Summary of

MWRA
Fish and Shellfish
and Benthic Workshops

of

February 19, 1998

Prepared by
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ms-53

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APPENDICES

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OVERVIEW

The Fish and Shellfish Workshop and Benthic Workshop summarized in this document were held to present the results of 1996 and 1997 data from the MWRA Harbor and Outfall Monitoring Program and to provide an initial forum to integrate results across the various disciplines. In addition, the agendas included a review of data gathered thus far, a forum for hypotheses concerning post discharge status of the Boston Harbor and Massachusetts and Cape Cod Bays, and preparation for the new HOM monitoring team. Scientists were asked to make predictions relevant to their discipline for the upcoming year as well as for the post discharge period. The adequacy of current thresholds and the effectiveness of the current monitoring program were discussed.

INTRODUCTION

The MWRA Harbor and Outfall Monitoring (HOM) Fish and Shellfish Workshop and Benthic Workshop were held on February 19, 1998 at the Holiday Inn in Boxborough, MA. These workshops presented the 1997 and 1996 results from the different programs and compared these results to previous data. There were approximately 45 attendees, including MWRA personnel, state and federal regulators, academics, nonprofit environmental groups, and project scientists (see Appendix A).

Ken Keay (MWRA) presented the monitoring overviews of the workshops and project scientists presented summaries of individual programs and made interannual comparisons. Mike Connor (MWRA) moderated a general discussion at the end of the day to address new issues raised, monitoring thresholds and future predictions.

MWRA Harbor and Outfall Monitoring (HOM) Fish and Shellfish Workshop and Benthic Workshop
Thursday, February 19, 1998
Holiday Inn, Boxborough

Fish and Shellfish Agenda

8:00-8:45 AM	**Setup and organization**
8:45 AM	**Monitoring Overview: Ken Keay (MWRA)**
9:00 AM	**Lobster Biology: James Blake and David Mitchell (ENSR)**
9:40 AM	**Fish Histopathology: Michael Moore (WHOI)**
10:20 AM	**Break**
10:30 AM	**Mussel Watch Results: Phil Downey (AQUATEC)**
11:10 AM	**Fish and Shellfish Discussion**
12:00 - 1:00 PM	**LUNCH (provided)**

Benthos Agenda

1:00 PM	**Monitoring Overview: Ken Keay (MWRA)**
1:15 PM	**Flux Measurements: Brian Howes (UMass/Dartmouth)**
1:50 PM	**1996 Massachusetts Bay Soft Bottom Benthic Results: Blake and Maciolek (ENSR)**
2:30 PM	**1996 Massachusetts Bay Hard Bottom Benthic Results: Barbara Hecker**
3:10 PM	**Sediment Profile Comparisons for Massachusetts Bay - 1992, 1995, and 1997: Rhoads and Williams**
3:40 PM	**Benthic Threshold Review 1992-1996 Data Analysis: Gallagher, Hecker, Blake and Maciolek**
4:20 PM	**Discussion of Benthic Thresholds**
5:00 PM	**Adjourn**

MWRA HOM Fish, Shellfish and Benthic Workshop Review
February 19, 1998

Fish and Shellfish

Monitoring overview, revisit of contaminant thresholds and discussion of appropriateness of replacing FDA advisory levels of contaminants based upon appreciable change from baseline conducted by Ken Keay (MWRA).

Lobster Biology: David Mitchell

1997 organic and inorganic contaminant trends comparable to previous years. With the exception of PCBs in lobster hepatopancreas in Deer Island Flats, concentrations of contaminants were below threshold and FDA warning levels. Impact on lobster population of the future outfall predicted to be negligible, as effluent will be too dilute to cause adverse effects on larval and adult lobsters.

Flounder: Michael Moore

No trends detected in flounder since 1991. Data collected represent an adequate baseline for human health concerns, although not to assess fish population health. Noted were:

- use of non-lethal, site specific biomarker (program designed to measure only live fish, and does not factor in fish migration)
- need to assess region wide population trends
- need to establish quantitative study of young in Boston Harbor
- suggestion for a study to monitor adult fish movements to determine if changes in future outfall population are the result of migration.

Mussels: Phil Downey

A lot of variation in interannual data noted, no significant trends determined. Possible causes:

- background noise
- sediment resuspension
- water quality vs. body burden-effect on uptake or metabolism.

1997 PCB concentrations were highest detected yet, correlation with lobster PCB concentrations? Program evaluation and comments:

- program can detect gross changes, not subtle changes, and in accordance to regulatory limits
- can also be used to determine relative changes (site specific increases in burdens)
- has established adequate baseline at future outfall to detect effluent impact
- cannot detect causality
- possible comparison of effluent and sediment characteristics vs. mussel burdens ("commonality") to determine sources?
- possible coordination of lobster, flounder and mussel results?

Benthos

Monitoring overview, discussion of soft bottom and hard bottom field surveys and predictions of change in ecosystems (expected in near and midfield, not in farfield) conducted by Ken Keay.

Sediment Processes in Massachusetts Bay and Boston Harbor, 1997: Brian Howes

1997 departures from interannual data included an increase in sediment oxygen demand (SOD) rates at stations MB03 and MB05 (southwestern nearfield and inner farfield, respectively). Possible relationship between higher SOD and large spring Phaeocystis bloom being investigated. SOD did not contribute to lower DO minimum during stratification due to a mid-summer physical "reaeration" event. Other issues:

- annual oxygen DO minimum driven primarily by spring bloom and physical water column processes
- increase in production (as a result of spring bloom increase from outfall) could affect DO minimum
- Boston Harbor 1996-97 sediments indicate a shift in amphipod reliance from stored organic matter to depositional material

Soft Bottom Benthic Results - Massachusetts Bay, 1996: James Blake and Nancy Maciolek

Benthic communities determined by sediment grain size in near and mid-field and by water depth and location in the farfield. Three basic faunal communities in the near and mid-field have been observed since the study's inception, with only slight changes attributed to physical processes. 1996 numbers of species recorded was higher than other years - possibility of species identification methods affecting results. Recommendations:

- record grain size from samples taken
- evaluate any apparent change in species diversity by first looking at baseline data to rule out taxonomic discrimination

Hard Bottom Benthic Results - Massachusetts Bay, 1996: Barbara Hecker

Heavy sedimentation associated with high abundance of algae. Algal communities observed primarily on the tops of drumlins, invertebrates on the flanks. *Lithothamnion* spp. was the most commonly observed species and least variable with location, correlation with sediment drape was made: abundance highest in areas of lower sedimentation. In general, high variability of benthic communities results in difficulty in detecting change. The species *Lithothamnion* spp. suggested as optimal indicator species, due to correlation with sediment drape and depth. Diffuser heads observed to support attached communities (anemones, tunicates), differences in communities attributed to localized circulation.

Sediment Profile Comparisons for Massachusetts Bay, 1992, 1995, and 1997: Rhoads and Williams

Noted high temporal and spatial variation. An increase in carbon loading predicted to cause:

- enhanced level of polychaete and tube mats
- increase in faunal densities
- increase in species richness.

Long term loading above threshold predicted to cause:

- decrease of bioturbators
- rebound redox
- increase in ammonia and sulfide

Benthic Threshold Review and Discussion: Eugene Gallagher, Barbara Hecker, James Blake, and Nancy Maciolek

Suggestions for monitoring benthic community decline:

- reference stations identified
- examination of trophic composition identified as possible methods, problems include high interannual variability and correlation between studies
- preliminary diversity of trophic communities and reduced species evenness analyses show potential for indicators of change
- faunal shift to near-shore assemblage suggested as potential "red flag".

Overview of the workshop provided for the 3/20/98 meeting of the Outfall Monitoring Task Force: Ken Keay (MWRA)

FISH AND SHELLFISH MONITORING

1) Flounder. The multi year study of flounder documents a strong, repeatable gradient in both contaminants and in the incidence of liver lesions within the flounder population in the system. There is ongoing strong evidence for decreases in the incidence of contaminant associated lesions in Harbor flounder. A better understanding of the movement of flounder would assist interpretation of tissue burdens at specific sites.

2) Lobster. A separate briefing expands upon the presentation and discussions relevant to our pursuit of the recommendations of the OMTF Lobster Larval Focus Group.

3) Mussels. The multi year results of the mussel bioaccumulation studies have documented low levels of contamination at the future outfall site, which would provide a very clear reference for studies once discharge begins.

BENTHIC MONITORING

1) Sediment Metabolism: Sediment metabolism in western Mass Bay may prove to be a sensitive measure of the moderate increases in enrichment predicted to occur by the Bays Eutrophication Model. Slight increases in metabolism at 2 sites seen in summer 1997 may have been a result of deposition of the spring Phaeocystis bloom.

2) RPD. Visual Redox Potential Discontinuities, a threshold parameter, were substantially shallower in 1997 than in either 1992 or 1995, when comparable sediment profile images were compiled. Sediment focusing in near-field depositional sites, driven by storms in late fall and early winter, might magnify the impacts of the outfall discharge on the soft-bottom communities that are the subject of intensive monitoring. But most of the labile carbon in material that might be focused in these depositional sites is likely to have been respired in place before it is resuspended and concentrated. If labile carbon in material temporarily deposited on hard-bottom environments in the near-field was NOT metabolized prior to redeposition, the soft-bottom focusing sites would probably already show communities, metabolism rates and RPDs suggestive of enrichment, which they do not. Radioisotope measurements routinely made by USGS can help address questions about the frequency and extent of sediment focusing in these depositional areas.

3) Hardbottom benthic biology. Attached hardbottom communities in the vicinity of the outfall are representative of those found throughout the Gulf of Maine at similar depths, and appear to be structured by substrate type (boulder, versus cobble, versus gravel/coarse sands) and depth. The abundance and

percent cover of attached algae, both encrusting corraline algae and attached filamentous red algae, appear to show promise as indicators of changing water clarity in the near-field.

4) Softbottom benthic biology. Work is in progress to refine the benthic community thresholds for the program. Existing thresholds are either not particularly sensitive to modest changes in the communities found in western Mass. Bay, or would require time-consuming data manipulation prior to computation. Promising analyses involving tracking the diversity of functional groups (animals of different feeding types) and analyses looking at excursions of the taxa from a logseries distribution were discussed. Further progress should be available by the April workshop, and the results of this refinement will be presented in the synthesis report on 1997 benthic monitoring, to be produced in summer 1998.

The following abstracts were not available at the time of print:

- Mussel Review: Phil Downey (Aquatec)
- Sediment Profile: Don Rhoads (UMB)

Lobster Monitoring Program:
1997 Results and Lobster Toxicity Evaluation

David F. Mitchell, Ph.D

This presentation reports on two aspects of the lobster biomonitoring program for the MWRA Harbor and Outfall Monitoring Project. A brief review of the results of the 1997 survey is given as well as a qualitative risk assessment of the potential for the new MWRA outfall to pose potential adverse risk to lobster populations in Massachusetts Bay.

In 1997 lobsters were collected throughout Boston Harbor, Massachusetts Bay, and Cape Cod Bay and analyzed for biological metrics and tissue concentrations in edible tissue and hepatopancreas (tomalley). Available results for the organic contaminants (i.e., PAH, PCBs, pesticides) indicate that the spatial and temporal patterns, in general, are comparable to those observed during previous years of the baseline data period (i.e, 1992-1997). With the exception of PCBs in Deer Island Flats hepatopancreas, concentrations of organics in lobster tissues were below threshold warning levels and applicable Food and Drug Administration's (FDA) Action Levels.

The qualitative risk assessment considered potential risk to two critical lobster life stages (larval lobster, early benthic phase) through several approaches. Risk evaluation of larval lobster included comparison of predicted water quality of diluted effluent to applicable ambient water quality criteria (AWQC); comparison of the sensitivity of lobster to other marine organisms used to determine the AWQC; and consideration of the spatial and temporal distribution of larval lobster vs. the effluent plume (i.e., interaction with pycnocline). Risk evaluation of early benthic phase lobsters included evaluation of the spatial extent of diluted effluent, with particular attention to overlap with hard-bottom cobble substrate areas, consideration of bottom substrate characteristics in the vicinity of the diffuser, and comparison of patterns of particulate organic matter (POC) deposition following relocation of the diffuser. Based on the weight-of-evidence of these findings, it was concluded that no significant potential risk is posed to these two critical lifestages from the MWRA outfall. Thus, the potential for the MWRA outfall to adversely impact lobster populations in Massachusetts Bay due to effluent toxics or deposition is considered negligible.

FEBRUARY 19TH FISH, SHELLFISH AND BENTHIC WORKSHOP.

FLOUNDER PRESENTATION BY MICHAEL MOORE

ABSTRACT

Milestones in our winter flounder knowledge base were discussed. Chemically induced lesions in flounder liver that are biomarkers of chemical effect were then described and illustrated, including the progression of vacuolation and liver tumors. Spatial and temporal trends in flounder lesions 1987 to present were then described using a map of stations, 1997 data and some representative scatter plots for 1991 - 1997. The lack of tumors after 1991 at Deer Island was commented on as was the absence of trends in the 5 stations since 1991. The goals of the flounder task as stated in 1992 and 1997 rfq/p's were reviewed, as was our current knowledge base in terms of meeting those goals.

Suggestions were then made for future concerns and activities, which included the question of what could be done to augment our understanding of population health? The need to look at the harbor flounder population in light of region wide population trends was mentioned as was the possibility of establishing a quantitative survey of young of the year at selected Boston Harbor sites comparable to the DMF annual beach seine survey on the south side of the Cape. A special project to study the movements of adult flounder using acoustic tags and low-powered, long-duration autonomous underwater vehicles was also suggested - this was noted to be a real issue to ensure that future changes in baselines at the future outfall site were not resulting from out-migration of Boston fish.

Sediment Processes in Massachusetts Bay and Boston Harbor, 1997

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Massachusetts Bay: Analysis of sediment properties and exchanges with the watercolumn during the 1997 field season indicated some departures from previous years (1992-1996). Most notably, 1997 rates of sediment oxygen demand (SOD) at stations MB03 and MB05 were significantly higher than the previous years, which all showed variations of less than $\pm$ 20% of the mean summer values for each station. Relationships between this higher SOD and the large spring Phaeocystis bloom are being investigated. Preliminary evaluation indicates higher sediment chlorophyll levels in the Nearfield in late spring consistent with the deposition of a bloom. Although SOD represents about half of the sub-pycnocline oxygen demand during stratification, the higher rates did not result in a lower D.O. minimum, due to the large physically driven "reaeration" event in mid summer.

Analysis of HOM respiration data suggests that the annual oxygen minimum is driven primarily by the spring bloom organic carbon deposition and physical processes controlling stratification and aeration and to a lesser extent organic input from the fall bloom. Sediment respiration rates indicate that only 30 g C m^{-2} of organic matter deposition is required to support the observed SOD during stratification. Data from the USGS moored sediment traps during the stratified interval, although subject to resuspension artifacts, indicate that organic deposition during stratification is much lower than that required to support SOD during this interval.

Evaluation of Eh as a monitoring tool indicates a high degree of inter-annual comparability. However, intra-annual analysis indicates that caution must be used, since there is a large seasonal cycle in sediment redox potential which follows the cycle of respiration.

Boston Harbor: Sediment/watercolumn exchanges of nutrients continue to show the effects of the colonization by amphipods. It is clear that the presence or absence of amphipod mats is the predominant feature structuring biogeochemical fluxes and in situ metabolic rates in this system. Dissolved inorganic nitrogen fluxes are predominantly as ammonium in non-amphipod areas and as nitrate in amphipod areas. The Massachusetts Bay sites have lower rates of DIN efflux than the Harbor, but show a fractionation similar to the amphipod sites.

Boston Harbor sediments clearly show higher rates of DIN efflux, SOD and denitrification in amphipod colonized areas. At site BHO3A, rates of DIN efflux and SOD have declined from year 1 to years 2 & 3, while denitrification has increased. This is consistent with the development of a more aerated sediment in which the "mining" of stored organic matter is declining in importance. The flux ratios support the contention that in 1995 significant mining of stored organic matter from previous years was occurring, while 1996-97 data indicate a system more reliant on recent deposition.

Massachusetts Bay--Soft-bottom Benthic Results for 1996.

James A. Blake and Nancy J. Maciolek

Soft-bottom benthic communities in Massachusetts Bay are monitored at three different sets of stations identified according to distance from the outfall: (1) Nearfield stations are within 2 km of the diffusers; (2) Midfield stations are 2-8 km from the outfall; and (3) Farfield Stations are reference stations greater than 8 km and distributed throughout Massachusetts and Cape Cod Bay.

Benthic community parameters observed in 1996 were generally similar to those seen in previous baseline monitoring years, both in the vicinity of the new outfall and throughout Massachusetts and Cape Cod Bays. The distribution of dominant species, as well as similarities among stations as measured by cluster analysis, reflected patterns seen in 1995.

The structure of the benthic communities in the nearfield and midfield was largely determined by sediment grain size, whereas in the farfield water depth and location were of primary importance. Three faunal assemblages have been identified in the nearfield/midfield study area; of these, the *Exogone-Corophium*-oligochaete assemblage found at the coarse-sand nearfield stations is the most consistent. Nearfield stations NF4 and NF17 have been dominated by this fauna for all five years of monitoring. *Prionospio steenstrupi* was the dominant spionid polychaete, as it was in 1995, and together with the capitellid polychaete *Mediomastus californiensis* and the lumbrinerid *Ninoe nigripes* characterized a second, very widespread assemblage that dominated the majority of midfield stations. These basic community structures have been observed in the area since the inception of this program in 1992, with slight annual changes reflecting the shifting of sediments as a result of storms or other sediment transport events.

Species richness (i.e., number of species recorded) was apparently higher in 1996 than in earlier years. This result may be due in part to better identification of juvenile polychaetes and molluscs. It will be of primary importance to maintain similar levels of taxonomic discrimination in the years after the outfall comes on line: any apparent changes in species diversity should be evaluated first by examination of the underlying database.

Calculation of an average species diversity (Shannon-Wiener H′) suggests that the nearfield stations are slightly higher in average diversity at the midfield and farfield stations. H′ values averaged over the period 1992-1996 were 2.71 ± 0.32 for the nearfield, 2.57 ± 0.35 for the midfield, and 2.62 ± 0.46 for the farfield. These values will be refined after the 1997 samples have been analyzed.

Similar calculations for number of species and numbers of individuals suggest that the farfield stations have the highest numbers of species (76.8 vs. 68.9 for nearfield and 63.2 for midfield) and the midfield has the greatest abundances (45,315 individuals/m^2 vs. 44,159 for the nearfield and 33,505 for the farfield.) For all three parameters, however, the standard deviations are large, thereby suggesting that the differences among study areas are not statistically significant.

High faunal similarities between the faunal community at Station FF1a and the communities found in the midfield suggest that FF1a can serve as a good qualitative reference site for benthic communities in the vicinity of the future outfall. This station is also a farfield monitoring site for an ongoing 301(h) program. Station NF24 may be a good sentinel station for the nearfield because it appears to be a depositional area, acting as a sediment trap. Station FF13 off Hull show high densities of *Ampelisca abdita*, an amphipod becoming increasingly common in the recovering sediments of Boston Harbor; this station may be a good reference station for the Harbor.

Nearfield Hardbottom ROV Surveys (1995-1997)

by

Barbara Hecker

Selected locations on drumlins in the vicinity of the diffuser outfall were surveyed annually using a Benthos Mini Rover ROV. Video images and color slides were collected at waypoints along transects located both near and further away (reference sites) from the diffuser outfall. Waypoints along six transects, 4 near the outfall and 2 reference, were occupied during June 1995 and July 1996 surveys, and an additional 2 reference sites were occupied during the June 1997 survey. The location and number of waypoints varied slightly among years, with 19 waypoints (17 near the diffuser and 2 reference sites) surveyed in 1995, 21 waypoints (2 additional reference sites) surveyed in 1996 and 24 waypoints (2 more reference sites and diffuser head #44) surveyed in 1997. Diffuser head #44 was added to the survey because this diffuser will not go on line and hence affords a worst case example in the extreme nearfield. The major emphasis of the ROV survey was shifted from video images in 1995 to still images in 1996 and 1997, because of the greater resolution afforded by still images. Approximately 15-30 minutes of video footage and 28-33 color slides were collected at each waypoint in 1996 and 1997. The video images were used qualitatively to evaluate sea floor characteristics (relief, substratum size class, habitat heterogeneity, sediment drape) and the occurrence of large motile organisms. The still photographs were used semi-quantitatively to asses the relative proportion of various taxa to provide rough variance estimates.

The sea floor on top of drumlins usually consisted of a mix of boulders and cobbles. Habitat relief varied from high (predominantly boulder areas) to moderate (cobble-boulder mix). Sediment drape on the top of drumlins was light to light-moderate at most locations and heavy at the few locations that supported high abundances of algae. The sea floor on flanks of drumlins usually consisted of a cobble pavement with patches of sand and gravel and occasional boulders. Habitat relief of these areas ranged from low to moderate, depending on how many boulders were present. Sediment drape in the drumlin flank areas usually ranged from moderate to heavy.

Both the qualitative data collected from the video images and the semi-quantitative data collected from the still photographs yielded similar patterns in benthic community distributions. Algae usually dominated the benthic communities on the tops of drumlins, while invertebrates (mostly encrusting or attached forms) were increasingly dominant on the flanks. The encrusting coralline alga *Lithothamnion* spp. was the most abundant and widely distributed alga encountered during this study. The distribution and abundance of *Lithothamnion* spp. were the least variable of all the taxa encountered and appeared to be mainly related to sediment drape; percent cover was highest in areas that had little sediment drape and lowest in areas with moderate to heavy sediment drape. Other algae commonly encountered, a filamentous red alga *Asparagopsis hamifera*, dulse and shot-gun kelp, were patchily distributed and were most common on the tops of boulders near the edge of drumlin tops. Sediment drape in areas supporting high abundances of these three algae ranged from moderate to high. The holdfasts of the algae appeared to actively trap sediment, thereby excluding the encrusting *Lithothamnion* spp. The distributions and abundances of the common invertebrate taxa were quite variable, both within and between areas. Generally, both invertebrates and fish (mainly cunner) were most abundant in areas of high relief and least abundant in areas of low relief.

The two new reference sites (T9 north of the diffuser outfall and T10 south of it) surveyed during 1997 were both high relief areas. The benthic community observed at T9 was similar to that observed at the other northern reference sites on T7. All of these areas supported relatively high abundances of algae, invertebrates and cunner. In contrast, the benthic community observed at T10 was quite dissimilar to that observed at the other southern reference sites on T8 or any of the other sites. The benthic community at T10 was characterized by low abundances of *Lithothamnion* spp., high abundances of the other common algae (*Asparagopsis hamifera*, dulse, and shot-gun kelp), very high abundances of the soft coral *Gersemia rubiformis*, and a number of encrusting invertebrates not seen elsewhere.

The benthic communities inhabiting the drumlins appear to be controlled by a combination of location on the drumlin (concurrent with depth), substratum size class and associated habitat relief, and degree of sediment drape. Some taxa exhibited strong substratum preferences (three of the algae, many of the encrusting invertebrates, many of the starfish, and cunner were all most abundant in high habitat relief areas),while other taxa exhibited more fidelity to topography (Lithothamnion spp., sea urchins, and horse mussels were most abundant on the top of drumlins). While some of the areas encountered were quite homogeneous with regard to sea floor characteristics and taxa, most of the areas encountered were very heterogeneous. The highest variability was found in areas characterized by high habitat relief.

The high within site variance of the benthic communities encountered during this study reflect the exceptionally patchy distributions of most of the taxa. This variability appears to be related to the high habitat heterogeneity found in most hardbottom environments. As a result of the high variability of the hardbottom areas, it is unlikely that small changes in the general composition of the hardbottom communities will be detectable. The distribution and abundance of *Lithothamnion* spp. was the least variable and most predictable. in that It appears to be largely controlled by depth and degree of sediment loading. Hence this species appears to hold the most promise as an "indicator" of environmental change or degradation.

Additionally, several diffuser heads were surveyed during this study. These heads have been colonized by several attached taxa. Diffuser #1 was surveyed in 1995 and 1996 and diffusers #2 and #44 were surveyed in 1997. Both diffusers #1 and #2 have been colonized by very many anemones *Metridium senile*. In contrast, diffuser #44 has been colonized by many tunicates (the sea peach *Halocynthia pyriformis*) and far fewer *M. senile*. Review of video taken during a diffuser inspection survey conducted in December 1995 show that a diffuser adjacent to #44 (diffuser #43) was similar to diffusers #1 and #2 in that it was also colonized by many *M. senile*. It appears that each diffuser head affords a slightly different microhabitat, which may reflect localized differences in small scale circulation patterns.

Development of Threshold Indicators for Outfall Monitoring

Benthic Community Parameter Summary 1992-1996: James A. Blake

Calculation of an average species diversity (Shannon-Wiener H′) suggests that diversity at the nearfield stations is slightly higher than average diversity at either midfield or farfield stations. H′ values averaged over the period 1992-1996 were 2.71 ± 0.32 for the nearfield, 2.57 ± 0.35 for the midfield, and 2.62 ± 0.46 for the farfield. These values will be refined after the 1997 samples have been analyzed.

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Trophic analysis: Barbara Hecker and James A. Blake

The trophic composition of samples collected between 1992 and 1996 was examined to ascertain if this type of analysis would be useful in identifying benthic degradation by reducing the signal to noise ratio. The reasoning behind this approach is that trophic composition would be expected to be less noisy (variable) than species composition, because different species can occupy similar niches. Additionally, the relationship between trophic composition and sediment characteristics was examined to determine how sediment type influences trophic strategies.

The 50 most abundant infaunal species were divided into one of eight trophic categories; suspension feeder, interface feeder, surface deposit feeder, subsurface deposit feeder, reverse conveyer-belt feeder, head-down conveyer belt feeder, omnivore/scavenger, and predator. Examination of the trophic patterns showed little correlation between feeding strategy and sediment characteristics, with the exception of dominance by suspension feeders in areas devoid of mud. A high amount of variability in trophic composition was found within most stations, both among years and among replicates within a year. At many stations trophic composition varied significantly between years. This variability sometimes reflected changes in sediment characteristics, but just as often it did not. Additionally, a number of shifts in sediment type were not accompanied by changes in trophic composition. Part of this problem may be related to the fact that sediment characteristics and benthic communities were determined from different samples. This would be a particular problem in areas with high spatial variance.

An example of high variance in trophic structure both among years and among replicates within a year was observed at NF17. The sediment at this station was predominantly sandy and sediment characteristics did not vary appreciably from 1992 to 1996. Yet the proportion of suspension feeders varied annually, from 52% in 1992, 72-90% in 1993, 64-81% in 1994, 37-53% in 1995 and 35-76% in 1996. Among replicate variation was also seen at NF 24, where in 1994 the proportion of interface feeders in replicate 2 was much higher (70%) than in replicates 1 (48%) and 3 (39%). Numerous examples of similarly variable trophic composition were also seen at many of the other stations.

One interesting aspect of the trophic composition analysis was noted. Lack of trophic diversity (ie. dominance by one trophic group) coincided with departures from a log normal distribution of species evenness. Hence higher trophic diversity may indicate a healthier benthic community. Our results in this aspect of the study are still quite preliminary.

Multivariate Analysis of Species & Functional Groups: Triggers and Red Flags: Eugene Gallagher.

Species diversity has been reexamined with regard to evenness which might be more informative than richness. Because rarefaction curves are log series, any departure from predictions might indicate less evenness and a possible disturbance. Results suggest that 30% of the stations are already disturbed from natural causes.

Diversity was also examined from the standpoint of functional groups. The 50 most abundant taxa were classified according to 8 functional groups: suspension feeders, interface feeders, surface deposit feeders, reverse conveyor-belt feeders, subsurface deposit feeders, top-down conveyor-belt feeders, omnivores/scavengers, and predators. Ordination analysis using PCA-H resulted in high correlation with functional groups. When species were plotted against functional evenness, high correlations suggested that Warning levels and Red Flags could be developed as indicators of change. Warning levels would include: reduced species evenness, changes in community composition, and changes in functional group diversity. Red flags would include faunal shifts to nearshore assemblages, loss of species richness, and development of an "inner-harbor" evenness pattern.

APPENDIX A
Attendance

1998 MWRA/ENSR Workshop Attendees

February 18, 1998
Fish and Shellfish

Name	Organization
Jim Blake	ENSR
Eugene D. Gallagher	UMass/Boston
Barbara Hecker	Hecker Environmental
Jerry Niff	Battelle
Don Rhoads	ENSR
Izzie Williams	ENSR
Paula Winchell	ENSR
Dave Mitchell	ENSR
Jeffrey Rosen	TPMC
Tom Fredette	US Army Corps of Engineers
Dave Tomey	EPA
Cathy Coniaris	OMTF Asst.
Joan Tracey	ENSR
Jessica Morton	ENSR
Stephanie Kelly	ENSR
Kelly Sullivan	ENSR
Kristyn Lemieux	ENSR
Anne Giblin	MBL
Chuck Hopkinson	MBL
Jack Kelly	Independent
Lisa Lefkouitz	Battelle
Heather Trulli	Battelle
Carlton Hunt	Battelle
Jim Fitzpatrick	HydroQual Inc.
Mike Connor	MWRA
Ken Keay	MWRA
Jennifer Sullivan	MWRA
Maury Hall	MWRA
Houte Yang	MWRA
Andrea Rex	MWRA
Roy K Ropp	Battelle
Brian Moffat	Aquatec Biological Sciences
Phil Downey	Aquatec Biological Sciences
Matt Liebman	EPA
Polly Bradley	SWIM
Emmanuele Farris (Italy)	Battelle
Joseph Lobuglio	MWRA
Doug Hersh	MWRA
Wendy Leo	MWRA
Brad Butman	USGS
Brian Howes	CMAST/UMass
Craig Taylor	WHOI
Ravi Ika	ENVITEC
Ed Shoncair	Planners Collaborative
Michael Moore	WHOI

APPENDIX B
Overheads, Graphics and Presentations

APPENDIX B-1
Lobster Biology: David Mitchell

Lobster Monitoring Program: 1997 Results and Lobster Toxicity Evaluation

Dr. David F. Mitchell

Lobster Monitoring Program

- Purpose
- Overview of 1997 Lobster Monitoring Program
- Summary of 1997 Lobster Tissue Chemistry
  - Spatial Trends
  - Temporal Trends
  - FDA Legal Limits/ Monitoring Thresholds
- Evaluation of Effluent Toxicity Risk to Lobsters
  - Lobster Catch Trends
  - Evaluation of Impacts to Larval Lobsters
  - Evaluation of Impacts to Juvenile Lobsters
  - Conclusions
- Summary

MWRA Lobster Survey

- **Purpose:**
  - To establish baseline, pre-discharge lobster toxic body burdens for assessing human health risks posed by accumulation of toxic contaminant in edible tissues
  - Monitor spatial and temporal trends of lobster body burdens prior to and following start-up of effluent outfall discharge
  - Compare absolute levels of lobster tissue contaminant levels to established FDA legal limits for mercury, PCBs, and other toxics

Lobster Survey Methods

- **Fifteen lobsters (*Homarus americanus*) are collected from three locations: Deer Island Flats (DIF); Future Outfall Site (FOS); and East Cape Cod Bay (ECCB)**
- **Weight and length are measured, gender determined, and external conditions or gross abnormalities noted**
- **Tissue samples are dissected and analyzed**
  - Hepatopancreas: mercury, trace metals, PCBs, PAHs, and pesticides.
  - Edible Tissue: mercury, PCBs, and pesticides

1997 Survey Deviations from CW/QAPP

- Twenty-two legal-size lobsters collected during trap set at all three stations
- Remaining 10 lobsters from Deer Island were purchased directly from lobstermen tending adjacent traps at or within two kilometers of sampling stations
- Remaining 13 lobsters from Cape Cod Bay were purchased from Cape Tip Fisheries

Summary of 1997 Lobster Tissue Data - Spatial Trends

- Edible Tissue
  - Gradient for organic contaminants decreasing from DIF to FOS to ECCB; DDT, Pesticides, Chlordane, PCBs
- Hepatopancreas
  - Organics follow the same trend as edible tissue

Summary of 1997 Lobster Tissue Data Historical Trends

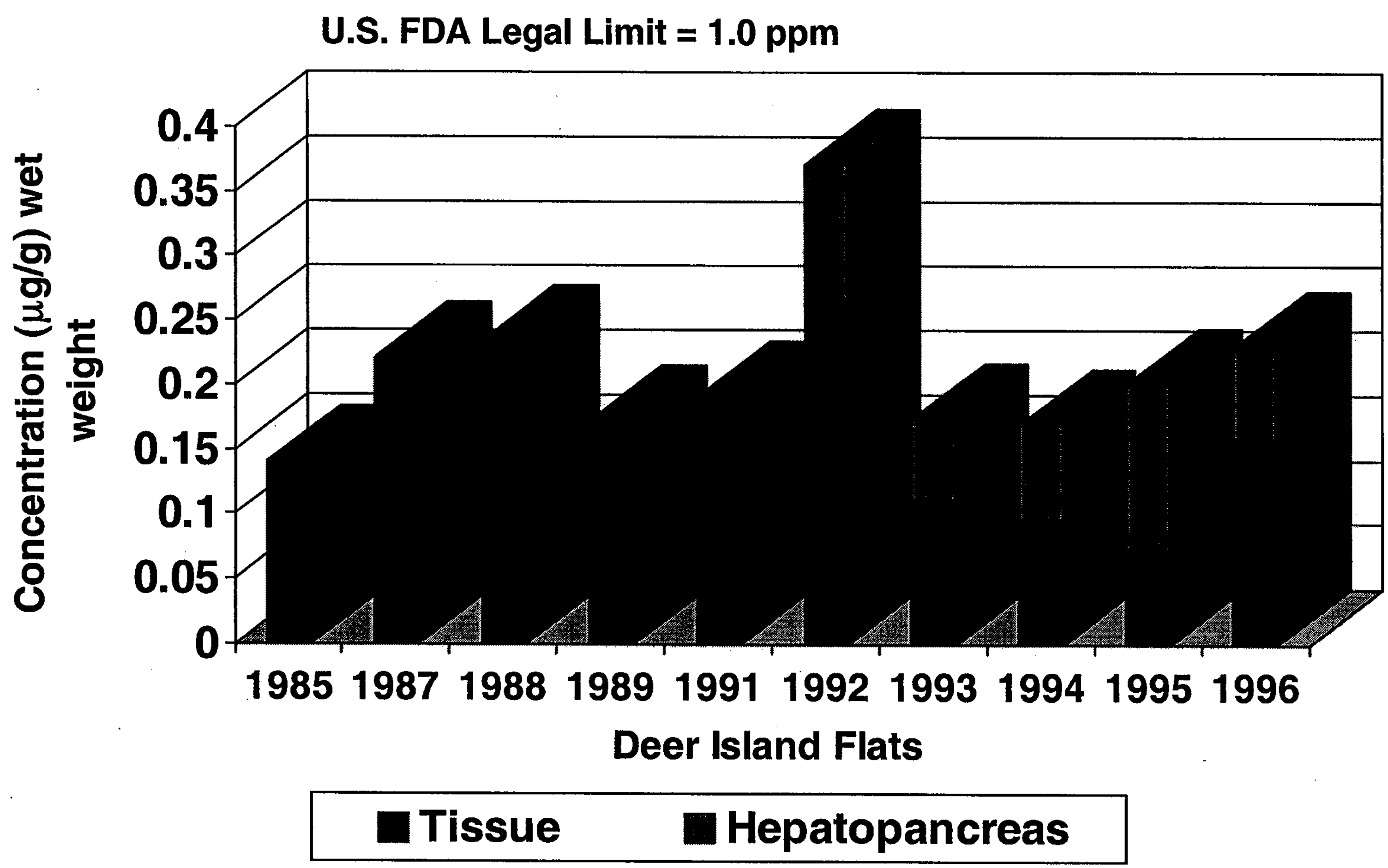
- Edible Tissue
  - DDT, chlordane, dieldrin, and PCB levels are within range of historically observed values for FOS and ECCB
  - Deer Island Flats (DIF) has highest total DDT and PCBs of baseline period
- Hepatopancreas
  - Pesticides, DDT, PCBs are within range of historically observed values
  - Total PAHs decreased at DIF and FOS; ECCB data highly elevated but suspect

Lobster Monitoring Trigger Parameters and Thresholds

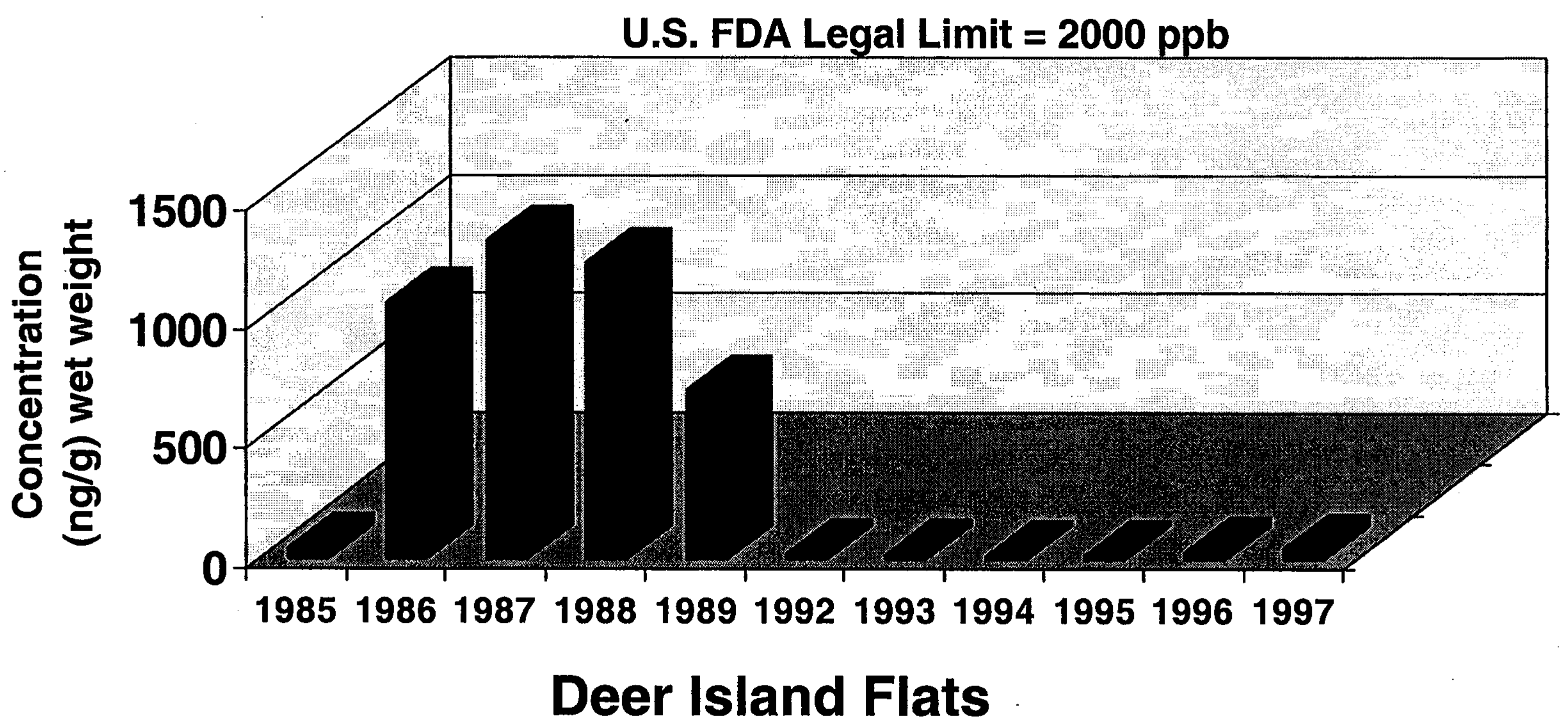
Parameter Type [1]	Location	Caution Level [2]	Warning Level
Mercury	FOS	0.5 ppm wet wt.	0.8 ppm wet wt.
PCBs	FOS	1000 ppb wet wt.	1600 ppm wet wt.
Lipid normalized DDT	FOS	677 ppb lipid wt.	NA
Lipid normalized PCB	FOS	5259 ppb lipid wt.	NA

[1] All parameters apply to edible lobster tissue.
[2] Caution level for mercury and PCBs is ½ FDA Action Level. For lipid normalized toxics, Caution level is 2 X baseline (i.e., 1992-1997 data)

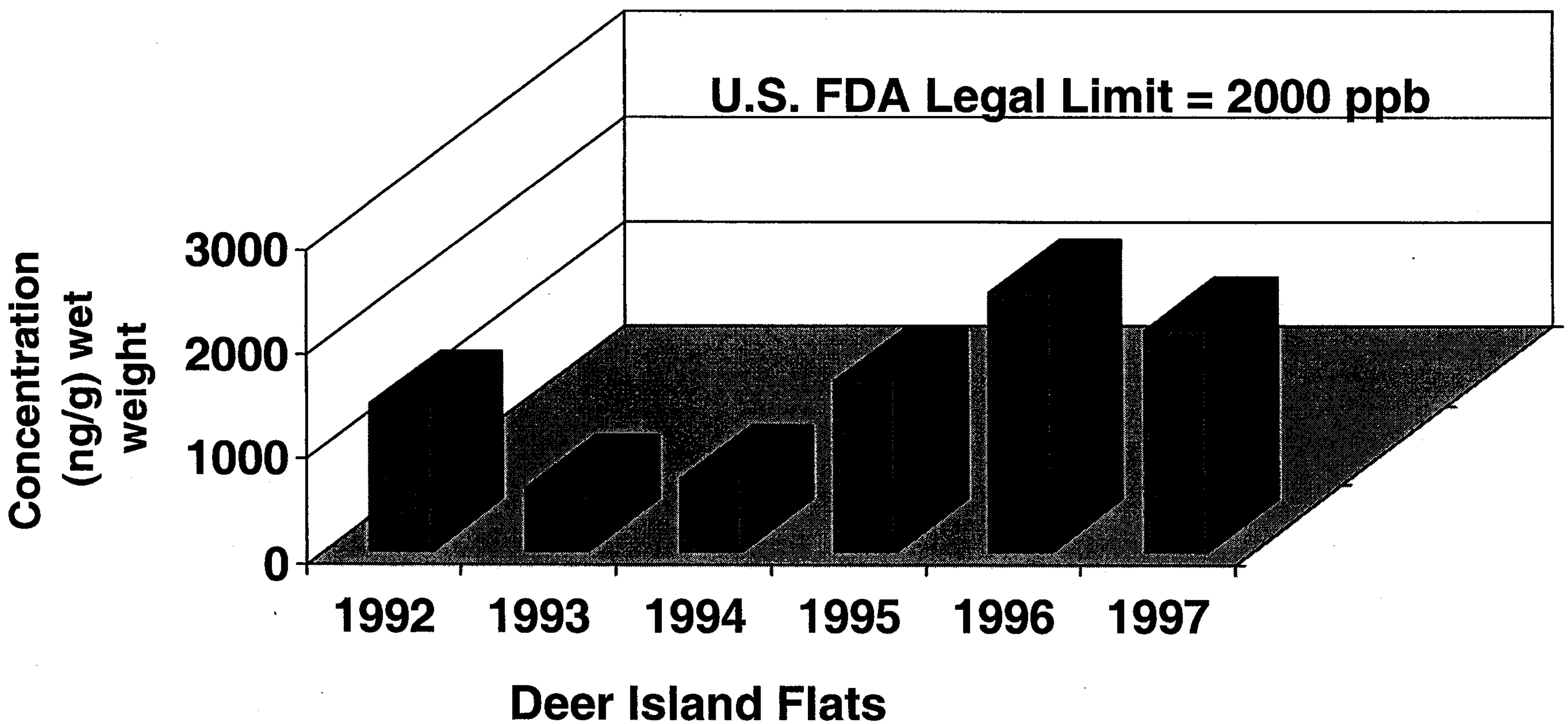
Comparison of U.S. FDA Legal Limit to Mean Concentration of Mercury in Lobster 1985-1996



Comparison of U.S. FDA Legal Limit to Mean Concentrations of PCBs Observed in Lobster Meat 1985-1997



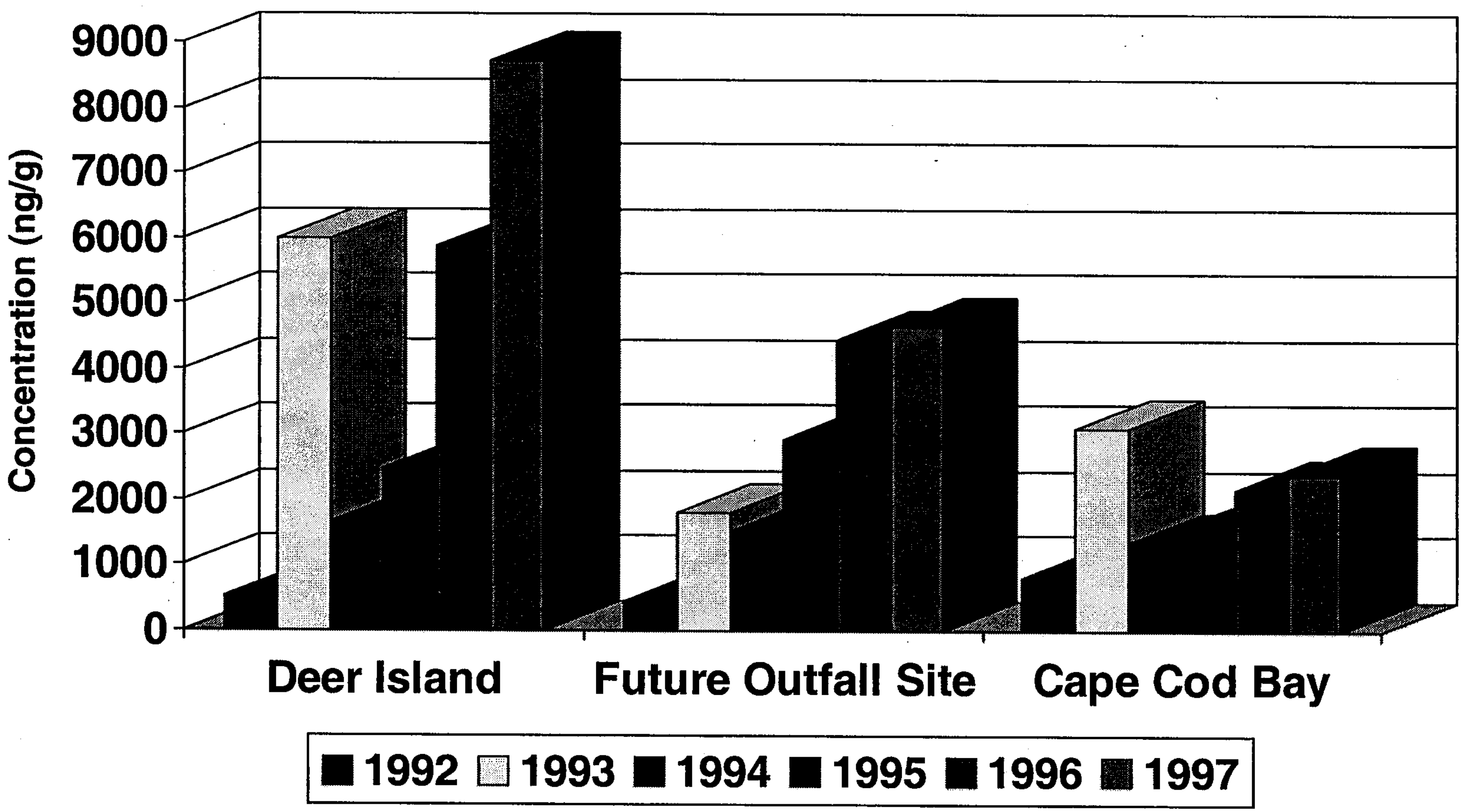
Comparison of U.S. EPA Legal Limit to Mean Concentration of PCBs in Lobster Hepatopancreas 1992-1997



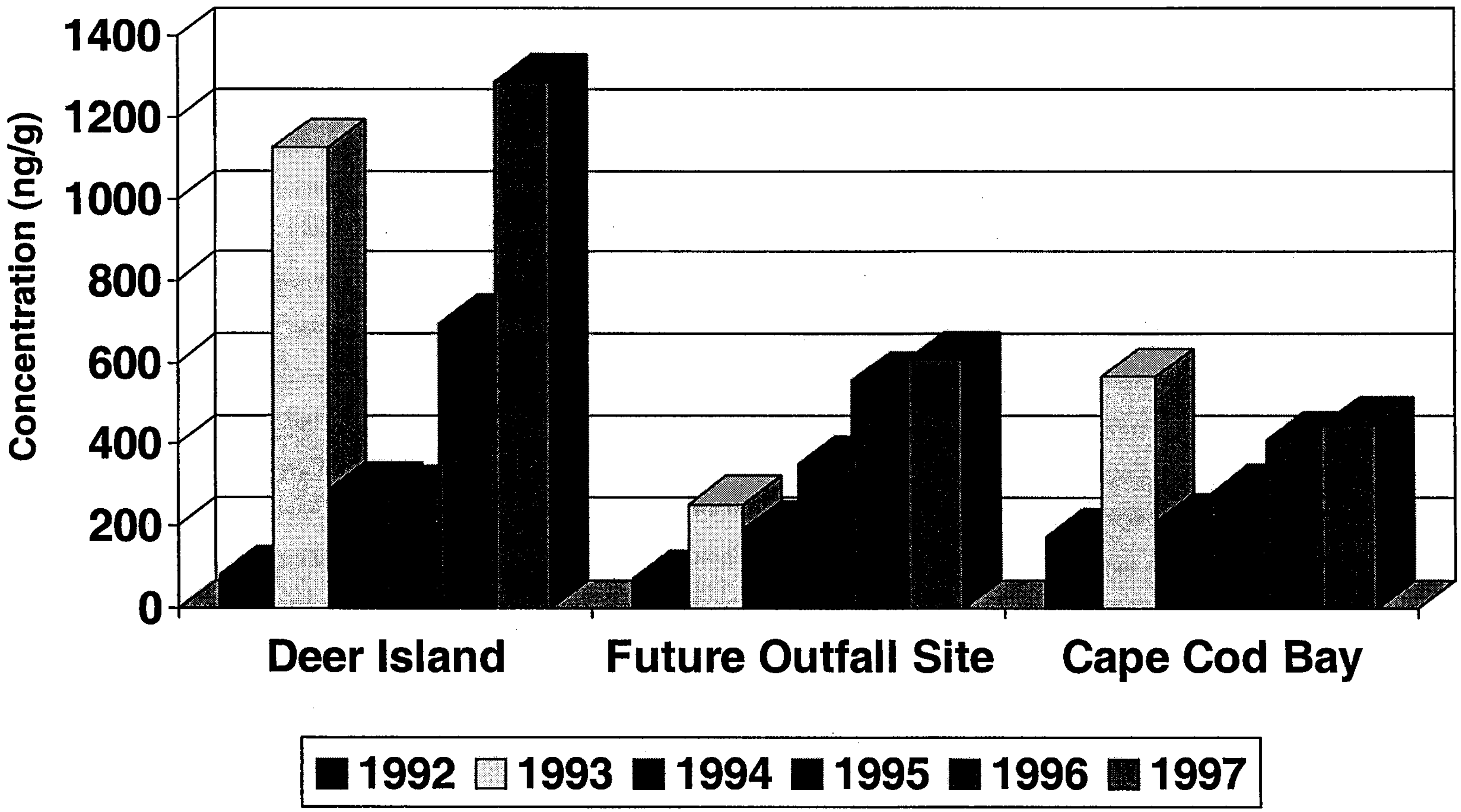
Comparison of FDA Legal Limits to Mean Concentrations (wet weight) of Select Compounds In Lobster Edible Tissues - 1997

Compound/Analyte	DIF Mean	FOS Mean	ECCB Mean	FDA Legal Limit[1]	Caution Level[3]	Warning Level[4]
Total DDT (ppb)	6.69	2.61	2.30	5,000[2]	NA	NA
Total Chlordanes (ppb)	0.89	0.47	0.29	300	NA	NA
Dieldrin (ppb)	0.94	0.82	0.66	300	NA	NA
Total PCBs (ppb)	44.77	20.78	12.30	2,000	1,000	1,600
Mercury (ppm)	NA	NA	NA	1	0.5	0.8

Lipid Normalized Total PCB Concentrations (Meat) 1995-1997



Lipid Normalized Total DDT Concentrations (Meat) 1995-1997



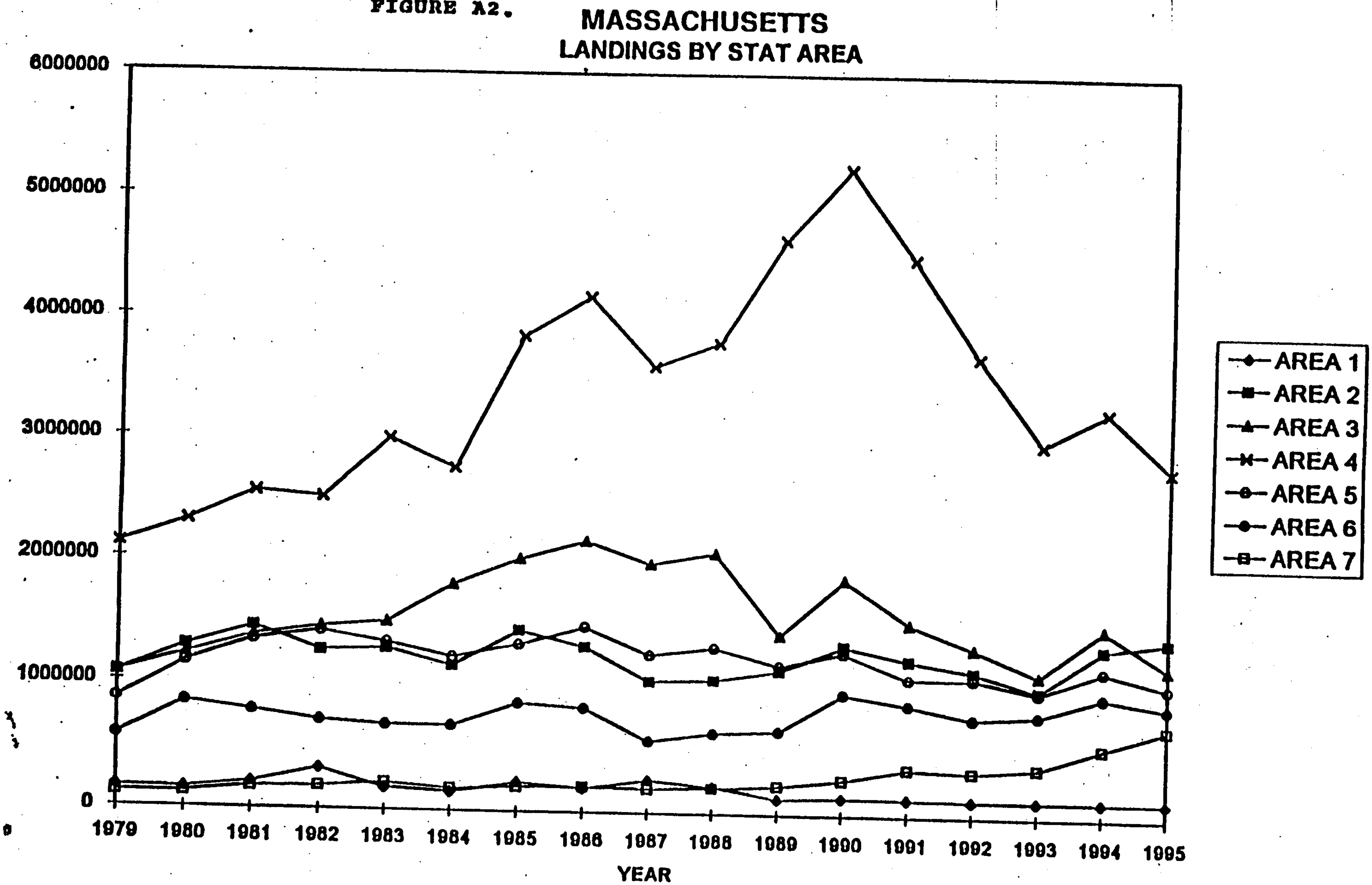
Monitoring Summary and Conclusions

- 1997 Lobster Survey successfully provided additional baseline data for establishing range of pre-operational tissue levels
- Comparison of edible tissue levels to FDA legal limits indicate that no Caution Levels or Warning Levels were exceeded, but hepatopancreas levels were above limits for PCBs.
- No exceedance of trigger parameters and thresholds

Evaluation of Potential Effluent Toxicity to Lobsters

- Lobster Catch Trends
- Evaluation of Impacts to Larval Lobsters
- Evaluation of Impacts to Juvenile Lobsters
- Conclusions

FIGURE A2.



MASSACHUSETTS
LANDINGS BY STAT AREA
6000000
5000000
4000000
3000000
2000000
1000000
0
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
YEAR
AREA 1
AREA 2
AREA 3
AREA 4
AREA 5
AREA 6
AREA 7

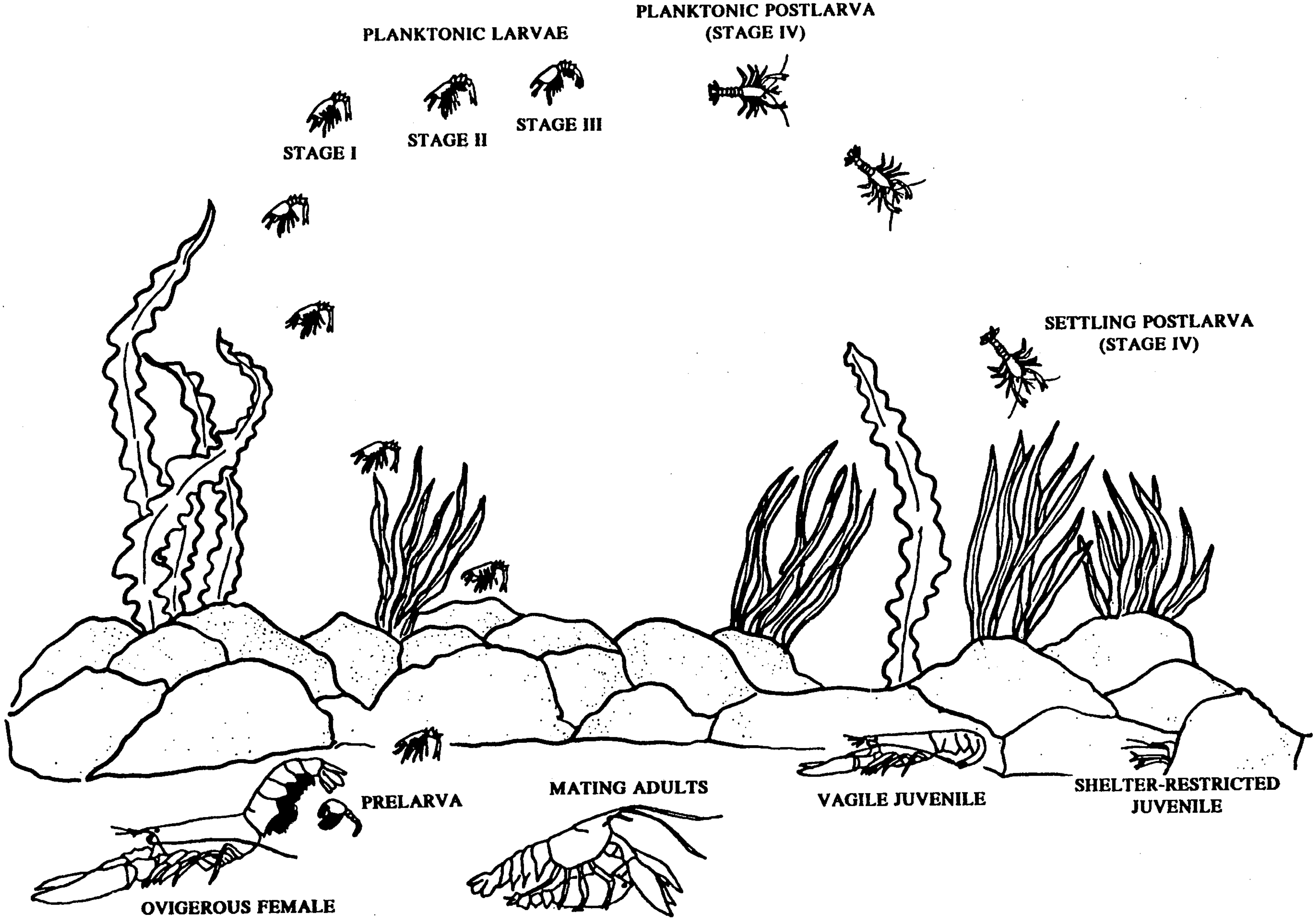


FIGURE 9 Diagrammatic summary of the life history of the American lobster, *Homarus americanus*. (Redrawn with permission by K. L. Lavalli, based on a drawing by R. E. Duggan as published in Harding, 1992.)

Toxics in MWRA Outfall Discharge

- Projected annual average flow of 383 mgd (95% - secondary treatment)
- Draft permit identifies 12 pollutants with potential to exceed, includes metals, pesticides, VOCs, and chlorinated organics
- Discharge must meet Ambient Water Quality Criteria (AWQC) within ZID
- Minimum 52:1 dilution in zone of initial dilution (ZID)
- Permit based on effluent data collected prior to full secondary treatment therefore conservative.

Ambient Water Quality Criteria

- "an estimate of the highest concentration of a substance in water which does not present a significant risk to the aquatic organisms in the water and their uses"
- AWQC developed based on a minimum of data from eight families to represent a wide spectrum of aquatic organisms
- Developed to be protective of 95% (cumulative probability) of all test organisms

Applicability of AWQC to Lobster

- Lobster (*Homarus americanus*) larvae and adults used in development of several AWQC (despite difficulty as a lab test organism)
- Relative toxicity of lobster varies however, numerous more sensitive organisms
- For Cd, Cu, Zn, ammonia, lobster is 2-20 times less sensitive than most sensitive saltwater test organism

AWQC Compliance Table

Discharge Constituent	1997 Outfall Discharge Average* Conc.[1] (ug/L)	1997 Outfall Discharge Maximum Conc.[2] (ug/L)	Ratio of Average to Chronic AWQC	Ratio of Max to Acute AWQC
Cu	0.668	1.898	NA	0.654
Pb	0.078	0.523	0.009	0.002
Hg	0.003	0.010	0.001	0.394
Total DDT	0.059	0.229	0.059	0.002

* = Average calculated as the average of monthly averages

1 = Diluted 52:1 to account for dilution at the edge of the outfall mixing zone

2 = Diluted 68:1 to account for dilution at the edge of the outfall mixing zone

NA = marine chronic AWQC unavailable

Lobster vs. Mysid Sensitivity/Organic Polymer

- Comparison of AWQC document suggests that lobster and mysid shrimps have comparable sensitivity within 2X; varies with chemical tested
- Limited WET testing with Pilot Plant effluent indicates that mysid shrimp less sensitive to polymer tested than lobster
- Data indicate that a 4:1 dilution of effluent with polymer needed for lobster

Lobster Life History

- Spawning adults typically found in Massachusetts Bay late March to October
- One prelarval and three pelagic larval stages (I,II,III) occur before settling to the bottom as benthic juvenile and adult stages
- Planktonic lobster larvae common in Mass Bay late May to early October

Lobster Larvae Exposure

- Lobster Larvae Exposure to MWRA Discharge limited due to temporal-spatial considerations
- Area of effluent dilution mixing zone constitutes a small portion of total Mass Bays
- Pelagic (Stage I-III) lobster larvae present primarily in surface waters during stratified period when plume trapped below surface by pycnocline (May-October)
- Worst-case scenario: Summer storm event resulting in heavy toxics load and breakdown of stratification; plume reaches surface at a minimum of 100:1 dilution

Spatial Plume Diagram

- shows restriction of plume below pycnocline

Evaluation of Impacts to Juvenile Lobster

- Concerns regarding early benthic phase (EBP) or "shelter-restricted juvenile" class
- Evaluation of potential impact of effluent to benthic juveniles
- Evaluation of potential sediment deposition on benthic habitat

Cobble/Hardbottom Areas Affected by Current and Future Discharge

Dilution Isopleth	Area Affected by Current Discharge (km^2)	Area Affected by Future Discharge (km^2)	% Change
<200:1	68.5	2.0	-97%
200-400:1	65.9	21.2	-68%
≤400:1	134.4	23.2	-83%

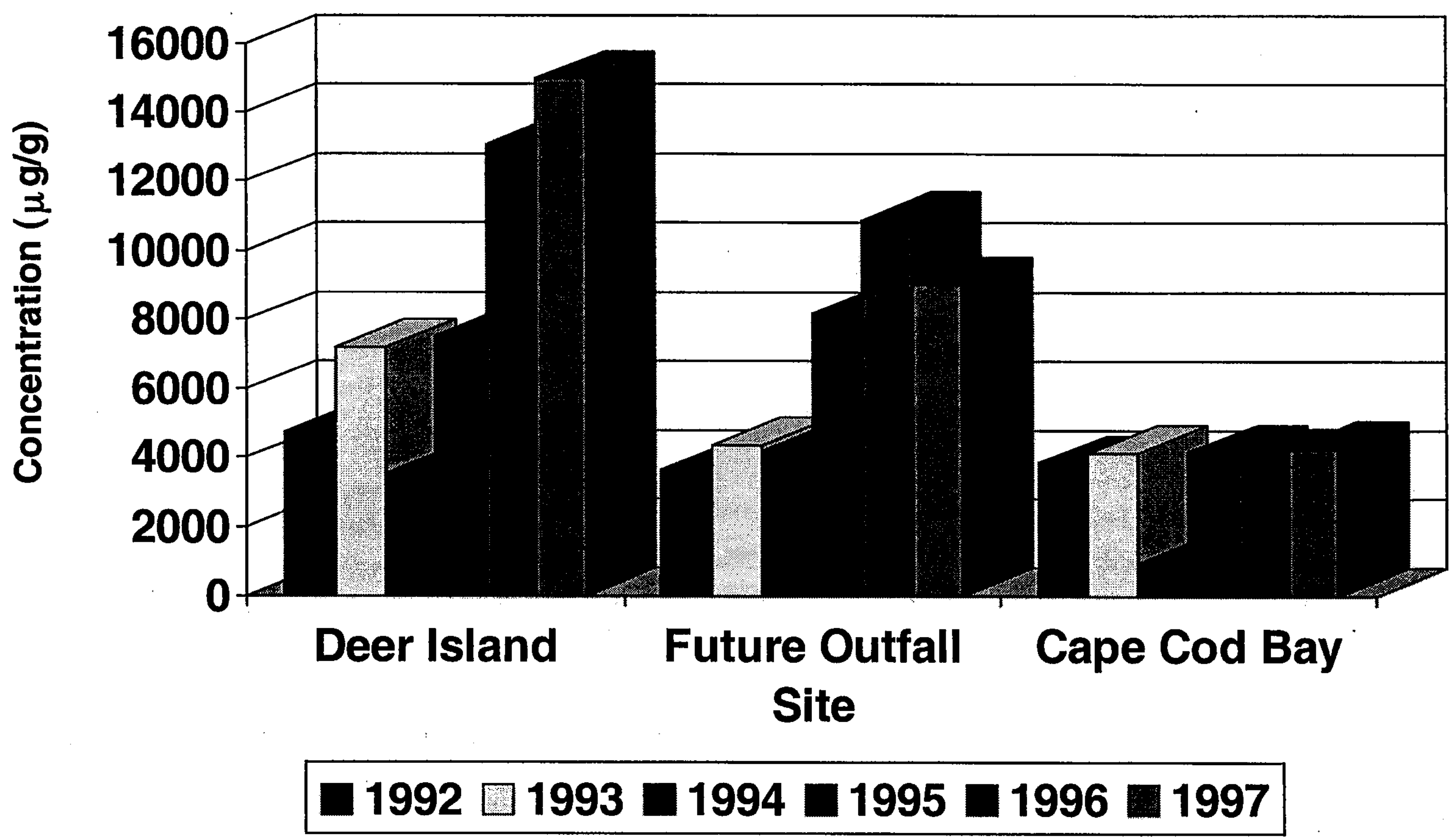
Potential Impacts to Hardbottom/Cobble Area

- Amount of hardbottom/cobble areas potentially impacted greatly reduced
- Potential sedimentation does not appear to be problem based on modeled deposition of particulate organic carbon and location of diffuser

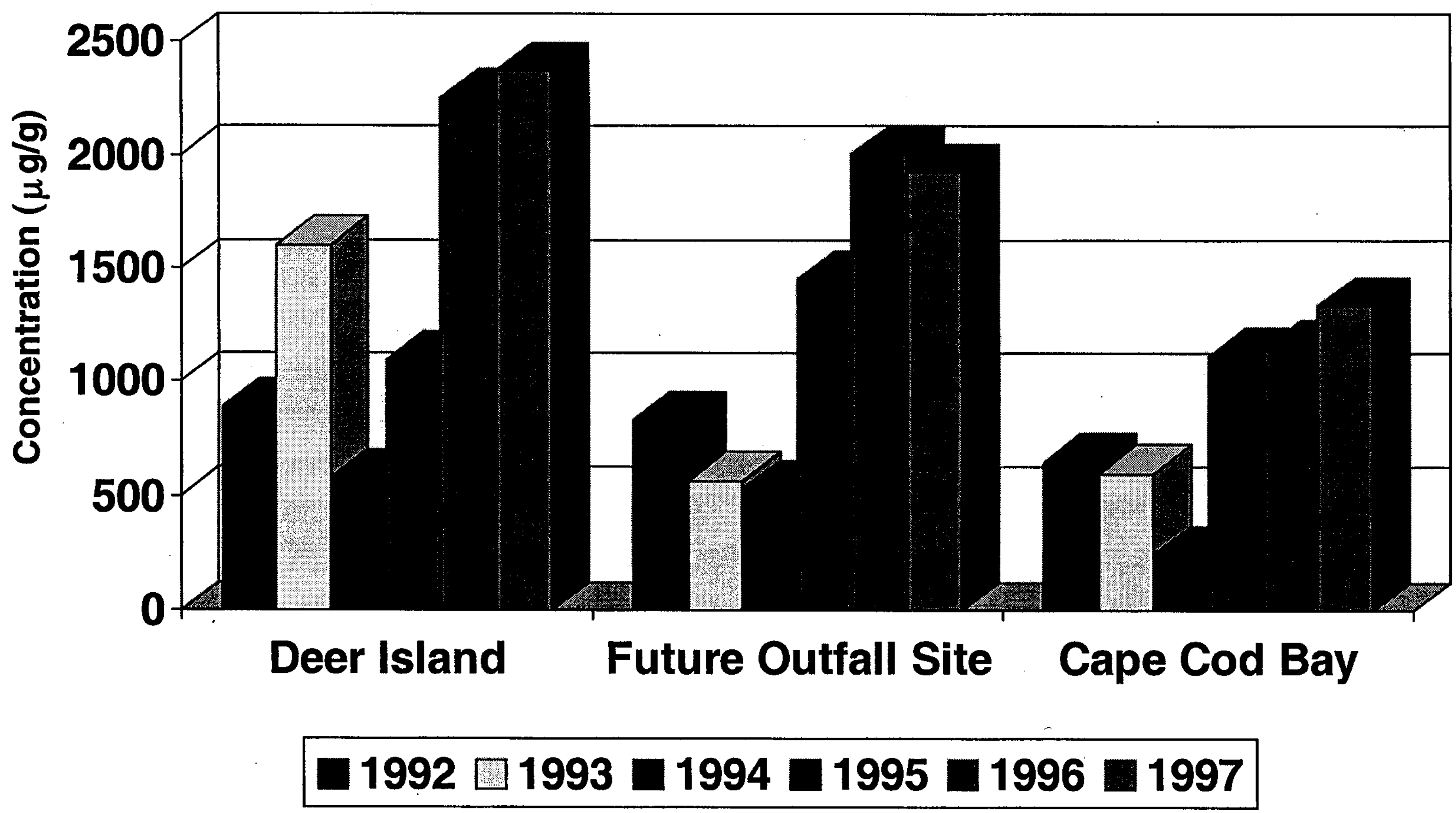
Summary

- Adequate dilution to meet AWQC well within ZID for all pollutants
- AWQCs developed to protect most sensitive organisms; no special sensitivity of lobster
- Lobster larvae exposure restricted based on spatial-temporal factors
- Potential effluent impact on hard-bottom habitat greatly reduced
- MWRA effluent not expected to pose a toxic threat to lobster populations in Mass Bay
- Other environmental factors may contribute to declines in lobster catch

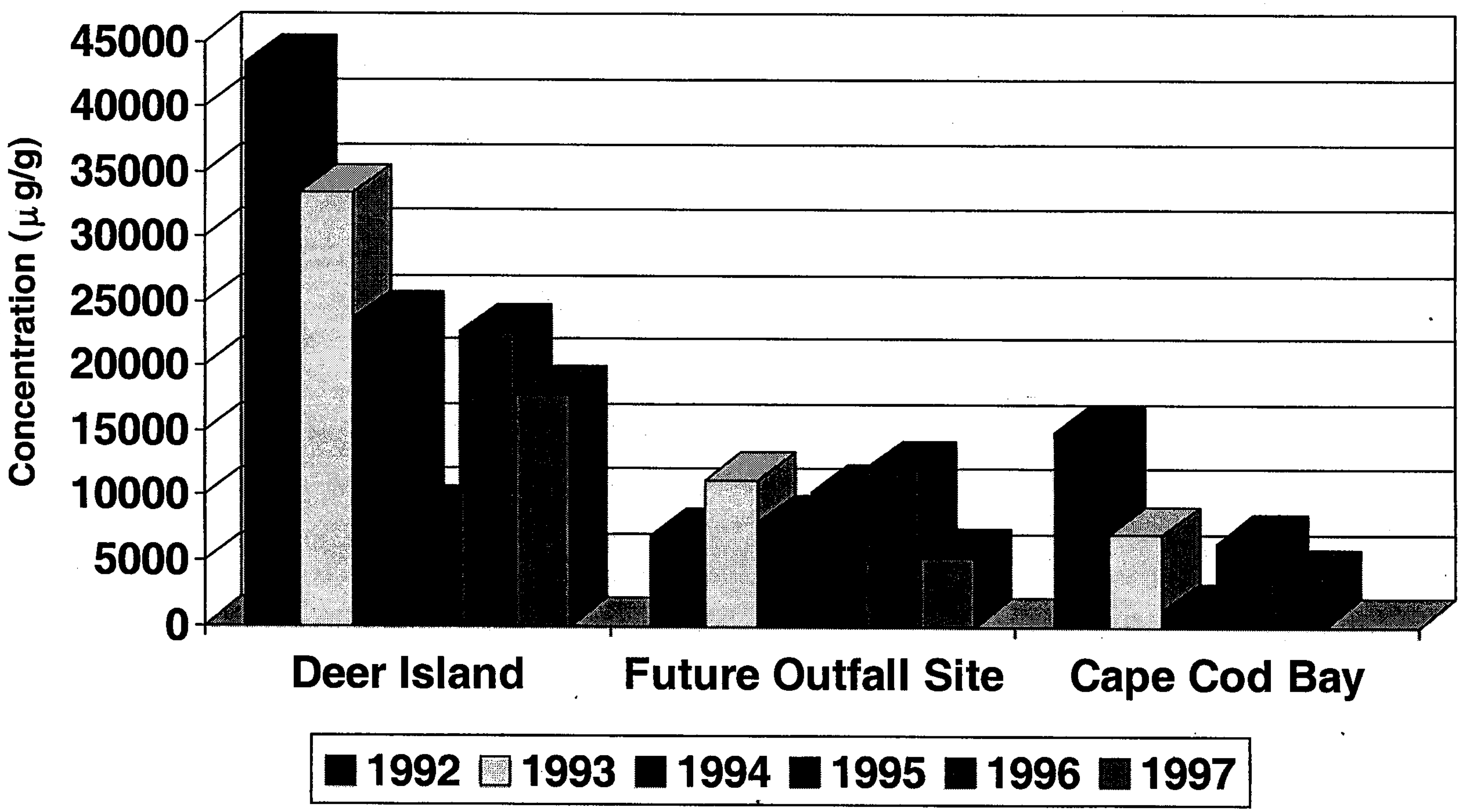
Lipid Normalized Total PCB Concentrations (Hepatopancreas) 1995-1997



Lipid Normalized Total DDT Concentrations (Hepatopancreas) 1995-1997



Lipid Normalized Total PAH Concentrations (Hepatopancreas) 1995-1997



Date of Test	Effluent Source	Treatment	M. bahia		H. americanus		A. punctulata		
			48 Hr LC-50	48 Hr NOEC	48 Hr LC-50	48 Hr NOEC	IC-25	NOEC	LOEC
June, 1997	Pilot Plant	none	>100%	100%	79.1%	75.0%	76.8%	50.0%	75.0%
		P	>100%	100%	45.6%	25.0%	27.9%	12.5%	25.0%
		P; C	>100%	100%	74.9%	50.0%	17.5%	12.5%	25.0%
		P; C; DC	>100%	100%	55.4%	25.0%	8.4%	1.0%	12.5%
August, 1997	Deer Island WWTP	none	>100%	100%	NT	NT	NT	NT	NT
		C	>100%	100%	NT	NT	NT	NT	NT
		C; DC	>100%	100%	NT	NT	NT	NT	NT
		P	>100%	100%	NT	NT	NT	NT	NT
		P; C	>100%	100%	NT	NT	NT	NT	NT
		P; C; DC	>100%	100%	NT	NT	NT	NT	NT
October, 1997	Deer Island WWTP	P (100% effluent)	1.36 mg/L*	1.0 mg/L*	NT	NT	<0.125 mg/L*	<0.125 mg/L*	<0.125 mg/L*
		P (50% effluent)	NT	NT	NT	NT	<0.125 mg/L*	<0.125 mg/L*	<0.125 mg/L*

Notes:
P = polymer added
C = Chlorinated
DC = Dechlorinated using sodium thiosulfate
LC-50 = Concentration estimated to cause 50% mortality of test organisms.
NOEC = No Observed Effect Concentration
IC-25 = Concentration estimated to cause inhibition of fertilization in 25% of test organisms.
LOEC = Lowest Observed Effect Concentration
NT = Not Tested
Unless otherwise noted, all concentrations are percent effluent diluted in laboratory sewater.
* = Values reported as mg polymer per L effluent solution

<u>Test types:</u>

M. bahia = *Mysidopsis bahia*; mysid shrimp; acute toxixity screen
H. americanus = *Homarus americanus*; Northern lobster; acute toxicity screen
A. punctulata = *Arbacia punctulata*; purple sea urchin; 60 minute chonic sperm fertilization test

General observations:
Deer Island effluent does not appear to be toxic to mysids in acute exposures
Sea urchins appear to be most sensitive to effluent when tested suing permit-mandated toxicity tests; still pass critical concentration
Significant mortality was observed in the laboratory controls for lobster tests - 37% mortality after 48 hours.

dc

1998 MWRA - ENSR HARBOR OUTFALL MONITORING WORKSHOP

LOBSTER MONITORING SESSION

BOXBOROUGH, MA

FEBRUARY 19, 1998

APPENDIX B-2
Flounder Histopathology: Michael Moore

OVERVIEW OF TALK

- Milestones in winter flounder knowledge
- Biomarker lesions of chemical exposure
- Spatial and temporal trends
- Original flounder monitoring goals
- Current knowledge in light of those goals
- Recommendations
- Summary

WINTER FLOUNDER MILESTONES

1975 Howe and Coates - migration south of the Cape (10's of miles) vs. North (~1 mile.) Hence a better station marker north of Cape.

1975 Murchelano describes finrot in NY Bight and associates with pollution.

1985 Murchelano and Wolke - tumors and vacuolated cells from Boston Harbor winter flounder.

1987 to 1991 - Moore - progression of vacuolation, definition of tumor types, initiation and initiation of monitoring database.

1988 Gardner et al. - Quincy Bay study - risk assessment and health advisory.

Gardner et al (1989) , Myers et al (1994) and HOM - linkage of tumors and vacuolated cells to contaminants - PAH and pesticides especially

1990 NOAA Reproductive Success study - no linkage to contaminants in Boston samples

1991 to present Moore, Hillman et al. - 5 station survey.

CHEMICALLY INDUCED LESIONS IN FLOUNDER LIVER THAT ARE BIOMARKERS CHEMICAL EFFECT

Progression of vacuolation

Liver tumors - images of tumors

Myers correlation's and data shown here

SPATIAL AND TEMPORAL TRENDS IN FLOUNDER LESIONS 1987 TO PRESENT

Station map, 1997 data and some representative scatter plots for 1991 - 1997. Lack of tumors after 91 at Deer Island. No trends in the 5 stations since 91.

GOALS OF FLOUNDER TASK AS STATED IN 1992 AND 1997 RFQ/P'S

To monitor:

1. Accumulation of toxic contaminants in edible tissues of flounder to assess human health risk.

2. Accumulation of toxic contaminants in flounder liver to assess impact on fish health

3. Physiological condition of flounder to assess impact on fish health

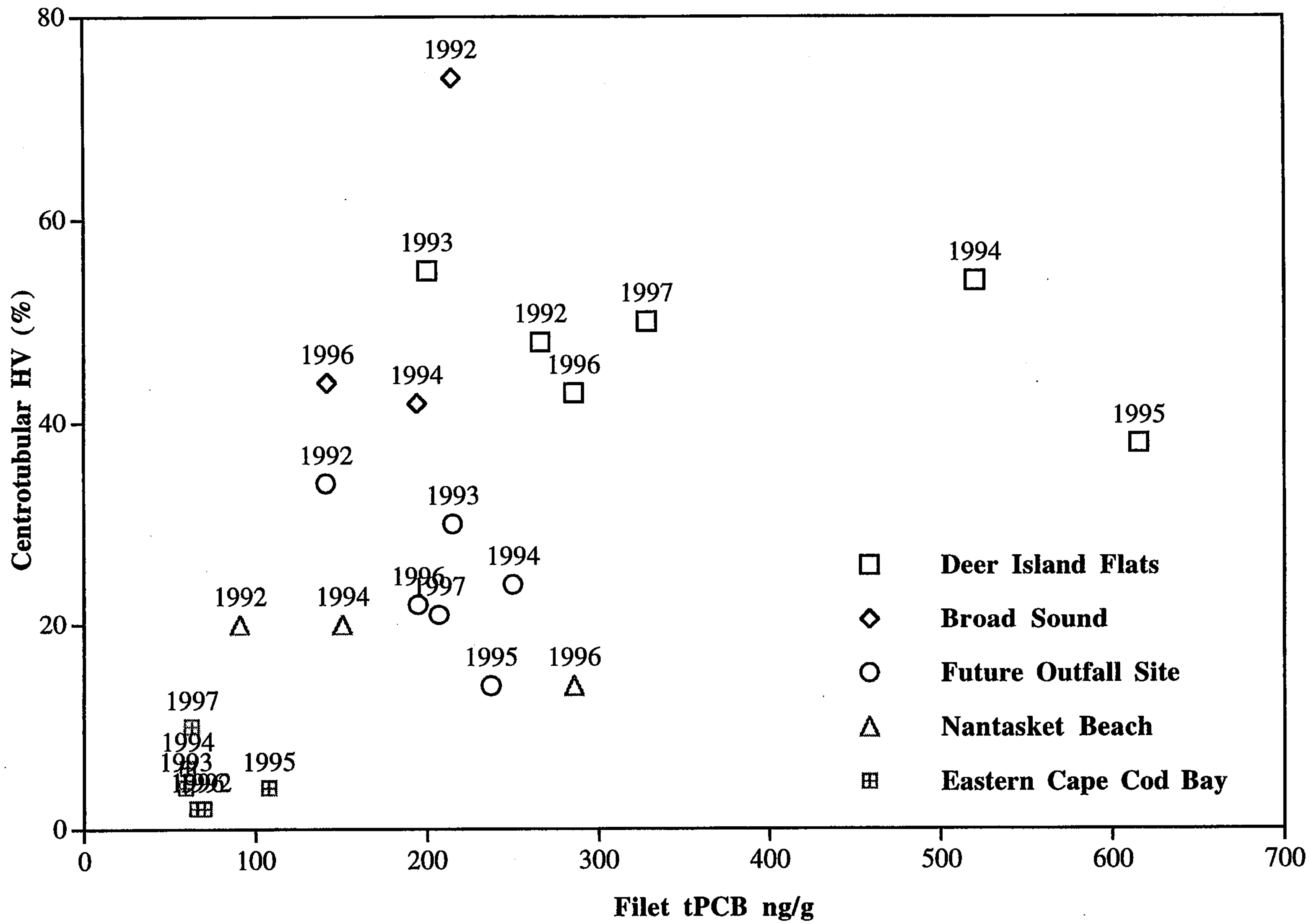
CURRENT KNOWLEDGE BASE IN TERMS OF MEETING THOSE GOALS

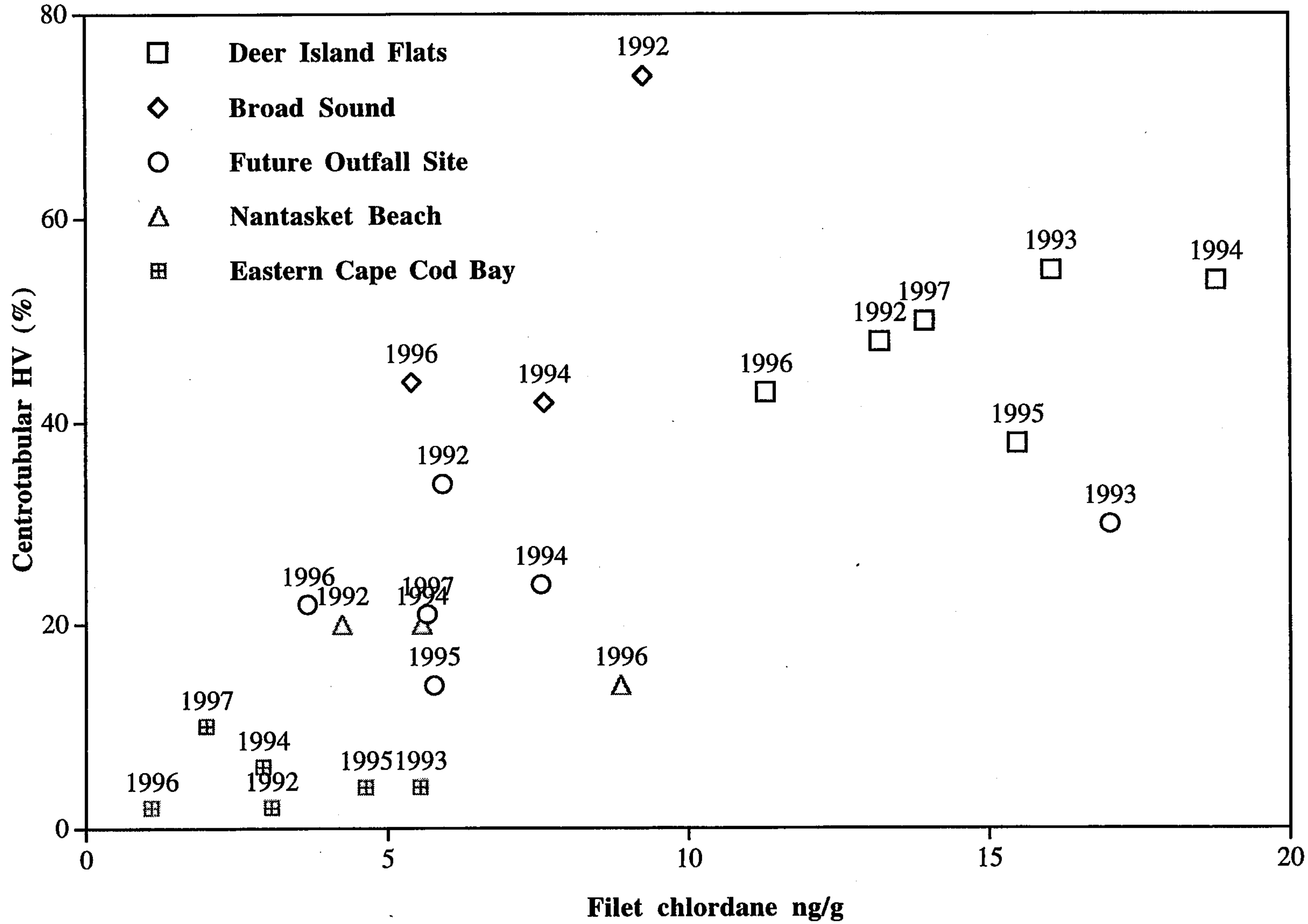
1. Fillets and human health - We know the contaminant burdens in flounder muscle, and how that relates to FDA guidelines. We do not really know what cooking does to contaminants and how that affects human risk. Most guidelines are based on carcinogenicity risks - issues of immunosupression, reproductive effects, cognition etc are less tangible but could be highly important.

2. Liver and fish health - by definition a biomarker of chronic chemical impact has to be a sublethal effect - otherwise it would not be there to monitor. Thus inevitably we use a marker that is of minor if any health impact. Even the flounder with severe tumors in the '80's still were running ripe with eggs and sperm. What the liver histology gives us is a biologically relevant harbinger of carcinogenic risk to both the fish and the consumer. It is a marker that is easily identified with, that has meaning to the consumer - if the fish don't have cancer - that is good. As such the trends we have seen have been very good PR - and justifiably so.

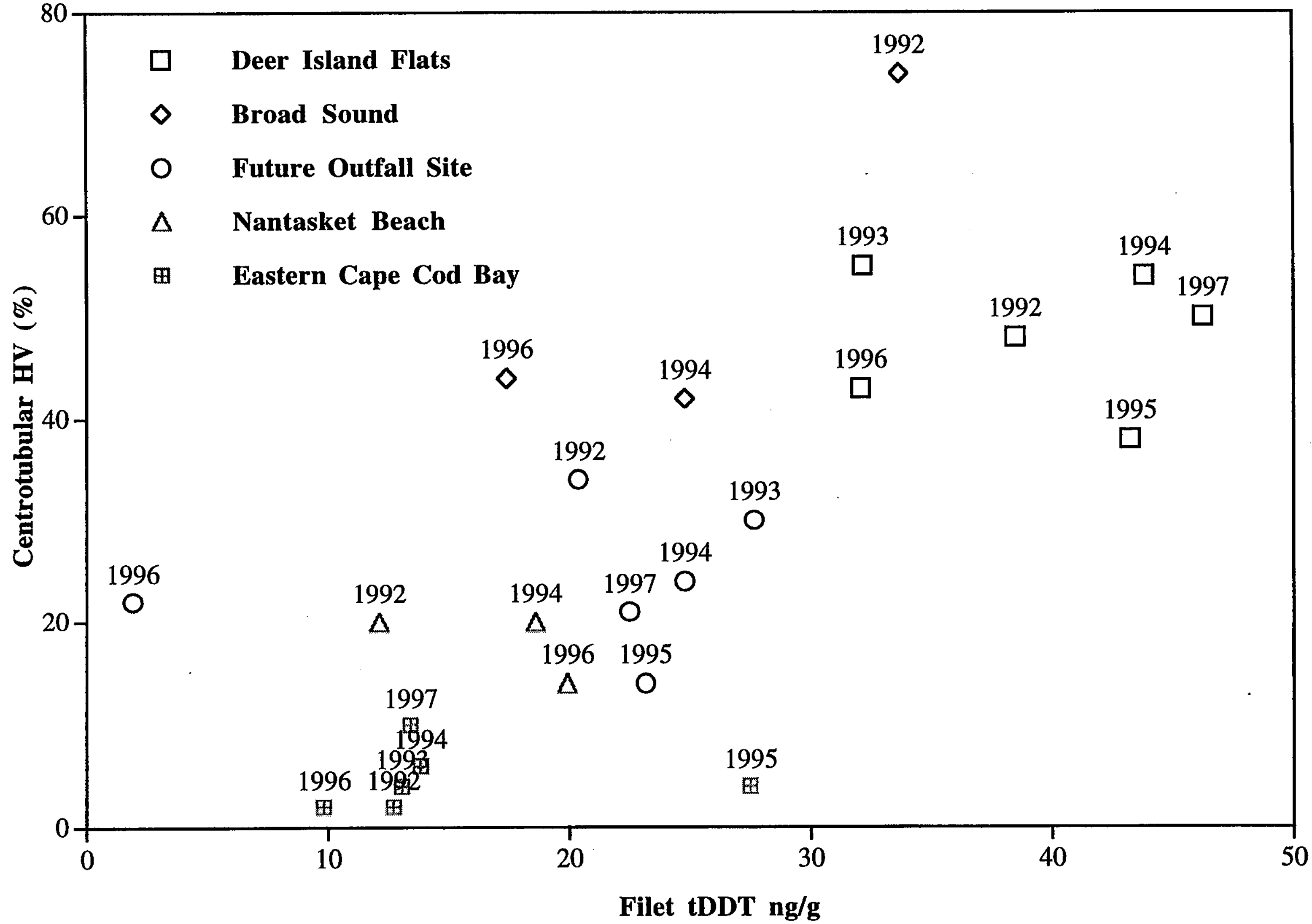
SUMMARY

- **We have a non-lethal biomarker for chemical exposure and carcinogenic risk.**
- **This biomarker appears to be quite site specific**
- **Monitoring program goals are well met re human health, less well for fish health**
- **Possible need for recruitment surveys and adult tagging studies**

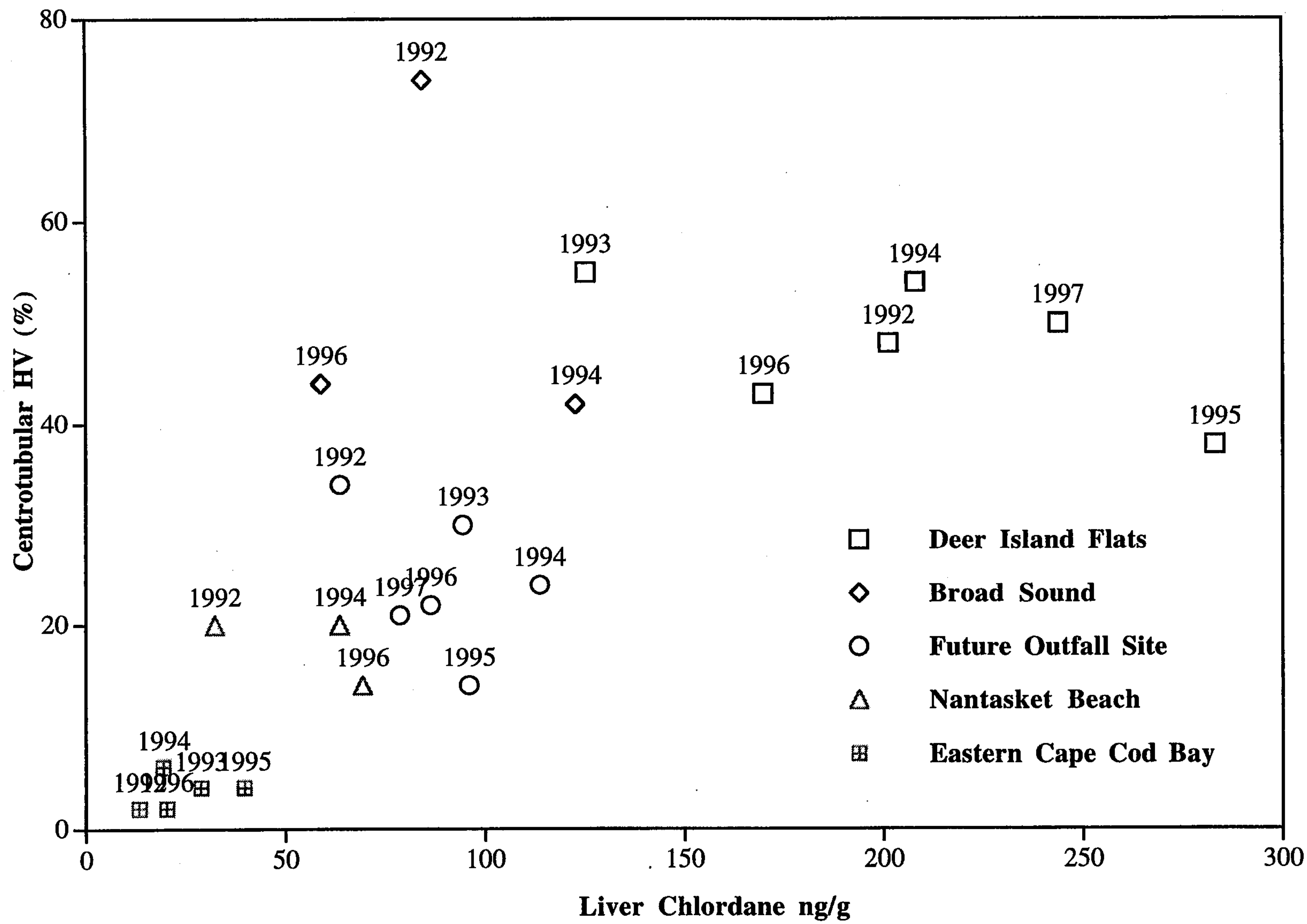

Centrotubular HV (%)
Filet tPCB ng/g
Deer Island Flats
Broad Sound
Future Outfall Site
Nantasket Beach
Eastern Cape Cod Bay

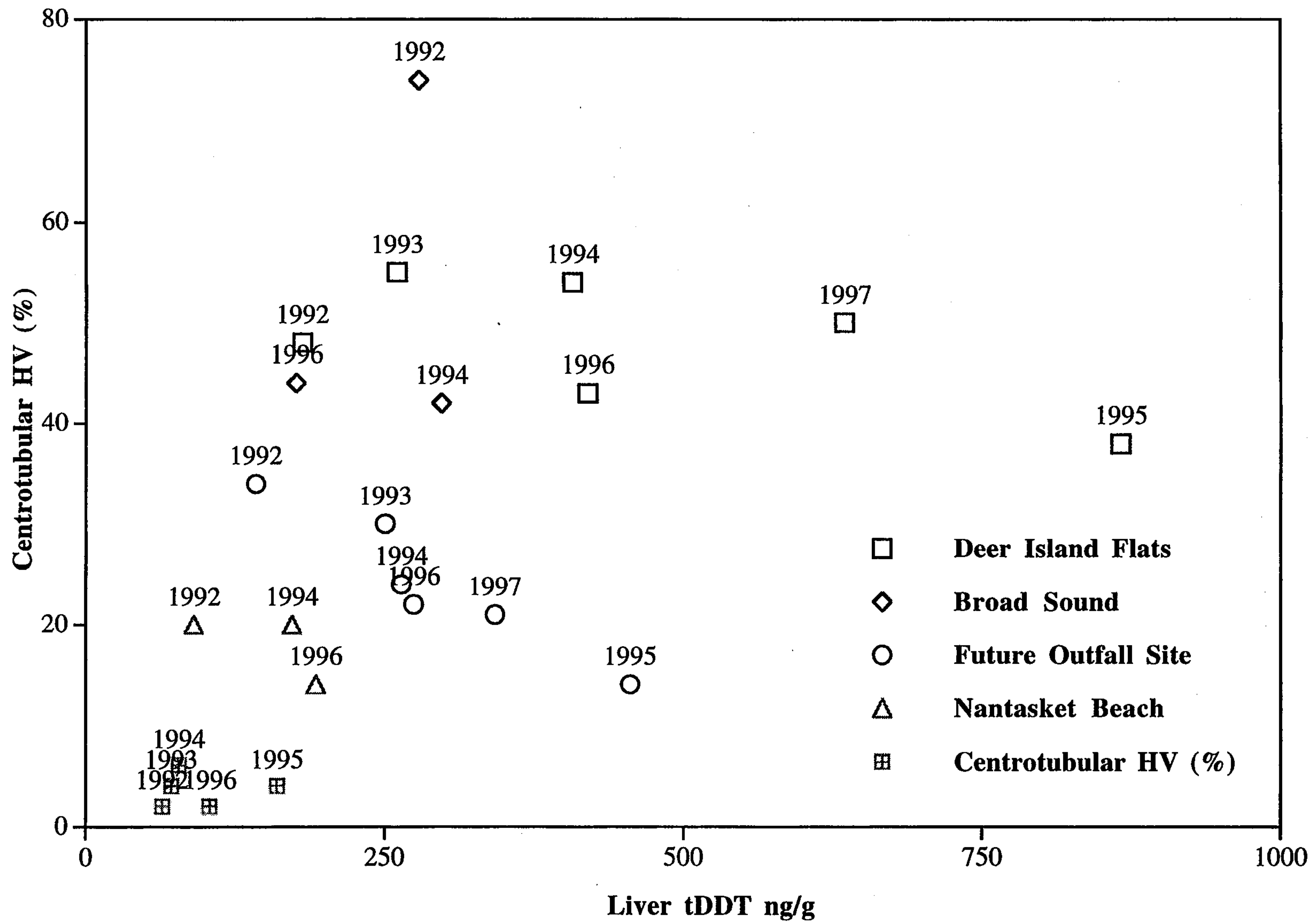


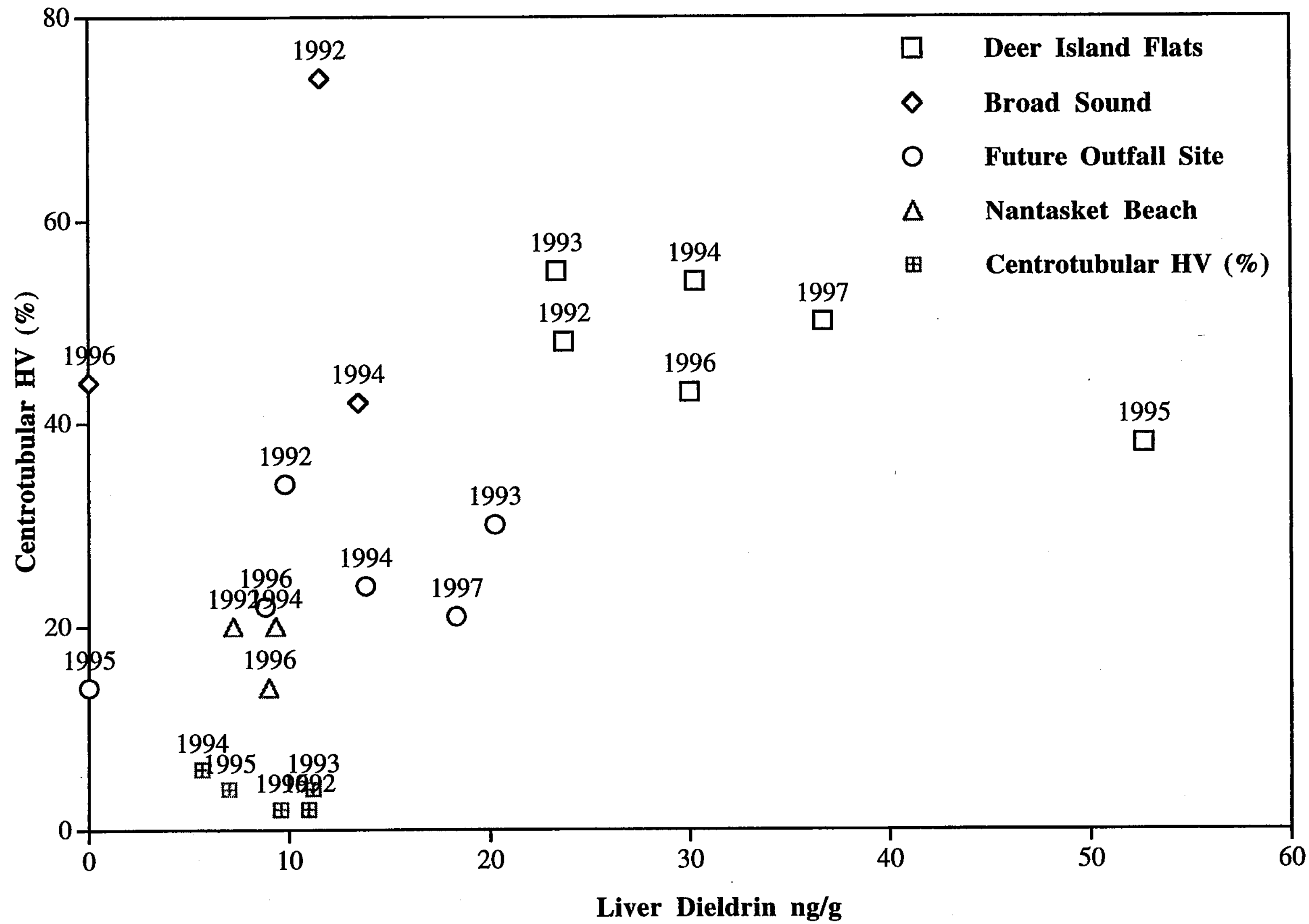
Deer Island Flats
Broad Sound
Future Outfall Site
Nantasket Beach
Eastern Cape Cod Bay
Centrotubular HV (%)
Filet chlordane ng/g
0
20
40
60
80
0
5
10
15
20
1992
1993
1994
1995
1996
1997



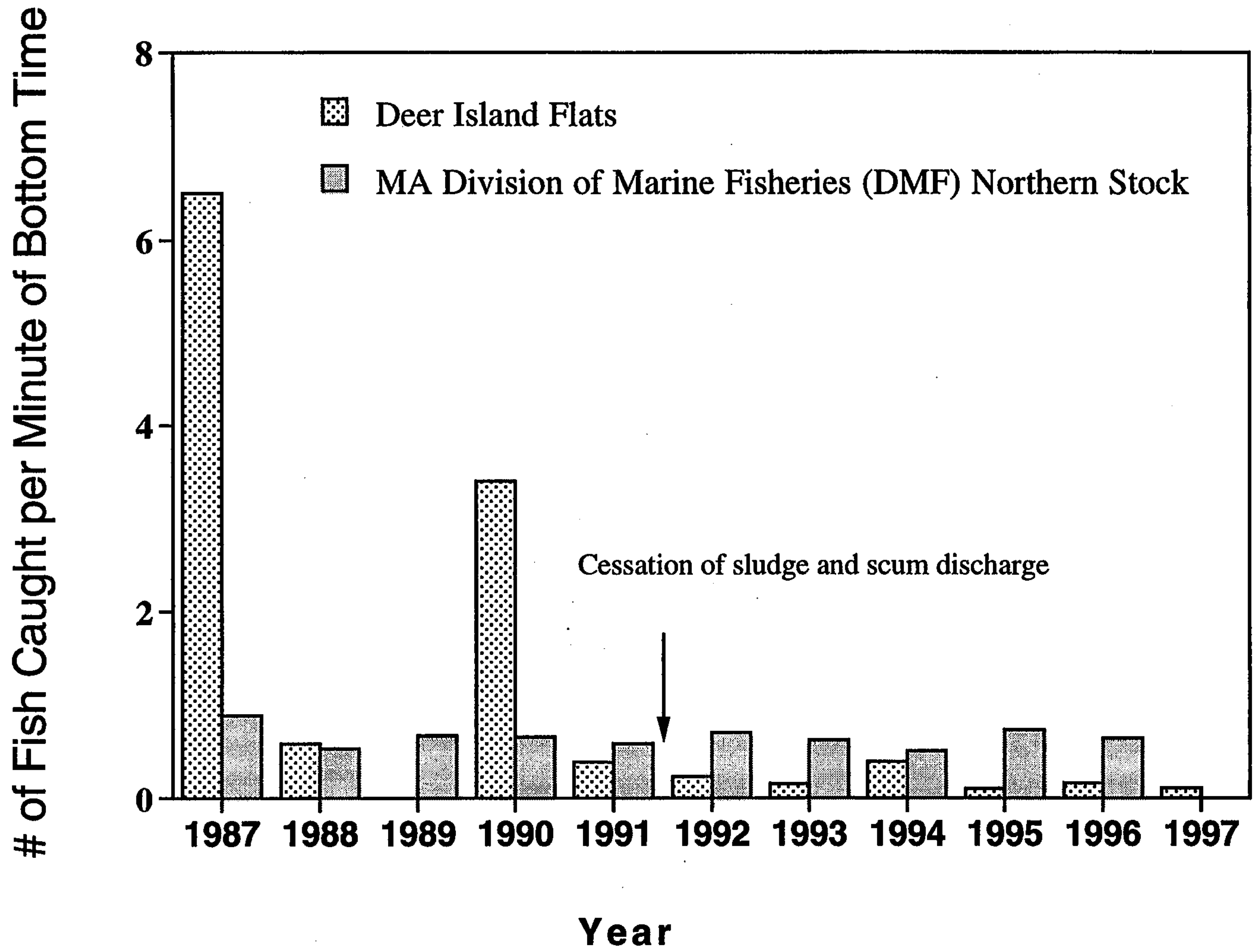
Deer Island Flats
Broad Sound
Future Outfall Site
Nantasket Beach
Eastern Cape Cod Bay
Centrotubular HV (%)
Filet tDDT ng/g
0
20
40
60
80
0
10
20
30
40
50
1992
1993
1994
1995
1996
1997


Centrotubular HV (%)
Liver Chlordane ng/g
Deer Island Flats
Broad Sound
Future Outfall Site
Nantasket Beach
Eastern Cape Cod Bay
0
20
40
60
80
0
50
100
150
200
250
300


Centrotubular HV (%)
Liver tDDT ng/g
Deer Island Flats
Broad Sound
Future Outfall Site
Nantasket Beach
Centrotubular HV (%)
0
20
40
60
80
0
250
500
750
1000


Deer Island Flats
Broad Sound
Future Outfall Site
Nantasket Beach
Centrotubular HV (%)
Centrotubular HV (%)
Liver Dieldrin ng/g

Winter Flounder Catch Per Unit Effort



Deer Island: trawls in 1987/88 made by RV Wilbur (25' headrope). No data for 1989. All later trawls made by FV Odessa (53' head rope).

DMF: all trawls made by RV Gloria Michelle (39' headrope).

SUGGESTIONS FOR FUTURE CONCERNS AND ACTIVITIES

- The largely unaddressed question is fish health - both in terms of the individual and the population. This is not a limitation limited to the MWRA HOM - it is a limitation of today's knowledge. Sick fish in the wild don't last long enough to be monitored - they are easy prey. That is not to say infectious and non-infectious disease is not important to population health, just that it is very hard to measure - my proposal to the WHOI/MIT PHd program purported to do just this - you have heard today what I actually did!

- What could be done to augment our understanding of population health?

- Catch per unit effort, and how it dropped after the cessation of sludge discharge. Discuss the seesaw between nutrient loading being a nutritional benefit that may outweigh chemical stress.

- Need to look at harbor flounder population in light of region wide population trends.

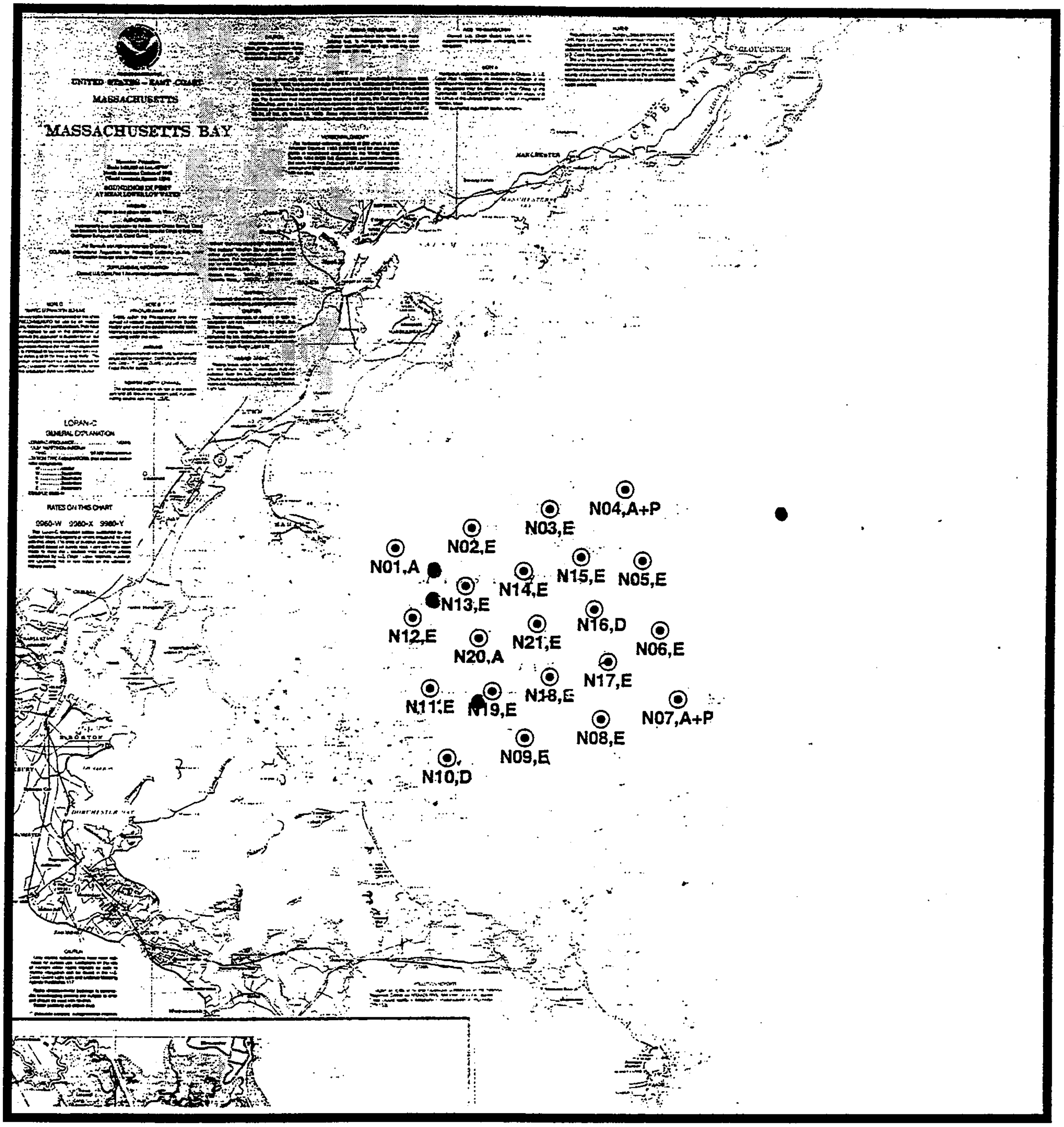
- Could establish a quantitative survey of young of the year at selected Boston Harbor sites. Currently DMF do an annual beach seine survey on the south side of the Cape only, along with Spring and Fall groundfish surveys statewide for adults.

- Could also revisit the flounder migration question given the current acoustic tracking technology - need a surface active robot to follow the tag and report back position. Can do this @ WHOI today for weeks at a time maybe - need proof of concept.

APPENDIX B-3
Not Available:
Mussel Watch Results: Phil Downey

APPENDIX B-4
Flux Measurements: Brian Howes

Station Map



N

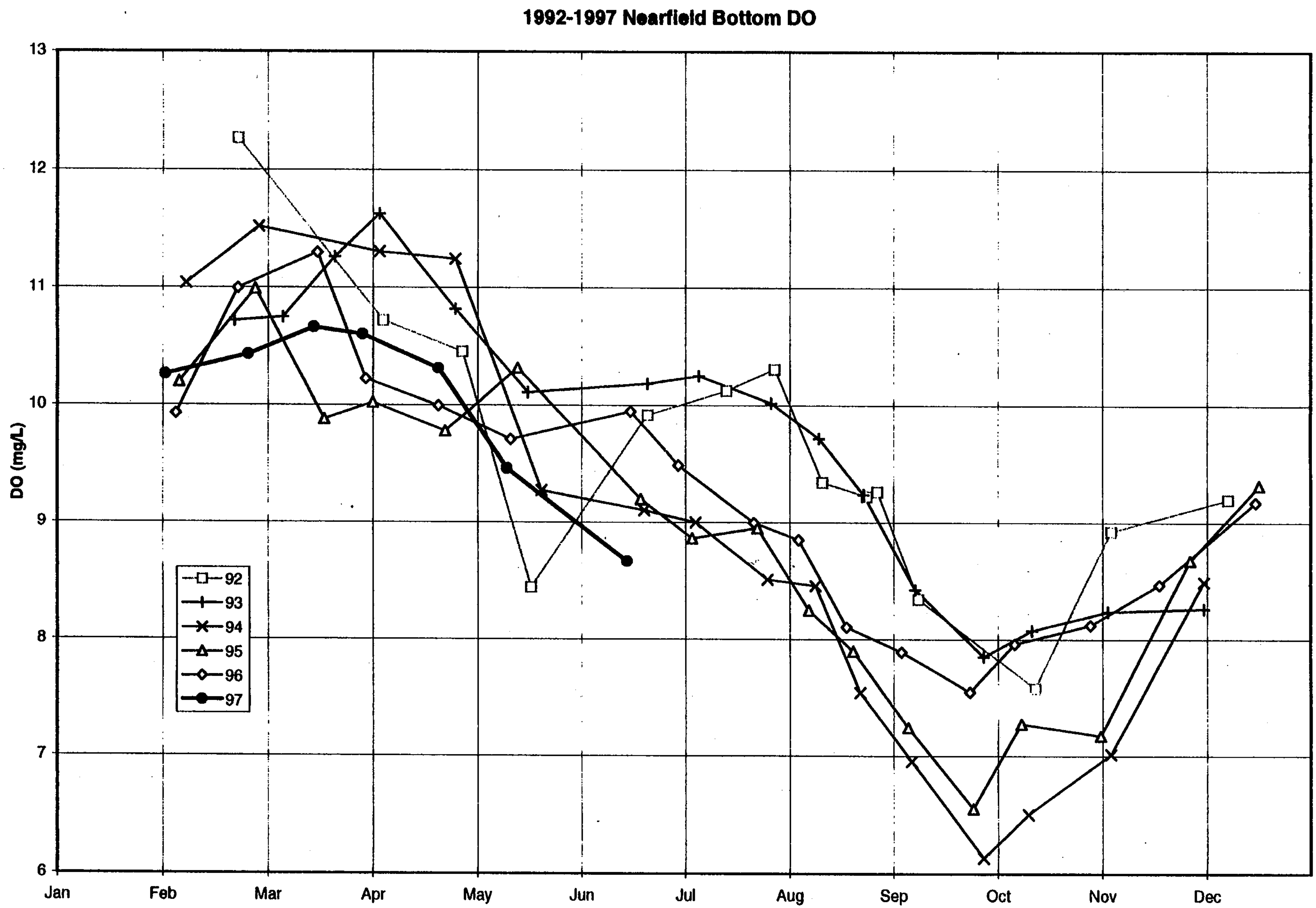
LEGEND

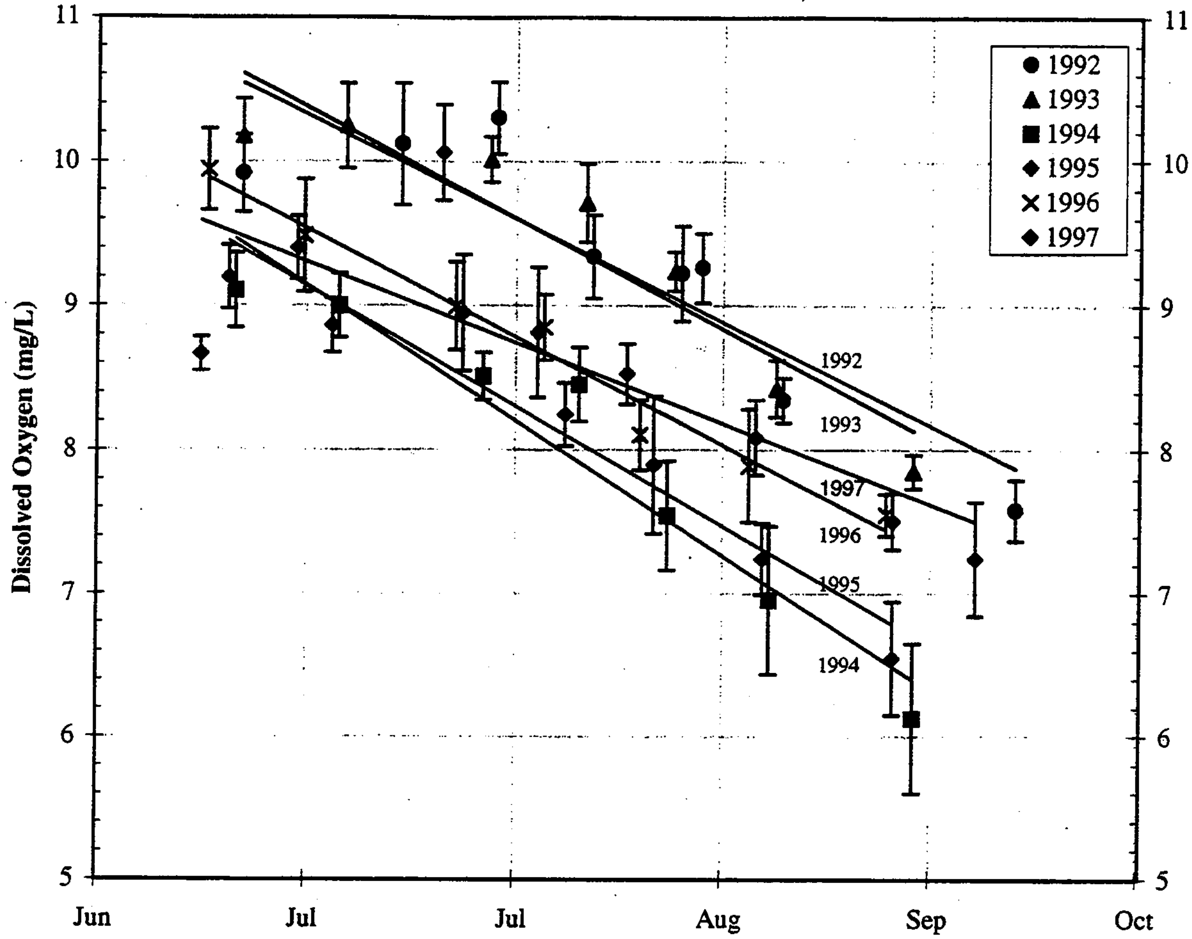
N01	Sampling Location Name
A,D,E	Sampling Type

0 5 10

Nautical Miles

Station Map courtesy of ENSR Consulting & Engineering


1992-1997 Nearfield Bottom DO
DO (mg/L)
13
12
11
10
9
8
7
6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
92
93
94
95
96
97



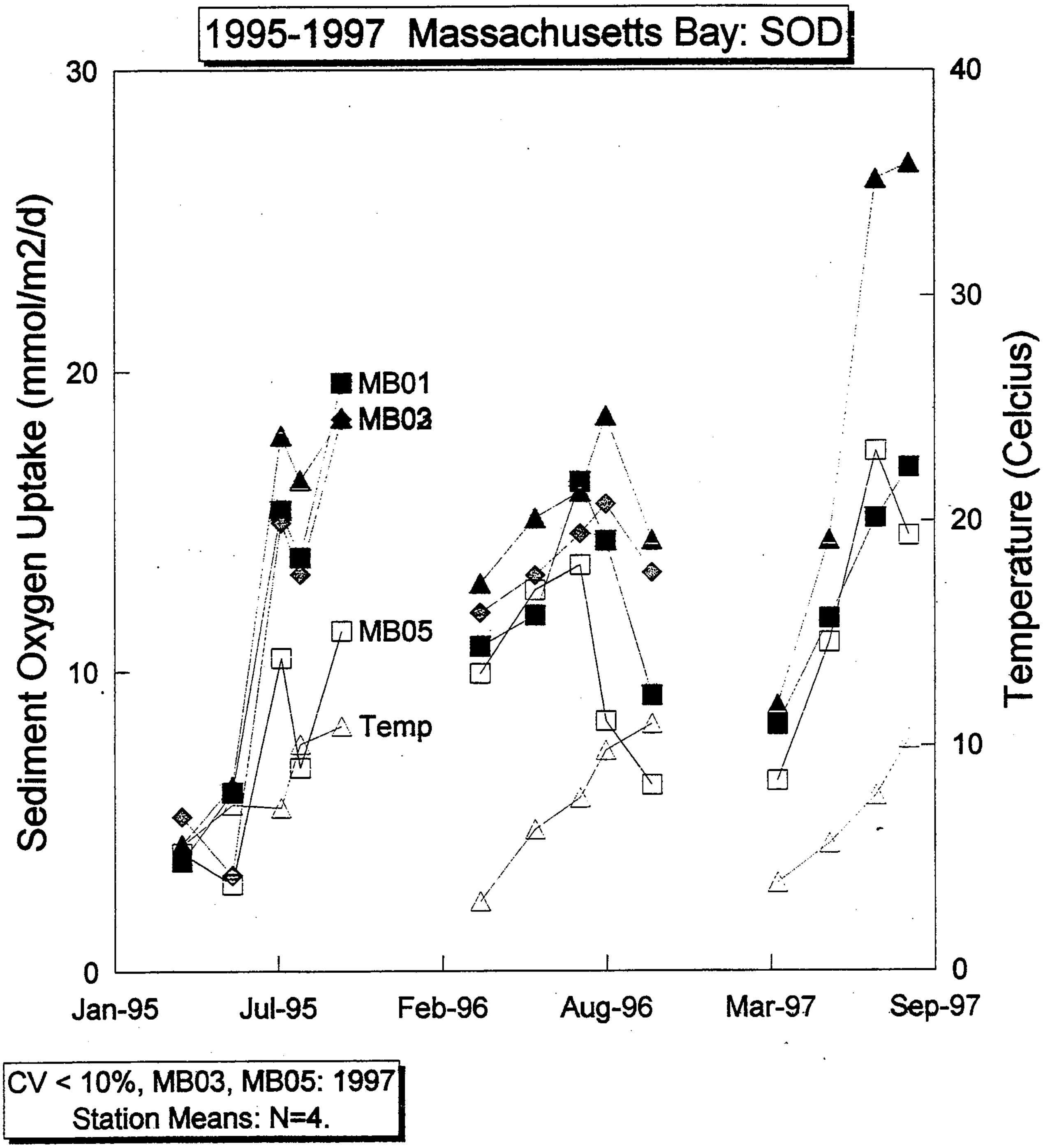
Year	Slope (mg/L/day)	Intercept* (mg/L)	R^2
1992	-0.024	11.0	0.808
1993	-0.025	11.1	0.885
1994	-0.031	10.1	0.929
1995	-0.027	9.9	0.932
1996	-0.025	10.3	0.978
1997	-0.020	9.8	0.632

FIGURE 6-3

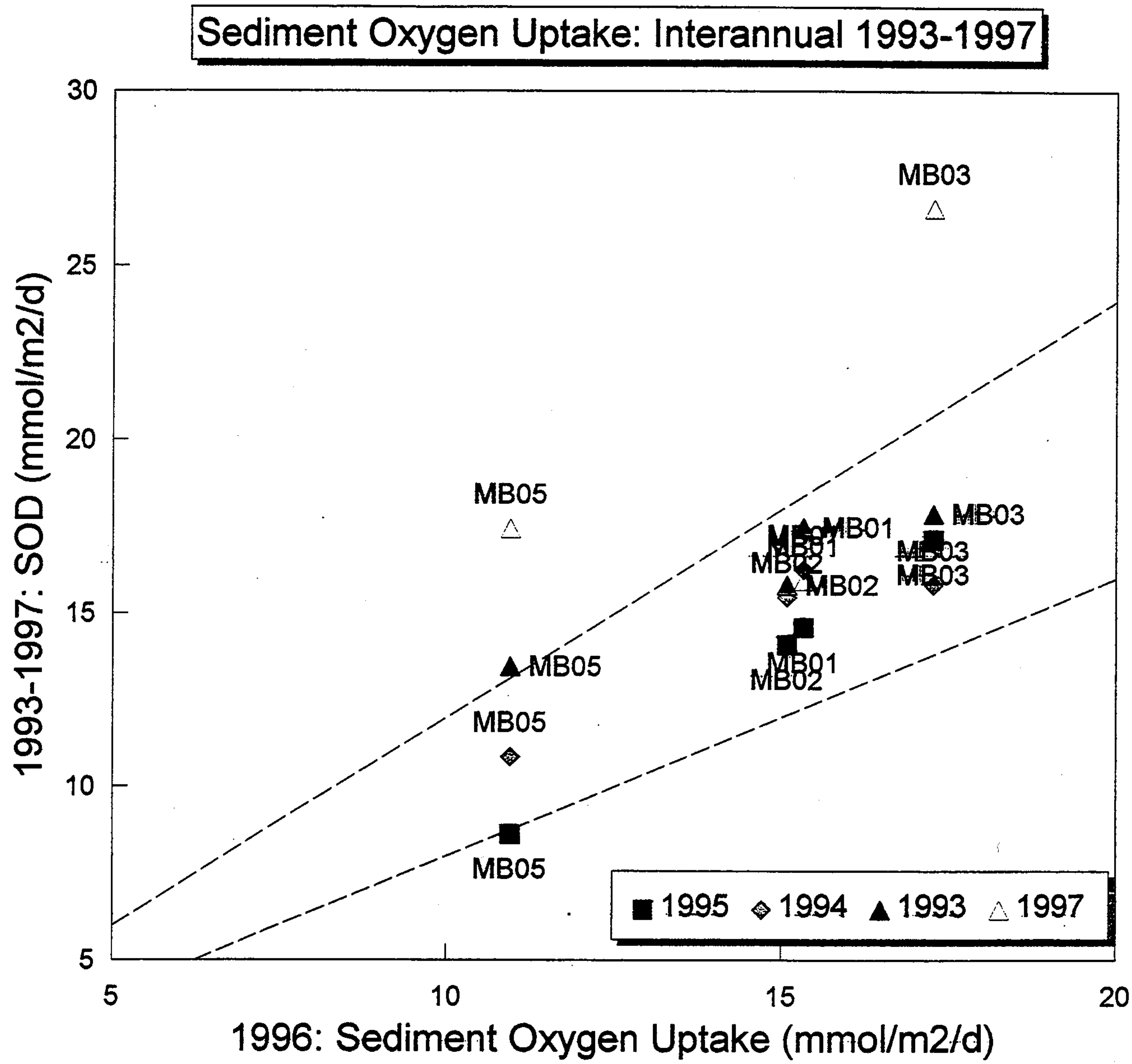
Nearfield Dissolved Oxygen Concentrations in Bottom Waters

Symbols indicate the mean of 17 nearfield stations; error bars represent +/- one standard deviation.

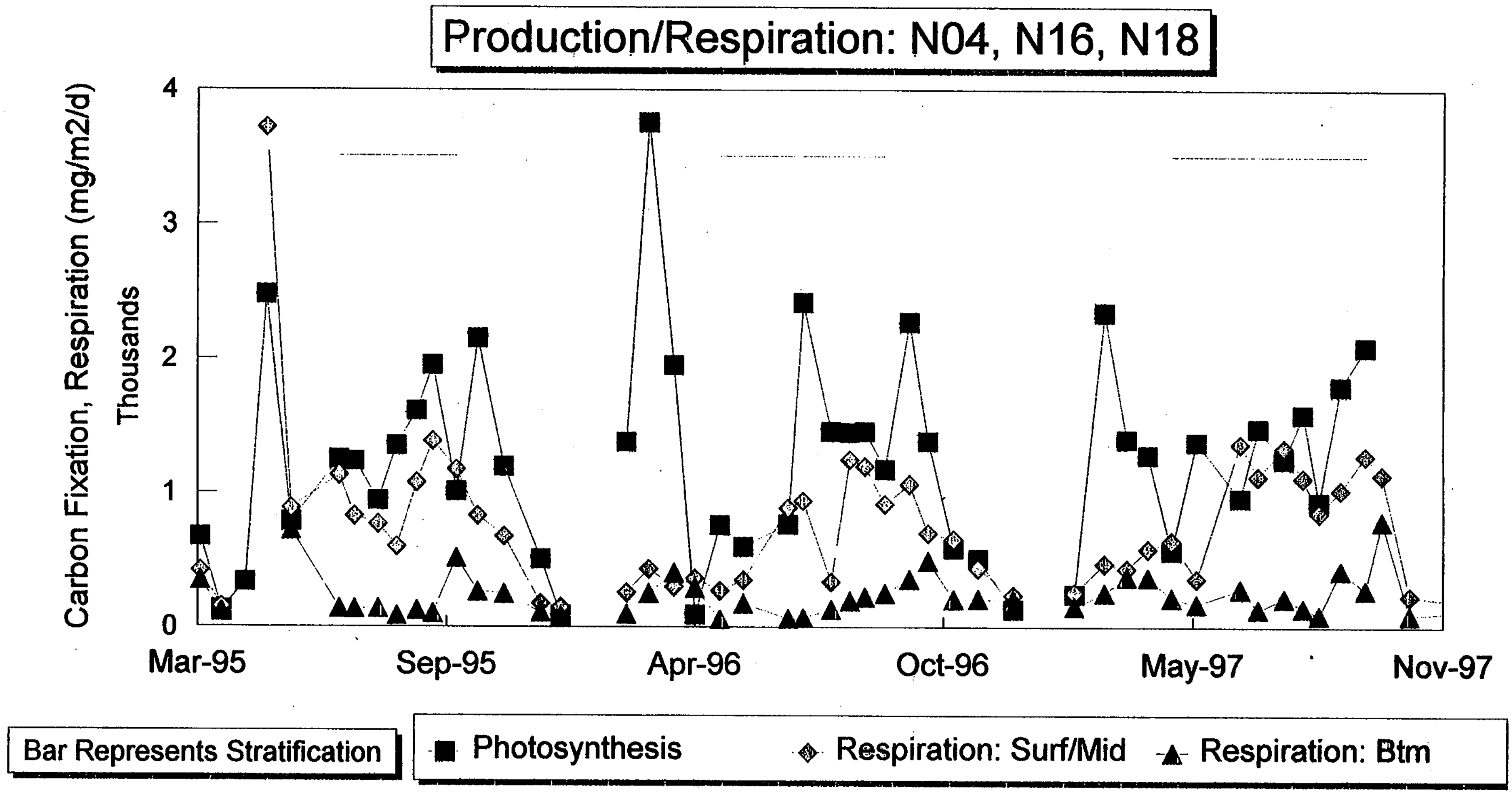
To Be Printed

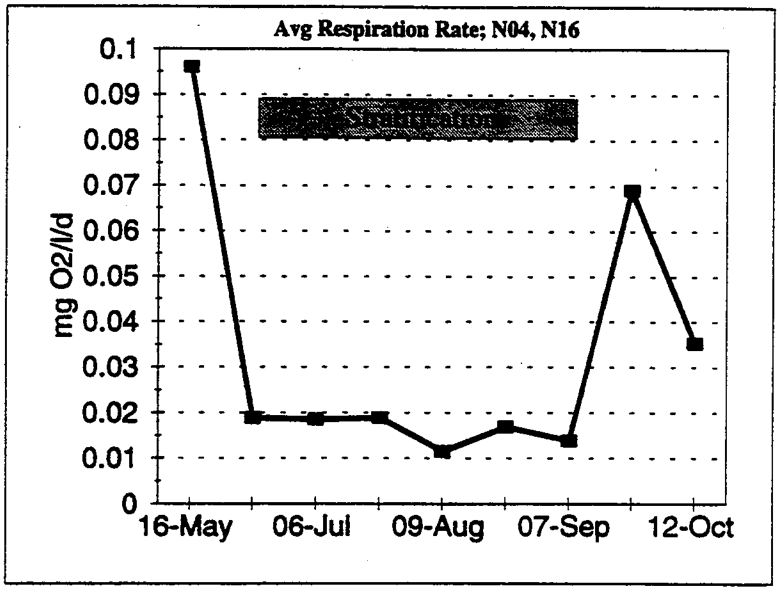


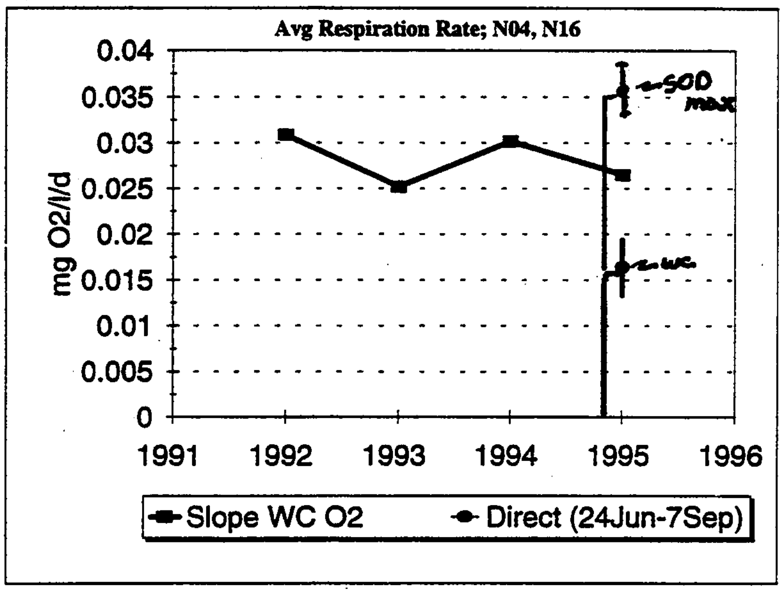
1995-1997 Massachusetts Bay: SOD
Sediment Oxygen Uptake (mmol/m2/d)
Temperature (Celcius)
30
20
10
0
40
30
20
10
0
MB01
MB03
MB05
Temp
Jan-95
Jul-95
Feb-96
Aug-96
Mar-97
Sep-97
CV < 10%, MB03, MB05: 1997
Station Means: N=4.



All Data: Mean of July and August
Lines represent 20% difference from 1996.


Production/Respiration: N04, N16, N18
Carbon Fixation, Respiration (mg/m2/d)
Thousands
4
3
2
1
0
Mar-95
Sep-95
Apr-96
Oct-96
May-97
Nov-97
Bar Represents Stratification
Photosynthesis
Respiration: Surf/Mid
Respiration: Btm


Avg Respiration Rate; N04, N16
Stratification
mg O2/l/d
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
16-May
06-Jul
09-Aug
07-Sep
12-Oct


Avg Respiration Rate; N04, N16
mg O2/l/d
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1991
1992
1993
1994
1995
1996
SOD max
WC
Slope WC O2
Direct (24Jun-7Sep)

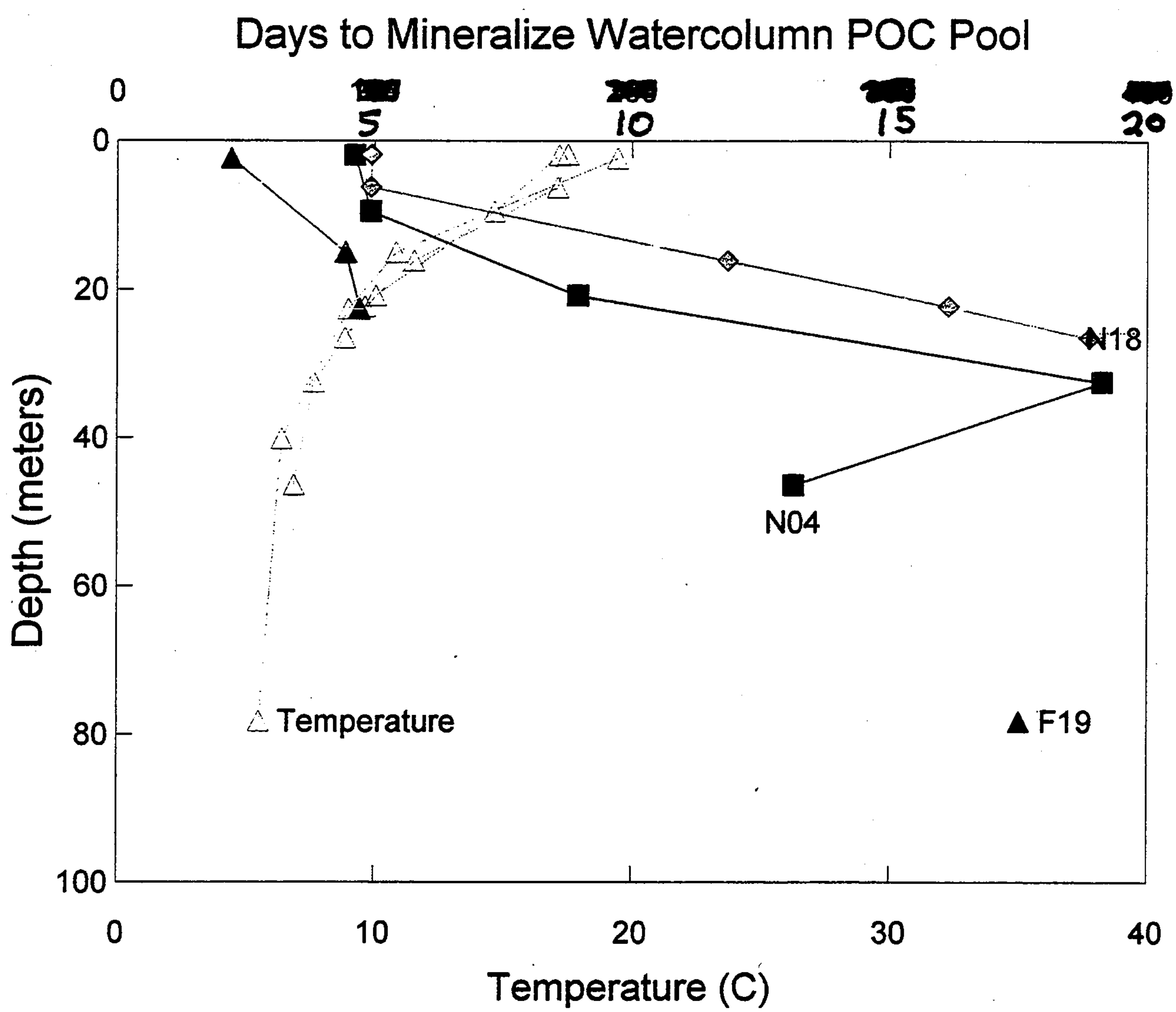
MASSACHUSETTS BAY OXYGEN DYNAMICS : STRATIFIED INTERVAL

Year	Observed Btm Water D.O. Decline (mg/L/d)	Watercolum Respiration Potential Decline (mg/L/d)	Sediment Respiration Potential Decline (mg/L/d)	Ratio Pot/Obs
1992	0.024			
1993	0.025			
1994	0.031			
1995	0.027	0.0168	0.0161	1.22
1996	0.025	0.0182	0.0213	1.58
1997	0.020 ***	0.0226	0.0262	2.44 (1.952) **

*** D.O. "intrusion" year.

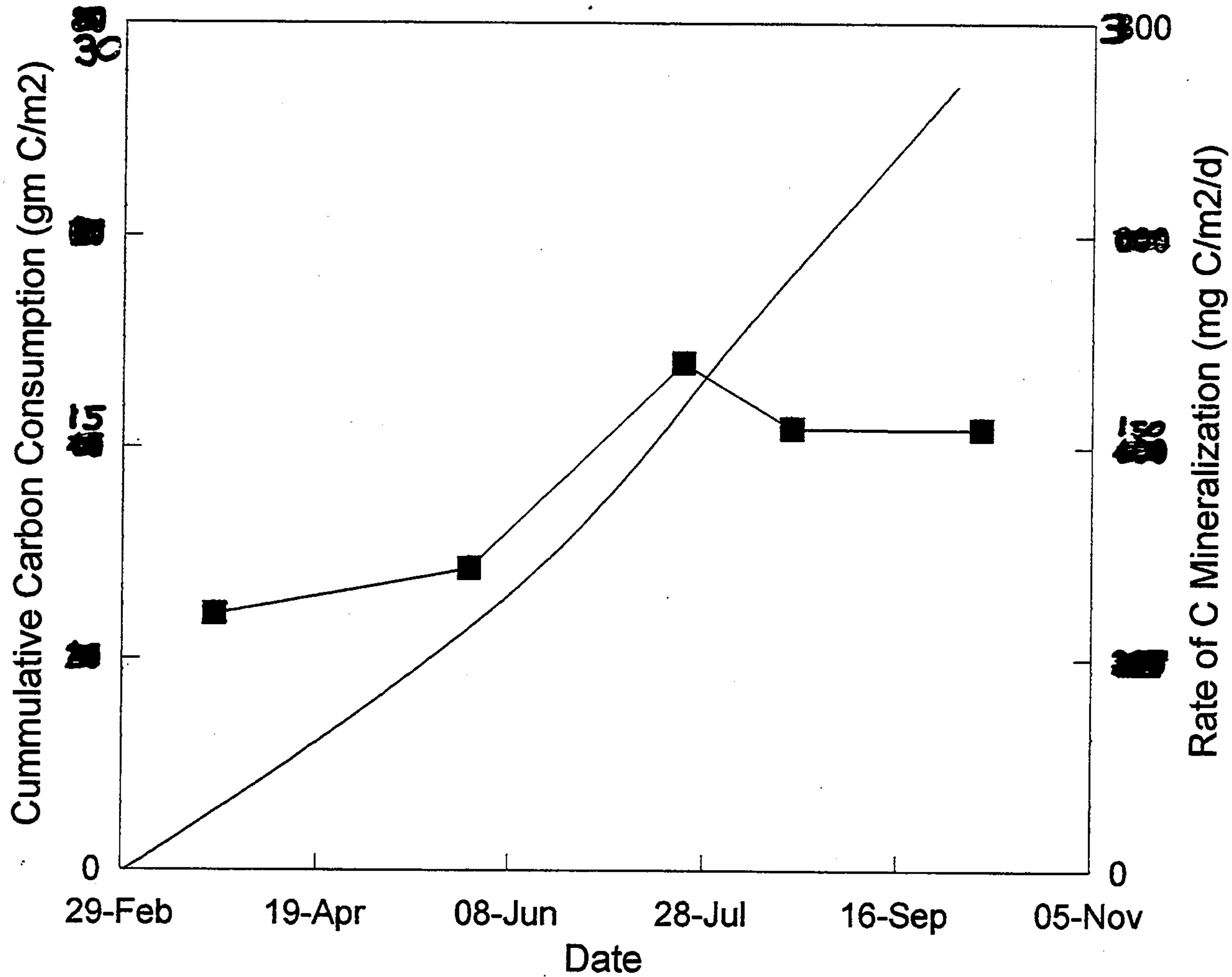
** using mean obs.

Stratified Period 1997: Watercolumn Profiles



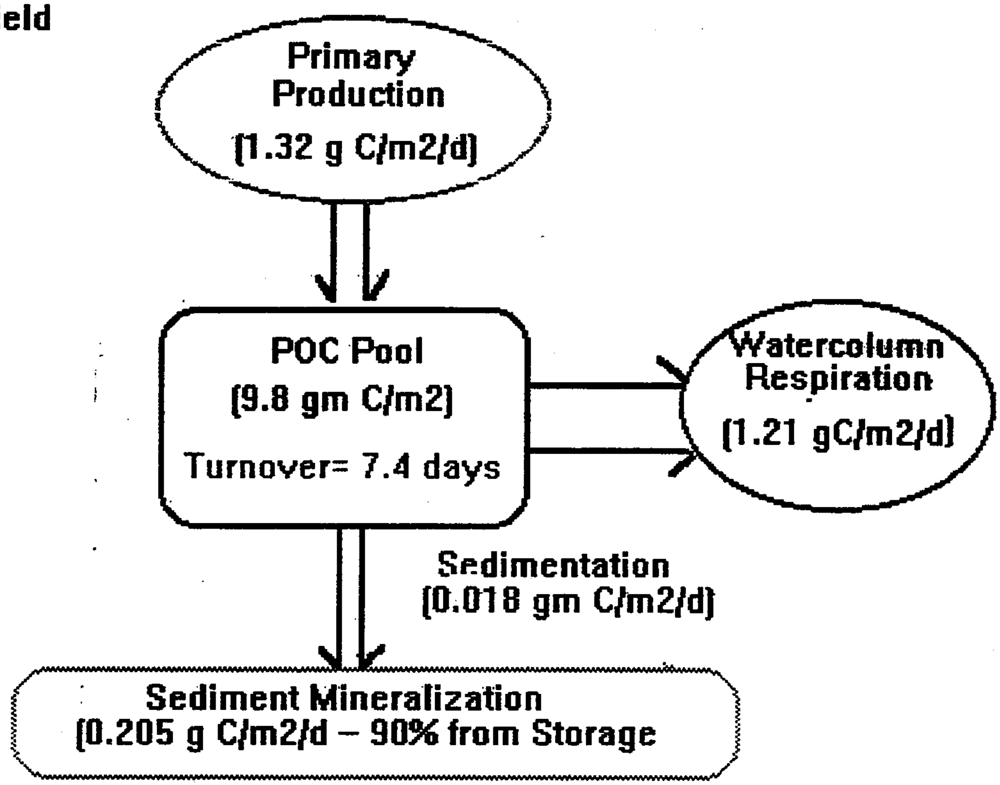
Based upon watercolumn respiration rates only.

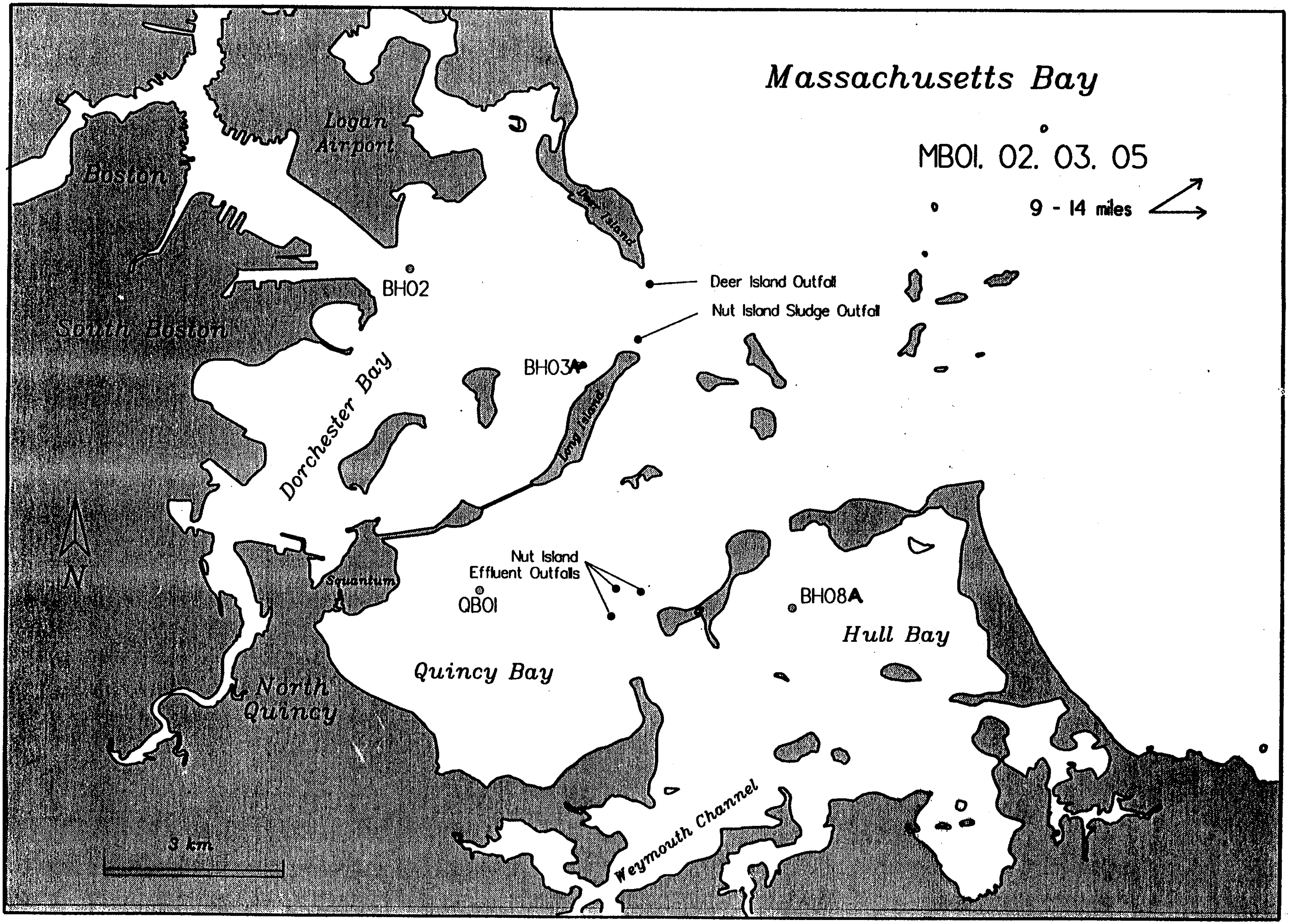
Mass Bay Sediment Carbon Mineralization: Stratified Period



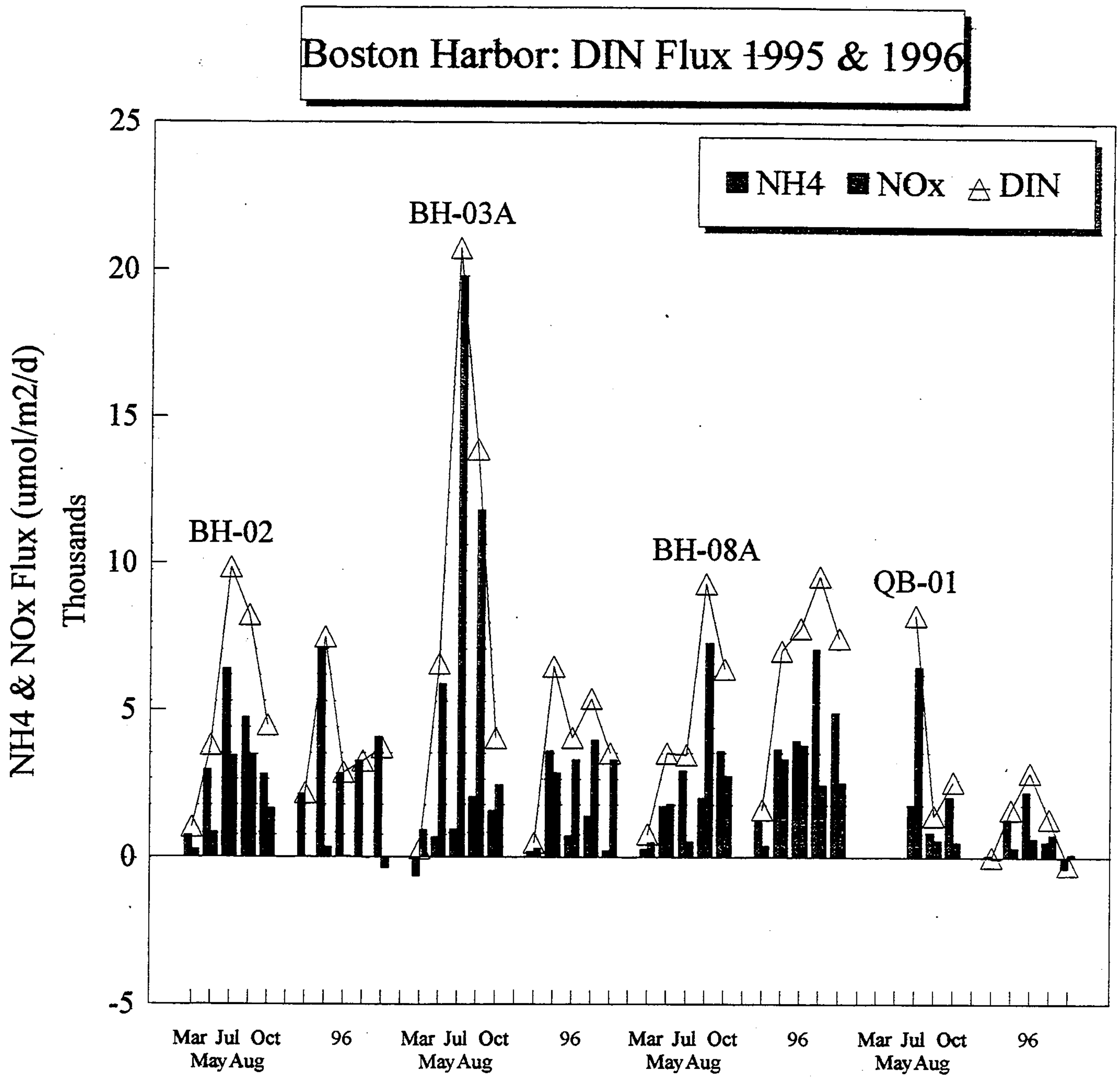
Means of 1995, 1996. Higher rates were found in 1997.
ca. 100 gm C of Unstratified Production is "Available for deposition.

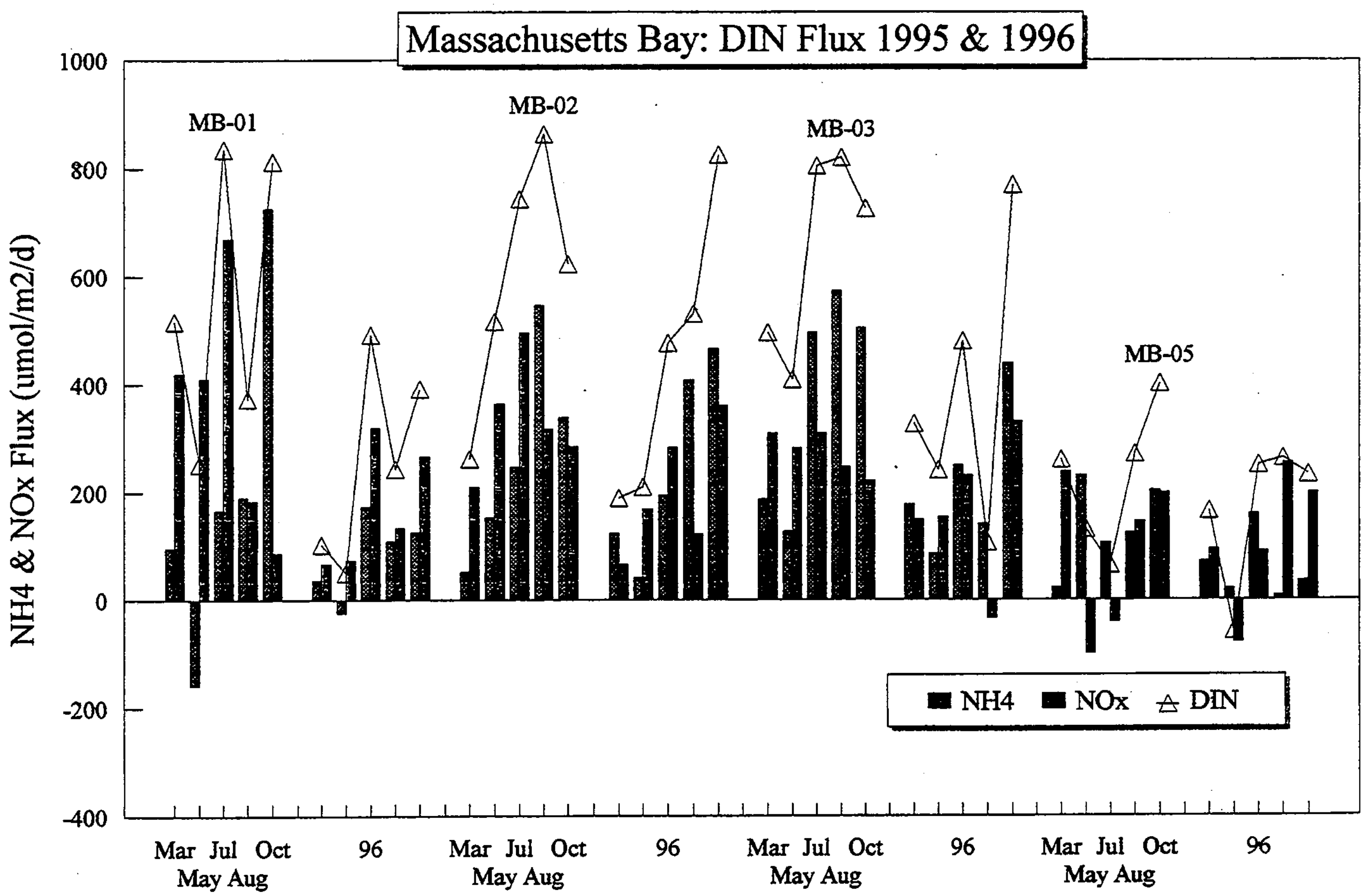
Mass Bay Nearfield Carbon Balance: Stratified Period

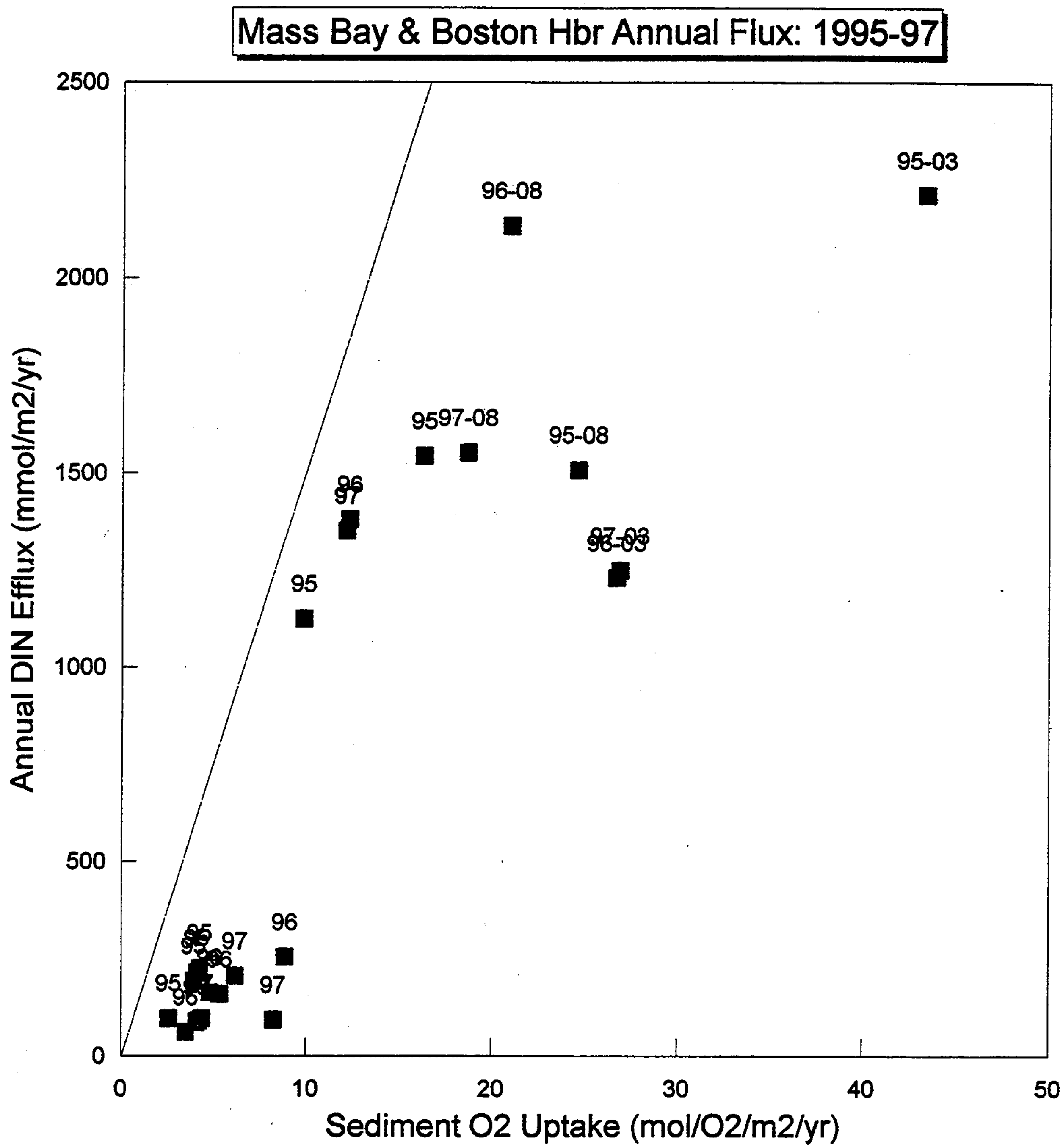




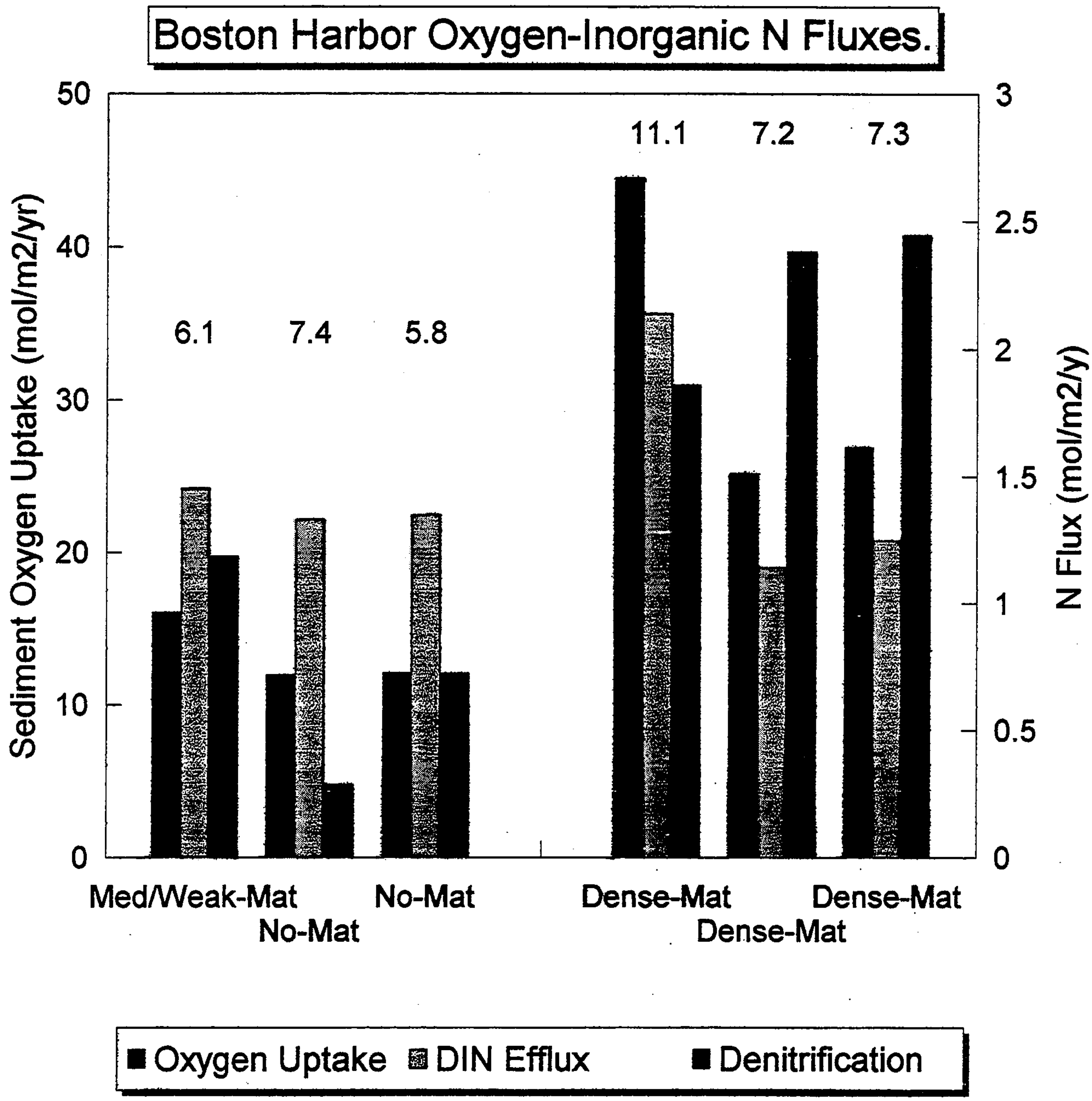
Massachusetts Bay
MB01. 02. 03. 05
9 - 14 miles
Logan Airport
Boston
South Boston
Deer Island
Deer Island Outfall
Nut Island Sludge Outfall
BH02
BH03A
Long Island
Dorchester Bay
Squantum
Nut Island Effluent Outfalls
QB01
BH08A
Hull Bay
Quincy Bay
North Quincy
Weymouth Channel
3 km
N


Boston Harbor: DIN Flux 1995 & 1996
NH4
NOx
DIN
BH-02
BH-03A
BH-08A
QB-01
NH4 & NOx Flux (umol/m2/d)
Thousands
25
20
15
10
5
0
-5
Mar Jul Oct
May Aug
96

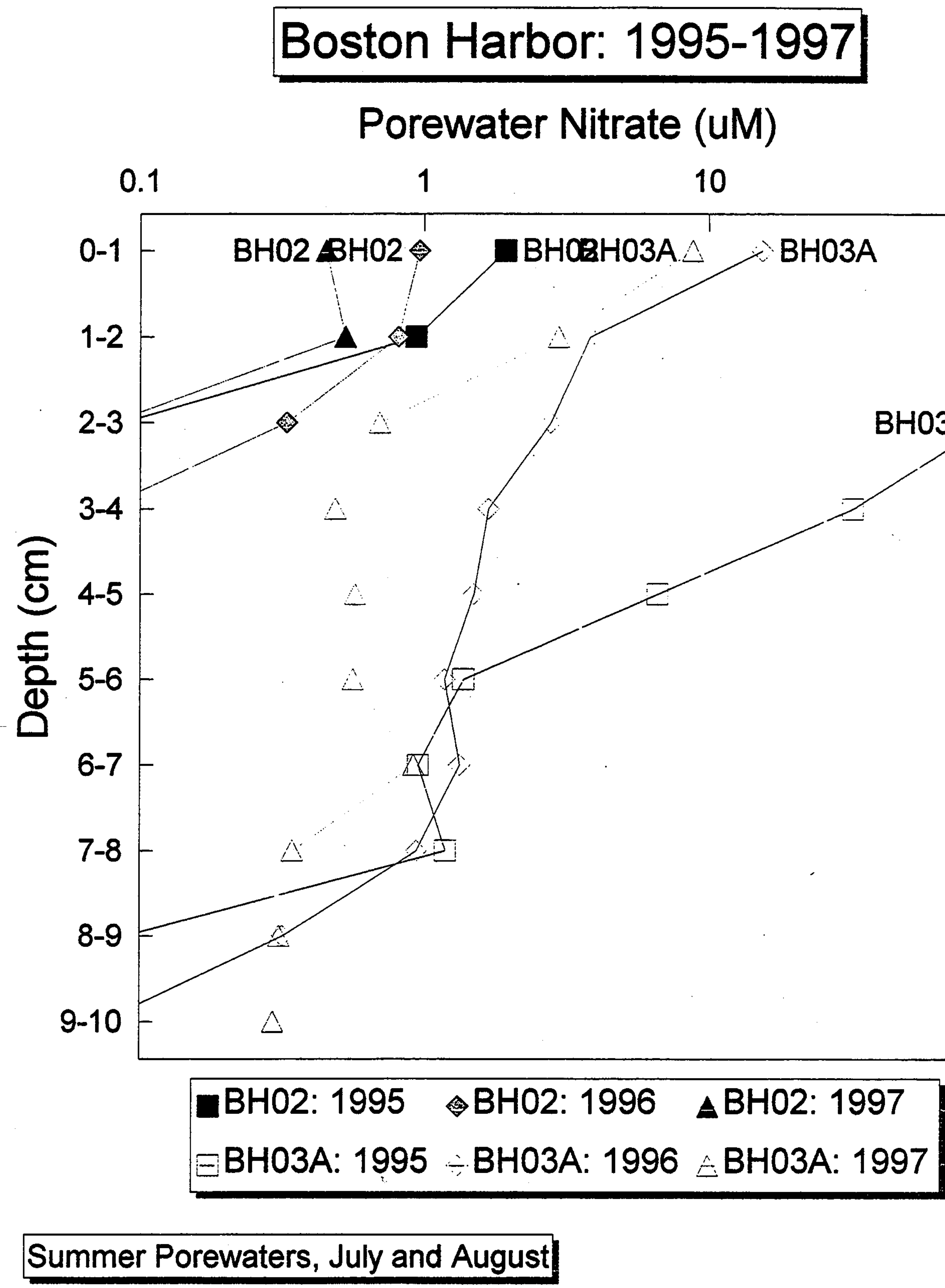

Massachusetts Bay: DIN Flux 1995 & 1996
NH4 & NOx Flux (umol/m2/d)
1000
800
600
400
200
0
-200
-400
MB-01
MB-02
MB-03
MB-05
NH4
NOx
DIN
Mar Jul Oct
May Aug
96
Mar Jul Oct
May Aug
96
Mar Jul Oct
May Aug
96
Mar Jul Oct
May Aug
96



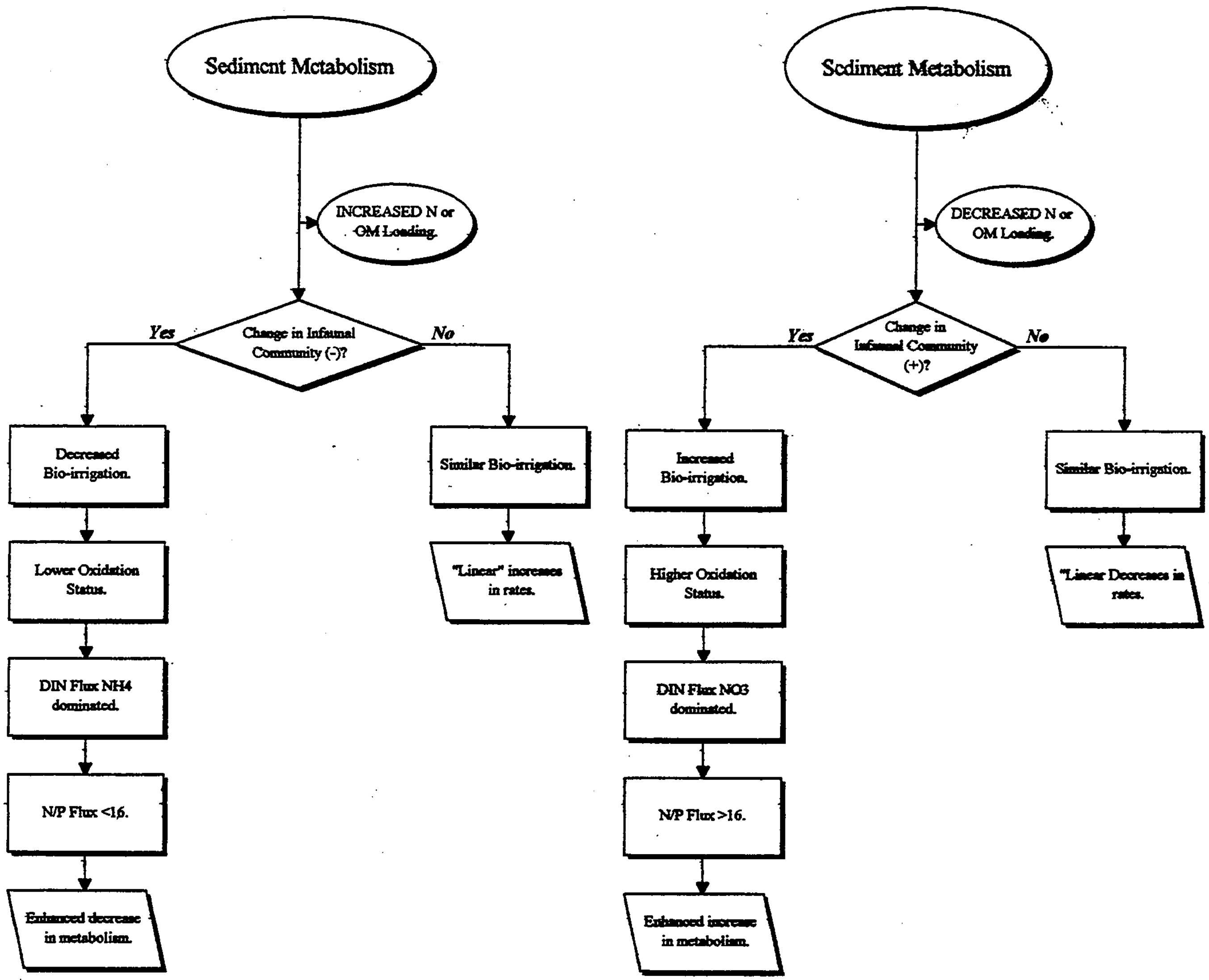
Annual Fluxes; Line indicates DIN Flux to meet C/N of 6.625
Values below line indicate N burial or denitrification.

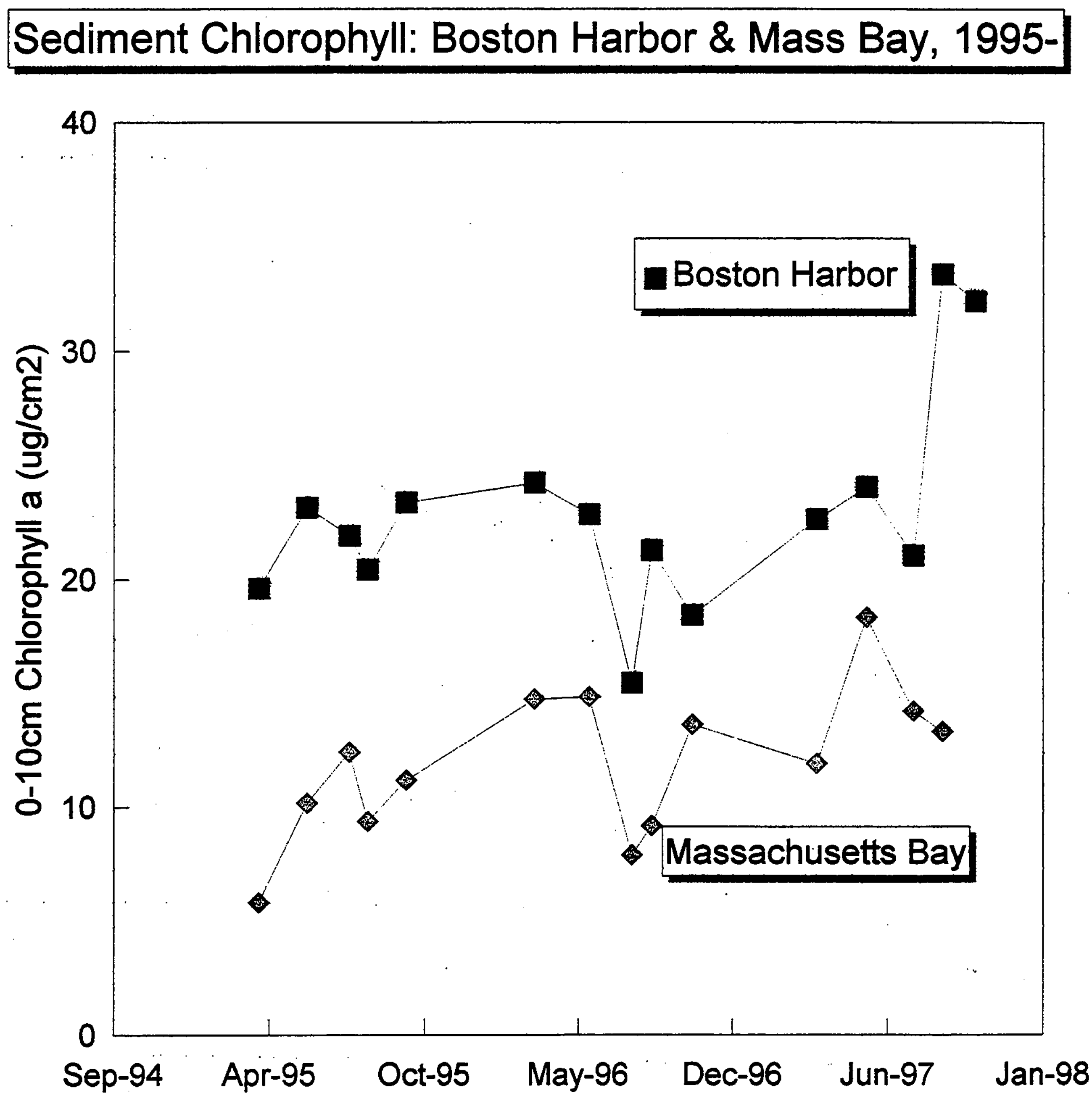


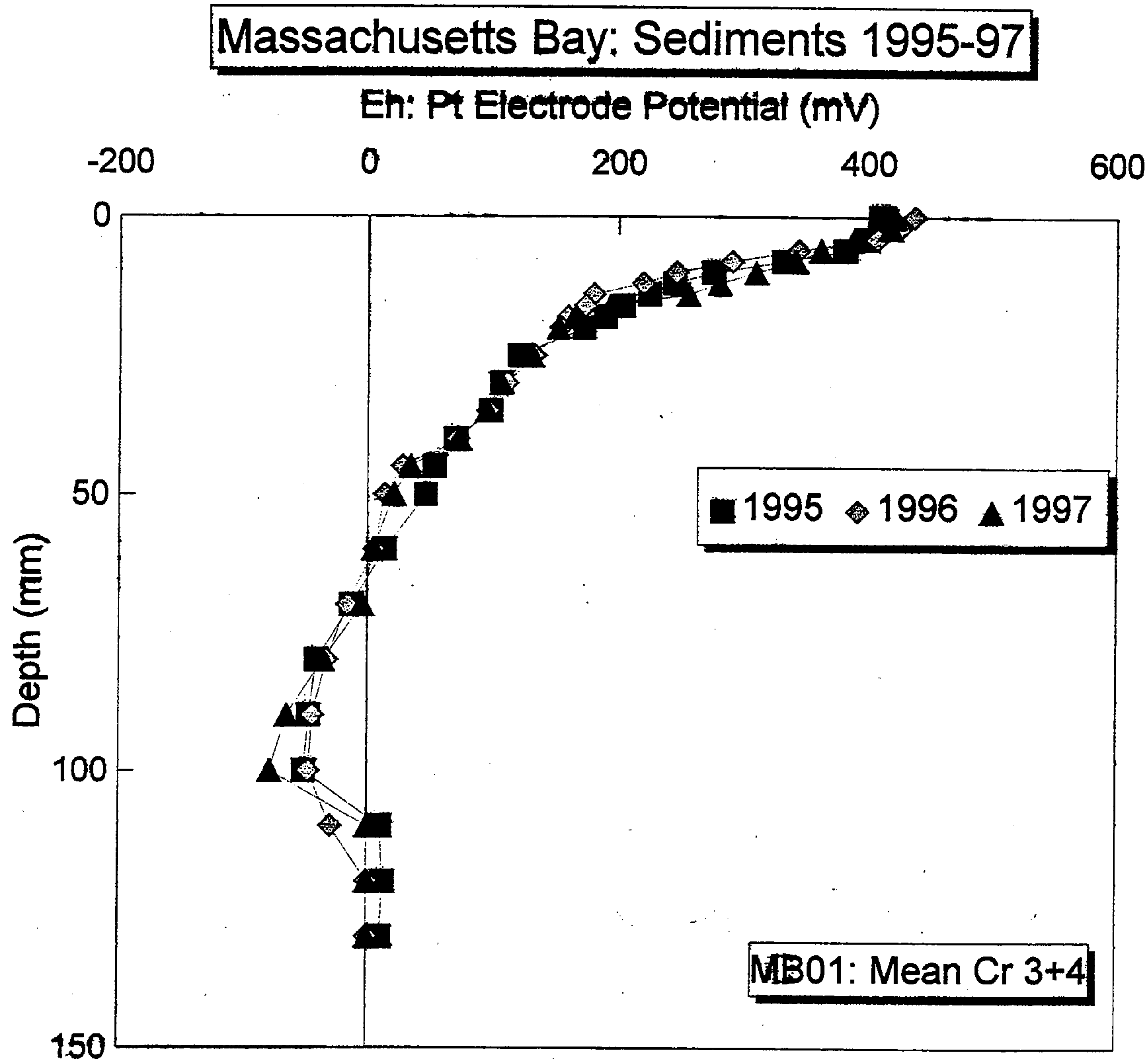
Values above bars are calculated "C/N" ratios.
Data: 1995, 1996, 1997

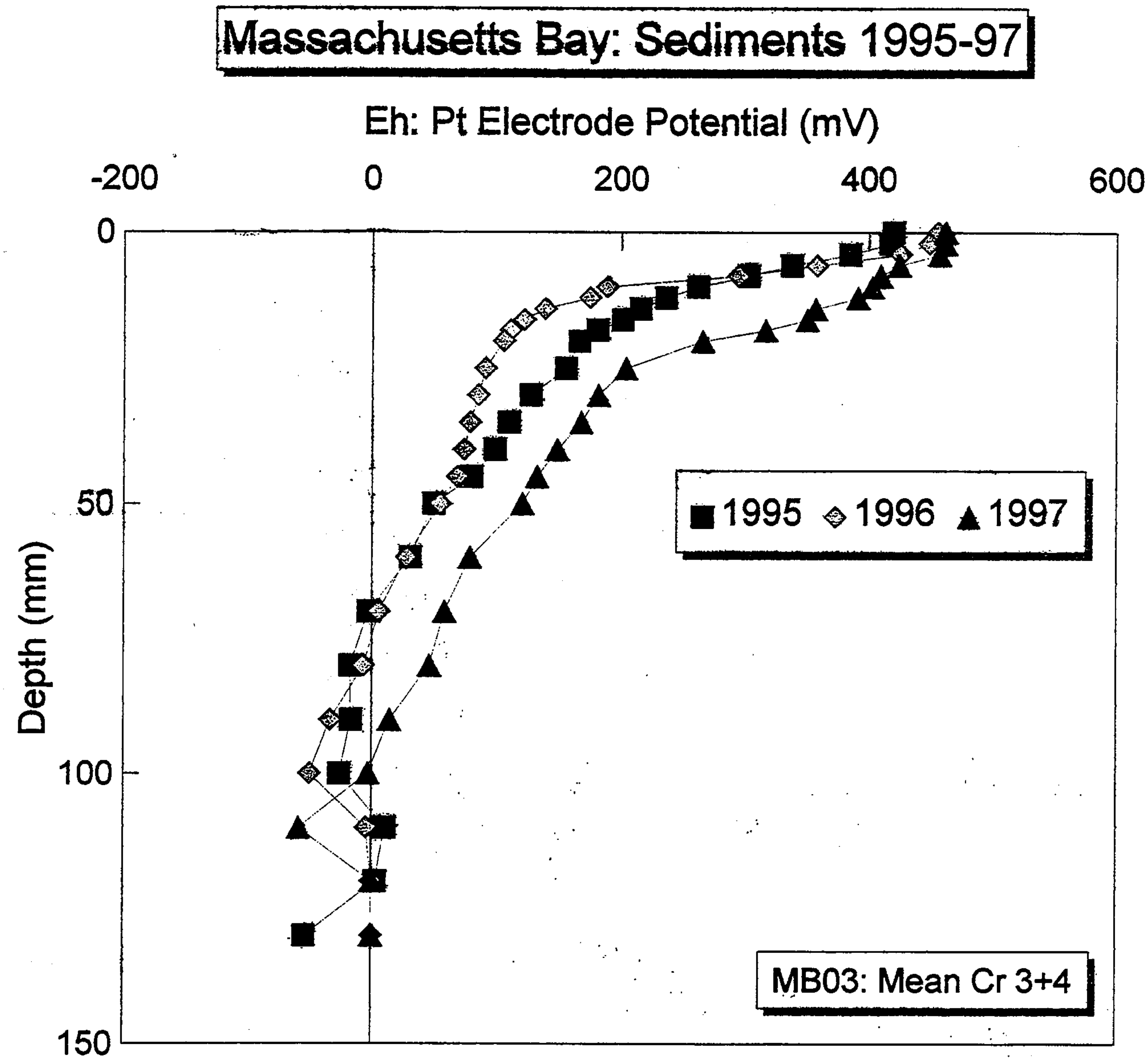

Boston Harbor: 1995-1997
Porewater Nitrate (uM)
0.1
1
10
100
Depth (cm)
0-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
BH02
BH02
BH02
BH03A
BH03A
BH03A
BH02: 1995
BH02: 1996
BH02: 1997
BH03A: 1995
BH03A: 1996
BH03A: 1997
Summer Porewaters, July and August

Bio-irrigation and Denitrification Case Study: Boston Harbor.




Sediment Chlorophyll: Boston Harbor & Mass Bay, 1995-
0-10cm Chlorophyll a (ug/cm2)
40
30
20
10
0
Boston Harbor
Massachusetts Bay
Sep-94
Apr-95
Oct-95
May-96
Dec-96
Jun-97
Jan-98


Massachusetts Bay: Sediments 1995-97
Eh: Pt Electrode Potential (mV)
-200
0
200
400
600
0
50
100
150
Depth (mm)
1995
1996
1997
MB01: Mean Cr 3+4



Massachusetts Bay: Sediments 1995-97
Eh: Pt Electrode Potential (mV)
-200
0
200
400
600
0
50
100
150
Depth (mm)
1995
1996
1997
MB03: Mean Cr 3+4

APPENDIX B-5
Soft Bottom Benthic 1996 Results: Blake and Maciolek

BENTHIC INFAUNAL MONITORING

1996 RESULTS

JAMES A. BLAKE AND NANCY J. MACIOLEK

Benthic Infaunal Monitoring

BIOLOGY TEAM

- **Polychaetes: Brigitte Hilbig; Gene Ruff; Jim Blake**
- **Oligochaetes: Russ Winchell**
- **Crustacea and Mollusca: Isabelle Williams**
- **Nemertea, Sipuncula, Echinoderms: Paula Winchell**
- **Data Analysis: Kristen Wandland; Karen Stocks; Barbara Hecker**
- **Data Synthesis and Reports: Nancy Maciolek; Brigitte Hilbig; Isabelle Williams; Jim Blake**

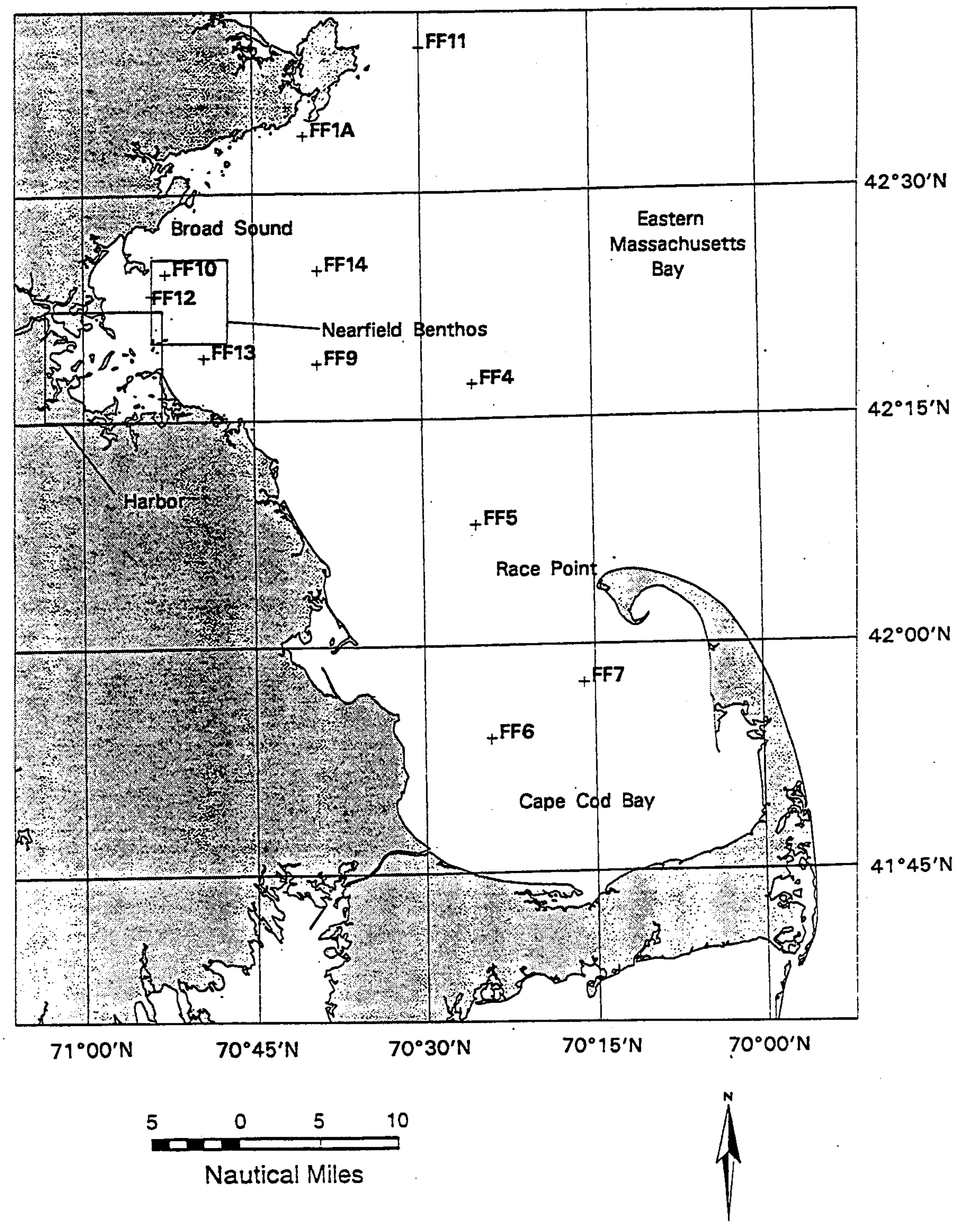
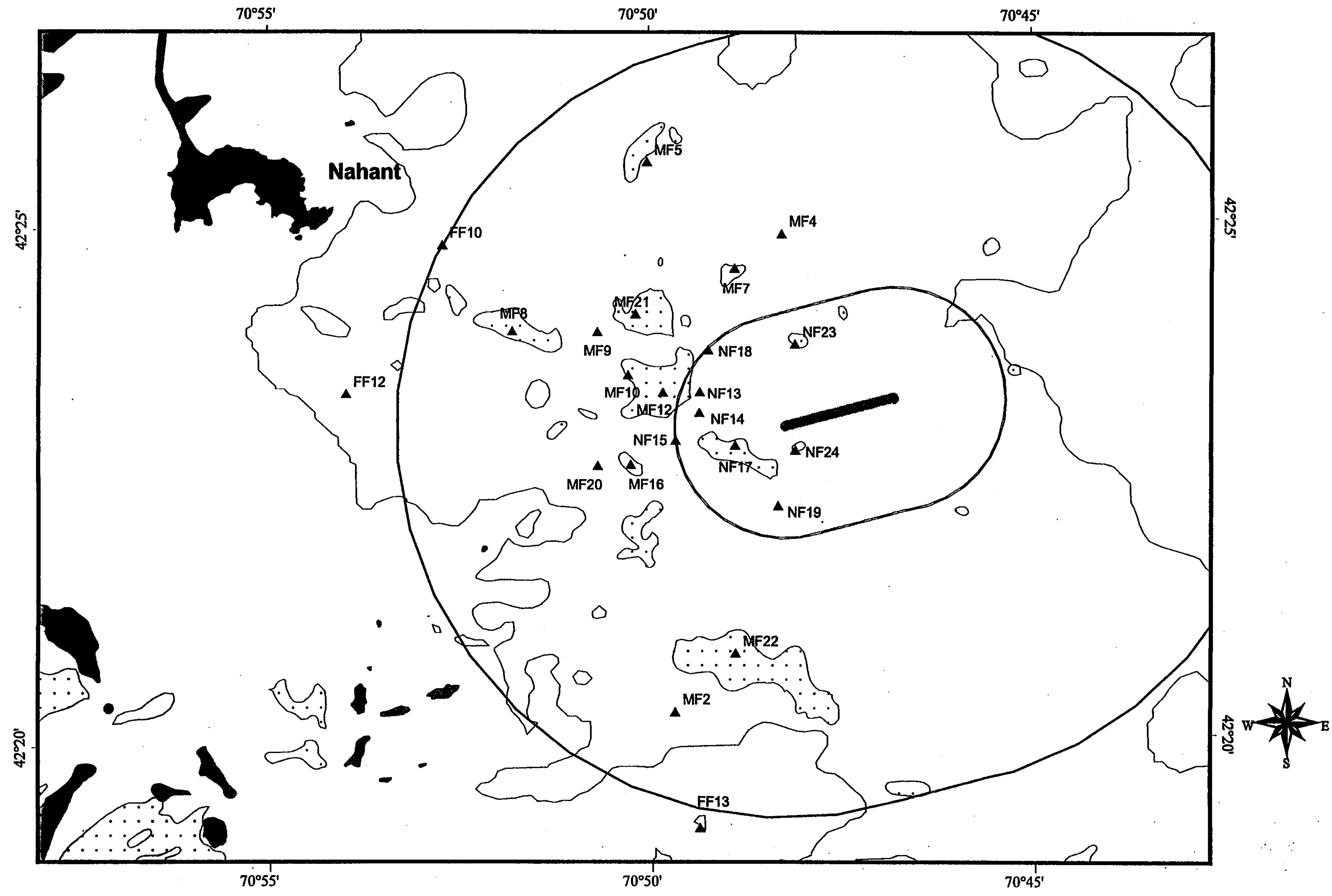


Figure 2. Station locations for farfield grab samples. Boxes indicate Boston Harbor and nearfield survey areas.

Basemap for NF/MF Stations



Benthic Infaunal Monitoring

Methods and Types of Samples

- **Samples collected with Kynar-coated Ted Young Grabs: (1) 0.04 m^2 for Biology and (2) 0.1 m^2 for Chemistry**
- **Biology samples live sieved through 300 μm sieves**
- **Sediment/Chemistry includes: grain-size, CHN, *Clostridium* spores, metals and organics (PAH, PCBs, pesticides, LABs).**
- **Navigation is with DGPS with accuracy of 5-15 m.**
- **Biology Sample processing includes in-house taxonomic identification to the lowest practical level; special effort has been devoted to identifying juveniles retained on the 300-μm sieves.**
- **Sediment/Chemistry samples are processed in various laboratories**
- **Database is fully verified prior to analysis. Analysis is performed with COMPAH and related programs.**

Benthic Infaunal Monitoring

Sediment Characteristics

- **Nearfield Sediments are coarse grained, except for NF24**
- **Midfield Sediments are finer grained**
- **Total Organic Carbon is generally low, highest in finer grained sediments, but always lower than 2%**
- **Carbon/Nitrogen Ratio is highest in the fine grained sediments (>10)**
- **Highs and lows of *Clostridium* also corresponds to fine versus coarse grained sediment**

Benthic Infaunal Monitoring

FAUNAL CHARACTERISTICS

- **Taxonomic Composition NF/MF, and FF: 323 species in 1995 & 1996**

Taxonomic Group	Number Species (Percent)	Number Species (Percent)
	1995	1996
Annelida	132 (51)	152 (47)
Crustacea	69 (27)	84 (26)
Mollusca	26 (10)	53 (16)
Other Taxa	31 (12)	34 (10)
Total Taxa	258	323

- **Taxonomic Compositon NF/MF Only 1995 & 1996**

Taxonomic Group	Number Species (Percent)	Number Species (Percent)
	1995	1996
Annelida	106 (51)	109 (47)
Crustacea	54 (26)	65 (28)
Mollusca	23 (11)	38 (16)
Other Taxa	26 (12)	22 (9)
Total Taxa	209	234

Benthic Infaunal Monitoring

Community Structure

- **Benthic community parameters 1996 were generally similar to those of previous years**

- **Three faunal assemblages have been identified:**

    - **An *Exogone-Corophium*-Oligochaete assemblage at the coarse-sand stations closest to the outfall**
    - **An intermediate spionid/syllid assemblage**
    - **A large *Prionospio-Mediomastus-Ninoe* assemblage in the finer sediments to the west**

- **Community Structure in the nearfield and midfield was largely determined by grain size**

Benthic Infaunal Monitoring

Community Parameters

- Species Richness was higher in 1996 in part due to greater emphasis on identifying small molluscs and other invertebrates
- A high degree of patchiness is evident between stations
- Species diversity varied between stations

Benthic Infaunal Monitoring

1992-1996 SUMMARY STATISTICS

- **Total Mean Infaunal Abundance for Nearfield Stations = 44,159 individuals m^{-2}**
- **Total Mean Infaunal Abundance for Midfield Stations = 45,315 individuals m^{-2}**
- **Average Total Number of Species for Nearfield Stations = 68.9±13.82**
- **Average Total Number of Species for Midfield Stations = 63.2±14.43**
- **Average Species Diversity (Shannon-Wiener-H′) for Nearfield Stations = 2.71±0.32**
- **Average Species Diversity (Shannon-Wiener-H′) for Midfield Stations = 2.57±0.35**

Benthic Infaunal Monitoring

1992-1996 Sediment Summaries

- **Nearfield Sediments are Sandy**
- **Midfield Sediments are Fine sands and Coarse Silts with some Clays**
- **Year to Year Changes in Sediments are most Evident in a Transitional Area between the *Corophium-Exogone* Dominated Sandy Stations and the Muddy Stations**
- **Higher TOC is Correlated with Finer Sediments and Shifts with that Parameter**
- **Spore Counts of *Clostiridium perfringens* are Higher in Finer Sediments**

Benthic Infaunal Monitoring

1992-1996 Faunal Summaries

- Omnivorous Syllids and Amphipods are most abundant at the Sandy Nearfield Station
- Interface Feeding Spionid Species Shift between Years: Ex. *Prionospio* to *Spio* and back
- Head-down Deposit Feeding *Mediomastus californiensis* is the predominant in the muddy Midfield Stations
- Paraonids (*Aricidea*) and Cirratulid (*Tharyx* and *Monticellina*) Polychaetes Occur mostly in Mixed Sediments.
-

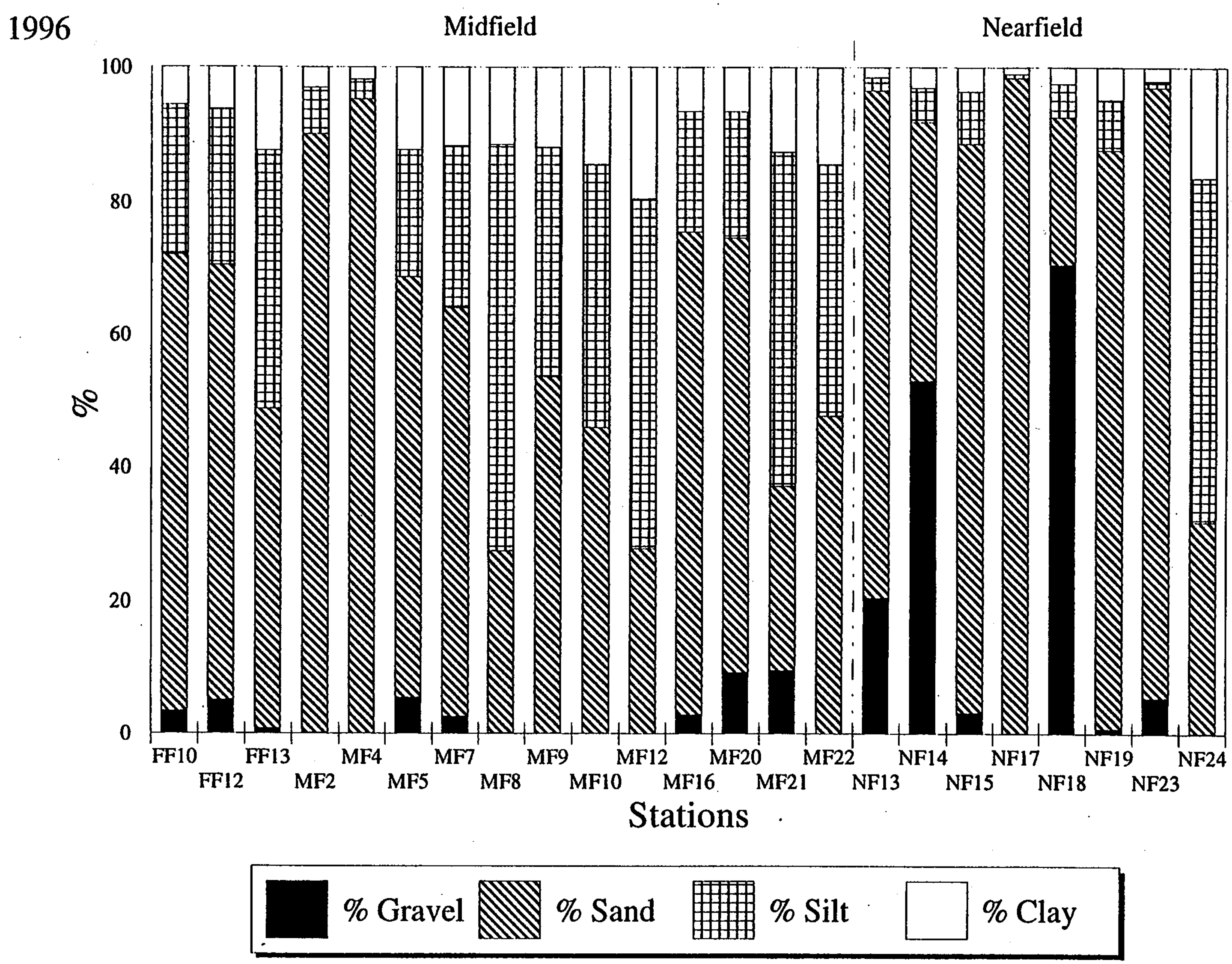
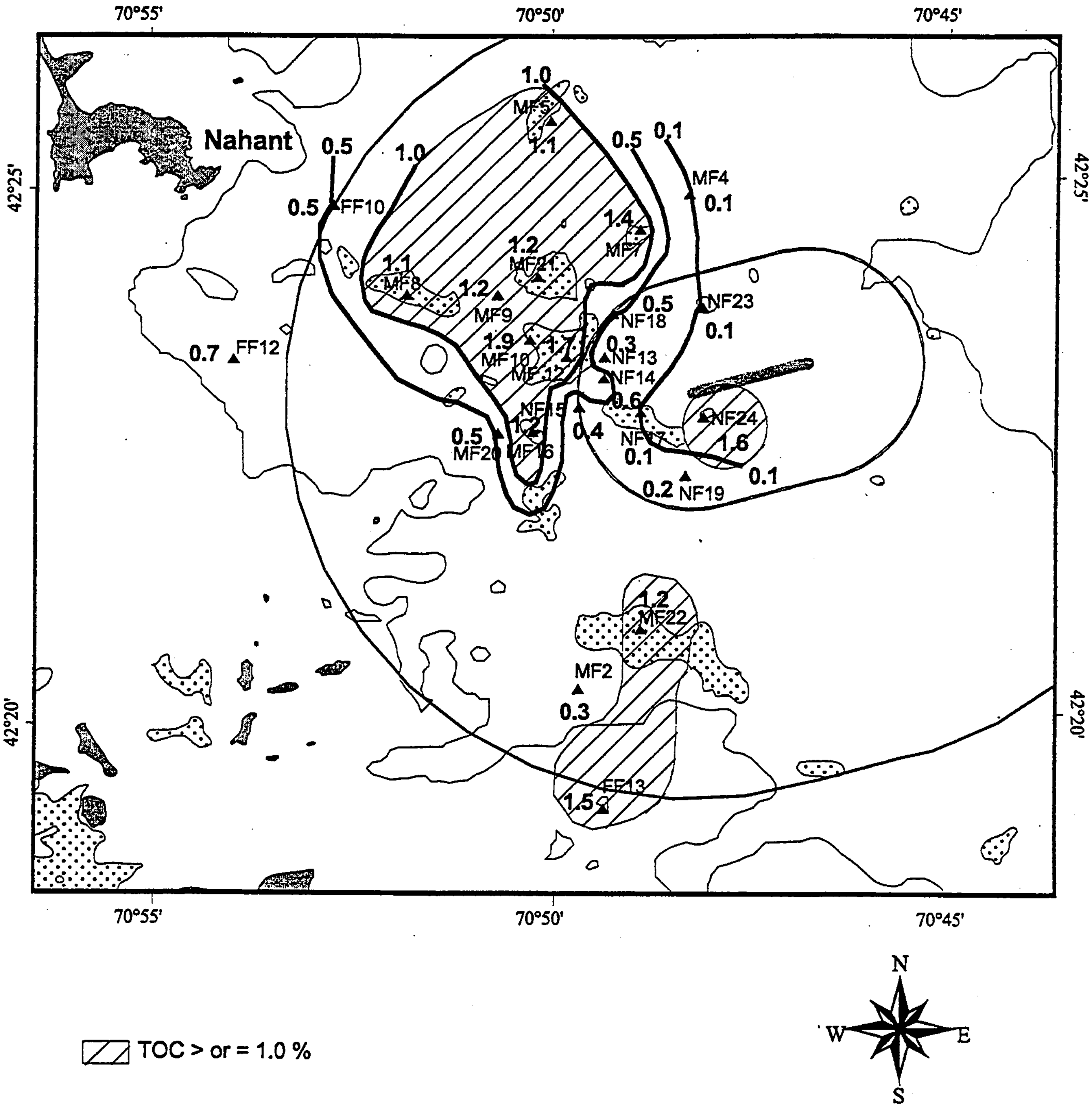


Figure 4. Sediment grain-size composition of the nearfield and midfield stations, August 1996.



TOC > or = 1.0 %

Figure 5. **Areal distribution of total organic carbon (TOC) in sediments of nearfield and midfield in August 1996.**

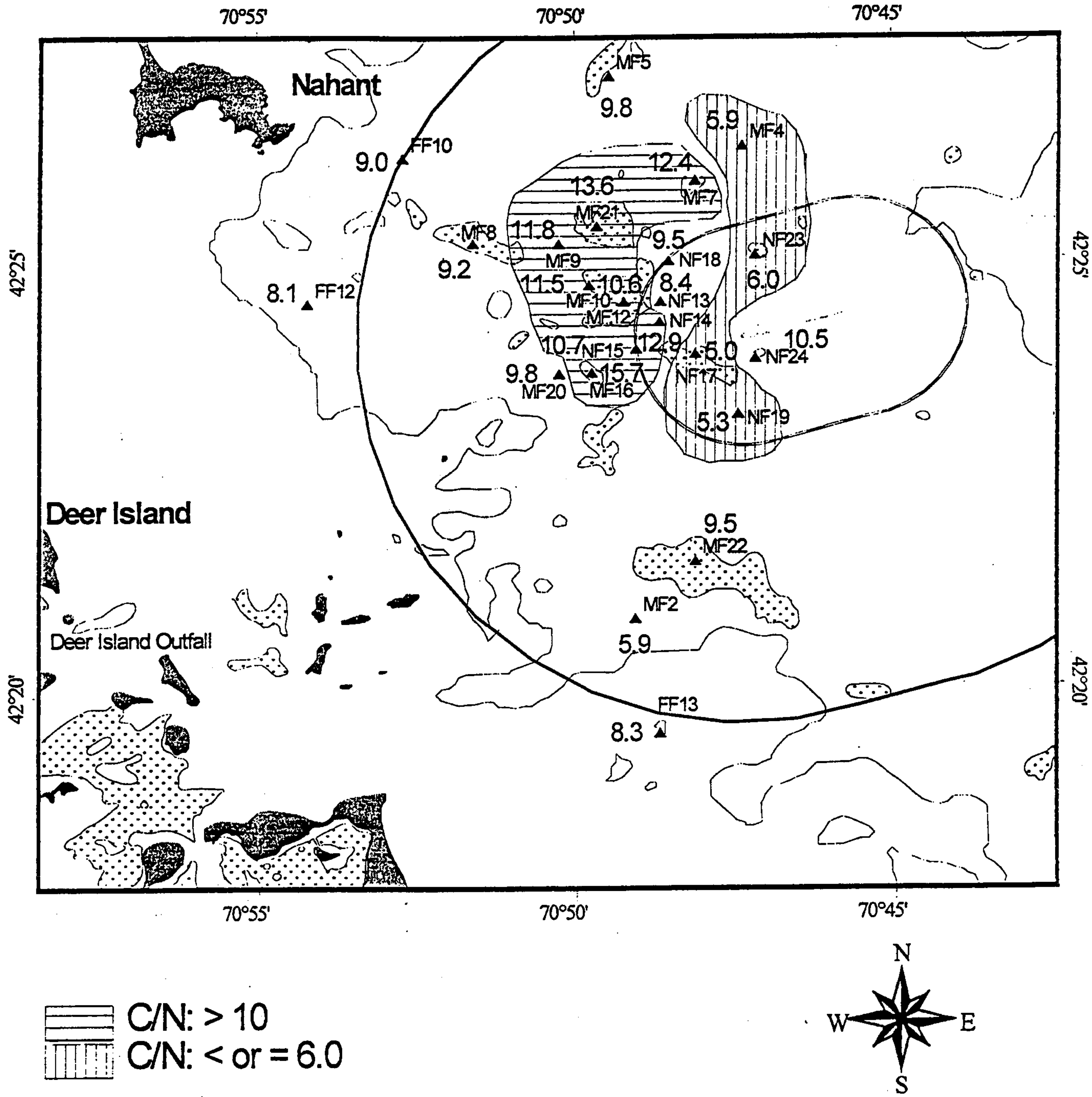


Figure 7. Carbon/nitrogen (C/N) ratio at nearfield and midfield stations in August 1996.

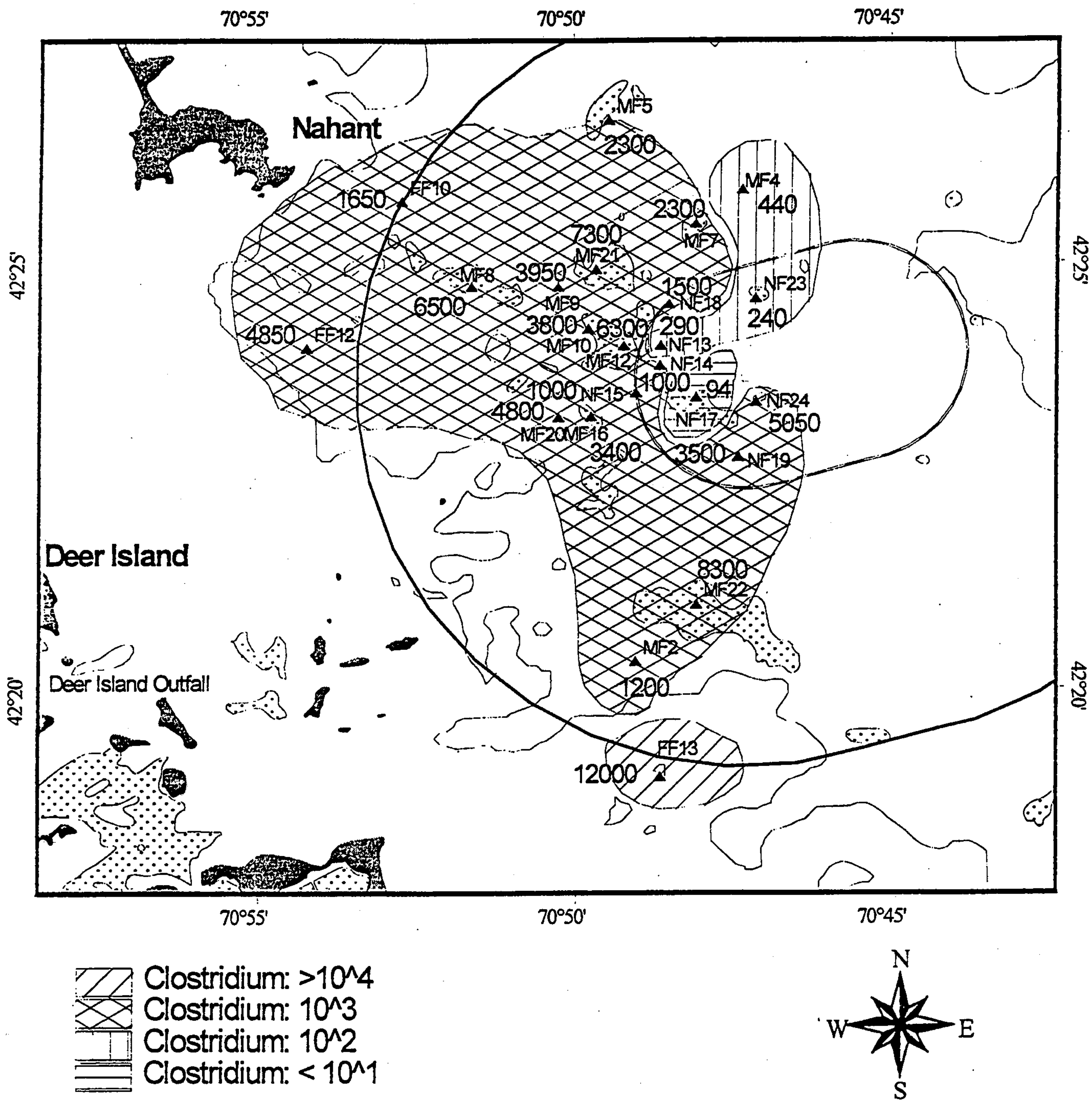


Figure 8. ***Clostridium perfringens*** **spore counts per gram dry weight at nearfield and midfield stations in August 1996.**

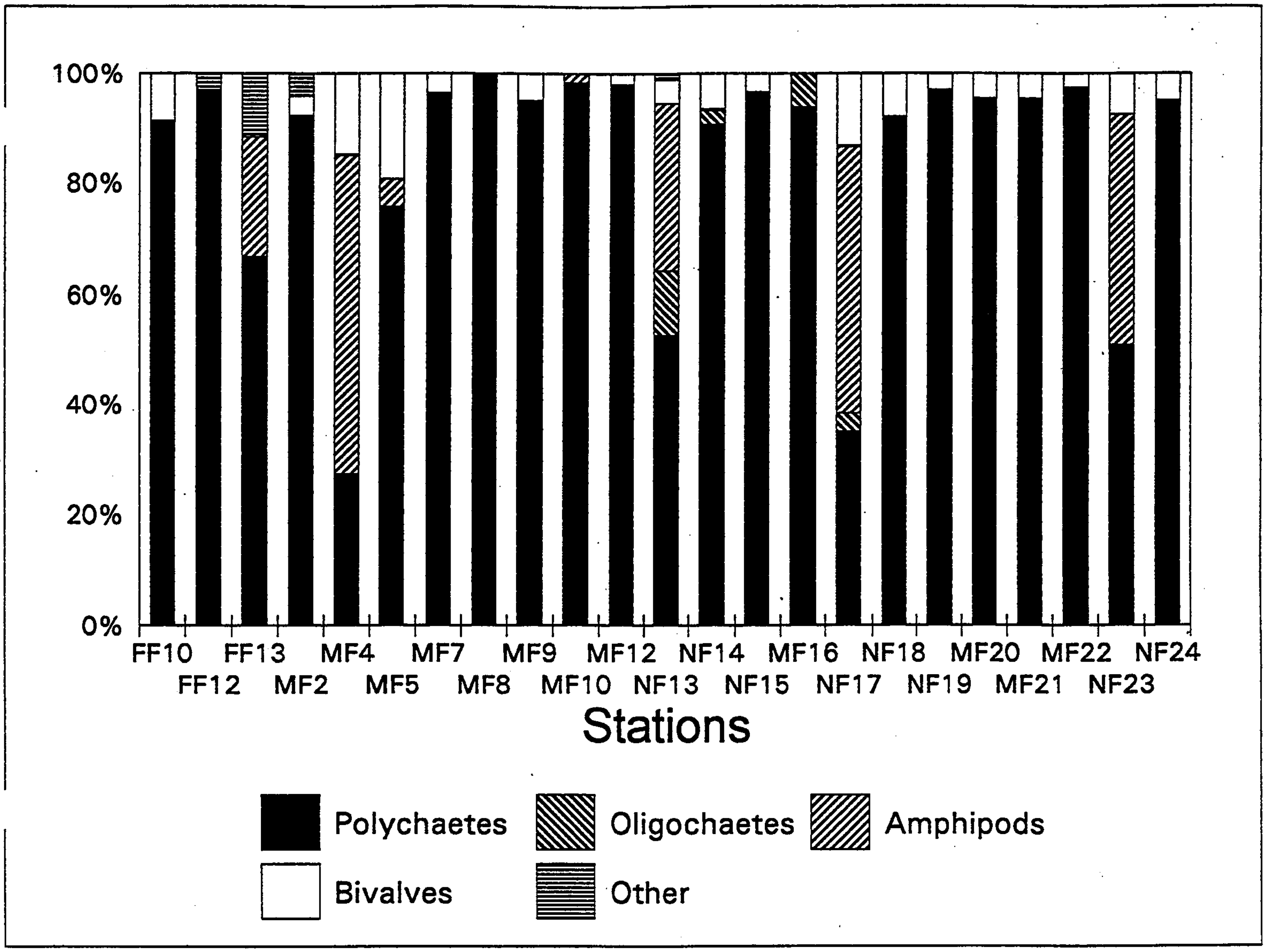


Figure 9. Taxonomic composition of benthic infauna samples taken at nearfield and midfield stations in August 1996.

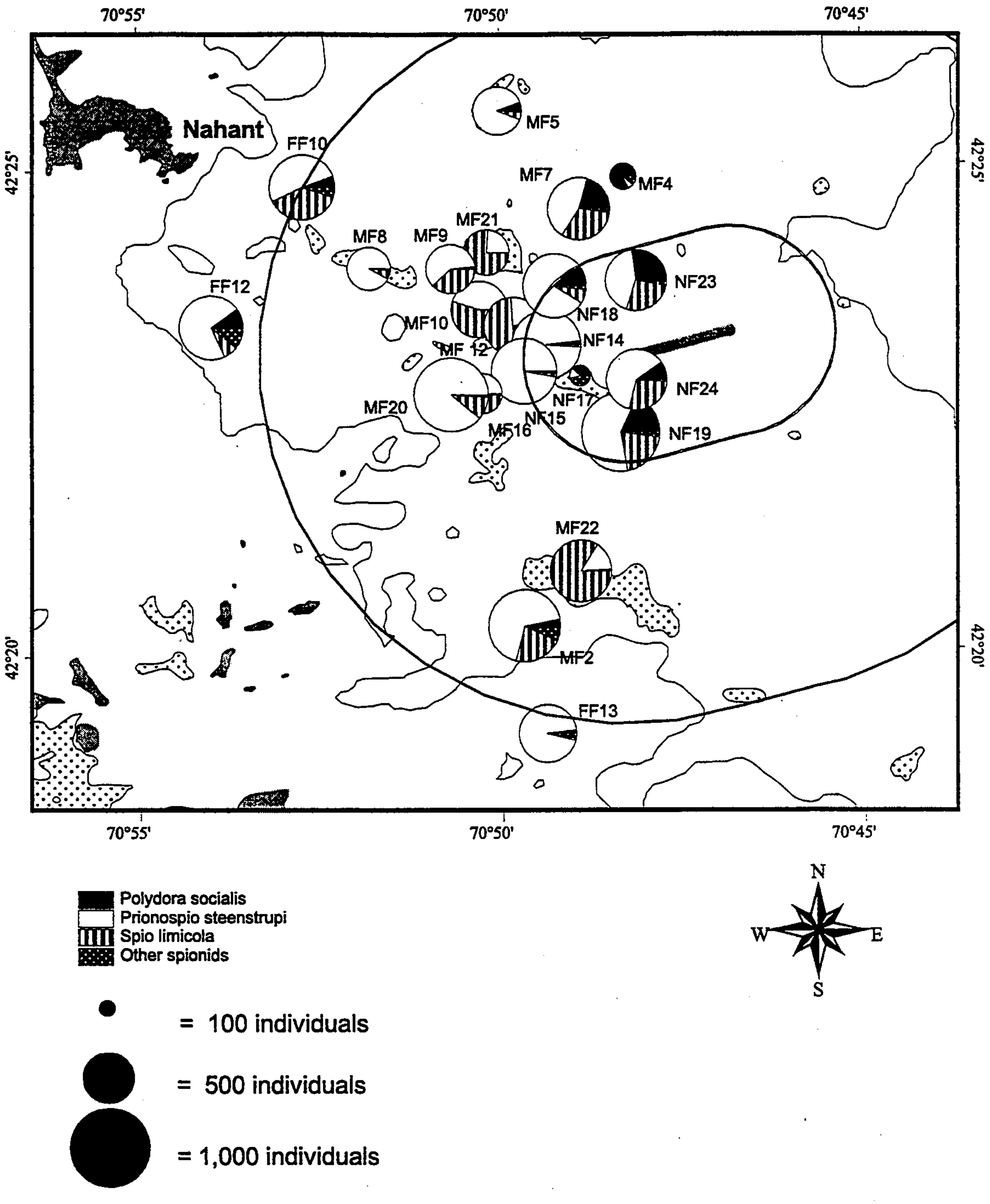


Figure 11. Densities of spionid polychaetes at the nearfield and midfield stations in August 1996.

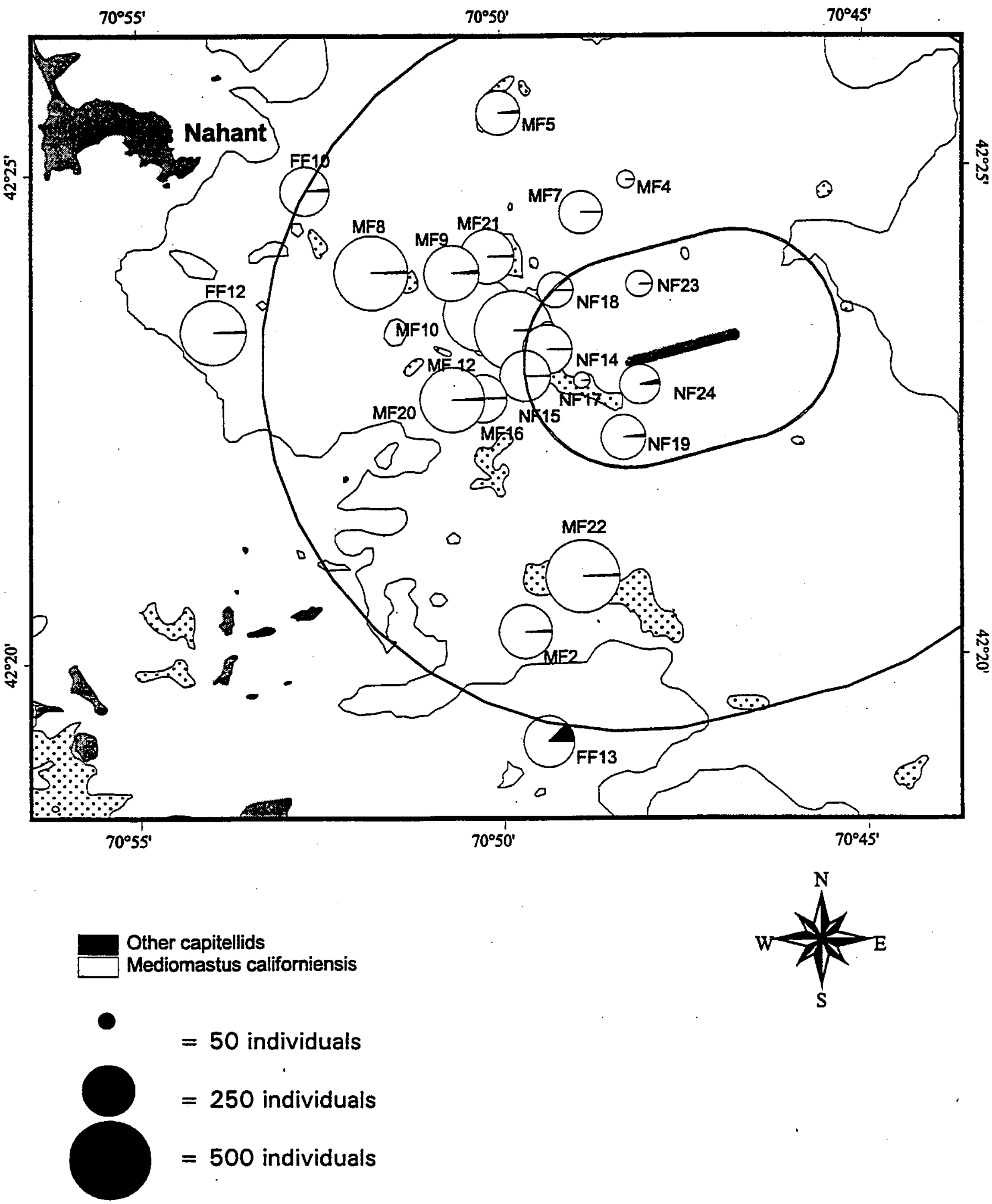


Figure 12. Densities of capitellid polychaetes at the nearfield and midfield stations in August 1996.

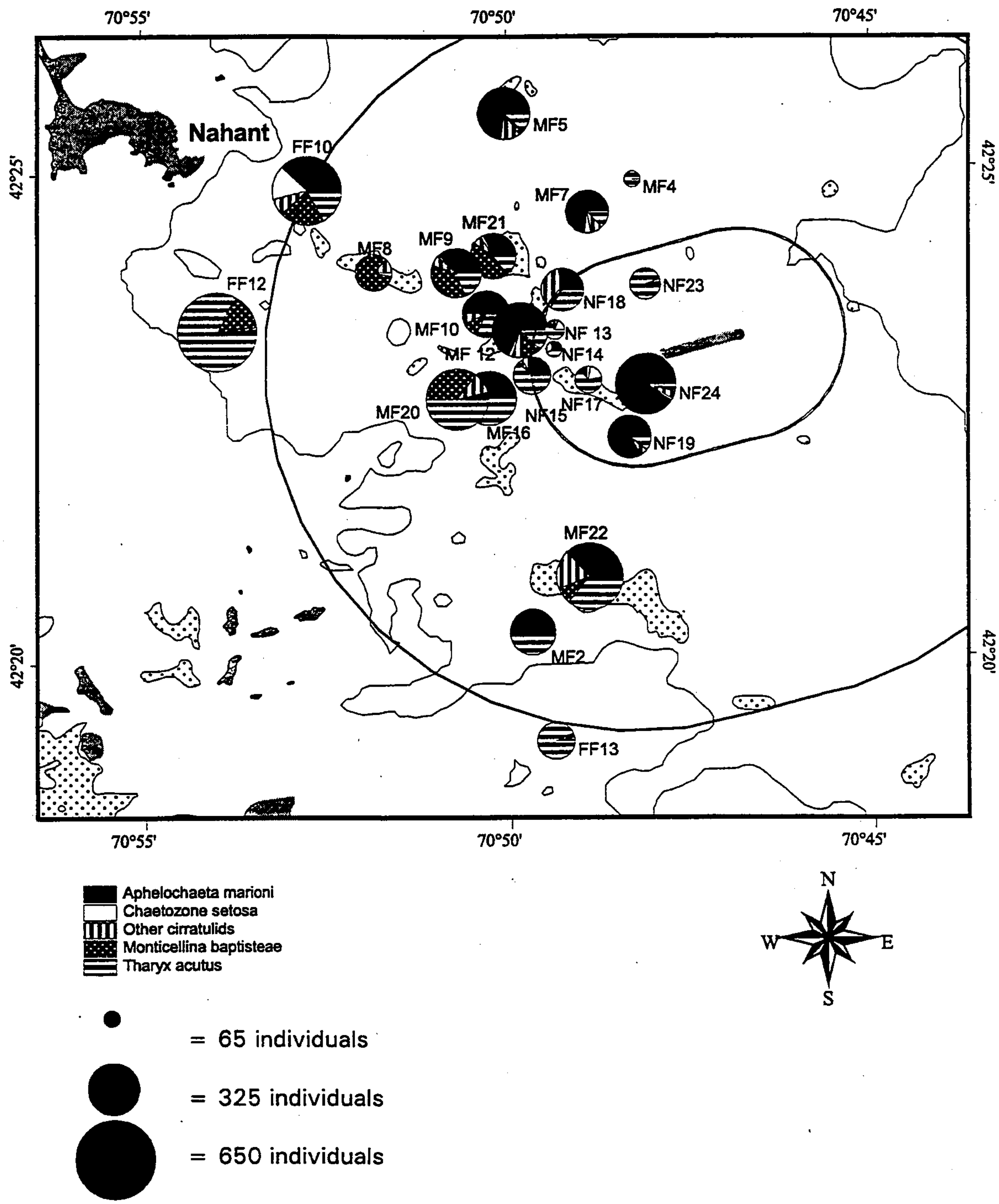


Figure 13. Densities of cirratulid polychaetes at the nearfield and midfield stations in August 1996.

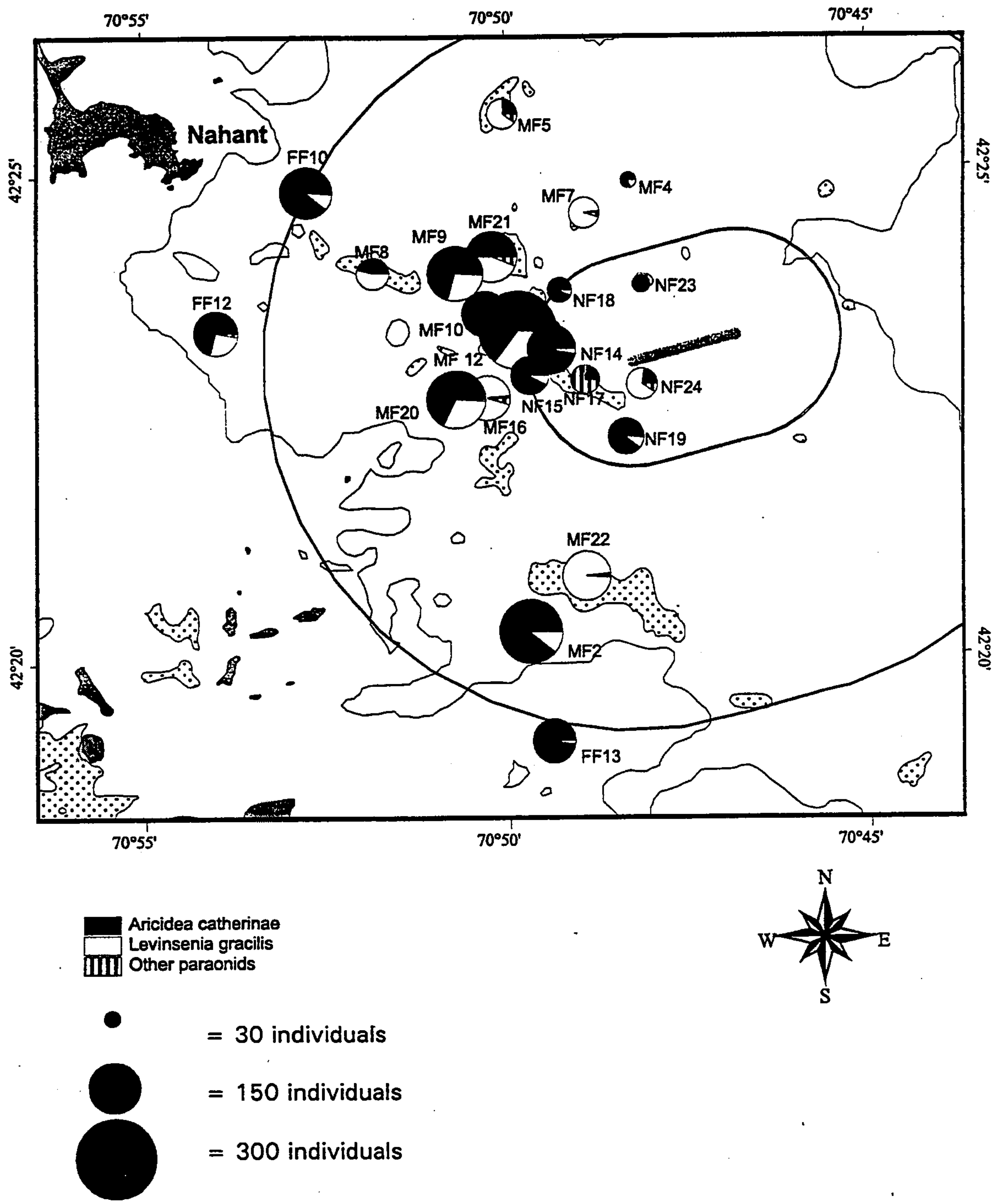


Figure 14. Densities of paraonid polychaetes at the nearfield and midfield stations in August 1996.

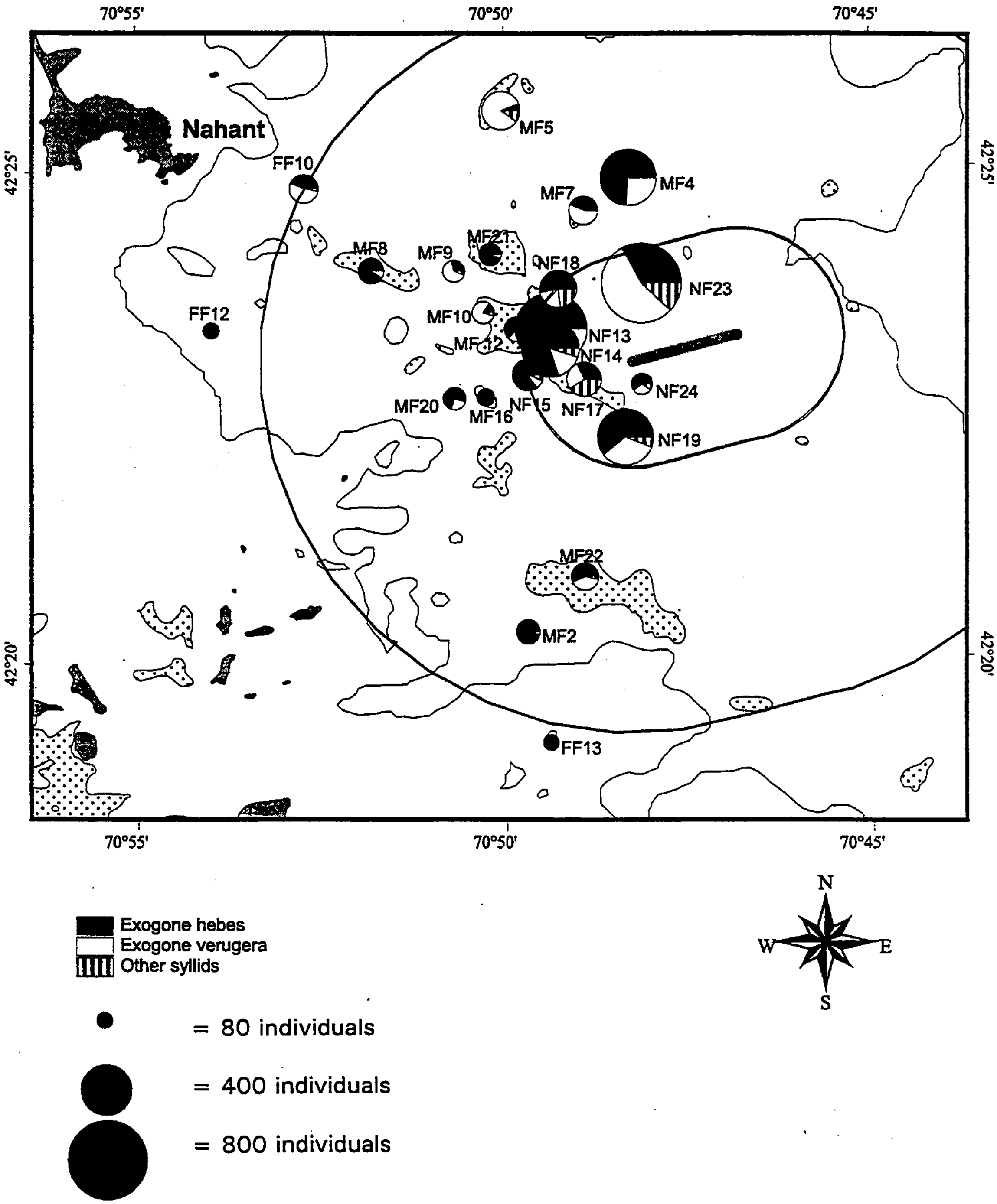


Figure 15. Densities of syllid polychaetes at the nearfield and midfield stations in August 1996.

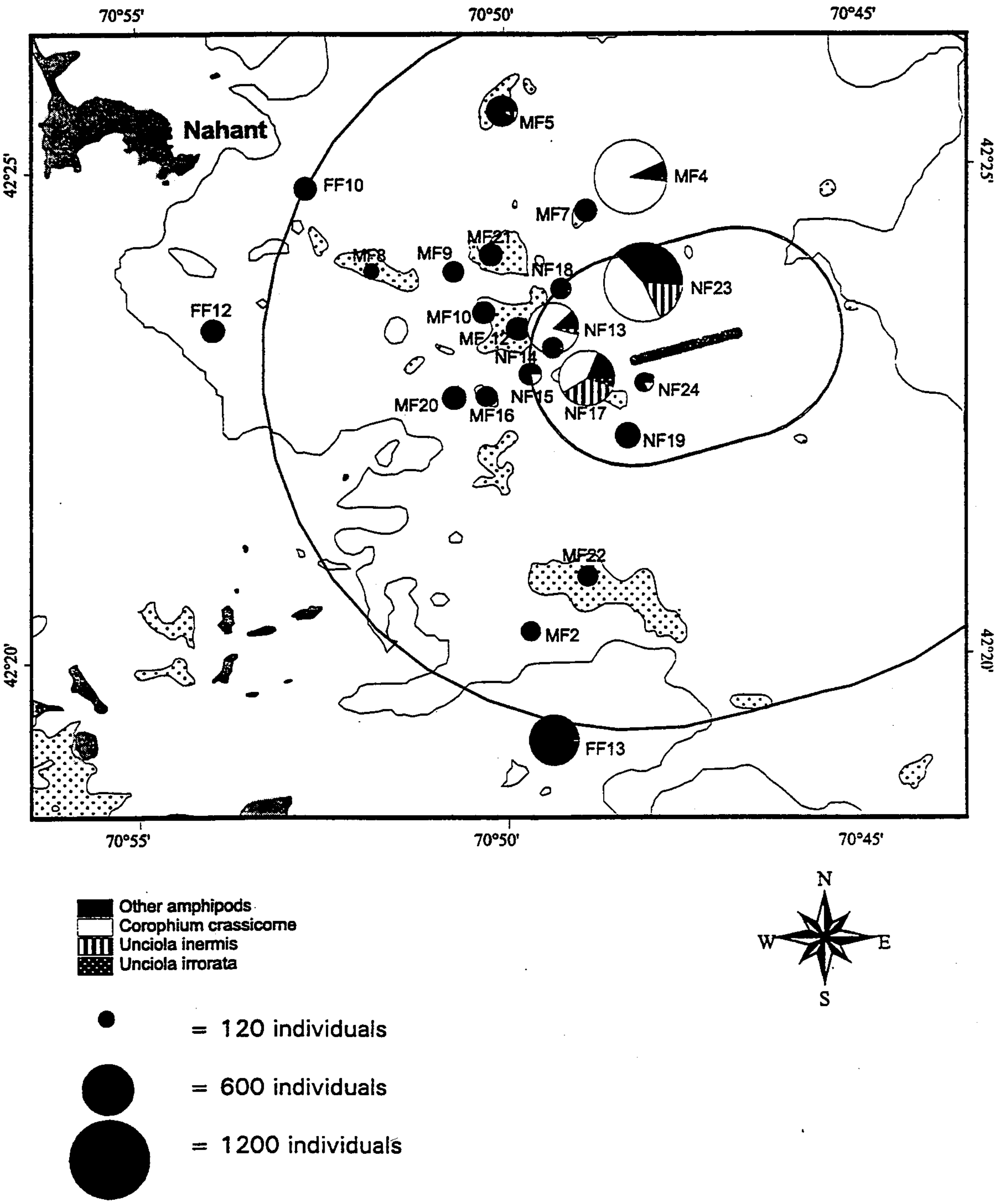


Figure 16. Densities of amphipods at nearfield and midfield stations in August 1996.

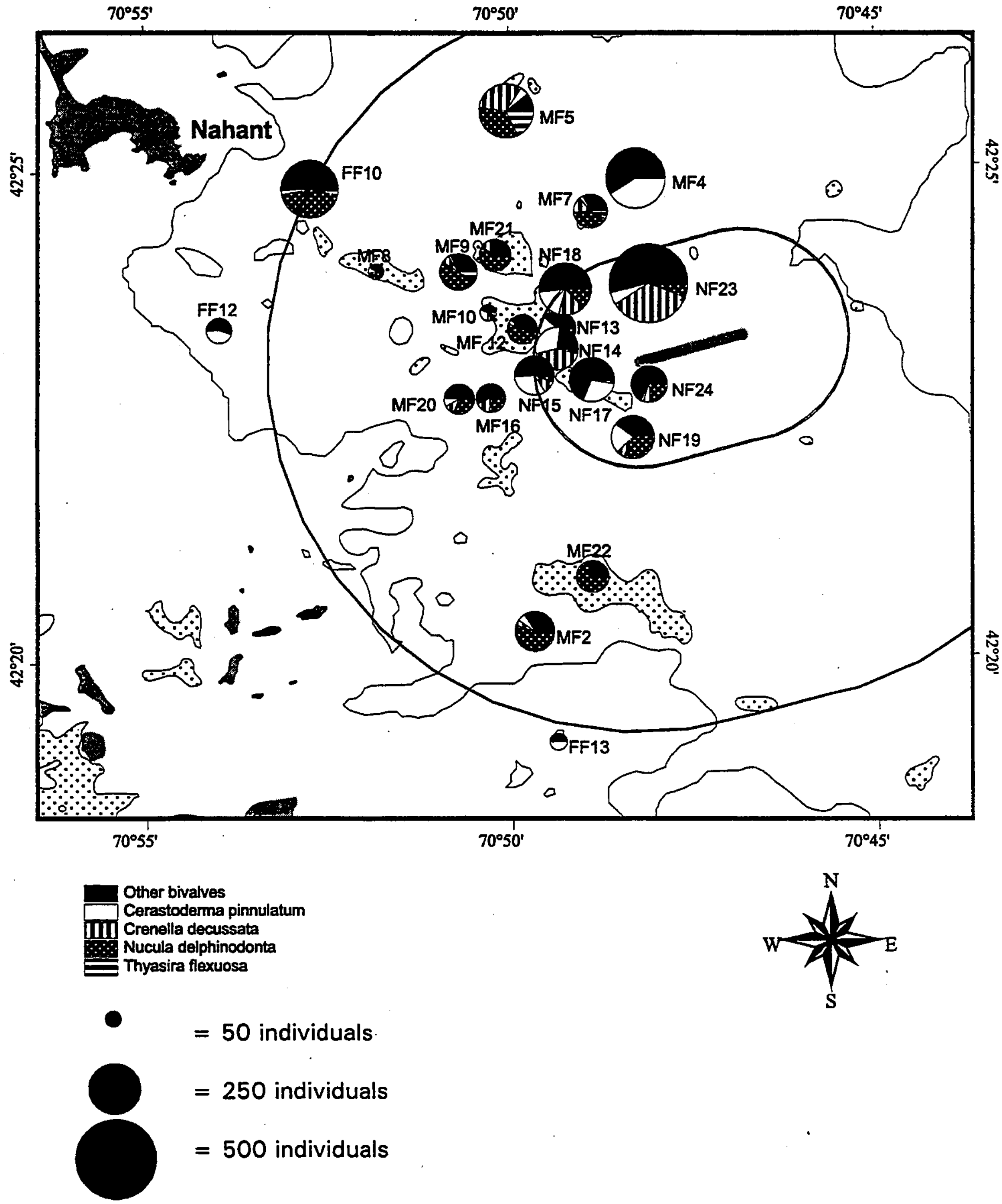


Figure 17. Densities of bivalves at nearfield and midfield stations in August 1996.

Table 4. Community parameters of nearfield and midfield stations, August 1996.

Station	No. spp. (0.04m^2)	No. indiv. (0.04 m^2)	spp./50 ind.	spp./100 ind.	spp./500 ind.	H′	J′
MF2	70	2456	17.01	22.96	41.69	2.80	0.66
MF4	58	1865	11.21	15.65	34.47	1.95	0.48
MF5	92	1500	20.73	30.65	65.38	3.16	0.70
MF7	74	1381	19.23	27.74	54.50	3.01	0.70
MF8	48	1329	13.76	19.09	35.16	2.38	0.61
MF9	76	1586	19.48	27.54	54.88	3.09	0.72
MF10	63	1580	14.82	20.37	41.39	2.58	0.62
MF12*	70	2222	16.46	22.70	43.92	2.76	0.65
NF13	56	1583	13.34	19.37	39.10	2.32	0.58
NF14	74	2024	15.48	21.94	45.20	2.52	0.59
NF15	69	1590	16.90	24.76	49.95	2.56	0.60
MF16	62	1389	17.93	23.77	43.10	2.98	0.72
NF17*	63	1455	16.73	23.80	45.52	2.57	0.62
NF18	81	1666	19.92	27.84	52.48	2.96	0.67
NF19	100	2342	20.19	29.34	59.73	3.10	0.67
MF20	83	2796	17.12	23.90	46.92	2.79	0.63
MF21	66	1341	18.68	25.06	46.48	2.98	0.71
MF22	70	2748	15.91	21.80	41.22	2.72	0.64
NF23	85	3315	19.44	26.23	47.55	3.09	0.69
NF24*	65	1499	15.97	22.84	45.35	2.62	0.63
FF10*	78	2115	21.87	31.01	58.31	3.30	0.70
FF12*	65	2974	15.32	21.16	39.96	2.64	0.59
FF13*	54	2343	16.88	22.30	38.66	2.83	0.66

*replicated station, numbers are means per replicate

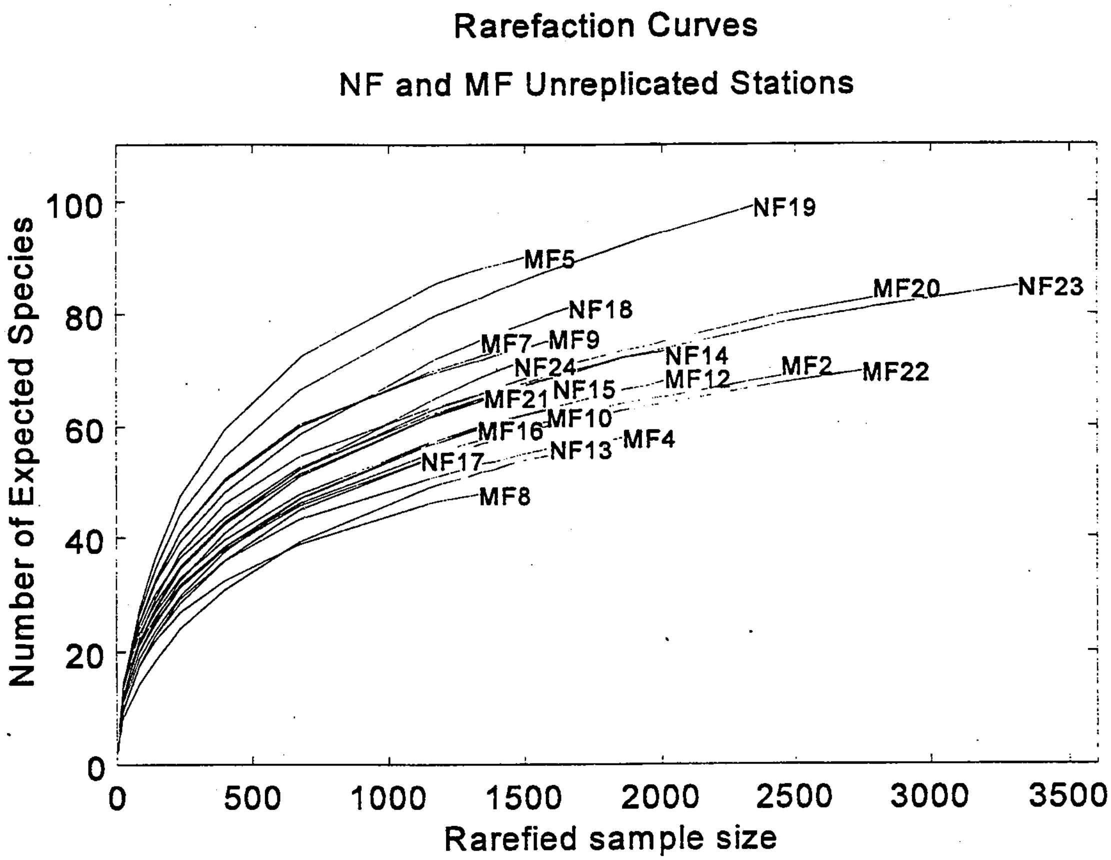


Figure 18. Rarefaction curves for nearfield and midfield unreplicated stations in August 1996.

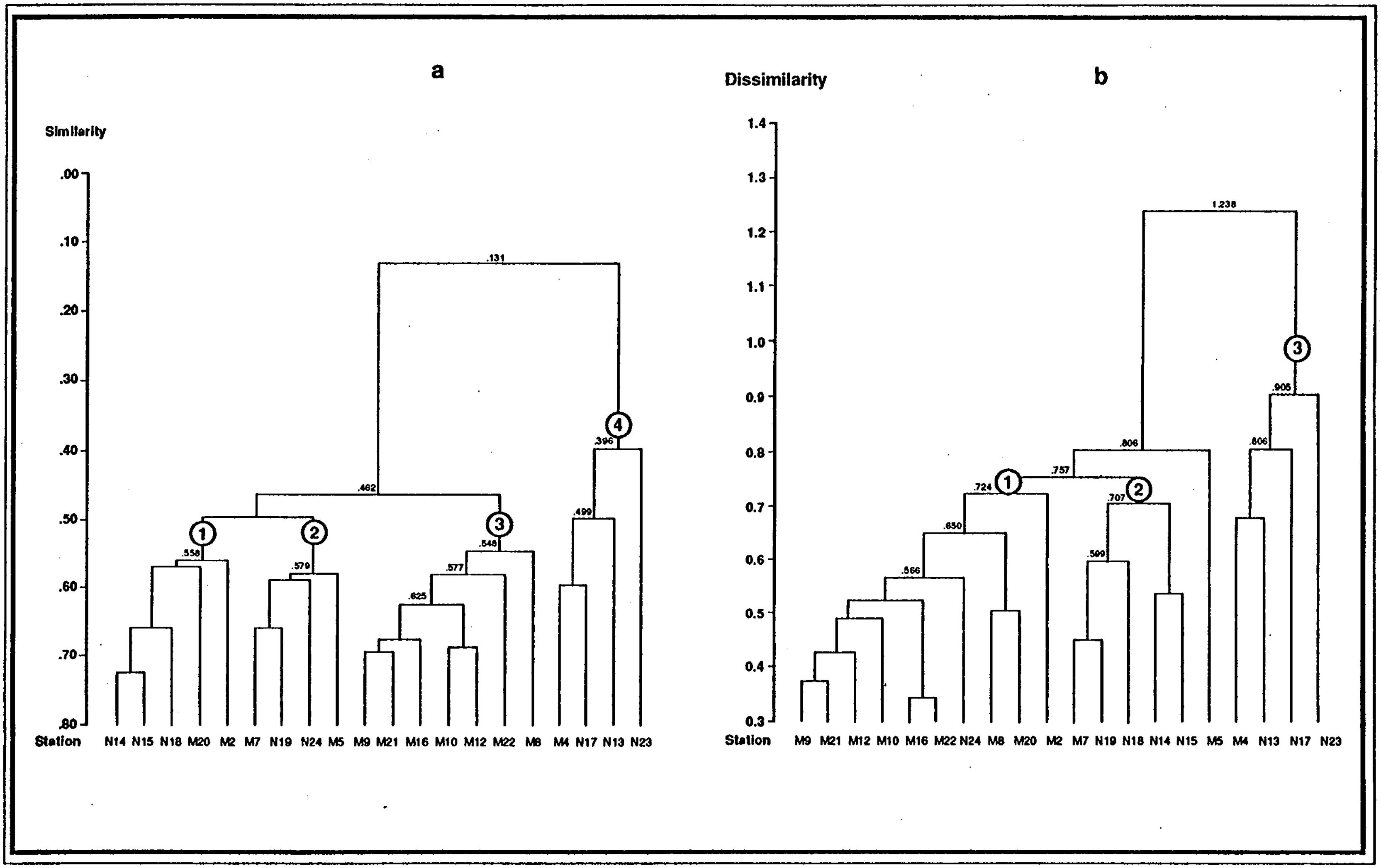


Figure 19. Bray-Curtis similarity (a) and CNESS dissimilarity (b) among nearfield and midfield stations (FF10, FF12, FF13 not included.)

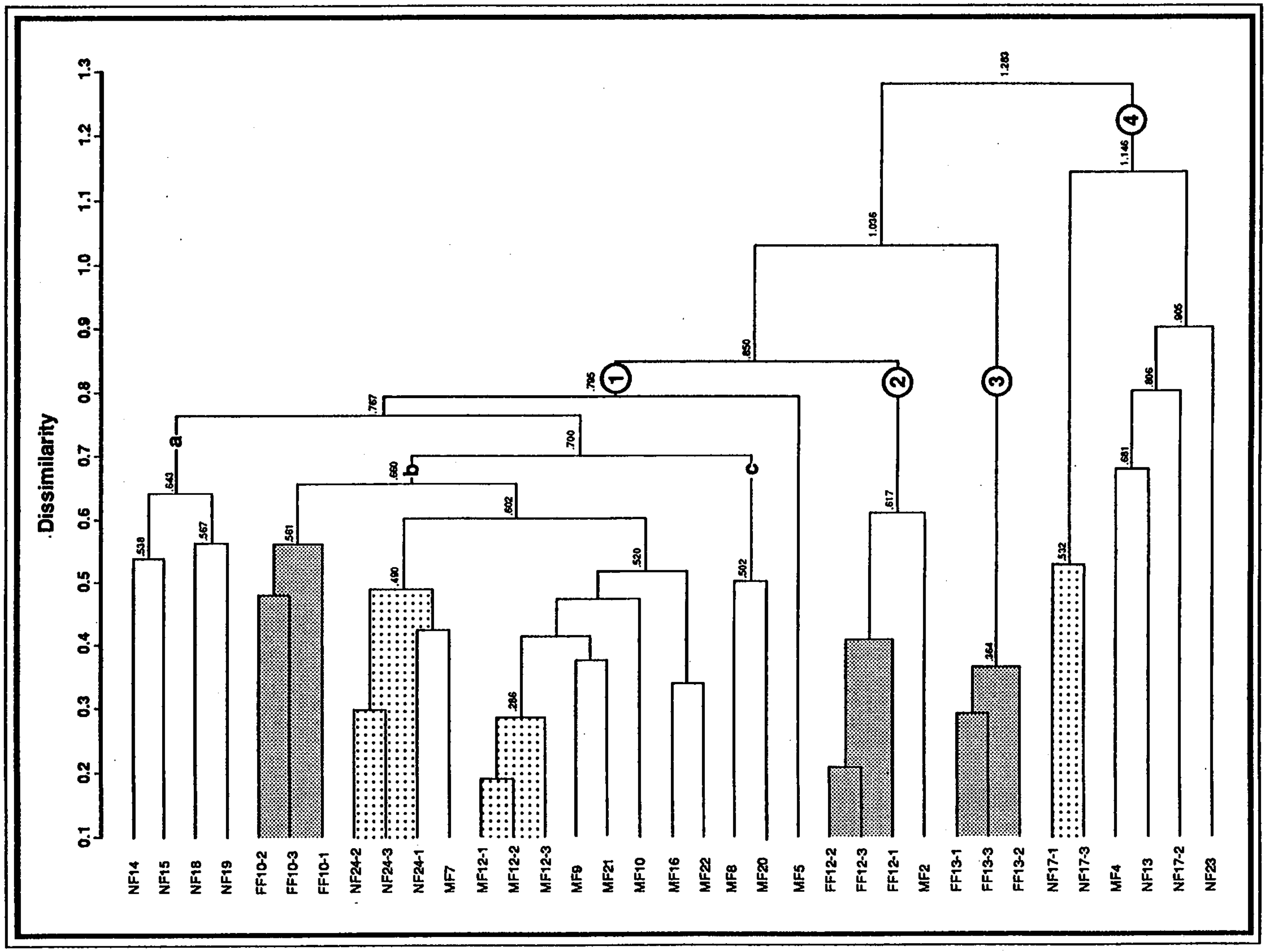


Figure 21. CNESS dissimilarity of nearfield and midfield stations, replicates kept separate (FF10, FF12, FF13 included.)

Table 6. Characterization of nearfield/midfield station clusters generated with the CNESS dissimilarity measure (FF10, FF12, FF13 not included).

Cluster	Stations	Location	Sediment Grain Size (mean phi)	TOC and C/N Ratio	Infaunal Assemblage (individuals /m^2)
1	MF2, 8, 9, 10, 12, 16, 20, 21, 22 NF24	nearly all of midfield and mud patch station in the nearfield	mostly silt+clay; sand 27 to 90% mean phi 4.5±1	TOC high, 1.2±0.5% C/N high, 11±2.7	moderate *Prionospio* (6900) high *Mediomastus* (14,000) high *Ninoe* (4700) also defining assemblage: *Euchone incolor*, *Levinsenia gracilis*, *Monticellina baptisteae*
2	MF7 NF14, 15, 18, 19	band of stations along western nearfield/midfield border	very variable, sand 22 to 87% mean phi 1.9±1.9	TOC moderate, 0.6±0.49% C/N high, 10±3	high *Prionospio* (14,000) moderate *Mediomastus* (3200) moderate *Ninoe* (2100) also defining assemblage: *Dipolydora socialis*, *Exogone verugera*
3	MF4 NF13, 17, 23	offshore, patch of stations close to diffuser	mostly medium sand; sand 90% mean phi 2±0.7	TOC low, 0.1±0.1% C/N low, 6±1.5	high *Corophium crassicorne* high *Exogone hebes* also defining assemblage: *Crenella decussata*, *Hiatella arctica*
outlier	MF5	northernmost station in midfield	very fine sand; sand 63% phi 3.7	TOC low, 0.1% C/N high, 10	moderate *Prionospio* (8000) moderate *Mediomastus* (3100) low *Ninoe* (800) high *Exogone verugera* (2800) high *Aphelochaeta marioni* (5000)

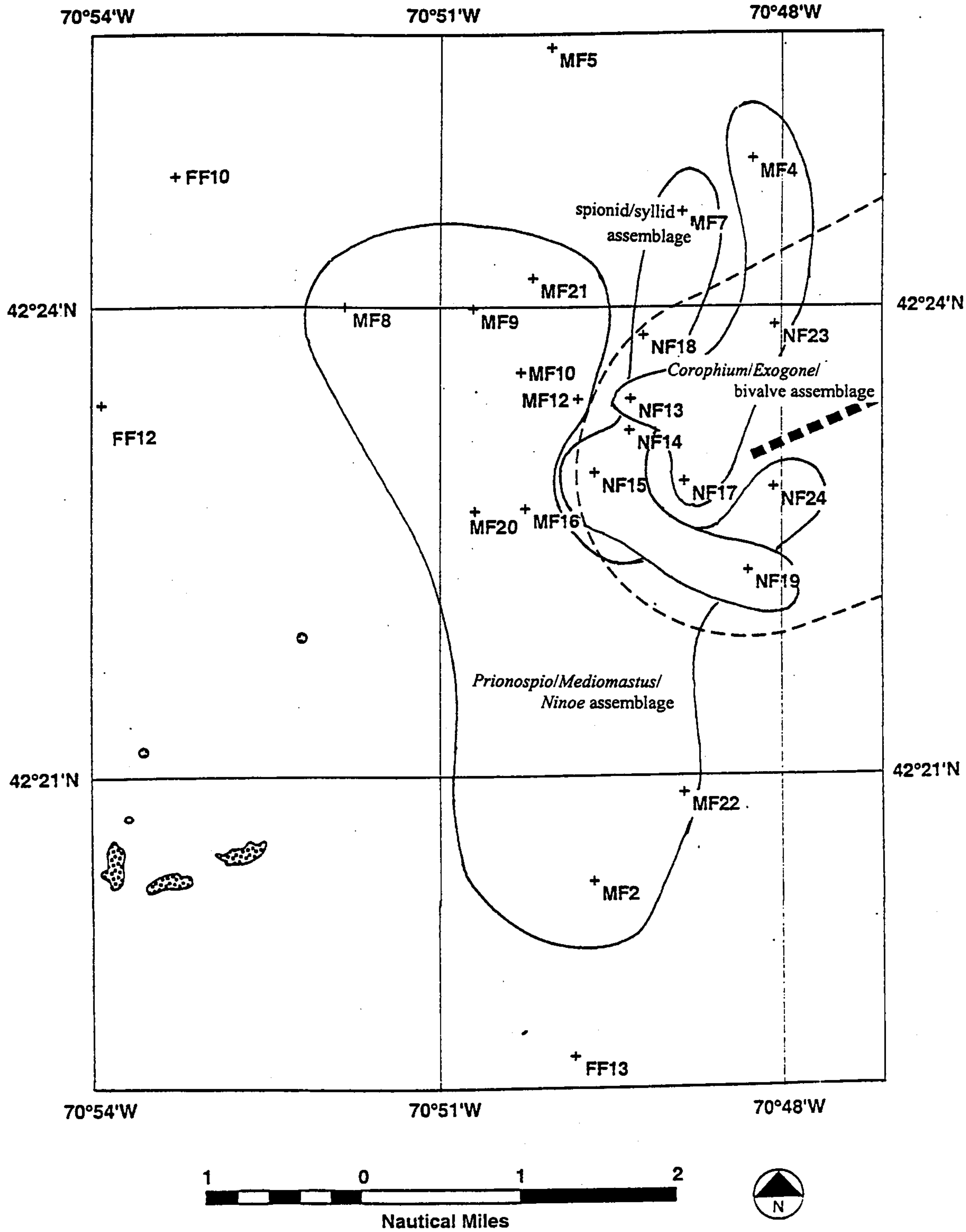


Figure 46. Faunal assemblages in the nearfield and midfield, based on the CNESS similarity analysis.

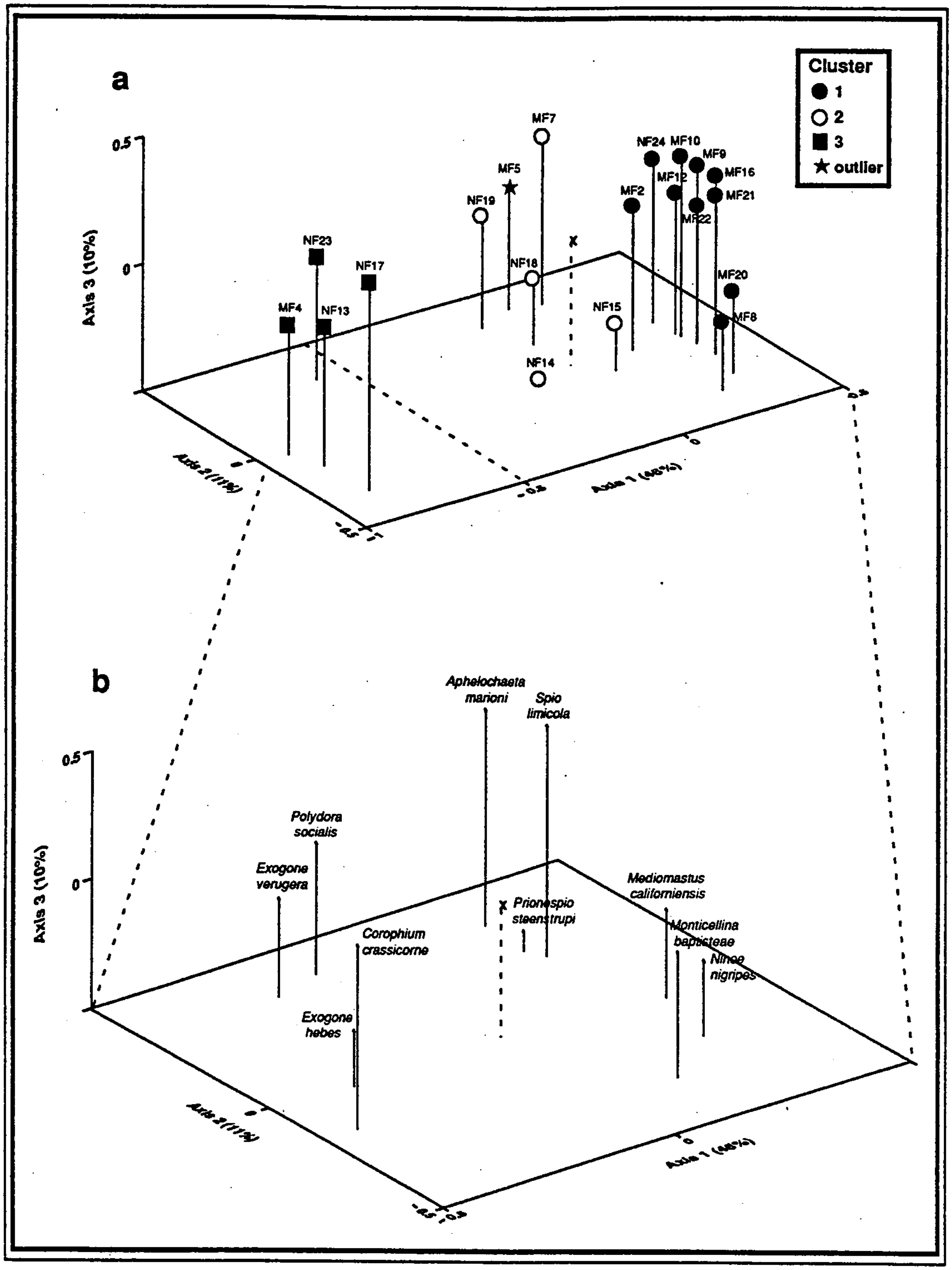


Figure 22. Principal components analysis of CNESS distances for nearfield and midfield stations (a) and species (b). The first three axes account for 67% of the total variation.

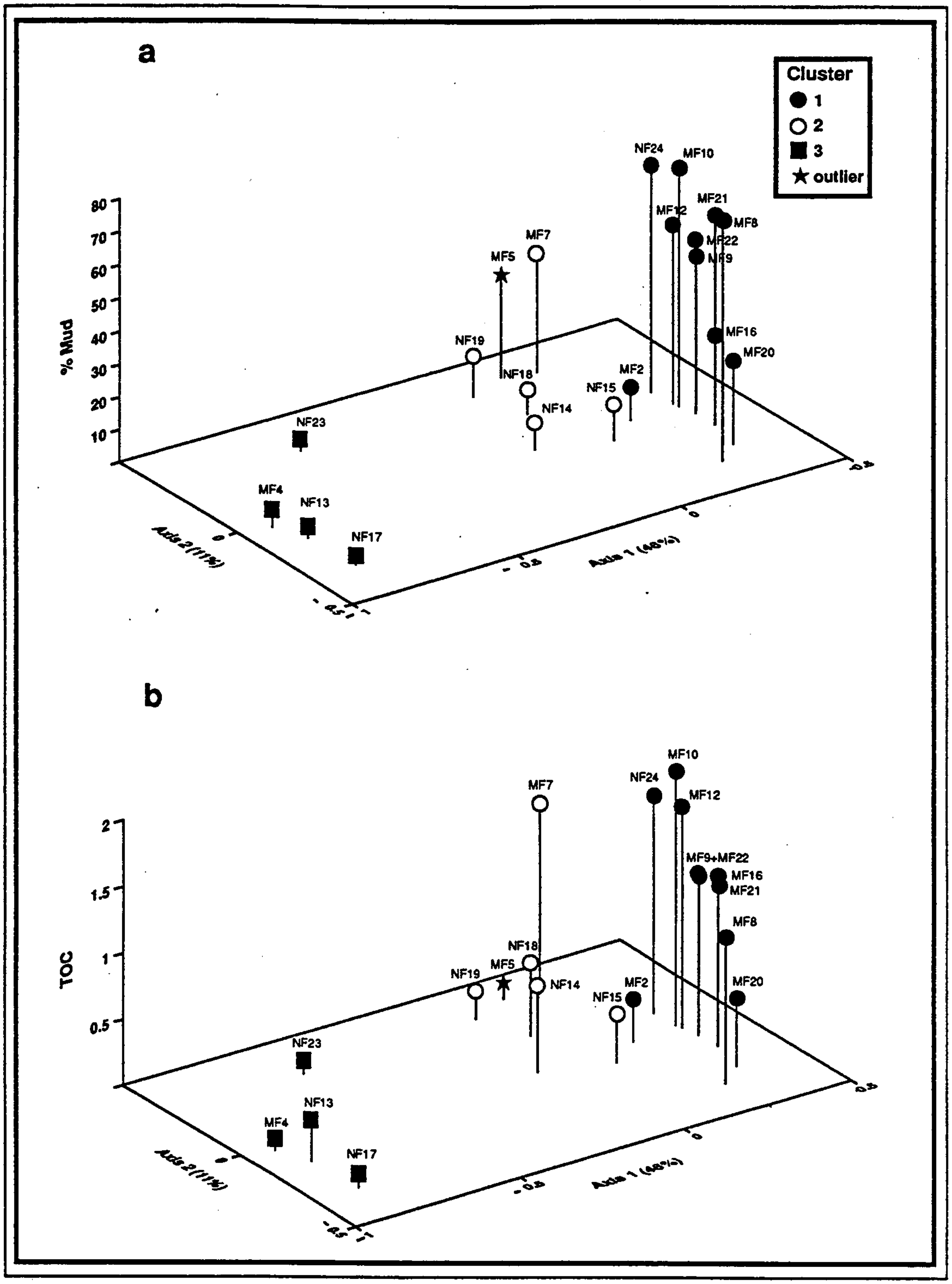


Figure 24. Principal components analysisaxes 1 and 2 vs percent mud (a) and total organic carbon (b).

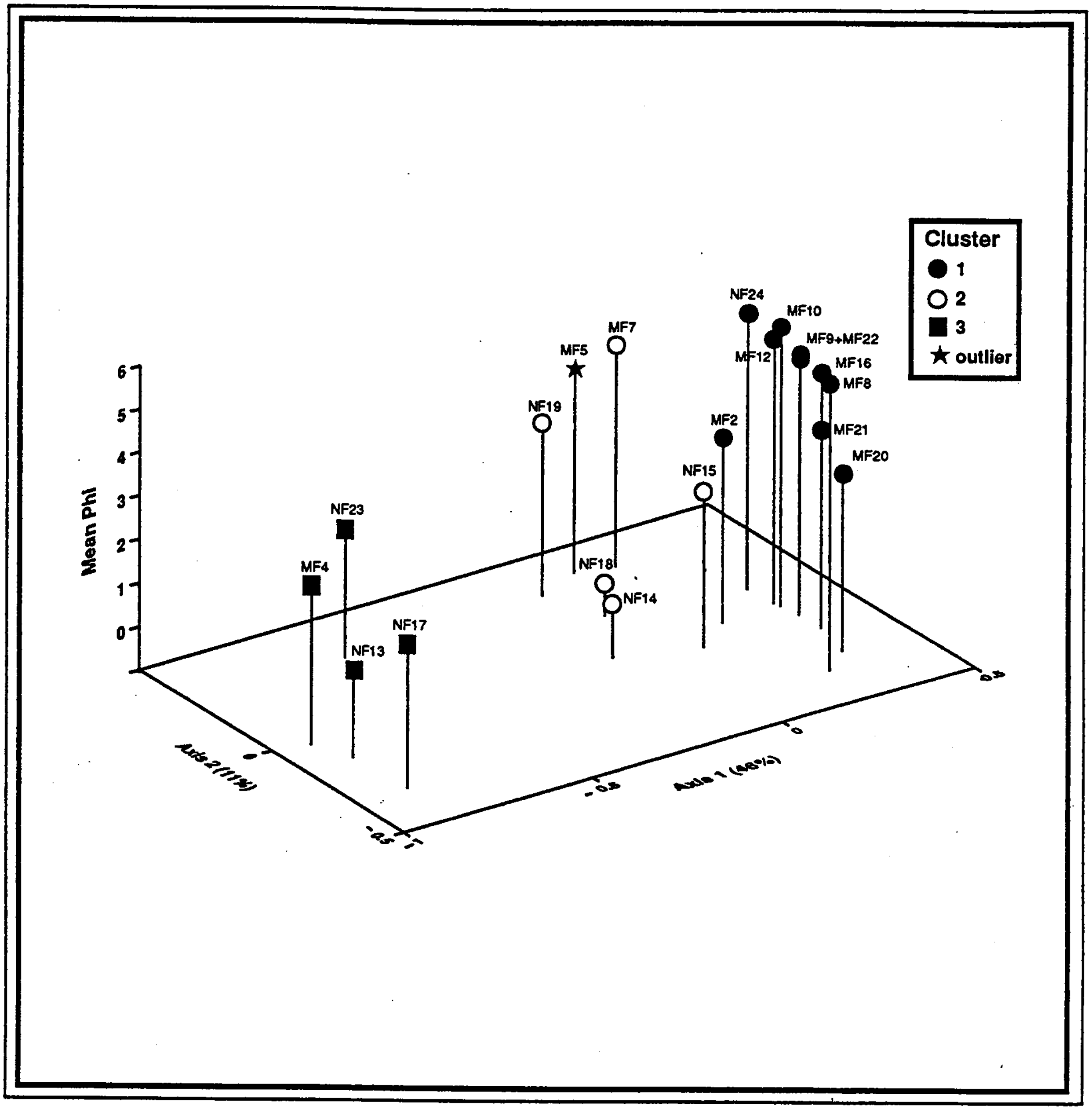
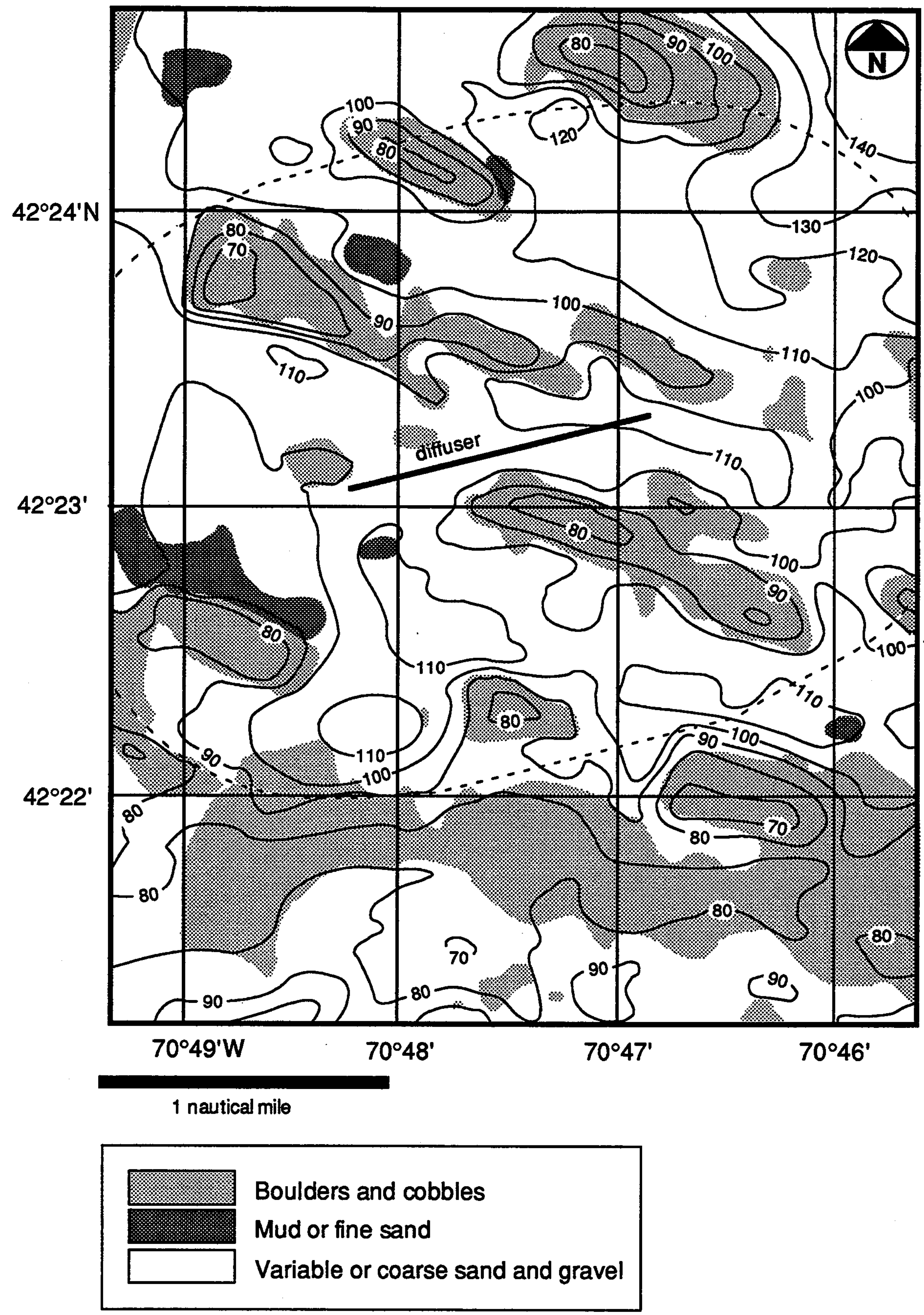
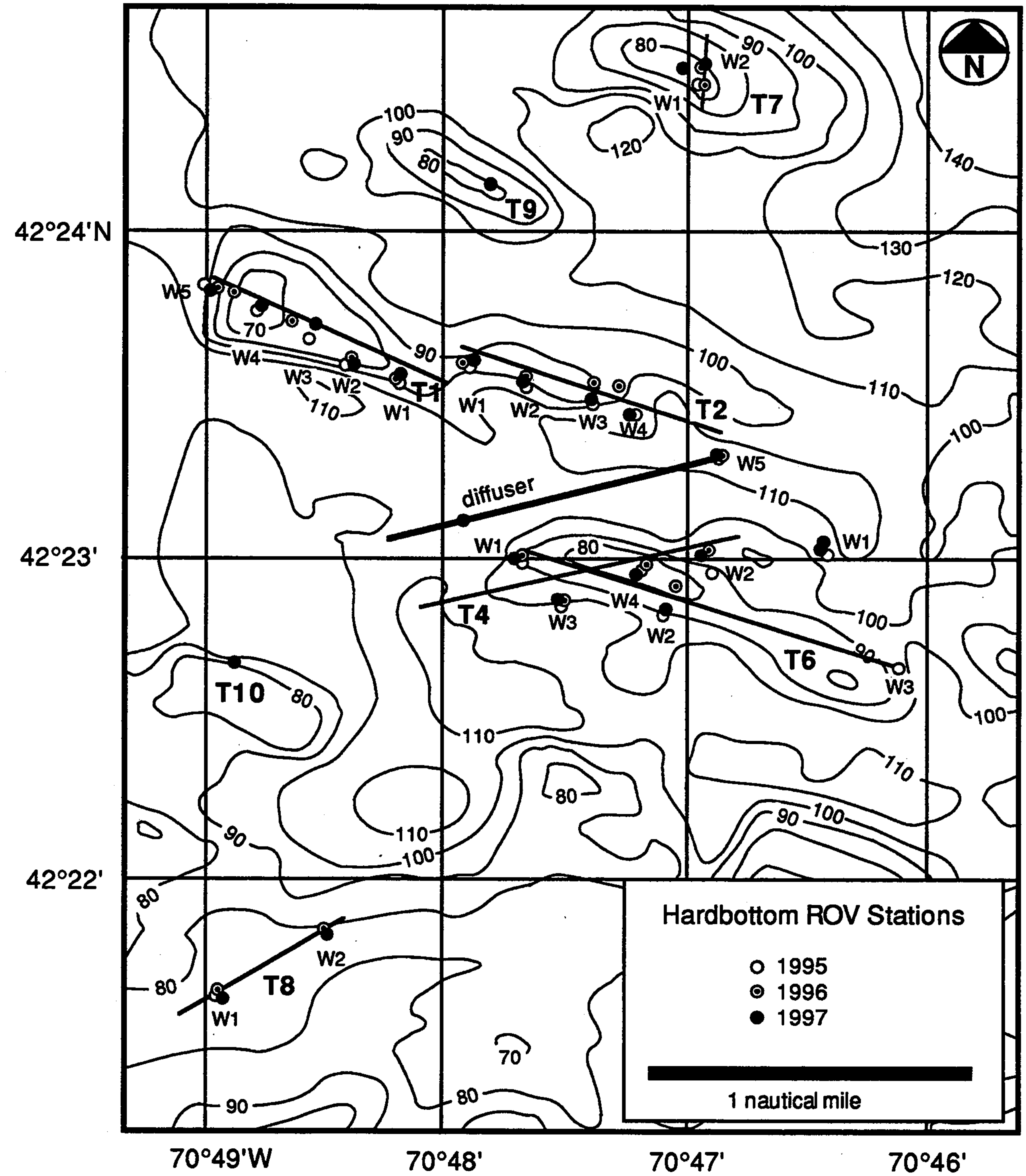


Figure 23. Principal components analysis axes 1 and 2 vs. mean phi.

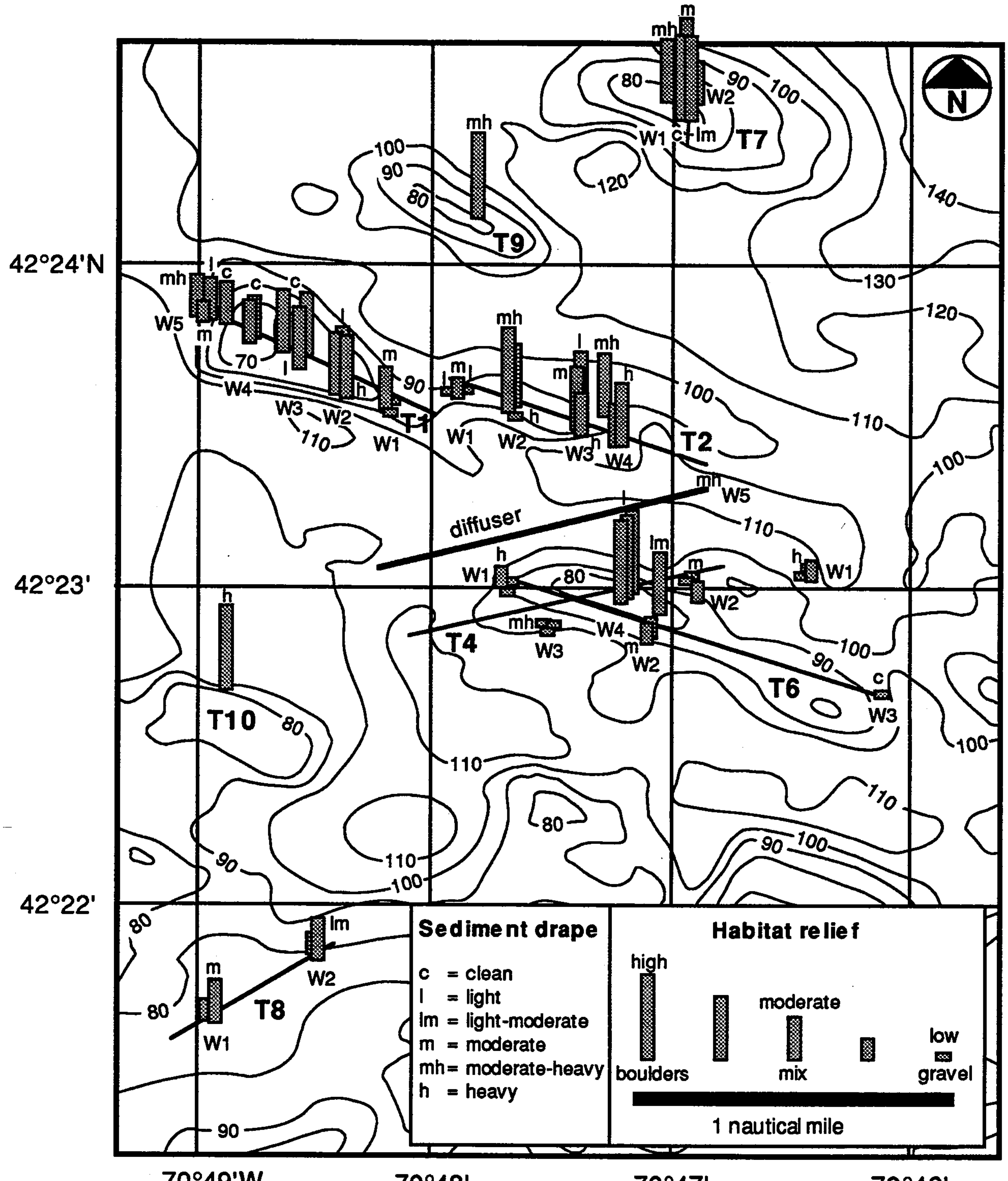
APPENDIX B-6
Hard Bottom Benthic 1996 Results: Barbara Hecker



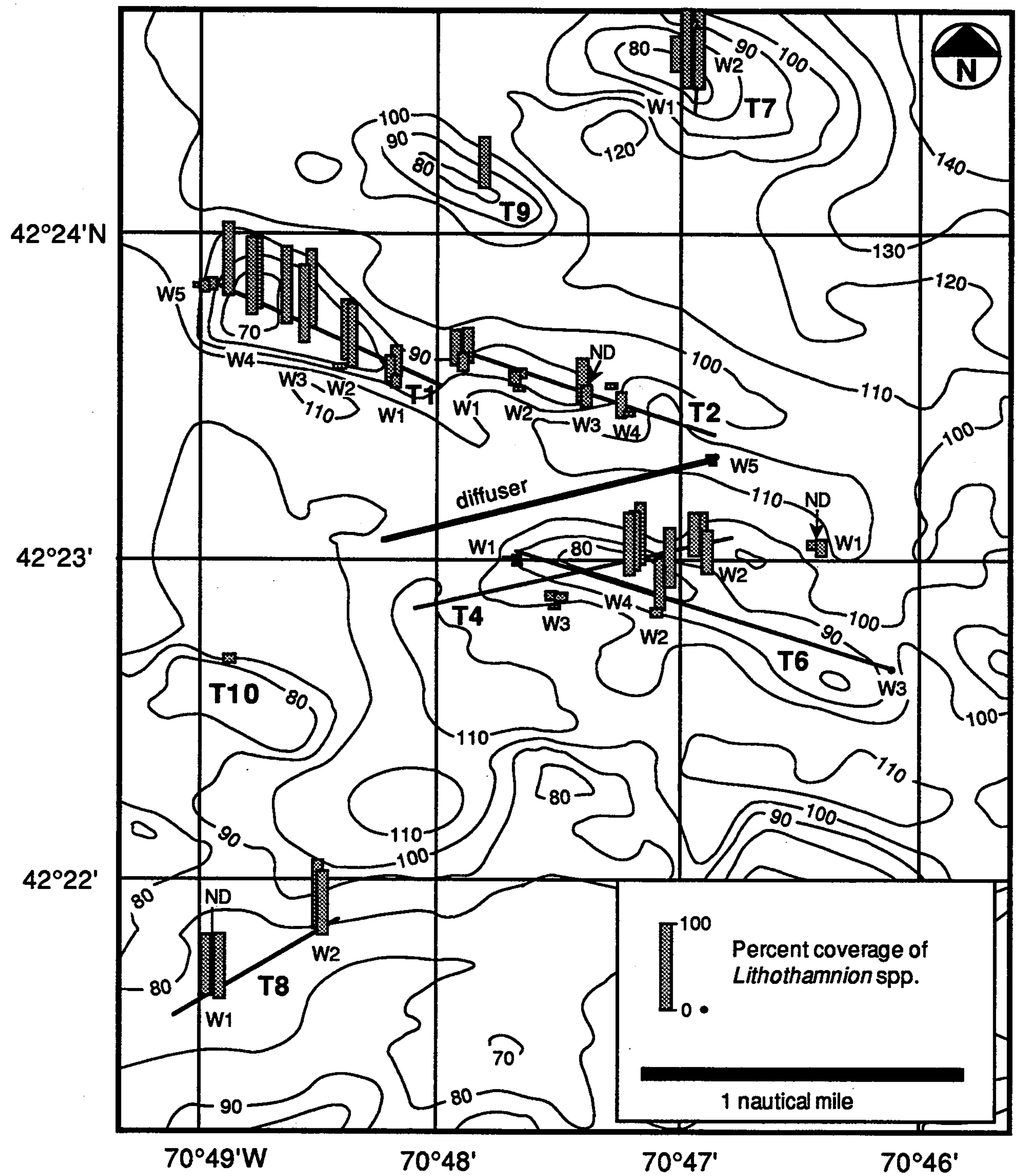
From Butman et al., 1992



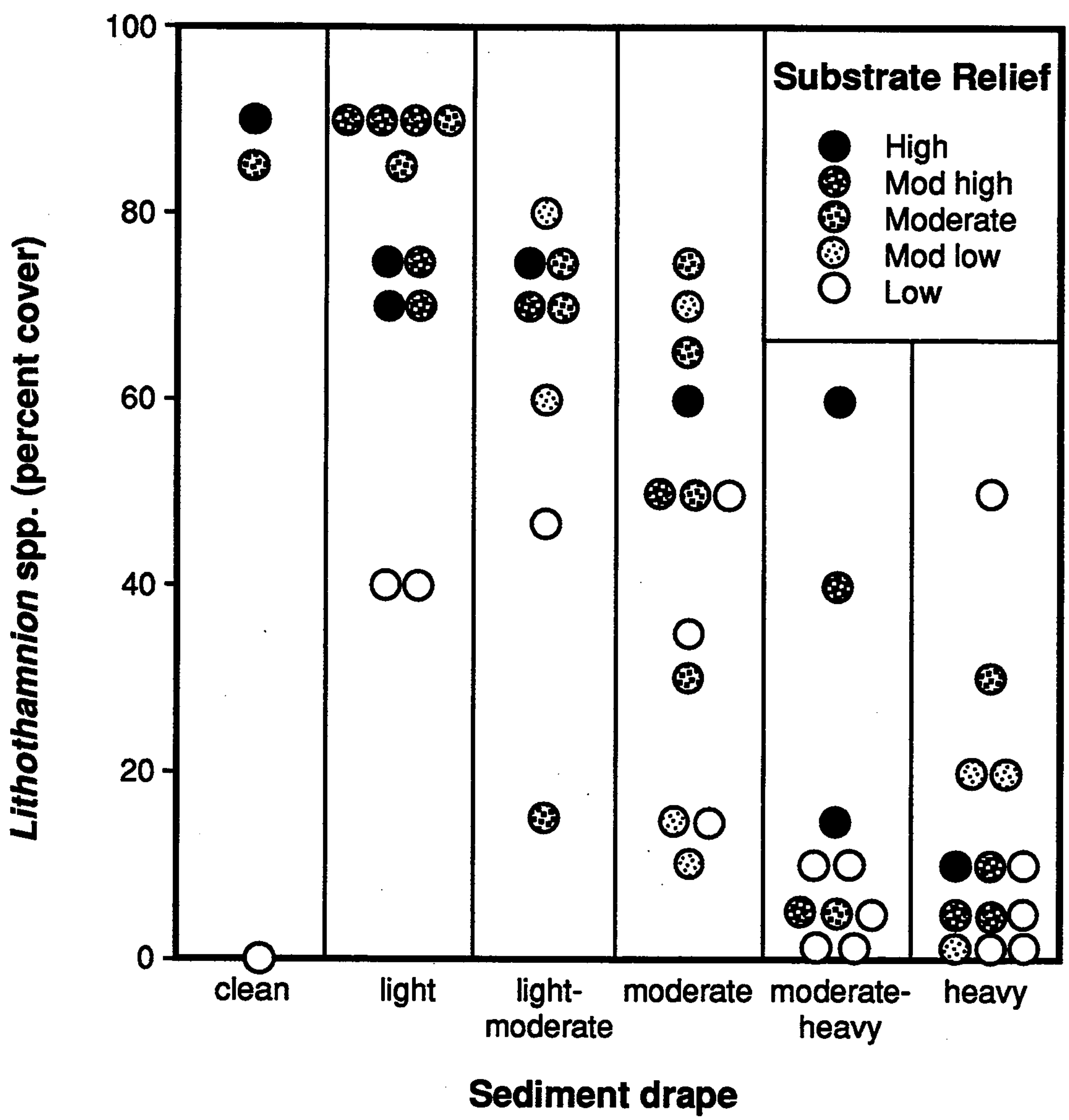
Hardbottom ROV Stations
1995
1996
1997
1 nautical mile
N
diffuser
T1
T2
T4
T6
T7
T8
T9
T10
W1
W2
W3
W4
W5
42°24'N
42°23'
42°22'
70°49'W
70°48'
70°47'
70°46'

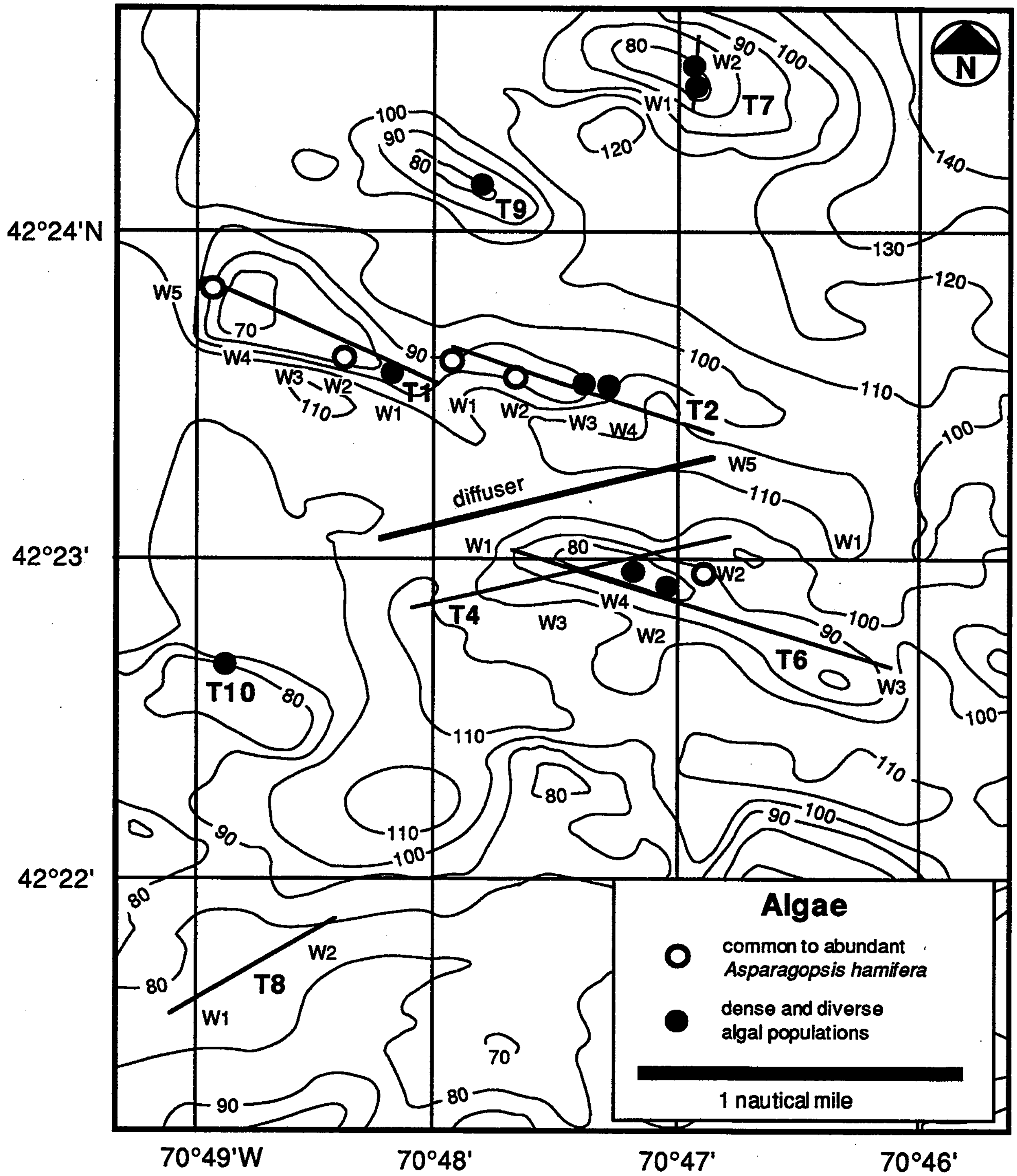


42°24'N
42°23'
42°22'
70°49'W
70°48'
70°47'
70°46'
N
T1
T2
T4
T6
T7
T8
T9
T10
diffuser
W1
W2
W3
W4
W5
Sediment drape
c = clean
l = light
lm = light-moderate
m = moderate
mh = moderate-heavy
h = heavy
Habitat relief
high
moderate
low
boulders
mix
gravel
1 nautical mile

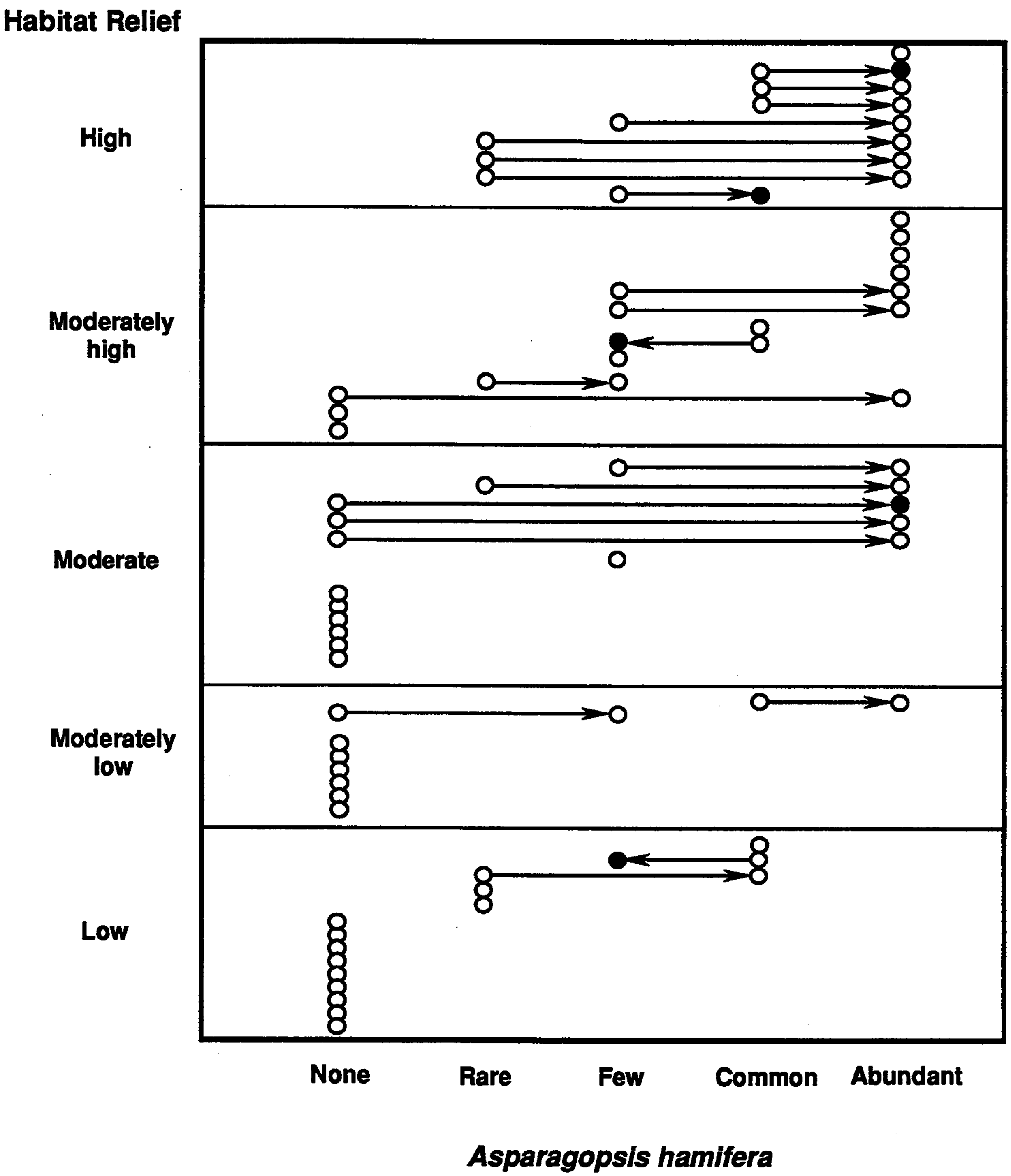


42°24'N
42°23'
42°22'
70°49'W
70°48'
70°47'
70°46'
N
T1
T2
T4
T6
T7
T8
T9
T10
W1
W2
W3
W4
W5
ND
diffuser
70
80
90
100
110
120
130
140
Percent coverage of *Lithothamnion* spp.
100
0
1 nautical mile


Substrate Relief
High
Mod high
Moderate
Mod low
Low
100
80
60
40
20
0
Lithothamnion spp. (percent cover)
clean
light
light-moderate
moderate
moderate-heavy
heavy
Sediment drape



Algae
common to abundant
Asparagopsis hamifera
dense and diverse
algal populations
1 nautical mile
N
42°24'N
42°23'
42°22'
70°49'W
70°48'
70°47'
70°46'
diffuser
T1
T2
T4
T6
T7
T8
T9
T10


Habitat Relief
High
Moderately high
Moderate
Moderately low
Low
None
Rare
Few
Common
Abundant
Asparagopsis hamifera

APPENDIX B-7
Sediment Profile Comparisons 1992, 1995, and 1997: Rhoads and Williams

Benthic Infaunal Monitoring

1992-1996 Sediment Summaries

- Nearfield Sediments are Sandy
- Midfield Sediments are Fine sands and Coarse Silts with some Clays
- Year to Year Changes in Sediments are most Evident in a Transitional Area between the *Corophium-Exogone* Dominated Sandy Stations and the Muddy Stations
- Higher TOC is Correlated with Finer Sediments and Shifts with that Parameter
- Spore Counts of *Clostiridium perfringens* are Higher in Finer Sediments

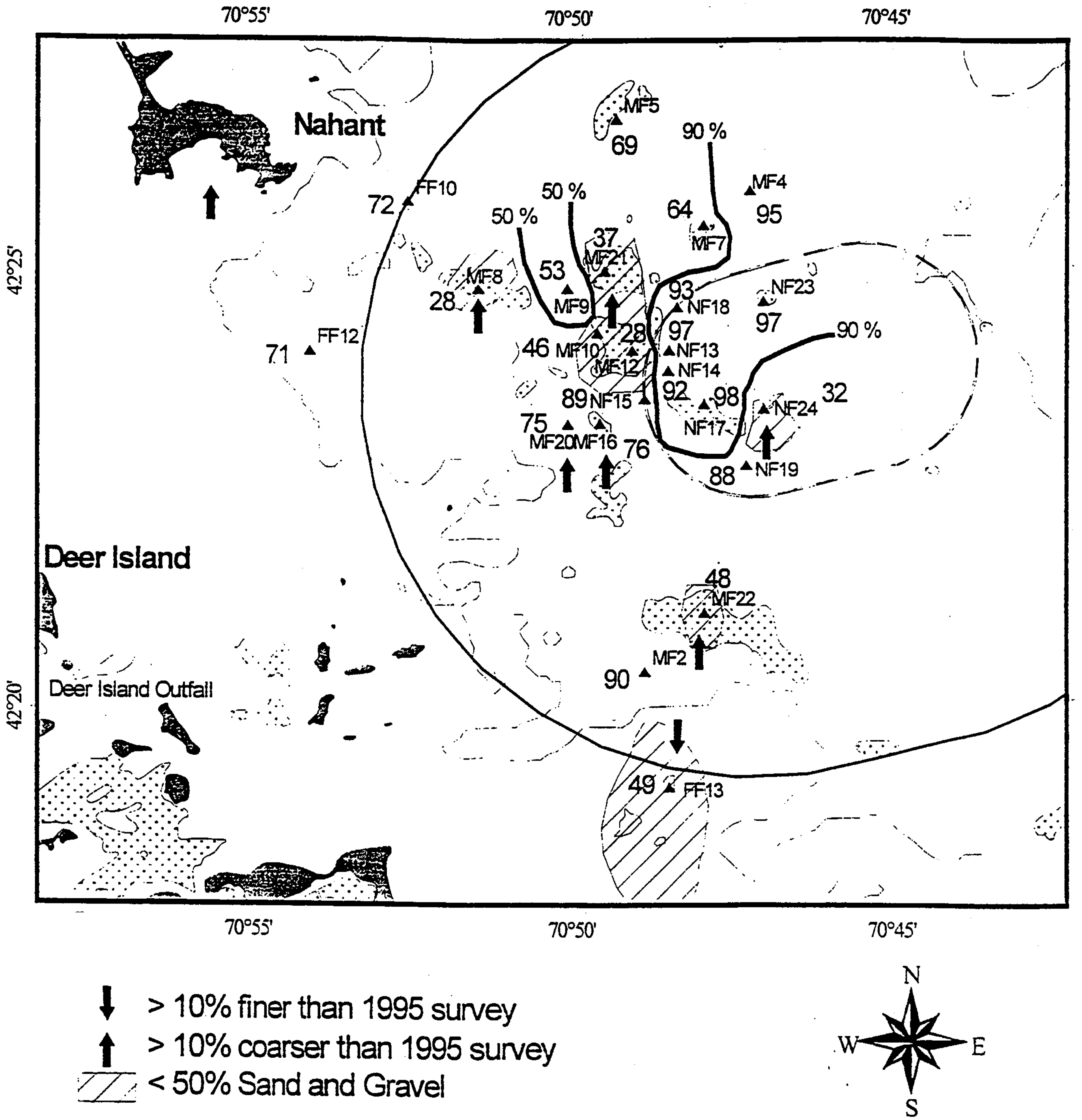


Figure 37. **Percent sand and gravel at nearfield and midfield stations in August 1996. Changes relative to August 1995 indicated by arrows.**

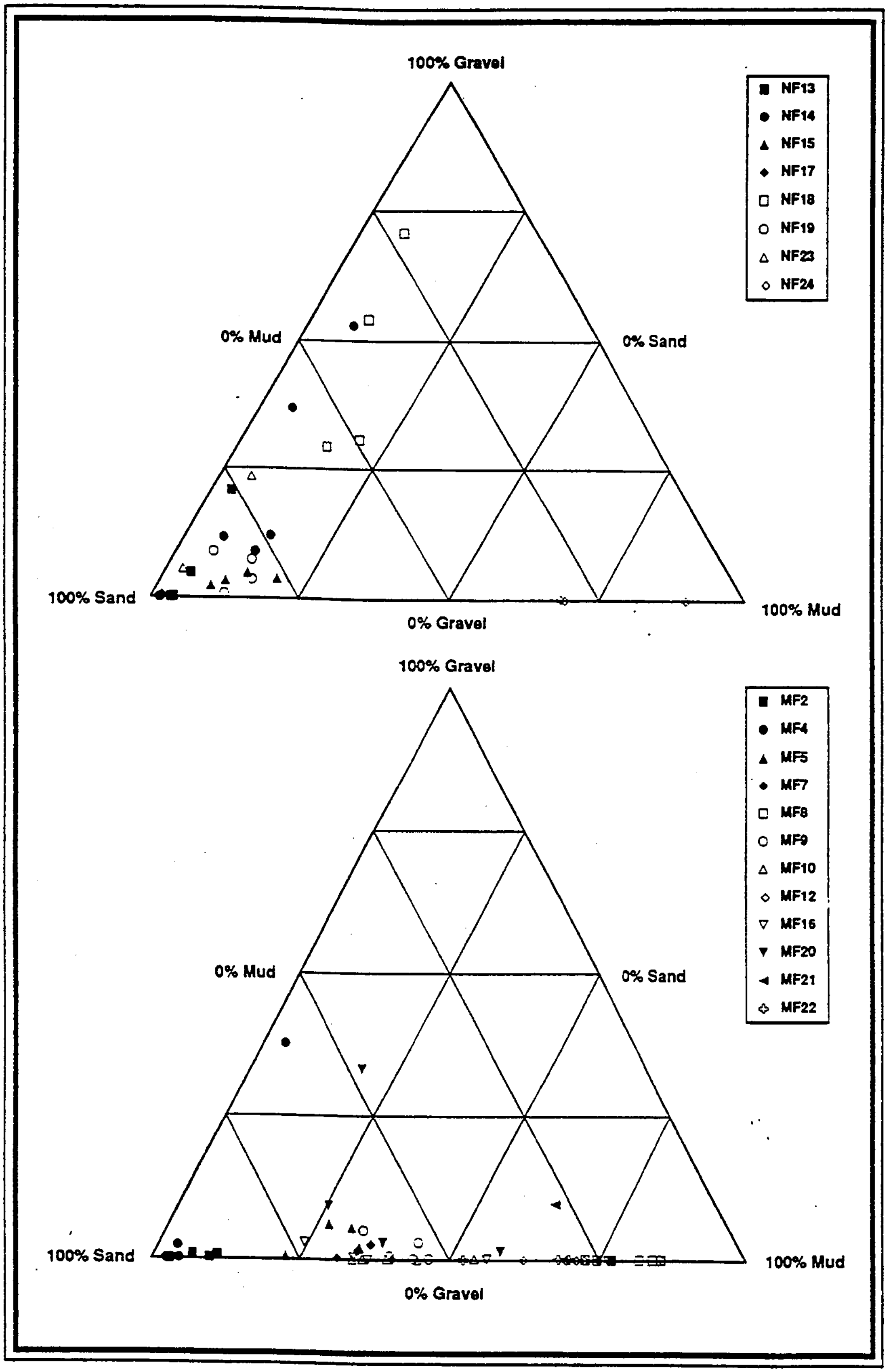


Figure 38. Sand/gravel/mud triangle diagrams showing relative sediment composition at nearfield and midfield stations for the period 1992-1996.

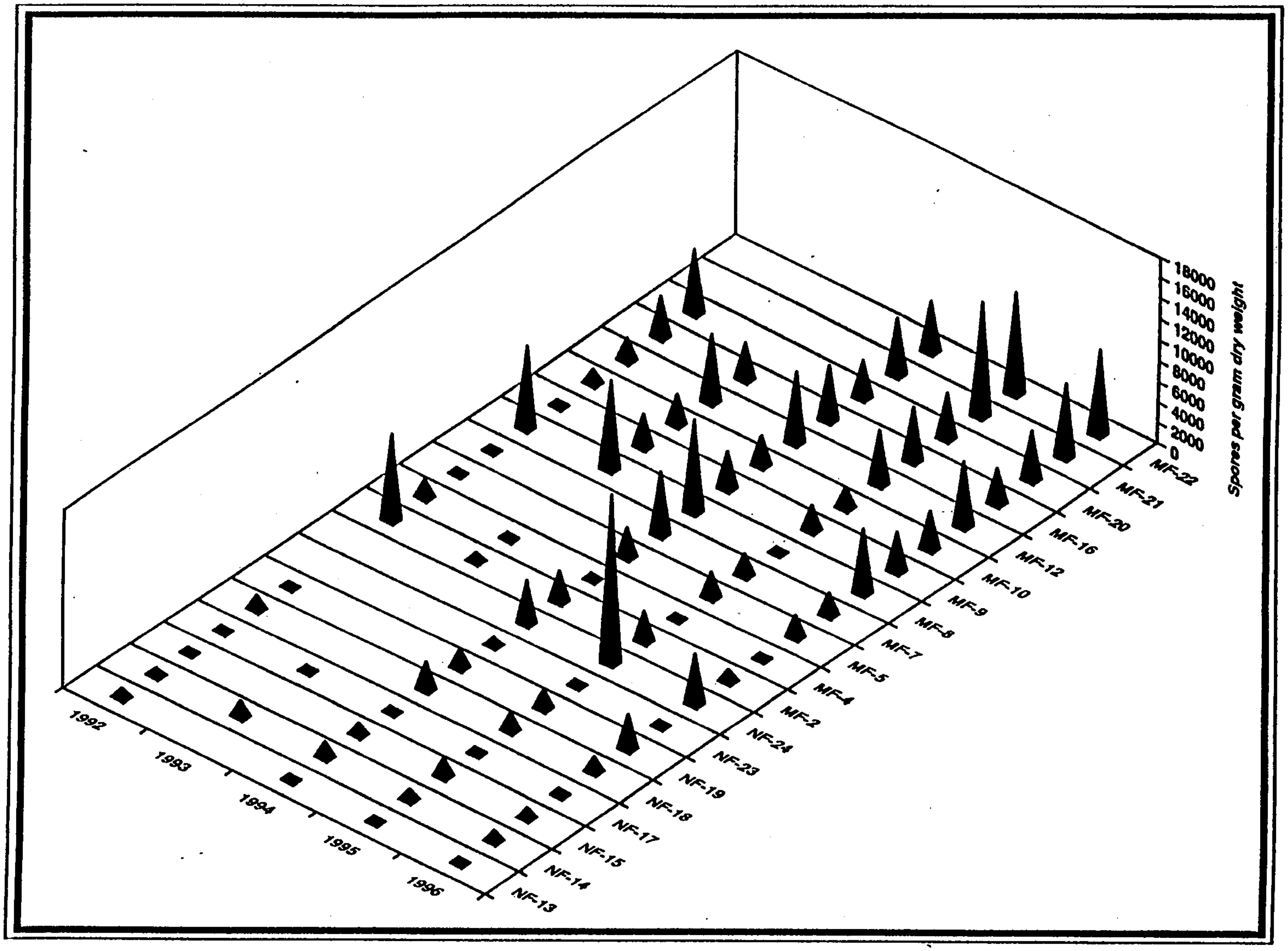


Figure 43. Densities of *Clostridium perfringens* spores at the nearfield and midfield stations for the period 1992-1996.

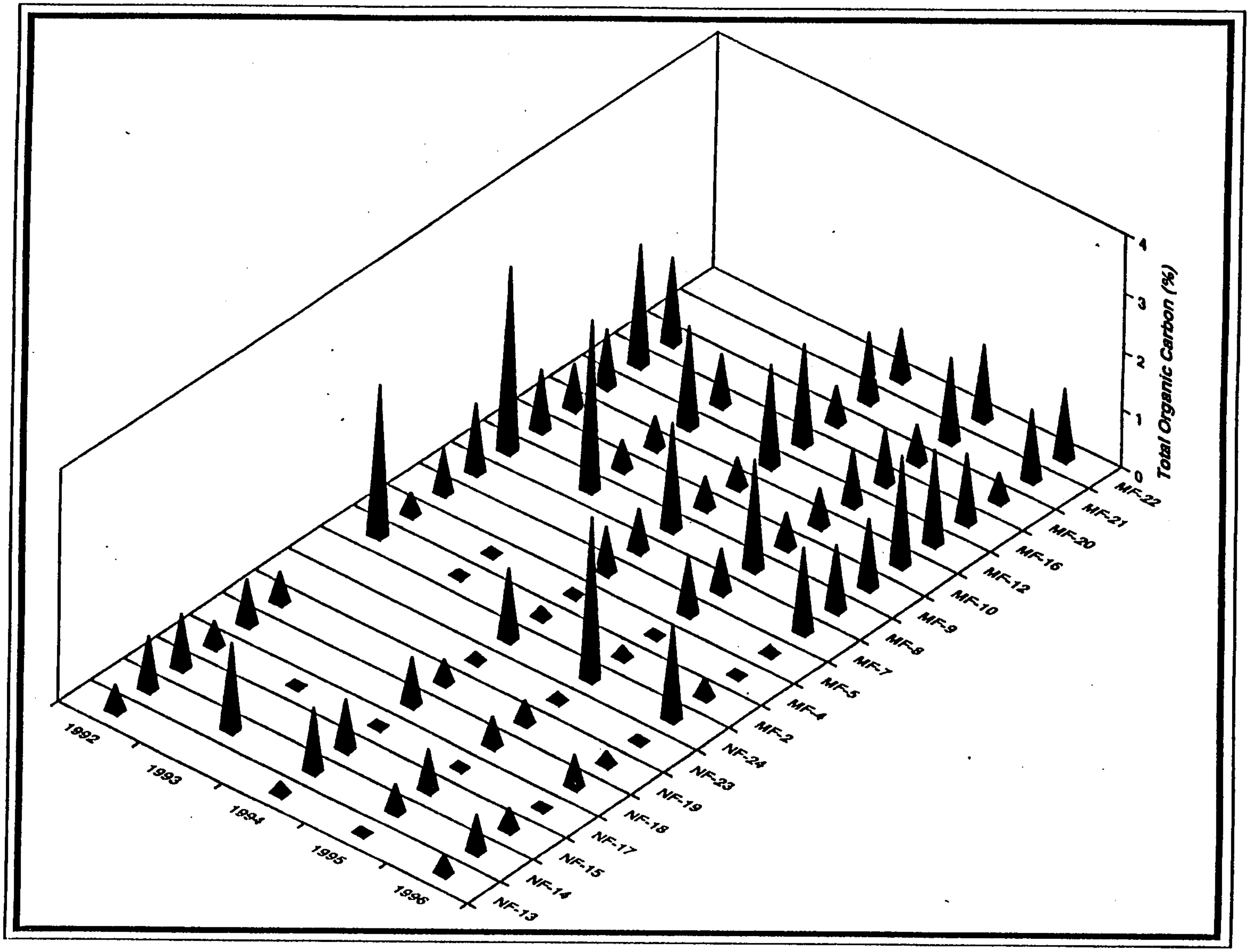


Figure 42. Total organic carbon concentrations at the nearfield and midfield stations for the period 1992-1996.

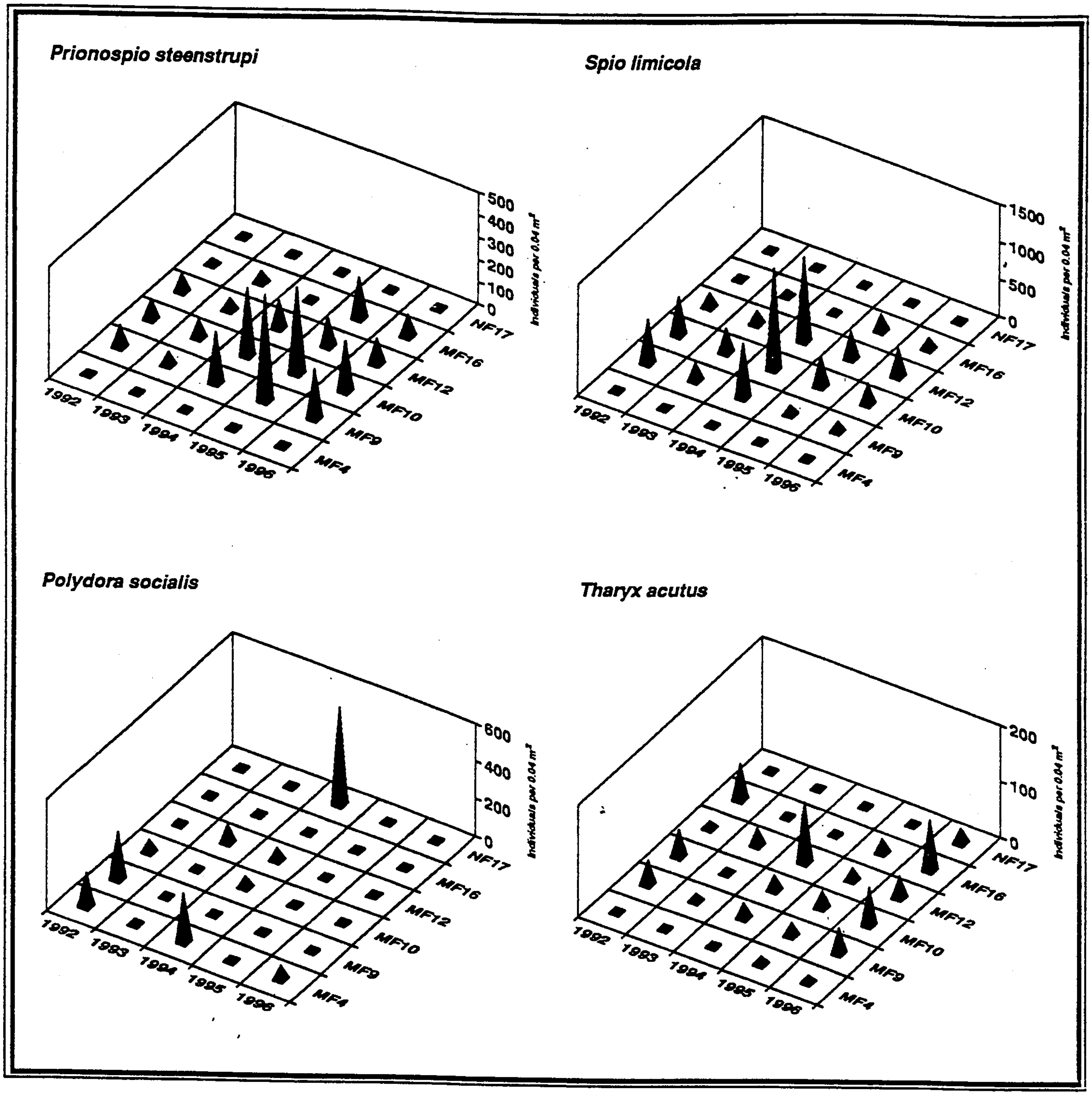


Figure 47. Relative abundances of three spionid and one cirratulid species at selected nearfield and midfield stations for the period 1992-1996.

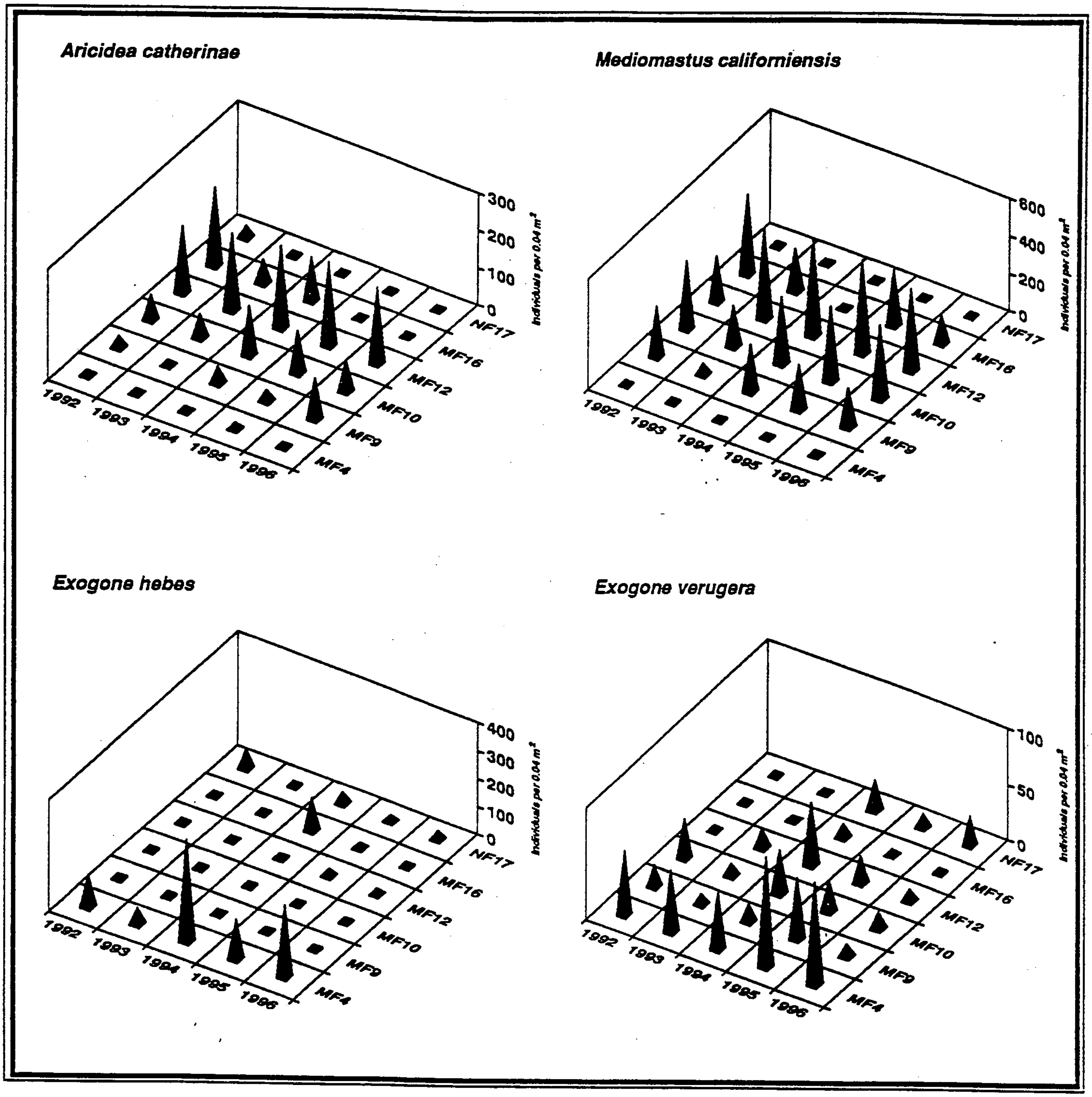


Figure 48. Relative abundances of a paraonid, a capitellid and two syllid species at selected nearfield and midfield stations for the period 1992-1996.

Benthic Infaunal Monitoring

1992-1996 SUMMARY STATISTICS

- Total Mean Infaunal Abundance for Nearfield Stations = 44,159 individuals m^{-2}
- Total Mean Infaunal Abundance for Midfield Stations = 45,315 individuals m^{-2}
- Average Total Number of Species for Nearfield Stations = 68.9±13.82
- Average Total Number of Species for Midfield Stations = 63.2±14.43
- Average Species Diversity (Shannon-Wiener-H′) for Nearfield Stations = 2.71±0.32
- Average Species Diversity (Shannon-Wiener-H′) for Midfield Stations = 2.57±0.35

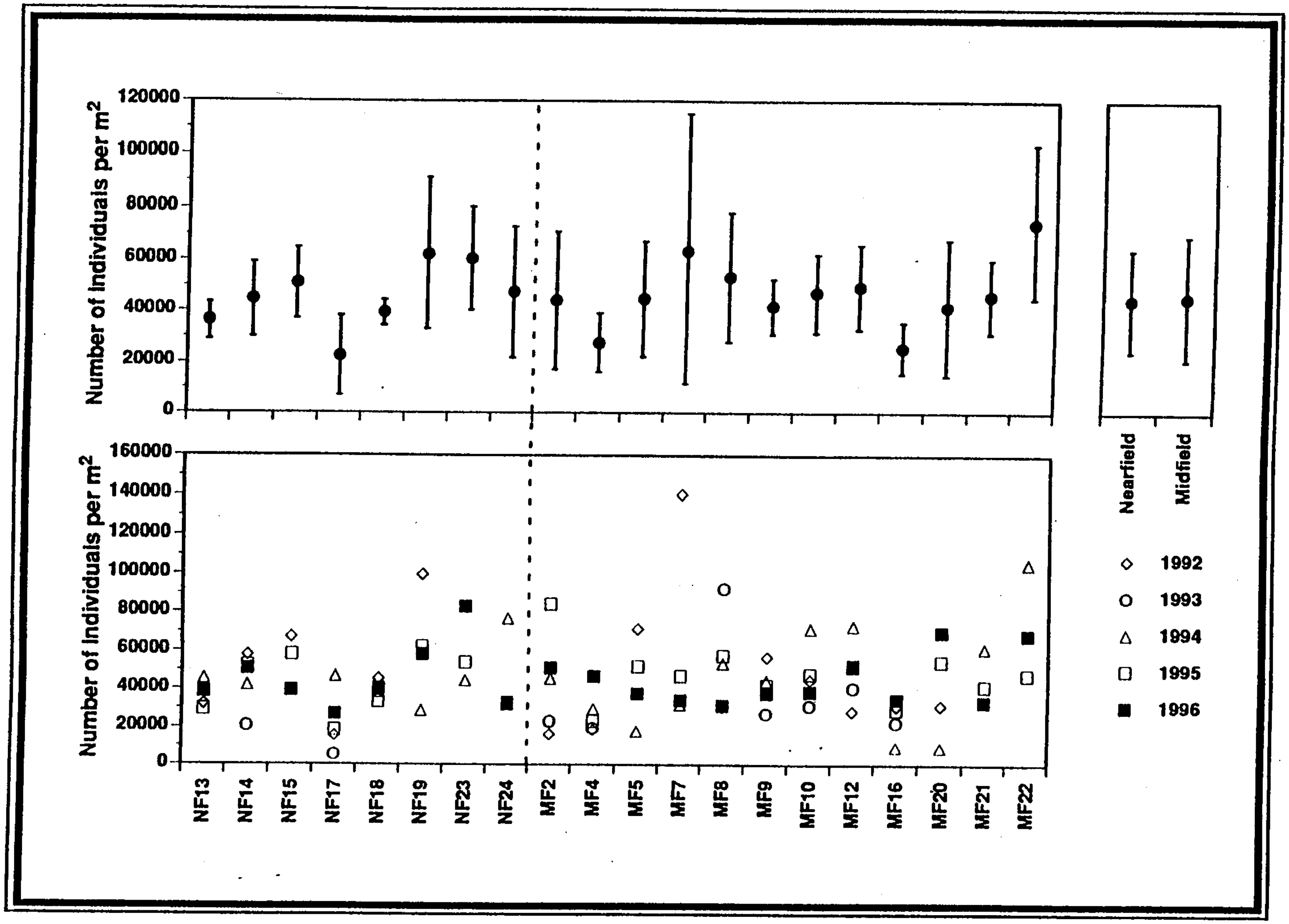


Figure 49. Infaunal densities at nearfield and midfield stations for the period 1992-1996. Top diagram shows the mean and one standard deviation for each station; bottom diagram shows abundances for each year.

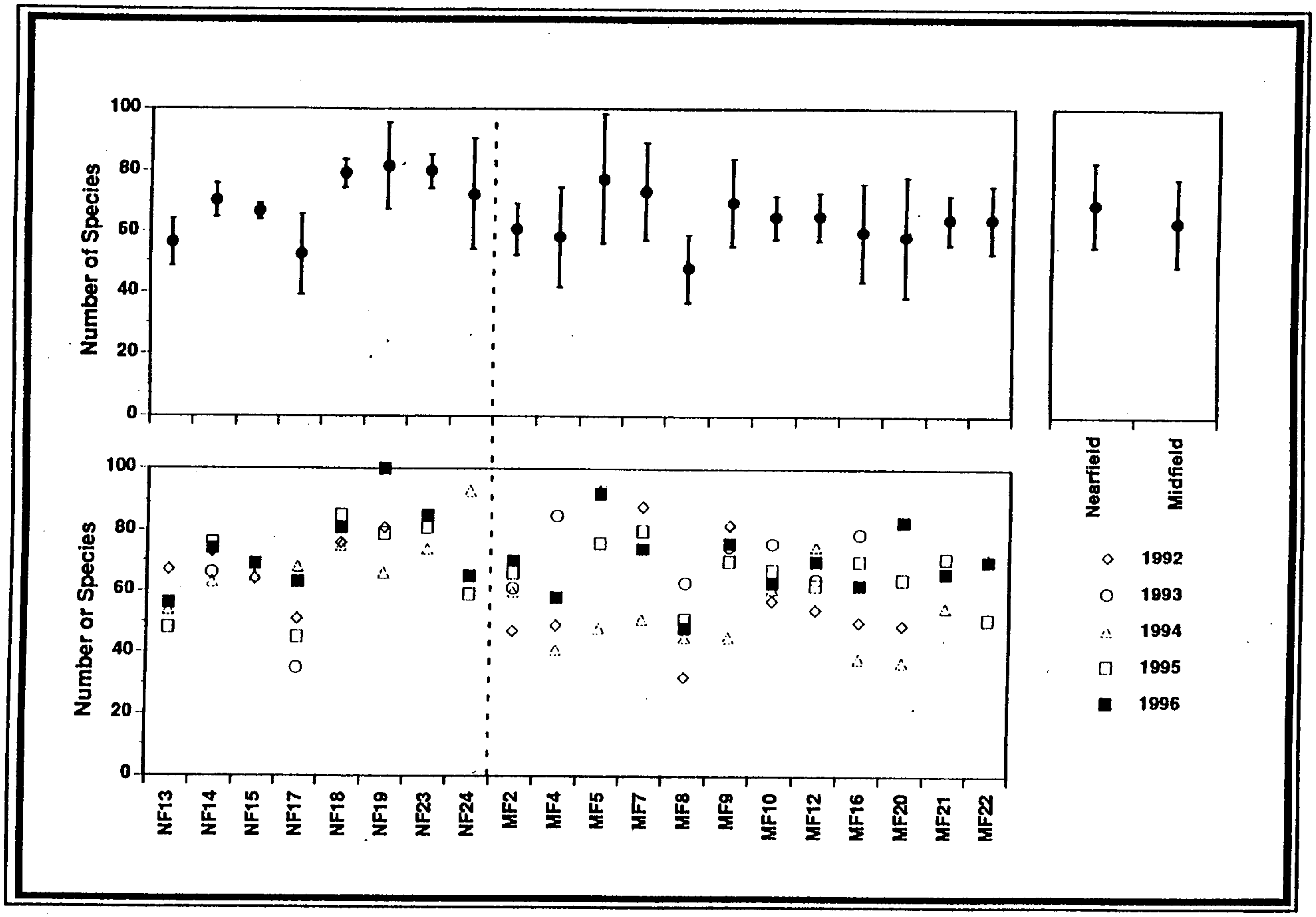
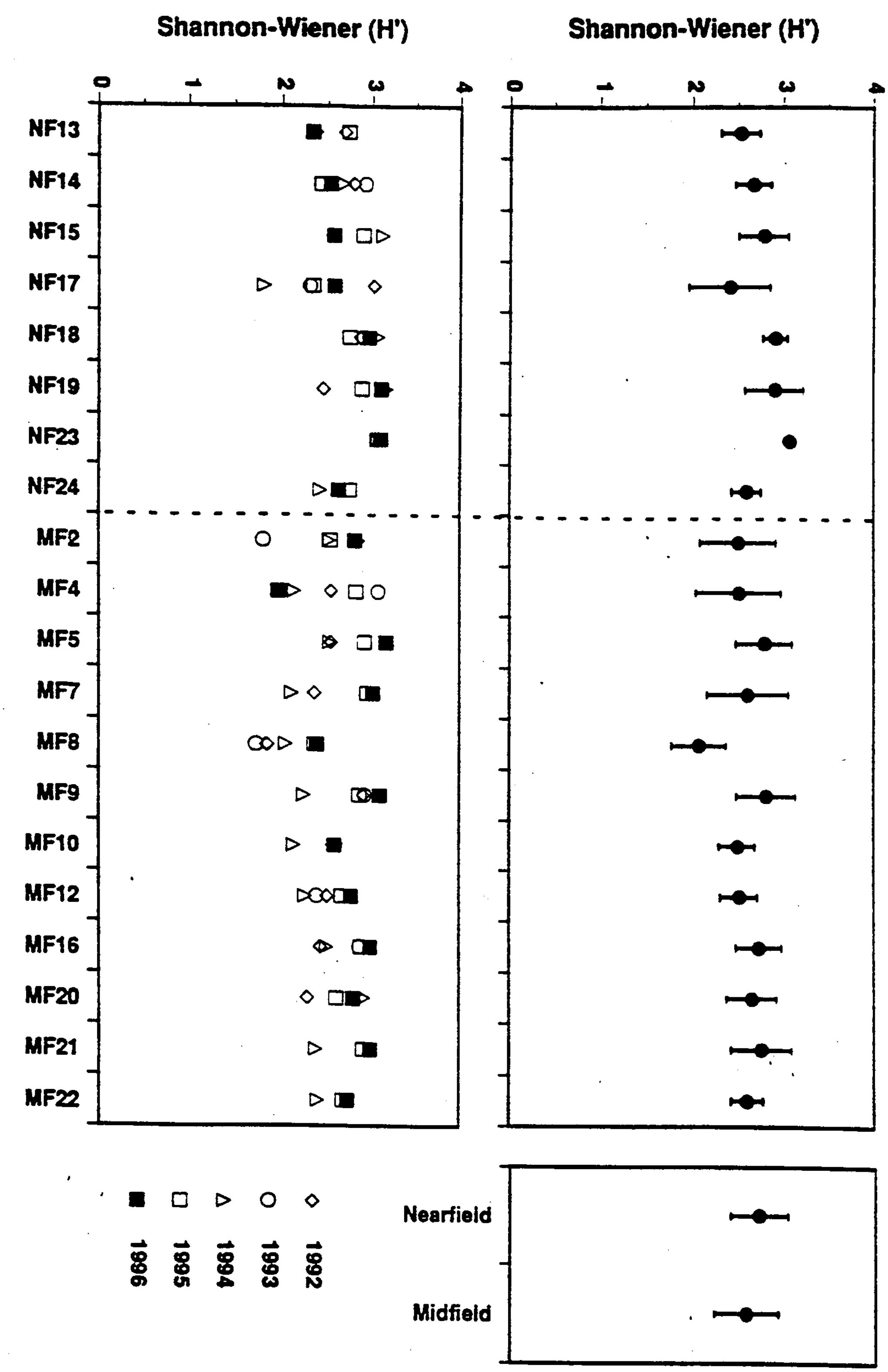
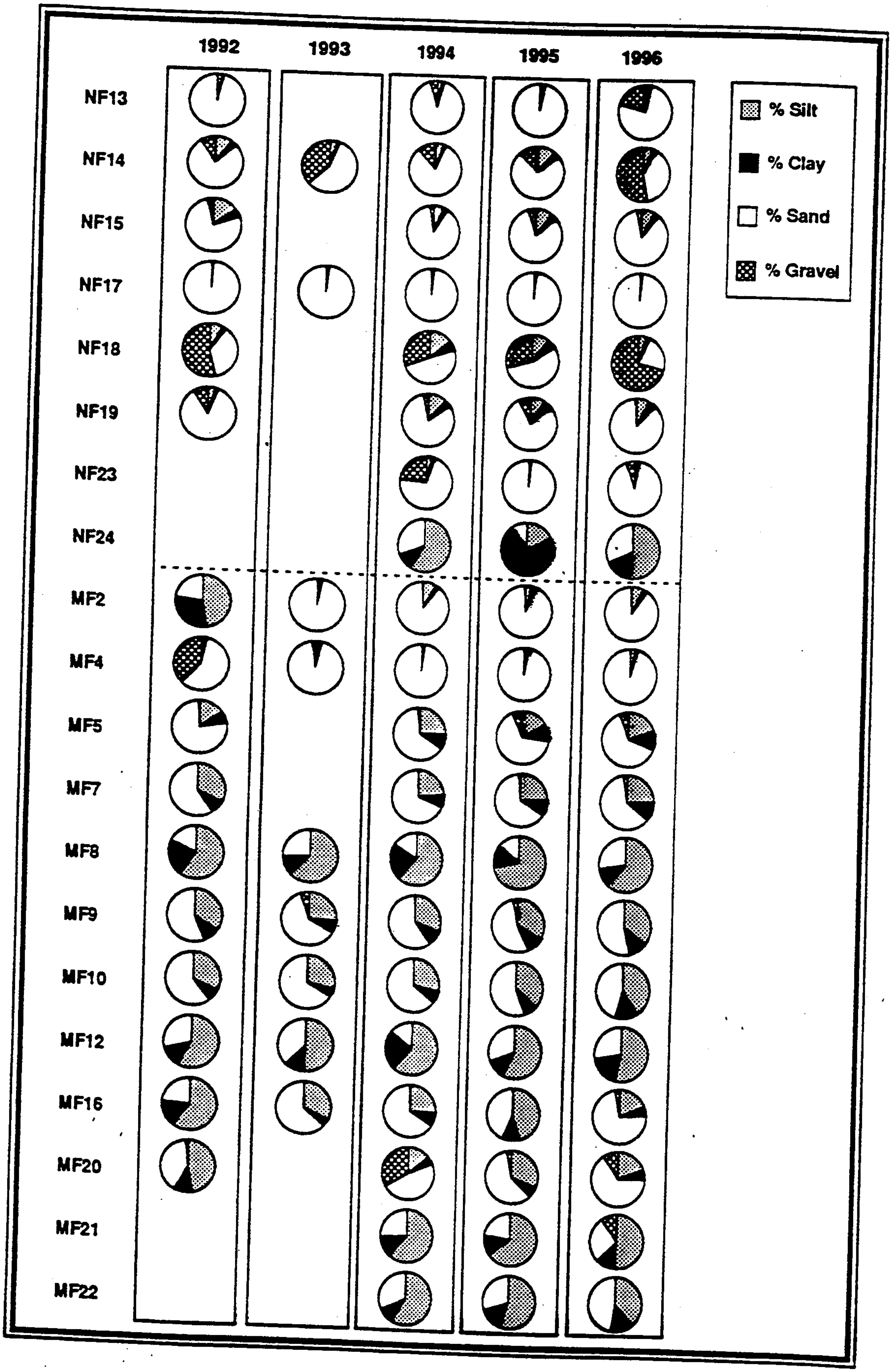


Figure 50. Number of species at nearfield and midfield stations for the period 1992-1996. Top diagram shows the mean and one standard deviation for each station; bottom diagram shows values for each year.



Shannon-Wiener (H')
Shannon-Wiener (H')
0
1
2
3
4
NF13
NF14
NF15
NF17
NF18
NF19
NF23
NF24
MF2
MF4
MF5
MF7
MF8
MF9
MF10
MF12
MF16
MF20
MF21
MF22
1996
1995
1994
1993
1992
Nearfield
Midfield


1992
1993
1994
1995
1996
NF13
NF14
NF15
NF17
NF18
NF19
NF23
NF24
MF2
MF4
MF5
MF7
MF8
MF9
MF10
MF12
MF16
MF20
MF21
MF22
% Silt
% Clay
% Sand
% Gravel

Important species

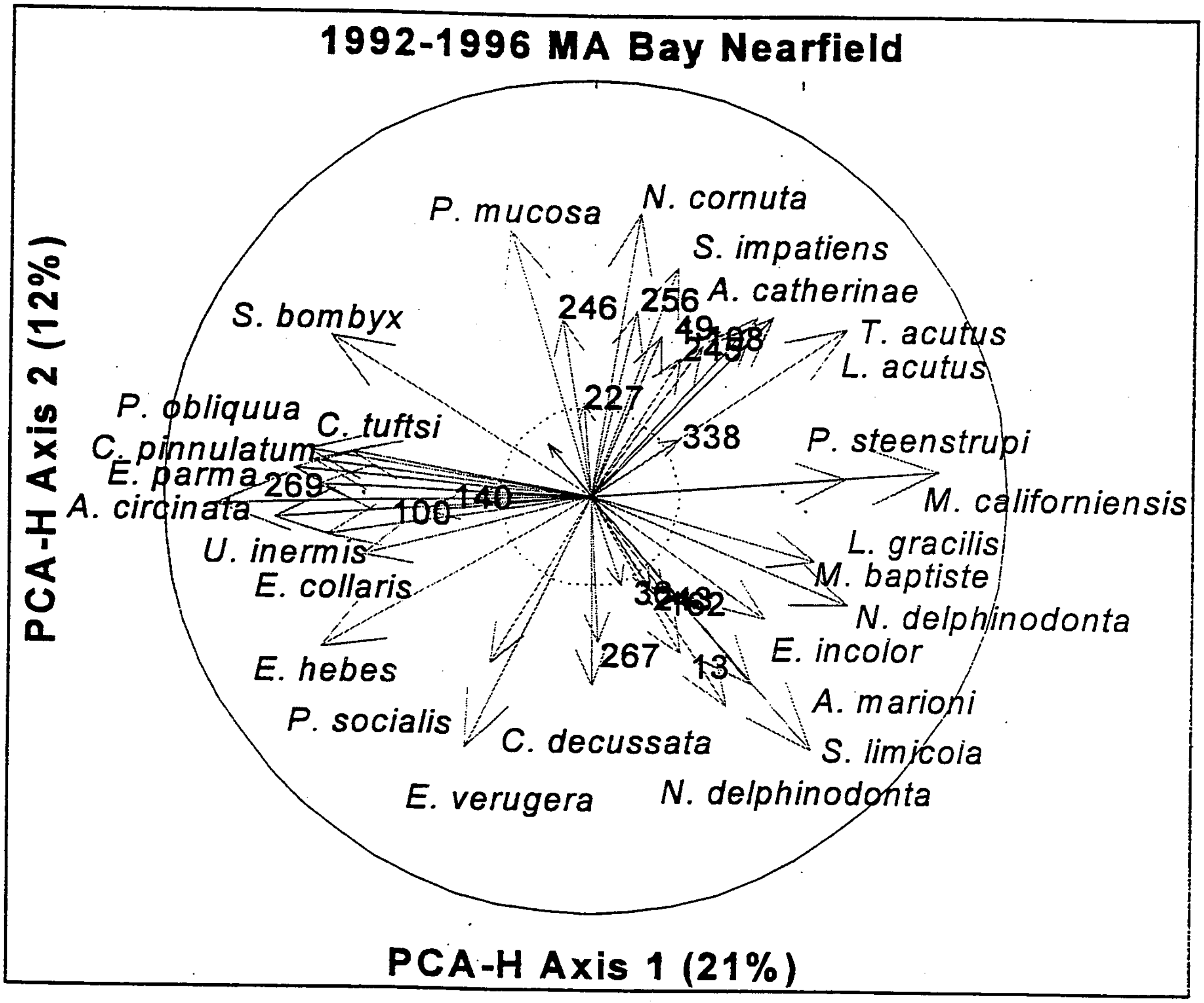
Table 1 shows the partition of CNESS (m=20) variation. Only forty-four of 349 species contribute 1% or more to the variation of CNESS, and these forty four species account for 88% of the variation in CNESS. The top twelve species account for 51% of the variation in CNESS, with Spio limicola being the most important, accounting for 7% of the variation in CNESS.

Table 1. Important species in the overall analysis.

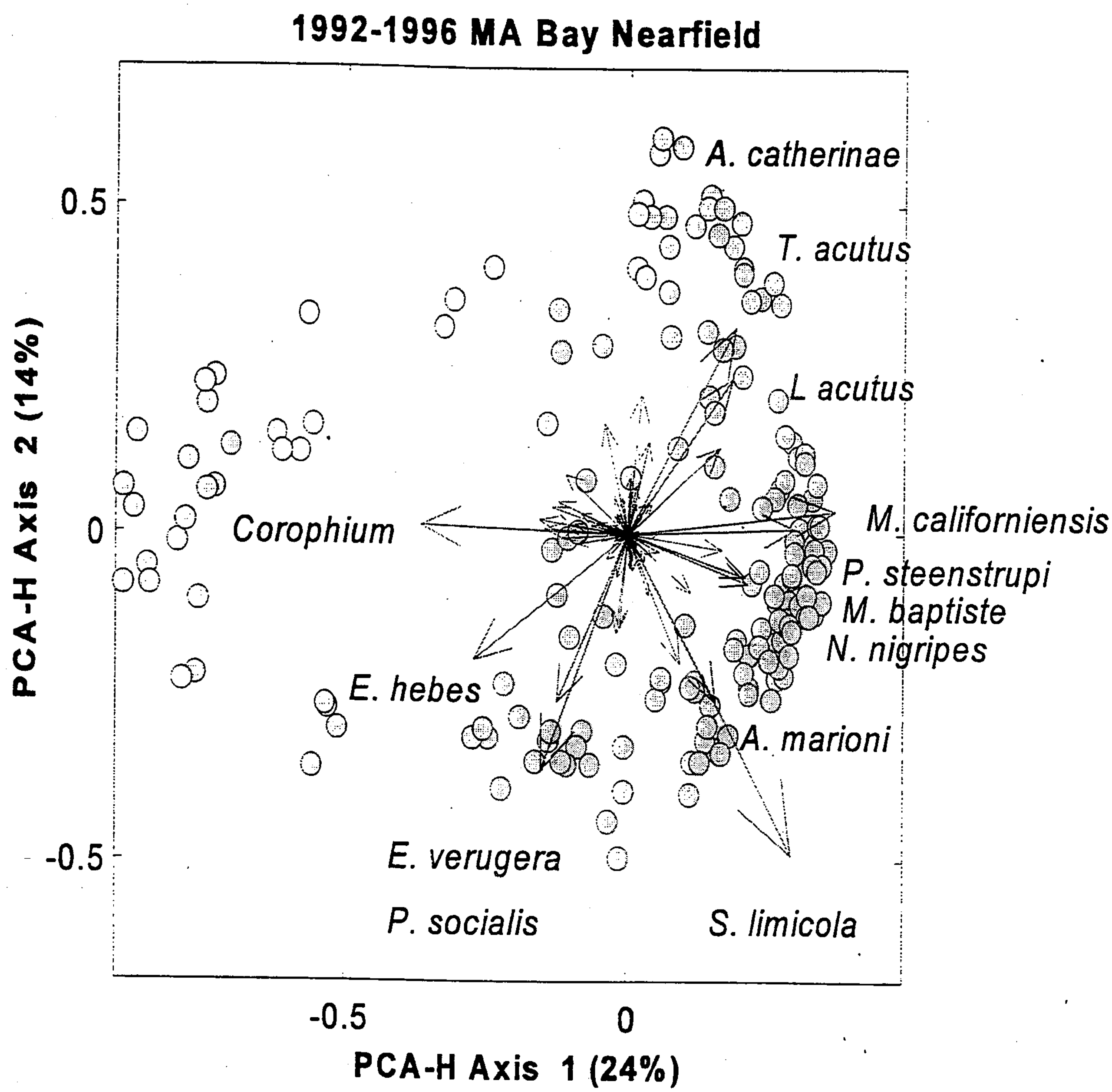
Rank	No	Spp.	Cont.	Σ Cont.	Axis 1	Axis 2	Axis 3	Axis 5	Axis 6	Axis 7
1	309	*Spio limicola*	7	7	9	24	0	2	2	0
2	268	*Polydora socialis*	5	12	2	13	16	13	7	3
3	277	*Prionospio steenstrupi* (Malmgren)	5	17	9	0	3	31	0	7
4	32	*Aricidea catherinae*	5	21	3	10	2	12	12	5
5	71	*Corophium crassicorne*	4	26	14	0	7	0	2	4
6	165	*Mediomastus californiensis*	4	30	14	0	1	0	0	4
7	119	*Exogone hebes*	4	34	7	4	0	2	7	5
8	330	*Tharyx acutus*	4	38	3	6	3	2	5	9
9	23	*Aphelochaeta marioni*	4	42	2	7	3	3	7	16
10	181	*Monticellina baptisteae*	3	45	4	0	6	7	1	1
11	121	*Exogone verugera* (Claparede)	3	48	1	7	1	2	13	0
12	206	*Ninoe nigripes*	3	51	4	1	4	0	3	2
13	140	*Hiatella arctica*	3	53	1	0	4	1	5	18
14	208	*Nucula delphinodonta*	2	55	1	4	0	1	0	0
15	157	*Levinsenia gracilis*	2	58	3	0	9	2	0	1
16	198	*Nephtys cornuta*	2	59	0	5	5	2	0	0
17	269	*Polygordius* Sp. A	2	61	2	0	2	1	0	0
18	76	*Crenella decussata*	2	63	0	2	1	0	4	0
19	152	*Leitoscoloplos acutus*	2	64	3	2	0	0	0	1
20	**267**	***Polydora quadrilobata*** (Jacobi)	**2**	**66**	**0**	**2**	**4**	**1**	**0**	**1**

Rank	No	Spp.	Cont.	Σ Cont.	Axis 1	Axis 2	Axis 3	Axis 5	Axis 6	Axis 7
21	227	*Owenia fusiformis* (Chiaje)	2	68	0	0	0	0	4	1
22	345	*Unciola inermis*	1	69	2	0	1	0	0	1
23	111	*Euchone incolor*	1	71	1	1	3	3	0	1
24	295	*Scoletoma impatiens*	1	72	0	2	1	1	1	1
25	283	*Pseudunciola obliquua*	1	73	2	0	3	0	5	1
26	251	*Phyllodoce mucosa*	1	75	0	3	3	1	0	0
27	54	*Cerastoderma pinnulatum*	1	76	1	0	0	1	0	1
28	338	Tubificidae Sp. 2 (Blake 1992)	1	77	0	0	0	2	1	0
29	314	*Spiophanes bombyx* (Claparede)	1	78	1	1	1	0	4	2
30	36	*Asabellides oculata*	1	79	0	0	2	1	2	0
31	245	*Phoronis architecta*	1	79	0	0	1	0	2	1
32	13	*Ampharete acutifrons* (Grube)	1	80	0	1	0	0	0	1
33	100	Enchytraeidae Sp. 1	1	81	0	0	0	1	1	0
34	246	*Photis pollex*	1	82	0	0	2	0	0	0
35	112	*Euclymene collaris*	1	83	1	0	0	0	1	0
36	61	*Chiridotea tuftsi*	1	83	1	0	1	0	1	0
37	8	*Aglaophamus circinata*	1	84	1	0	0	0	0	1
38	108	*Eteone longa*	1	84	0	0	0	1	0	0
39	243	*Pholoe minuta* (Fabricius)	1	85	0	0	0	0	0	1
40	162	*Maldane glebifex*	1	86	0	0	0	0	0	0
41	49'	*Capitella* spp.	1	86	0	0	2	0	0	0
42	221	*Ophiura robusta*	1	87	0	0	0	0	0	3
43	96	*Echinarachnius parma*	1	87	1	0	1	0	1	0
44	256	*Pleurogonium rubicundum*	1	88	0	0	0	0	0	0

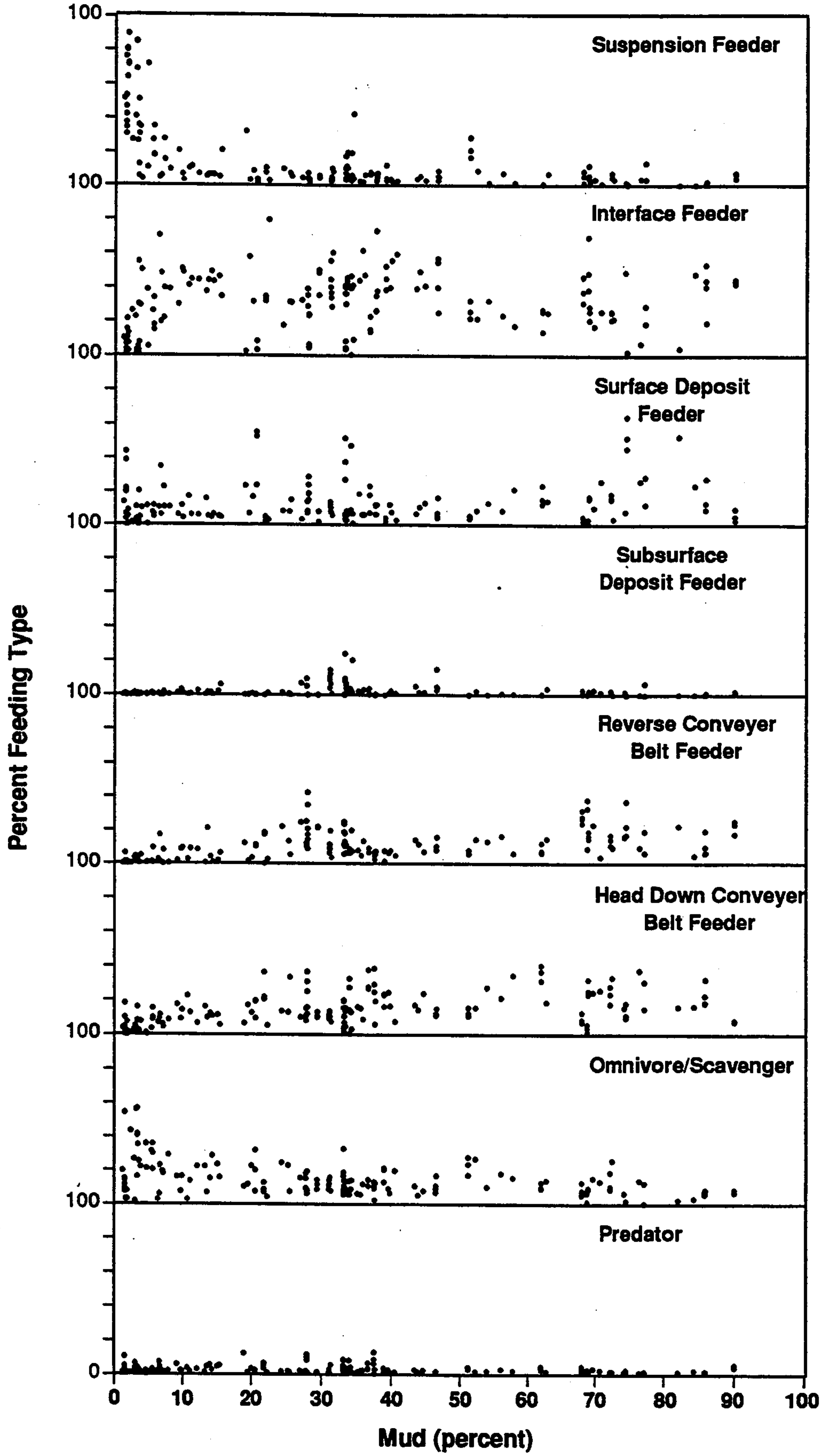
COVARIANCE BIPLOT



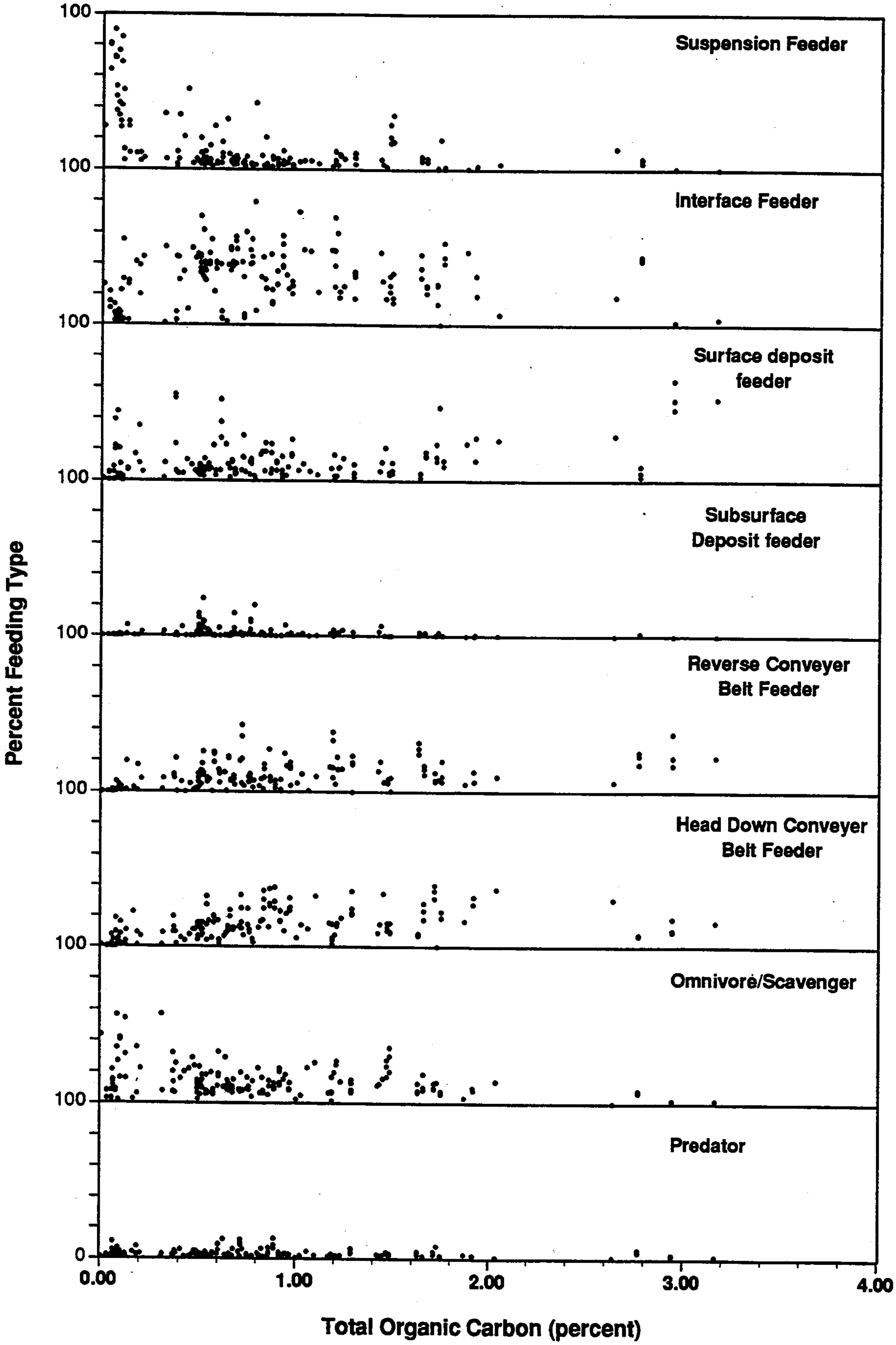
EUCLIDEAN DISTANCE BIPLOTS



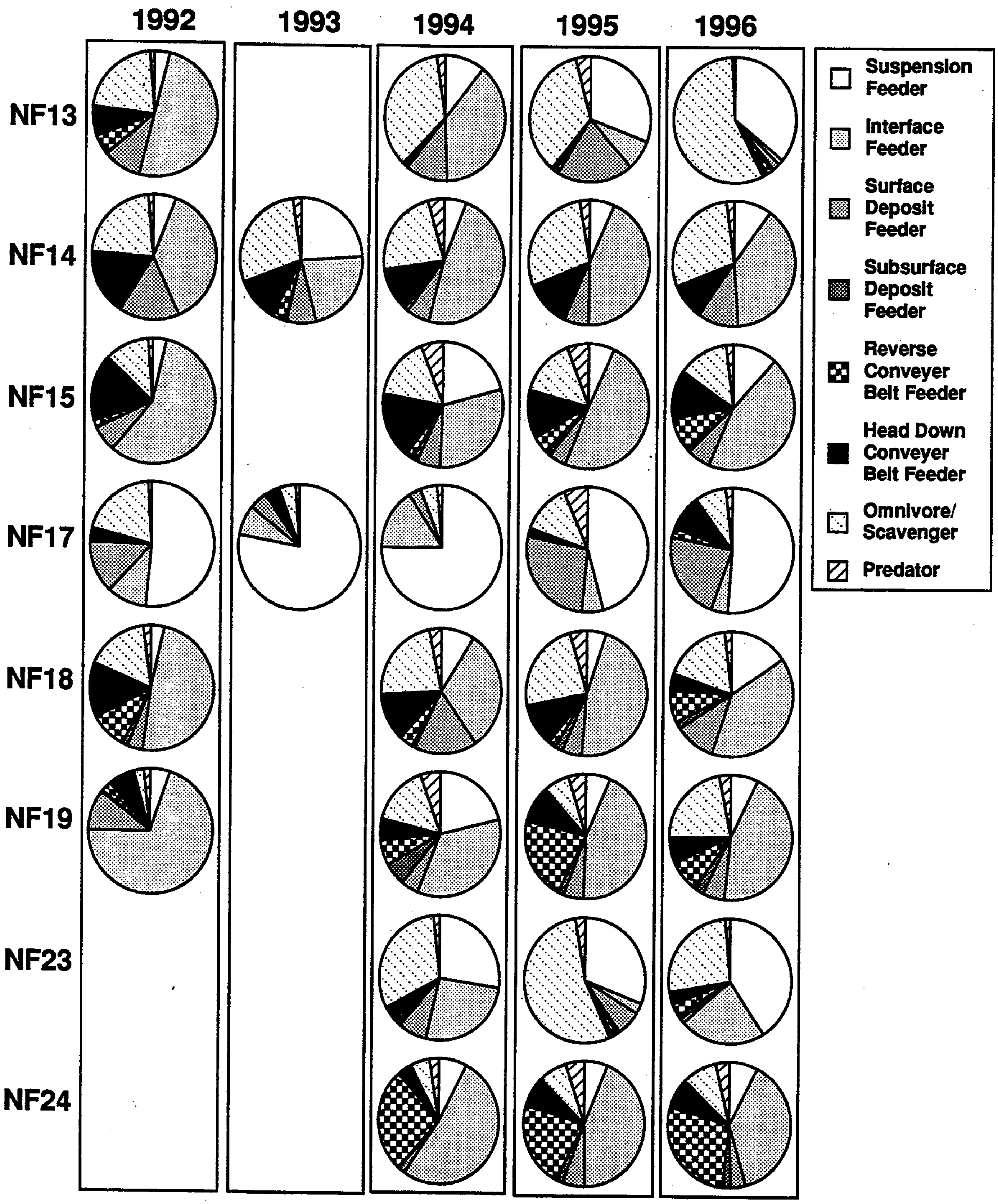
Species vectors accounting for >2% of plot variation in green
Other species vectors plotted in red and unlabelled



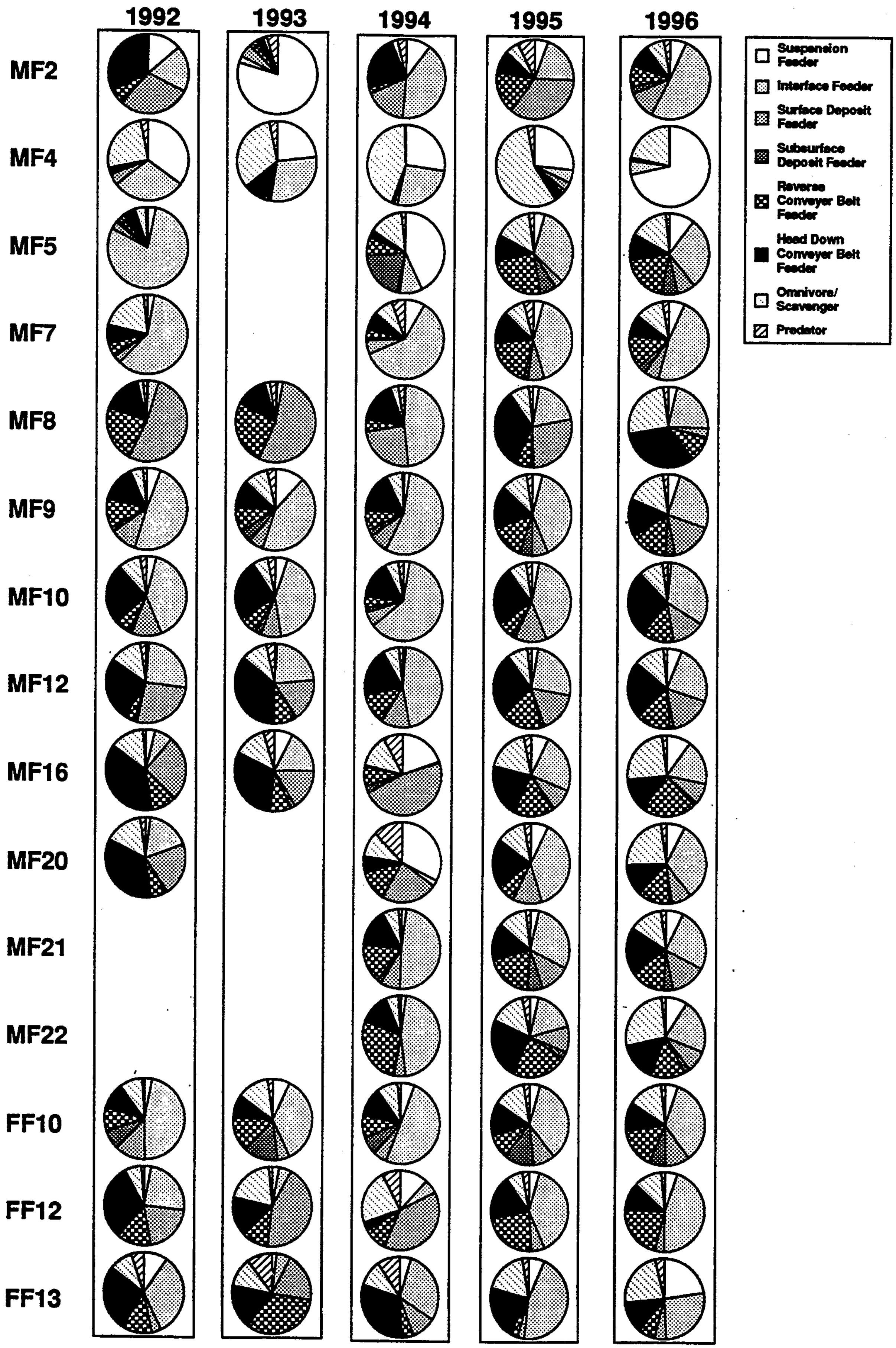
Suspension Feeder
Interface Feeder
Surface Deposit Feeder
Subsurface Deposit Feeder
Reverse Conveyer Belt Feeder
Head Down Conveyer Belt Feeder
Omnivore/Scavenger
Predator
Percent Feeding Type
Mud (percent)
0
10
20
30
40
50
60
70
80
90
100

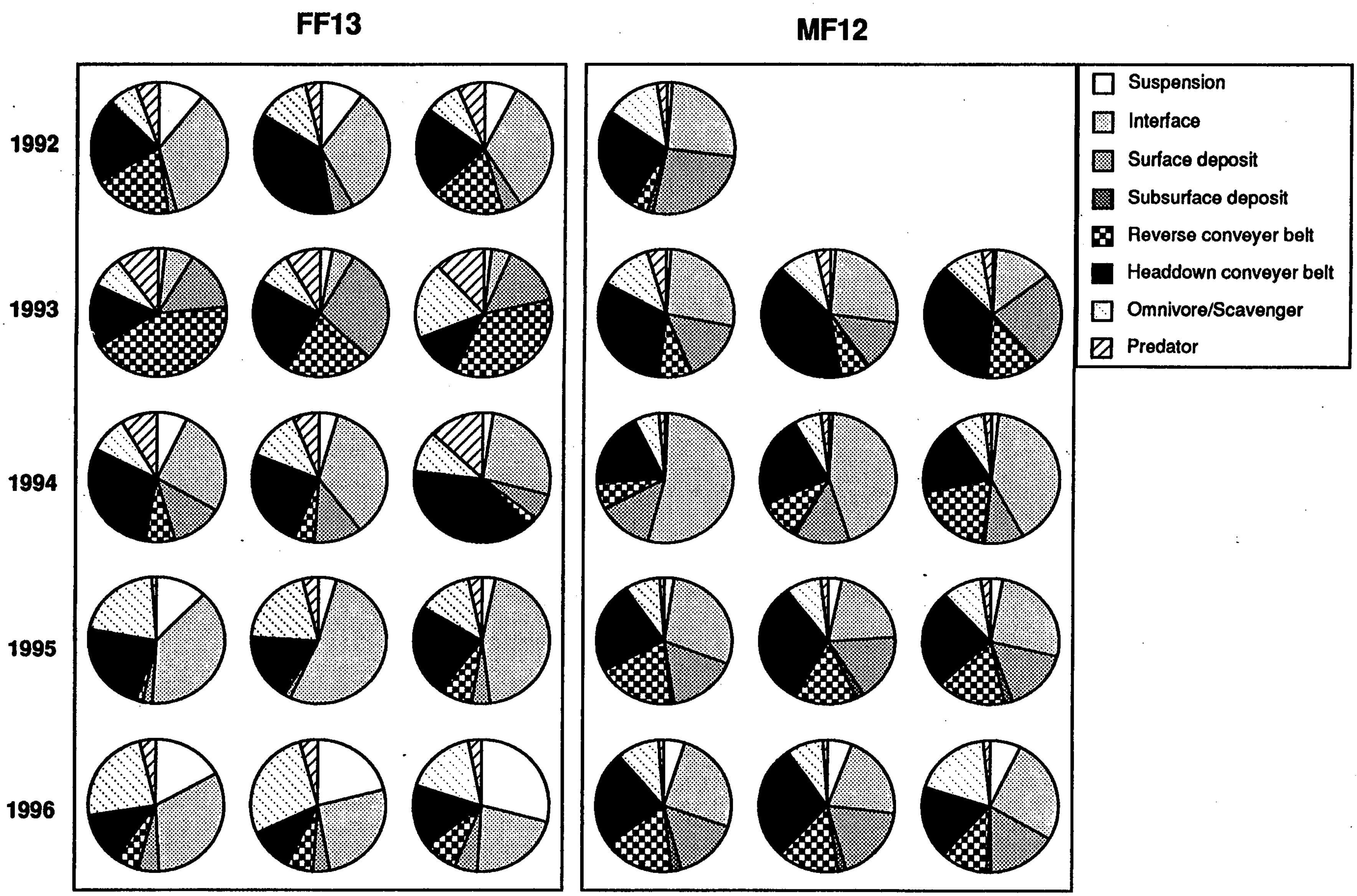


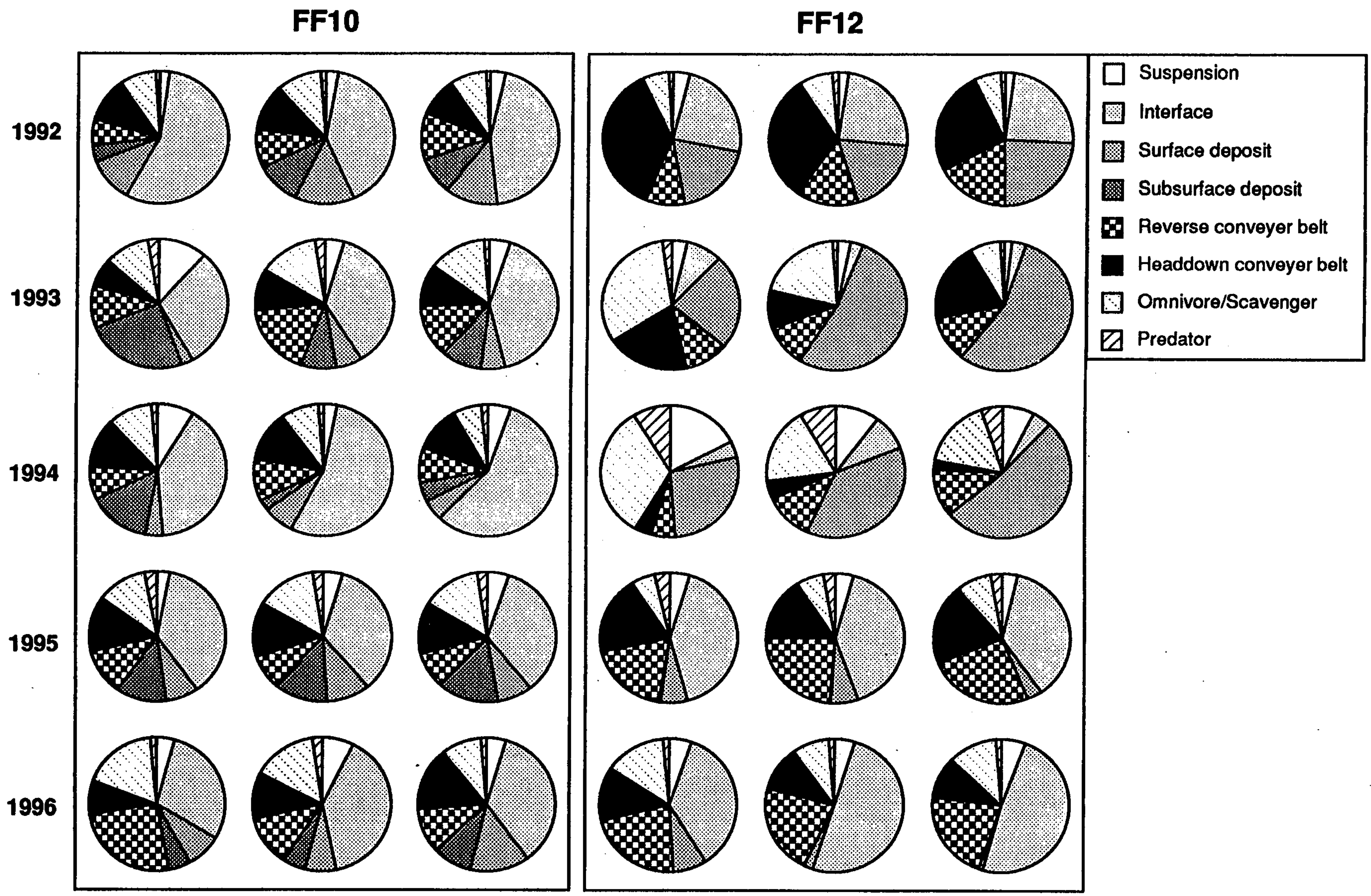
Suspension Feeder
Interface Feeder
Surface deposit feeder
Subsurface Deposit feeder
Reverse Conveyer Belt Feeder
Head Down Conveyer Belt Feeder
Omnivore/Scavenger
Predator
100
100
100
100
100
100
100
100
0
Percent Feeding Type
0.00
1.00
2.00
3.00
4.00
Total Organic Carbon (percent)

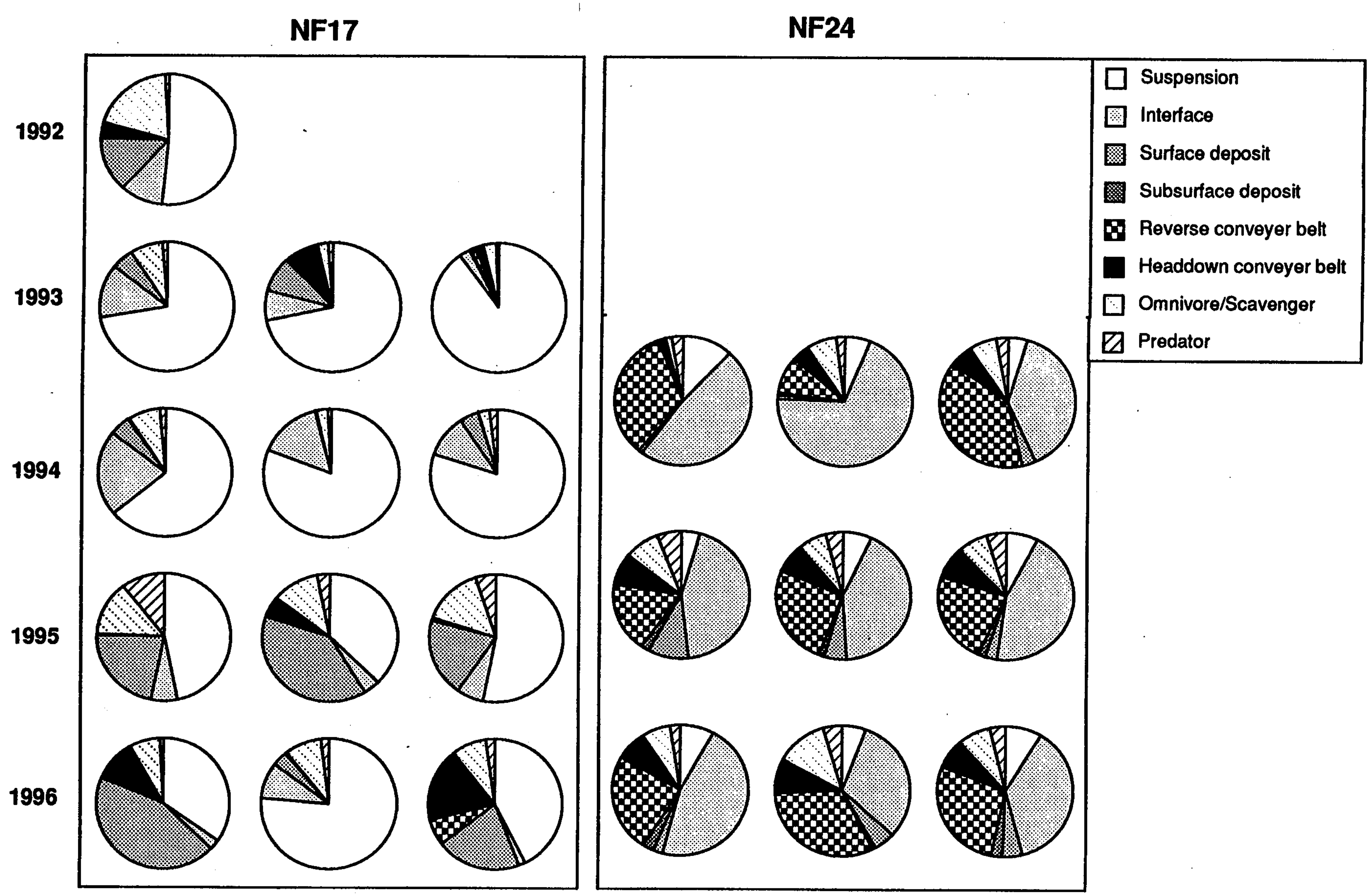


1992
1993
1994
1995
1996
NF13
NF14
NF15
NF17
NF18
NF19
NF23
NF24
Suspension Feeder
Interface Feeder
Surface Deposit Feeder
Subsurface Deposit Feeder
Reverse Conveyer Belt Feeder
Head Down Conveyer Belt Feeder
Omnivore/ Scavenger
Predator


1992
1993
1994
1995
1996
MF2
MF4
MF5
MF7
MF8
MF9
MF10
MF12
MF16
MF20
MF21
MF22
FF10
FF12
FF13
Suspension Feeder
Interface Feeder
Surface Deposit Feeder
Subsurface Deposit Feeder
Reverse Conveyer Belt Feeder
Head Down Conveyer Belt Feeder
Omnivore/ Scavenger
Predator

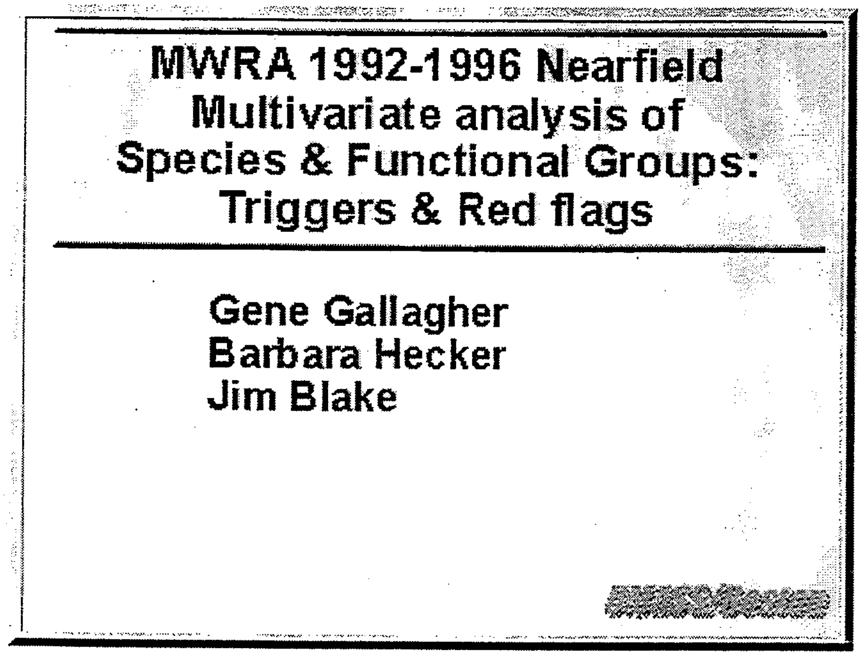

FF13
MF12
1992
1993
1994
1995
1996
Suspension
Interface
Surface deposit
Subsurface deposit
Reverse conveyer belt
Headdown conveyer belt
Omnivore/Scavenger
Predator


FF10
FF12
1992
1993
1994
1995
1996
Suspension
Interface
Surface deposit
Subsurface deposit
Reverse conveyer belt
Headdown conveyer belt
Omnivore/Scavenger
Predator


NF17
NF24
1992
1993
1994
1995
1996
Suspension
Interface
Surface deposit
Subsurface deposit
Reverse conveyer belt
Headdown conveyer belt
Omnivore/Scavenger
Predator

MWRA 1992-1996 Nearfield

Slide 1 of 22



TOC Next

Go to slide: 1: MWRA 1992-1996 Nearfield

Deactivate cloack

Methods for assessing change

Methods for assessing change

Species & functional groups

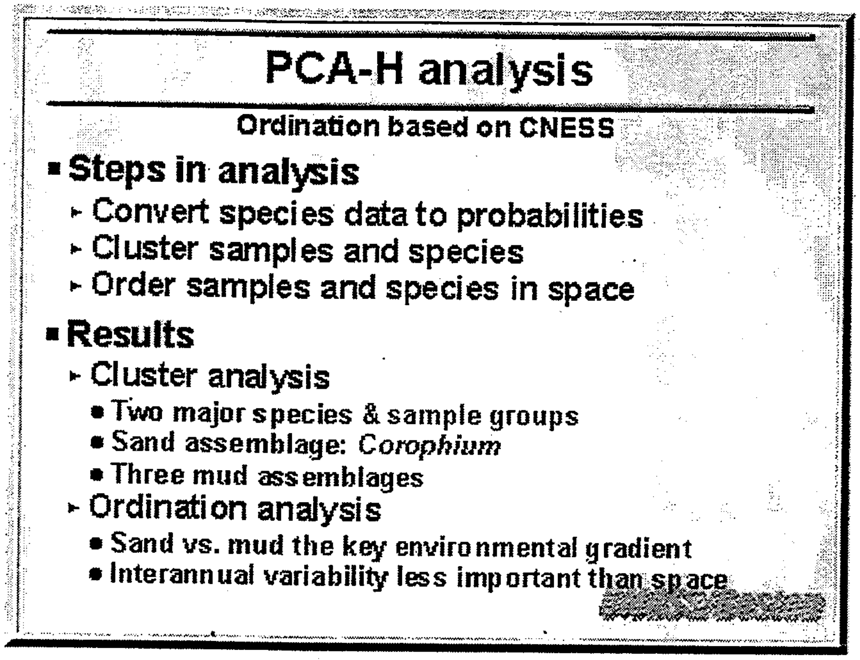
- Changes in species composition
  - There are no "classic" pollution indicating assemblages in MA Bay nearfield
  - Coats multivariate analysis
    - Similar to ter Braak's canonical correspondence analysis
    - Environmental variables (% Silt-clay, TOC, clostridium)
- Decreases in diversity
  - Richness vs. Evenness
- Changes in functional groups
  - Changes in the diversity of functional groups

Prev TOC Next

Go to slide: 2: Methods for assessing change

PCA-H analysis

Slide 3 of 22



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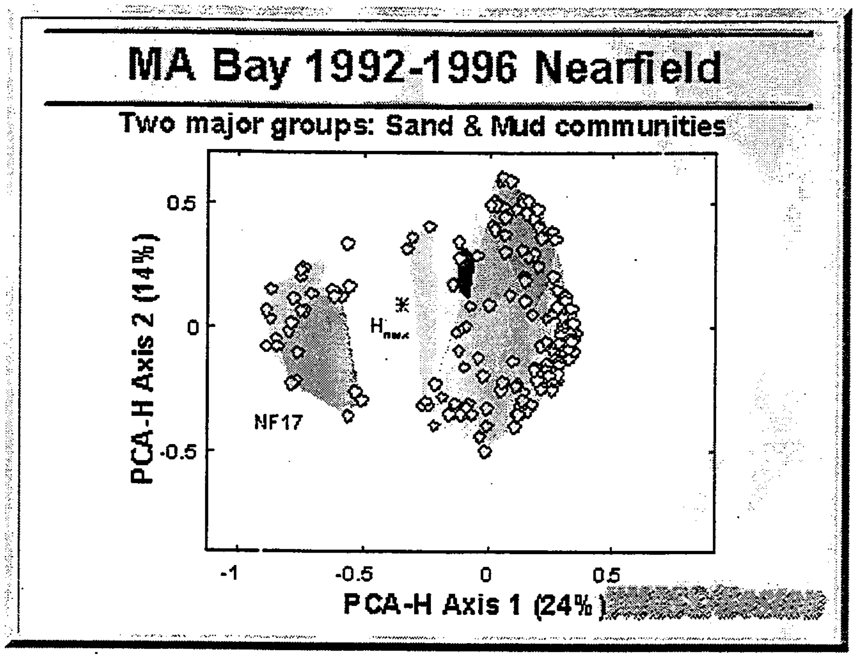
Go to slide: 3: PCA-H analysis

MA Bay 1992-1996 Nearfield



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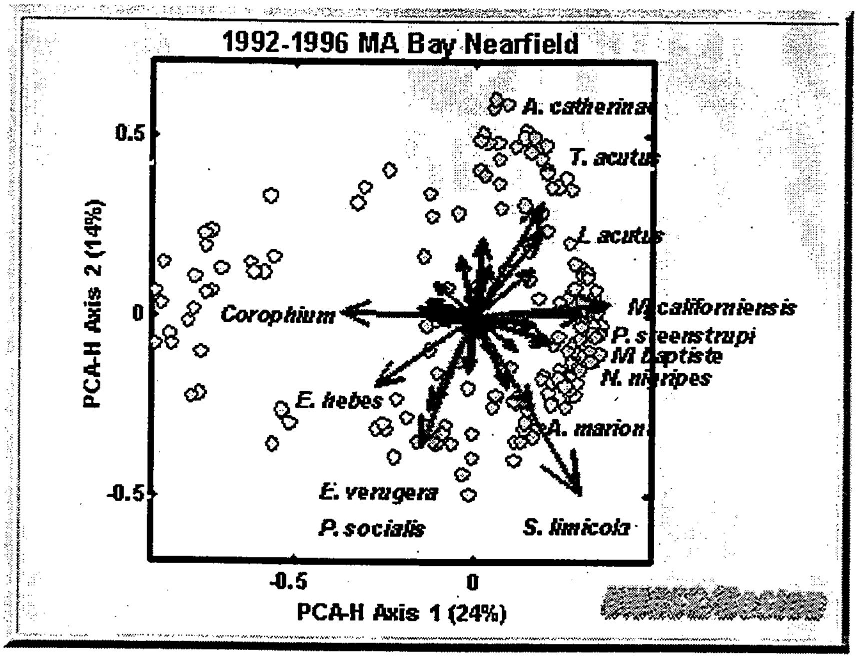
Go to slide: 4: MA Bay 1992-1996 Nearfield

(Untitled)

Slide 5 of 22



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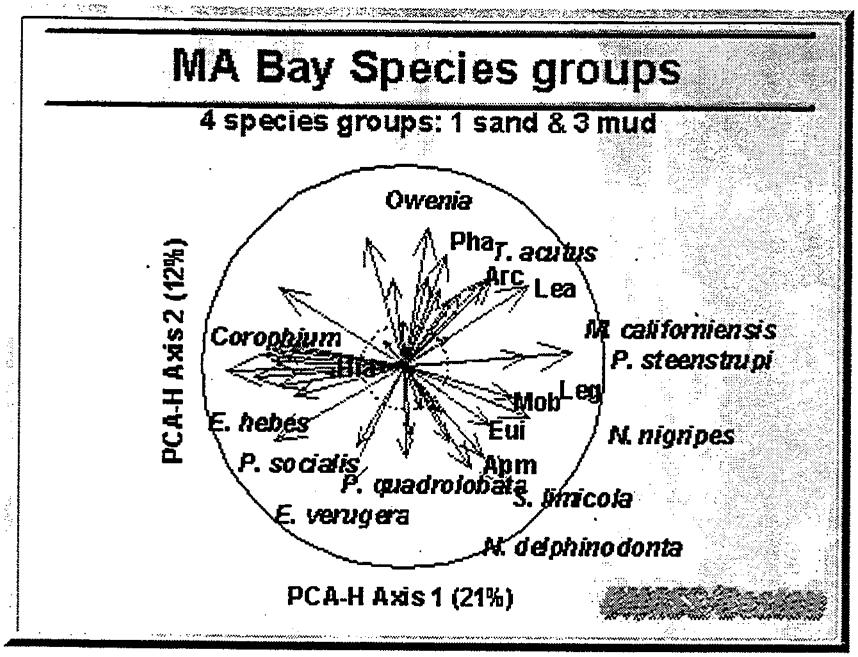
Go to slide: 5: (Untitled)

MA Bay Species groups

Slide 6 of 22



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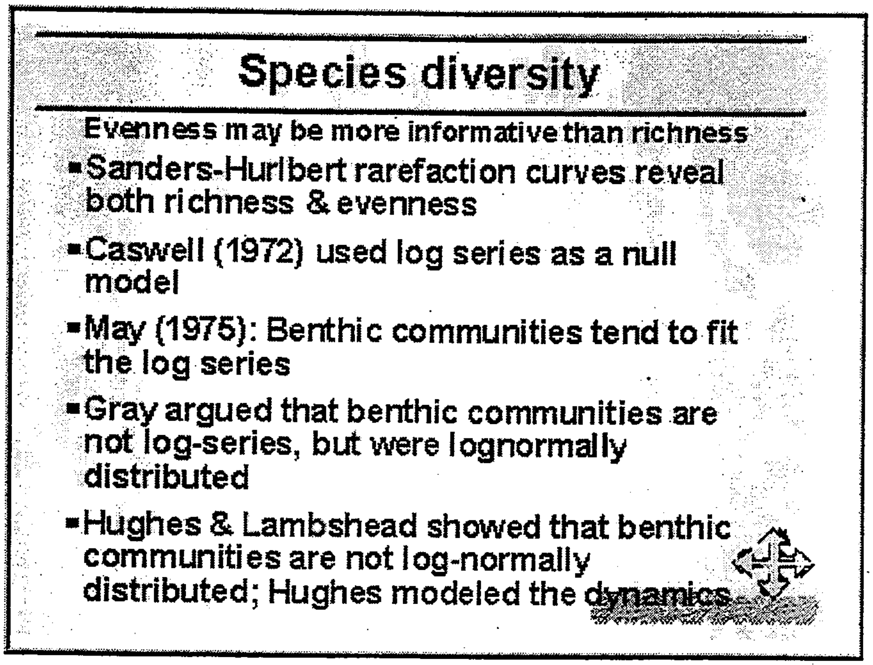
Go to slide: 6: MA Bay Species groups

Deactivate cloack

Species diversity

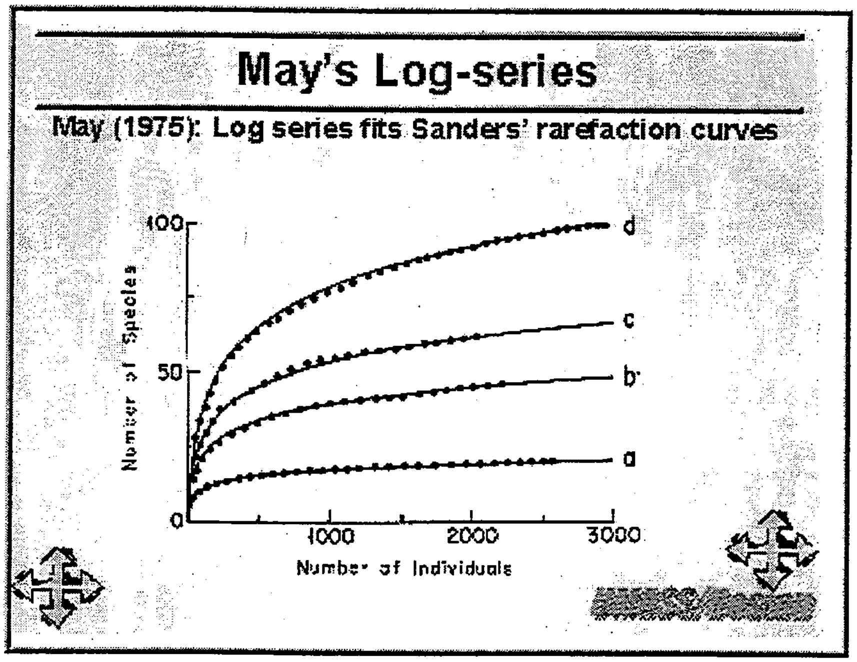


Prev TOC Next

Go to slide: 7: Species diversity

Deactivate cloack

May's Log-series



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Next

Go to slide: 8: May's Log-series

Deactivate cloack

Non-dimensional diversity

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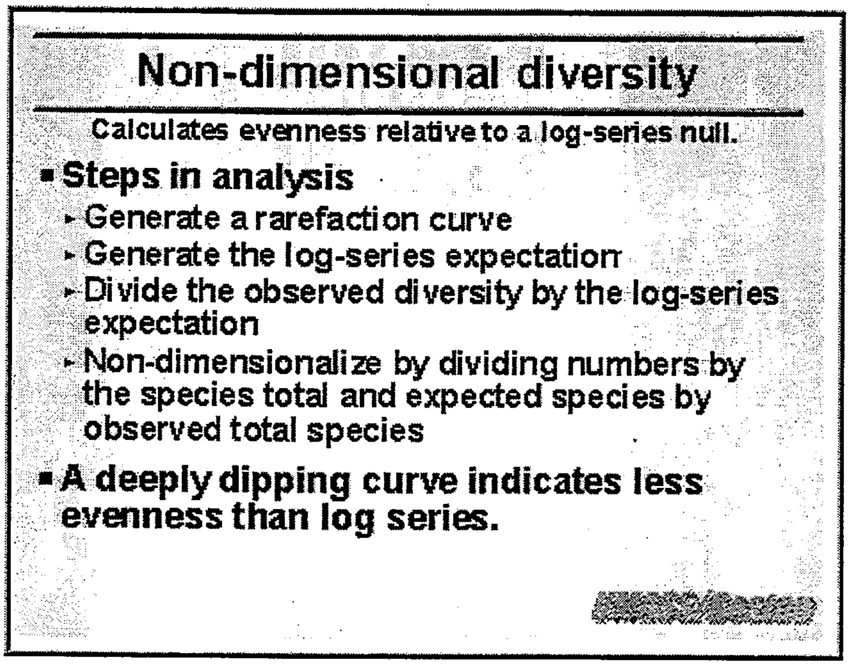

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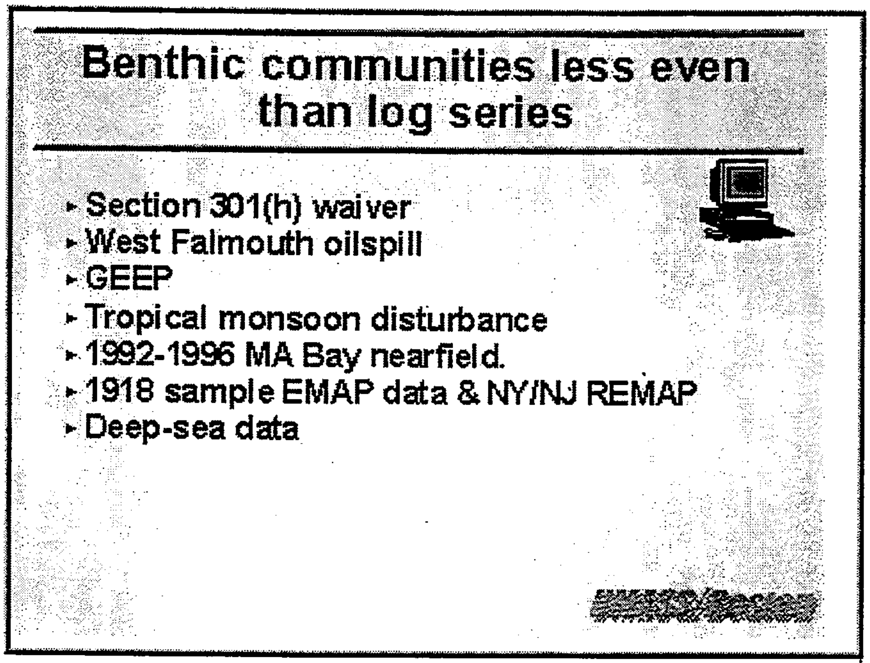
Benthic communities less even than log series



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Go to slide: 10: Benthic communities less even than log series

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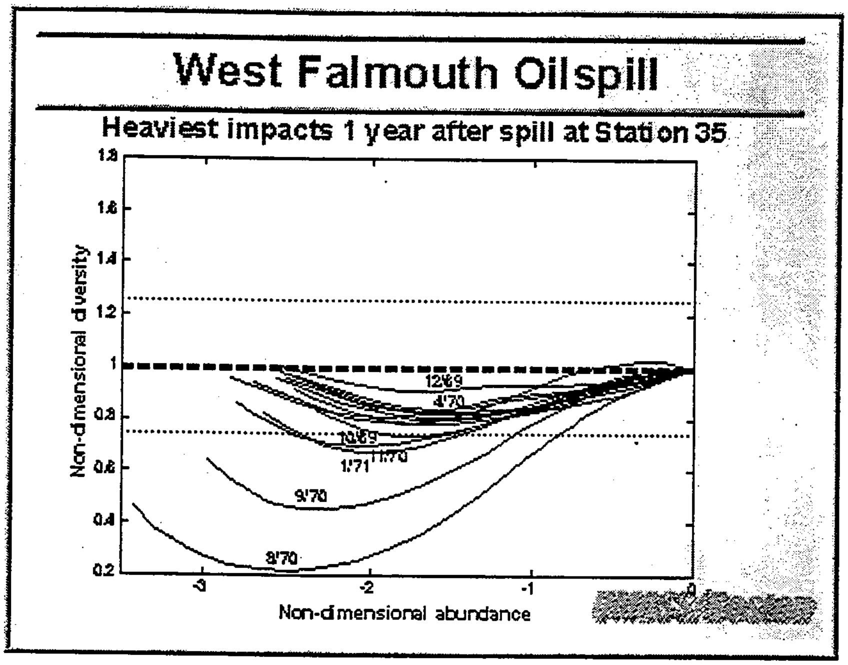
West Falmouth Oilspill



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1992-1996 MA Bay

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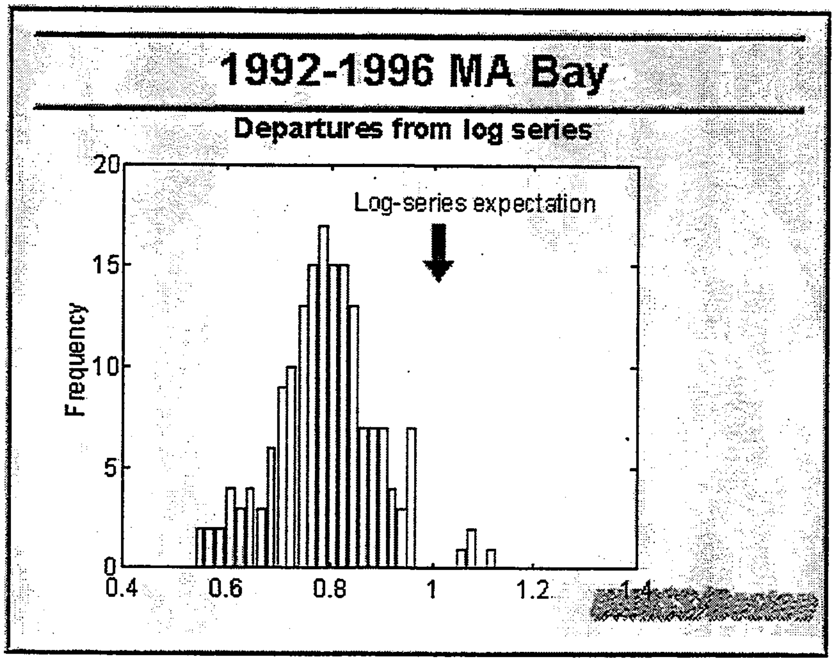

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Go to slide: 12: 1992-1996 MA Bay

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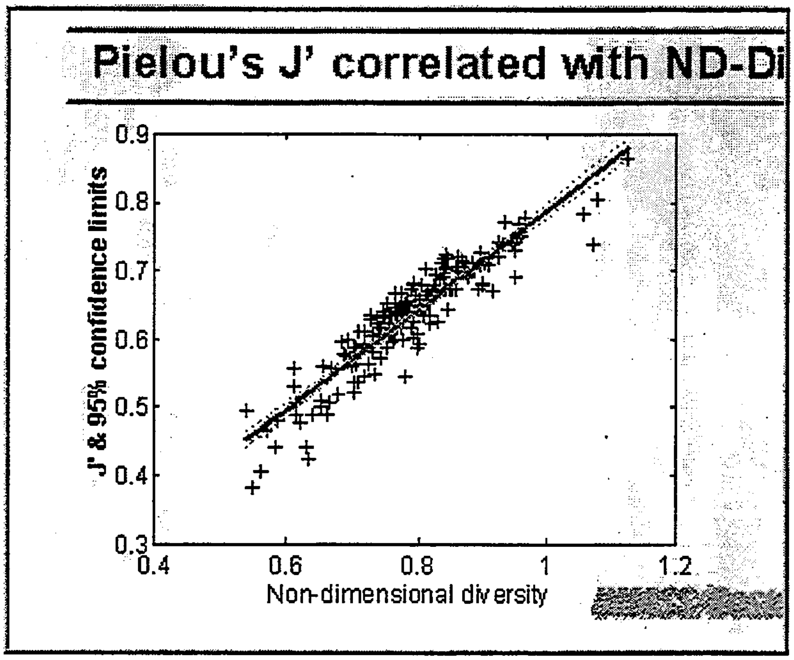
Pielou’s J’ correlated with ND-Div



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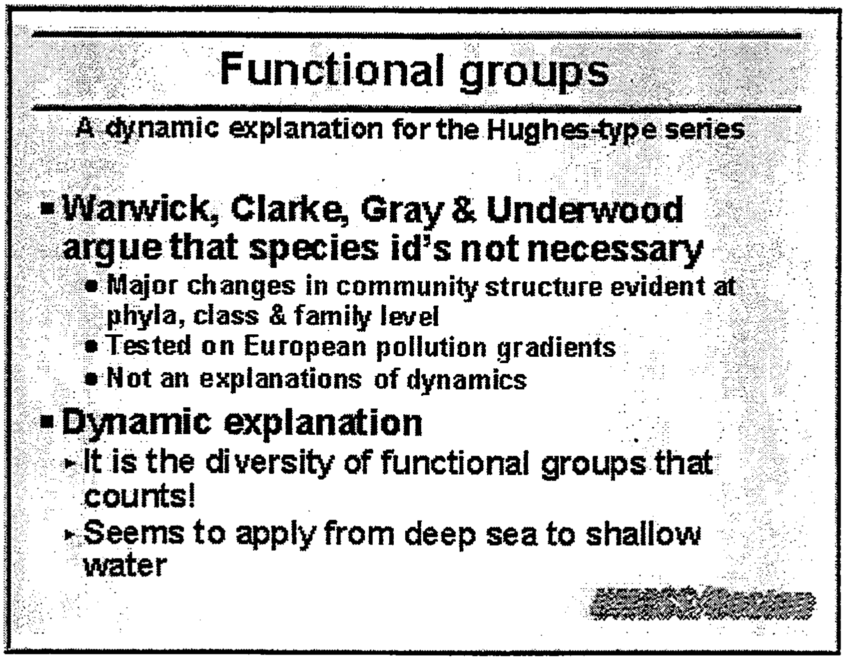
Functional groups



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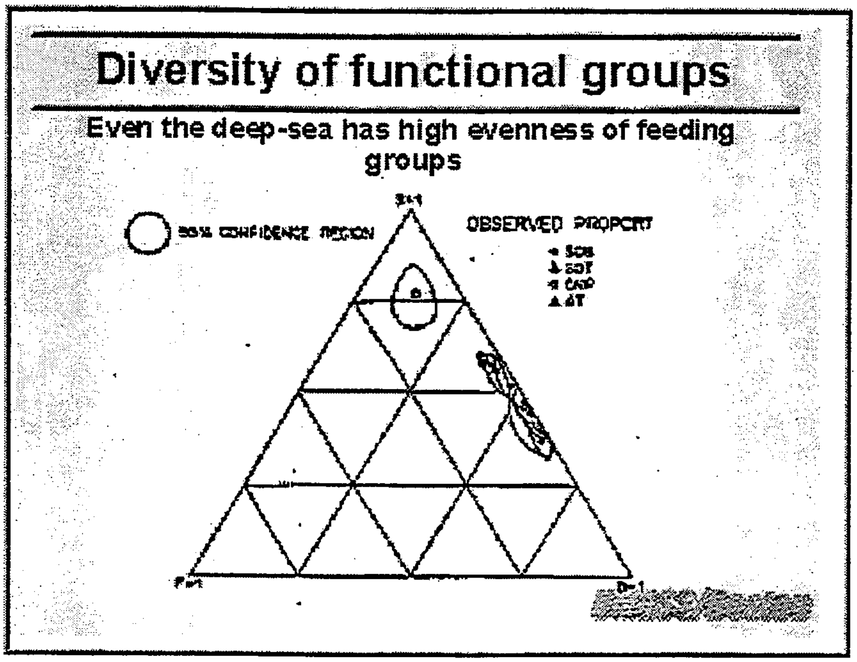
Diversity of functional groups



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Go to slide: 15: Diversity of functional groups

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Functional groups

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Functional groups

50 most abundant species classified

- Suspension feeders
- Interface feeders
- Surface deposit feeders
- Reverse conveyor-belt feeders
- Subsurface deposit feeders
- Top-down conveyor-belt species
- Omnivores/scavengers
- Predators

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Go to slide: 16: Functional groups

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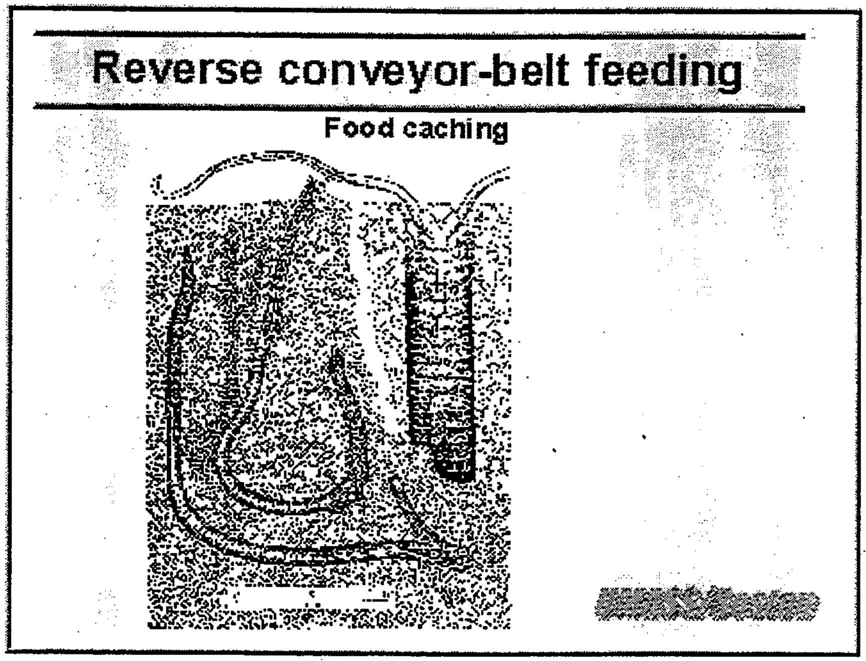
Reverse conveyor-belt feeding



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Go to slide: 17: Reverse conveyor-belt feeding

Reverse conveyor-belt feeding Food caching This figure, from Schafer (1972) shows the spionid polychaete Polydora ciliata "caching" food as fecal pellets into its tube. There might be several reasons for this feeding behavior: As a true cache of food for later ingestion To clear the sediment surface of feces

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Ordination based on functional groups

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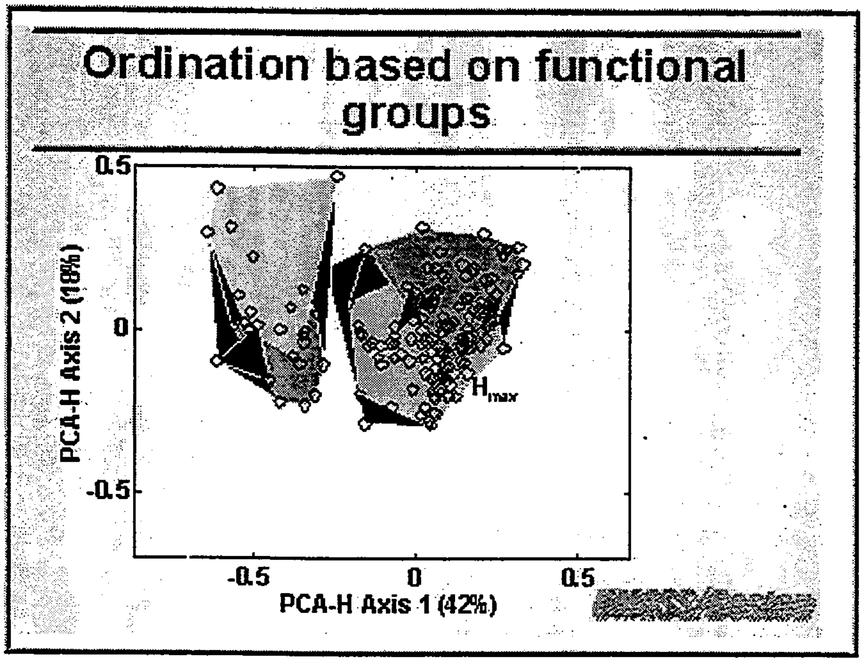

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Ordination based on functional groups

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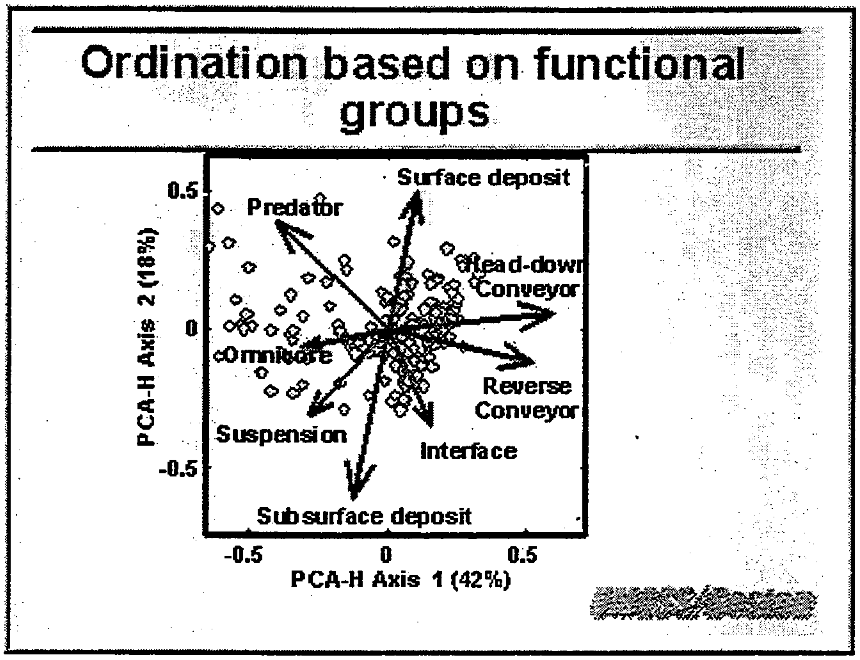

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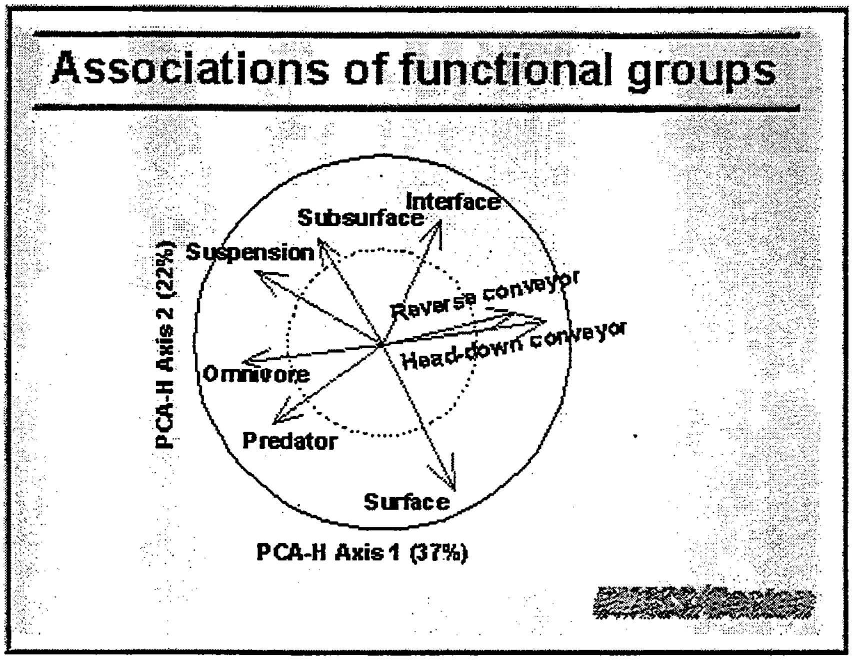
Associations of functional groups



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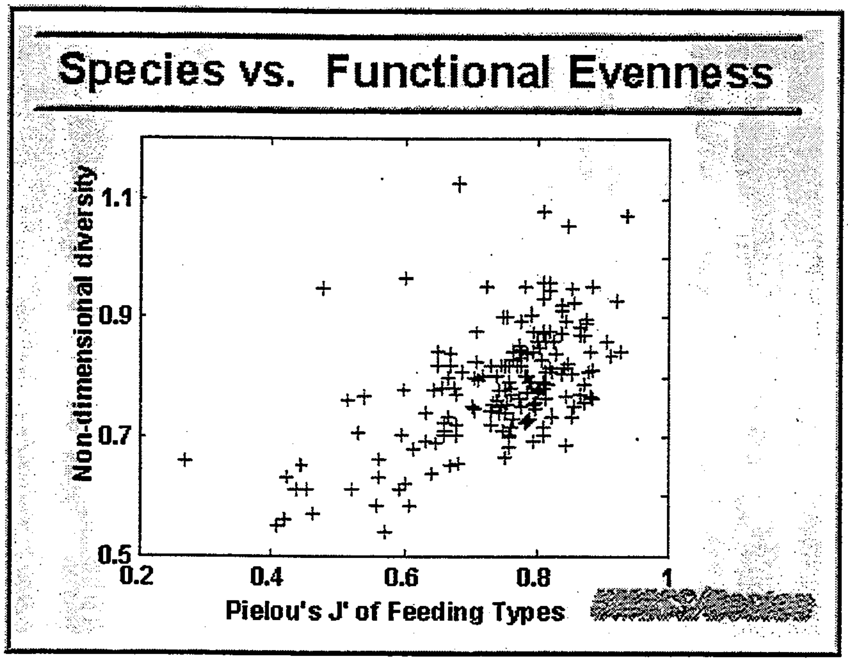
Species vs. Functional Evenness



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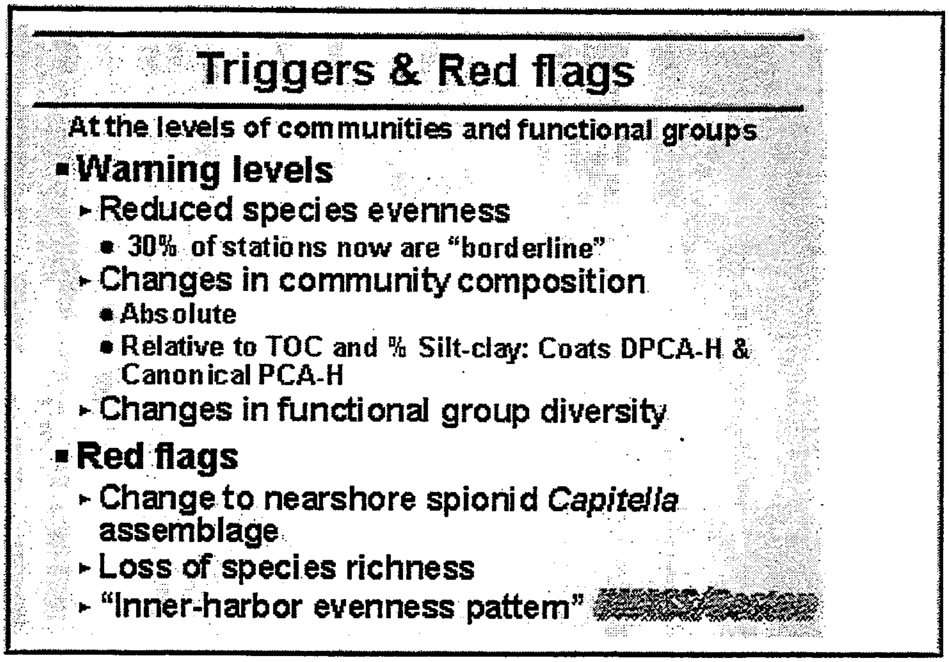
Triggers & Red flags



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