15.4	20.1	19.9
CV		13.3	31.3	45	73.3	14.4	33.7	43.6	23.4

Parameter	Year	T01	T02	T03	T04	T05A	T06	T07	T08
Silt (pct)	1993	5.99	48.2	41	64.3	31.1	43.2	59.9	6.14
	1994	13.7	18.9	43.8	63.1	22.2	28.1	46.1	1.8
	1995	9.4	33.3	50.1	54.9	9.7	20.8	27.9	2.6
	1996	16.4	39.1	31.7	59.6	9.6	46.1	29.1	6.2
	1997	13.9	32.1	44.7	57.8	27.5	30.6	3.6	34.1
	1998	13.2	45.4	30.2	58.5	14.2	26.7	38.8	17.6
	1999	17.4	20.1	35	32	15.7	33.5	17.3	3.7
	2000	15.3	35.2	41	51	21	34.1	35.3	1.2
	2001	19.5	32.7	34.1	48.5	22.2	24.9	35	1.38
	2002	28.1	30.4	33.2	59.4	11.4	25.7	38.6	2
Grand Station Mean		15.3	33.5	38.5	54.9	18.5	31.4	33.2	7.67
Stdev		5.94	9.41	6.57	9.43	7.5	8.08	15.3	10.5
CV		38.9	28	17.1	17.2	40.6	25.8	46.3	137
Clay (pct)	1993	0.267	13.2	20.6	19.3	6.15	19.7	20.5	2.66
	1994	4.7	10.9	4	8.9	3.1	3	6	0.3
	1995	4	20	40.2	36.3	6.1	14.2	16	1.2
	1996	10.3	23.1	20.7	31	4.8	31.2	20.7	7
	1997	8.3	20.9	37.4	37	16.4	21.6	4.2	29.2
	1998	8.8	38.2	32.3	38.7	6.6	21.8	32.8	19.5
	1999	10.9	20.3	32.9	37.4	10.7	36.9	27	4.77
	2000	8.7	22.3	44.6	37.8	12.4	34.7	26.2	1.9
	2001	12.3	23.2	34.7	41.3	17.3	28	32	3.09
	2002	15.3	17.1	18.9	34.7	7.7	17.5	22.1	2.93
Grand Station Mean		8.36	20.9	28.6	32.2	9.13	22.9	20.7	7.26
Stdev		4.37	7.35	12.3	10.2	4.88	10.2	9.75	9.48
CV		52.3	35.1	43	31.7	53.5	44.8	47	131
Fines (pct)	1993	6.25	61.4	61.6	83.6	37.2	62.9	80.4	8.81
	1994	18.4	29.8	47.8	72	25.3	31.1	52.1	2.1
	1995	13.4	53.3	90.3	91.2	15.8	35	43.9	3.8
	1996	26.7	62.2	52.4	90.6	14.4	77.3	49.8	13.2
	1997	22.2	53	82.1	94.8	43.9	52.2	7.8	63.3
	1998	22	83.6	62.5	97.2	20.8	48.5	71.6	37.1
	1999	28.3	40.4	67.9	69.4	26.4	70.4	44.3	8.47
	2000	24	57.5	85.6	88.8	33.4	68.8	61.5	3.1
	2001	31.8	55.9	68.8	89.7	39.5	52.9	67	4.48
	2002	43.4	47.5	52.1	94.1	19.1	43.2	60.7	4.93
Grand Station Mean		23.6	54.5	67.1	87.1	27.6	54.2	53.9	14.9
Stdev		10.2	14.2	14.8	9.44	10.4	15.4	20.1	19.9
CV		42.9	26.2	22.1	10.8	37.7	28.5	37.2	133

Parameter	Year	T01	T02	T03	T04	T05A	T06	T07	T08
TOC (pct)	1993	1.38	2.2	2.89	3.58	1.14	2.51	2.87	0.84
	1994	1.38	2.2	2.64	5.35	0.28	1.82	2.18	0.22
	1995	0.93	1.49	3.49	6.25	0.68	1.6	3.06	0.18
	1996	0.926	2.02	2.84	3.81	0.419	2.64	2.83	0.69
	1997	1.05	1.59	3.38	4.07	1.13	3	3.16	0.373
	1998	1.19	2.16	2.78	6.59	0.42	1.17	2.15	1.3
	1999	0.98	1.14	2.95	6.94	1	2.84	2.77	0.65
	2000	1.61	1.87	3.45	4.44	1.2	2.36	2.88	0.4
	2001	0.85	1.54	2.99	5.29	1.01	2.5	2.9	0.35
	2002	1.41	1.52	2.84	4.9	1.2	2.03	2.95	0.31
Grand Station Mean		1.17	1.77	3.02	5.12	0.847	2.25	2.77	0.531
Stdev		0.26	0.368	0.302	1.18	0.361	0.58	0.34	0.345
CV		22.3	20.7	9.99	23	42.7	25.8	12.3	64.9
Clostridium perfringens (cfu/g dw)	1993	3870	3690	12500	10500	2610	10300	13700	3420
	1994	6180	18500	14600	12000	2460	11900	10600	5230
	1995	7300	40000	75000	29000	6800	22000	34000	2900
	1996	600	14000	9600	7800	1500	15000	7200	6050
	1997	6500	20000	39000	20000	5600	42000	25000	3850
	1998	4030	10500	16500	29800	2780	9050	8640	8430
	1999	4620	3670	12600	16100	2000	4460	4720	1090
	2000	5910	9520	12700	9880	2800	6950	8980	395
	2001	1540	6510	5480	13400	1470	2510	12900	294
	2002	2530	6900	6910	7620	860	1810	10000	360
Grand Station Mean		4310	13300	20500	15600	2890	12600	13600	3200
Stdev		2230	11000	21300	8180	1880	12000	9030	2770
CV		51.8	82.2	104	52.4	65.1	95.2	66.6	86.5

APPENDIX C4

Grain size, TOC, and *Clostridium perfringens* Data from Sediments Collected at Traditional Stations in September 1991 and August 1992–2002.

(Results reported on dry-weight basis to three significant figures)

Table C4-1. Grain size, TOC, *Clostridium perfringe*ns data from sediments collected at Traditional stations in September 1991 and August 1992–2002.

Parameter	Year	T01	T02	T03	T04	T05A	T06	T07	T08
Gravel (pct)	1991	1.26	0.155	0	0	0.294	0.0841	1.75	0
	1992	65.3	21.3	0	0	92.5	0.4	4.5	2.9
	1993	8.03	3.14	0.489	0	0	0.212	10.3	1.9
	1994	8.15	2.08	6.2	0	0.3	1.4	3	3.1
	1995	6.7	0	0	0.6	0.5	2.5	24.3	0.4
	1996	12.4	0	0.9	0	0.2	0	5.1	0
	1997	15.1	0.0667	0.233	0.6	0.167	2	15.8	0.533
	1998	6.8	0.4	0.5	0	0	0.6	7.28	1.45
	1999	25.1	0.4	0	3.8	0.167	0.12	9.6	2.4
	2000	2.5	0.1	1.7	1.5	0.3	0.2	11	0.6
	2001	0.401	0.246	0.865	0	0.389	0.466	5.78	3.01
	2002	2.57	3.03	1	1.7	0.233	0.633	12.2	0.833
Grand Station Mean		12.9	2.58	0.991	0.683	7.92	0.718	9.22	1.43
Stdev		17.9	6.01	1.72	1.16	26.6	0.813	6.28	1.19
CV		139	233	174	169	336	113	68.1	83.5
Sand (pct)	1991	83.6	63.6	44.1	32.3	93.4	65.6	57.3	12.1
	1992	17.8	47.6	43.5	20.8	5.6	64.8	40.2	93.4
	1993	75.3	66	50.3	13.9	85.3	67.1	39.7	93.7
	1994	60.8	57.7	57	4.8	87.1	64.7	38.9	91.5
	1995	32.2	41.3	11.8	5.7	87.8	31.1	17.9	95.4
	1996	67.3	53.1	20.5	5.6	89.1	19.7	27.2	82.6
	1997	64.1	44.4	17.2	2	67.7	57	29.2	93.5
	1998	68.8	44.2	11.2	20.4	81.4	38.3	30.3	92.3
	1999	53.4	39.8	8.9	1.6	75.6	37.5	23.5	93
	2000	67.5	54	49.4	29.4	93.5	58.3	30.6	94.7
	2001	66.9	43.7	33.7	5.41	77.7	61	37.5	89.1
	2002	65.6	42.5	39.3	7.5	87.4	73	33.3	88.8
Grand Station Mean		60.3	49.8	32.2	12.5	77.6	53.2	33.8	85
Stdev		18.3	8.91	17.4	10.7	23.9	17	10.1	23.2
CV		30.3	17.9	53.9	86.2	30.8	32	29.8	27.3
Gravel + Sand (pct)	1991	84.9	63.8	44.1	32.3	93.7	65.7	59	12.1
	1992	83.1	68.9	43.5	20.8	98.1	65.2	44.7	96.3
	1993	83.3	69.1	50.8	13.9	85.3	67.3	50	95.6
	1994	69	59.8	63.2	4.8	87.4	66.1	41.9	94.6
	1995	38.9	41.3	11.8	6.3	88.3	33.6	42.2	95.8
	1996	79.7	53.1	21.4	5.6	89.3	19.7	32.3	82.6
	1997	79.2	44.5	17.4	2.6	67.9	59	44.9	94.1
	1998	75.6	44.6	11.7	20.4	81.4	38.9	37.6	93.7
	1999	78.5	40.2	8.9	5.4	75.8	37.6	33.1	95.4
	2000	70	54.1	51.1	30.9	93.8	58.5	41.6	95.3
	2001	67.3	43.9	34.6	5.41	78.1	61.4	43.3	92.1
	2002	68.2	45.5	40.3	9.2	87.6	73.6	45.5	89.6

Parameter	Year	T01	T02	T03	T04	T05A	T06	T07	T08
Gravel + Sand (pct) (cont)									
Grand Station Mean		73.1	52.4	33.2	13.1	85.6	53.9	43	86.4
Stdev		12.5	10.7	18.4	10.5	8.54	16.9	7.17	23.7
CV		17.1	20.4	55.2	80	9.98	31.4	16.7	27.4
Silt (pct)	1991	11.9	27.8	39.1	48.6	4.24	25.1	27.3	52.2
	1992	8	19.1	39	59.8	1	22.2	38.8	1.7
	1993	11.7	20.4	30.7	60.4	9.43	20.6	33.7	1.9
	1994	24	28	26.2	70.4	9.1	21.8	43.8	3.08
	1995	58.3	38.6	52	57.7	8.1	41.6	34.9	1.8
	1996	14.9	36.5	53.4	79.8	7.2	54.7	52.1	9.7
	1997	13.2	33.6	44.5	56.4	20.8	26.3	39.1	2.57
	1998	17	35.9	42.7	43.3	11.2	32	38.3	3.39
	1999	13.4	34.6	46.4	48.6	13.7	33.7	33.7	1.6
	2000	23.7	31	36.3	55.5	4.9	26.7	34	2.6
	2001	20.7	34.3	40.1	61	13.7	23.1	33.5	4.72
	2002	15	36	33	63.1	5.2	14.9	35	4.1
Grand Station Mean		19.3	31.3	40.3	58.7	9.05	28.6	37	7.44
Stdev		13.2	6.32	8.17	9.85	5.32	10.8	6.24	14.3
CV		68.4	20.2	20.3	16.8	58.8	37.7	16.9	192
Clay (pct)	1991	3.2	8.46	16.8	19.1	2.07	9.21	13.6	35.7
	1992	9	12.1	17.5	19.4	0.9	12.6	16.5	2
	1993	5.05	10.4	18.6	25.6	5.24	12.1	16.2	2.51
	1994	7.03	12.3	10.6	24.8	3.6	12	14.3	2.33
	1995	2.8	20	36.2	36	3.6	24.8	22.9	2.4
	1996	5.4	10.4	25.3	14.6	3.5	25.6	15.6	7.6
	1997	7.53	21.9	38	41	11.3	14.8	16	3.4
	1998	7.48	19.6	45.6	36.3	7.4	29.2	24.2	2.83
	1999	8.1	25.2	44.7	46	10.5	28.7	33.3	3
	2000	6.3	14.9	12.7	13.5	1.4	14.8	24.4	2.1
	2001	12	21.8	25.3	33.6	8.18	15.4	23.2	3.21
	2002	16.8	18.5	26.7	27.7	7.17	11.5	19.5	6.33
Grand Station Mean		7.56	16.3	26.5	28.1	5.4	17.6	20	6.12
Stdev		3.84	5.53	12.1	10.5	3.48	7.31	5.78	9.48
CV		50.8	33.9	45.6	37.4	64.4	41.7	28.9	155
Fines (pct)	1991	15.1	36.2	55.9	67.7	6.32	34.3	41	87.9
	1992	17	31.2	56.5	79.2	1.9	34.8	55.3	3.7
	1993	16.7	30.9	49.2	86.1	14.7	32.7	50	4.42
	1994	31.1	40.2	36.8	95.2	12.7	33.8	58.1	5.4
	1995	61.1	58.6	88.2	93.7	11.7	66.4	57.8	4.2
	1996	20.3	46.9	78.7	94.4	10.7	80.3	67.7	17.3
	1997	20.7	55.5	82.6	97.4	32.1	41.1	55.1	5.97
	1998	24.5	55.5	88.3	79.6	18.6	61.2	62.4	6.23
	1999	21.5	59.8	91.1	94.6	24.2	62.4	67	4.6
	2000	30	45.9	49	69	6.3	41.5	58.4	4.7
	2001	32.7	56.1	65.4	94.6	21.9	38.6	56.7	7.93

Parameter	Year	T01	T02	T03	T04	T05A	T06	T07	T08
Fines (pct) (cont)									
	2002	31.8	54.4	59.7	90.8	12.4	26.4	54.5	10.4
Grand Station Mean		26.9	47.6	66.8	86.9	14.5	46.1	57	13.6
Stdev		12.5	10.7	18.3	10.5	8.53	17	7.18	23.7
CV		46.4	22.4	27.5	12.1	59	36.8	12.6	175
TOC (pct)	1991	2.64	1.75	3.69	3.7	1.46	1.81	2.73	0.87
	1992	1.91	1.71	3.57	3.95	1.61	2.12	3.18	0.66
	1993	2.96	1.39	3.41	3.25	0.88	1.62	2.31	0.37
	1994	1.9	1.73	2.8	3.1	0.5	1.9	2.5	0.9
	1995	1.18	2.05	3.54	3.69	0.42	1.83	3.17	0.21
	1996	1.9	1.98	3.84	4.75	0.884	3.89	2.73	0.893
	1997	1.83	1.46	3.57	3.88	1.42	1.88	3.09	0.45
	1998	1.55	1.5	2.46	8.86	0.62	2.17	2.21	0.398
	1999	2.8	1.61	3.14	4.15	1.26	2.36	2.77	0.23
	2000	1.8	1.51	3.03	3.9	0.93	2.16	2.53	0.37
	2001	1.13	1.69	3.03	4.08	1.02	1.97	2.6	0.43
	2002	0.973	1.77	2.8	3.64	0.873	1.6	2.73	0.497
Grand Station Mean		1.88	1.68	3.24	4.25	0.99	2.11	2.71	0.523
Stdev		0.646	0.2	0.426	1.51	0.382	0.605	0.313	0.249
CV		34.3	11.9	13.2	35.6	38.6	28.7	11.5	47.5
Clostridium perfringens (cfu/g dw)	1991	11700	22900	207000	30000	30400	29400	13700	7330
	1992	4300	14800	938	3330	30000	7000	7500	3890
	1993	7030	9090	20200	5750	1910	13800	7100	1580
	1994	5490	12500	20300	9080	2840	7110	7290	2160
	1995	1200	15000	33000	12000	1100	6200	11000	955
	1996	9400	23000	29000	67000	3400	59000	35000	7000
	1997	7720	18300	18700	17000	4300	17200	18000	1900
	1998	4390	6870	6840	15100	1400	7280	7740	1750
	1999	920	5260	7720	1800	750	2560	8520	350
	2000	3130	6820	11300	1960	1700	3430	6040	330
	2001	2910	3310	9650	4900	1240	3320	6910	320
	2002	2160	6730	9110	3220	453	1770	8120	387
Grand Station Mean		5030	12000	31100	14300	6620	13200	11400	2330
Stdev		3360	6790	56200	18500	11100	16400	8190	2490
CV		66.7	56.4	180	130	167	125	71.8	107

APPENDIX C5

Supporting Plots Showing Comparison of April and August Surveys with Results from the Flux Program (1993–2002)

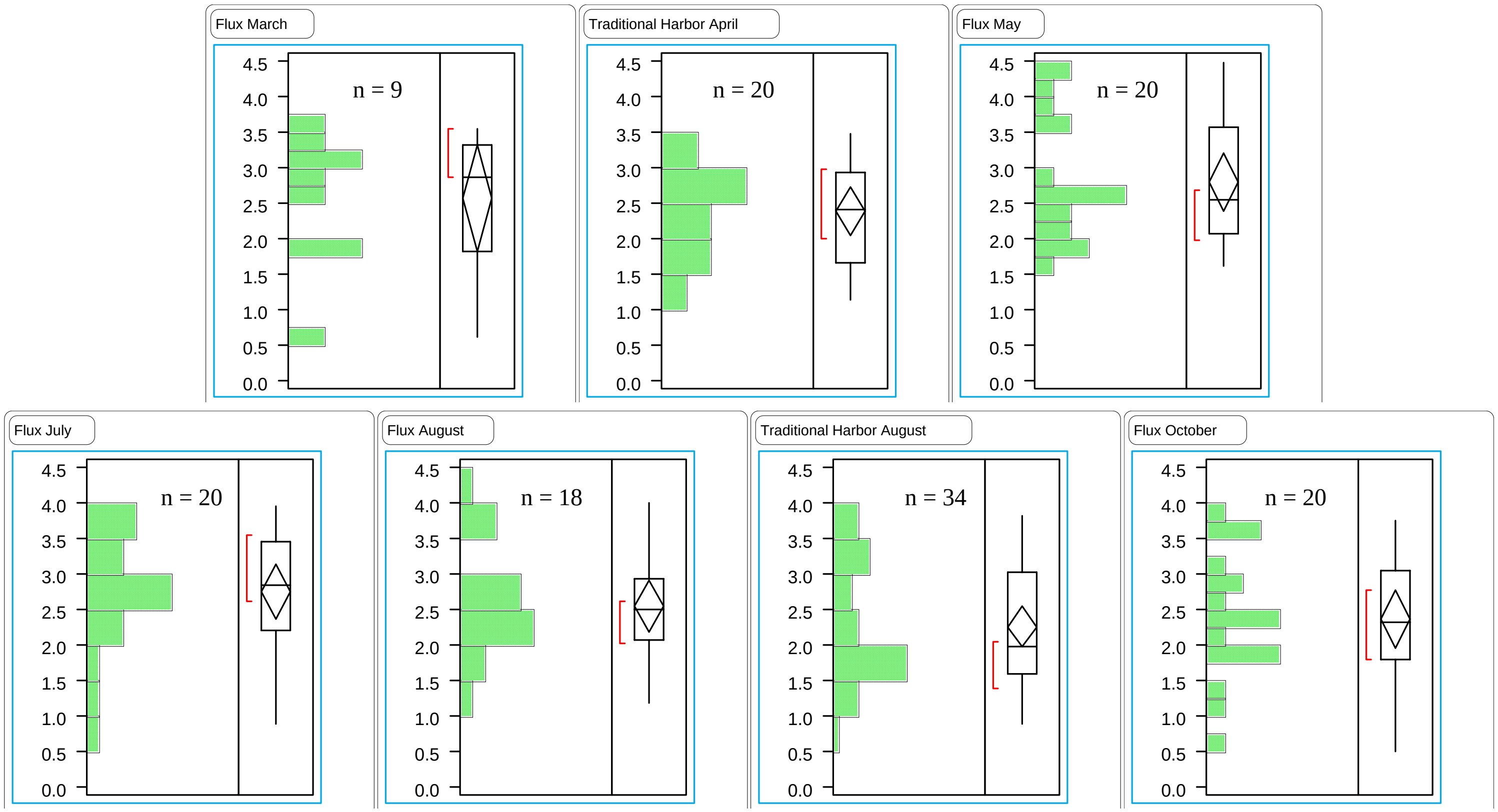


Figure C5-1. Distributions of flux (BH02, BH03 and BH03A only) and Traditional Harbor (stations T02 and T03 only) TOC results (% dry weight) from 1993 to 2002. The quantile box plot shows selected quantities on the response axis. The box shows the median as a line across the middle and the quartiles (25th and 75th percentiles) as its ends. The means diamond identifies the mean of the sample and the 95% confidence interval about the mean.

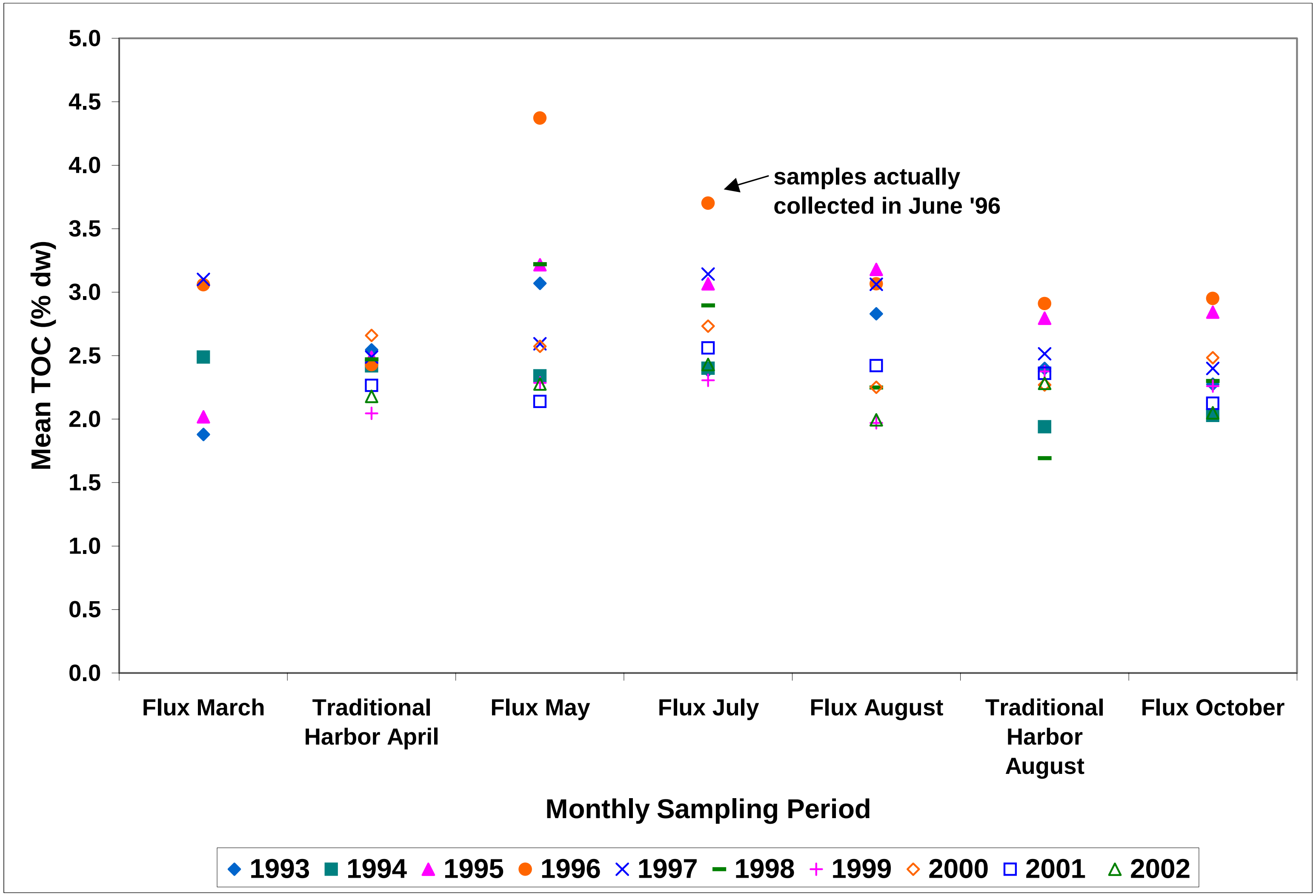


Figure C5-2. Comparison of mean TOC results from the Flux program (BH02 and BH03 only) to Traditional Harbor April and August events (T02 and T03 only), by sampling month and year, from 1993 to 2002.

APPENDIX C6

Correspondence within Ancillary Measurements, April (1993–2002) and August (1991–2002) Surveys

Table C6-1. Correspondence within bulk sediment properties and against *Clostridium perfringens* for April surveys from 1993 to 2002.

Year	TOC by Fines			*Clostridium perfringens* by Fines			*Clostridium perfringens* by TOC		
	r	*n*	*p*	*r*	*n*	*p*	*r*	*n*	*p*
1993	0.909	8	<0.01	0.756	8	<0.05	0.843	8	<0.01
1994	0.896	8	<0.01	0.479	8	>0.05	0.585	8	>0.05
1995	0.883	8	<0.01	0.831	8	<0.05	0.528	8	>0.05
1996	0.914	8	<0.01	0.707	8	>0.05	0.580	8	>0.05
1997	0.351[a]	8	>0.05	0.233[a]	8	>0.05	0.760	8	<0.05
1998	0.807	8	<0.05	0.798	8	<0.05	0.972	8	<0.01
1999	0.759	8	<0.05	0.754	8	<0.05	0.879	8	<0.01
2000	0.929	8	<0.01	0.892	8	<0.01	0.843	8	<0.01
2001	0.919	8	<0.01	0.837	8	<0.01	0.831	8	<0.05
2002	0.951	8	<0.01	0.778	8	<0.05	0.723	8	<0.05

[a] Grain size data for stations T07 and T08 in 1997 are "anomalous." Correlation between percent fines and TOC in 1997 improved when these stations were excluded from the correlation analysis ($r = 0.900$, $n = 6$, $p < 0.05$). Similarly, the correlation between percent fines and *Clostridium perfringens* in 1997 also improved when these stations (T07, T08) were excluded from the correlation analysis ($r = 0.496$, $n = 6$, $p > 0.05$).

Table C6-2. Correspondence within bulk sediment properties and against *Clostridium perfringens* for September 1991 and August surveys from 1992 to 2002.

Year	TOC by Fines			*Clostridium perfringens* by Fines			*Clostridium perfringens* by TOC		
	r	*n*	*p*	*r*	*n*	*p*	*r*	*n*	*p*
1991	0.087[a]	8	>0.05	0.148	8	>0.05	0.552	8	>0.05
1992	0.939	8	<0.01	0.511	8	>0.05	0.381	8	>0.05
1993	0.712	8	<0.05	0.323	8	>0.05	0.561	8	>0.05
1994	0.843	8	<0.01	0.334	8	>0.05	0.660	8	>0.05
1995	0.888	8	<0.01	0.664	8	>0.05	0.762	8	<0.05
1996	0.963	8	<0.01	0.925	8	<0.01	0.919	8	<0.01
1997	0.899	8	<0.01	0.790	8	<0.05	0.712	8	<0.05
1998	0.624[b]	8	>0.05	0.798	8	<0.05	0.931	8	<0.01
1999	0.797	8	<0.05	0.632	8	>0.05	0.344	8	>0.05
2000	0.909	8	<0.01	0.486	8	>0.05	0.417	8	>0.05
2001	0.960	8	<0.01	0.696	8	>0.05	0.752	8	<0.05
2002	0.942	8	<0.01	0.616	8	>0.05	0.646	8	>0.05

[a] Percent fines data for station T08 in 1991 is unusually high (see Appendix C1, Figure C1-8). Correlation between percent fines and TOC in 1991 improved when this station was excluded from the correlation analysis ($r = 0.780$, $n = 7$, $p < 0.05$).

[b] TOC data for station T04 in 1998 unusually high, likely due to a storm event in June 1998. The correspondence between percent fines and TOC in 1998 improved when this station (T04) was excluded from the correlation analysis ($r = 0.920$, $n = 7$, $p < 0.01$).

APPENDIX D1

Data Manipulations on Infaunal Data
Prior to Statistical Analyses

Benthic Species Data Boston Harbor Surveys 1991-2002

Prior to running analyses of the Boston Harbor database, the following changes were implemented. These changes are either made only for reporting purposes, or are permanent, as indicated.

1. Re-identification of specimen

Please make a permanent change in the BH database

Station T2-Rep 3, 1999 *Nuculana acuta* change to *Yoldia limatula*
per IW (ENSR)and N Mountford (Cove)

2. Merge permanently (use second name and code in each grouping):

NODC Code	Taxon
5105080102	*Nassarius vibex*
5105080202	*Ilyanassa trivittata*
5001240404	*Nereis procera*
5001240409	*Nereis grayi*

3. Merge for Report Only (use final—bolded—name and code in each grouping):

NODC Code	Taxon
8401SPP	Ascidiacea spp.
84060301SPP	*Molgula* spp.
8406030108	***Molgula manhattensis***
500162SPP	Arenicolidae spp.
5001620204	***Arenicola marina***
55151901SPP	*Astarte* spp.
5515190113	***Astarte undata***
50017013SPP	*Fabricia* spp.
50017013STEL	***Fabricia stellaris stellaris***
61692107SPP	*Gammarus* spp.
6169210713	***Gammarus lawrencianus***
61692702SPP	*Ischyrocerus* spp.
6169270202	***Ischyrocerus anguipes***
50010211SPP	*Lepidonotus* spp.
5001021103	**Lepidonotus squamatus**
50016303SPP	*Maldane* spp.
5001630302	**Maldane glebifex**
61631202SPP	Pleurogonium spp.
6163120204	**Pleurogonium inerme**
8201SPP	Enteropneusta spp.
8201010303	**Saccoglossus bromophenolosus**
5520050206	*Lyonsia hyalina*
55200502SPP	Lyonsia spp.
5520050201	***Lyonsia arenosa***

NODC Code	Taxon
61690604SPP	*Microdeutopus* spp.
6169060402	***Microdeutopus anomalus***
50016806SPP	*Nicolea* spp.
5001680602	***Nicolea zostericola***
5001680805	*Polycirrus* cf. *haematodes*
5001680807	***Polycirrus phosphoreus***
55200201SPP	*Pandora* spp.
5520020107	***Pandora gouldiana***
50012308SPP	*Sphaerosyllis* spp.
5001230817	*Sphaerosyllis longicauda*
5001230801	***Sphaerosyllis erinaceus***
5001500305	*Tharyx acutus*
50015003SP02	*Tharyx* sp. A
50015003SP03	*Tharyx* sp. B
50015003SPP	***Tharyx* spp.**
50014502SPP	*Trochochaeta* spp.
5001450203	***Trochochaeta multisetosa***
61691507SPP	*Unciola* spp.
6169150703	***Unciola irrorata***
50014304SPP	*Polydora* spp.
	Polydora cornuta

Note:
Regarding *Ampelisca abdita* and *A. vadorum*: According to the SOP/Kropp memo, these good species are merged with *Ampelisca* spp. into one category for report purposes. We would like to keep them separate for the data export, because the species have been distinguished since 1995. Similarly, please keep separate *Pholoe minuta*, *P. tecta* and *Pholoe* spp. These categories will be merged for some analyses.

4. Exclude from data prior to analyses:

NODC Code	Taxon
510205SPP	Acmaeidae spp.
6171010801	*Aeginina longicornis*
5509090202	*Anomia simplex*
6134020104	*Balanus crenatus*
6134020114	*Balanus improvisus*
61340201SPP	*Balanus* spp.
6171010703	*Caprella linearis*
6171010727	*Caprella penantis*
61710107SPP	*Caprella* spp.
617101SPP	*Caprellidae* spp.
5103640204	*Crepidula fornicata*
5103640207	*Crepidula plana*
51036402SPP	*Crepidula* spp.
5001430414	*Dipolydora concharum*
5001500501	*Dodecaceria concharum*
50015005SPP	*Dodecaceria* spp.
3701SPP	*Hydrozoa* spp.
6161050101	*Limnoria lignorum*
5103100108	*Littorina littorea*
5507010601	*Modiolus modiolus*
550701SPP	*Mytilidae* spp.
5507010101	*Mytilus edulis*
500201SPP	*Nerillidae* spp.
6171010901	*Paracaprella tenuis*
5001430412	*Polydora websteri*
5001650202	*Sabellaria vulgaris*

5. Include for calculations of total density, but not diversity or multivariate analyses.

NODC Code	Taxon		NODC Code	Taxon
3758SPP	Actiniaria spp.		6151SPP	Mysidacea spp.
61690201SPP	*Ampelisca* spp.		510376SPP	Naticidae spp.
50016702SPP	*Ampharete* spp.		43SPP	Nemertea spp.
500167SPP	Ampharetidae spp.		500125SPP	Nephtyidae spp.
6168SPP	Amphipoda spp.		50012501SPP	*Nephtys* spp.
43060501SPP	*Amphiporus* spp.		500124SPP	Nereididae spp.
50016801SPP	Amphitritinae spp.		50012404SPP	*Nereis* spp.
3740SPP	Anthozoa spp.		55020202SPP	*Nucula* spp.
616906SPP	Aoridae spp.		550204SPP	Nuculanidae spp.
50015003ASPP	*Aphelochaeta* spp.		550202SPP	Nuculidae spp.
8104SPP	Asteroidea spp.		5127SPP	Nudibranchia spp.
55SPP	Bivalvia spp.		616937SPP	Oedicerotidae spp.
6184SPP	Brachyura spp.		500158SPP	Opheliidae spp.
500160SPP	Capitellidae spp.		8120SPP	Ophiuroidea spp.
50015002SPP	*Caulleriella* spp.		500140SPP	Orbiniidae spp.
50015004SPP	*Chaetozone* spp.		61695101SPP	*Orchestia* spp.
500150SPP	Cirratulidae spp.		61830602SPP	*Pagurus* spp.
50015001SPP	*Cirratulus* spp		50016603SPP	*Pectinaria* spp.
5001500ASPP	*Cirratulus* spp. or *Cirriformia* spp.		50010601SPP	*Pholoe* spp.
616915SPP	Corophiidae spp.		50011314SPP	*Phyllodoce* spp.
511004SPP	Cylichnidae spp.		500113SPP	Phyllodocidae spp.
615405SPP	Diastylidae spp.		50016808SPP	*Polycirrus* spp.
61540501SPP	*Diastylis* spp.		500102SPP	Polynoidae spp.
8136SPP	Echinoidea spp.		510801SPP	Pyramidellidae spp.
50011302SPP	*Eteone* spp.		500170SPP	Sabellidae spp.
500163EUSPP	Euclymeninae spp.		50014320SPP	*Scolelepis* spp.
50012307SPP	*Exogone* spp.		50013101SPP	*Scoletoma* spp.
5001709SPP	Fabricinae spp.		50014003SPP	*Scoloplos* spp.
50015402SPP	*Flabelligera* spp.		500106SPP	Sigalionidae spp.
500154SPP	Flabelligeridae spp.		72SPP	Sipuncula spp.
616921SPP	Gammaridae spp.		50014307SPP	*Spio* spp.
51SPP	Gastropoda spp.		500143SPP	Spionidae spp.
50010206SPP	*Gattyana* spp.		616948SPP	Stenothoidae spp.
50012701SPP	*Glycera* spp.		500123SPP	Syllidae spp.
500127SPP	Glyceridae spp.		50012315SPP	*Syllides* spp.
50010208SPP	*Harmothoe* spp.		551531SPP	Tellinidae spp.
500102HARSPP	Harmothoinae spp.		500168SPP	Terebellidae spp.
500121SPP	Hesionidae spp.		43060602SPP	*Tetrastemma* spp.
50014016SPP	*Leitoscoloplos* spp.		55200802SPP	*Thracia* spp.
500131SPP	Lumbrineridae spp.		552008SPP	Thraciidae spp.
500163SPP	Maldanidae spp.		500902SPP	Tubificidae spp.
616921MESPP	Melitidae spp.		50012305SPP	*Typosyllis* spp.
50015003MSPP	*Monticellina* spp.		551547SPP	Veneridae spp.
55070104SPP	*Musculus* spp.		55020405SPP	*Yoldia* spp.

APPENDIX D2

List of Species Recorded from Boston Harbor Infaunal Samples

Table D2-1. Species identified from Boston Harbor Monitoring Program samples from 1991-2002 and used in the 2002 community analysis. Species collected in April and August 2002 samples are marked with an asterisk (*). Species new to the list in 2002 are underlined.

CNIDARIA
- *Ceriantheopsis americanus* (Verrill, 1866) *
- *Edwardsia elegans* Verrill, 1869 *
- Actiniaria sp. 2

PLATYHELMINTHES
- Turbellaria spp. *

NEMERTEA
- *Amphiporus angulatus* (Fabricius, 1774) *
- *Amphiporus cruentatus* Verrill, 1879 *
- <u>*Amphiporus ochraceus* (Verrill, 1873) *</u>
- *Amphiporus* sp. 1
- *Carinomella lactea* Coe, 1905 *
- Cephalothricidae sp. 1
- *Cerebratulus lacteus* (Leidy, 1851) *
- *Micrura* spp. *
- Nemertea sp. 2 *
- Nemertea sp. D
- Nemertea sp. 5
- Nemertea sp. 12 *
- Nemertea sp. 13 *
- *Proneurotes* spp.
- *Tetrastemma vittatum* Verrill, 1874
- *Tubulanus pellucidus* (Coe, 1895)

ANNELIDA
- Polychaeta
  - Ampharetidae
    - *Ampharete finmarchica* (Sars, 1865) *
    - *Ampharete lindstroemi* Malmgren, 1867 *
    - *Anobothrus gracilis* (Malmgren, 1866)
    - *Asabellides oculata* (Webster, 1879) *
  - Amphinomidae
    - Amphinomidae spp.
  - Arenicolidae
    - *Arenicola marina* (Linnaeus, 1758)
    - *Branchiomaldane* spp.
    - <u>Arenicolidae spp. *</u>
      (merged with *Arenicola marina* for report)
  - Capitellidae
    - *Capitella capitata* complex (Fabricius, 1780) *
    - *Heteromastus filiformis* (Claparède, 1864)
    - *Mediomastus ambiseta* (Hartman, 1947)
    - *Mediomastus californiensis* Hartman, 1944 *
  - Cirratulidae
    - *Aphelochaeta marioni* (Saint-Joseph, 1894)
    - *Aphelochaeta monilaris* (Hartman, 1960) *
    - *Aphelochaeta* sp. 1
    - *Caulleriella* sp. B
    - *Chaetozone* cf. *setosa* (Boston Harbor) Malmgren, 1867 *
    - *Chaetozone vivipara* (Christie, 1985) *
    - *Cirratulus cirratus* (O.F. Müller, 1776)
    - <u>*Cirratulus* sp. 1 *</u>
    - *Cirriformia grandis* (Verrill, 1873) *
    - *Monticellina baptisteae* Blake, 1991 *
    - *Monticellina dorsobranchialis* (Kirkegaard, 1959) *
    - *Tharyx acutus* Webster & Benedict, 1887 *
      (merged with *T*. spp. for report)
    - <u>*Tharyx* sp. A *</u>
      (merged with *T*. spp. for report)
    - <u>*Tharyx* sp. B *</u>
      (merged with *T*. spp. for report)
  - Cossuridae
    - *Cossura longocirrata* Webster & Benedict, 1887
  - Dorvilleidae
    - Dorvilleidae sp. A
    - *Ophryotrocha* spp.
    - *Parougia caeca* (Webster & Benedict, 1884) *
    - *Protodorvillea gaspeensis* Pettibone, 1961
  - Flabelligeridae
    - *Brada villosa* (Rathke, 1843)*
    - *Pherusa affinis* (Leidy, 1855) *
  - Glyceridae
    - *Glycera dibranchiata* Ehlers, 1868
  - Hesionidae
    - *Microphthalmus pettiboneae* Riser, 2000 *
  - Lumbrineridae
    - *Scoletoma acicularum* (Webster & Benedict, 1887) *
    - *Scoletoma fragilis* (O.F. Mhller, 1776) *
    - *Scoletoma hebes* (Verrill, 1880) *
    - *Ninoe nigripes* Verrill, 1873 *
  - Maldanidae
    - *Clymenella torquata* (Leidy, 1855) *
    - *Maldane glebifex* Grube, 1860
    - *Sabaco elongatus* (Verrill, 1873) *
  - Nephtyidae
    - *Aglaophamus circinata* (Verrill, 1874) *
    - *Nephtys caeca* (Fabricius, 1780) *
    - *Nephtys ciliata* (O.F. Müller, 1776) *
    - *Nephtys cornuta* Berkeley & Berkeley, 1945 *
    - *Nephtys incisa* Malmgren, 1865 *
    - *Nephtys longosetosa* Oersted, 1843
    - *Nephtys picta* Ehlers, 1868
  - Nereididae
    - *Neanthes virens* Sars, 1835 *
    - *Neanthes arenaceodentata* Moore, 1903
    - *Nereis diversicolor* O.F. Müller, 1776
    - *Nereis grayi* Pettibone, 1956 *
    - *Nereis zonata* Malmgren, 1867 *
  - Opheliidae
    - *Ophelina acuminata* Oersted, 1843 *
  - Orbiniidae
    - *Leitoscoloplos acutus* (Verrill, 1873)
    - *Leitoscoloplos robustus* (Verrill, 1873) *
    - *Naineris quadricuspida* (Fabricius, 1780)
    - *Scoloplos armiger* (O.F. Müller, 1776) *
  - Oweniidae
    - *Galathowenia oculata* (Zachs, 1923) *
  - Paraonidae
    - *Aricidea catherinae* Laubier, 1967 *
    - *Aricidea quadrilobata* Webster & Benedict, 1887
    - *Levinsenia gracilis* (Tauber, 1879) *
    - *Paradoneis armatus* GlJmarec, 1966
    - *Paraonis fulgens* (Levinsen, 1883)
    - <u>*Paraonis pygoenigmatica* Jones, 1968 *</u>
  - Pectinariidae
    - *Pectinaria gouldii* (Verrill, 1873)
    - *Pectinaria granulata* (Linnaeus, 1767) *
    - *Pectinaria hyperborea* (Malmgren, 1866)
  - Pholoidae
    - *Pholoe minuta* (Fabricius, 1780) *

Pholoe tecta Stimpson, 1854 *

Phyllodocidae
Eteone flava (Fabricius, 1780)
Eteone heteropoda Hartman, 1951 *
Eteone longa (Fabricius, 1780) *
Eulalia bilineata (Johnston, 1840)
Eulalia viridis (Linnaeus, 1767)
Eumida sanguinea (Oersted, 1843) *
Paranaitis speciosa (Webster, 1870) *
Phyllodoce arenae Webster, 1879
Phyllodoce groenlandica Oersted, 1843
Phyllodoce maculata (Linnaeus, 1767) *
Phyllodoce mucosa Oersted, 1843 *
Polygordiidae
Polygordius sp. A *
Polynoidae
Enipo torelli (Malmgren, 1865)
Gattyana amondseni (Malmgren, 1867)
Gattyana cirrosa (Pallas, 1766) *
Harmothoe extenuata (Grube, 1840) *
Harmothoe imbricata (Linnaeus, 1767)
Hartmania moorei Pettibone, 1955 *
Lepidonotus squamatus (Linnaeus, 1758)
Sabellidae
Euchone incolor Hartman, 1978 *
Fabricia stellaris stellaris (Müller, 1784) *
Scalibregmatidae
Scalibregma inflatum Rathke, 1843
Sigalionidae
Sthenelais limicola (Ehlers, 1864)
Sphaerodoridae
Sphaerodoridium sp. A
Spionidae
Dipolydora caulleryi Mesnil, 1897 *
Dipolydora quadrilobata Jacobi, 1883 *
Dipolydora socialis (Schmarda, 1861) *
Polydora aggregata Blake, 1969
Polydora cornuta Bosc, 1802 *
Polydora sp. 1 *
Prionospio steenstrupi Malmgren, 1867 *
Pygospio elegans Calparède, 1863 *
Scolelepis bousfieldi Pettibone, 1963 *
Scolelepis squamata (O.F. Mhller, 1806)
Scolelepis texana Foster, 1971 *
<u>*Scolelepis* cf. *tridentata* (Southern, 1914) *</u>
Spio filicornis (O.F.Müller, 1766) *
Spio limicola Verrill, 1880 *
Spio setosa Verrill, 1873 *
Spio thulini Maciolek, 1990 *
Spiophanes bombyx Claparède, 1870 *
Streblospio benedicti Webster, 1879 *
Syllidae
Autolytus fasciatus (Bosc, 1802)
Brania wellfleetensis Pettibone, 1956
Exogone arenosa Perkins, 1980
Exogone hebes (Webster & Benedict, 1884) *
Exogone verugera (Claparède, 1868)
Parapionosyllis longicirrata (Webster & Benedict, 1884) *
Pionosyllis spp.
Proceraea cornuta Agassiz, 1863 *
Sphaerosyllis erinaceus ClaparJde, 1863
Syllides longocirrata Oersted, 1845
Typosyllis alternata (Moore, 1908)
Typosyllis cornuta Rathke, 1843
Typosyllis sp. 1

Terebellidae
Lanassa spp.
Neoamphitrite figulus (Dalyell, 1853)
Nicolea zostericola (Oersted, 1844)
<u>*Nicolea* spp. *</u>
(merged with <u>*N. zostericola*</u> for report)
Pista cristata (O.F. Müller, 1776) *
Polycirrus eximus (Leidy, 1855) *
Polycirrus medusa Grube, 1850
Polycirrus phosphoreus Verrill, 1880 *
Polycirrus sp. A
Trochochaetidae
Trochochaeta multisetosa (Oersted, 1844)

Oligochaeta
Enchytraiedae
Enchytraiedae sp. 1
Enchytraiedae sp. 2
Enchytraiedae sp. 3
Grania postclitellochaeta longiducta
Naididae
Paranais litoralis (Müller, 1784) *
Tubificidae
Tubificidae sp. 2
Tubificoides apectinatus Brinkhurst, 1965 *
Tubificoides benedeni Udekem, 1855 *
Tubificoides nr. *pseudogaster* Dahl, 1960 *
Tubificoides sp. 1 *
Tubificoides sp. 2 *

ARTHROPODA
Pycnogonida
Achelia spinosa (Stimpson, 1853)
Phoxichilidium femoratum (Rathke, 1799)

CRUSTACEA
Amphipoda
Ampeliscidae
Ampelisca abdita Mills, 1964 *
Ampelisca vadorum Mills, 1963 *
Ampithoidae
Cymadusa compta (Smith, 1873)
Aoridae
Lembos websteri Bate, 1856 *
Leptocheirus pinguis (Stimpson, 1853) *
Microdeutopous anomalus (Rathke, 1843) *
Pseudunciola obliquua (Shoemaker, 1949)
Unciola irrorata Say, 1818 *
Argissidae
Argissa hamatipes (Norman, 1869) *
Corophiidae
Apocorophium acutum Chevreus, 1908
Crassicorophium crassicorne (Bruzelius, 1859) *
Crassicorophium bonellii (Milne Edwards, 1830)*
Monocorophium acherusicum (Costa, 1857) *
Monocorophium insidiosum (Crawford, 1937) *
Monocorophium tuberculatum (Shoemaker,1934)
Corophiidae sp. 1
Dexaminidae
Dexamine thea Sars, 1893 *
Gammaridae
Gammarus lawrencianus Bousfield, 1956
Isaeidae
Photis pollex Walker, 1895 *
Protomedeia fasciata Krryer, 1846
Ischyroceridae
Erichthonius brasiliensis (Dana, 1853)
Ischyrocerus anguipes (Krøyer, 1842) *
Jassa marmorata Holmes, 1903

Liljeborgiidae
Listriella barnardi Wigley, 1966
Lysianassidae
Orchomenella minuta (Krøyer, 1842) *
Orchomene pinguis (Boeck, 1861)*
Oedicerotidae
Ameroculodes sp. 1
Deflexilodes tuberculatus (Boeck, 1870) *
Phoxocephalidae
Phoxocephalus holbolli (Krøyer, 1842) *
Rhepoxinius hudsoni Barnard & Barnard, 1982
Pleustidae
Pleusymtes glaber (Boeck, 1861)
Podoceridae
Dyopedos monacanthus (Metzger, 1875) *
Pontogeniidae
Pontogenia inermis (Krøyer, 1842) *
Stenothoidae
Metopella carinata Shoemaker, 1949
Metopella angusta Shoemaker, 1949 *
Proboloides holmesi Bousfield, 1973 *
Stenothoe gallensis Walker, 1904
Stenothoe minuta Holmes, 1905
Stenothoe sp. 1 *

Cumacea
Diastylidae
Diastylis polita (S.I. Smith, 1879) *
Diastylis sculpta Sars, 1871 *
Lampropidae
Lamprops quadriplicata S.I. Smith, 1879
Leuconidae
Eudorella pusilla Sars, 1871

Decapoda
Brachyura
Cancridae
Cancer irroratus Say, 1817 *
Portunidae
Carcinus maenas (Linnaeus, 1758)
Caridea
Crangonidae
Crangon septemspinosa Say, 1818 *
Paguridae
Pagurus acadianus Benedict, 1901
Pagurus annulipes (Stimpson, 1860) *
Pagurus longicarpus Say, 1817 *

Isopoda
Anthuriidae
Ptilanthura tenuis Harger, 1879
Chaetiliidae
Chiridotea tuftsi (Stimpson, 1883)
Cirolanidae
Politolana polita (Stimpson, 1853)
Idoteidae
Edotia triloba (Say, 1818) *
Erichsonella spp.
Munnidae
Munna spp.
Paramunnidae
Pleurogonium inerme Sars, 1882

Mysidacea
Heteromysis formosa S.I. Smith, 1873 *
Neomysis americana (S.I. Smith, 1873) *

Tanaidacea
Nototanaidae
Tanaissus psammophilus (Wallace, 1919) *

MOLLUSCA
Bivalvia
Arcidae
Arctica islandica (Linnaeus, 1767) *
AstartidaeJ
Astarte undata Gould, 1841 *
Cardiidae
Cerastoderma pinnulatum (Conrad, 1831) *
Carditidae
Cyclocardia borealis (Conrad, 1831) *
Hiatellidae
Hiatella arctica (Linnaeus, 1767) *
Lasaeidae
Aligena elevata (Stimpson, 1851)
Lyonsiidae
Lyonsia arenosa Möller, 1842 *
Lyonsia hyalina Conrad, 1831 *
Mactridae
Mulinia lateralis (Say, 1822)
Spisula solidissima (Dillwyn, 1817)
Montacutidae
Mysella planulata (Stimpson, 1857) *
Pythinella cuneata Dall, 1899 *
Myidae
Mya arenaria Linnaeus, 1758 *
Mytilidae
Crenella decussata (Montagu, 1808)
Musculus niger (Gray, 1824) *
Nuculanidae
Yoldia limatula (Say, 1831) *
Yoldia sapotilla (Gould, 1841)
Nuculidae
Nucula annulata Hampson, 1971
Nucula delphinodonta Mighels & Adams, 1842 *
Pandoridae
Pandora gouldiana Dall, 1886 *
Periplomatidae
Periploma papyratium (Say, 1822) *
Petricolidae
Petricola pholadiformis (Lamarck, 1818) *
Solenidae
Ensis directus Conrad, 1843 *
Siliqua costata Say, 1822
Tellinidae
Macoma balthica (Linnaeus, 1758)
Tellina agilis Stimpson, 1857 *
Thraciidae
Asthenothaerus hemphilli Dall, 1886
Bushia elegans (Dall, 1886)
Thracia conradi Couthouy, 1838 *
Thyasiridae
Thyasira gouldi Philippi, 1845
Turtoniidae
Turtonia minuta (Fabricius, 1780)
Veneridae
Pitar morrhuanus Linsley, 1848
Bivalvia sp. 1

Gastropoda
Nudibranchia
Doridoida sp. A

Ophisthobranchia
Diaphanidae
Diaphana minuta (Brown, 1827) *
Prosobranchia
Columbellidae
Mitrella lunata (Say, 1826)
Lacunidae
Lacuna vincta (Montagu, 1803) *
Nassariidae
Ilyanassa obsoleta (Say, 1822)
Ilyanassa trivittata (Say, 1822) *
Naticidae
Euspira heros (Say, 1822)
Euspira triseriata (Say, 1826) *
Polinices duplicatus (Say, 1822) *

SIPUNCULA
Nephasoma diaphanes (Gerould, 1913)
Phascolion strombi (Montagu, 1804)*

ECHIURA
Echiurus echiurus (Pallas, 1767)

PHORONIDA
Phoronis architecta Andrews, 1890 *

ECHINODERMATA
Echinoidea
Echinarachnius parma (Lamarck, 1816)
Strongylocentrotus droebachiensis (Müller, 1776)
Ophiuroidea
Axiognathus squamatus (Delle Chiaje, 1828) *
Ophiura robusta (Ayres, 1851)

HEMICHORDATA
Harrimaniidae
Saccoglossus bromophenolosus King, Giray, & Kornfield, 1997 *

CHORDATA
Ascidiacea spp.
Molgulidae
Bostrichobranchus pilularis (Verrill, 1871)
Molgula manhattensis (DeKay, 1843) *

APPENDIX D3

Dominant Species at
Boston Harbor Stations in 2002

April/ May Benthic Grab Samples (HT021)
August Benthic Grab Samples (HT022)

Rank	Species	Mean	Std. Dev.	%	Cum %	2001 Rank	2000 Rank
	STATION T01 APRIL 2002						
1	*Polydora cornuta*	340.0	469.1	37.1	37.1		
2	*Leptocheirus pinguis*	97.7	85.7	10.7	47.8		
3	*Aricidea catherinae*	79.7	59.7	8.7	56.5	2	7
4	*Tubificoides* sp. 2	69.3	39.3	7.6	64.1	1	1
5	*Paranais litoralis*	40.0	24.3	4.4	68.4		
6	*Microphthalmus pettiboneae*	31.7	33.2	3.5	71.9	8	3
7	*Clymenella torquata*	28.7	15.7	3.1	75.0		
8	*Exogone hebes*	25.3	14.3	2.8	77.8	4	11
9	*Scoletoma hebes*	23.0	17.0	2.5	80.3		
10	*Pygospio elegans*	20.7	21.9	2.3	82.6		
11	*Ampelisca* spp.	16.7	17.8	1.9	84.8		
11	*Tubificoides* nr. *pseudogaster*	16.7	17.6	1.8	86.2		
12	*Tharyx* spp.	16.3	5.8	1.8	88.0	5	9
13	*Ilyanassa trivittata*	12.0	4.0	1.3	89.3	6	6
14	*Dipolydora socialis*	10.7	5.1	1.2	90.5	12	4
	(Total good spp)	(2748)					
	(Total Station Density)	(2833)					
	STATION T01 AUGUST 2002						
1	*Aricidea catherinae*	235.3	185.7	26.3	26.3	6	5
2	*Polydora cornuta*	131.0	69.9	14.6	40.9	1	2
3	*Tubificoides* sp. 2	105.7	32.6	11.8	52.7	7	1
4	*Tubificoides nr. pseudogaster*	47.3	41.0	5.3	58.0	8	4
5	*Tharyx* spp.	32.0	8.0	3.6	61.5	9	11
6	*Exogone hebes*	31.7	13.6	3.5	65.1	10	8
7	*Clymenella torquata*	30.7	30.1	3.4	68.5	4	
8	*Leptocheirus pinguis*	24.3	22.1	2.7	71.2	2	
9	*Ilyanassa trivittata*	22.7	15.9	2.5	73.7	12	10
9	*Prionospio steenstrupi*	22.3	11.0	2.5	76.2		
10	*Mediomastus californiensis*	20.3	11.9	2.3	78.5		
11	*Ampelisca* spp.	20.0	27.0	2.2	80.7		
12	*Spiophanes bombyx*	19.0	9.5	2.1	82.8		
13	*Pholoe minuta*	16.3	6.5	1.9	84.7	12	
14	*Pygospio elegans*	14.7	14.0	1.6	86.4		
15	*Microphthalmus pettiboneae*	11.7	5.9	1.3	87.7	5	3
16	*Dipolydora socialis*	11.0	13.5	1.2	88.9		
16	*Nephtys caeca*	11.0	4.0	1.2	90.1		
16	*Scoletoma hebes*	11.0	2.6	1.2	91.4		
17	*Streblospio benedicti*	8.3	2.1	0.9	92.3		
	(Total good spp)	(2688)					
	(Total Station Density)	(3076)					

Rank	Species	Mean	Std. Dev.	%	Cum %	2001 Rank	2000 Rank
	STATION T02 APRIL 2002						
1	*Tubificoides apectinatus*	456.0	157.2	56.0	56.0	1	3
2	*Aricidea catherinae*	81.0	7.2	10.0	66.0	7	8
3	*Nephtys cornuta*	36.0	16.7	4.4	70.4	10	4
4	*Tubificoides* sp. 2	34.0	7.0	4.2	74.6	2	1
5	*Microphthalmus pettiboneae*	25.0	12.0	3.1	77.7	5	2
6	*Ampelisca* spp.	24.7	28.0	3.0	80.7	3	12
7	*Tharyx* spp.	24.3	7.1	3.0	83.7	4	5
8	*Dipolydora socialis*	15.7	17.6	1.9	85.6		
9	*Prionospio steenstrupi*	13.0	7.2	1.6	87.2		
10	*Capitella capitata* complex	12.3	14.0	1.5	88.7		
11	*Nemertea* sp. 2	12.0	11.4	1.5	90.2	11	12
12	*Polydora cornuta*	10.0	9.2	1.2	91.4		
13	*Mediomastus californiensis*	9.7	1.5	1.2	92.6	8	10
14	*Tubificoides* nr. *pseudogaster*	6.7	6.7	0.8	93.4		
15	*Ninoe nigripes*	6.3	2.3	0.8	94.2		
	(Total good spp)	(2441)					
	(Total Station Density)	(2614)					
	STATION T02 AUGUST 2002						
1	*Aricidea catherinae*	243.0	236.2	20.3	20.3	5	7
2	*Tubificoides apectinatus*	239.0	76.9	19.9	40.2	3	2
3	*Ampelisca* spp	230.0	180.5	19.2	59.4	2	3
4	*Nephtys cornuta*	141.3	39.7	11.8	71.2	6	8
5	*Prionospio steenstrupi*	121.3	25.3	10.1	81.3		
6	*Polydora cornuta*	44.0	25.0	3.7	85.0	1	1
7	*Nephtys ciliata*	40.7	7.8	3.4	88.3		
8	*Microphthalmus pettiboneae*	18.7	10.1	1.6	89.9	7	9
8	*Mediomastus californiensis*	18.7	6.7	1.6	91.5	9	10
9	*Tubificoides nr. pseudogaster*	14.7	11.0	1.2	92.7	10	
10	*Tharyx* spp.	13.3	9.0	1.1	93.8	8	6
11	*Ilyanassa trivittata*	10.7	4.7	0.9	94.7		
12	*Streblospio benedicti*	9.3	2.5	0.8	95.5		
13	*Ninoe nigripes*	9.0	2.6	0.8	96.2		
14	*Orchomenella minuta*	6.3	7.8	0.5	96.7		
14	*Pholoe minuta/tecta*	5.7	6.7	0.5	97.2		
	(Total good spp)	(3599)					
	(Total Station Density)	(3619)					

Rank	Species	Mean	Std. Dev.	%	Cum %	2001 Rank	2000 Rank
	STATION T03 APRIL 2002						
1	*Tubificoides apectinatus*	1528.0	199.5	40.0	40.0	3	4
2	*Aricidea catherinae*	713.3	110.6	18.7	58.6	4	2
3	*Polydora cornuta*	543.3	934.2	14.2	72.8	12	
4	*Tubificoides* nr. *pseudogaster*	314.0	73.1	8.2	81.0	2	3
5	*Ampelisca* spp.	153.0	50.8	4.0	85.0	1	1
5	*Tubificoides* sp. 1	151.7	48.6	4.0	89.0		
7	*Photis pollex*	93.3	46.7	2.4	91.4	7	5
8	*Phoxocephalus holbolli*	62.7	102.5	1.6	93.1	5	6
9	*Tharyx* spp.	53.7	5.7	1.4	94.5	8	8
10	*Prionospio steenstrupi*	47.3	32.6	1.2	95.7		
11	*Ilyanassa trivittata*	41.7	17.2	1.1	96.8	9	10
12	*Dipolydora socialis*	22.7	9.1	0.6	97.4		
13	*Mediomastus californiensis*	20.7	4.6	0.5	97.9		
14	*Dyopedos monacanthus*	11.3	18.8	0.3	98.2		
15	*Microphthalmus pettiboneae*	9.7	5.7	0.3	98.5		
	(Total good spp)	(11,473)					
	(Total Station Density)	(12,276)					
	STATION T03 AUGUST 2002						
1	*Ampelisca* spp.	1950.3	271.3	34.4	34.4	1	1
2	*Aricidea catherinae*	1287.3	236.0	22.7	57.1	4	5
3	*Tubificoides apectinatus*	1004.3	282.7	17.7	74.9	2	2
4	*Tubificoides* nr. *pseudogaster*	315.0	162.6	5.6	80.4	3	4
5	*Prionospio steenstrupi*	232.7	21.7	4.1	84.5		
6	*Tharyx* spp.	198.7	60.3	3.5	88.0	11	7
7	*Polydora cornuta*	189.3	30.1	3.3	91.4		
8	*Photis pollex*	96.0	34.0	1.7	93.1	8	11
9	*Tubificoides* sp. 1	67.7	39.2	1.2	94.3		
10	*Nephtys ciliata*	63.3	9.1	1.1	95.4		
11	*Ilyanassa trivittata*	49.0	35.6	0.9	96.2		
12	*Phyllodoce mucosa*	46.3	2.1	0.8	97.1	11	
13	*Mediomastus californiensis*	37.0	6.1	0.7	97.7		
14	*Phoxocephalus holbolli*	36.0	7.0	0.6	98.3	5	6
15	*Microphthalmus pettiboneae*	17.7	28.9	0.3	98.7		
16	Nemertea sp. 2	15.3	4.7	0.3	98.9		
	(Total good spp)	(17,000)					
	(Total Station Density)	(17,026)					

Rank	**Species**	**Mean**	**Std. Dev.**	**%**	**Cum %**	**2001 Rank**	**2000 Rank**
	STATION T04 APRIL 2002						
1	*Paranais litoralis*	1950.3	271.3	80.8	80.8	3	2
2	*Streblospio benedicti*	1287.3	236.0	10.6	91.4	2	3
3	*Polydora cornuta*	1004.3	282.7	3.0	94.4	8	
4	*Capitella capitata* complex	315.0	162.6	2.8	97.2	1	1
5	*Tharyx* spp.	232.7	21.7	0.7	98.0		
6	*Tubificoides* sp. 2	198.7	60.3	0.7	98.6	5	10
7	*Spio filicornis*	189.3	30.1	0.4	99.0		
8	*Dipolydora quadrilobata*	96.0	34.0	0.3	99.4	12	9
9	*Spio setosa*	67.7	39.2	0.2	99.5	5	5
	(Total good spp)	(3082)					
	(Total Station Density)	(3116)					
	STATION T04 AUGUST 2002						
1	*Streblospio benedicti*	272.7	132.6	78.9	78.9	1	1
2	*Tharyx* spp.	47.7	32.1	13.8	92.7	5	4
3	*Tubificoides* sp. 2	13.7	8.1	4.0	96.6	2	2
4	*Polydora cornuta*	3.0	3.5	0.9	97.5		
5	*Ilyanassa trivittata*	1.7	2.9	0.5	98.0		
6	*Crangon septemspinosa*	1.3	0.6	0.4	98.4		
6	*Pagurus longicarpus*	1.3	2.3	0.4	98.7		
7	*Ensis directus*	1.0	0.0	0.3	99.0		
7	*Neomysis americana*	1.0	1.0	0.3	99.3		
8	*Nephtys caeca*	0.7	0.6	0.2	99.5		
9	*Amphiporus angulatus*	0.3	0.6	0.1	99.6		
9	*Scoletoma hebes*	0.3	0.6	0.1	99.7		
9	*Prionospio steenstrupi*	0.3	0.6	0.1	99.8		
9	*Capitella capitata* complex	0.3	0.6	0.1	99.9		
9	*Monocorophium insidiosum*	0.3	0.6	0.1	100.0		
	(Total good spp)	(1037)					
	(Total Station Density)	(1058)					

Rank	Species	Mean	Std. Dev.	%	Cum %	2001 Rank	2000 Rank
	STATION T05A APRIL 2002						
1	*Tubificoides apectinatus*	251.3	22.7	23.0	23.0	2	8
2	*Tharyx* spp.	148.0	26.1	13.5	36.5	4	
3	*Aricidea catherinae*	112.7	4.2	10.3	46.8	3	
4	*Tubificoides* sp. 1	82.3	41.1	7.5	54.3		
5	*Exogone hebes*	70.0	29.5	6.4	60.7	10	
6	*Polygordius* sp. A	50.3	22.0	4.6	65.3	5	
7	*Spiophanes bombyx*	46.3	17.4	4.2	69.5	8	2
8	*Photis pollex*	43.7	24.3	4.0	73.5		
9	*Ilyanassa trivittata*	32.7	15.3	3.0	76.5	9	7
10	*Prionospio steenstrupi*	26.7	1.5	2.4	78.9		
11	Nemertea sp. 2	24.3	12.4	2.2	81.1		
12	*Dipolydora socialis*	22.3	2.1	2.0	83.2		
12	*Chaetozone vivipara*	22.3	15.9	2.0	85.2		
13	*Tubificoides benedeni*	22.0	10.1	2.0	87.2	12	
14	*Capitella capitata* complex	14.7	8.1	1.3	88.6	1	5
	(Total good spp)	(3285)					
	(Total Station Density)	(4328)					
	STATION T05A AUGUST 2002						
1	*Tubificoides apectinatus*	210.7	133.6	21.0	21.0	9	8
2	*Spiophanes bombyx*	142.3	38.5	14.2	35.3		
3	*Tharyx* spp.	90.7	38.1	9.1	44.3	8	4
4	*Diastylis sculpta*	61.0	11.4	6.1	50.4		
5	*Nephtys ciliata*	58.3	25.5	5.8	56.2		
6	*Exogone hebes*	50.7	62.0	5.1	61.3		
7	*Aricidea catherinae*	43.7	31.2	4.4	65.6	7	9
8	*Tubificoides nr. pseudogaster*	35.7	24.0	3.6	69.2	11	
9	*Ilyanassa trivittata*	34.3	13.1	3.4	72.6		
10	*Ampelisca* spp.	28.0	27.4	2.8	75.4	1	
11	*Prionospio steenstrupi*	25.3	4.0	2.5	78.0		
12	*Unciola irrorata*	24.7	9.5	2.5	80.4	2	5
13	*Diastylis polita*	22.7	13.1	2.3	82.7		
13	*Edotia triloba*	22.7	10.5	2.3	85.0		
14	*Orchomenella minuta*	22.3	10.5	2.2	87.2	4	
	(Total good spp)	(3004)					
	(Total Station Density)	(3040)					

Rank	Species	Mean	Std. Dev.	%	Cum %	2001 Rank	2000 Rank
	STATION T06 APRIL 2002						
1	*Tubificoides* nr. *pseudogaster*	1438.7	566.2	49.5	49.5	3	1
2	*Tubificoides apectinatus*	530.7	189.5	18.3	67.8	6	5
3	*Aricidea catherinae*	350.7	15.5	12.1	79.9	9	4
4	*Ampelisca* spp.	159.7	17.4	5.5	85.4	1	2
5	*Photis pollex*	118.7	48.2	4.1	89.4	4	3
6	*Phoxocephalus holbolli*	108.7	14.2	3.7	93.2	7	6
7	*Nucula delphinodonta*	41.3	18.5	1.4	94.6		
8	*Prionospio steenstrupi*	19.7	11.6	0.7	95.3		
9	*Dipolydora socialis*	19.3	11.9	0.7	95.9		
10	*Phyllodoce mucosa*	18.7	1.2	0.6	96.6		
11	*Orchomenella minuta*	17.3	4.0	0.6	97.2	5	7
12	*Mediomastus californiensis*	15.0	1.0	0.5	97.7		
13	*Tubificoides* sp. 1	13.0	9.5	0.4	98.2		
14	*Unciola irrorata*	9.0	7.8	0.3	98.5	10	8
15	*Scoletoma hebes*	7.7	1.5	0.3	98.7		
	(Total good spp)	(8715)					
	(Total Station Density)	(8829)					
	STATION T06 AUGUST 2002						
1	*Tubificoides nr. pseudogaster*	1657.7	325.8	47.8	47.8	2	2
2	*Aricidea catherinae*	496.0	154.2	14.3	62.0	4	7
3	*Tubificoides apectinatus*	458.0	24.6	13.2	75.2	5	5
4	*Ampelisca* spp.	323.7	204.6	9.3	84.6	1	1
5	*Polydora cornuta*	168.3	14.2	4.8	89.4	12	3
6	*Prionospio steenstrupi*	124.0	14.4	3.6	93.0		
7	*Nucula delphinodonta*	57.0	20.0	1.6	94.6		
8	*Photis pollex*	32.3	8.5	0.9	95.6	3	6
9	*Phyllodoce mucosa*	27.3	12.7	0.8	96.3	8	
10	*Phoxocephalus holbolli*	27.0	23.3	0.8	97.1	6	4
11	*Mediomastus californiensis*	24.3	7.6	0.7	97.8		
12	*Ilyanassa trivittata*	14.0	6.6	0.4	98.2		
13	*Scoletoma hebes*	12.0	4.0	0.3	98.6		
14	*Nephtys ciliata*	5.3	2.5	0.2	98.7		
15	*Eteone longa*	4.3	3.1	0.1	98.8		
	(Total good spp)	(10,414)					
	(Total Station Density)	(10,422)					

Rank	Species	Mean	Std. Dev.	%	Cum %	2001 Rank	2000 Rank
	STATION T07 APRIL 2002						
1	*Tubificoides apectinatus*	568.3	256.9	51.3	51.3	2	1
2	*Aricidea catherinae*	344.7	22.2	31.1	82.4	3	3
3	*Scoletoma hebes*	74.3	25.5	6.7	89.1	7	6
4	*Tubificoides nr. pseudogaster*	18.3	15.0	1.7	90.8	9	7
5	*Tharyx* spp.	13.3	2.3	1.2	92.0	4	5
6	*Nephtys cornuta*	11.0	7.2	1.0	93.0	5	2
7	*Polydora cornuta*	9.0	3.0	0.8	93.8		
8	*Tubificoides* sp. 1	7.7	6.8	0.7	94.5		
9	*Nemertea* sp. 2	5.3	3.8	0.5	94.9	12	12
10	*Leitoscoloplos robustus*	4.7	3.8	0.4	95.4		
11	*Microphthalmus pettiboneae*	4.3	2.5	0.4	95.8	8	
11	*Ninoe nigripes*	4.3	2.1	0.4	96.1		
11	*Mediomastus californiensis*	4.3	0.6	0.4	96.5		
12	*Leptocheirus pinguis*	4.0	0.0	0.4	96.9	10	
13	*Turbellaria* spp.	3.7	0.6	0.3	97.2		
	(Total good spp)	(3324)					
	(Total Station Density)	(3383)					
	STATION T07 AUGUST 2002						
1	*Aricidea catherinae*	523.3	140.9	37.5	37.5	1	2
2	*Tubificoides apectinatus*	444.7	197.2	31.8	69.3	2	1
3	*Tubificoides* nr. *pseudogaster*	98.7	131.3	7.1	76.4	10	10
4	*Polydora cornuta*	94.3	26.6	6.8	83.1	3	3
5	*Scoletoma hebes*	65.7	17.2	4.7	87.8	8	8
6	*Nephtys cornuta*	46.3	8.1	3.3	91.1	7	7
7	*Streblospio benedicti*	18.0	8.5	1.3	92.4		
8	*Ampelisca* spp.	15.3	7.6	1.1	93.5	6	9
9	*Tharyx* spp.	11.0	5.6	0.8	94.3	5	6
9	*Leptocheirus pinguis*	11.0	6.6	0.8	95.1		
10	*Mediomastus californiensis*	10.0	2.6	0.7	95.8		
11	*Microphthalmus pettiboneae*	6.3	2.1	0.5	96.3		
12	*Ninoe nigripes*	5.7	3.2	0.4	96.7		
12	*Prionospio steenstrupi*	5.7	3.1	0.4	97.1		
13	*Ilyanassa trivittata*	4.0	1.7	0.3	97.4		
	(Total good spp)	(4191)					
	(Total Station Density)	(4327)					

Rank	Species	Mean	Std. Dev.	%	Cum %	2001 Rank	2000 Rank
	STATION T08 APRIL 2002						
1	*Aricidea catherinae*	177.0	85.1	18.0	18.0	6	5
2	*Spiophanes bombyx*	134.3	94.7	13.7	31.7	1	3
3	*Dipolydora socialis*	92.3	30.7	9.4	41.1		
4	*Polygordius sp. A*	82.7	34.0	8.4	49.5	2	1
5	*Ampelisca spp.*	73.7	84.2	7.5	57.0	3	11
6	*Exogone hebes*	58.0	26.7	5.9	63.0	8	8
7	*Tharyx spp.*	49.3	27.6	5.0	68.0	10	
8	*Ilyanassa trivittata*	46.3	18.3	4.7	72.7	7	7
9	*Nucula delphinodonta*	32.3	18.6	3.3	76.0	4	6
10	*Tellina agilis*	22.0	10.4	2.2	78.2	5	4
11	*Nemertea sp. 12*	15.7	12.4	1.6	79.8		
12	*Clymenella torquata*	12.3	10.2	1.3	81.1		
12	*Tubificoides nr. pseudogaster*	12.3	7.0	1.3	82.3	9	10
13	*Molgula manhattensis*	11.0	14.7	1.1	83.5		
	(Total good spp)	(2945)					
	(Total Station Density)	(3131)					
	STATION T08 AUGUST 2002						
1	*Spiophanes bombyx*	368.7	170.1	33.0	33.0	2	1
2	*Ampelisca* spp.	199.7	143.7	17.9	50.8	4	2
3	*Aricidea catherinae*	144.0	72.5	12.9	63.7	1	7
4	*Nucula delphinodonta*	61.0	27.5	5.5	69.2	12	8
5	*Tubificoides* nr. *pseudogaster*	54.0	17.1	4.8	74.0	9	9
6	*Exogone hebes*	38.3	9.9	3.4	77.4	6	4
7	*Ilyanassa trivittata*	30.0	11.0	2.7	80.1	8	6
8	*Dipolydora socialis*	22.3	16.8	2.0	82.1		
9	*Phyllodoce mucosa*	19.0	8.5	1.7	83.8		
10	*Prionospio steenstrupi*	17.0	13.1	1.5	85.3		
11	*Tellina agilis*	13.3	4.9	1.2	86.5	11	5
12	*Clymenella torquata*	12.7	5.1	1.1	87.7	10	
13	*Tharyx* spp.	11.7	7.0	1.0	88.7	7	
13	*Polygordius* sp. A	11.7	15.3	1.0	89.7	3	3
14	*Nephtys ciliata*	10.3	6.0	0.9	90.7		
	(Total good spp)	(3354)					
	(Total Station Density)	(3401)					

APPENDIX D4

Supplementary Plots and Tables for PCA-H Analyses of Infauna

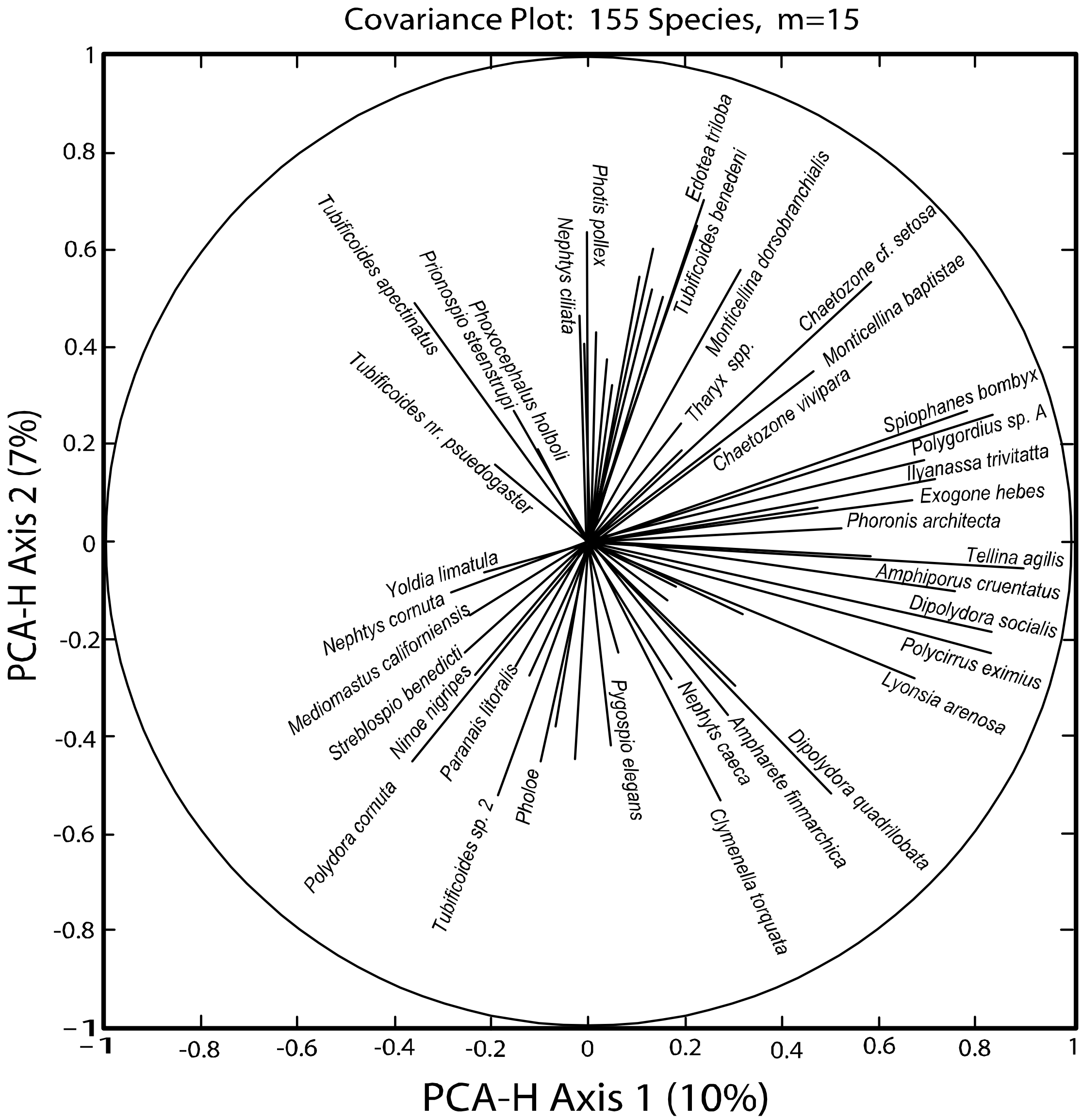


Figure D4-1. Covariance Plot for Boston Harbor 2002 Infaunal data; using 155 species (*Ampelisca* species are merged to one taxon, and *Pholoe* species are also merged to one taxon) and 24 samples. The angle between the lines for two species indicates the degree of covariance. Arrows have not been added to the vectors for legibility.

Table D4-1. Boston Harbor T01. Important species identified by the Gabriel Euclidean Distance biplot for the 69 samples collected 1991–2002.

Axis 1 vs. Axis 2

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2
1	*Polydora cornuta*	25	25	10	50
2	*Tubificoides* nr. *pseudogaster*	20	45	30	2
3	*Tubificoides* sp. 2	16	60	21	6
4	*Streblospio benedicti*	14	74	19	6
5	*Aricidea catherinae*	7	81	7	7
6	*Ilyanassa trivittata*	3	84	0	7
7	*Clymenella torquata*	2	86	1	4

Axis 1vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 3
1	*Tubificoides* nr. *pseudogaster*	26	26	30	15
2	*Thayrx* spp.	16	42	2	52
3	*Tubificoides* sp. 2	15	57	21	0
4	*Streblospio benedicti*	13	70	19	0
5	*Ppolydora cornuta*	8	79	10	4
6	*Aricidea catherinae*	5	84	7	3
7	*Micropthalmus pettiboneae*	5	89	1	16

Axis 2 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 2	Axis 3
1	*Polydora cornuta*	31	31	50	4
2	*Thayrx* spp.	21	53	0	52
3	*Micropthalmus pettiboneae*	7	60	2	16
4	*Tubificoides* nr. *pseudogaster*	7	67	2	15
5	*Aricidea catherinae*	5	72	7	3
6	*Ilyanassa trivittata*	4	77	7	0
7	*Tubificoides* sp. 2	4	80	6	0
8	*Streblospio benedicti*	3	84	6	0
9	*Clymenella torquata*	3	87	4	0
10	*Spio limicola*	2	89	0	5

Table D4-2. Boston Harbor T02. Important species identified by the Gabriel Euclidean Distance biplot for the 69 samples collected 1991–2002.

Axis 1 vs. Axis 2

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2
1	*Tubificoides apectinatus*	22	22	29	7
2	*Tubificoides* nr. *pseudogaster*	20	42	28	4
3	*Polydora cornuta*	14	57	2	41
4	*Streblospio benedicti*	11	68	16	1
5	*Ampelisca* spp.	9	77	5	17
6	*Aricidea catherinae*	5	82	6	3
7	*Chaetozone vivipara*	4	86	0	12
8	*Tubificoides* sp. 2	4	90	5	2
9	*Nepthys cornuta*	4	93	5	1

Axis 1vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 3
1	*Tubificoides apectinatus*	23	23	29	0
2	*Tubificoides* nr. *pseudogaster*	23	46	28	1
3	*Streblospio benedicti*	13	59	16	1
4	*Ampelisca* spp.	12	71	5	42
5	*Aricidea catherinae*	5	76	6	0
6	*Tubificoides* sp. 2	5	81	5	6
7	*Polydora cornuta*	4	85	2	16
8	*Nepthys cornuta*	4	90	5	1
9	*Tharyx* spp.	4	94	1	18
10	*Microphthalmus pettiboneae*	2	96	0	9

Axis 2 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 2	Axis 3
1	*Polydora cornuta*	32	32	41	16
2	*Ampelisca* spp.	25	58	17	42
3	*Chaetozone vivipara*	9	66	12	2
4	*Tharyx* spp.	8	75	3	18
5	*Tubificoides apectinatus*	5	80	7	0
6	*Microphthalmus pettiboneae*	4	83	1	9
7	*Tubificoides* nr. *pseudogaster*	3	87	4	1
8	*Tubificoides* sp. 2	3	90	2	6

Table D4-3. Boston Harbor T03. Important species identified by the Gabriel Euclidean Distance biplot for the 68 samples collected 1991–2002.

Axis 1 vs. Axis 2

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2
1	*Polydora cornuta*	22	22	30	1
2	*Ampelisca* spp.	19	41	0	65
3	*Tubificoides apectinatus*	14	55	20	0
4	*Crassicorophium bonelli*	13	67	13	12
5	*Tubificoides* nr. *pseudogaster*	9	77	8	12
6	*Aricidea catherinae*	7	84	10	0
7	*Leptocheirus pinguis*	6	90	8	2
8	*Unciola irrorata*	4	94	5	1

Axis 1 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 3
1	*Polydora cornuta*	25	25	30	6
2	*Tubificoides apectinatus*	15	40	20	0
3	*Leptocheirus pinguis*	15	55	8	42
4	*Crassicorophium bonelli*	10	66	13	1
5	*Aricidea catherinae*	9	75	10	4
6	*Tharyx* spp.	8	83	1	34
7	*Tubificoides* nr. *pseudogaster*	7	90	8	5
8	*Unciola irrorata*	5	95	5	2

Axis 2 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 2	Axis 3
1	*Ampelisca* spp.	40	40	65	1
2	*Leptocheirus pinguis*	18	57	2	42
3	*Tharyx* spp.	13	71	0	34
4	*Tubificoides* nr. *pseudogaster*	9	80	12	5
5	*Crassicorophium bonelli*	8	88	12	1
6	*Polydora cornuta*	3	91	1	6
7	*Photis pollex*	2	93	1	4

Table D4-4. Boston Harbor T04. Important species identified by the Gabriel Euclidean Distance biplot for the 68 samples collected 1991–2002.

Axis 1 vs. Axis 2

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2
1	*Capitella capitata* complex	43	43	54	1
2	*Streblospio benedicti*	32	75	38	8
3	*Paranais litoralis*	13	88	3	52
4	*Polydora cornuta*	7	95	2	27

Axis 1 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 3
1	*Capitella capitata* complex	48	48	54	17
2	*Streblospio benedicti*	35	84	38	20
3	*Paranais litoralis*	5	89	3	14
4	*Crangon septemspinosus*	3	91	1	14

Axis 2 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 2	Axis 3
1	*Paranais litoralis*	37	37	52	14
2	*Polydora cornuta*	16	53	27	0
3	*Streblospio benedicti*	13	66	8	20
4	*Crangon septemspinosus*	8	74	4	14
5	*Capitella capitata* complex	7	81	1	17
6	*Tubificoides* sp. 2	4	85	1	9
7	*Ilyanassa trivittata*	4	89	4	4
8	*Neomysis americana*	3	92	1	5

Table D4-5. Boston Harbor T05 and T05A. Important species identified by the Gabriel Euclidean Distance biplot for the 69 samples collected 1991–2002.

Axis 1 vs. Axis 2

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2
1	*Ampelisca* spp.	17	17	27	0
2	*Capitella capitata* complex	13	30	7	23
3	*Polydora cornuta*	12	42	18	1
4	*Tubificoides apectinatus*	12	54	7	19
5	*Tharyx* spp.	11	65	6	20
6	*Tubificoides* nr. *pseudogaster*	9	74	8	10
7	*Unciola irrorata*	7	81	11	0
8	*Aricidea catherinae*	4	85	2	8
9	*Ilyanassa trivittata*	4	88	5	2
10	*Spiophanes bombyx*	2	90	0	6

Axis 1 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 3
1	*Ampelisca* spp.	25	25	27	20
2	*Polydora cornuta*	16	41	18	9
3	*Unciola irrorata*	8	49	11	0
4	*Tubificoides* nr. *pseudogaster*	8	57	8	6
5	*Spiophanes bombyx*	7	64	0	26
6	*Tubificoides apectinatus*	6	70	7	3
7	*Capitella capitata* complex	5	75	7	0
8	*Ilyanassa trivittata*	5	80	5	7
9	*Tellina agilis*	5	85	0	18
10	*Tharyx* spp.	4	90	6	1
11	*Tubificoides benedeni*	2	92	2	2

Axis 2 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 2	Axis 3
1	*Spiophanes bombyx*	14	14	6	26
2	*Capitella capitata* complex	14	28	23	0
3	*Tharyx* spp.	12	40	20	1
4	*Tubificoides apectinatus*	12	52	19	3
5	*Tubificoides nr. pseudogaster*	8	60	10	6
6	*Ampelisca* spp.	8	69	0	20
7	*Tellina agilis*	8	76	0	18
8	*Aricidea catherinae*	6	82	8	2
9	*Ilyanassa trivittata*	4	86	2	7
10	*Polydora cornuta*	4	90	1	9

Table D4-6. Boston Harbor T06. Important species identified by the Gabriel Euclidean Distance biplot for the 69 samples collected 1991–2002.

Axis 1 vs. Axis 2

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2
1	*Polydora cornuta*	31	31	17	56
2	*Tubificoides* nr. *pseudogaster*	15	46	21	4
3	*Photis pollex*	11	58	6	21
4	*Tubificoides apectinatus*	11	68	16	1
5	*Crassicorophium bonelli*	9	78	15	0
6	*Aricidea catherinae*	6	83	8	2
7	*Phoxocephalus holbolli*	4	88	3	7
8	*Unciola irrorata*	3	91	5	0
9	*Ampelisca* spp.	3	94	4	1

Axis 1 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 3
1	*Aricidea catherinae*	21	21	8	45
2	*Tubificoides apectinatus*	18	39	16	21
3	*Tubificoides* nr. *pseudogaster*	15	54	21	4
4	*Crassicorophium bonelli*	13	67	15	9
5	*Polydora cornuta*	12	78	17	2
6	*Photis pollex*	5	83	6	4
7	*Ampelisca* spp.	4	88	4	6
8	*Unciola irrorata*	4	91	5	1

Axis 2 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 2	Axis 3
1	*Polydora cornuta*	30	30	56	2
2	*Aricidea catherinae*	22	52	2	45
3	*Photis pollex*	12	65	21	4
4	*Tubificoides apectinatus*	11	76	1	21
5	*Crassicorophium bonelli*	4	80	0	9
6	*Tubificoides* nr. *pseudogaster*	4	84	4	4
7	*Orchomenella minuta*	4	88	3	4
8	*Phoxocephalus holbolli*	3	91	7	0
9	*Ampelisca* spp.	3	94	1	6

Table D4-7. Boston Harbor T07. Important species identified by the Gabriel Euclidean Distance biplot for the 69 samples collected 1991–2002.

Axis 1 vs. Axis 2

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2
1	*Ampelisca* spp.	26	26	34	9
2	*Streblospio benedicti*	24	49	14	42
3	*Tubificoides apectinatus*	19	68	28	0
4	*Polydora cornuta*	12	80	6	24
5	*Nephtys cornuta*	6	86	5	6
6	*Tubificoides nr. pseudogaster*	4	90	0	11
7	*Scoletoma hebes*	3	93	5	0

Axis 1 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 3
1	*Ampelisca* spp.	31	31	34	23
2	*Tubificoides apectinatus*	21	52	28	0
3	*Polydora cornuta*	15	67	6	38
4	*Nephtys cornuta*	11	77	5	26
5	*Streblospio benedicti*	10	88	14	0
6	*Scoletoma hebes*	4	92	5	0
7	*Aricidea catherinae*	3	95	3	5

Axis 2 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 2	Axis 3
1	*Polydora cornuta*	30	30	24	38
2	*Streblospio benedicti*	25	55	42	0
3	*Ampelisca* spp.	15	69	9	23
4	*Nephtys cornuta*	14	84	6	26
5	*Tubificoides nr. pseudogaster*	7	90	11	0
6	*Leptocheirus pinguis*	4	94	3	5

Table D4-8. Boston Harbor T08. Important species identified by the Gabriel Euclidean Distance biplot for the 69 samples collected 1991–2002.

Axis 1 vs. Axis 2

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 2
1	*Ampelisca* spp.	32	32	33	29
2	*Polygordius* sp. A	20	51	27	1
3	*Spiophanes bombyx*	12	63	8	22
4	*Tubificoides nr. pseudogaster*	10	73	5	20
5	*Tubificoides apectinatus*	5	78	3	11
6	*Tellina agilis*	4	83	6	0
7	*Ilyanassa trivittata*	4	87	6	0
8	*Exogone hebes*	4	91	5	1

Axis 1 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 1	Axis 3
1	*Ampelisca* spp.	27	27	33	0
2	*Polygordius* sp. A	22	50	27	0
3	*Aricidea catherinae*	11	61	1	61
4	*Spiophanes bombyx*	7	68	8	1
5	*Ilyanassa trivittata*	6	74	6	8
6	*Tellina agilis*	5	80	6	2
7	*Exogone hebes*	5	84	5	4
8	*Tubificoides nr. pseudogaster*	5	89	5	1
9	*Tubificoides apectinatus*	3	92	3	3

Axis 2 vs. Axis 3

PCA-H Rank	Species	Contr.	Cum. Contr.	Axis 2	Axis 3
1	*Aricidea catherinae*	23	23	4	61
2	*Ampelisca* spp.	19	42	29	0
3	*Spiophanes bombyx*	14	57	22	1
4	*Tubificoides nr. pseudogaster*	14	71	20	1
5	*Tubificoides apectinatus*	8	79	11	3
6	*Nucula delphinodonta*	6	85	5	7
7	*Ilyanassa trivittata*	3	88	0	8
8	*Tharyx* spp.	3	90	1	7

Massachusetts Water Resources Authority
100 First Avenue • Boston, MA 02129
www.mwra.com
617-242-6000