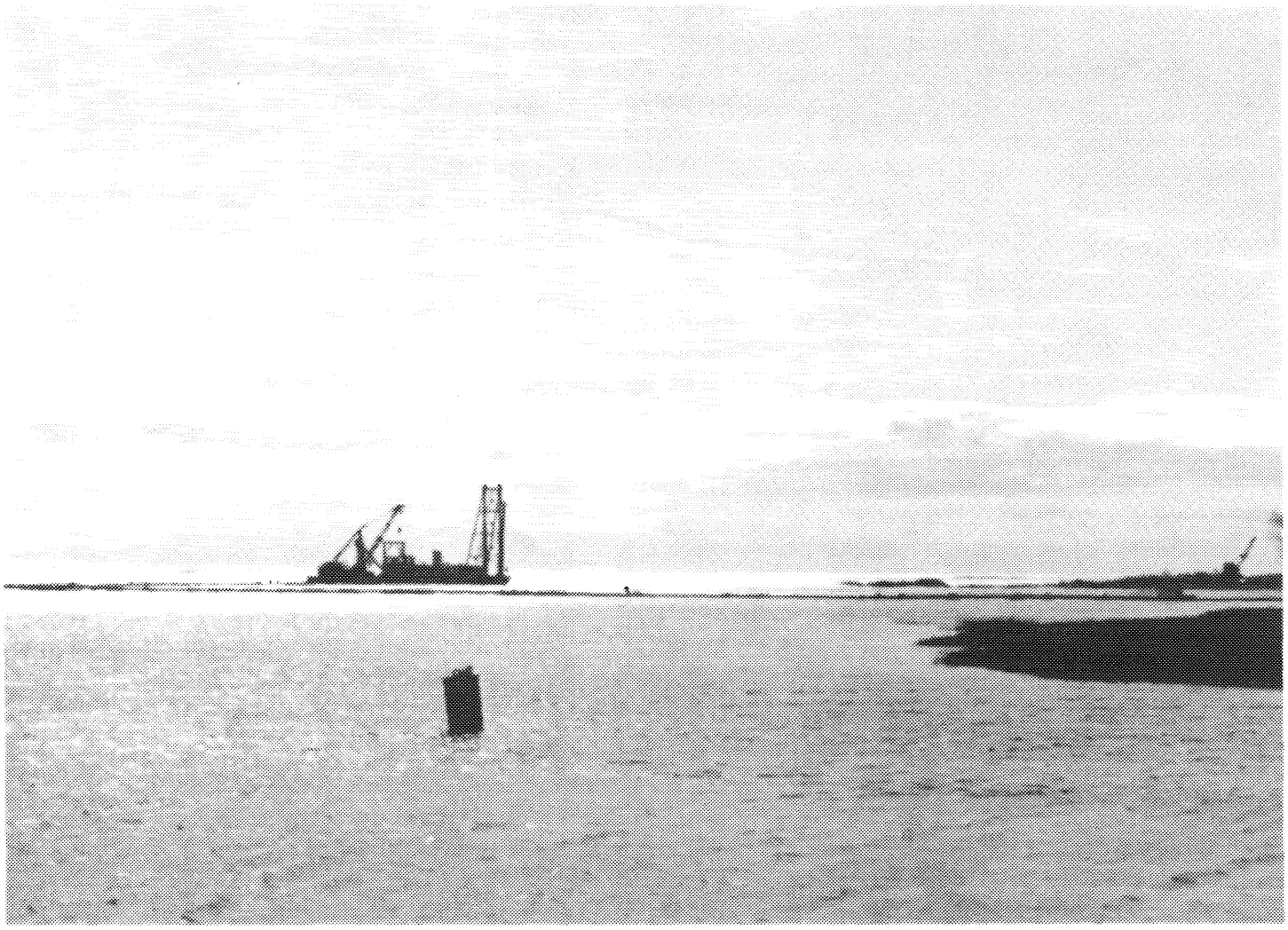
Long Island Sound Studies
Supplemental Data Reports

Dredged Material Containment



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New England Division

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Environmental Reports (Black Ledge, Milford, Penfield Reef, Sherwood Borrow Pit Mamaroneck)

U.S. Fish and Wildlife - Planning Aid Letters

Report to

Department of the Army
New England Division
Corps of Engineers

on

Contract DACW33-81-C-0016

Environmental Baseline Data Collections and Site Evaluations, Long Island Sound Container Disposal Study Black Ledge, Groton-New London Harbor, Connecticut

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Environmental Baseline Data Collections and Site Evaluations, Long Island Sound Container Disposal Study Black Ledge, Groton-New London Harbor, Connecticut

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1.0. INTRODUCTION

1.1. Background

The Groton-New London Harbor area is one of several locations in Long Island Sound being considered for construction of a dredged material containment facility (DMCF). A DMCF is a structure designed to contain dredged material and prevent its transport away from the containment site with consequent reentry into the natural ecosystem. Although DMCFs are particularly valuable in the case of contaminated or toxic spoils, they also have application for relatively clean materials which could otherwise cause environmental degradation through, for example, smothering, sediment alteration, and increased turbidity. Properly designed and constructed DMCFs have the potential of being an environmental enhancement in certain areas through the creation of desirable habitat types.

The work reported herein was contracted by the New England Division, Corps of Engineers (NED/CE) as part of the Long Island Sound Dredged Material Containment Study, a multi-phased program to examine the feasibility of the containment alternative, assess economic and social impacts, screen potential DMCF sites, and perform environmental baseline field surveys and assessments. The purpose of this study is directed toward the latter two objectives.

The proposed DMCF site at Groton-New London, shown in Figure 1, is located approximately one mile outside of the entrance to New London Harbor, to the east of the harbor entrance channel. The site comprises a rocky shoal area known as Black Ledge where water depths rise rapidly from the surrounding 20'-30' (MLW) to less than 10' over much of the shoal. A small pile of rocks approximately $10m^2$ near the western limit of the ledge is exposed at most tidal elevations. The total area of the shoal (depths within the 18' isobath) is approximately $320,000m^2$, or about .1 square mile.

The Black Ledge site was recommended by the City of Groton Conservation Commission and Harbor Study Commission. The area is reported to be a navigational hazard to recreational boating and of minimal value for fishing and lobstering. Proposed benefits of a DMCF

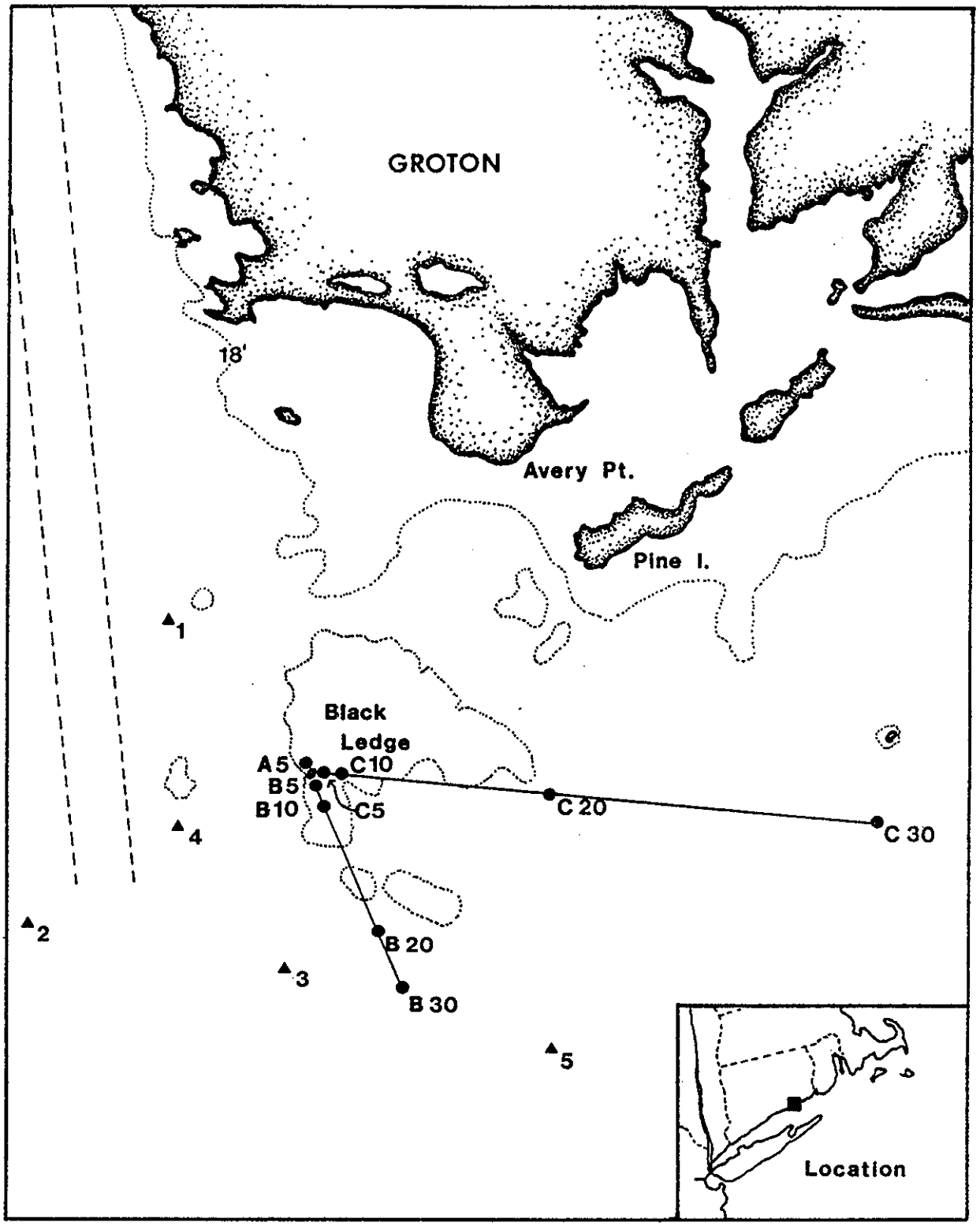

Figure 1: Black Ledge Project study area location, showing extent of ledge (18' isobath), relationship to shoreline and harbor channel, and stations sampled.

island at the site include the establishment of a preserve for controlled ecological studies and storm protection for the southern shore of the City of Groton.

1.2. Study Objectives and Organization

The purpose of this study was to provide preliminary environmental baseline information on the biotic communities both at Black Ledge and in the immediate environs. Primary emphasis was placed on the benthic macrofauna since this group would be most directly impacted by DMCF construction. An evaluation of the present habitat was needed in order to compare the potential habitat value of the DMCF with the value of the natural area.

In order to meet these objectives, Taxon designed a sampling plan comprising diver-operated suction sampling and traditional grab sampling. Taxon was responsible for the collection and processing of all macrofaunal and macroalgal materials. In order to develop information on the habitat value of soft-substrata in the Black Ledge vicinity, a subcontract was let to Marine Surveys, Inc. (MSI), New Haven, CT, who conducted a REMOTS™ survey at deeper stations to the south and west of the shoal. The results of the two survey techniques are fully integrated into this report, however, the complete MSI report is included as Appendix 1.

2.0. METHODS

2.1. Sampling Plan

The location of all stations sampled is shown in Figures 1 and 2 and the bearings and landmarks used to determine position are provided in Appendix 2. The diver sampling of rocky bottoms was conducted along three transects (A,B,C) with samples to be taken at 5', 10', 20' and 30' on each transect, respectively. The original sampling plan included six transects for a total of 24 stations; subsequent problems with equipment and weather allowed the collection of samples from only nine stations, as shown in Figure 2.

In addition to the transect stations, five additional stations were established in areas which were expected to have soft substratum. These

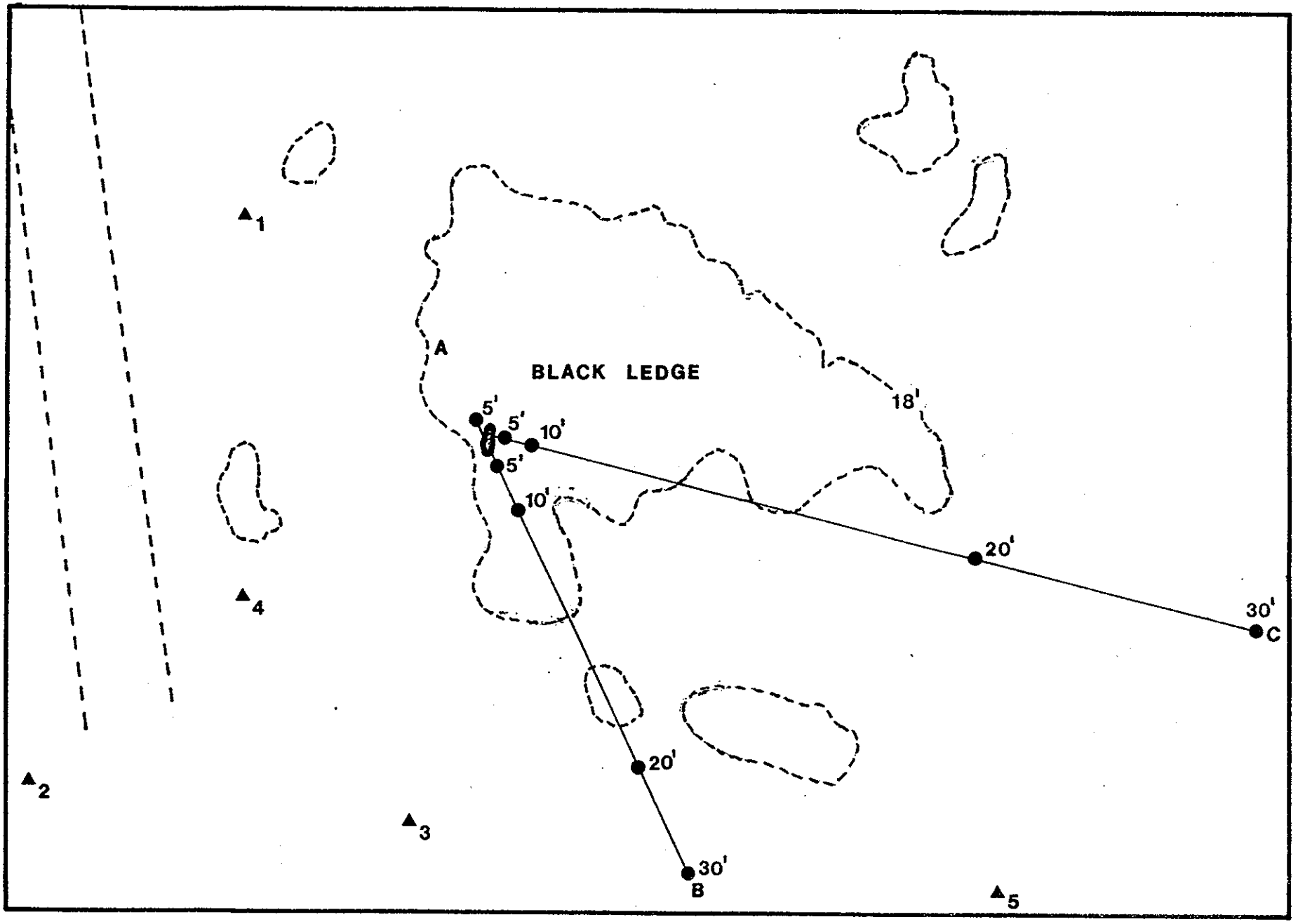

Figure 2: Detail of Black Ledge Project station locations.

stations were located primarily to the west and south of the shoal. At these stations, macrofaunal samples were collected by grab and sediment-water interface (REMOTS) imagery was obtained.

2.2. Sample Collection

The five soft-bottom stations were sampled on 31 August 1982; macrofaunal sampling and REMOTS photography were conducted simultaneously to ensure consistency of station location. Two replicate samples were collected at each station with a $0.04m^2$ modified VanVeen grab. All samples were immediately sieved at 0.5mm through a stainless-steel sieve and fixed in 10% buffered seawater formalin. An aliquot for sediment grain-size analysis was removed from each grab prior to sieving. MSI obtained up to six replicate sediment profile images per station at Stations 1 - 4; the nature of the substratum at Station 5 did not permit REMOTS imagery.

SCUBA sampling of transect stations was conducted on 16 October and 3 November 1981. At each of the deeper stations, sampling was first attempted with the grab sampler. If sufficient penetration was obtained, no diver samples were collected. When sampling by grab was not possible, a team of divers collected two replicate samples using a $0.1m^2$ pipe-frame quadrat and air-lift suction device fitted with a 0.5mm mesh Nitex bag (Figure 3). At stations with gravel substratum, the bottom within the quadrat was excavated with the air-lift to a depth of 10cm; at rock stations, all algal and faunal material within the quadrat was scraped off the rock and suctioned into the collecting bag. All samples were preserved in 10% buffered seawater formalin.

2.3. Laboratory Analysis

All grab samples were washed and transferred to 70% isopropanol prior to processing. Samples were then stained with Rose Bengal to facilitate recognition of macrofauna and separated into basic macrofaunal groups by technicians using low power stereoscopes. Taxonomic identifications were determined by experienced taxonomists using high resolution stereoscopes or compound microscopes, as necessary. Identifications were carried to species level where possible and all species were enumerated.

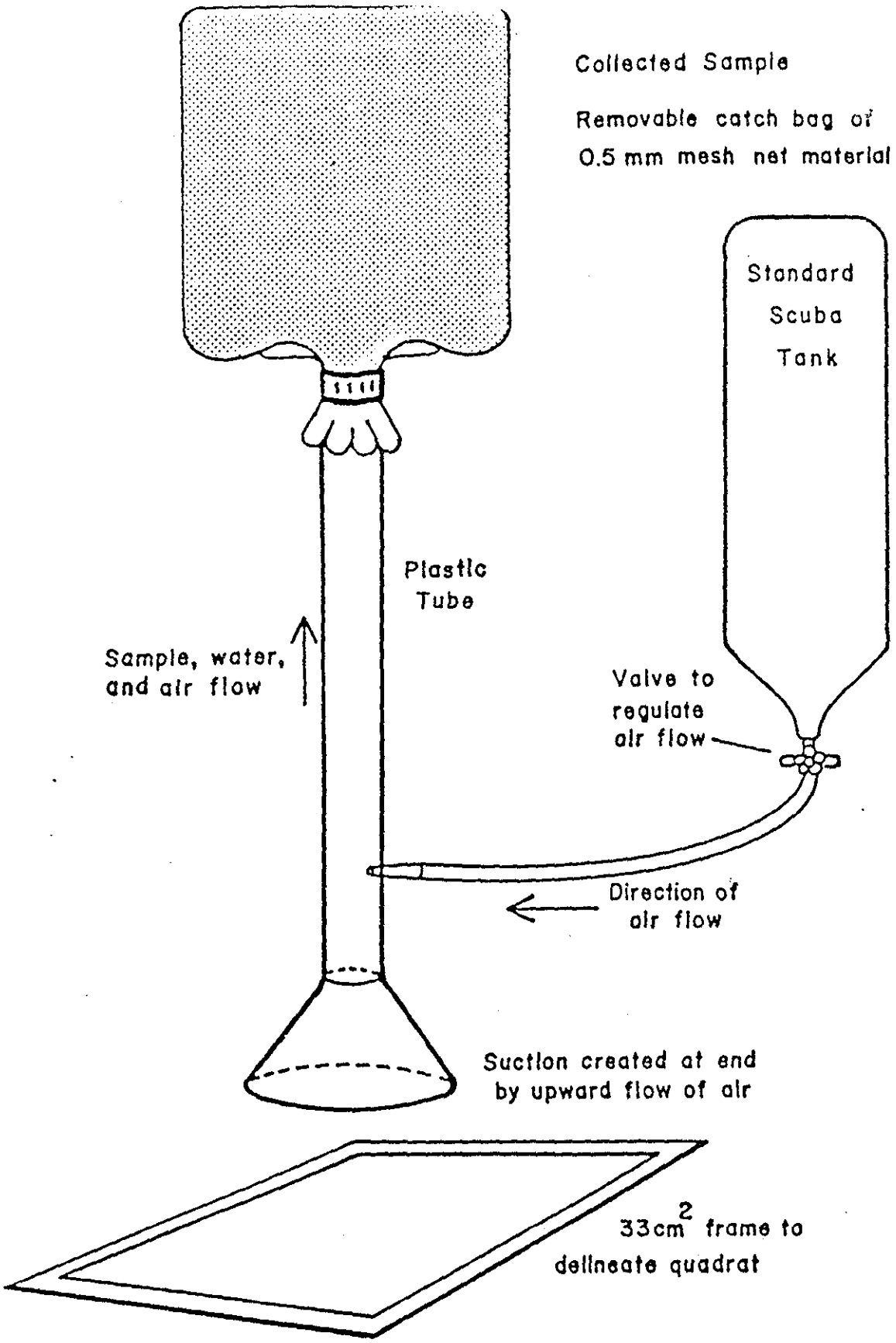

Figure 3: Diagram of diver-operated air-lift rock substratum sampling equipment.

For the diver-collected samples, all material was washed and the algal and faunal fractions were separated; when large numbers of adult Mytilus edulis were present they were removed by hand and counted at this stage. Faunal material was transferred to 70% isopropanol and processed in the same manner as the grab samples. Algal material was transferred to 5% formalin and subsequently identified using stereo and compound microscopes. Algal dominance heirarchies were determined according to frequency of occurrence of each taxon within a sample. Algal biomass was determined by drying the algal fraction at 80°C for 72 hrs. and weighing on an analytical balance. Because the Black Ledge flora comprised exclusively small filamentous forms, separate biomass determinations by taxa could not be performed reliably.

Sediment profile images were measured for: 1) modal grain-size (visual comparison of photos with prepared grain-size standards), 2) camera penetration depth (P), 3) presence of methane gas pockets, 4) aerated sediment (positive redox) area, and 5) faunal successional stage. Variables 3 - 5 were used to generate a habitat index based on the following scaling:

Planimetered Oxidized Area	Index Value
0.1 - 10.0 cm^2	1
10.1 - 20.0 cm^2	2
20.1 - 30.0 cm^2	3
30.1 - 40.0 cm^2	4
40.1 - 50.0 cm^2	5
$>$50.0 cm^2	6

Successional Stage	Index Value
Azoic	-5
Stage 1	1
Stage 1 - 2	2
Stage 2	3
Stage 3 - 4	4

Chemical Parameters	Index Value
Methane present	-2
No/Low dissolved O_2	-4

Sediment grain-size aliquots from the grab samples were analyzed gravimetrically at 1Ø intervals using dry sieving for the coarse fraction ($<$63u) and standard pipette technique for the silt-clay

fraction.

All quantitative macrofaunal data were entered directly into the WHOI VAX 11/780 computer from a remote terminal located at Taxon. Classification analysis was performed using programs BMDP1M and BMDP2M of the Biomedical Computer Programs package of the University of California. Computational details are discussed in Section 3.2.3. of this report. Diversity and evenness values for each replicate were calculated on a programmable hand calcualtor.

3.0. RESULTS

3.1. Substratum

Bottom substrata in the Black Ledge vicinity fall into three general categories: rock, sand/gravel, and silt/clay. The distribution of these bottom types in the area sampled is shown in Figure 4, and the grain-size data are summarized in Table 1.

On the ledge, the bottom consists of large angular boulders with generally flat sides; these are evidently not of natural origin, and it was apparent that much of the exposed portion of Black Ledge was transported to the site as rip-rap. The placement of these is such that crevices and small caves are abundant, providing a variety of microhabitats. All of the 5' and 10' transect stations had rock substratum and this bottom type is characteristic of the shallower shoal areas.

Sand/gravel substratum was found at the 20' and 30' transect stations to the east and south of Black Ledge. Station C30 was markedly sandier than the other three and was sampled by grab; thus, grain size data are available. The substratum at C30 was a muddy sand of 0.23mm diameter with approximately 12% silt-clay content. The complete grain-size frequency distribution for all soft-bottom stations is provided in Appendix 3.

Sediments at the grab stations 1 - 4 were silts with substantial (up to 35%) amounts of fine sand. Median grain size at these stations ranged from 0.020mm to 0.028mm and the general pattern of the frequency distributions was similar among the stations. Station 5, to the southwest of the ledge, was intermediate between the sandy

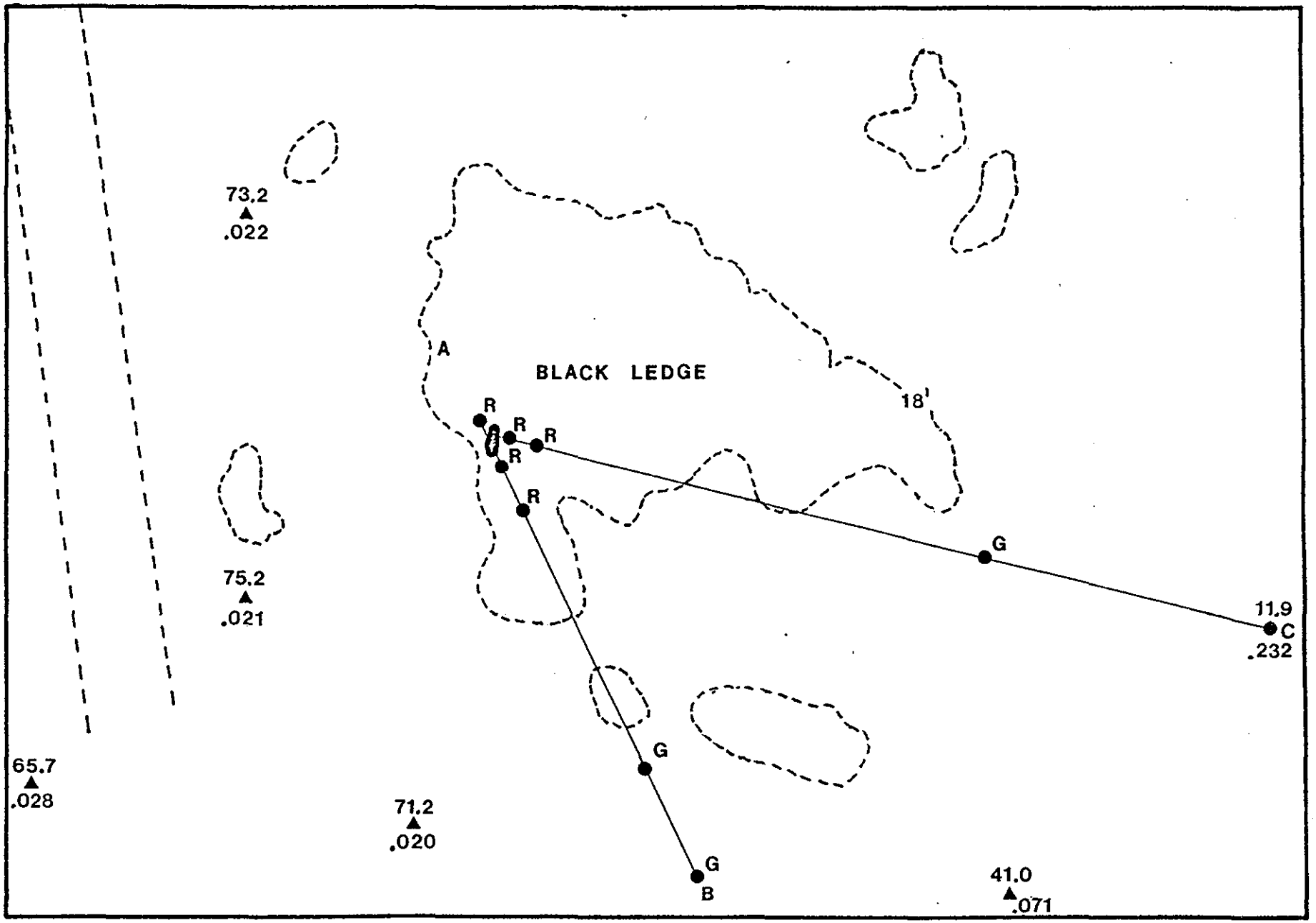

Figure 4: Substratum characteristics: % silt/clay (above station point), median grain size in mm (below station point). For stations which were sampled by divers: R = rock substratum, G = gravel substratum.

Table 1: Summary grain-size frequency distribution parameters for all stations sampled by grab.

Station - Replicate	Median(mm)	Modal Class(Ø)	% Silt-Clay
1-1	.017	4 - 8	79.6
1-2	.027	4 - 8	66.8
2-1	.031	4 - 8	62.7
2-2	.025	4 - 8	68.7
3-1	.021	4 - 8	71.6
3-2	.021	4 - 8	70.9
4-1	.018	4 - 8	78.6
4-2	.022	4 - 8	71.7
5-1	.074	3 - 4	37.8
5-2	.068	3 - 4	44.3
C30-1	.136	3 - 4	14.5
C30-2	.327	1 - 2, 3 - 4(bimodal)	9.3

transect stations and the silts, and had a poorly-sorted substratum of about 40% silt/clay intermixed with fine and some coarse sand.

3.2. Black Ledge Fauna

3.2.1. Species Composition

The list of species or taxa found in the 30 macrofaunal samples collected from Black Ledge is presented in Table 2 and all faunal raw data are included as Appendix 4. The list contains 184 taxa representing all major taxonomic groups. This is an extremely extensive list for the number of samples processed and is indicative of the variety of habitats sampled.

Polychaetes were the dominant faunal group, comprising 76 species, or 41.3% of the total species list. Molluscs and crustaceans were approximately equal in diversity, being represented by 46 (25.0%) and 48 (26.1%), respectively. Amphipods were particularly numerous among the crustaceans; this was related to the extensive algal/mussel mats at the rock stations which provide ideal habitat for a wide variety of amphipod species. This factor was probably also responsible for the extensive inventory of gastropods.

When the extent of the Black Ledge species list is compared with those from some recent surveys of northern Long Island Sound estuaries, the diversity of the area becomes even more striking. In a survey of Black Rock Harbor and Bridgeport Harbor (CEM, 1981) a total list of 123 taxa was reported. That study was much more extensive than the present survey, including two seasonal collections at 64 stations distributed over a much greater area. More recently, in a survey of Clinton Harbor also associated with the potential creation of a DMCF, McGrath et al. (1982) reported 145 taxa from 16 stations which were sampled twice. Hartzband et al. (1979) reported 302 taxa from New Haven Harbor from a very extensive program encompassing two laboratories, nearly 30 stations, and intensive sampling over several years.

3.2.2. Species Richness and Faunal Density

Species richness, faunal density, and Shannon-Wiener diversity values are shown in Table 3 for all samples collected during the study.

Table 2: Inventory of all benthic macrofaunal species collected in grab and diver-collected samples from Black Ledge area.

POLYCHAETA

Aglaophamus neotenus
Ampharete arctica
Ampharetidae unid.
Amphecteis gunneri
Amphitrite johnstoni
Amphitrite sp.
Anaitides mucosa
Anaitides sp.
Aricidea sp.
Asabellides oculata
Autolytus sp.
Capitella capitata
Cirratulus sp.
Clymenella torquata
Cossura longocirrata
Disoma carica
Dorvilleidae unid.
Drilonereis longa
Drilonereis magna
Ephesiella minuta
Euchone sp.
Eulalia viridis
Eumida sanguinea
Eunicea unid.
Exogone sp.
Glycera americana
Harmothoe imbricata
Lepidonotus squamatus
Lepidonotus sublevis
Lumbrineris sp.
Maldanopsis elongata
Marphysa sanguinea
Mediomastus ambiseta
Melinna cristata
Nephtys incisa
Nephtys picta
Nereis arenaceodonta
Nereis pelagica
Nereis succinea
Nereis virens
Nicolea venustula
Ninoe nigripes
Notomastus sp.
Oligochaeta
Onuphis quadricuspis
Orbiniidae unid.
Paraonis fulgens
Paraonis sp.
Parapionosyllis longicirrata
Pectinaria gouldii
Pherusa affinis
Pholoe minuta
Phyllodocidae unid.
Pista palmata
Polycirrus eximius
Polydora socialis
Polydora sp.
Polygordius sp.
Potamilla neglecta
Potamilla reniformis
Prionospio cirrifera
Pygospio elegans
Sabellaria vulgaris
Scalibregma inflatum
Scolelepis squamata
Scoloplos acutus
Sigambra tentaculata
Sphaerosyllis sp.
Spiochaetopterus oculatus
Spionidae unid.
Spiophanes bombyx
Sthenelais boa
Sthenelais limicola
Streblospio benedicti
Syllinae/Eusyllinae unid.
Tharyx acutus

GASTROPODA

Acteocina canaliculata
Alvania sp.
Anachis avara
Buccinum sp.
Busycon canaliculatum
Cingula aculeus
Colus obesa
Crassinella lunulata
Crepidula fornicata
Crepidula plana
Cylichna oryza
Epitonium humphreysi
Lacuna vincta
Lunatia heros
Lunatia triseriata
Mitrella dissimilis
Mitrella lunata
Nassarius trivittatus
Odostomia gibbosa
Odostomia seminuda
Philine lima
Skeneopis planorbis
Turbonilla sp.
Urosalpinx cinerea

Table 2 (cont.)

BIVALVIA

Astarte undata
Bivalvia unid.
Cerastoderma pinnulatum
Crenella glandula
Cumingia tellinoides
Cyclocardium borealis
Ensis directus
Lyonsia hyalina
Macoma balthica
Mercenaria mercenaria
Modiolus modiolus
Mulinia lateralis
Mytilus edulis
Nucula delphinodonta
Nucula proxima
Petricola pholadiformis
Pitar morrhuanus
Solemya velum
Tellina agilis
Thracia conradi
Yoldia limatula

AMPHIPODA

Ampelisca abdita
Ampelisca vadorum
Ampelisca verrilli
Amphithoe longimana
Byblis serrata
Caprellidae unid.
Corophium acutum
Corophium bonelli
Dexamine thea
Elasmopus levis
Erichthonius rubricornis
Jassa falcata
Lembos websteri
Leptocheirus pinguis
Lysianopsis alba
Microdeutopus gryllotalpa
Paraphoxus spinosus
Photis sp.
Phoxocephalus holbolli
Pleusymtes glaber
Stenothoe minuta
Trichophoxus epitomus
Unciola irrorata

CRUSTACEA

Campylaspis rubicunda
Cancer borealis
Cancer irroratus
Crangon septemspinosa
Cylindroleberis mariae
Cythereis vineyardensis
Edotea triloba
Erichsonella filiformis
Eudorella pusilla
Heteromysis formosa
Idotea phosphorea
Iphinoe trispinosa
Leptochelia savignyi
Libinia dubia
Libinia sp.
Mysidacea unid.
Neopanope sayi
Ostracoda unid.
Oxyurostylis smithi
Pagurus longicarpus
Pinnotheres maculatus
Ptilanthura tenuis
Pycnogonida unid.
Sarsiella sp.
Upogebia affinis

MISCELLANEOUS

Amphipholis squamata
Arbacia sp.
Asterias forbesi
Cerebratulus sp.
Cerianthus sp.
Edwardsia sp.
Enteropneusta unid.
Henricia sanguinolenta
Metridium senile
Nemertea unid.
Phoronida unid.
Sipuncula unid.
Tubulanus pellucidus

Table 3: Faunal sample parameter summary: S = number of species/taxa; N = number of individuals/m^2; H' = Shannon-Wiener diversity; J' = evenness.

Station	S	N	H'	J'
1-1	35	30,575	2.1604	.4212
1-2	20	43,825	1.4644	.3388
2-1	24	18,375	2.0321	.4432
2-2	26	26,875	1.9969	.4248
3-1	45	32,950	2.1326	.3883
3-2	37	29,000	1.6079	.3087
4-1	38	30,800	1.5787	.3008
4-2	45	29,075	1.4146	.3716
5-1	41	65,250	0.6973	.1301
5-2	40	60,000	1.1754	.2194
A5-1	46	6,924	2.2326	.5831
A5-2	25	5,978	1.5781	.4903
B5-1	24	10,404	1.2934	.4070
B5-2	24	5,574	1.6983	.5344
B10-1	41	14,160	2.7567	.5145
B10-2	23	6,795	1.5586	.3446
B20-1	47	6,033	4.0859	.7356
B20-2	60	7,824	4.4363	.7510
B30-1	59	5,069	4.1092	.6985
B30-2	47	7,521	3.9836	.7172
C5-1	23	18,935	1.4649	.3238
C5-2	35	9,036	2.7458	.5353
C10-1	23	16,630	2.3797	.5261
C10-2	30	4,637	2.9465	.6005
C20-1	38	4,968	4.2017	.8006
C20-2	35	6,924	4.0017	.7802
C30-1	34	9,925	3.9905	.7844
C30-2	35	10,225	3.7368	.7285

Species richness values are raw numbers of species (and/or taxa) for each sample; the faunal density values have been extrapolated to numbers per square meter due to the difference in sample size between the grab ($0.04m^2$) and the diver-quadrat ($0.11m^2$) samples. Because of this difference, the species richness and diversity values are not strictly comparable between the two sampling methods. There is no way to correct for sample size for these parameters with so few replicates per station.

Species richness, plotted in Figure 5, varied from 20 to 60 taxa per station ($\bar{x}$ = 35.7). The shallow rocky substratum stations typically supported fewer taxa ($\bar{x}$ = 29.4) than either the sand/gravel stations ($\bar{x}$ = 44.4) or the silt/clay stations ($\bar{x}$ = 35.1). Because of the difference in sample size, it is not possible to determine whether the silt/clay or sand/gravel group supported more taxonomic variety per unit area. The difference between the rock and sand/gravel stations can be tested statistically because both were sampled with the air-lift method. Species richness at the sand/gravel stations was found to be significantly greater at $p < .01$.

The pattern of faunal density, shown in Figure 6, did not follow that described above for species richness. The silt/clay substratum stations had greatest densities ($\bar{x}$ = $36,672/m^2$), followed by the rock stations ($\bar{x}$ = $9,907/m^2$) and the sand/gravel stations ($\bar{x}$ = $7,311/m^2$). These values do not exhibit the extreme variation between stations typical of areas which are receiving anthropogenic impacts in the form of organic overenrichment. In Bridgeport and Black Rock Harbors (CEM, 1981), stations receiving the most acute impacts were azoic or supported very few species and individuals. At Black Ledge, no areas with faunal characteristics approaching this type of situation were found. Greatest faunal densities at Bridgeport and Black Rock were found at stations adjacent to the zone of most acute impacts in sand/gravel sediments. Faunal populations in these areas comprised predominantly Stage I polychaete species. At Black Ledge, greatest densities were in silt/clay strata which were not in proximity to any azoic areas. The elevated densities in these areas were due to extremely dense populations of the the amphipod *Ampelisca abdita*, a Stage II species, and the polychaete *Aricidea* sp., which is not considered to be a Stage I species.

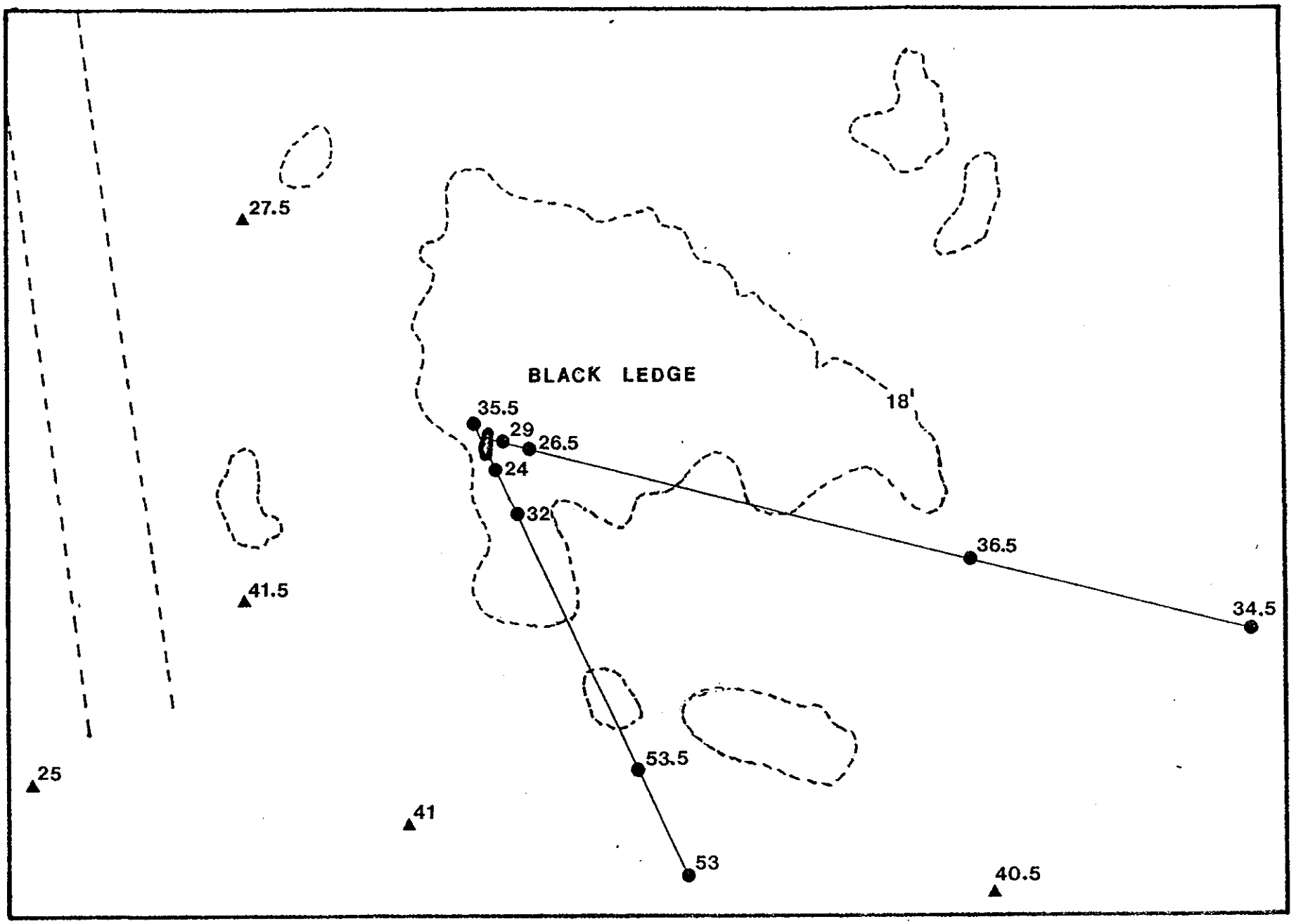

Figure 5: Plot of species richness values for stations sampled at Black Ledge. Counts are number of species or taxa per $0.04m^2$ for grab samples, per $0.1m^2$ for diver collected samples.

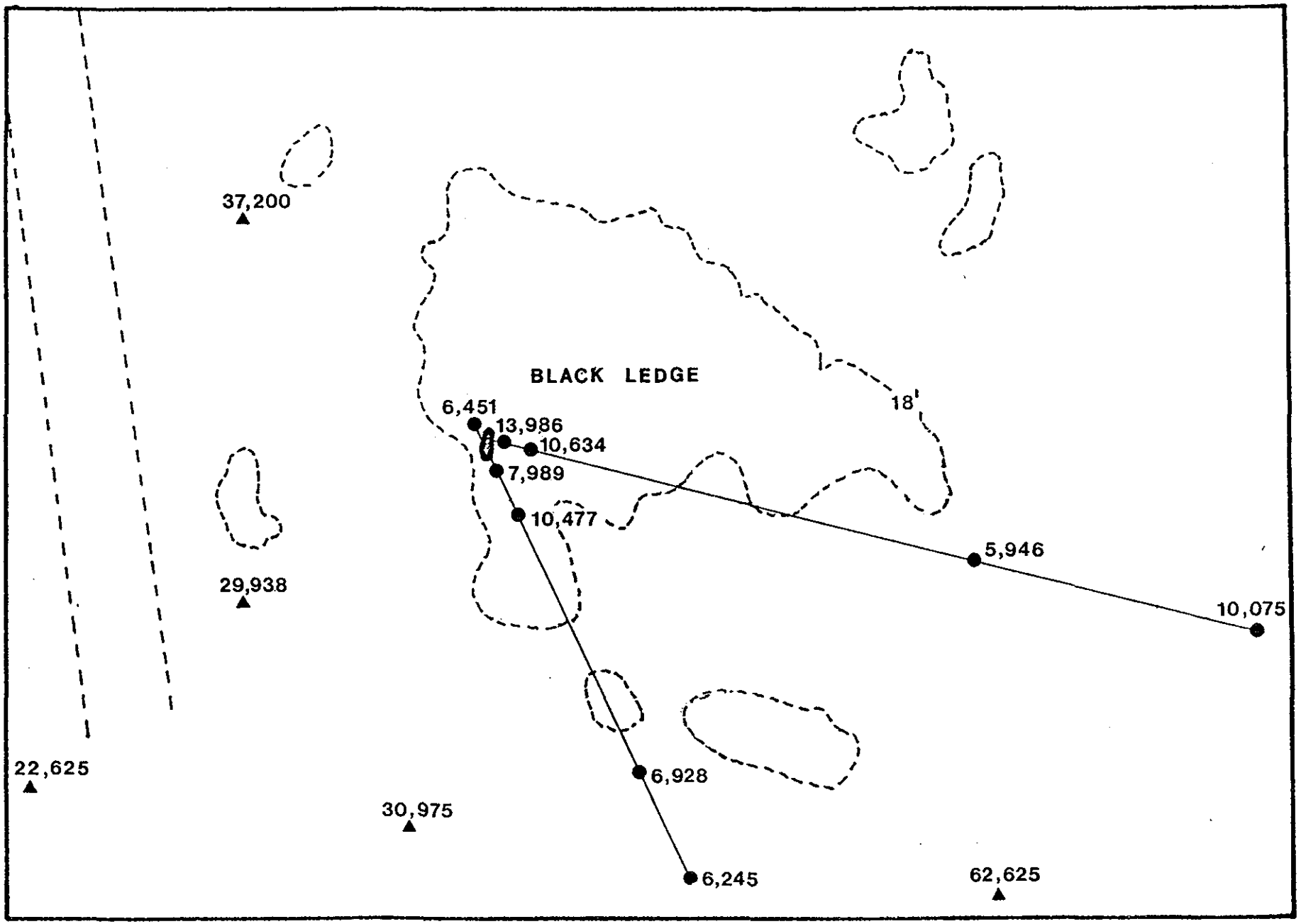

Figure 6: Plot of faunal density values for stations sampled at Black Ledge. All counts normalized to individuals/m^2.

Shannon-Wiener species diversity (H') and evenness (J') are shown in Table 3. As is typically the case with these indices, diversity was not strongly related to the species richness of the communities sampled ($r = .1044$) but was very dependent ($r = .5856$) on J', which is considered to be a measure of how evenly resources are partitioned between the various species. The relationship of evenness to diversity must be considered when interpreting a set of diversity values, particularly when large differences in evenness are apparent between stations, as is the case for the Black Ledge data.

Because of this relationship between diversity and evenness, the deeper silt/clay substrata stations, where dense populations of Aricidea sp. or Ampelisca abdita occurred, generally had low diversity values (<2.2) in spite of their moderately high species richness and extremely high faunal density. Evenness values in these areas were typically less than 0.45, indicating that most of the contribution to the overall faunal density was by a few dominant species.

Diversities at the shallow rock substratum stations were higher than at the silt/clay stations despite the depressed species richness and markedly lower faunal density found in the former area. Evenness values were sufficiently higher here to explain this result. In addition, all faunal community parameters were more variable in this area, reflecting the greater spatial heterogeneity inherent in a shallow hard-bottom habitat.

The intermediate depth sand/gravel stations on the transects to the south and east of Black Ledge, although they had the least dense faunal populations, had the highest diversities. This was primarily due to the elevated evenness values in this area ($>.70$) in combination with the high species richness noted earlier.

The observed patterns of species richness, faunal density and species diversity, when all three parameters are considered, appear clearly related to bottom stability. The shallow hard rock substrata are occupied by a community of low species richness and standing stocks which displays marked spatial and, presumably, temporal variation. The intermediate depth sand/gravel substrata in the area support a transitional community which has low standing stocks but elevated species

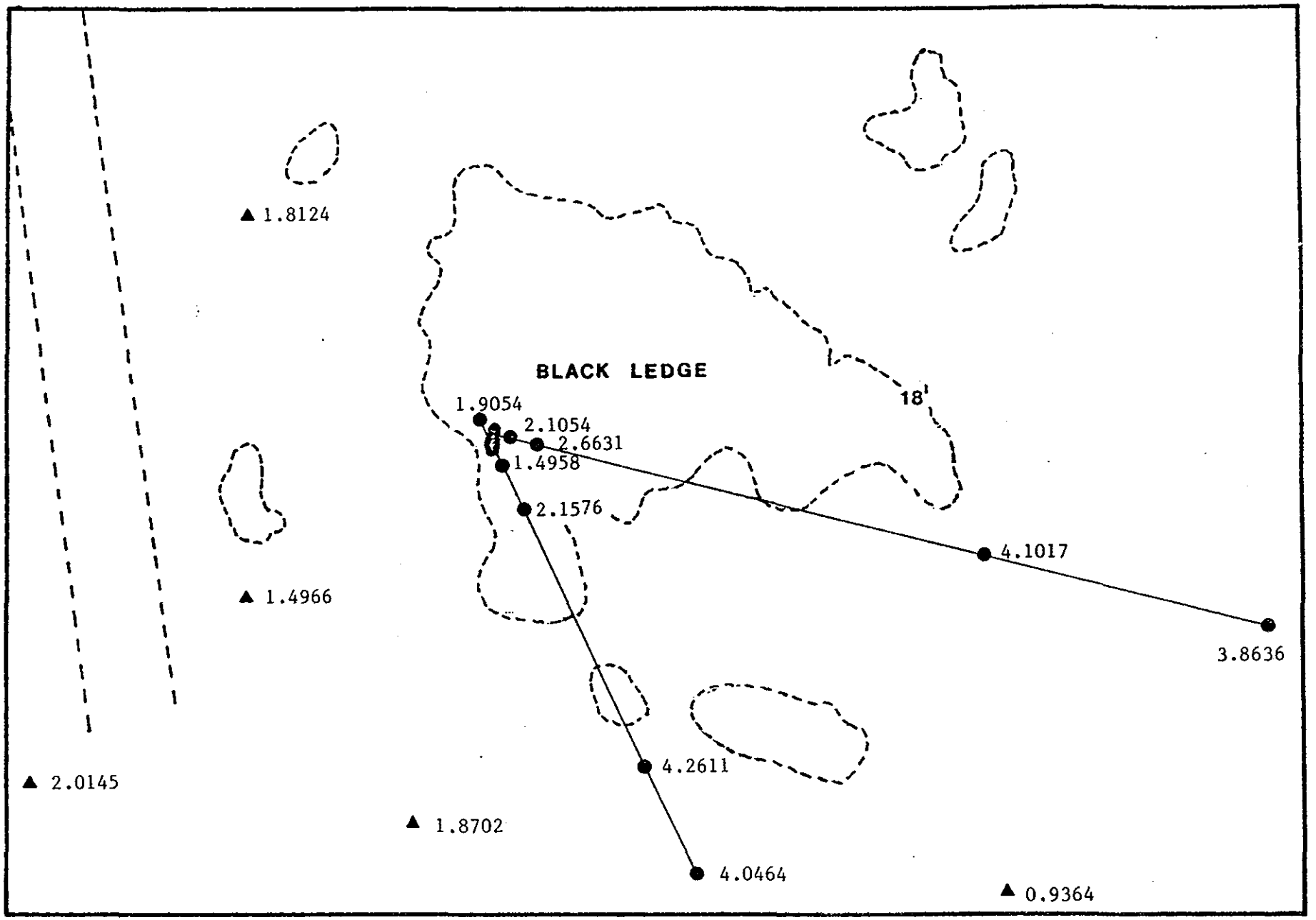

Figure 7: Shannon-Wiener diversity (H') values for stations sampled at Black Ledge. Values displayed are means for two replicates.

richness and diversity. The relatively greater spatial and temporal homogeneity at the deeper silt/clay stations results in a community with elevated species richness and standing stock, but depressed diversity due to strong dominance by one or two species. The community characteristics of this last group of stations will be discussed in greater detail in Section 3.2.4. of this report.

3.2.3. Community Classification Analysis

A classification, or cluster, analysis was performed using data on dominant species. A dominant species was defined as one which occurred among the top five numerical dominants in at least two replicates; 26 species (or taxa) qualified under that criterion.

An inverse (R-mode) analysis was conducted using program BMDP1M of the Biomedical Computer Programs package, on the VAX 11/780 system at WHOI. The similarity index used in the analysis was product-moment correlation and linkage was accomplished using unweighted pair-group arithmetic averages (UPGMA). Results are shown as a dendrogram in Figure 9. Program BMDP2M was used to perform a normal (Q-mode) analysis on the same data. The similarity index used for the normal analysis was the chi-square test of equality and the linkage procedure was UPGMA. Results are shown as a dendrogram in Figure 8.

Inspection of the inverse dendrogram indicates six recognizable clusters among the 26 species, as indicated by the dashed lines. The first group (A) includes the polychaetes *Aricidea* sp., *Mediomastus ambiseta* and *Nephtys incisa*, and the bivalve *Nucula proxima*. A second, somewhat related group (B) includes two amphipod species, *Ampelisca abdita* and *Corophium bonelli*, and *Anaitides maculata*, a polychaete. The largest group (C) occupies the center of the dendrogram and includes the polychaetes *Exogone* sp., *Polycirrus* sp., and *Capitella capitata*, the oligochaetes, *Polygordius* sp., an archiannelid, and the tanaid *Leptochelia savignyi*. The (C) group is followed by the related group (D) which comprises the amphipods *Unciola irrorata* and *Ampelisca vadorum* and the polychaete *Spiophanes bombyx*. All four of the preceding groups were more closely related to each other than to the two following groups.

Group (E) included the gastropod *Mitrella lunata*, the bivalve

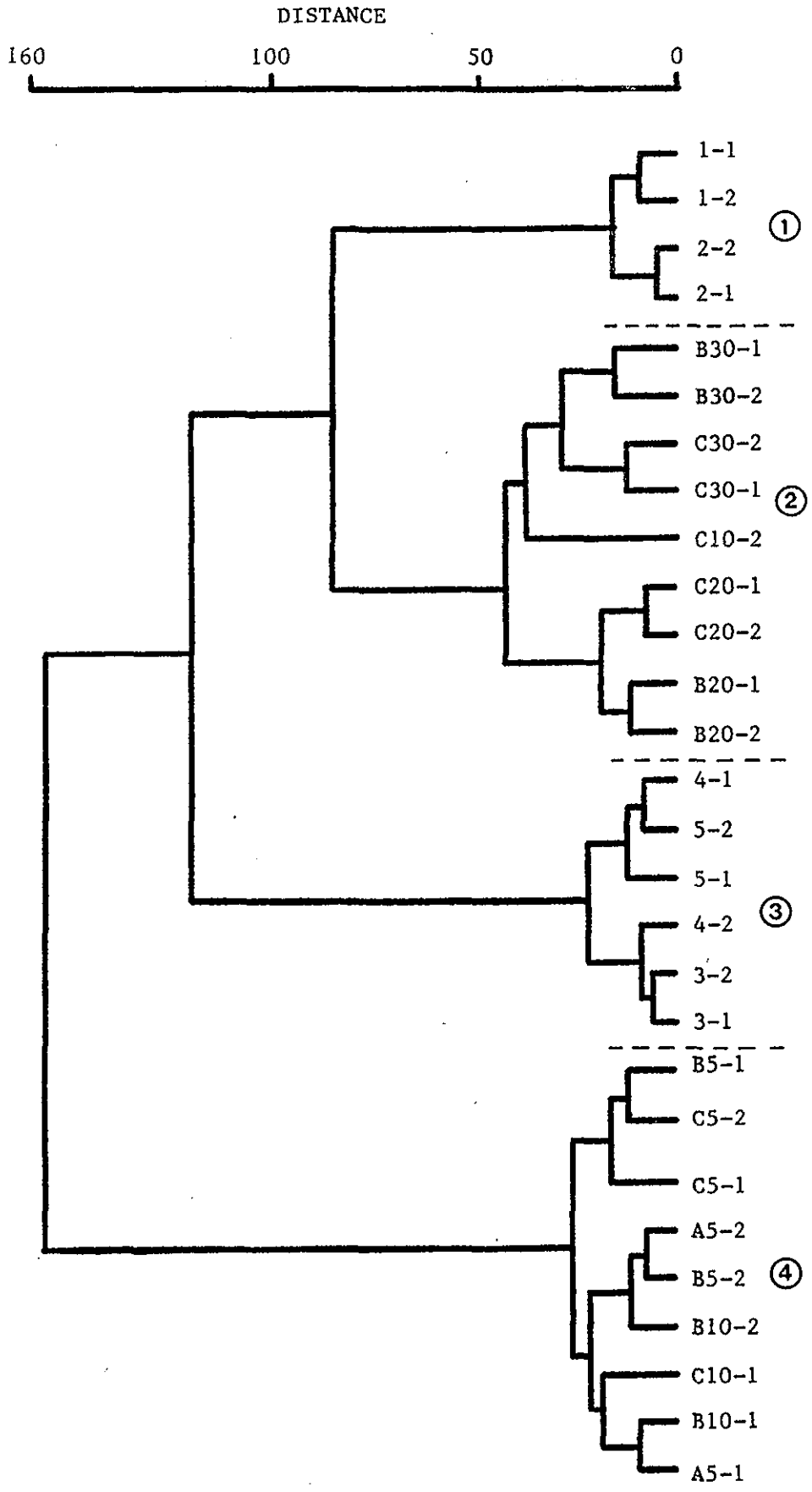

Figure 8: Normal (Q-mode) dendrogram showing relationships among stations/replicates for Black Ledge sampling.

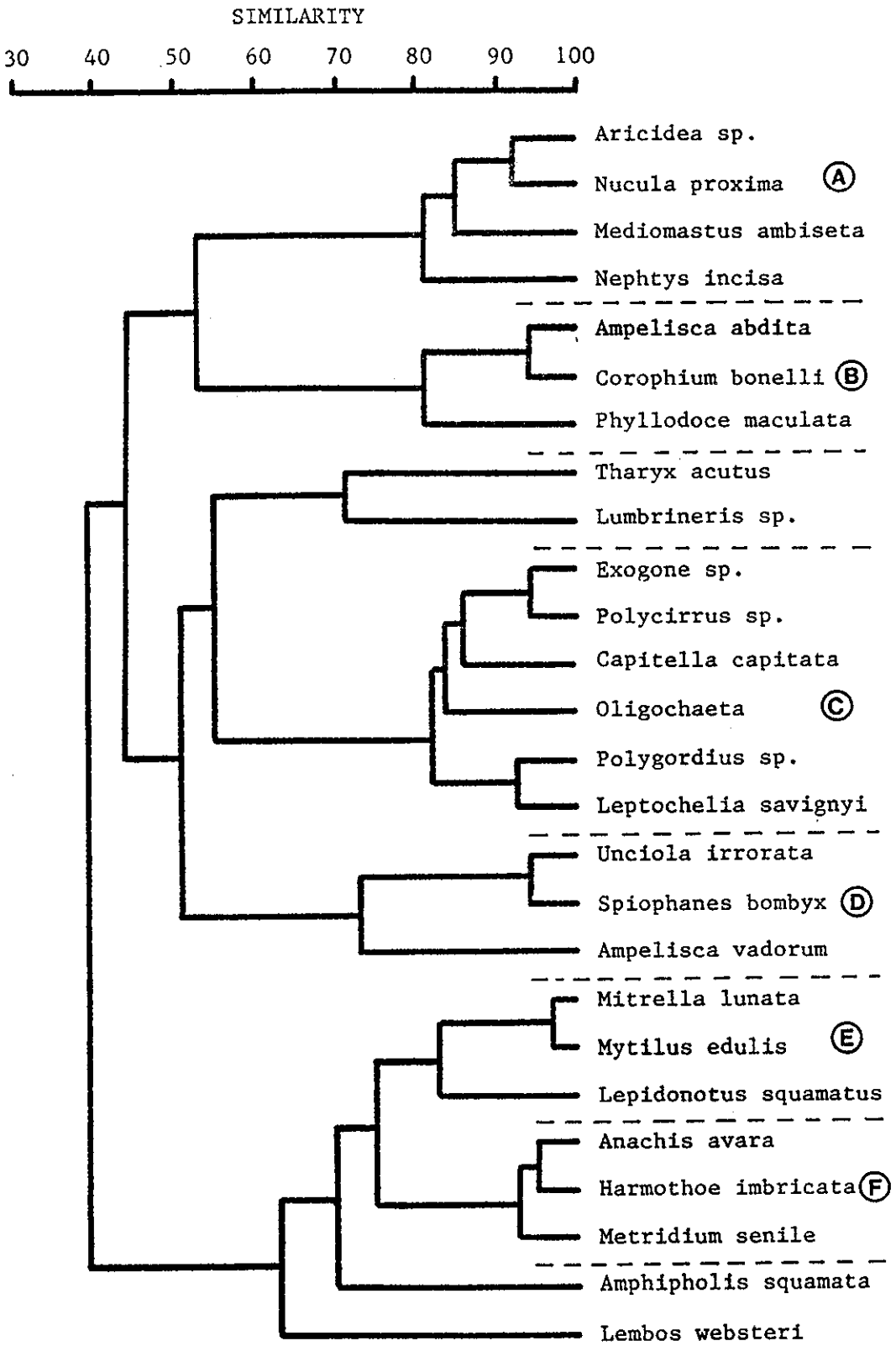

Figure 9: Inverse (R-mode) dendrogram showing relationships among 26 most common species from Black Ledge sampling.

Mytilus edulis, and the polychaete Lepidonotus squamatus. The related group (F) comprised the gastropod Anachis avara, the polychaete Harmothoe imbricata and the anthozoan Metridium senile.

Inspection of the normal dendrogram (Figure 8) revealed four distinct and homogeneous clusterings. The first of these (Group 1) included Stations 1 and 2, which were of moderate depth (25' - 30') and had a silty substratum. Group 2 included stations to the south and east of Black Ledge which were of moderate to shallow depth (10' - 30') and had a sand/gravel substratum. Group 3 included the three deepest (>30') stations sampled, all of which had silty bottoms, and Group 4 comprised the five rock substratum stations on Black Ledge proper. These clusters correspond nearly exactly to the groupings discussed earlier which were identified on the basis of substratum characteristics.

The relationships among the six species groups and four station groups identified above were examined via nodal analysis (Boesch, 1977). Scores at each station/species node were calculated as the percent of the maximum possible number of occurrences of the species as dominants (top five, numerically) at the stations. For example, the intersection of a three-member species group with a five-member station group would have a maximum of 15 possible "occurrences" if each of the species were present as a dominant at each of the stations. If the species were present as dominants a total of 12 times, the score at that node would be 80.0% (12/15 X 100). The calculated nodal density scores, arranged into four density levels, are presented in Figure 10.

Species Group A, dominated by Aricidea sp., was restricted to the deep silt substratum stations, being most commonly found at station Group 1, but also occurring at Group 3. Species Group B, dominated by Ampelisca abdita, was characteristic of the deepest stations (Group 3) and occurred nowhere else. Based upon this pattern, these stations are clearly unique in relation to the remainder of the area surveyed.

Station Group 2, the moderately deep sand/gravel stations, was dominated by species Group C but also contained moderate densities of Group D, containing species which appeared to be transitional between the shallower hard substrata and the deeper silt/clays. Species Group E and Group F were characteristic of the rock stations, with Group F being more strongly restricted to this habitat than Group E.

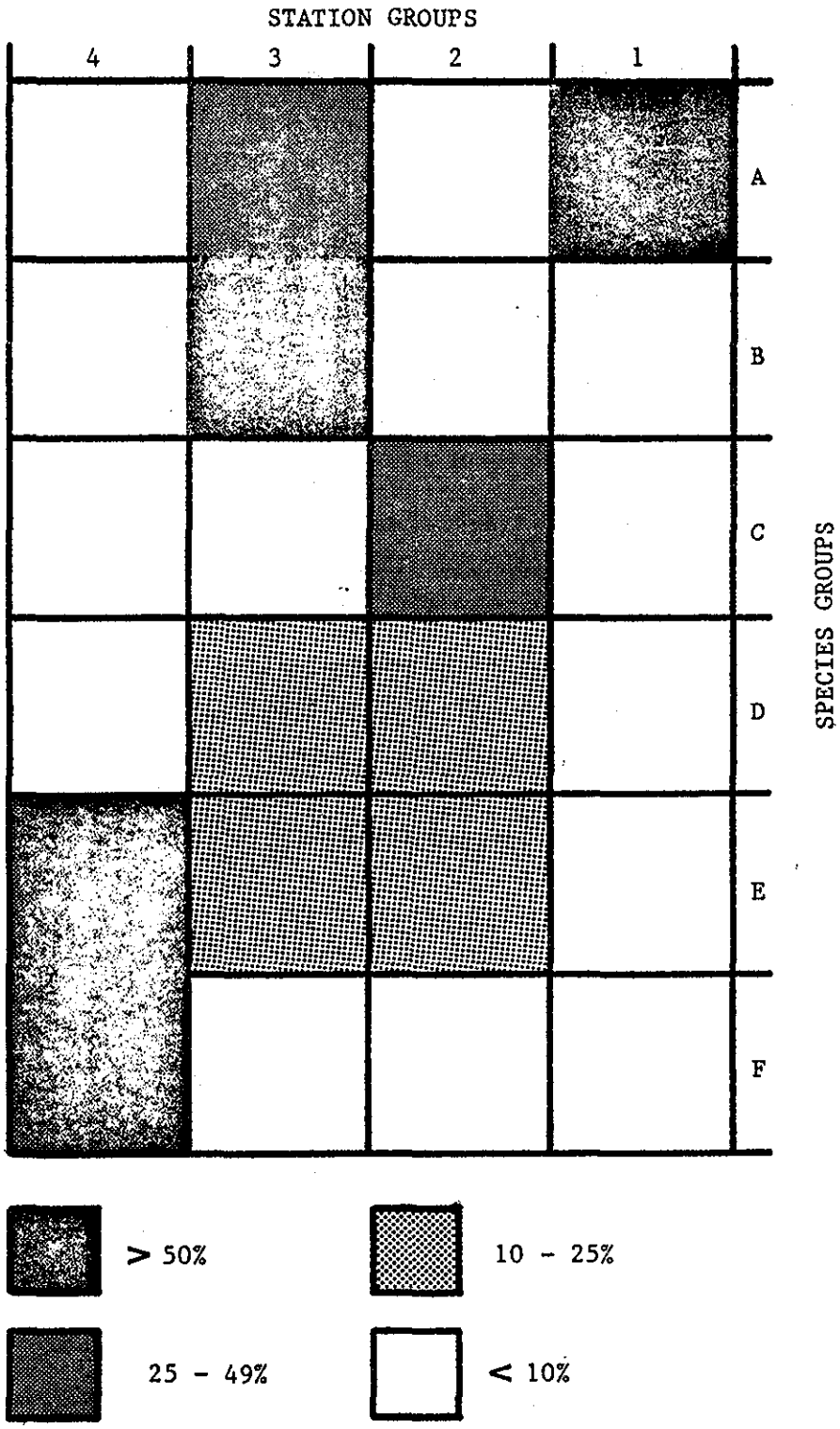

Figure 10: Nodal analysis showing occurrence of species groups (A-F) at station groups (1-4) at Black Ledge. For explanation of nodal density scores, see text.

3.2.4. Habitat Valuation

Three distinct community types were identified from the classification anlysis; one of these (silt/clay)was further divided into two sub-classes. Four of the five stations grouped into the silt/clay group were sampled via REMOTS methodology in addition to the conventional macrofaunal sampling, and therefore more data are available for the habitat analysis phase of the program. The results of the analysis of the REMOTS imagery are shown in Table 4.

Stations 1 and 2 were unlike any other stations and comprised a silt/clay substratum dominated by a suite of polychaete species, primarily the paraonid, Aricidea sp. Also common were the polychaetes Scoloplos acutus and Tharyx acutus. The most common non-polychaete species was the bivalve Nucula proxima. REMOTS imagery indicated that these stations had an average oxidized area of approximately $25cm^2$ with no sediment methane. Although the dominant polychaete in this assemblage (Aricidea) is not one of the more typical Stage I species, the remainder of the community is indicative of Stage I (polychaete-dominated) succession.

Based upon the habitat evaluation procedure described earlier, this area was awarded a habitat index of 4 - 5, with Station 2 scoring slightly higher than Station 1. These are relatively high indices for this community type and suggests that the area has not been subjected to a great amount of pollution-related stress. More typical Stage I assemblages in heavily polluted regions of harbors have habitat values of 1 to 3.

The remainder of the silt/clay substratum stations (3,4,5) supported faunal communities dominated by the ampeliscid amphipod, Ampelisca abdita. Prominent sub-dominant species included Nephtys incisa, Nucula proxima, N. delphinodonta and Mitrella lunata. Although there was no discernable difference in sediment type between the two silt/clay community types, the amphipod-dominated community definitely presents a picture of greater stability.

REMOTS imagery from Stations 3 and 4 (Table 4) also indicated a lack of methanogenesis and a considerably larger oxidized layer

Table 4: Scores by station and replicate for parameters used in evaluating imagery obtained by REMOTS photography.

Station	Sediment Type	P	Redox(cm^2)	CH_4	Successional Stage	Habitat Index
1-1	4 - 3Ø	4.6	19.2	no	I	3
1-2	4 - 3Ø	5.1	27.5	no	I	4
1-3	4 - 3Ø	4.6	26.6	no	I	4
1-4	4 - 3Ø	4.6	28.9	no	I	4
1-5	4 - 3Ø	4.8	23.2	no	I	4
2-1	4 - 3Ø	3.9	30.8	no	I	5
2-2	4 - 3Ø	4.3	19.6	no	I	3
2-3	4 - 3Ø	3.5	34.1	no	I	5
2-4	4 - 3Ø	4.2	33.1	no	I	5
2-5	4 - 3Ø	3.9	21.5	no	I	4
2-6	4 - 3Ø	4.8	28.2	no	I	4
3-1	4 - 3Ø	4.0	37.0	no	II	7
3-2	4 - 3Ø	3.9	41.3	no	II	8
3-3	4 - 3Ø	3.9	40.2	no	II	8
3-4	4 - 3Ø	3.9	39.1	no	II	7
3-5	4 - 3Ø	4.0	37.3	no	II	7
4-1	4 - 2Ø	4.1	44.0	no	II	7
4-2	4 - 2Ø	5.2	31.8	no	II	7
4-3	4 - 2Ø	3.0	36.3	no	II	6
4-4	4 - 2Ø	4.2	41.0	no	II	7
4-5	4 - 2Ø	4.8	60.3	no	II	8

than Stations 1 and 2 ($\bar{x}$ = 42.5cm^2). Primarily because of the Stage II amphipod-dominated community at Stations 3 and 4, this area received a higher habitat index of 7 - 8, with no difference between the two stations. Although Station 5 was not sampled with the REMOTS methodology, it is clear from the similarity in the faunal and sediment composition that this station would also receive a similarly high index. The distribution of mean habitat indices over the four stations sampled via REMOTS methodology is shown in Figure 11.

The four sand/gravel substratum stations (B20, B30, C20, C30) represent a heterogeneous group of faunal assemblages which have characteristics of both Stage I and Stage II communities. Polychaete species dominate most of the samples from these stations, particularly at B20 and B30, but crustaceans are also common and Ampelisca abdita is one of the dominants at Station C30.

It was not possible to obtain REMOTS imagery at these stations due to the nature of the substratum and the program scope. Therefore, it is not possible to assign a habitat index value which can be compared directly with those assigned to the silt/clay stations. Based upon the faunal assemblages at these locations, however, it appears that the sand/gravel stations would have indices intermediate between the Stage I and Stage II silt/clay stations. Stations on the B transect, which were more strongly polychaete-dominated, would score toward the lower end of this range while stations on the C transect, with their larger crustacean components, would be ranked toward the upper end of the range.

The remaining five stations (A5, B5, B10, C5, C10) are all located on the shallower area of Black Ledge and share a rock substratum. These stations are occupied by a faunal assemblage which is entirely different from that described at the deeper stations. The dominant species in all cases was the edible mussel, Mytilus edulis, and subdominants included the gastropods Mitrella lunata and Anachis avara, the polychaete Harmothoe imbricata and the ophiuroid Amphipholis squamata. These are all typical hard-substratum species with a wide distribution in the northeast littoral.

REMOTS technology is not applicable to hard bottoms and therefore was not used at any of the rock substratum stations.

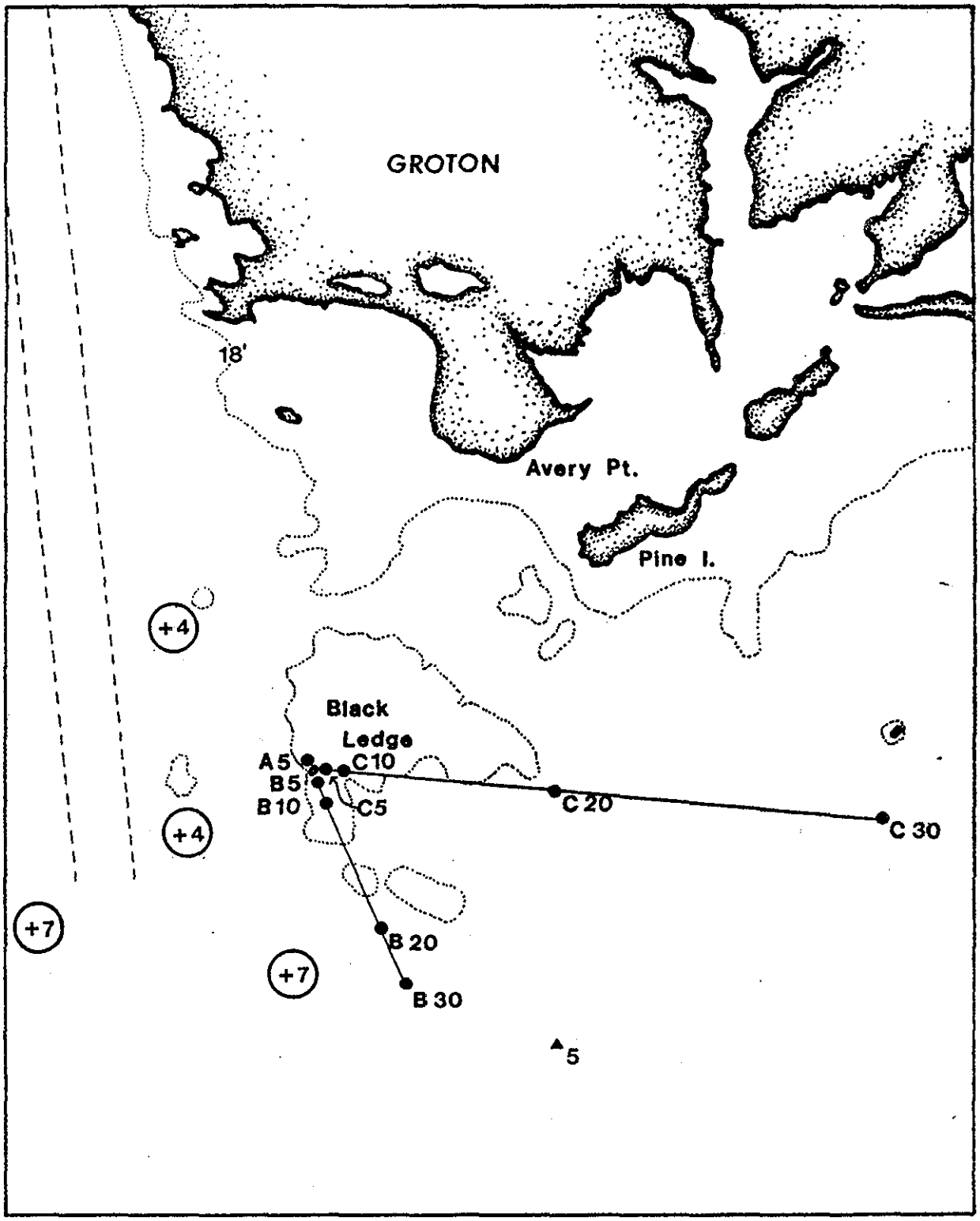

Figure 11: Plot of habitat index scores for four stations at Black Ledge evaluated by REMOTS imagery. Scale ranges from -10 to +10.

Because much of the habitat index is based upon sedimentary parameters (redox layer, methanogenesis), it is not possible to develop habitat index values for the rock substratum stations which would be comparable to those described for the silt/clay and sand/gravel substrata.

Based upon our experience with rock substratum communities in other areas, however, the faunal assemblage at Black Ledge appears normal and unimpacted by pollution-related stress. Mytilus is a common dominant species in similar communities in similar situations and is capable of reaching extremely high levels of productivity. Because of that, it is likely that the rock substratum communities at Black Ledge represent a very valuable ecological resource in spite of their reduced species richness and faunal density.

3.3. Black Ledge Algae

3.3.1. Species Richness

Algal colonization at Black Ledge was restricted to the rock substratum stations, i.e. the 5' and 10' stations of the A, B, and C transects. The rocks sampled were all large and artificially-cut; naturally occurring rocks associated with the ledge structure itself were not present in the sampling area.

A total of 52 algal species was recorded from the Black Ledge subtidal stations (Table 5). Species richness did not appear to be correlated with either depth or transect; richness was relativey high throughout the survey area for all replicates and stations. The number of species contained in individual replicates (Table 6) showed moderate variation, and ranged from a minimum of 22 to a maximum of 33; the average number of species contained in each replicate was 27. The number of species recorded for each station showed considerably less variation, ranging from a low of 36 to a high of 38.

The number of species representing each major algal division was also similar for all stations, regardless of depth or transect. Red algal species (Rhodophyta) predominated throughout the survey area, and comprised between 64 and 70% of the total species number at the individual stations. Green algal species (Chlorophyta) and brown algal species

Table 5. Algal species collected at the subtidal (5' and 10' MLW) rock substratum Black Ledge stations, by depth, transect, and replicate.

Division	Depth (Transect)									
	5' (A)		5' (B)		5' (C)		10' (B)		10' (C)	
Species	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
Green algae (Chlorophyta)										
Enteromorpha clathrata	X	X								
Enteromorpha flexuosa		X				X		X		
Enteromorpha intestinalis			X				X			
Enteromorpha prolifera				X	X					X
Ulva lactuca	X	X	X	X	X	X	X	X	X	X
Chaetomorpha linum		X	X			X	X	X		
Chaetomorpha melagonium			X							
Cladophora albida					X			X		X
Cladophora sericea		X	X	X		X				
Rhizoclonium riparium				X						
Bryopsis plumosa		X					X		X	
Brown algae (Phaeophyta)										
Ectocarpus fasciculatus				X		X	X			
Ectocarpus siliculosus	X	X	X	X	X	X	X	X	X	X
Giffordia granulosa	X	X	X	X	X	X	X	X	X	X
Giffordia mitchelliae		X		X			X		X	X
Giffordia sandriana		X		X		X			X	
Desmarestia aculeata			X						X	
Laminaria saccharina	X							X		X
Sphacelaria cirrosa		X				X			X	X
Red algae (Rhodophyta)										
Goniotrichum alsidii	X					X				X
Bangia atropurpurea		X		X	X		X		X	X
Porphyra leucosticta		X	X							

Table 5. (continued)

	Depth (Transect)									
	5' (A)		5' (B)		5' (C)		10' (B)		10' (C)	
	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
Porphyra umbilicalis					X			X		X
Audouinella daviesii	X	X	X	X	X	X	X	X	X	X
Audouinella secundata	X						X	X		X
Nemalion helminthoides		X								
Bonnemaisonia hamifera							X		X	
Polyides rotundus		X	X		X		X	X		
Cystoclonium purpureum		X		X		X		X	X	X
Ahnfeltia plicata				X	X		X	X		X
Phyllophora pseudoceranoides		X	X		X	X		X		X
Phyllophora truncata	X				X	X	X		X	
Chondrus crispus	X	X				X		X	X	X
Corallina officinalis			X	X	X		X		X	
Champia parvula		X	X			X			X	X
Lomentaria baileyana		X				X		X		
Lomentaria orchadensis	X	X	X	X	X	X	X	X	X	X
Antithamnion americanum			X				X			
Antithamnion cruciatum	X	X	X	X	X	X	X	X	X	X
Callithamnion baileyi	X	X	X	X	X	X		X	X	X
Callithamnion byssiodes	X	X	X		X					X
Callithamnion corymbosum			X				X		X	
Callithamnion roseum	X	X	X		X	X		X		
Ceramium rubrum	X	X	X	X	X	X	X	X	X	X
Spermothamnion repens	X	X	X	X	X	X	X	X	X	X
Grinnellia americana	X	X			X		X	X	X	X
Daysa baillouviana	X		X	X	X	X		X	X	X
Chondria tenuissima	X	X	X	X	X	X	X	X	X	X
Polysiphonia denudata	X	X	X	X	X	X	X	X	X	X
Polysiphonia harveyi	X	X	X	X	X	X	X	X	X	X
Polysiphonia nigrescens			X			X				X
Polysiphonia urceolata		X					X	X		

Table 6. Algal species richness and community structure at the subtidal (5' and 10') rock substratum Black Ledge stations a) by replicate and b) by station.

a) By replicate

Depth, transect, and replicate	Chlorophyta (green algae)	Phaeophyta (brown algae)	Rhodophyta (red algae)	Species richness
5,A,1	2 (9%)	3 (14%)	17 (77%)	22
5,A,2	6 (18%)	5 (15%)	22 (67%)	33
5,B,1	5 (18%)	3 (11%)	20 (71%)	28
5,B,2	4 (17%)	5 (22%)	14 (61%)	23
5,C,1	3 (12%)	2 (8%)	20 (80%)	25
5,C,2	4 (14%)	5 (18%)	19 (68%)	28
10,B,1	4 (15%)	4 (15%)	19 (70%)	27
10,B,2	4 (14%)	3 (11%)	21 (75%)	28
10,C,1	2 (8%)	6 (22%)	19 (70%)	27
10,C,2	3 (10%)	5 (17%)	22 (73%)	30

b) By station

Depth and transect	Chlorophyta (green algae)	Phaeophyta (brown algae)	Rhodophyta (red algae)	Species richness
5,A	6 (16%)	6 (16%)	26 (68%)	38
5,B	7 (19%)	6 (17%)	23 (64%)	36
5,C	6 (16%)	5 (14%)	26 (70%)	37
10,B	6 (16%)	5 (13%)	27 (71%)	38
10,C	4 (11%)	7 (19%)	26 (70%)	37

(Phaeophyta) were considerably less well represented; green algae comprised between 11 and 19% of the total species number at each station, while brown algal composition ranged between a very similar 13 to 19%. The prevalence of Rhodophycaen species is a characteristic feature of New England subtidal algal populations (Taylor, 1962).

3.3.2. Species Dominance

Species dominance patterns were also similar throughout the survey area and dominance appeared to be unrelated to both depth and transect. As a group, the dominant species at all replicates and stations consisted primarily of ephemeral and annual species of less than 5cm in height. More than 50% of the dominants were small ($<$4cm) filamentous epiphytic or epizoic species. Larger, perennial species (*Chondrus crispus*, *Phyllophora* spp., *Polyides rotundus*, *Corallina officinalis*, etc.) were poorly represented throughout the survey area, and were not among the dominant species for any replicate or station.

Table 7 presents the dominance heirarchies for each replicate and station. The red algae *Chondria tenuissima* was the dominant species throughout the survey area; *Chondria* was the single most dominant taxa in over 50% of the replicates, and was also the only taxa to be recorded as one of the five dominant species for every replicate. A second tier of dominant species comprised the brown alga *Giffordia granulosa* and the red algae *Lomentaria orchadensis* and *Callithamnion baileyi*. All three were among the five dominant species in 70 - 80% of the replicates. In addition, *Giffordia* was the most dominant species in three of the replicates, while *Callithamnion* was the dominant species in one replicate. A third tier of dominant species included the brown alga *Ectocarpus siliculosus*, the green alga *Ulva lactuca*, and the red algae *Polysiphonia denudata*, *P. harveyi*, and *Grinnellia americana*; all taxa were among the five dominant species in 20 - 30% of the replicates. A fourth tier of dominants comprised the red algae *Callithamnion roseum*, *Ceramium rubrum*, *Daysa baillouviana*, and *Cystoclonium purpureum*; all species were among the five dominant taxa in 10% of the replicates.

Dominance patterns were strongly influenced by the dense concentrations of *Mytilus* occurring at all stations. The benthic macroalgal

Table 7. Algal dominance at the subtidal (5' and 10') rock substratum Black Ledge stations, by depth, transect, and replicate.

Species	Depth (transect)									
	5' (A)		5' (B)		5' (C)		10' (B)		10' (C)	
	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
Chondria tenuissima	1	2	4	1	3	1	1	1	3	1
Giffordia granulosa	3	1	1	-	2	-	3	3	1	2
Lomentaria orchadensis	2	3	5	2	-	2	2	5	-	3
Callithamnion baileyi	4	-	-	5	1	3	-	2	2	4
Ectocarpus siliculosus	5	-	2	-	-	-	-	4	-	-
Polysiphonia denudata	-	4	-	3	-	-	-	-	-	5
Ulva lactuca	-	-	3	-	4	-	-	-	5	-
Polysiphonia harveyi	-	5	-	-	-	-	4	-	-	-
Grinnellia americana	-	-	-	4	-	-	-	-	4	-
Callithamnion roseum	-	-	-	-	-	4	-	-	-	-
Ceramium rubrum	-	-	-	-	-	5	-	-	-	-
Daysa baillouviana	-	-	-	-	-	-	5	-	-	-
Cystoclonium purpureum	-	-	-	-	5	-	-	-	-	-

species Chondrus crispus and Phyllophora spp., which typically dominate the New England subtidal flora (NUSCo, 1979; BECo, 1980), were not able to successfully compete against Mytilus for space. Dominance was instead shown by those epiphytic and ephemeral species which were able to germinate and grow directly upon Mytilus.

3.3.3. Community Overlap

Community overlap between stations was determined using Jaccard's Coefficient of Community (Grieg-Smith, 1964). Overlap did not appear to be related to either depth or transect (Table 8). Overlap values were generally high and uniform, ranging from 51.0 to 70.4%. The data indicate that algal species composition was relatively similar throughout the Black Ledge survey area.

3.3.4. Biomass

Biomass data for all replicates and stations are given in Table 9. Biomass varied considerably at both the replicate and station level; replicate biomass ranged from 4.3 to 152.1 g/m^2, and station biomass from 19.0 to 90.4 g/m^2. Biomass and depth appeared to be inversely related. 50% of the 5' replicates had biomass in excess of 100 g/m^2, while 100% of the 10' replicates had biomass below 50 g/m^2. In addition, the 5' stations consistently had greater biomass (67.9 - 90.4 g/m^2) than the 10' stations (19.0 - 42.5 g/m^2). Biomass and transect appeared to be unrelated.

Black Ledge biomass values were low compared to those recorded for corresponding shallow subtidal localities in New England. In studies conducted at Plymouth, Massachusetts (BECo, 1980), algal biomass typically ranged from 500 - 600 g/m^2, and values as high as 900 g/m^2 were not uncommon. The appreciably lower Black Ledge biomass was due to the scarcity of benthic macroscopic species; the small filamentous and blade-like species which dominated the Black Ledge populations contributed comparatively little to overall station biomass.

Table 8. Community overlap (Jaccard's Coefficient of Community) between the subtidal (5' and 10') rock substratum Black Ledge stations.

Station pair	number of shared species	community overlap
5A/5B	25	51.0%
5A/5C	31	70.4%
5A/10B	29	61.7%
5A/10C	28	59.6%
5B/5C	28	62.2%
5B/10B	26	54.2%
5B/10C	26	55.3%
5C/10B	29	63.0%
5C/10C	30	68.2%
10B/10C	29	63.0%

Table 9. Algal biomass (g/m^2) at the subtidal (5' and 10') rock substratum Black Ledge stations, by replicate and station.

Depth, transect, and replicate	replicate biomass (g/m^2)	station biomass (g/m^2)
5,A,1	44.6	90.4
5,A,2	136.2	
5,B,1	107.4	67.9
5,B,2	28.4	
5,C,1	152.1	89.0
5,C,2	26.9	
10,B,1	46.2	42.5
10,B,2	38.8	
10,C,1	33.7	19.0
10,C,2	4.3	

4.0. DISCUSSION AND CONCLUSIONS

The presence of mixed groups of Stage I and II faunal assemblages in the Black Ledge area is a typical pattern of successional mosaics in harbors. Periodic physical disturbance in these areas surrounding Black Ledge is apparently sufficient to prevent the establishment of communities with higher successional states. The frequency of disturbance appears to be greater for areas within the 30' isobath than for stations below this depth. However, even the deepest stations sampled exhibited evidence of a history of recurring periodic disturbance of sufficient magnitude to prevent establishment of a Stage III faunal assemblage. This pattern of disturbance may be related to winter storms, although Station 4 indicated more recent scouring in the REMOTS imagery.

On Black Ledge itself, wind and tidally driven currents and waves create a hydrodynamic regime which limits the fauna to those species adapted to a hard-bottom high-energy habitat. The depth to which this situation occurs at Black Ledge was not precisely determined by the present survey but would necessarily be between 10' and 20', and the ledge appeared to end abruptly at approximately 15' (MLW).

The most conspicuous feature of all stations on the ledge was a dense and virtually uninterrupted covering of mussels (*Mytilus edulis*) on all available rock surfaces. The mussel cover was at least one layer thick on most rocks, but occasionally swelled to two and even three layers in thickness. Mussel cover was commonly so complete that the underlying rock surfaces were not visible to divers. All mussels were similar in size (5 - 7cm) and were judged to be approximately one to two years of age.

The algal population on Black Ledge were characterized by an overall scarcity of benthic macroscopic species (*Chondrus crispus*, *Phyllophora* spp., and *Laminaria* spp.), and an abundance of smaller ephemeral and epiphytic species (*Chondria tenuissima*, *Lomentaria orchadensis*, *Callithamnion* spp., and *Giffordia granulosa*). The scarcity of benthic macrophytic species reflected on an inability to successfully compete for space against the extensive mussel populations.

The ephemeral and epiphytic species, in contrast, were not in direct competition for space with the mussels, and their increased numbers resulted from their ability to utilize the mussels themselves as substratum. The algal populations of all stations were also characterized ty relatively high species diversity (a function of the large number of epiphytic and ephemeral species) and low biomass (a reflection of the overall lack of benthic macroscopic species).

Because of the evidence of strong scouring on the ledge and periodic scouring even beyond the 30' isobath, it is obvious that uncontained spoils deposited on Black Ledge would experience rapid dispersal. Any design for dredge spoils disposal in this area should strongly consider total containment within a rock breakwater. In order to approach the one half mile square area mentioned in the RFP for this survey, the rock breakwater would have to be constructed near the 20' isobath. A rock breakwater of this size and length would provide an extremely large area for the re-establishment of a community similar to that which is presently found on Black Ledge. Assuming a square configuration ½ mile on each side, the 20' breakwater would be approximately 10,500' in length. Allowing for a slope on the outer face of 45°, and an increase in colonizable area of 3X due to the numerous crevices between individual stones, the total new area available would be approximately 900,000 square feet. Approximately 50% of the 7×10^6 square feet of area which would be occupied by the proposed DMCF is hard bottom which presently supports *Mytilus* populations. Thus, construction of the DMCF would remove approximately 75% of this community type from the local ecosystem.

Literature Cited

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. EPA Ecological Research Series No. EPA-600/3-77-033. 115p.

The Center for the Environment & Man, Inc. 1981. Biological survey of Bridgeport Harbor, Black Rock Harbor and Adjacent Environments. Report to New England Division, U.S. Army Corps of Engineers.

Boston Edison Company. 1980. Benthic studies in the vicinity of Pilgrim Station. In: Marine ecology studies related to operation of Pilgrim Station. Semi-annual Report Number 16. January - June 1980.

Grieg-Smith, P. 1964. Quantitative Plant Ecology. 2nd Edition. Butterworths, Washington. 265 p.

Hartzband, D.J., A.J. McCusker, R. McGrath, A.D. Michael and D.A. Rhoads. 1979. Subtidal benthos. Section 6 in: New Haven Harbor Ecological Studies Summary Report, 1979. Normandeau Associates, Inc., Bedford, N.H. Report to United Illuminating Co.

McGrath, R., W. Grocki, P. Sevigny and D. Ryder. 1982. Biotic survey of Clinton Harbor. Section III in: Environmental Baseline Data Collections and Site Evaluations, Long Island Sound Container Disposal Study. Clinton Harbor, Connecticut. Taxon, Inc., Salem, MA. Report to New England Division, Corps of Engineers.

Northeast Utilities Service Company, Inc. 1979. Rocky shore in 1978. In: Annual Report on Ecological and Hydrographic Studies at the Millstone Nuclear Power Station.

Taylor, W.R.T. 1957. Marine algae of the Northeastern coast of North America. 2nd Edition. University of Michigan Press, Ann Arbor.

Appendix 1

Report on Results of REMOTS Survey of
Black Ledge, Connecticut

Marine Surveys, Inc.
275 St. John Street
New Haven, CT

Introduction

On August 31, 1981, a REMOTS™ benthic survey was conducted at four of five stations located west and south of the rocky shoal area called Black Ledge at the mouth of New London Harbor. Between 5 and 6 replicate sediment profile images were obtained at each of the four stations. Station locations are as follows (see Clinton Report for format explanation):

STATION DESCRIPTIONS -- BLACK LEDGE

August 31, 1981

STATION BL1
25'
7:50 AM
60° - Tank and Frank Ledge "BRC" lined up
170 yds to "BRC"

STATION BL2
30'
8:30 AM
250 yds NW of can #3
55° to Tank

STATION BL3
39'
9:45 AM
200 yds SW of Nun "4"
48° - Nun "4" to Pine Island tower

STATION BL4
33'
9:05 AM
55° - 62° - Tower on Pine Island
400 yds SW of Nun "6"
due south of New London Light

STATION BL5
35'
10:15 AM
Line up New London Harbor light house with N "2" & N "6"
Line up west side of mansion with water tank (10° N)

Methods

Sediment profile images were measured for: 1) modal grain-size; 2) camera penetration depth; 3) presence of sediment methane; 4) aerated sediment area (positive redox are); and 5) faunal successional stage. Variables 3 - 5 were used to generate a habitat index based on the following scaling:

Planimetered RDP Area	Index Value
0 - 10cm^2	1
10.1 - 20.0cm^2	2
20.1 - 30.0cm^2	3
30.1 - 40.0cm^2	4
40.1 - 50.0cm^2	5
>50.1cm^2	6

Successional Stage	Index Value
Azoic	-5
Stage 1	1
Stage 1 - 2	2
Stage 2	3
Stage 2 - 3	4

Chemical Parameters	Index Value
Methane present	-2
No/low dissolved O_2	-4

The values for the above parameters are given in Table I.

Results

The dominant grain sizes at stations 1 - 4 fall within the Udden-Wentworth size class of 4 - 2 phi (very fine sand). Stations 1 and 2 were found to be in Stage 1 (polychaete dominated) succession while stations 3 and 4 were in Stage II (amphipod-dominated) succcession (Figure 1). Tube mats of Ampelisca abdita at station 4 were recently scoured and broken up. Photos of this station show abundant evidence of recent bottom erosion. For this reason, we have designated station 4 as being retrograde.

No stations were found to contain evidence of methane gas production at depth, and all stations were covered with aerobic water. The mapped habitat indices are shown in Figure 2. The values are means of the replicate samples and are shown beside each station number. All indices

are positive. Stations 1 and 2, located in water depths > 30 feet have indices of 4, while those located in water deeper than 30 feet have indices of 7.

Conclusions

The presence of faunal stages I and II in the region of Black Ledge is a typical pattern of successional mosaics in harbors. The relatively high habitat indices (especially for August) suggest however that these assemblages have not experienced a great deal of pollution. Stage I assemblages in heavily polluted regions of harbors typically have habitat values of 1 - 3.

We can make assumptions about the history of bottom disturbance (current scour) from the mapped successional stages. The mapped indices suggest that those areas located above the 30 foot isobath are more frequently disturbed than areas below this depth. Because we did not observe any Stage III development in the studied area, we might assume that even stations 3 and 4 experience disturbance sometime during the year, causing them to "retrograde". This disturbance is probably related to winter storm wave activity. We suggest than bottom turbulance affects the area of study but that the frequency of disturbance differs between stations. Stations 1 and 2 are more frequently disturbed than stations 3 and 4. The 30-foot isobath may be an important depth contour for defining this disturbance gradient. Uncontained spoils deposited in this region would probably experience dispersal on the time scale of one year. Turbulent mixing probably affects the bottom to depths of at least 40 feet during the winter months.

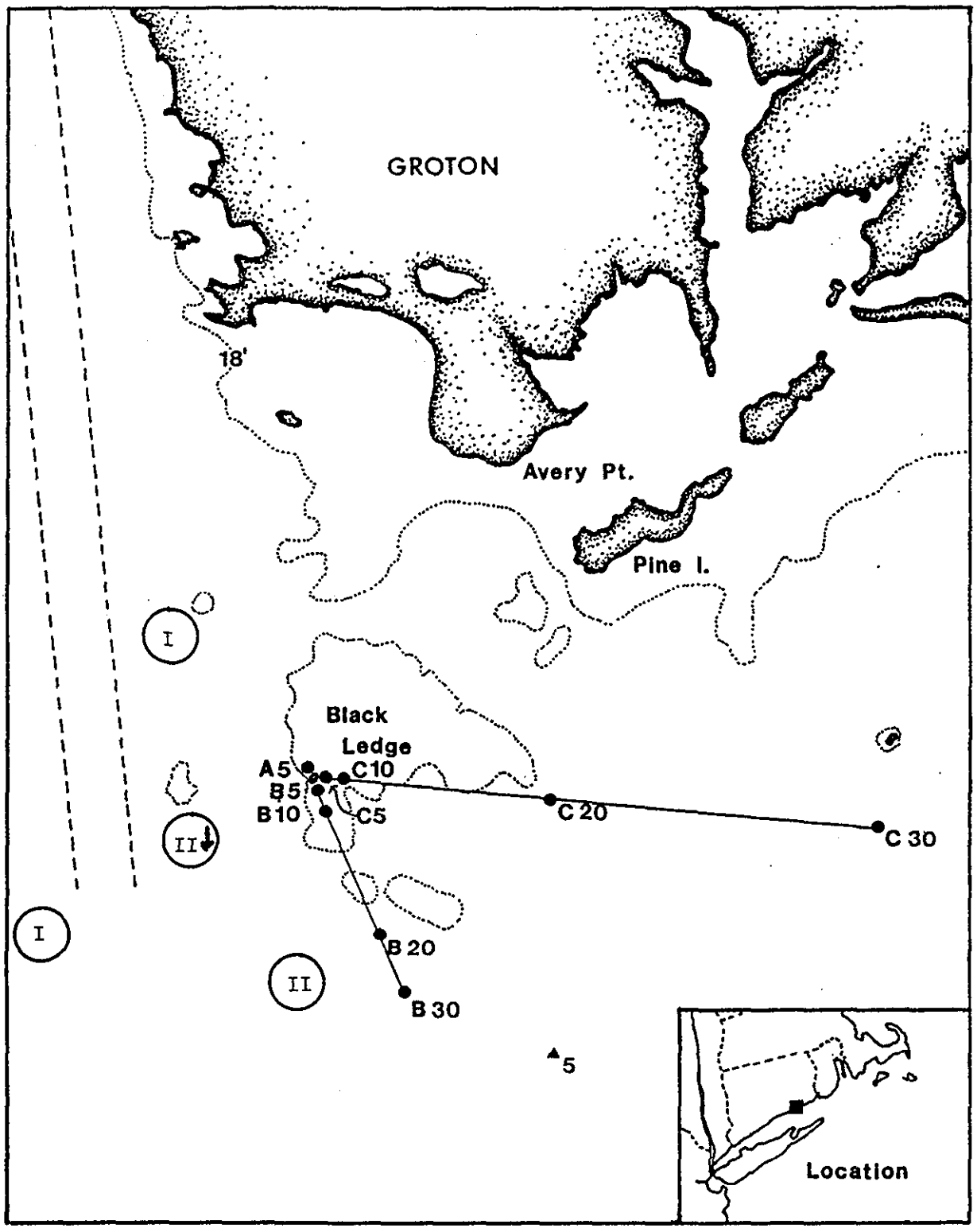

Figure 1: Community successional stages: I = polychaete dominated II = amphipod dominated.

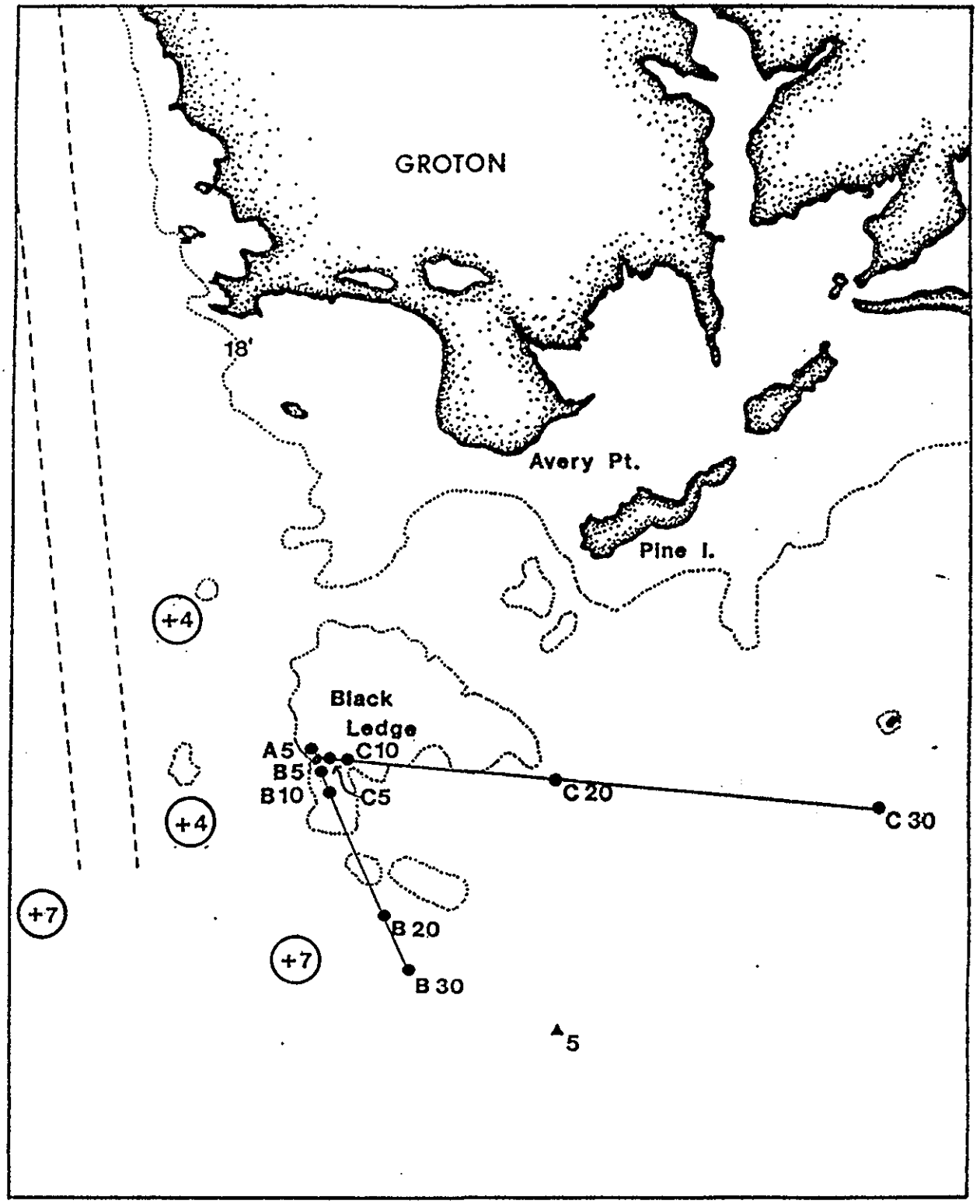

Figure 2: Plot of habitat index scores for four stations at Black Ledge evaluated by REMOTS imagery. Scale ranges from -10 to +10.

Table 1: Scores by station and replicate for parameters used in evaluating imagery obtained by REMOTS photography.

Station	Sediment Type	P	Redox(cm^2)	CH_4	Successional Stage	Habitat Index
1-1	4 - 3Ø	4.6	19.2	no	I	3
1-2	4 - 3Ø	5.1	27.5	no	I	4
1-3	4 - 3Ø	4.6	26.6	no	I	4
1-4	4 - 3Ø	4.6	28.9	no	I	4
1-5	4 - 3Ø	4.8	23.2	no	I	4
2-1	4 - 3Ø	3.9	30.8	no	I	5
2-2	4 - 3Ø	4.3	19.6	no	I	3
2-3	4 - 3Ø	3.5	34.1	no	I	5
2-4	4 - 3Ø	4.2	33.1	no	I	5
2-5	4 - 3Ø	3.9	21.5	no	I	4
2-6	4 - 3Ø	4.8	28.2	no	I	4
3-1	4 - 3Ø	4.0	37.0	no	II	7
3-2	4 - 3Ø	3.9	41.3	no	II	8
3-3	4 - 3Ø	3.9	40.2	no	II	8
3-4	4 - 3Ø	3.9	39.1	no	II	7
3-5	4 - 3Ø	4.0	37.3	no	II	7
4-1	4 - 2Ø	4.1	44.0	no	II	7
4-2	4 - 2Ø	5.2	31.8	no	II	7
4-3	4 - 2Ø	3.0	36.3	no	II	6
4-4	4 - 2Ø	4.2	41.0	no	II	7
4-5	4 - 2Ø	4.8	60.3	no	II	8

Appendix 2

Location Data for All Stations Sampled at
Black Ledge, Connecticut

Location Descriptions for Black Ledge Stations

Station 1:

200 yds. SW of Frank Ledge RB buoy
Range: RB buoy and tank behind Avery Point

Station 2:

250 yds. NW of harbor entrance lighted buoy #3
Range: New London Ledge Light and tank behind Avery Point

Station 3:

200 yds. SW of Black Ledge nun buoy #4
Range: Nun "4" and extreme western end of Pine Island

Station 4:

400 yds. W of Black Ledge nun buoy #6
200 yds. S of New London Ledge Light

Station 5:

700 yds. (approx.) SE of Black Ledge nun buoy #2
Range: Nun "2", Nun "6", and New London Harbor Light
Range: Western end of mansion on Avery Point and tank behind Avery Point

Transect A:

Determined by harbor channel buoy #6 and water tank at Ft. Trumbull.

Transect B:

180° from Transect A, determined by Black Ledge rocks and water tank at Ft. Trumbull.

Transect C:

Determined by Black Ledge Rocks and New London Ledge Light.

Appendix 3

Sediment Grain-Size Analysis Raw Data

LOCATION OF SAMPLE Black Ridge SAMPLE NO. BL S1 R1

GRAVEL ____ % MEDIAN .017 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ ø DATE 18 Feb 82

C7

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				84	29.4148 / 29.4129			.0019	.02	.02
SAND	2.000 / 1.000	-1				29.4194			.0046	.05	.07
	1.000 / .500	0				29.4314			.0120	.14	.21
	.500 / .250	1				29.4516			.0202	.23	.44
	.250 / .125	2				29.5120			.0604	.69	1.13
	.125 / .062	3				31.2121			1.7001	19.29	20.42
	< .062	4				31.4903			.2782		
	> .062							12.0142			
SILT	.062 TO .031	4	25 cm.	0 00	55	27.1356 / 26.8422	2934	11.7360	5.4782	62.16	82.58
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	109	27.9759 / 27.8125	1634	6.5360	1.536	17.43	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 1.1992

WT. FINE 1.0142

WT. TOTAL SAMPLE 2.2134

79.59

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S1 R2

GRAVEL _____ % MEDIAN .027 mm. CLASSIFICATION _____

SAND _____ % P _____ mm. σ _____

SILT _____ % P _____ mm. Sk. _____

CLAY _____ % DISPERSING AGENT WEIGHT _____ gms./50 ml.

ANALYSIS BY _____ Qd _____ ø DATE 18 Feb 82

C8

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				161	29.0109 / 28.9578			.0531	.44	.44
SAND	2.000 1.000	-1				29.0617			0508	.42	.86
	1.000 .500	0				29.1194			0577	.47	1.33
	.500 .250	1				29.1807			0613	50	1 83
	.250 .125	2				29.2998			.1191	.98	2.81
	.125 .062	3				33.0000			3 7002	30 42	33.23
	< .062	4				33.5209			5209		
	> .062							13 1209			
SILT	.062 TO .031	4	25 cm.	0 00	152	29.7825 / 29.4675	3150	13 6000	6.7649	55 52	88.85
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	169	28.7878 / 28.6289	1589	6 3560	1.356	11.15	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5 00

WT. COARSE 4.0422

WT. FINE 8.1209

WT. TOTAL SAMPLE 12.1631

66.77

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S2 R1

GRAVEL ____ % MEDIAN 0.031 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ ø DATE 18 Feb 82

C5

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				220	31.4412 / 31.4340			.0072	.05	.05
SAND	2.000 1.000	-1				31.4582			0170	.12	.17
	1.000 .500	0				31.4815			.0233	.17	.34
	.500 .250	1				31.5229			0414	.30	.64
	.250 .125	2				31.7161			1932	1.39	2.03
	.125 .062	3				36.6276			4.9115	35.29	37.32
	< .062	4				37.0318			.4042		
	> .062							13.7242			
SILT	.062 TO .031	4	25 cm.	0 00	179	26.4870 / 26.1540	.3330	13.3300	6.8522	49.23	86.55
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	77	27.6852 / 27.5134	.1718	6.8720	1.8722	13.45	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 5.1926

WT. FINE 8.7242

WT. TOTAL SAMPLE 13.9178

62.68

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S2 R2

GRAVEL ____ % MEDIAN 0.025 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ Ø DATE 19 Feb 82

a1

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				94	26.5627 / 26.5627			.0000	0.00	0.00
SAND	2.000 / 1.000	-1				26.5751			.0124	.11	0.11
	1.000 / .500	0				26.5952			.0301	.18	0.29
	.500 / .250	1				26.6222			.0270	.24	0.53
	.250 / .125	2				26.7548			.1326	1.17	1.70
	.125 / .062	3				30.1134			3.3586	29.64	31.34
	< .062	4				30.5169			.4035		
	> .062					28.2625		12.7795			
SILT	.062 TO .031	4	25 cm.	0 00	93	27.9531	3094	12.3760	6.3315	55.82	87.22
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	31	28.1898 / 28.0286	.1612	6.4480	1.448	12.78	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 3.5507

WT. FINE 7.7795

WT. TOTAL SAMPLE 11.3302

68.66

ARTIFACTS:

LOCATION OF SAMPLE Black Ridge SAMPLE NO. BL S3 R1

GRAVEL _____ % MEDIAN 0.021 mm. CLASSIFICATION _____

SAND _____ % P _____ mm. σ _____

SILT _____ % P _____ mm. Sk. _____

CLAY _____ % DISPERSING AGENT WEIGHT _____ gms./50 ml.

ANALYSIS BY _____ Qd _____ ø DATE 18 Feb 82

C1

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				189	27.0221 / 27.0221			.0000	0.00	0.00
SAND	2.000 1.000	-1				27.0275			.0054	.05	.05
	1.000 .500	0				27.0394			.0119	.11	.16
	.500 .250	1				27.0683			.0289	.26	.42
	.250 .125	2				27.2205			.1522	1.39	1.81
	.125 .062	3				28.1460			2.9255	26.65	28.46
	< .062	4				30.3303			.1843		
	> .062							12.8523			
SILT	.062 TO .031	4	25 cm.	0 00	51	27.3836 / 27.0669	3167	12.6680	5.9603	54.30	82.76
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	106	28.5181 / 28.3458	1723	6.8920	1.8922	17.24	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 3.1239

WT. FINE 7.8523

WT. TOTAL SAMPLE 10.9762

71.54

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S3 R2

GRAVEL ____ % MEDIAN 0.021 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ ø DATE 18 Feb 82

Cb

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				27	27.0434 / 27.0434			0000	0 00	0 00
SAND	2.000 1.000	-1				27.0591			.0157	.11	.11
	1.000 .500	0				27 0903			.0312	.21	.32
	.500 .250	1				27.1646			.0743	.50	.82
	.250 .125	2				27 4051			.2405	1.62	2 44
	.125 .062	3				31.3725			3 9674	26 68	29.12
	< .062	4				31.7473			.3748		
	> .062							15 5388			
SILT	.062 TO .031	4	25 cm.	0 00	149	26.7472 / 26.3681	.3791	15 1640	7.9508	53 48	82 60
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	204	29.2649 / 29 0752	.1897	7.5880	2.588	17.41	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5 00

WT. COARSE 4.3291

WT. FINE 10.5388

WT. TOTAL SAMPLE 14.8679

70.29

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S4 R1

GRAVEL ____ % MEDIAN .018 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ Ø DATE 18 Feb 82

C4

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				184	28.1760 / 28.1760			.0000	0.00	0.00
SAND	2.000 1.000	-1				28.1930			0170	0.12	0.12
	1.000 .500	0				28.2275			0345	0.24	0.36
	.500 .250	1				28.2749			0474	0.33	0.69
	.250 .125	2				28.3605			0856	0.59	1.28
	.125 .062	3				31.2879			2.9274	20.12	21.40
	< .062	4				31.5460			2851		
	> .062							16.4371			
SILT	.062 TO .031	4	25 cm.	0 00	226	31.2908 / 38.8870	4038	16.1520	9.0971	62.53	83.93
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	87	28.0210 / 27.8375	1835	7.3400	2.34	16.08	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 2.1119

WT. FINE 11.4371

WT. TOTAL SAMPLE 14.5490

78.61

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S4 R2

GRAVEL ____ % MEDIAN .022 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ ø DATE 18 Feb 82

C2

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				68	26.2572 / 26.2563			.0009	0.00	0.00
SAND	2.000 1.000	-1				26.2676			.0104	0.07	0.07
	1.000 .500	0				26.3124			.0448	0.31	0.38
	.500 .250	1				26.3975			.0851	0.58	0.96
	.250 .125	2				26.7483			.3508	2.40	3.36
	.125 .062	3				30.2437			3.6454	24.92	28.28
	< .062	4				30.6071			.3134		
	> .062							15.4894			
SILT	.062 TO .031	4	25 cm.	0 00	99	29.6670 / 29.2851	.3819	15.2760	2.2934	56.70	84.98
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	19	27.0132 / 26.8333	.1799	7.1960	2.196	15.01	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 4.1374

WT. FINE 10.4214

WT. TOTAL SAMPLE 14.6268

71.71

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S5 R1

GRAVEL ____ % MEDIAN .074 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ Ø DATE 18 Feb 82

C3

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				108	27.1850 / 27.0202			1648	.85	.85
SAND	2.000 1.000	-1				27.2731			0881	.45	1.30
	1.000 .500	0				27.5682			2951	1.52	2.82
	.500 .250	1				28.2665			6983	3.61	6.43
	.250 .125	2				29.6485			13820	7.14	13.57
	.125 .062	3				39.0666			94181	48.63	62.20
	< .062	4				39.5035			4369		
	> .062							12.3209			
SILT	.062 TO .031	4	25 cm.	0 00	165	31.9184 / 31.6213	2971	11.8840	55809	28.51	90.71
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	13	26.3116 / 26.1416	1700	6.800	1800	4.29	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 12.0464

WT. FINE 7.3204

WT. TOTAL SAMPLE 19.3613

37.8

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL S5 R2

GRAVEL ____ % MEDIAN .068 mm. CLASSIFICATION ____

AND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ Ø DATE 19 Feb 82

R2

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				97	25 3019 / 25.3019			0 00	0 00	0 00
SAND	2.000 / 1.000	-1				25.3266			0247	0 20	0 20
SAND	1.000 / .500	0				25 4758			.1492	1.24	1.44
SAND	.500 / .250	1				25.7927			3169	2.63	4 07
SAND	.250 / .125	2				26.3706			5779	4.79	8.86
SAND	.125 / .062	3				32.0216			5.6510	46.86	55 72
	< .062	4				32.4094			3878		
	> .062							10 3398			
SILT	.062 TO .031	4	25 cm.	0 00	208	35.4179 / 30.1691	.2488	9.9520	5 8918	32.27	87 99
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	17	28.7830 / 28 5618	1612	5 4480	1 4448	12 81	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5 00

WT. COARSE 5 7197

WT. FINE 2 3548

WT. TOTAL SAMPLE 17.3595

44.28

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL C30 R1

GRAVEL ____ % MEDIAN .136 mm. CLASSIFICATION ____

SAND ____ % P ____ mm. σ ____

SILT ____ % P ____ mm. Sk. ____

CLAY ____ % DISPERSING AGENT WEIGHT ____ gms./50 ml.

ANALYSIS BY ____ Qd ____ ø DATE 19 Feb 82

a3

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR.+SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				28	27.2989 / 26.8956			.4033	1.97	1.97
SAND	2.000 1.000	-1				28.0312			.7323	3.57	5.54
	1.000 .500	0				30.7229			2.6917	13.14	18.68
	.500 .250	1				35.4883			4.7654	23.26	41.94
	.250 .125	2				37.3796			1.8913	9.23	51.17
	.125 .062	3				44.4070			7.0274	34.30	85.47
	< .062	4				44.7339			.3269		
	> .062							7.9749			
SILT	.062 TO .031	4	25 cm.	0 00	191	30.1406 / 30.5494	.1912	7.6480	2.3149	11.30	96.77
	.031 TO .016	5	10 cm.	0 02							
	.016 TO .008	6	10 cm.	0 08							
	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	203	28.2373 / 28.0952	.1415	5.6600	0.66	3.22	100
	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5.00

WT. COARSE 17.5114

WT. FINE 2.9749

WT. TOTAL SAMPLE 20.4863

14.52

ARTIFACTS:

LOCATION OF SAMPLE Black Ledge SAMPLE NO. BL C30 R2

GRAVEL _____ % MEDIAN .327 mm. CLASSIFICATION _____

SAND _____ % P _____ mm. σ _____

SILT _____ % P _____ mm. Sk. _____

CLAY _____ % DISPERSING AGENT WEIGHT _____ gms./50 ml.

ANALYSIS BY _____ Qd _____ Ø DATE 19 Feb 82

a4

	DIAM. mm.	φ	TIME	RDG.	BKR. NO.	BKR. + SPL. / BKR. WT.	WT. SPLE.	20 x WT. SPLE.	WT. FRACT.	%	CUM. %
GRAVEL	2.000				160	30.8393 / 29.8621			9772	5.96	5 96
SAND	2.000 1.000	-1				31.9971			1578	7.06	13 02
SAND	1.000 .500	0				35 3033			3.3062	20 16	33 18
SAND	.500 .250	1				39.8158			4.5125	27.51	60 69
SAND	.250 .125	2				41.0637			1 2479	7.61	68.30
SAND	.125 .062	3				44.7431			3 6794	22 43	90 73
	< .062	4				44.8576			1165		
	> .062							6.5205			
SILT	.062 TO .031	4	25 cm.	0 00	39	39.7345 / 39 5744	1601	6 4048	1 3165	8.03	98.76
SILT	.031 TO .016	5	10 cm.	0 02							
SILT	.016 TO .008	6	10 cm.	0 08							
SILT	.008 TO .004	7	10 cm.	0 32							
CLAY	.004 TO .002	8	10 cm.	2 08	3	24.8403 / 24 7102	.1301	5 2040	0 204	1 24	100
CLAY	.002 TO .001	9	7 cm.	5 58							
	< .001	10	7 cm.	24 00							

WEIGHT DISPERSING AGENT x 20 5 00

WT. COARSE 14.8810

WT. FINE 1.5205

WT. TOTAL SAMPLE 16.4015

9.27

ARTIFACTS:

Appendix 4

Macrofaunal Analysis Raw Data

Note:

Counts for grab samples per $0.04m^2$, counts for diver-collected samples per $0.11m^2$ (see text).

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
POLYCHAETA																
Aglaophamus neotenus																
Ampharete arctica																
Ampharetidae unid.				1	11	1	3							2		
Amphecteis gunneri						1		1								
Amphitrite johnstoni																
Amphitrite sp.														2	2	
Anaitides mucosa					32	21	9	9	6	21						
Anaitides sp.	2															
Aricidea sp.	824	1291	429	638		1	11	3	9	18						
Asabellides oculata	1								1	3						
Autolytus sp.																
Capitella captitata											17		2		12	6
Cirratulus sp.															2	
Clymenella torquata	21	4	6	6	2	2	8	10	4	7						
Cossura longocirrata		25	3	3				1								
Disoma carica					2											
Dorvilleidae unid.											1					
Drilonereis longa																
Drilonereis magna									1							
Ephesiella minuta																
Euchone sp.					1		2		2	1						
Eulalia viridis																
Eumida sanguinea																
Eunicea unid.																
Exogone sp.								1	2		1				20	
Glycera americana																
Harmothoe imbricata					1		1		1		40	24	32	22	32	12
Lepidonotus squamatus												6	4	6	3	12
Lepidonotus sublevis																
Lumbrineris sp.	2	2	10		22	21	34	30	1	16						
Maldanopsis elongata	2	1	3	3					2							
Marphysa sanguinea											2	6	4	6	4	
Mediomastus ambiseta	36	44	79	101	17	3	27	9	25	55						

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
Melinna cristata										20						
Nephtys incisa	24	22	19	30	14	24	23	36	7	11						
Nephtys picta																
Nereis arenaceodonta																
Nereis pelagica												2				4
Nereis succinea																
Nereis virens												2				
Nicolea venustula																
Ninoe nigripes	24	4	1	1	3		2		1	1						
Notomastus sp.																
Oligochaeta	6	1	7	4	3	1	4	1	1	19	8	8	2	6	24	
Onuphis quadricuspis							1	1		2						
Orbiniidae unid.																
Paraonis fulgens							1									
Paraonis sp.			2		2	2		1	1	1						
Parapionosyllis longicirrata											6					
Pectinaria gouldii											1					
Pherusa affinis									1	1						
Pholoe minuta	7		1	2	4	9	2	5	3	7						
Phyllodocidae unid.																
Pista palmata																
Polycirrus eximius	18		5	2	2	3	15	7	15		3	2		14	4	6
Polydora socialis	1															
Polydora sp.						1										
Polygordius sp.																
Potamilla neglecta																
Potamilla reniformis											1					
Prionospio cirrifera	2	1		3	2	1	3	1	8	1						
Pygospio elegans							2									
Sabellaria vulgaris																
Scalibregma inflatum									1							
Scolelepis squamata			1	2												
Scoloplos acutus	71	18	4	1	4	2	5	4	2	3						
Sigambra tentaculata	1		1	5	2	2		1		3						

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
Sphaerosyllis sp.											2					
Spiochaetopterus oculatus					1				1	5						
Spionidae unid.																
Spiophanes bombyx	1								2							
Sthenelais boa																
Sthenelais limicola			1													
Streblospio benedicti	1	2		2												
Syllinae/Eusyllinae unid.												2			2	
Tharyx acutus	69	72	14	35	17	10	13	16	23	28	9	10				
GASTROPODA																
Acteocina canaliculata										4						
Alvania sp.											1				2	
Anachis avara											41	22	20	4	77	6
Buccinium sp.															2	
Busycon canaliculatum											1				2	
Cingula aculeus											3				12	
Colus obesa																
Crassinella lunulata																
Crepidula fornicata													12			
Crepidula plana											14	2			2	4
Cylichna oryza	1				4	1	1	1								
Epitonium humphreysi											1					
Lacuna vincta													2		2	
Lunatia heros			1							1						
Lunatia triseriata									1						2	
Mitrella dissimilis																
Mitrella lunata					39	23	6	27		11	134	36	234	46	260	26
Nassarius trivittatus					1	2		1			3			8		
Odostomia gibbosa											2					
Odostomis seminuda																
Philine lima																
Skeneopis planorbis																
Turbonilla sp.				2	10			4		2		6			14	2
Urosalpinx cinerea												2				

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
BIVALVIA																
Astarte undata					4		1	2	6	5						
Bivalvia unid.																
Cerastoderma pinnulatum	1						1			1						
Crenella glandula																
Cumingia tellinoides																
Cyclocardium borealis					5	3			2	10						
Ensis directus					1				1							
Lyonsia hyalina					6	1	3	6		1						
Macoma balthica	1	1														
Mercenaria mercenaria			1						1							
Modiolus modiolus											2					
Mulinia lateralis	1															
Mytilus edulis											324	423	723	361	777	582
Nucula delphinodonta	2	6		8	35	19	3	25	1	4	1					
Nucula proxima	45	243	143	209	42	48	10	74	1	7	2	2	6	2	6	2
Petricola pholadiformis						1										
Pitar morrhuanus						1										
Solemya velum								1								
Tellina agilis		2			2			1	2						2	
Thracia conradi						1			2							
Yoldia limatula	2		2		1		1	2	1	1						
AMPHIPODA																
Ampelisca abdita	8	9	4	2	949	909	979	833	2421	2072						
Ampelisca vadorum														2		
Ampelisca verrilli																
Amphithoe longimana											8		4		6	2
Byblis serrata																
Caprellidae unid.										1	3		4		10	2
Corophium acutum											4	2	2	2	12	
Corophium bonelli					12	3	1	1	22	26	3					
Dexamine thea											10	8	4	8	12	10
Elasmopus levis													2		4	
Erichthonius rubricornis					14	5	10	19	4	5						

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
Jassa falcata											8		2	4	8	18
Lembos websteri											8	10	8	4	44	2
Leptocheirus pinguis	4			1	3	10		3	5	1						
Lysianopsis alba												8	2	2		
Microdeutopus gryllotalpa															2	
Paraphoxus spinosus															2	2
Photis sp.					1	3	3	3								
Phoxocephalus holbolli												2			2	
Pleusymtes glaber																
Stenothoe minuta																
Trichophoxus epistomus											3					
Unciola irrorata			5	2	8	7	4	1	16	30						
CRUSTACEA																
Campylaspis rubicunda																
Cancer borealis											1					
Cancer irroratus														2		
Crangon septemspinosa																
Cylindroleberis mariae																
Cythereis vineyardensis																
Edotea triloba					5	3	4	1								
Erichsonella filiformis											8		2		6	
Eudorella pusilla							1	1								
Heteromysis formosa																
Idotea phosphorea													2		2	2
Iphinoe trispinosa																
Leptochelia savignyi																
Libinia dubia										1	2					
Libinia sp.																
Mysidacea unid.																
Neopanope sayi											2	2		4	2	
Ostracoda unid.	3			1	7	2		5		9						
Oxyurostylis smithi							1									
Pagurus longicarpus					1											
Pinnotheres maculatus											5		4		2	4

	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	A5-1	A5-2	B5-1	B5-2	B10-1	B10-2
Ptilanthura tenuis	1															
Pycnogonida unid.											1					
Sarsiella sp.	27		1		22	2	25	11		7	1				12	
Upogebia affinis																
MISCELLANEOUS																
Amphipholis squamata											47	36	24	56	138	2
Arbacia sp.														2		
Asterias forbesi															2	
Cerebratulus sp.							1									
Cerianthus sp.		1														
Edwardsia sp.	2	3		1												
Enteropneusta unid.					2											
Henricia sanguinolenta											1					2
Metridium senile											14	28	30	22	10	30
Nemertea unid.	3								1	1						
Phoronida unid.	2															
Sipuncula unid.						2		2								
Tubulanus pellucidus			1	3												

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
POLYCHAETA												
Aglaophamus neotenus												1
Ampharete arctica											1	
Ampharetidae unid.	3	1	3	4					1			
Amphecteis gunneri												
Amphitrite johnstoni						2						
Amphitrite sp.												
Anaitides mucosa	1	1	1	2							4	3
Anaitides sp.												
Aricidea sp.	29	21	2	2					6	20	14	4
Asabellides oculata										2		
Autolytus sp.								1				
Capitella captitata	31	45			8	4	8		13	14		
Cirratulus sp.					2							
Clymenella torquata		1									25	35
Cossura longocirrata												
Disoma carica												
Dorvilleidae unid.	13	27		2						36	3	3
Drilonereis longa	3											
Drilonereis magna												
Ephesiella minuta									1			
Euchone sp.												
Eulalia viridis						2						
Eumida sanguinea	4		1	6					14	14		4
Eunicea unid.		1										
Exogone sp.	141	188		88	14				70	96	39	12
Glycera americana		2		2						2	2	1
Harmothoe imbricata	1	1	5	2	24	36	90	18	4			
Lepidonotus squamatus		1			20	6		7	1			
Lepidonotus sublevis				4								
Lumbrineris sp.	3	2	3	102					7	26	2	4
Maldanopsis elongata											1	
Marphysa sanguinea	1				4			11				
Mediomastus ambiseta		1	1								9	21

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
Melinna cristata												
Nephtys incisa			1	2					1	2		
Nephtys picta											8	
Nereis arenaceodonta		3								2		
Nereis pelagica					2			11	4			
Nereis succinea							10					
Nereis virens	1											
Nicolea venustula						2						
Ninoe nigripes	2		1	3		2						
Notomastus sp.	1											
Oligochaeta	99	89	1	27				110	36	76	17	23
Onuphis quadricuspis												
Orbiniidae unid.										2		
Paraonis fulgens												
Paraonis sp.		5										
Parapionosyllis longicirrata		5				10	2			10		
Pectinaria gouldii			1									
Pherusa affinis	1	1										
Pholoe minuta	3		7	4	2			1		4	4	3
Phyllodocidae unid.		34	2									1
Pista palmata			1									
Polycirrus eximius	52	98	23	94				2	32	76	6	12
Polydora socialis												
Polydora sp.		6							2		7	2
Polygordius sp.	45	89							55	132	8	8
Potamilla neglecta						4						
Potamilla reniformis											2	
Prionospio cirrifera												
Pygospio elegans												
Sabellaria vulgaris						2					1	
Scalibregma inflatum		1										
Scolelepis squamata												
Scoloplos acutus												
Sigambra tentaculata				6								

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
Sphaerosyllis sp.												
Spiochaetopterus oculatus												2
Spionidae unid.		1										
Spiophanes bombyx		8								2	70	59
Sthenelais boa				2								
Sthenelais limicola								1				
Streblospio benedicti												
Syllinae/Eusyllinae unid.	4	17	4					1	13	46	3	
Tharyx acutus	11	20	31	170	2	2		4	67	56	40	36
GASTROPODA												
Acteocina canaliculata												
Alvania sp.							2					
Anachis avara	1	2	5		40	10	180	3	3			
Buccinium sp.												
Busycon canaliculatum												
Cingula aculeus								2				
Colus obesa					2							
Crassinella lunulata			1									
Crepidula fornicata		1										
Crepidula plana	3	3		8	14	28	26	2				
Cylichna oryza												
Epitonium humphreysi												
Lacuna vincta	3				2							
Lunatia heros		7										
Lunatia triseriata			1				8	2				
Mitrella dissimilis												1
Mitrella lunata	43	3	7	54	424	154	318	40			1	
Nassarius trivittatus												
Odostomia gibbosa							4					
Odostomis seminuda						2						
Philine lima	2	3	3	9					8			
Skeneopis planorbis				6								
Turbonilla sp.	11	17		14			10					
Urosalpinx cinerea												

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
BIVALVIA												
Astarte undata												
Bivalvia unid.		3				2			2			
Cerastoderma pinnulatum												
Crenella glandula				14								
Cumingia tellinoides							2					
Cyclocardium borealis												
Ensis directus												1
Lyonsia hyalina	2			4					4			1
Macoma balthica	3								1			
Mercenaria mercenaria		1										
Modiolus modiolus							4					
Mulinia lateralis												
Mytilus edulis					1454	490	959	201				
Nucula delphinodonta				2								1
Nucula proxima	1	3	2	5			16	1				1
Petricola pholadiformis												
Pitar morrhuanus												
Solemya velum												
Tellina agilis	2	1	2	4							2	
Thracia conradi												
Yoldia limatula												
AMPHIPODA												
Ampelisca abdita		3	37	2								83
Ampelisca vadorum	1								4	24	57	4
Ampelisca verrilli											16	
Amphithoe longimana						6	10					
Byblis serrata											1	
Caprellidae unid.	30	11	7	6		4		1	20	24		
Corophium acutum		8	25			2			2	4		
Corophium bonelli	2	6	4	4					3			
Dexamine thea		3	2		10	34	10	2				
Elasmopus levis						2						
Erichthonius rubricornis			10	4								

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
Jassa falcata				4	2	16	20					
Lembos websteri	4		18		14	78		4	3	2		
Leptocheirus pinguis	13	22	5	4					10		7	3
Lysianopsis alba	2	1	7				12	20	17	4		
Microdeutopus gryllotalpa								7				
Paraphoxus spinosus	4	12	4					2	30	24		
Photis sp.												
Phoxocephalus holbolli	14	14	2	12					23			
Pleusymtes glaber						4						
Stenothoe minuta						6					3	
Trichophoxus epistomus							2					
Unciola irrorata		6								2	39	66
CRUSTACEA												
Campylaspis rubicunda	1											
Cancer borealis								1				
Cancer irroratus					2			1				
Crangon septemspinosa			1									
Cylindroleberis mariae			1			4						
Cythereis vineyardensis										2		
Edotea triloba												
Erichsonella filiformis	1	1	4	4		2			1	4		
Eudorella pusilla				2								
Heteromysis formosa			18		2			2	1			1
Idotea phosphorea			1			20				8		
Iphinoe trispinosa				2								
Leptochelia savignyi	31	26							79	62		
Libinia dubia	1		2	2								1
Libinia sp.												
Mysidacea unid.		2										
Neopanope sayi		1			6	2	6	5				
Ostracoda unid.			6	52							1	4
Oxyurostylis smithi	11	14	5						1	2		1
Pagurus longicarpus	9	1							6	2		1
Pinnotheres maculatus						2						

	B20-1	B20-2	B30-1	B30-2	C5-1	C5-2	C10-1	C10-2	C20-1	C20-2	C30-1	C30-2
Ptilanthura tenuis		1	1	2								
Pycnogonida unid.			3	2								
Sarsiella sp.	7	3	72	57					3		2	4
Upogebia affinis												
MISCELLANEOUS												
Amphipholis squamata				2	12	4	24	41	1			
Arbacia sp.												
Asterias forbesi												
Cerebratulus sp.												
Cerianthus sp.												
Edwardsia sp.												
Enteropneusta unid.												
Henricia sanguinolenta	1											
Metridium senile						14	88	1				
Nemertea unid.		1	1	2		2						
Phoronida unid.	1											
Sipuncula unid.		1										
Tubulanus pellucidus												

ECOLOGICAL SURVEYS

OF PENNFIELD REEF AND MILFORD HARBOR

Report to

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1.0 INTRODUCTION

The objective of this program was to conduct two ecological surveys of the inshore waters around Pennfield Reef and off Burns Point in Milford Harbor. The purpose of the Pennfield Reef Study was to deliniate the extent of the reef and document the substrate and fauna through diver observations and destructive samples. The Milford study was conducted to provide information on the faunal composition of the area adjacent and inshore of the Burns Point Jetty.

2.0 METHODOLOGY

2.1 PENNFIELD REEF

The Pennfield Reef sampling was conducted on August 30-31 and September 1-2, 1982. Initially, six diver transects were plotted on the coastal chart, beginning at the top of the reef and extending one-half mile outward (Figure 2.1-1). At the site, an initial reconnaissance of the area was conducted and the Motorola Mini-Ranger transponders were positioned: (1) the reef transponder was placed on a tripod at the top of Pennfield Reef; (2) the inshore transponder was attached to Buoy 2A to the north.

Once the transponders were positioned, divers were placed in the water to swim the transects (Table 2.1-1). Information was recorded on bottom type, cover of algae, occurrence of commercial species during each 0.1 nm of the transects (Table 2.1-2). Bottom photographs were taken at selected lcoations to document the divers observations. At two selected hard substrate lcoations on each transect, a 1/16 m^2 (0.0625 m^2) sample was scraped and collected using a diver operated airlift. These samples were designated A & B, with A being the sample closest to the reef (Figure 2.1-1; Table 2.1-1). Samples were placed in jars with 6% formalin for transportation to the laboratory.

TABLE 2.1-1. TRANSPONDER READINGS FOR THE TRANSECT STATIONS.

		TRANSECTS					
		I	II	IV	V	VI	VII
DIRECTION	(**)	210	195	139	103	71	35
Sample A	R	114	318	99	50	35	32
	I	1950	-	1859	1830	1824	1828
	D	6	10	-	5	5	-
Sample B	R	133	329	182	643	40	35
	I	1969	-	-	1517	1813	1825
	D	6	11	-	20	5	-
0-1 nm	R	164	160	182	157	164	160
	I	2001	-	-	1721	1689	1684
	D	5	10	10	-	-	-
0.2 nm	R	296	318	318	324	324	321
	I	2130	-	-	1692	1535	1552
	D	5	10	9	4	17	-
0.3 nm	R	473	483	475	481	489	484
	I	2307	-	1821	1620	1389	1360
	D	3	14	11	4	22	23
0.4 nm	R	617	659	645	631	625	645
	I	2453	-	-	1520	1273	1190
	D	11	15	16	15	23	26
0.5 nm	R	801	804	804	807	805	804
	I	2610	-	-	1452	1127	1032
	D	15	18	30	22	26	-

R = Reef readings from tranponder
I = Inshore readings from transponder
D = Water depth in feet
* = Degrees magnetic

TABLE 2.1-2. DIVER OBSERVATIONS FROM TRANSECTS ON PENNFIELD REEF. RECORDED INFORMATION REFLECTS OBSERVATIONS DURING THE ENTIRE INTERVAL.

TRANSECT I 210°	0 - 500'	500' - 1000'	1000' - 1500'	1500' - 2000'	2000' - 2500'
SUBSTRATE	10% mussels covered with barnacles and algae 90% small rock, cobble with sand matrix	50% cobble with sand 50% sand with few small rocks	90% sand with a few small rocks 10% small rocks with cobble	90% sand 10% cobble covered with barnacles	sand
ALAGE COVER	60% *Laminaria* sp., *Chondrus crispus*, *Ulva lactuca* and *Agardhiella* sp.	~250'-60% *Chondrus*, *Laminaria* sp., *Ulva* and *Agardhiella sp.* last 250'-5% cover on small rocks	0% on sand 90% on small rocks (*same species as* before)	0%	0%
FISH	Several juvenile cunner	Few juvenile cunner and flounders	Several juvenile cunner A few small flounder A school of small Jacks	Few small flounder	1 pipe fish Few small flounder
LOBSTER					
CRABS	1 *Libinia* sp. 1 *Limulus polyphemus* Few *Pagurus* sp.	Few *Pagurus* sp.	1 *Limulus polyphemus* 12 *Pagurus* sp. 1 *Libinia*	26 *Pagurus* sp.	1 *Ovalipes* sp. 21 *Pagurus* sp.
OTHER FAUNA	1 *Mercenaria mercenaria* Few Asteriidae Orange sponge on many of small rocks	Few Asteriidae Small amount of orange sponge	Few Asteriidae Lots of sponges 11 worm tubes (*Chaetopterus* sp.)	10 worm tubes (*Chaetopterus* sp)	7 worm tubes (*Chaetopterus* sp.)
COMMENTS					

(Continued)

TABLE 2.1-2. (Continued)

TRANSECT II 195°	0 - 500'	500' - 1000'	1000' - 1500'	1500' - 2000'	2000' - 2500'
SUBSTRATE	Small rocks, pebble with sand matrix	Sandy (wave rows) small rock, gravel	Cobble, small rock with few boulders Sand with rocks poking through	Patchy sand Gravel, cobble Small boulders	Small boulders in sandy plain
ALGAE COVER	1/2-40% *Laminaria* *Chondrus, Ulva,* Reds some *Fucus* 1/2-10% same	1/3-10% *Laminaria,* *Chondrus, Ulva,* *Fucus*, Reds 1/3-0% 1/3-30% same	3/4-20% same 1/4-100% same	3/4-5% same 1/4-70% same	1/5-70% same 4/5-0% same
FISH	Few flounder Several juvenile cunner	1 flounder Few juvenile flounder	Few juvenile flounder Sculpin?	Several juvenile flounder	Several flounder
LOBSTER					
CRABS	1 *Limulus polyphemus*	Several *Paguarus* sp. 2 *Ovalipes* sp. 1 *Limulus polyphemus* 1 Rock crab		1 *Limulus polyphemus*	1 *Libinia* sp. 1 *Pagurus* sp.
OTHER FAUNA	Ctenophores Several mussels Several barnacles Few Asteriidae Few snails Few ribbed bivalve shells	Few Asteriidae Snails Bivalve shells	Few Asteriidae Few sponges	Few Asteriidae 1 *Lunatia* sp.	Holes? (mud shrimp) Colonials
COMMENTS	Intertidal reef Sandy patch	Reef Real sand Cobble like		Rock Cobble	Sandy plain

(Continued)

TABLE 2.1-2. (Continued)

TRANSECT IV 139°	0 - 500'	500' - 1000'	1000' - 1500'	1500' - 2000'	2000' - 2500'
SUBSTRATE	40% mussels covered with barnacles and algae 60% small rocks, cobble with sand matrix	Small rocks, cobble with sand matrix	10% small rocks, cobble with sand matrix 89% small boulders with sand matrix 1% sand	10% sand, gravel 80% small rocks with sand matrix 10% rocks	Rocks Small boulders Patchy sand, gravel sand
ALGAE COVER	100% *Lamineria* sp., *Chondrus crispus*, *Ulva lactuca*, other Reds	100% same	100% same	80% of this section had 1% cover of algae 20% of section had 100% cover of algae Same	1/2-10% same 2/5-50% 1/10-100%
FISH	3 cunner Several juvenile cunner	1 sea raven 1 cunner Several juvenile cunner	2 flounder several juvenile cunner	Several flounder Several juvenile flounder	Several juvenile flounder
LOBSTER					
CRABS	3 *Limulus polyphemus*	1 *Limulus polyphemus*			2 *Limulus polyphemus*
OTHER FAUNA	Several Asteriidae Orange sponge	Several Asteriidae Yellow and orange sponges	Several Asteriidae Yellow and orange sponges	Barnacles Worm tubes A lot of sponges Coral? Ctenophores Few Asteriidae	Massive sponge Anemone Coral? Worm tubes
COMMENTS				Patchy kelp bed	Small kelp bed Bare rock Ended in sand with small rocks

(Continued)

TABLE 2.1-2. (Continued)

TRANSECT V 103°	0 - 500'	500' - 1000'	1000' - 1500'	1500' - 2000'	2000' - 2500'
SUBSTRATE	Patchy Rock to sandy rock Mixed rock and sand	Gravel Sand	Small rocks with gravel patches	Drop off ~15' Small-large rocks	Bare large boulders Small rock with gravel, sand
ALGAE COVER	1/2-100% *Laminaria, Ulva,* Reds 1/2-50% +10%	(1/2) 0-10% patchy (1/2) *Laminaria, Chondrus, Ulva,* Reds	95% *Laminaria, Ulva, Chondrus,* Reds	1/3-100% *Laminaria, Ulva,* Reds, *Chondrus* 1/3-10% same 1/3-90% same	5% filamentous Reds
FISH	Several flounders juveniles 3 flounders 1 cunner	Several juvenile flounder	Several juvenile flounder	Several juvenile cunner Few flounder	Few flounder Few juvenile cunner
LOBSTER				1 lobster	
CRABS		Few *Limulus polyphemus*	Few *Limulus polyphemus*	Few *Limulus polyphemus*	Few *Limulus polyphemus*
OTHER FAUNA	Few Asteriidae *Mercenaria mercenaria* Red sponge	Razor clam Yellow and orange sponges Worm tubes Few Asteriidae	Ribbed clams Worm tubes Ctenophores Sponge	Soft coral Whirl ectoproct Massive sponge Anemone	Soft coral Sponge Worm tubes
COMMENTS	Lots of barnacles Mussels Shells-oyster, clam	Patchy kelp bed and sandy gravel spots		Drop off to sand	Rise up again to rock surface

(Continued)

TABLE 2.1-2. (Continued)

TRANSECT VI 71°	0 - 500'	500' - 1000'	1000' - 1500'	1500' - 2000'	2000' - 2500'
SUBSTRATE	1/3-mussels, small rocks 2/3-sand with small rocks	Silty sand with small rocks and broken shells	Silty sand with small rocks and broken shells	Silty sand Mud wear end of this section	Mud
ALGAE COVER	1/3-100% *Laminaria*, *Chondrus*, *Ulva*, Reds 2/3-75%	10% same	5% same	0%	0%
FISH	Many juvenile cunner	3 flounder	2 flounder	5 flounder	3 flounder
LOBSTER					
CRABS	Several small *Pagurus* sp.	Several *Pagurus* sp.	1 *Limulus polyphemus* Several *Pagurus* sp.	Few *Pagurus* sp.	Few *Pagurus* sp.
OTHER FAUNA	Several Asteriidae Many mussels Several Ctenophores	Few Asteriidae Many Ctenophores Few clam holes	Few Asteriidae Few clam holes	Few Asteriidae Few clam holes	Several *Mercenaria mercenaria*
COMMENTS	Rock - sand Large rock				

(Continued)

TABLE 2.1-2. (Continued)

TRANSECT VII 35°	0 - 500'	500' - 1000'	1000' - 1500'	1500' - 2000'	2000' - 2500'
SUBSTRATE	1/2-small rock, cobble 1/2 sand	Silty sand, broken shells (oyster)	Fine sand, silt with broken shells	2/3 fine sand, silt 1/3 mud	Mud
ALGAE COVER	1/2-100% *Laminaria, Ulva, Chondrus,* Reds 1/2-25% same	10% same	5% same	0%	0%
FISH	Few flounders Several juvenile cunner	Several juvenile cunner	4 flounder		
LOBSTER				2 lobster	
CRABS		7 *Limulus polyphemus*	4 *Limulus polyphemus* 1 *Pagurus* sp.	1 rock crab Several small *Pagurus*	Few *Pagurus*
OTHER FAUNA	1/2-90% mussels Several clam holes Several Asteriidae 1/2-60% barnacles on mussels	Few Asteriidae Few mussels Few clam holes Few barnacles	Few Asteriidae Few barnacles		Few clam holes Several *merceneria merceneria*
COMMENTS	Cobble, small rock sand			Fine sand Silty mud	

During the diving operation the divers encountered both wave surge and visability problems. They were able to conduct the survey of the six transects but many of the photographs were not clear enough to observe the substrate. The photographs that were clear are included as an attachment to the report.

In addition to the transect observations and destructive samples, 16 grab stations were also visited (Figure 2.1-1; Table 2.1-3). At each of these stations a 0.1 m^2 grab sample was taken, sieved through a 0.5 mm screen and preserved in 6% formalin. At Stations 3G, 4G, 7G, 9G, 11G repeated grabs were attempted. In addition, divers were placed in the water to try and trip the grab manually. In all cases, the substrate was a hard bottom with a veneer of fine sediment and cobbles and there was no penetration at all into this rocky bottom.

2.2 MILFORD HARBOR

Twelve grab samples were taken in the area adjacent to and seaward of Burns Point Jetty on August 25, 1982 (Figure 2.2-1). The substrate at all stations, except 9, was hard-packed fine sand. At Station 9, there was a mixture of cobbles and sand. Stations 10, 11 and 12, designated as part of the work-scope, were intertidal at low tide. These stations, however, were sampled by boat in the same manner as all other stations. Samples were sieved through a 0.5 mm screen preserved in 6% formalin and transported to the laboratory.

2.3 LABORATORY PROCEDURES

All samples collected were transferred to the Piscataqua Marine Laboratory for processing. Samples were logged in according to the laboratory procedure (TPM No. 14). Soft substrate samples were elutriated and then sorted to remove all of the fauna. Animals were

TABLE 2.1-3. TRANSPONDER READINGS FOR THE PENNFIELD GRABS.

	1G	2G	3G	4G	5G	6G	7G	8G	9G	10G	11G	12G	13G	14G	15G	16G
DIRECTION (°*)	240	225	225	205	185	165	139	139	135	135	103	85	53	71	28	35
R	955	805	934	957	810	802	650	815	740	889	815	445	405	812	485	834
I	2652	2634	2736	-	-	-	-	-	-	1998	-	4504	1446	1078	1355	1010
D	14	17	15	22	18	24	15	32	28	35	24	18	19	25	22	25

R = Reef readings from transponder
I = Inshore readings from transponder
D = Water depth in feet
* - Degrees magnetic

identified to the lowest possible taxonomic category and counted; colonial organisms were recorded as present or absent. A dry weight biomass was attained for the fauna of each sample.

The hard substrate samples were very diverse and had extremely high densities. The samples were initially separated into algae and fauna. The enclosed photographs indicate the nature of the samples. The algal fraction of the samples was identified to species, the dominants designated and the biomass attained for the sample.

The fauna was so dense in the hard substrate samples that a splitting technique, approved by Corps Representative Gilbert Chase, was utilized to eliminate some of the extensive counting. Samples were split using a Folsom Plankton Splitter to a size where 30 or more individuals of the dominant taxa were still present. The splitting procedure is outlined in Section VI of the Piscataqua Marine Laboratory TPM No. 14. The organisms are all counted in the initial split; those taxa that exceed 30 individuals are not counted in the next split. Each succeeding split is counted until 30 individuals are counted or until the whole sample is analyzed. The density of taxa that achieve the 30 individual cut off is normalized for the entire sample. Taxa with a density of less than 30 in the whole sample retain the sample raw count.

The colonial taxa were examined from the destructive faunal portion of the sample. In addition, 1/4 of the algal sample was examined for attached colonials. The colonial fauna was recorded as present. Following the processing of the samples, a dry weight biomass was attained for all samples.

The NAI quality assurance program was applied to all phases of this project. The laboratory paperwork is subject to the monthly audit by the company quality assurance staff. Ten percent of all the samples were reanalyzed to check for completeness of sorting, consistency of identification and counting.

3.0 RESULTS

3.1 PENNFIELD REEF

The results of the sample analysis of Pennfield Reef hard-substrate and grab samples is contained in Tables 3.1-1 and 2; the dominant taxa are ranked in Tables 3.1-3 and 4. The numbers of taxa, diversity, and biomass are in Tables 3.1-5 and 6. The algal species and biomass are presented in Table 3.1-7. The data indicate a unique assemblage of taxa on the reef dominated by three amphipods, *Caprella penantis, Jassa falcata* and *Corophium* spp. Two of these taxa *C. penantis* and *J. falcata* are distinctly hard substrate taxa; *Corophium* spp. can be observed in both hard and soft substrate communities. Although the samples are dominated by these three taxa, there is a high diversity of other species, most of which are associated with hard substrates. There are a number of taxa associated with soft substrate, probably as a result of the matrix of sediment surrounding the rocks, boulders and cobbles.

The grabs taken at Pennfield Reef show a mixture of taxa; some stations resemble the reef stations (hard-substrate) while others are dominated by typical soft-substrate dominants like oligochaetes, *Streblospio benedicti* and *Mediomastus* sp. These grabs may provide an indication of soft/hard-substrate community delineation in some areas.

3.2 MILFORD HARBOR

Milford Harbor represents a more typical estuarine habitat. Tables 3.2-1, 2 and 3 provide the data for these stations. The fauna is primarily dominated by polychaetes. *Streblospio benedicti* dominates many of the samples while *Scoloplos* and *Scolecolepides* are also important. Stations 8 and 9 are the most diverse stations. This may result from a more heterogeneous substrate, particularly at Station 9. Biomass

TABLE 3.1-1. NUMBER OF INDIVIDUALS OF EACH TAXA (m^2) FROM PENNFIELD REEF HARD SUBSTRATE STATIONS.

TAXA	STATIONS 1A	1B	2A	2B	4A	4B	5A	5B	6A	6B	7A	7B
Corophium spp.	75,776	36,352	104,448	92,160	274,432	33,824	36,864	8,448	39,936	17,408	52,736	22,016
Jassa falcata	93,184	31,744	59,392	29,184	247,808	102,400	81,920	80	92,160	12,032	36,352	9,984
Caprella penantis	55,296	3,008	84,992	12,800	143,360	208,896	55,808	11,776	114,688	30,080	22,528	14,848
Lacuna vincta	4,096	896	368	128	2,688	1,200	6,528	64	528	480	384	96
Mitrella lunata	1,376	1,216	1,104	432	1,120	576	544	16	1,152	256	436	304
Fabricia sabella	384	80	144	1,056	48							
Polydora ligni	48	32			48	32			16	32	32	112
Ampithoe longimana	336	32	160	16	240	64	608		544	80	224	256
Sabellidae	32		32	32	64			80				16
Eumida sp.	272	48	128	32	400	96	160	48	368	272	176	960
Proceraea sp.	272	32		16	1,504	208	288	32	160	80	64	96
Nereis succinea	1,312	320	1,344	512	2,240	6,016	2,112	256	4,992	1,984	1,888	3,136
Balanus sp.	48	32			48					16		16
Asteriidae	192	32		32	1,136	192	32	560	560	304	176	880
Platyhelminthes	240	16	64		464	96	64				16	112
Mytilidae	368	96	800	912	9,728	31,774	7,808	368	1,936	1,360	560	2,496
Spionidae	16			16								
Molgula sp.	80		32		32				16	64	32	
Petricola phladiformis	160	64			1,488	672	48	816	2,432	1,056	32	1,280
Ampithoe valida	64	16	192	80	560	544	2,136		800	144	368	144
Doridella obscura	80	32	32	16	656	272	32		256	240	176	160
Xanthidae	128	32	16		32	64		80	448	112	16	96
Autolytus sp.	672		16		352	16			96			160
Polydora websteri	336	128				224				48		144
Elasmopus levis	128					32			944	128		208
Dendrodoa sp.	128					32		240	16	16		
Styela sp.	64								16			
Lepidonotus squamatus	80	64	16		128	48	16	96		224		16
Callipallene brevirostris	48				160			16				16
Nudibranchia	144			16	304	16			16	32		112
Paraphoxus sp.	16											
Balanus improvisus	32				16				16		16	16
Harmothoe sp.	48	48							16			
Sabella micropthalmus	16	16				16		416	16	16		
Serpulidae	16											
Rhynchocoela	16		16		80	16						48
Musella planulata	16				16							
Crepidula fornicata	32				16			144				16
Mitrella rosacea	32											
Anachis avara	16											

(Continued)

TABLE 3.1-1. (Continued)

Conopeum sp.	P	P										
Campanularia volubilis	P		P			P	P			P		
Campanularia integra	P	P			P	P	P		P		P	P
Creverillia armata	P	P	P	P	P	P	P		P	P	P	P
Clytia gracilis	P											
Hippothoa hyalina	P			P			P					
Smittinidae	P		P									
Obelia dichotoma	P				P	P	P		P	P	P	
Cryptosula pallasiana	P	P	P	P	P	P	P		P	P	P	P
Polydora sp.		32	160	304	16	48	2,112	16				
Schizoporella unicornis		P	P	P	P		P		P	P	P	P
Halichondria panacea		P				P						
Bowerbankia gracilis		P										
Obelia geniculata		P	P	P	P							P
Alcyondium parasiticum			P	P	P				P	P	P	P
Conopeum tenuissimum			P		P	P			P	P	P	P
Nereis sp.				320	2,112	80	592	256				
Caulleriella sp. D				16								
Pagurus pollicaris					16							
Pagurus longicarpus					32				32		16	16
Cancer irroratus					16	16				16		
Terebellidae					16	16		192		16		112
Micropthalmus sp.					16							
Hirudinea					16				16			
Harmothoe imbricata					16	32	16	16	16	16		16
Doto coronota					16							
Idotea phosphorea					16							
Buccinum sp.					32	16			16			80
Erichsonella filiformis					96		16		112	48		128
Edotea triloba					16							
Xanthidae megalops					240		176					192
Phyllodocidae					16							
Anadara sp.					16							
Crustacean megalops		32				16			320	80	32	
Anenome					32							
Tonicella sp.					16							
Electra pilosa					P							
Erichthonius braziliensis						16			192	32		336
Asterias vulgaris						128		16		64		
Buccinum undatum						16				16		
Coryphella sp.						16						
Ampithoe sp. juv						16			560	16	128	
Botryllus schlosseri						P				P		
Urosalpinx cinera							32					
Pontogenia inermis							16					
Balanus venustus							64			32		16
Ophiopholis aculeata							16					
Microdeutopus gryllotalpa									32	96		496
Anthozoa								16				
Euclymene collaris								16				
Hydroides dianthus								32		96		
Diadema sp.								80				
Holothuroidea								48				
Echinoidea								16		32		

(Continued)

TABLE 3.1-1. (Continued)

Rictaxis punctostriatus	16				
Bugula sp.	P				
Amaroucium sp.	P				
Hiatella sp.		16			
Crepidula plana		16			
Crepidula sp.		16			
Erichthonius sp.		96	16		
Gastropoda			16		
Bittium alternatum			16		
Neopanope sayi			16		
Paracaprella pusilla			80		80
Sabrellaria vulgaris			48		
Diopatra sp.			32		
Microporella ciliata			P		P
Hydractina sp.			P		
Mycale linguia			P		
Polydora colonia			32		
Syllidae				16	
Heteromysis formosa					16
Jaera marina					16
Anomia sp.					16
Calliopius laevicus					48
Potamilla reniformis					16
Olostomia dealbata					16
Amphitrite sp.					32
Campanularidae					P
Alcyondium sp.					P
Isodictya deichmanne					

TABLE 3.1-2. NUMBER OF INDIVIDUALS OF EACH TAXA (m^2) FROM PENNFIELD REEF GRAB SAMPLES.

	STATIONS										
TAXA	1G	2G	5G	6G	8G	10G	12G	13G	14G	15G	16G
Balanus crenatus	20										
Cryptosula pallasiana	P		P	P				P	P		
Glycera dibianchiata	10			10	10			30	50		
Oligochaeta	190			90	30	190				20	20
Libinia larvae	10										
Tellina agilis	20	10	40	50	40	40	60	100	40	90	
Caprella penantis	80		20		80			30			
Corophium insidiosum	40	20			10						
Jassa falcata	50			30							
Elosmopus levis	10										
Nereis succinea	10		70							90	
Streblospio benedicti		60		10	30	180	260	190	10	310	
Pinnixa zoea		10									
Cirratulidae		20		50			10	10		50	
Rithropanopeus harrisi zoea		40	20								
Corophium sp.			10	10			20				
Spiophanes bombyx		20	250	20	10		80	150		160	
Mediomastus sp.		260		20	10	40	110	400		370	
Caprella sp.		10	30	10				10			
Crangon septemspinosa		10	10								
Caullierella sp. D		10			20						
Conopeum tenuissimum			P	P	P			P		P	
Obelia dichotoma			P								
Aeverillia armata			P	P	P	P	P		P	P	
Conopeum sp.			P								
Conopeum reticulum			P								
Asterias sp.			20								
Bowerbankia gracilis			P	P							
Hydroides dianthus			10								
Schizoporella unicornis			P								
Lofoea sp.			P								
Pagurus juv.			20						20		10
Sabella micropthalmus			20								
Alcyondium sp.			P								
Polydora sp.			30								
Polydora ligni			10			90		10		20	
Nassarius trivittatus			30		10	10	30	40		20	
Mitrella lunata			30								
Phyllodocidae juv			40								
Phyllodoce sp.			10					10			
Nephtys picta			10								
Leptognatha caeca			30								
Rhynchocoela			30					10		40	
Phoxocephalidae			30								
Amphipoda juv			10			50	30	10			
Paracaprella tenuis			260								
Terebellidae			10								
Turbellaria			60								
Mytilidae spat			10			10	10	10	10		10
Proceraea sp.			10	10							
Chaetopteridae			10							10	
Lyonsia sp.			10					40			
Petricola phladiformis			30				10			20	
Pandora sp.			10								
Asteriidae				20	10	10		30		40	
Nereis sp.				20				10		130	
Lumbrineris fragilis				10		10					
Micropthalmus sp.				20							
Eumida sp.				90							
Eteone heteropoda				20							
Eteone sp.				20							
Nephtyidae juv				10				20			
Ampharete sp.				10							
Cancer irroratus				10				10			
Ampithoe sp.				10							
Paraphoxus spinosus				20							
Erichsonella filiformis				10							
Unciola sp.				10				10			

(Continued)

TABLE 3.1-2. (Continued)

	1G	2G	5G	6G	8G	10G	12G	13G	14G	15G	16G
Sertularia cupressina				P							
Botryllus schlosseri				P							
Hipothoa hyalina				P							
Cribulina punctata				P							
Harmothoe imbricata				10							
Ampelisca sp.					10						
Lunatia triseriata					10						
Fagurus longicarpus					10					30	
Microdeutopus sp.					10						
Alcyondium parastiticum					P						
Balanus sp.						20				70	
Ensis directus						10	10				
Cossura soyeri						10					
Micropthalmus aberrans						10					
Phyllodoce mucosa						10	20	60		40	
Zanthidae juv						10					
Sabellaria vulgaris						70				1900	
Nucula proxima						30					
Turtonia minuta						10					
Mulinia lateralis							10	20	940	20	580
Nicolea sp.							10				
Caulleriella sp. B							20	50		60	
Crepidula fornicata								10			
Turbonilla sp.								10			
Pectinariidae								10			
Nematoda								1060			
Clymonella torquata								10		10	
Scoloplos robustus								10			
Chaetozone sp.								10			
Goniadidae juv								10			
Nephtys caeca								10			
Gemma gemma								10			
Ostracoda								P			
Acteocina canaliculata									450		140
Yoldia sp.									50		30
Nucula sp.									10		
Cylichna oryza									10		
Semibalanus balanoides									10		
Nephtys incisa									10		
Sertularia robusta									P		
Hydractinia sp.										P	
Balanus improvius										220	
Cliona lobata										P	
Archiannelida										30	
Polydora websteri										60	
Eumida sanguinea										180	
Unciola irrorata										10	
Unciola dissimils										10	
Unciola serrata										20	
Crepidula juv										10	
Doridella obscura										20	
Bivalvia juv										30	
Turbonilla interrupta										10	
Lyonsia hyalina										30	
Sthenelais limicola										10	
Yoldia limatula											10
Rictaxis punctostriatus											30

TABLE 3.1-3. THE DOMINANT TAXA IN EACH PENNFIELD REEF HARD-SUBSTRATE SAMPLE. PERCENT COMPOSITION AND RANK ( ).

TAXA	STATIONS 1A	1B	2A	2B	4A	4B	5A	5B	6A	6B	7A	7B
Jassa falcata	39.5 (1)	42.7 (2)	23.4 (3)	21.1 (2)	35.8 (2)	14.9 (3)	40.2 (1)		15.2 (3)	17.7 (3)	31.3 (2)	16.8 (3)
Corophium spp.	32.1 (2)	48.8 (1)	41.2 (1)	66.7 (1)	39.6 (1)	48.5 (1)	18.1 (3)	27.9 (2)	34.9 (2)	25.6 (2)	45.3 (1)	37.0 (1)
Caprella penantis	23.5 (3)	4.0 (3)	33.5 (2)	9.3 (3)	20.7 (3)	30.3 (2)	27.4 (2)	38.9 (1)	43.5 (1)	44.2 (1)	19.3 (3)	24.9 (2)
Lacuna vincta	1.7 (4)	1.2 (5)	0.1 (7)	0.1 (9)	0.4 (5)	0.2 (6)	3.2 (5)			0.7 (7)	0.3 (7)	
Mitrella lunata	0.5 (5)	1.6 (4)	0.4 (5)	0.3 (7)		<0.1 (3)	0.3 (10)		0.4 (7)	0.4 (10)	0.4 (6)	
Nereis succinea	0.5 (6)	0.4 (6)	0.5 (4)	0.3 (6)	0.3 (6)	0.9 (5)	1.0 (7)	0.8 (7)	1.9 (4)	2.9 (4)	1.6 (4)	5.3 (4)
Autolytus sp.	0.2 (7)											
Fabricia sabella	0.2 (8)	<0.1 (9)	<0.1 (10)	0.7 (4)								
Mytilidae	0.2 (9)	<0.1 (8)	0.3 (6)	0.6 (5)	1.4 (4)	4.6 (4)	3.8 (4)	1.2 (6)	0.7 (6)	2.0 (5)	0.5 (5)	4.2 (5)
Polydora websteri	0.1 (10)	0.2 (7)										
Ampithoe longimana	0.1 (10)		<0.1 (9)				0.3 (8)				0.2 (9)	
Lepidonotus squamatus			<0.1 (10)									
Polydora sp.			<0.1 (9)	0.2 (9)			1.0 (7)					
Ampithoe valida			<0.1 (8)	<0.1 (10)		<0.1 (9)	1.0 (6)		0.3 (9)		0.3 (8)	

(continued)

TABLE 3.1-3. (Continued)

	1A	1B	2A	2B	4A	4B	5A	5B	6A	6B	7A	7B
Nereis sp.				0.2 (8)			0.3 (9)	0.8 (7)				
Petricola phladiformis					0.2 (9)	0.1 (7)		2.7 (3)	0.9 (5)	1.6 (6)		2.1 (6)
Proceraea sp.					0.2 (8)							
Caulleriella sp. B					0.3 (7)							
Asteridae					0.1 (10)			1.8 (4)	0.2 (10)	0.4 (8)	0.2 (10)	1.4 (8)
Doridella obscura						<0.1 (10)					0.2 (10)	
Sabella micropthalmus								1.4 (5)				
Dendrodoa sp.								0.8 (8)				
Terebellidae								0.6 (9)				
Crepidula fornicata								0.5 (10)				
Elasmopus levis									0.4 (8)			
Ampithoe juv									0.2 (10)			
Eumida sp.										0.4 (9)	0.2 (10)	1.6 (7)
Microdeutopus gryllotalpa												0.8 (9)
Erichtharius braziliensis												0.6 (10)

TABLE 3.1-4. THE DOMINANT TAXA IN EACH PENNFIELD REEF GRAB SAMPLE. PERCENT COMPOSITION AND RANK ( ).

TAXA	1G	2G	5G	6G	8G	10G	12G	13G	14G	15G	16G
Oligochaeta	43.2 (1)			15.0 (1)	8.8 (3)	23.4 (1)		1.2 (8)	3.1 (3)		2.3 (4)
Caprella penantis	18.2 (2)				23.5 (1)			1.2 (8)			
Jassa falcata	11.4 (3)			5.0 (3)							
Corophium insidiosum	9.1 (4)	4.3 (4)									
Tellina agilis	4.5 (5)	2.1 (5)	3.4 (5)	8.3 (2)	11.8 (2)	4.9 (6)	8.6 (4)		2.5 (4)	2.2 (8)	
Balanus crenatus	4.5 (5)										
Elasmopus levis	2.3 (6)										
Nereis succinea	2.3 (6)		5.8 (3)								
Glycera dibranchiata	2.3 (6)										
Libinia larvae	2.3 (6)										
Mediomastus sp.		55.3 (1)		3.3 (4)		4.9 (6)	15.9 (6)	16.5 (2)		8.9 (2)	
Streblospio benedicti		12.8 (2)			8.8 (3)	22.2 (2)	37.7 (1)	7.9 (3)		7.5 (3)	
Rhithropanopeus harrisi zoea		8.5 (3)									
Cirratulidae		4.3 (4)		8.3 (2)							
Spiophanes bombyx		4.3 (4)	21.0 (2)	3.3 (4)			11.6 (3)	6.2 (4)		3.8 (6)	
Pinnixa zoea		2.1 (5)									
Caprella sp.		2.1 (5)	2.5 (6)								

TABLE 3.1-4. (Continued)

	1G	2G	5G	6G	8G	10G	12G	13G	14G	15G	16G
Crangon septemspinosa		2.1 (5)									
Caulleriella sp. D		2.1 (5)			5.9 (4)						
Paracaprella tenuis		21.8 (1)									
Polydora sp.		2.5 (6)									
Nassarius trivittatus		2.5 (6)				4.3 (5)	1.7 (7)				
Phyllodoce sp.		3.4 (5)									
Leptognathia caeca		2.5 (6)									
Rhynchocoela		2.5 (6)									
Phoxocephalidae		2.5 (6)									
Turbellaria		5.0 (4)									
Petricola phladiformis		2.5 (6)									
Eumida sp.				15.0 (1)							
Asteriidae				3.3 (4)			1.2 (8)				
Nereis sp.				3.3 (4)					3.1 (7)		
Micropthalmus sp.				3.3 (4)							
Eteone sp.				3.3 (4)							
Eteone heteropoda				3.3 (4)							
Ampithoe sp.				3.3 (4)							
Polydora ligni						11.1 (3)					

TABLE 3.1-4. (Continued)

	1G	2G	5G	6G	8G	10G	12G	13G	14G	15G	16G
Sabellaria vulgaris						8.6 (4)				45.7 (1)	
Amphipoda juv						6.2 (5)	4.3 (5)				
Nucula proxima						3.7 (7)					
Balanus juv						2.5 (8)				1.6 (9)	
Phyllodoa mucosa							2.8 (6)	2.5 (5)			
Caulleriella sp. B							2.8 (6)	2.1 (6)			
Corophium sp.							2.8 (6)				
Nematoda								43.9 (1)			
Lyonsia sp.								1.7 (7)			
Mulinia lateralis									58.3 (1)		67.4 (1)
Acteocina canaliculata									28.0 (2)		16.2 (2)
Yoldia sp.									3.1 (3)		3.5 (3)
Pagurus larvae									1.2 (5)		
Balanus improvius										5.3 (4)	
Eumida sanguinea										4.3 (5)	
Polydora websteri										1.4 (10)	
Cylichna oryza											3.5 (3)
Rictaxis punctostriatus											3.5 (3)

TABLE 3.1-5. NUMBER OF TAXA AND INDIVIDUALS, DIVERSITY AND BIOMASS AT THE PENNFIELD REEF HARD SUBSTRATE STATIONS.

	STATIONS											
PENNFIELD HARD SUBSTRATE	1A	1B	2A	2B	4A	4B	5A	5B	6A	6B	7A	7B
No. of Taxa	49	33	28	27	57	48	33	34	47	54	33	59
No. of Individuals (per m^2)	235,680	74,400	253,486	138,080	691,920	687,728	203,600	30,272	263,568	68,048	116,404	59,536
Margalefs' H	0.579	0.461	0.512	0.423	-	-	0.679	0.715	0.578	0.688	0.468	0.817
Evenness J	0.361	0.332	0.394	0.320	-	-	0.485	0.481	0.379	0.215	0.338	0.491
Shannon-Weaver H'	0.581	0.465	0.513	0.425	0.529	0.520	0.681	0.728	0.585	0.696	0.473	0.827
Evenness J'	0.362	0.332	0.394	0.321	0.316	0.312	0.487	0.483	0.378	0.424	0.338	0.492
Faunal Biomass (gm)	6.82	2.03	1.92	1.23	7.66	4.77	0.76	1.76	16.92	63.27	2.56	1.00
Algal Biomass (gms)	62.23	46.05	23.34	13.15	51.21	29.09	31.23	0.14	33.20	17.46	21.64	15.00

TABLE 3.1-6. NUMBERS OF SPECIES, INDIVIDUALS AND DIVERSITY OF EACH SAMPLE FROM PENNFIELD REEF.

AREA	STATIONS										
Pennfield Grab Samples	1	2	5	6	8	10	12	13	14	15	16
No. of Taxa	11	11	45	33	20	20	16	36	15	39	9
No. of Individuals (per m^2)	440	470	1190	560	340	810	690	2410	1610	4150	860
Margalefs H	0.652	0.589	1.084	1.021	0.878	0.897	0.784	0.857	0.490	0.932	0.447
Evenness J	0.758	0.657	0.656	0.764	0.895	0.798	0.551	0.608	0.482	0.639	0.510
Shannon-Weaver H'	0.766	0.700	1.240	1.231	1.104	1.022	0.900	0.933	0.531	0.987	0.502
Evenness J'	0.766	0.673	0.802	0.892	0.897	.798	0.765	0.614	0.492	0.644	0.525
Faunal Biomass (gm)	0.01	0.01	0.32	0.26	0.20	3.53	0.78	0.28	0.11	0.73	0.06

TABLE 3.1-7. ALGAL SPECIES DISTRIBUTION FROM THE PENNFIELD REEF HARD SUBSTRATE STATIONS.

TAXA	STATIONS 1A	1B	2A	2B	4A	4B	5A	5B	6A	6B	7A	7B
Chondrus crispus	P*	P*	P*	P*	P*	P*	P*		P*	P*	P*	P*
Laminaria saccharina	P*	P*	P*	P*		P*				P*	P*	P*
Soliera tenera	P	P	P	P	P	P*	P	P*	P	P*	P	P
Ulva lactuca	P	P	P	P	P	P*	P*	P	P*	P*	P	P
Sargassum filipendula			P									
Polysiphonia harveyi	P	P	P	P	P	P	P	P	P	P	P	P
Ceramium rubrum	P	P	P	P	P	P	P	P	P	P	P	P
Ahnfeltia plicata		P	P	P								P
Phyllophora truncata				P								
Phyllophora pseudoceranoides				P				P				
Gracilaria tirvahiea	P		P	P	P		P		P			P
Grinnellia americana	P		P					P	P	P	P	P
Dasya baileviana										P	P	P
Ectocarpus siliculosus	P	P	P	P		P	P			P	P	
Callithamnion tetragonium	P	P	P	P		P		P				
Enteromorpha flexuosa spp. *paradoxa*	P	P	P	P	P	P	P		P	P	P	P
Polysiphonia nigra	P	P									P	
Polysiphonia nigrescens						P			P			
Antithamnion sp.	P											
Colaconema sp.		P										
Polysiphonia urceolata	P	P		P				P				
Bryopsis plumosa			P	P		P					P	P
No. of Taxa	14	13	14	15	7	11	8	8	9	10	12	12
Biomass (gm)	62.23	46.05	26.34	13.15	51.21	29.09	31.23	0.14	33.20	17.46	21.64	15.00

*Dominant taxa

TABLE 3.2-1. NUMBER OF INDIVIDUALS OF EACH TAXA (m^2) FROM MILFORD HARBOR STATION.

TAXA	STATION 1	2	3	4	5	6	7	8	9	10	11	12
Streblospio benedicti	113		3232	3289	57	57	661	13,230	737	208	302	19
Nephtyidae juv	19											
Scoloplos juv	19	38			132	170	57			208		302
Eteone heteropoda	38	57	38	19			19	132	19	95	19	95
Caulleriella sp.	38											
Spionidae juv	19	227	1058	1323	151		226	57	57	19		266
Spio sp.	19											
Scolecolepides viridis	19	139	624	926								284
Rhynchocoela		19			38	57	19			19		
Oligochaeta		38	19						208			57
Nereis sp. juv		19	38					38	435			38
Eteone sp.		19	19	57				76	76		19	38
Illyanassa obsoleta		57	642	19		38				57	151	19
Cirratulidae		19	57	189			19	19	378			
Glycera sp.		57		113		19	57	57	57	19	19	57
Gemma gemma		152	57	794				208		57		189
Crepidula fornicata		19							76			
Polydora ligni			38	38				38				
Pectinaria sp.			19	38		19		454			19	38
Oligo chaeta			19	113				1266	340			
Mya arenaria			38					38				
Mediomastus sp.			95	492			19	1021	113			
Caulleriella sp. B			95	38								
Glycera americana			19		19	19	19	19	19	19		
Tellina agilis			19			57		737				19
Pagurus sp.			19	19					38			
Phyllodoce mucosa				38								
Polydora sp.				19				170	1625			
Crisia eburnea				P								
Aeverrillia armata				P				P				
Alcyonidium parasiticum					P			P	P			
Spiophanes bombyx					19	75	38					
Scolelepis sp.					170	264	38			19		
Caulleriella sp. D					19		19		19			
Ostracoda					P			P				P
Nephtys caeca						19						
Limulus polyphemus						19						
Scoloplos robustus							19	19				151
Phyllodoce sp.								57	208			
Capitella capitata								2646				
Modiolus sp.								19				
Balanus sp.								1266	113			
Mytilidae spat								95				
Asteriidae								19	95			
Phyllodocidae								38				
Mulinia lateralis								19				
Pectinaria gouldii								19				
Nereis succinea								19	132			
Balanus improvius								4612	38			
Turbellaria								38	95			
Ampelisca sp.								454	38	19		
Ensis directus								19				
Corophium sp.								76	170			
Edotea montosa								19				
Neomysis americana								19				
Jassa falcata								19				
Melita nitida								38	529			
Conopeum tenuissimum								P	P			
Obelia dichotoma								P	P			
Cryptosula pallasiana								P	P			
Cancer irroratus									19			
Doridella obscura									359			
Crepidula plana									95			
Sthenelais sp.									57			
Fabricia sabella									359			
Lepidontus squamatus									95			
Eumida sp.									756			
Botryllus schlosseri									P			
Dendrobenia murrayana									P			

(Continued)

TABLE 3.2-1. (Continued)

	STATIONS											
	1	2	3	4	5	6	7	8	9	10	11	12
Lafoeidae									P			
Bowerbankia gracilis									P			
Pagurus longicarpus									19			
Unciola serrata									132			
Unciola sp.									151			
Corophium insidiosum									95			
Obelia geniculata									P			
Campanularidae									P			
Ovalipes ocelatus											19	
Crangon septemspinosa											19	
Conopeum reticulum												P
Pontogenia inermis												19
Uca megalops												19

TABLE 3.2-2. NUMBER OF SPECIES, INDIVIDUALS AND DIVERSITY OF EACH SAMPLE FROM MILFORD HARBOR.

AREA	STATIONS											
Milford Harbor	1	2	3	4	5	6	7	8	9	10	11	12
No. of Taxa	8	13	19	19	10	12	13	43	48	11	8	18
No. of Individuals (per m^2)	284	851	6199	7522	624	775	1210	24872	7711	832	567	1607
Margalef's H	0.577	0.803	0.672	0.736	0.666	0.762	0.598	0.737	1.21	0.679	0.483	0.922
Evenness J	0.865	0.854	0.540	0.340	0.595	0.841	0.609	0.480	0.564	0.761	0.642	0.604
Shannon-Weaver H'	0.784	0.951	0.709	0.765	.798	0.909	0.696	.756	1.280	0.800	0.594	1.031
Evenness J'	0.868	0.853	0.544	0.622	.836	0.842	0.624	.482	0.810	0.769	0.658	0.856
Faunal Biomass (gm)	0.01	0.81	20.59	0.83	0.01	0.25	0.03	1.81	0.83	1.07	4.35	1.18

TABLE 3.2-3. THE DOMINANT TAXA IN EACH MILFORD HARBOR SAMPLE. COMPETITION AND RANK ( ).

TAXA	STATION 1	2	3	4	5	6	7	8	9	10	11	12
Streblospio benedicti	40 (1)		52 (1)	44 (1)	9 (4)	7 (4)	55 (1)	53 (1)	10 (3)	25 (1)	53 (1)	
Eteone heteropoda	13 (2)	7 (4)						<1 (8)		11 (2)	3 (3)	6 (6)
Caulleriella sp.	13 (2)											
Nephtyidae juv.	7 (3)											
Scoloplos juv.	7 (3)	4 (5)			21 (3)	22 (2)	5 (3)			25 (1)		19 (1)
Spionidae juv.	7 (3)	27 (1)	17 (2)	18 (2)	24 (2)		19 (2)			2 (4)		17 (3)
Spio juv.	7 (3)											
Scolecoledipes viridis	7 (3)	16 (3)	10 (4)	12 (3)								18 (2)
Gemma gemma												
Illyanassa obsoleta		7 (4)	10 (3)			5 (5)				7 (3)	26 (2)	
Glycera sp.		7 (4)		2 (7)			5 (3)			2 (4)	3 (3)	4 (7)
Nematoda		4 (5)							3 (9)			4 (7)
Mediomastus sp.			2 (5)	7 (5)				4 (3)				
Caulleriella sp. B			2 (5)	3 (6)								
Cirratulidae			1 (6)						5 (6)			
Gemma gemma		18 (2)	1 (6)	11 (4)				1 (6)		7 (3)		(12) (4)
Oligochaeta				2 (7)				5 (2)	4 (8)			
Eteone sp.				1 (8)								2 (8)
Scolelpis sp.					27 (1)	34 (1)	3 (4)			2 (4)	3 (3)	
Rhynchocoela					6 (5)	7 (4)				2 (4)		
Glycera americana					3 (6)					2 (4)		
Spiophanes bombyx					3 (6)	10 (3)	3 (4)					
Caulleriella sp. D					3 (6)							
Tellina agilis						7 (4)		3 (4)				
Pectinaria sp.								2 (5)			3 (3)	2 (8)
Polydora sp.								1 (7)	21 (1)			
Melita nitida									7 (4)			
Eumida sp.									10 (2)			

(Continued)

TABLE 3.2-3. (Continued)

	STATION											
	1	2	3	4	5	6	7	8	9	10	11	12
Doridella obscura									4 (7)			
Fabricia sabella									4 (7)			
Nereis sp. juv									6 (5)			2 (8)
Phyllodoce sp.									3 (9)			
Ovalipes ocelatus											3 (3)	
Crangon septemspinosa											3 (3)	
Scoloplos robustus												9 (5)

is generally low, except at stations where *Ilyanassa obsoletus* is important.

3.3 GENERAL OBSERVATIONS

The area around Pennfield Reef is extremely productive and supports a diverse fauna. Faunal densities for the Pennfield samples were generally higher than other north temperate hard substrate communities we are familiar with. This data provides no temporal information so densities at other periods are unknown. One of the major dominant amphipods, *Jassa falcata*, is known to have multiple generations and other amphipods are suspected to have similar recruitment patterns; thus, densities may remain high throughout most of the year. However, only a seasonal program could verify this information.

Diver observations indicate the presence of numerous epibenthic organisms and fish, further indicating the richness of the area. A trapping and tagging program would certainly provide more definite information on epibenthic crustacea.

The diversity indices provided in this study should be used with caution. Margalef's (1958) or Brillouin's (1962) index are appropriate measures when a sample represents an entire collection. In the case of Pennfield Reef and Milford Harbor and most marine studies when only the diversity of a large community is being estimated (statistical sample), Shannon-Weaver's H' is a more appropriate measure. For a more definitive explanation see Pielou (1975).

4.0 LITERATURE CITED

Brillouin, L. 1962. Science & Information Theory. 2nd ed. Academic Press. New York.

Margalef, D.R. 1958. Information Theory in Ecology. Gen Syst. 3:36-71.

Pielou, E.C. 1975. Ecological Diversity. Wiley-Interscience. New York.

ANALYSIS AND SITE EVALUATION

FOR

LONG ISLAND SOUND

CONTAINER DISPOSAL SITES
Black Ledge, Penfield Reef and Sherwood Borrow Pit

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EXECUTIVE SUMMARY

The primary objective of this study is to provide a preliminary analysis of the physical, chemical, and biological impacts of dredged material containment at three sites in Long Island Sound: Black Ledge, Penfield Reef, and Sherwood Borrow Pits. At the two former sites, a dredged material containment facility (DMCF) would be constructed. At Sherwood Borrow Pits, dredged material would be disposed of in the existing excavations. The study includes a description of the existing physical and biological characteristics of the three sites based on a review of previous investigations, data collected from biological field surveys, and computer modeling of local wave propagation effects. Environmental impacts resulting from the proposed containment strategy at each site are assessed in accordance with EPA 404 guidelines.

Impact on the physical environment is most significant at the Black Ledge site. In this case, the structure will provide a sheltering effect from storm waves over a large portion of Pine Island Channel and a section of the Groton shoreline centered on Avery Point. This contrasts with the focusing of wave energy in these areas by the Ledge under existing conditions. At Penfield Reef, the physical impact will be limited to the prevention of overwash to the north side of the Reef in the area fronting Fairfield Beach. Alongshore sediment transport will not be impacted with the presently proposed lay-out of the containment structure. The wave field will not be impacted by the filling and capping of the Sherwood Borrow Pits; the model results

suggest that a coarse sand will be stable as a cap material under moderate storm conditions.

The biological characteristics of the three sites are summarized in Table A-1. The information can be used to provide a qualitative assessment of habitat value. Black Ledge and Penfield Reef support rich and diverse hard bottom communities and provide habitat for larger invertebrates (e.g., lobsters) and many fish species. Areas adjacent to Penfield Reef support extensive shellfish beds. The Borrow Pits are not characterized by hard bottom areas. However, the pits are adjacent to shellfish bed and fishing (e.g., winter flounder) areas. In addition, the pits are heavily fished at certain times of the year for lobsters.

The impacts of the proposed DMCF to marine life can be divided among three categories: destruction of natural habitat, impacts related to changes in the sedimentary environment of adjacent areas, and construction related impacts. These three categories of impacts are summarized in Table A-2 for each of the three sites. There are no threatened or endangered species at any of the sites and thus, no impacts of this kind are expected. Of the three sites, the greatest potential for impacts on wildlife exists at Penfield Reef. The reef is utilized by waterfowl such as black ducks and scaup and provides feeding and resting habitat for a variety of seabirds and shorebirds.

Table A-1. Synopsis of Biological Conditions

Area	Physical Habitat	Abundance of Benthic Macrofauna	Number of Benthic Taxa Reported	General Formation On Shellfish/Fishery Resources	Other Comments
Black Ledge	Rock shoal with water depth of 10-30 feet	~9,907/m^2 on the shoal 6,373 - 36,350/m^2 on gravel to silt habitats	140 (soft bottom) 184 (hard and soft bottom)	Mussels dominate hard bottom areas; rocky areas are expected to provide food and habitat for larger invertebrates and fish.	Four benthic community types are present
Penfield Reef	Comprised of eroded remnants of an offshore island and tombolo	Up to 235,000/m^2 on hard bottom areas 1230/m^2 - 5516/m^2 were average densities for soft bottom areas	122 (hard bottom) 112-125 (soft bottom)	Support large population of blue mussels; large natural bed of oysters and hard clams extends east from reef. Shellfish beds located north and west; rocky habitat supports lobsters and many fish species.	Extremely rich hard bottom communities
Sherwood Island Borrow Pit Site	Sandy habitat with excavations Burrow) Pits)	4,000-5,000/m^2 in pit (July 1982); 4,096-10,500/m^2 in study area overall (Sept., July, 1983). Densities in pit were low where malodorous samples were obtained	49	Area is occassionally fished heavily for lobsters located near clam and oyster beds; adjacent sport fishery for winter flounder and pelagic species.	Pits occassionally become anaerobic

Table A-2. Preliminary Analysis of Impacts

Area	Destruction of Natural Habitat	Alterations of Sediments in Adjacent Areas	Construction-Related Impacts
Black Ledge	The DMCF will affect most of the rocky area and a larger area of bottom consisting primarily of sand and gravel. Thus, most of the hard-bottom community will be eliminated. The impact will be mitigated somewhat through availability of habitat created by the structure itself.	Reductions of wave energy are expected in the "shadow" of the structure. Increases in the fraction of sandy sediments are anticipated. Thus, some of the sand and gravel community eliminated south of the ledge might be returned in areas north of ledge.	Temporary increases in turbidity and dissolved nutrients are expected. Decreases in dissolved oxygen levels are possible. Such disturbances would be local and short-term.
Penfield Reef	Construction of a DMCF would cause direct impacts that would be regarded as severe. Impacts would be mitigated to some extent through provision of new hard substrate by the DMCF structure.	Presence of DMCF will enhance deposition of fine sediments north of the structure leading to a greater preponderance of deposit-feeding forms.	Same as above
Sherwood Borrow Pits	Filling in and capping the pits would not destroy an ecologically significant bottom area. A net improvement in bottom area would be anticipated.	No changes in sediment characteristics of adjacent areas are expected.	Same as above

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1. INTRODUCTION

1.1 GENERAL INTRODUCTION

The Long Island Sound Dredged Material Containment Study is being conducted by the U.S. Army Corps of Engineers, New England Division, to determine the feasibility of nearshore containment facilities for the disposal of dredged materials originating in the Long Island Sound area. Previous phases of this study (see COE, 1983) have screened a number of candidate sites for dredged material containment facilities (DMCF), and produced detailed environmental information about some of these sites, including the Black Ledge and Penfield Reef sites. The objectives of the present study are to augment the environmental baseline data available for Black Ledge and Penfield Reef, to generate similar data for the Sherwood Island Borrow Pit site and, with this information, to provide a preliminary evaluation of the potential impacts of proposed containment facilities on the physical, chemical, and biological characteristics of the aquatic ecosystem at each site in accordance with EPA's 404 procedures and guidelines (Federal Register, 24 December 1980).

This report is organized in five sections. Sections 2, 3, and 4 consider existing conditions and potential impacts of containment facilities at each of the three study sites: Black Ledge, Penfield Reef, and Sherwood Island Borrow Pit, respectively. References are listed in Section 5. Three appendices conclude the report. The first, Appendix A, includes detailed information on certain aspects of the wave modeling methodology used in the report which are not as yet available in the coastal

engineering literature. Appendix B presents station location data for the biological surveys, while Appendix C presents the biological data collected as well as the sample collection and processing methodology.

1.2 INTRODUCTION TO WAVE MODELING EFFORT

1.2.1 Wave Modeling Methodologies

The investigation of wave effects produced by the proposed containment structures is based on two numerical models recently developed at the University of Delaware. The first of these (Kirby and Dalrymple, 1982) predicts the effects of wave refraction, shoaling, and energy dissipation due to bottom friction and percolation. This model is appropriately applied in cases where the bottom topography is gradually varied and the direction of wave propagation remains approximately normal to the depth contours. The refractive effect of a spatially varied current system can also be analyzed. The model formulation is based on a finite difference representation of the time- and depth-averaged energy equation for linear, small-amplitude waves combined with an expression for the "conservation of waves" (Phillips, 1966). The numerical scheme used to solve the resulting equations for wave height, length and direction is identical to that presented by Noda et al. (1974). The full capability of the model extends to the problem of wave-current interaction and the prediction of wave-induced nearshore circulation (e.g., rip currents). In the present study, this capability is not exploited in view of the primary emphasis on wave as opposed to current characteristics. The approach offered by this model to the general refraction problem provides a fundamental improvement over the conventional ray-tracing methodology.

The second model (Kirby and Dalrymple, 1983) is a combined refraction-diffraction analysis applicable to nearshore sites with irregular bottom topography or where strong wave focusing or sheltering effects are present. The mathematical basis for this model was initially outlined by Berkhoff (1972) and later

extended by Radder (1979). The model formulation of Kirby and Dalrymple provides a capability to apply the refraction-diffraction analysis to practical coastal engineering problems involving large areas of complex topography. It is important to note that this and other related models have appeared in the literature only within the past year. The numerical methods involved are undergoing rapid development and the validity of the results reported to date has been confirmed primarily by comparisons with data from wave tank experiments. Applications to realistic design problems remain limited.

The refraction-diffraction model is utilized in this report to investigate wave characteristics for the Black Ledge site where the bottom topography consists of a roughly circular, submerged shoal. Several experimental data sets are available for this type of topography and the problem of predicting the measured wave height variations has been the specific focus of recent efforts to verify the refraction-diffraction modeling methodology. Consistently close agreement has been obtained between model predictions and experimental results by several investigators, including Kirby and Dalrymple. In addition, it has been shown in these cases that the model predictions are substantially superior to results obtained by means of conventional ray-tracing techniques. Moreover, the conventional results are likely to indicate unrealistic distortions of the wave field which are fundamentally misleading (e.g., ray intersection points or caustics). Consequently, the use of the refraction-diffraction model offers a means of analyzing the Black Ledge site where there is no suitable alternative method available aside from physical model testing. This approach is obviously beyond the scope and resources of the present study. The relative lack of prior design experience with the model is compensated by an encouraging degree of experimental verification

and a sound theoretical basis for the case being considered which is lacking in other conventional methods of analysis.

1.2.2 Wave Climatology for Long Island Sound

Comprehensive field measurements sufficient to characterize the seasonal offshore wave climatology in detail for the three sites of interest, were not available for this study. It has been learned recently that a full year of wave data (bottom pressure records) from a site located near Penfield Reef has been collected and summarized in atlas form under the direction of Dr. Frank Bohlen at the Univerity of Connecticut. Although it was not possible to incorporate this information in the present study, the data base offers a basic starting point for any further design or impact assessment efforts at the sites under consideration in western Long Island Sound.

As an alternate source of wave climatology information, the National Climatic Center provides a summary of offshore wave height statistics based on visual observation. These observations do not include directional information and have a resolution of 0.5 meters. The statistics are intended to describe general conditions over the Sound as a whole. According to this source, the wave climatology is conveniently separated into two seasonal periods: (1) a fall/winter/spring period extending from September through April, and (2) a spring/summer period from May through August. During the winter period, wave heights are within the range from 1.0 to 2.7 meters 50 to 60% of the time. Heights exceed 2.7 meters with a frequency of less than 10% and are less than 1.0 meters with a frequency of 30 to 40%. Wind direction during this period is predominantly from the northeast to northwest. During the summer wave activity is reduced with wave heights less than 1.0 meter 50 to 70% of the time. Waves 1.0

to 2.7 meters occur with a frequency of roughly 40% and the frequency of wave heights over 2.7 meters is negligible. Wind direction is predominantly southwesterly.

In assessing the impact of the proposed containment structures on the local wave climate, primary emphasis is placed on analyzing storm wave conditions. For this purpose it appears reasonable to assume an offshore wave height of 2.0 meters and period of 5 seconds as representative for each of the three sites. The available data are not sufficient to warrant more precise distinctions in these cases. The frequency of such a storm event is almost certainly more than once per year, and so represents a relatively common occurrence. The intent is not to examine an extreme event, as would be appropriate for design purposes, but rather one which represents a significant environmental influence within a seasonal time frame. The choice of wave direction appears to be arbitrary in the sense that storm waves of 2.0 meter height can be expected to occur at least once per year in deepwater from any given point on the compass. Accordingly, this specification should be made consistent with the topographic constraints of the local coastline and the environmental characteristics of interest.

2. BLACK LEDGE SITE

2.1 DESCRIPTION OF THE EXISTING ENVIRONMENT

2.1.1 Physical Environment

The proposed DMCF for Groton-New London is located on a rocky shoal known as Black Ledge located roughly one mile seaward of the entrance to New London Harbor and east of the main shipping channel. The outline of the shoal, as indicated by the 18 ft depth contour (MLW), is irregularly shaped and measures roughly 2500 ft along a transect from east to west. The shoal rises abruptly from surrounding water depths of 20 to 30 ft. Depths over the shoal are reduced to 10 ft or less (MLW) at several points, posing a significant navigational hazard. A navigational buoy marks a small area on the southwest portion of the shoal which is exposed over most of the tidal cycle. Figure 2-1 indicates the major bathymetric and shoreline features of the local area together with the outline of the DMCF.

The exposure of the site to storm waves is limited to a relatively narrow directional window from south to southwest. Fishers Island reduces the fetch to 5 miles or less for waves approaching from the southeastern quadrant. NOAA tidal current tables (NOAA, 1982b) indicate generally weak currents in the vicinity of the shoal, with velocities of 0.4 knots being listed for the entrance to New London Harbor. The mean tidal range for the harbor entrance is 2.7 ft and the spring range increases to 3.1 ft (NOAA, 1982a).

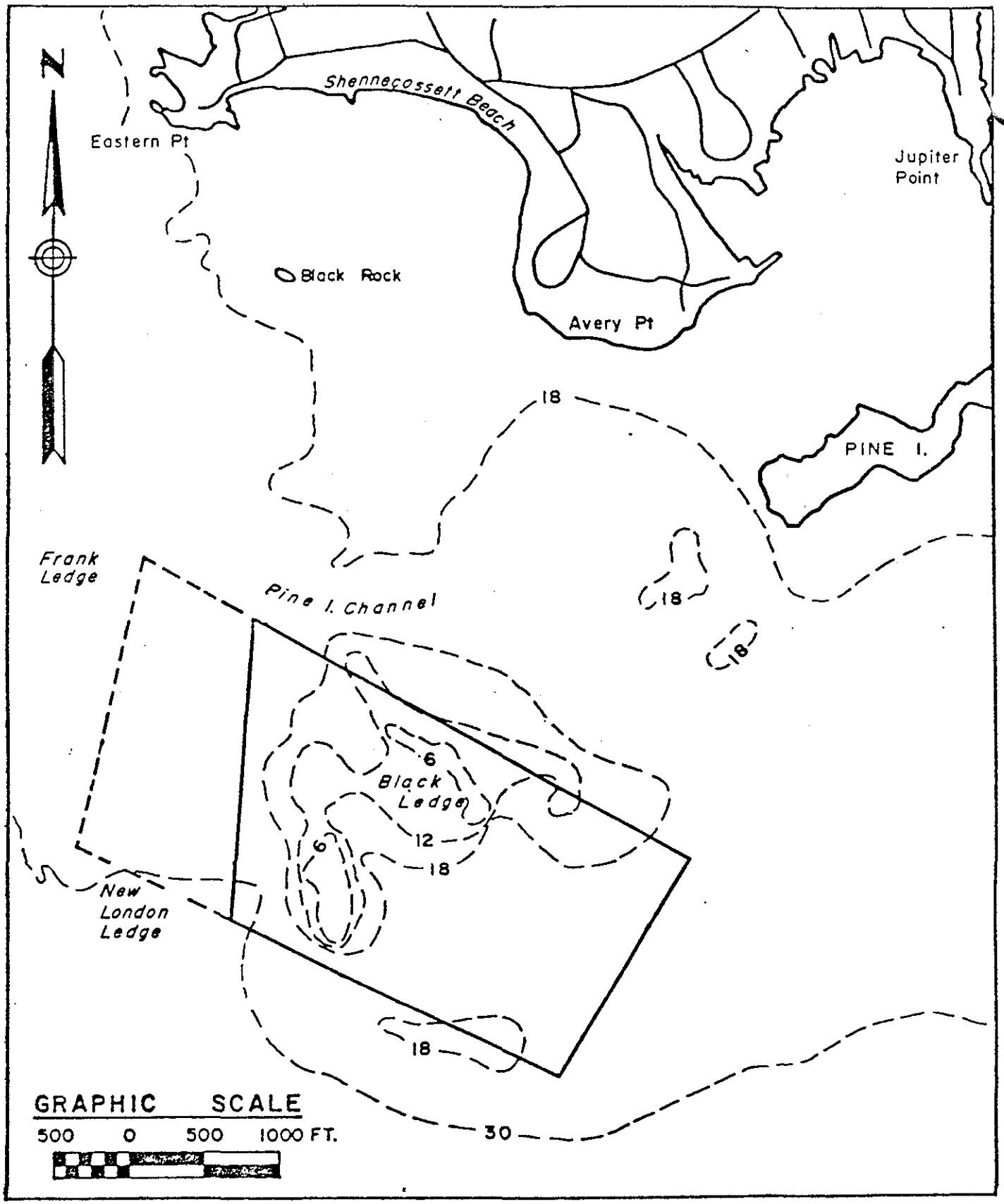

Figure 2-1. Location map of the Black Ledge site showing the outline of the proposed containment facility (from COE, 1983).

Pine Island Channel lies immediately to the north of the shoal and allows east-west passage by recreational boating traffic between the shoal and Avery Point. The channnel bed appears to be armored with coarse gravel (see subsection 2.1.2), indicating energetic scouring by tidal currents and/or wave action. Although the tides are not pronounced at this site and the currents in the adjacent harbor area are reported to be moderate, the channel does converge sharply to form a narrow neck east of Frank Ledge. This may produce a substantial acceleration of the local currents at intermittent points in the tidal cycle. However, there are no known field measurements of current characteristics in the area to confirm this effect. Further east between Pine Island and Avery Point, a shallow inlet provides access to a small anchorage within the embayment formed by Jupiter Point. It is presumed that this channel is naturally maintained by the scouring action of tidal currents, although again there are no direct measurements to confirm the magnitude of the velocity.

Shennecossett Beach lies along the shoreline north of Black Ledge flanked by Eastern and Avery Points. This is a pocket beach which is presumably sheltered from storm waves approaching from the south and southeast by Black Ledge. Waves from the southwest are expected to be refracted onto the Eastern and Avery Point headlands and Black Rock shoal. Consequently, this beach appears to be naturally well-protected from serious erosion under storm conditions.

On the basis of biological observations (see subsection 2.1.2) and the coarse characteristics of the bottom material, it is evident that Black Ledge is a high-energy environment. Furthermore, the irregularity of the bottom topography implies complex wave patterns over the shoal and adjacent portions of

Pine Island Channel, characterized by alternating areas of wave focusing and defocusing. The sharp relief also implies large variations in wave height due to shoaling effects. It is apparent that conventional methods of refraction analysis are inadequate to account for such processes.

In an attempt to quantify accurately these aspects of the local wave climate, the refraction-diffraction model was used to simulate a variety of storm wave conditions. A series of model runs was performed using an offshore wave height of 2.0 meters and a period of 5 seconds, as discussed in Section 1.2.2. Table 2-1 lists the various combinations of wave direction and still-water surface level (tidal stage) specified as input conditions for each run. As mentioned previously, the Black Ledge site has a rather narrow window of exposure to deepwater storm waves from south to southwest. Consequently, three discrete directions are sufficient as input specifications to represent this range in the model runs. (Note that Table 2-1 lists these in terms of the orientation of the wave vector; i.e., direction of wave propagation.) In addition, conditions of high and low stillwater surface levels were considered. The high water condition (6.6 ft MLW) was chosen to represent a spring tide combined with a superimposed storm surge. The resulting six cases are sufficient to represent a reasonably complete range of storm conditions expected at Black Ledge.

The model grid covers an area of roughly one square mile centered on Black Ledge shoal and oriented with an onshore-offshore direction (x-coordinate) aligned with a heading of 25° True. The finite-difference discretization consists of an array of 36 rows in the x-direction and 41 columns in the y-direction, with a uniform spacing of 150 ft between rows and columns. The overall dimensions are thus 5280 ft (x) by 6000 ft (y). Depths

Table 2-1. Summary of wave model runs used to describe existing storm wave conditions over Black Ledge and Pine Island Channel. The initial direction of wave propagation at the offshore grid boundary is listed according to compass heading (° True) and also according to the internal model or grid convention used in the figures.

Run	Offshore Wave Direction Compass Hdg.	Offshore Wave Direction Grid Conv.	Stillwater Surface Elevation (MLW)	Figure Reference
1	25°	0°	0	2-2
2	0°	+25°	0	2-3
3	50°	-25°	0	2-4
4	25°	0°	6.6 ft (2.0 m)	2-5
5	0°	+25°	6.6 ft (2.0 m)	2-6
6	50°	-25°	6.6 ft (2.0 m)	2-7

at each grid point were taken from NOS Chart No. 13213. The offshore grid boundary was located 1350 ft seaward of the 18-ft depth contour shown in Figure 2-1.

The model results are presented in Figures 2-2 through 2-7 in the form of plots of wave height and direction as a function of distance (y-coordinate) along the last grid row, beginning at the unnamed shoal immediately south of Pine Island and terminating at Black Rock. This transect runs approximately parallel to the centerline of Pine Island Channel with an offset to the north of several hundred meters. This generally corresponds to the point where the waves begin to shoal and subsequently break on the Groton shoreline.

In the presentation of the model results, wave direction is plotted according to an internal model convention related to the grid lay-out. Specifically, the direction of the wave vector is measured relative to the onshore (+x axis) orientation of the grid which in the present case lies along a compass direction of 25° true. Positive angles denote a deflection of the wave vector toward the west (counter-clockwise) and negative angles, a deflection toward the east (clockwise). Note that the wave vector points in the direction of wave propagation as opposed to wave approach. The wave height (amplitude) is plotted in non-dimensional form, normalized with respect to the wave height (amplitude) specified along the offshore grid boundary. Further details concerned wtih the mathematical basis of the modeling methodology are presented in Appendix A.

In general, the wave height plots have a realistic, multi-lobed appearance, as should be expected in a case involving wave scattering processes over such irregular bathymetry. The wave direction plots are also realistic, indicating alternating

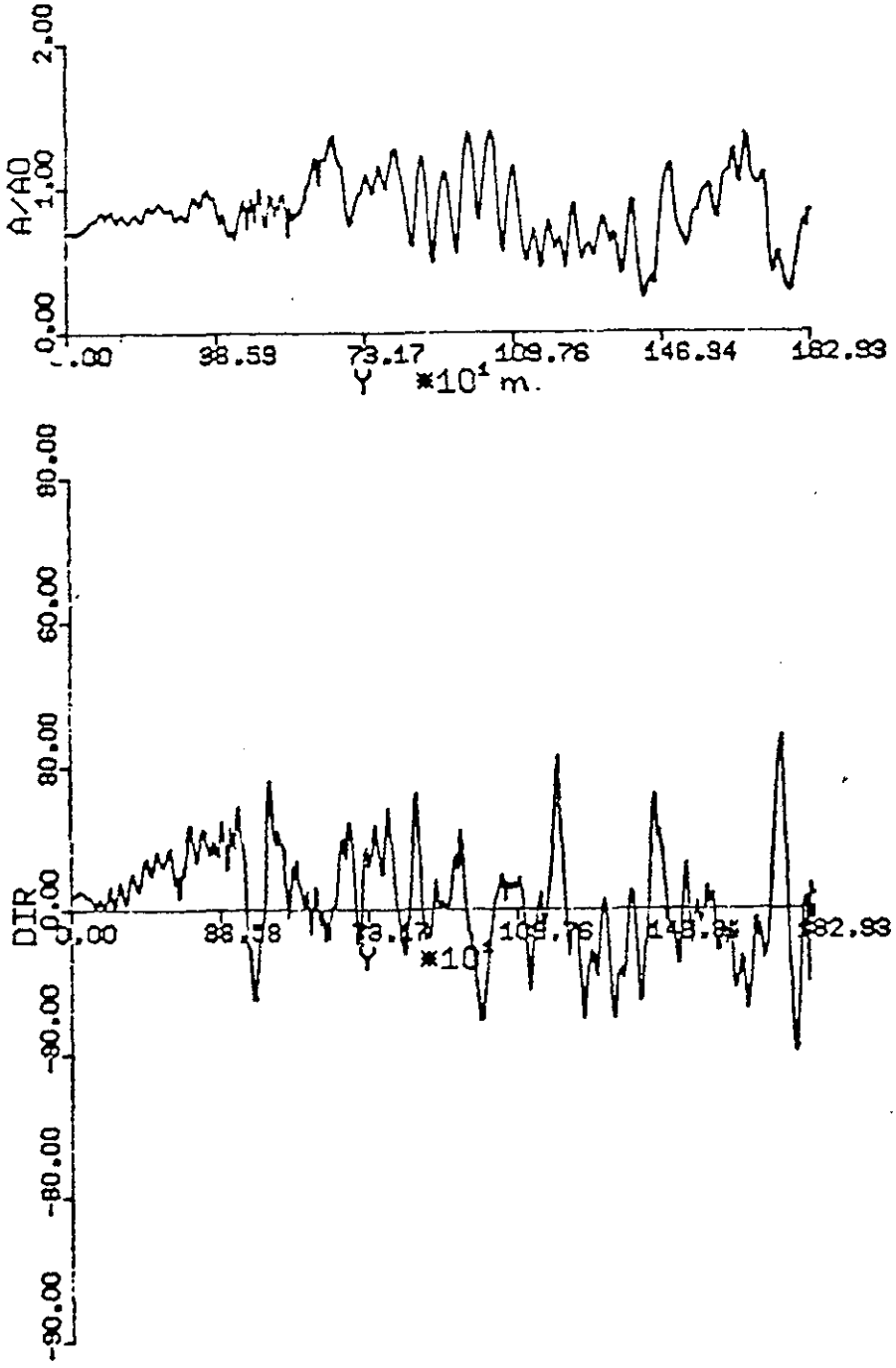

Figure 2-2. Wave height and direction from Pine Island to Black Rock for waves from the south-southwest based on existing bathymetry at low water.

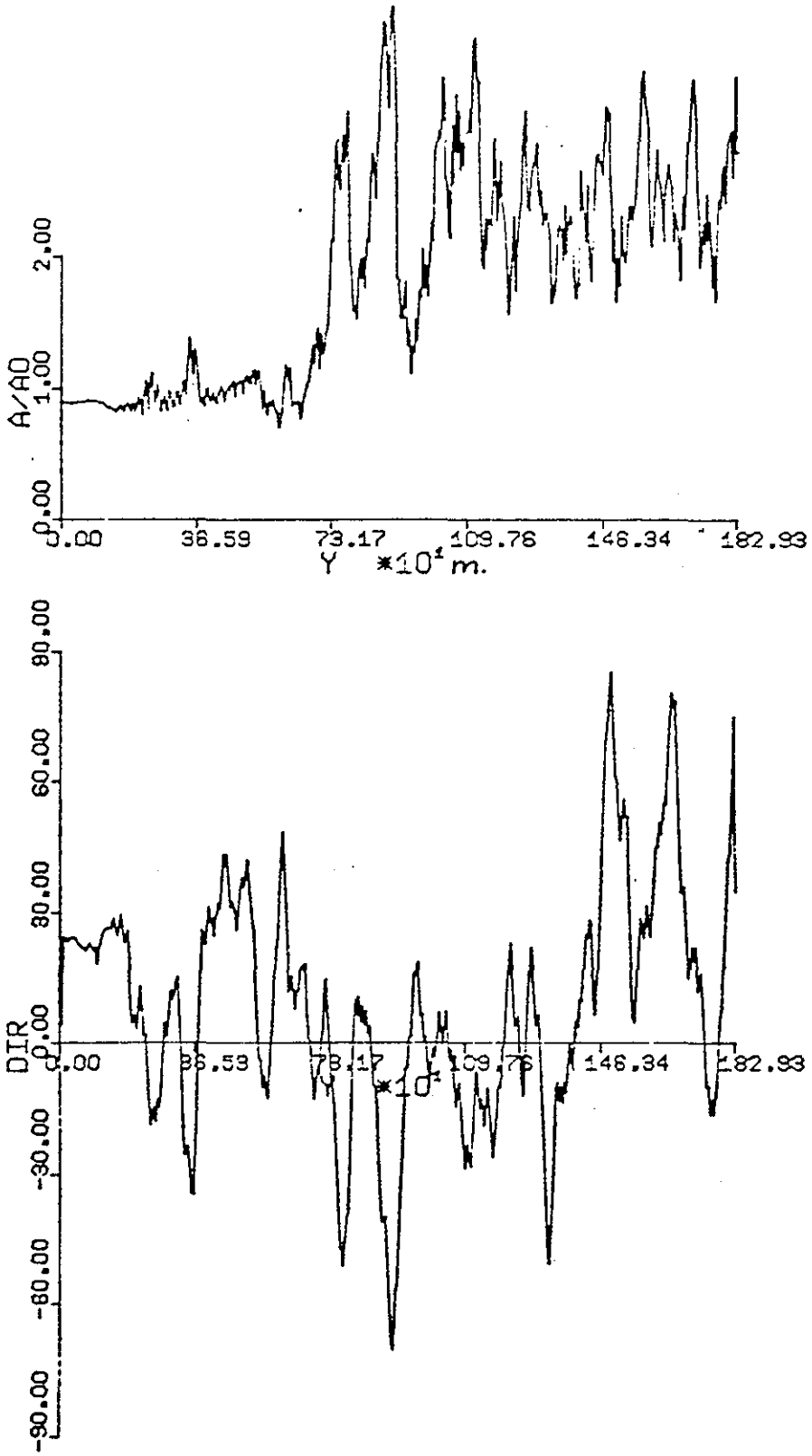

Figure 2-3. Wave height and direction from Pine Island to Black Rock for waves from the south based on existing bathymetry at low water.

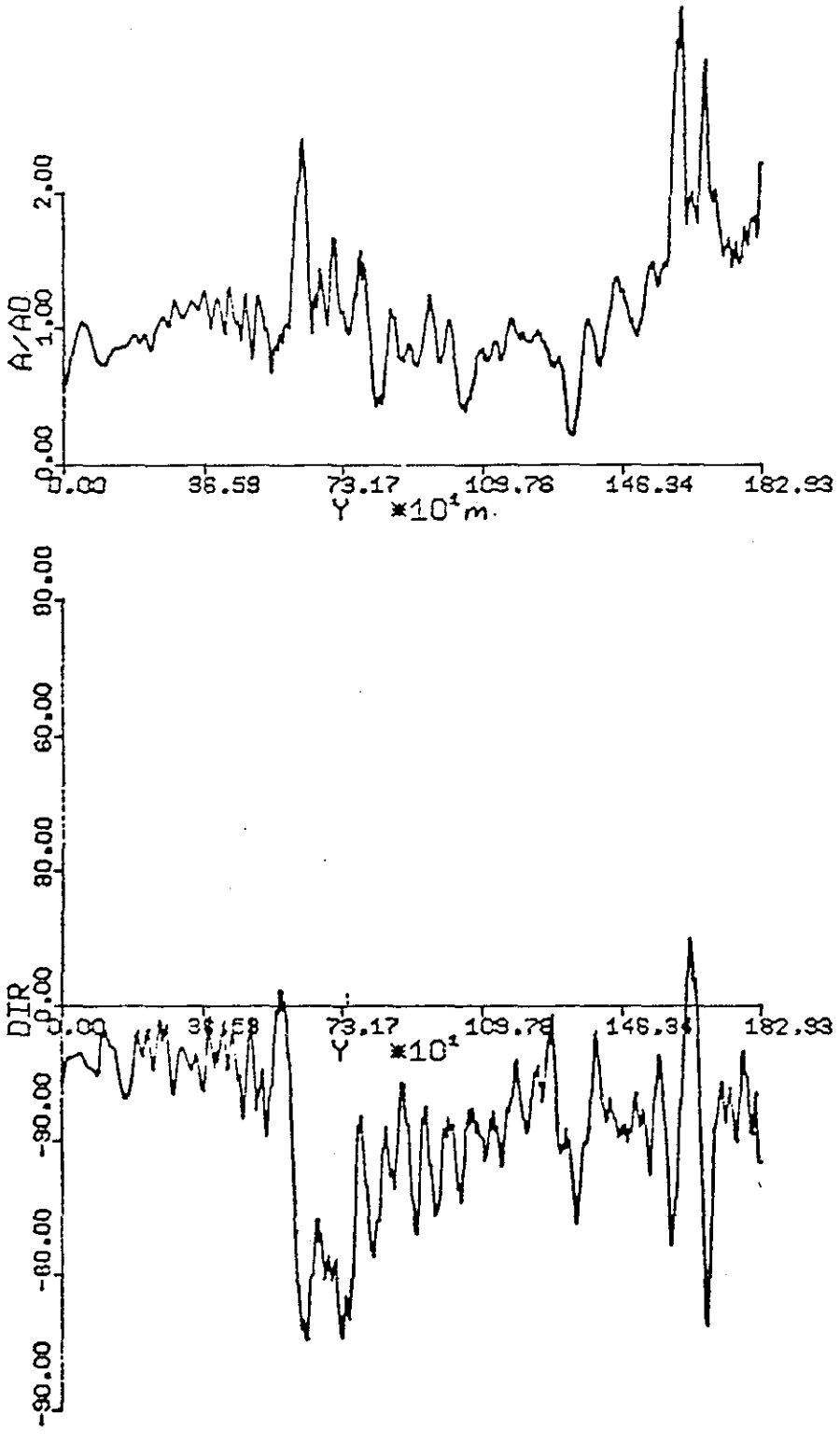

Figure 2-4. Wave height and direction from Pine Island to Black Rock for waves from the southwest based on existing bathymetry at low water.

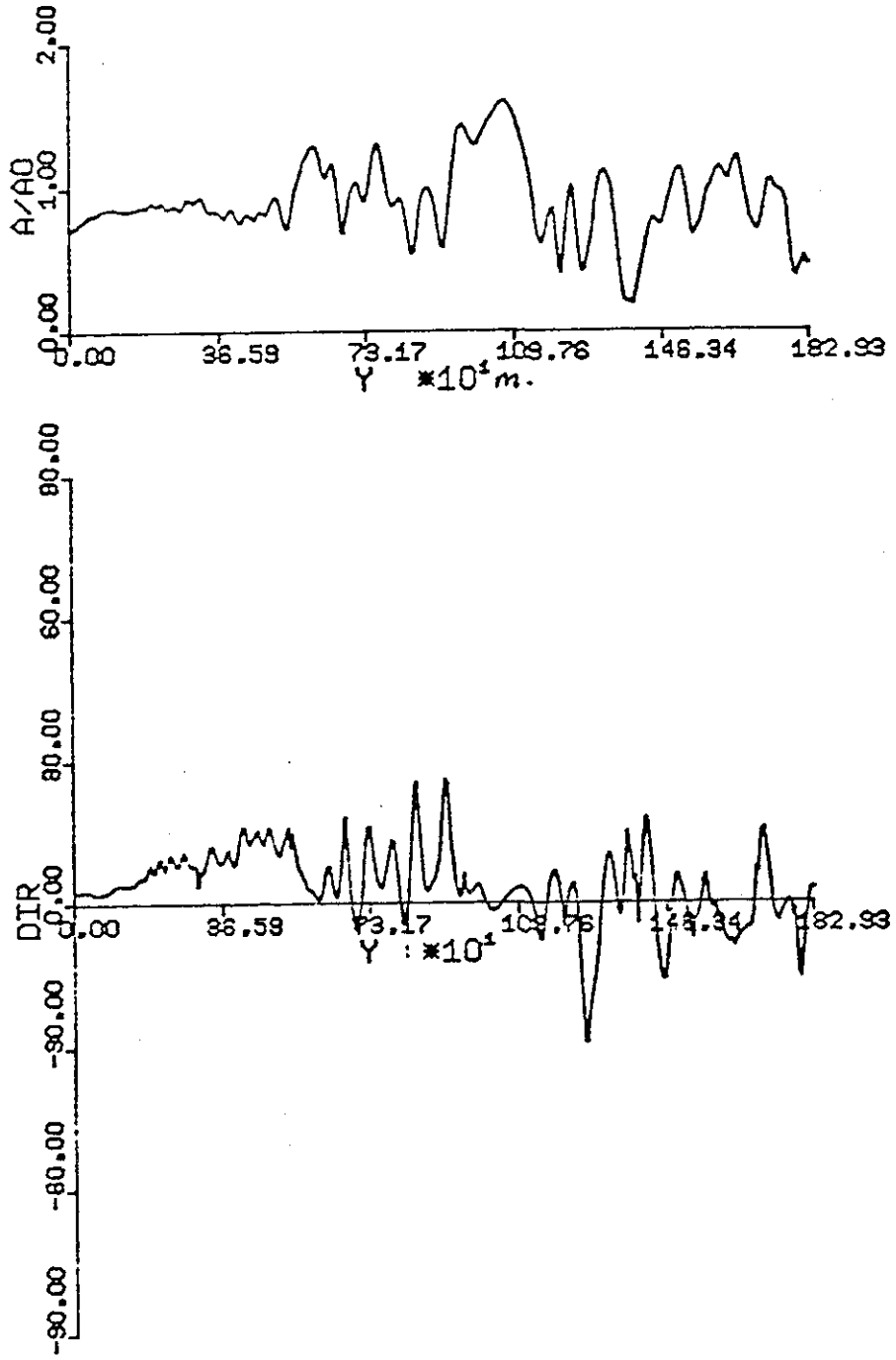

Figure 2-5. Wave height and direction from Pine Island to Black Rock for waves from the south-southwest based on existing bathymetry at high water.

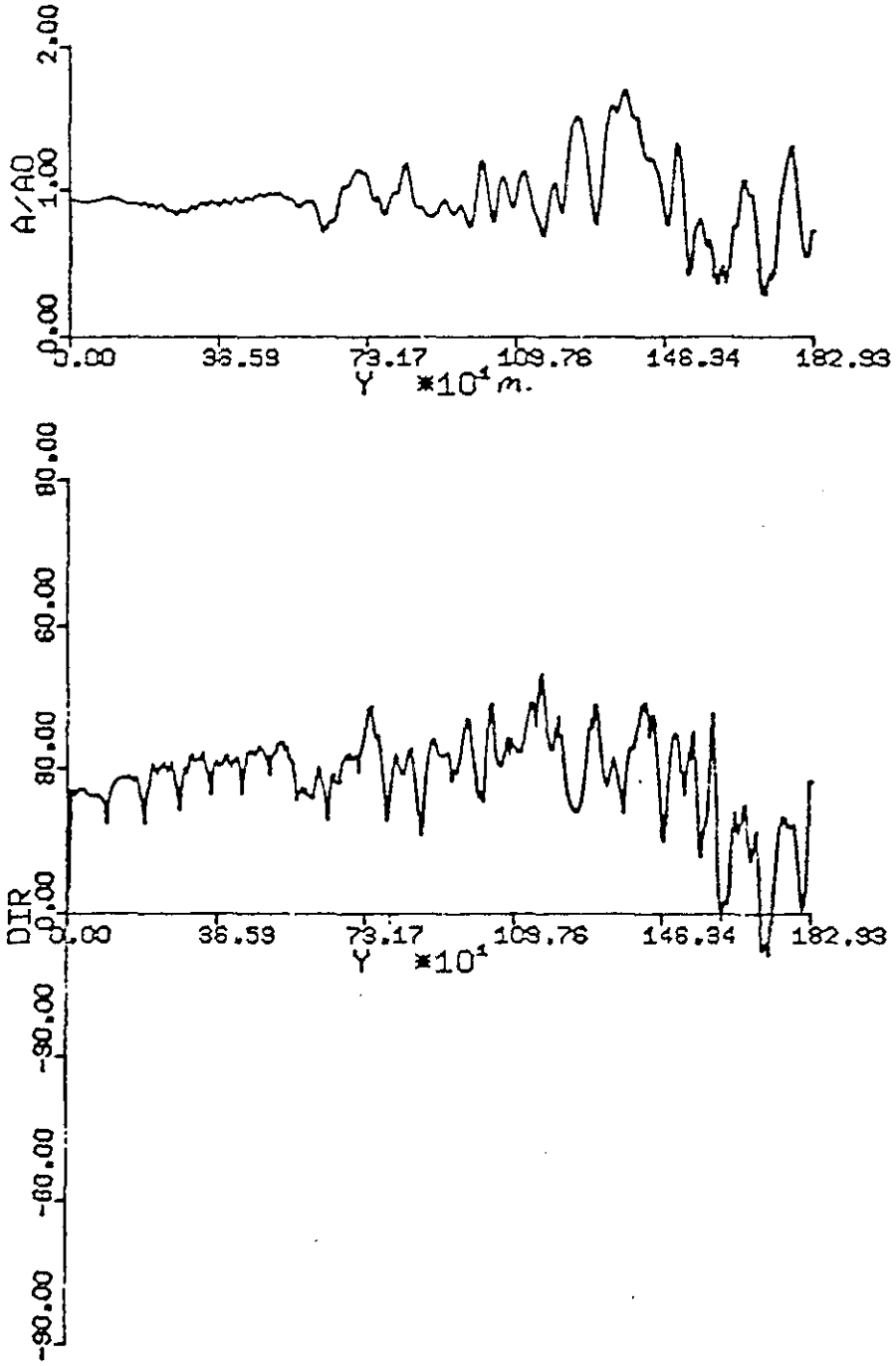

Figure 2-6. Wave height and direction from Pine Island to Black Rock for waves from the south based on existing bathymetry at high water.

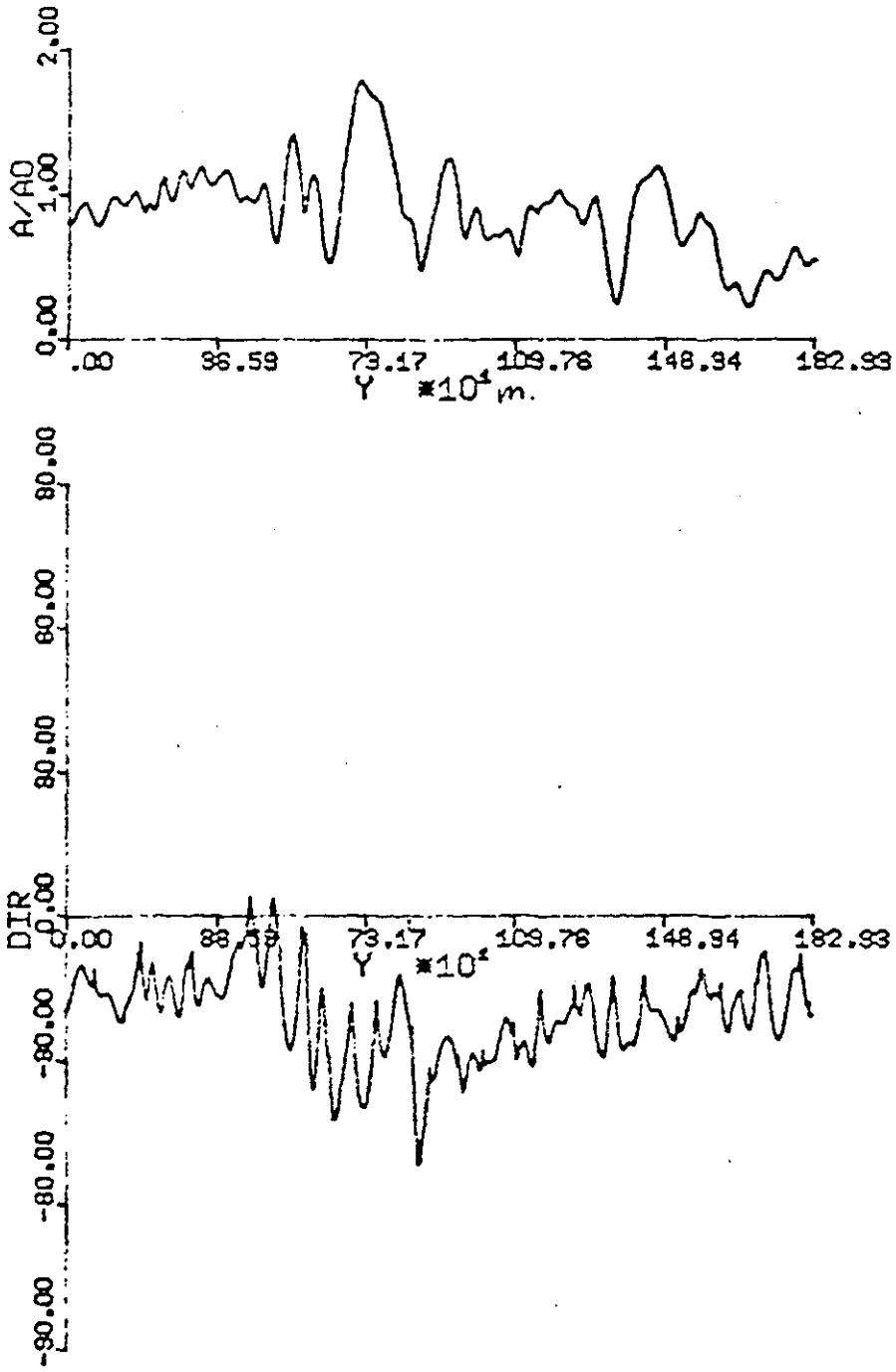

Figure 2-7. Wave height and direction from Pine Island to Black Rock for waves from the southwest based on existing bathymetry at high water.

regions of wave focusing and defocusing. According to the convention being used, a peak in the wave direction plot indicates divergence of the wave vector (defocusing) and a trough indicates convergence (focusing). There are particular features evident in the results which appear anomalous and should be regarded with caution. For example, the model run shown in Figure 2-3 exhibits dramatically higher amplification and directional variability in comparison with the other five runs. Dr. Dalrymple (personal communication) suggests that this is attributable, in part, to a realistic effect of the bathymetry encountered by waves approaching from the south under low-tide conditions. It is also possible that the model behavior is due to a spurious numerical oscillation produced by the necessarily approximate lateral boundary conditions used in cases involving obliquely incident waves. In any event, the prediction of amplification peaks approaching a factor of four must be considered unrealistic. The model incorporates a mathematical mechanism for initiating wave breaking by means of a depth-dependent relationship. However, wave breaking will also occur whenever waves exceed a critical steepness. This mechanism is not incorporated in the model, but would surely act to limit the amplification of five second waves under prototype conditions to factors of less than four. It can be anticipated that the effect of this type of breaking process will be to smooth the spatial distribution of wave heights predicted by the model in regions of sharp focusing and defocusing. While no exact criteria can be given for a maximum amplification ratio, it is suggested that a reasonable range in the present case might be limited to a magnitude of 2.5 or less.

The important conclusion to be drawn from this preliminary model analysis is that the shoal acts to focus certain incident storm waves, producing significantly amplified wave heights

within the area of Pine Island channel adjacent to Avery Point. This is qualitatively similar to the results of wave tank experiments performed with simple circular or elliptical shoal configurations. While there is no direct confirmation of this effect from field measurements at the site, it is consistent with the observed scouring of the channel bed and the rocky profile of the shorelines along Avery Point and Pine Island. It was initially surmised that Black Ledge might shelter this shoreline, especially from waves approaching from the south. This may still be true under conditions not represented in the model runs, for example in cases involving longer period waves. The conclusion remains, however, that the shoal has the effect of substantially amplifying incident storm waves over a wide range of commonly occurring conditions.

2.1.2 Biological Environment

Black Ledge was the subject of a biological reconnaisance survey conducted during the summer and fall of 1981 by McGrath et al. (1982). Samples were collected on the Ledge proper--consisting of large angular boulders with generally flat sides--as well as in some of the surrounding sediments. Figure 2-8 indicates the station locations. Stations A5, B5, B10, C5 and C10 were on the Ledge and, therefore, were hard-bottom stations. Sediments at Stations 1 through 4 were predominantly silts; Stations 5 and C30 were somewhat sandier, while gravel was the main sediment type found at Stations B20, B30 and C20. Thus, a variety of bottom types are encountered in the area and this environmental heterogeneity was reflected in the rather high number of 184 macrofaunal species collected during the survey. Of this total, polychaetes contributed 76 species (41%) and were taxonomically dominant. Crustaceans and molluscs contributed 48 (26%) and 46 (25%) species, respectively.

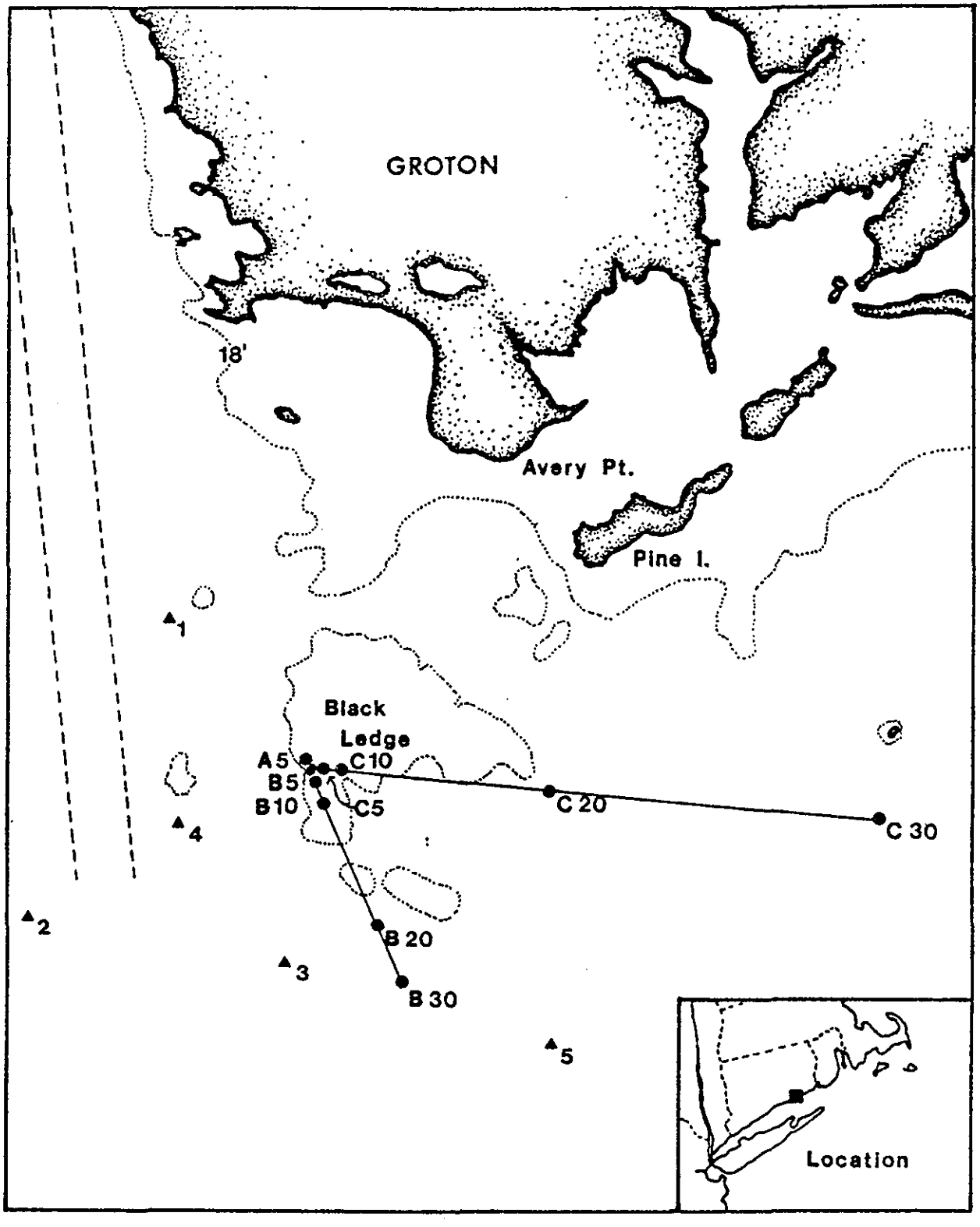

Figure 2-8. Black Ledge study area showing locations of sample stations during the 1981 survey (from McGrath et al., 1982).

The macrofauna at the five hard-bottom stations on Black Ledge were dominated by mussels (Mytilus edulis), which formed a mat covering much of the exposed rock surface. Subdominants included the gastropods Mitrella lunata and Amachis avara, the polychaete Harmothoe imbricata and the ophiuroid Amphipholis squamata, all typical hard-bottom forms in northeast coastal areas. The mussels themselves formed a suitable substratum for a variety of small epiphytic algal species including Chondria tenuissima, Lomentaria orchadensis, Callithamnion spp., and Giffordia granulosa. The mussel/algal mats create a topographically complex environment providing excellent habitat for a number of species. McGrath et al. (1982) noted a large variety of amphipods at the rock stations, which they attributed to the environmental heterogeneity, and suggested that the diversity of gastropods found at these stations might also be due to this factor.

Not found in much abundance at the stations sampled on Black Ledge were large algal species such as Chondrus crispus, Phyllophora spp., or Laminaria spp., which compete for space on the hard substratum against mussels. Kelp (Laminaria) stands are found elsewhere on the Ledge, however, as noted on the nautical chart covering this area.

Macrofaunal density at the five stations on Black Ledge proper averaged 9907 m^{-2} (calculated from data in McGrath et al., 1982). Density at the four stations (1-4) west and southwest of the Ledge and characterized by silty sediments were higher (mean = 30,185 m^{-2}). Stations 1 and 2 were dominated by Aricidea sp., a paraonid polychaete, although the protobranch bivalve Nucula proxima was also relatively abundant. Both are deposit-feeding forms common in muddy bottoms. Stations 3 and 4 were dominated by the amphipod Ampelisca abdita, a tube-building surface-

particle feeder. Ampelisca abdita was also the overwhelming dominant at Station 5, characterized by a sandier bottom. The other sand station, C30, had no clear dominant although the spionid polychaete Spiophanes bombyx and the amphipod Unciola irrorata, as well as the genus Ampelisca, were well represented; all are surface-particle feeders. The mean density found at the two sand stations was 36,350 m^{-2}. Mean density was lowest, 6373 m^{-2}, at the three gravel stations (B20, B30, and C20). Again, no clear dominants emerged although the polychaetes Tharyx acutus and Exogone sp. were important components of the fauna.

The present survey of the Black Ledge site was conducted in July 1983 and was designed to extend the results of the earlier survey in the sediments surrounding the Ledge. Figure 2-9 shows the placement of the 15 stations sampled during this survey and indicates the prominent sediment types found. (Additional details of station placement can be found in Appendix B.) In general, the sedimentary environment encountered during this survey was very similar to that reported earlier by McGrath et al. (1982). Silt and silt/clay bottom materials characterized areas generally west of the Ledge while sand and gravel were found south and southeast of the Ledge in waters less than 30 feet deep. The coarsest sediments were found north of the Ledge in Pine Island Channel.

Appendix C presents the complete biological data for the Black Ledge site. Polychaetes were taxonomically dominant contributing 64 (46%) of the 140 species or taxa recorded. Crustaceans accounted for 34 (24%) and molluscs 31 (22%) of the species total. The total mean density of macrofauna (0.5 mm sieve fraction) in the entire study area was 11,400 m^{-2}, although there was considerable variability among the stations. In general, the finer sediment stations supported the higher

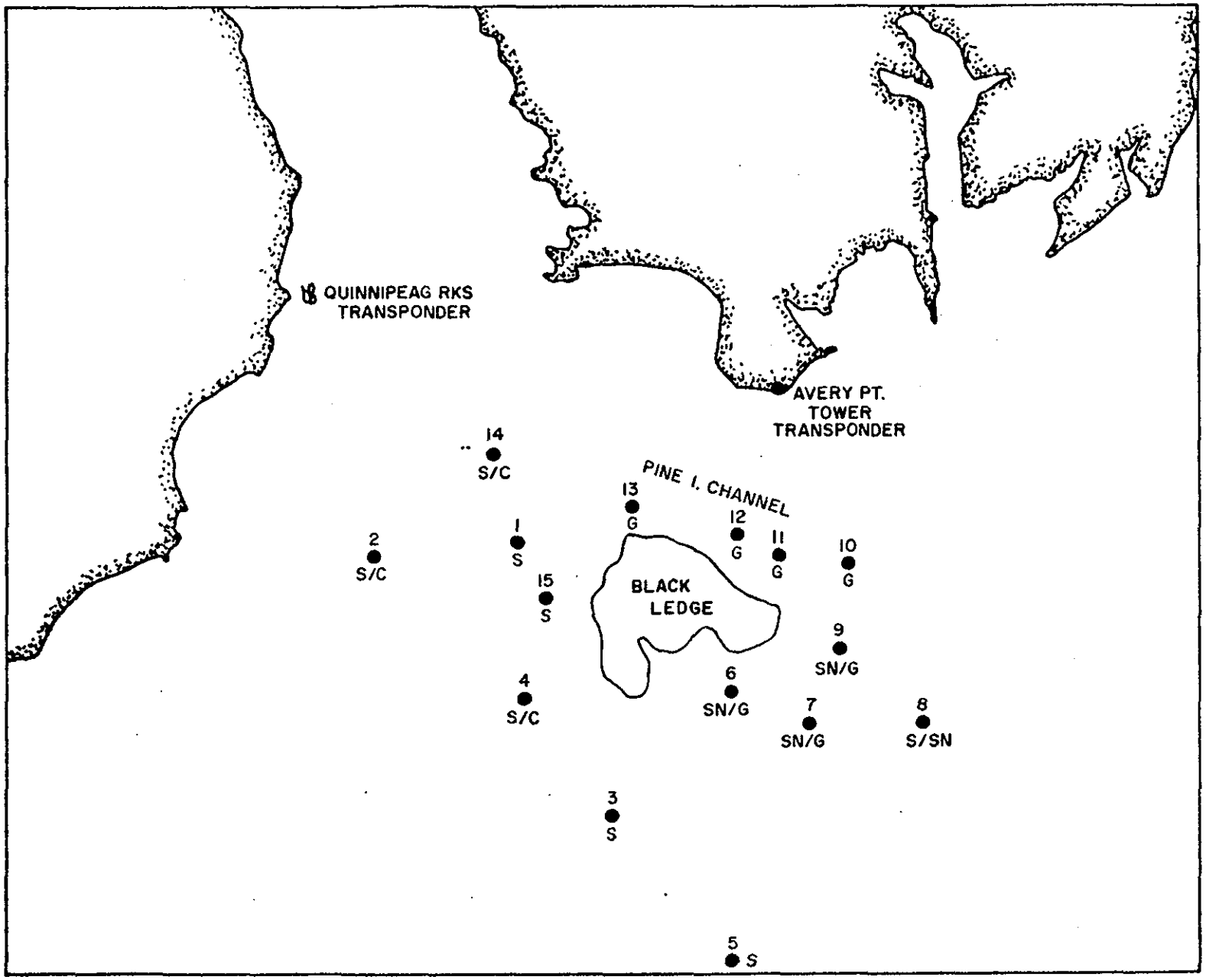

Figure 2-9. Station locations and sediment types at the Black Ledge Site, July 1983.
C: Clay; G: Gravel; Sn: Sand; S: Silt.

densities (up to 40,454 m^{-2} at Station 15), and the coarser sediment stations the lower densities (down to 3161 m^{-2} at Station 9).

The ten numerically dominant species in the study area are listed in Table 2-2. Three species--the bivalve Nucula proxima and two amphipods, Leptocheirus pinguis and Ampelisca abdita--together contributed about 42% of the total number of individual organisms counted, but were not strongly dominant in the study area considered as a whole. However, mean Shannon diversity (H'; see Appendix C for station data) for the 15 stations was a relatively low 1.82, and evenness (J') only 0.56.

These results suggest that dominance at the individual stations was generally much more pronounced than suggested by Table 2-2. That this is the case can be seen in Figure 2-10 which indicates the most abundant species at each station and its percentage share of the total number of organisms found at that station. The fine-sediment stations west of the Ledge were dominated primarily by the deposit-feeding bivalve Nucula proxima, although the deposit-feeding polychaete Aricidea catherinae contributed the most individuals at Station 14. To the south and southeast of the Ledge where the sediments were sandier and some gravel was encountered, the surface-particle-feeding amphipods Leptocheirus pinguis and Ampelisca abdita tended to dominate. Among the stations (10-13) having the coarsest sediments, clear dominants, with the exception of L. pinguis at Station 12, did not emerge. Among the important forms, however, were the polychaetes Spiophanes bombyx and Exogone hebes.

These results are consistent with those obtained earlier by McGrath et al. (1982). In general, there are four community

Table 2-2. Ten numerically most important macrofauna taxa at the Black Ledge Site, July 1983. A: amphipod; B: bivalve; P: polychaete.

		No./m^2	% Total Density
1.	*Nucula proxima* (B)	1707	15.0
2.	*Leptocheirus pinguis* (A)	1656	14.5
3.	*Ampelisca abdita* (A)	1458	12.8
4.	*Aricidea catherinae* (P)	303	2.7
5.	*Tharyx annulosus* (P)	242	2.1
6.	*Exogene hebes* (P)	178	1.6
7.	Oligochaeta	174	1.5
8.	*Nephtys incisa* (P)	160	1.4
9.	*Prionospio steenstrupi* (P)	158	1.4
10.	*Pholoe minuta* (P)	148	1.3
	Total	6184	54.2

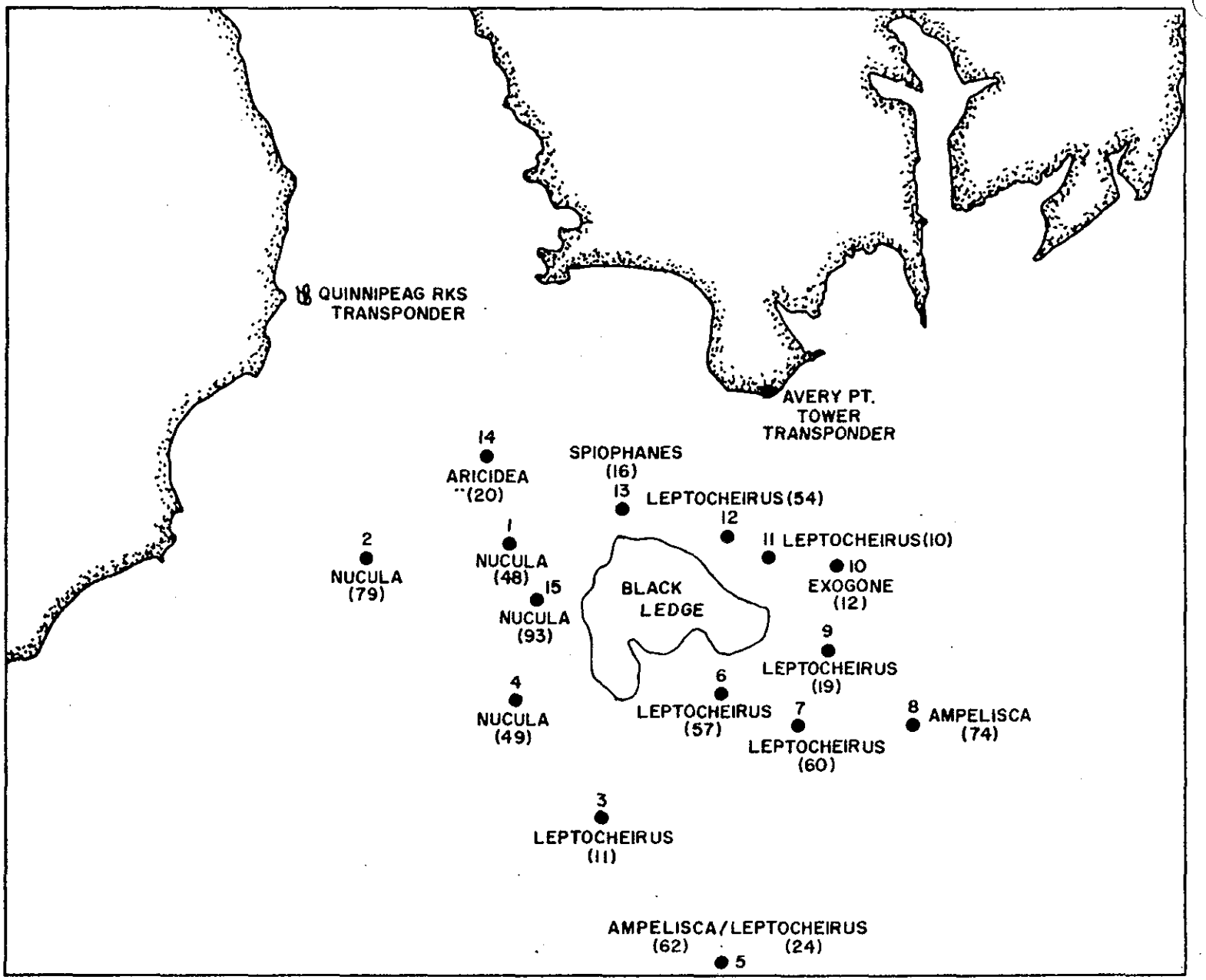

Figure 2-10. Dominant species of macrofauna at the Black Ledge Site, July 1983. Figures in parentheses indicate the percentage of total macrofaunal density contributed by dominant species at each station.

types in the study area corresponding to the four sedimentary environments encountered. The first is the deposit-feeding community in the muddy area west of the Ledge corresponding to the classic Nucula-Nephtys assemblage described by Sanders (1960). Next is the amphipod-dominated community on the muddy sands and sand/gravel areas south and east of the Ledge; surface particle feeding is the primary trophic mode. A mixed community characterized by relatively high (for the area) diversity (2.5) and evenness (0.71) prevails on the gravel area north and northeast of the Ledge; dominance tends to be low and surface-particle feeders and filter feeders are the important trophic groups. Finally, there is the hard-bottom community of Black Ledge proper, strongly dominanted by the filter-feeding bivalve Mytilus edulis.

Based upon the work of McGrath et al. (1982) and the present investigation, the Black Ledge area is judged to be a heterogeneous benthic environment supporting a diversity of species. The present and past surveys of the reef have resulted in species numbers in the range from 140 (silt/sand sediments) to 184 (silt/sand/rock environment). This may be compared with 123 taxa reported for Black Rock and Bridgeport harbors (CEM, 1981) and 145 in Clinton Harbor (McGrath et al., 1982). Benthic abundance (and probably production) are judged to be high in the Black Ledge area and it is likely that the area provides a source of food and habitat to larger invertebrates (e.g., lobsters) and fish.

The biotic and sedimentary environments of the Black Ledge site outlined above correspond to increasing levels of environmental energy: from the tranquil, low-energy environment of the muddy areas west of Black Ledge to the shallow, high-energy environment of the Ledge itself. However, as McGrath et al.

(1982) point out, all four areas are subject to perturbation by winter or other storms. Outside of the direct impacts to the aquatic biota caused by the construction of a Dredged Material Containment Facility (DMCF) at the construction site, indirect effects will be a function of changes in the mean hydrodynamic environment surrounding the facility which could lead to changes in the sedimentary environment. Such effects are explored in the following subsection.

2.2 POTENTIAL IMPACTS OF A DREDGED MATERIAL CONTAINMENT FACILITY

This section provides a preliminary analysis of the impacts of a dredged material containment facility on the physical, chemical, and biological characteristics of the Black Ledge environment.

2.2.1 Description of Wave Modeling Results

The potential effects of the DMCF on the local wave field were investigated using the same grid lay-out as described in Section 2.1.1, but with the containment structure superimposed on the shoal as indicated by the solid outline in Figure 2-1. Model runs using the same input specifications as before were repeated for the modified grid, as summarized in Table 2-3. The resulting wave heights and directions are plotted in Figures 2-11 through 2-16, and may be compared directly with the previous results shown in Figures 2-2 through 2-7.

In the interpretation of these results, caution must be applied in the cases involving obliquely incident waves. These results are contaminated by "edge" effects along the leading or windward lateral boundary of the grid, similar to the effect apparent in Figure 2-3. As previously mentioned, the distortion is due in part to the approximate nature of the lateral boundary conditions. In the present cases, there may also be a contribution from partial reflections between the windward side of the DMCF and the adjacent lateral grid boundary. As a consequence, the distortion grows with distance toward the rear of the grid and becomes concentrated in either the eastern or western inshore corner, depending upon whether the incident wave direction is positive or negative, respectively, as measured according to the grid convention. Therefore, the large wave height amplification

Table 2-3. Summary of wave model runs used to predict wave conditions surrounding the proposed dredged material containment facility. The initial direction of wave propagation at the offshore grid boundary is listed according to compass heading (° True) and also according to the internal model or grid convention used in the figures.

Run	Offshore Wave Direction Compass Hdg.	Offshore Wave Direction Grid Conv.	Stillwater Surface Elevation (MLW)	Figure Reference
7	25°	0°	0	2-11
8	0°	+25°	0	2-12
9	50°	-25°	0	2-13
10	25°	0°	6.6 ft (2.0 m)	2-14
11	0°	+25°	6.6 ft (2.0 m)	2-15
12	50°	-25°	6.6 ft (2.0 m)	2-16

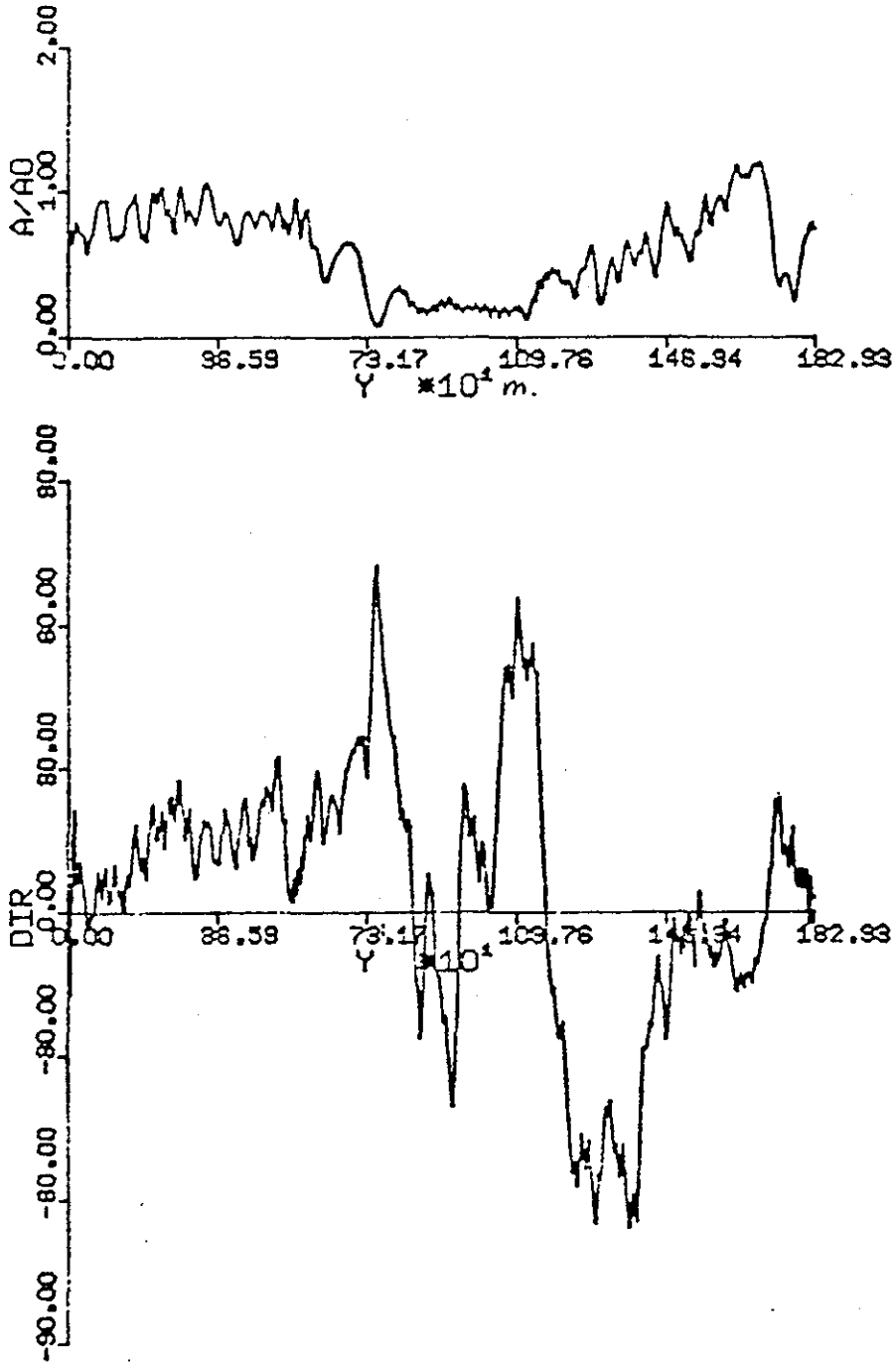

Figure 2-11. Wave height and direction from Pine Island to Black Rock for waves from the south-southwest with the containment structure in place at low water.

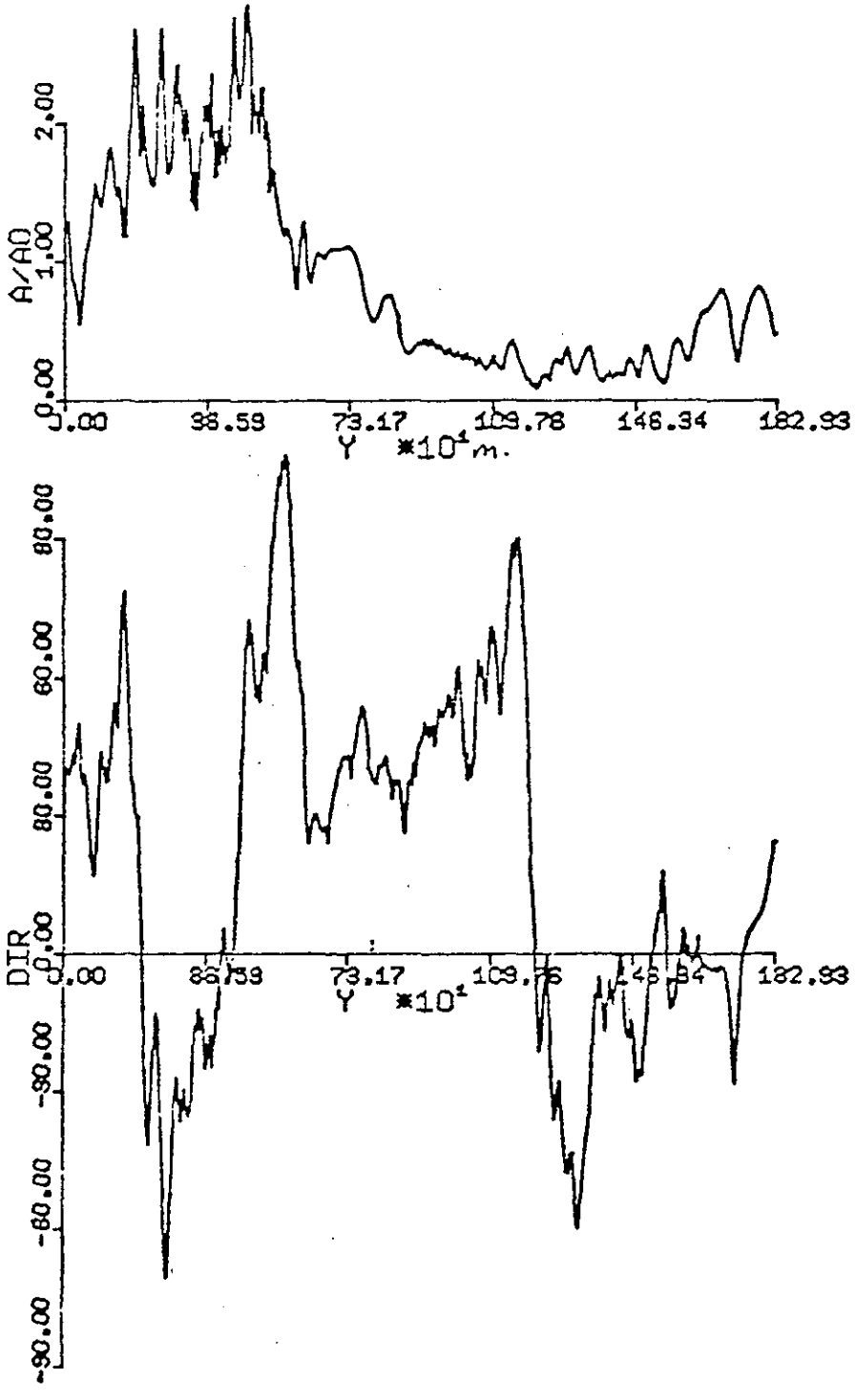

Figure 2-12. Wave height and direction from Pine Island to Black Rock for waves from the south with the containment structure in place at low water.

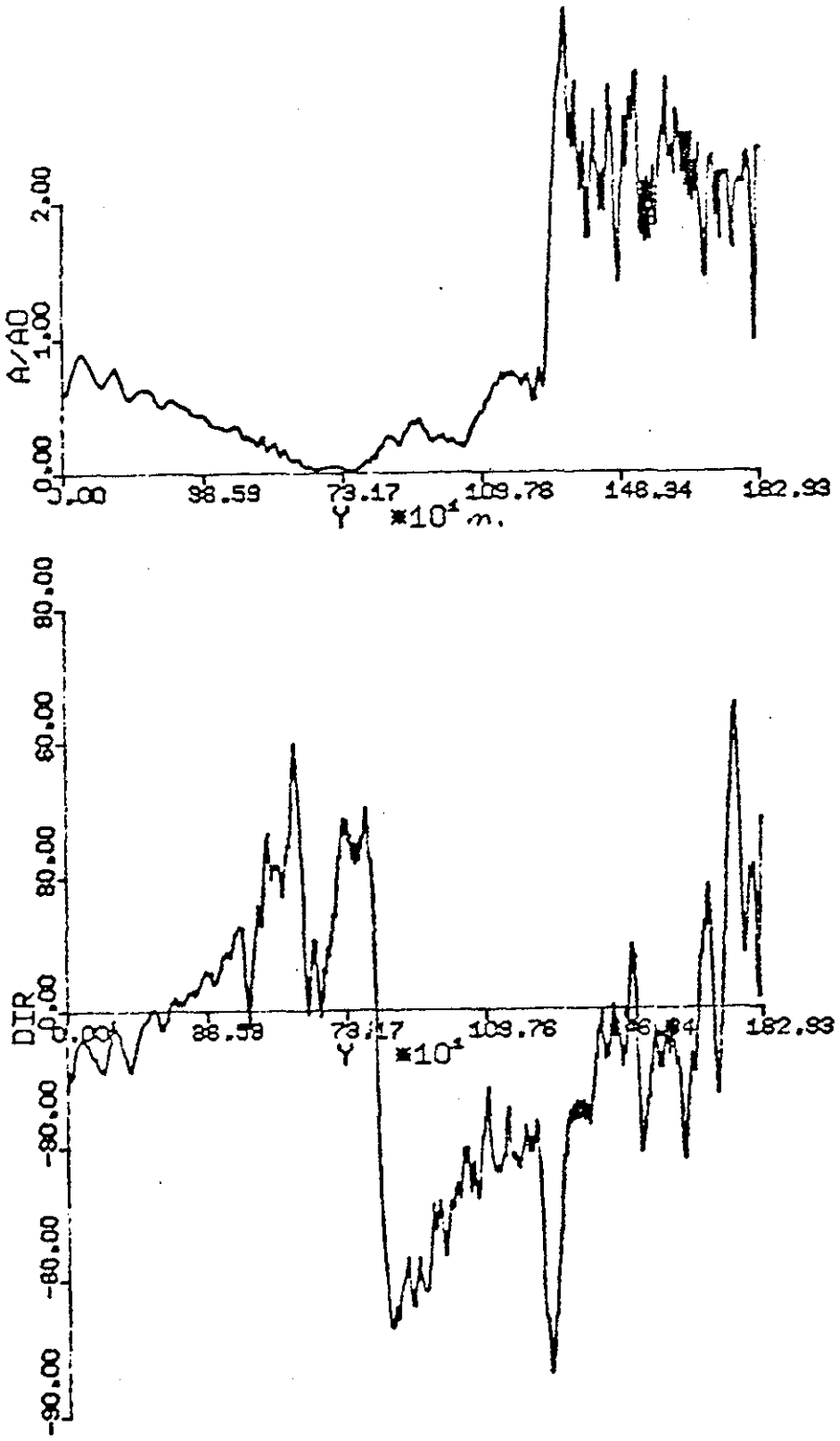

Figure 2-13. Wave height and direction from Pine Island to Black Rock for waves from the southwest with the containment structure in place at low water.

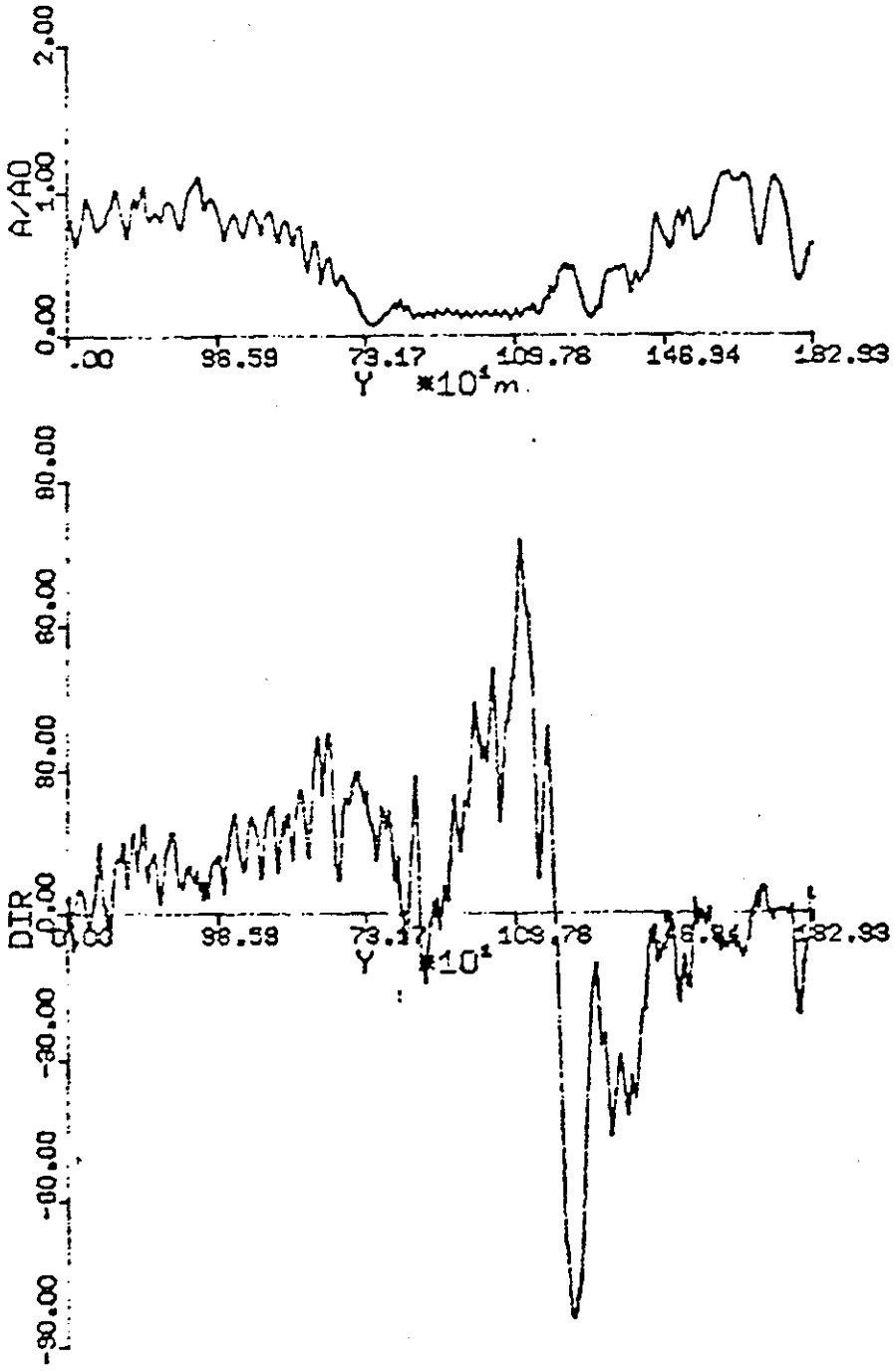

Figure 2-14. Wave height and direction from Pine Island to Black Rock for waves from the south-southwest with the containment structure in place at high water.

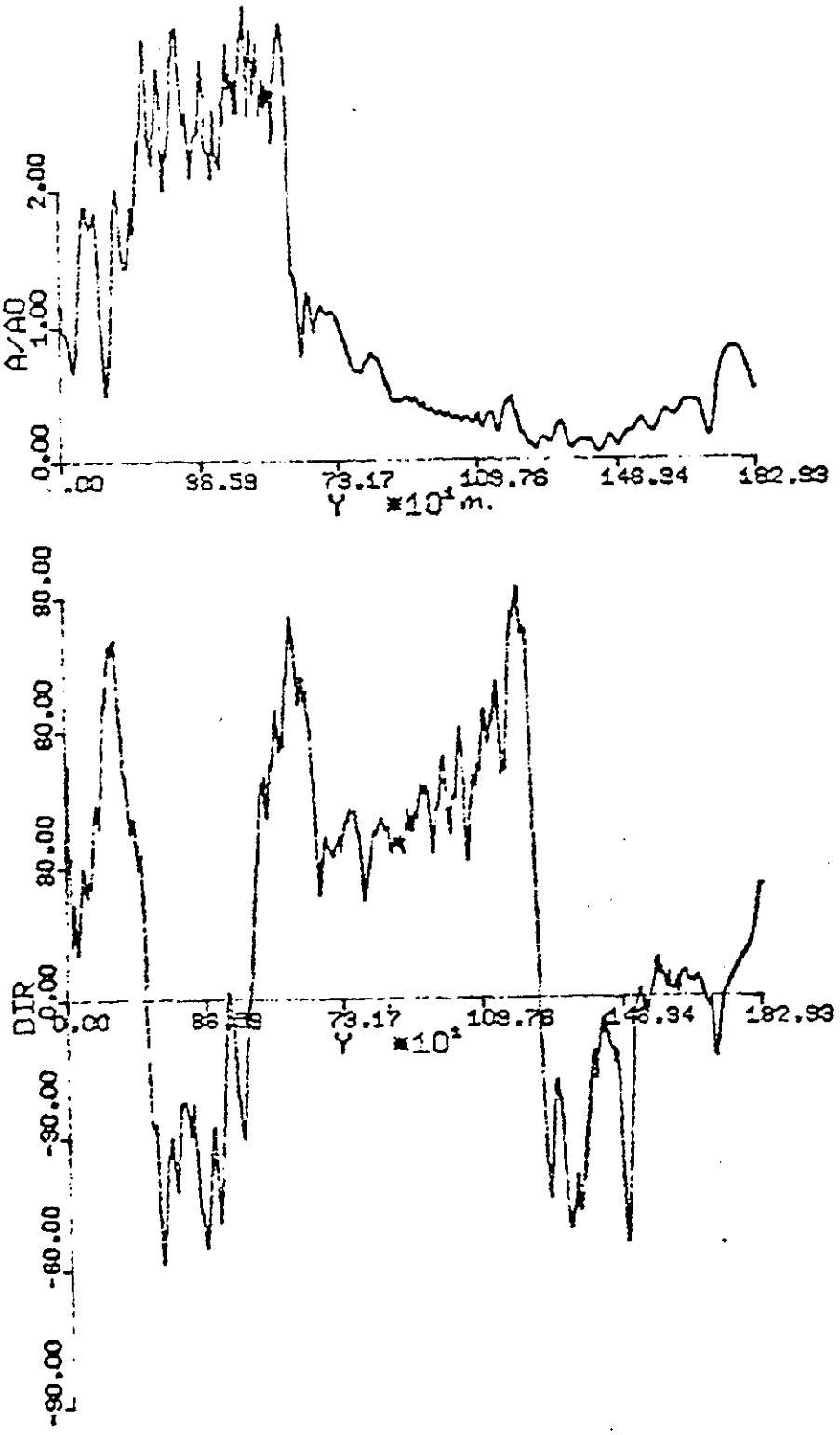

Figure 2-15. Wave height and direction from Pine Island to Black Rock for waves from the south with the containment structure in place at high water.

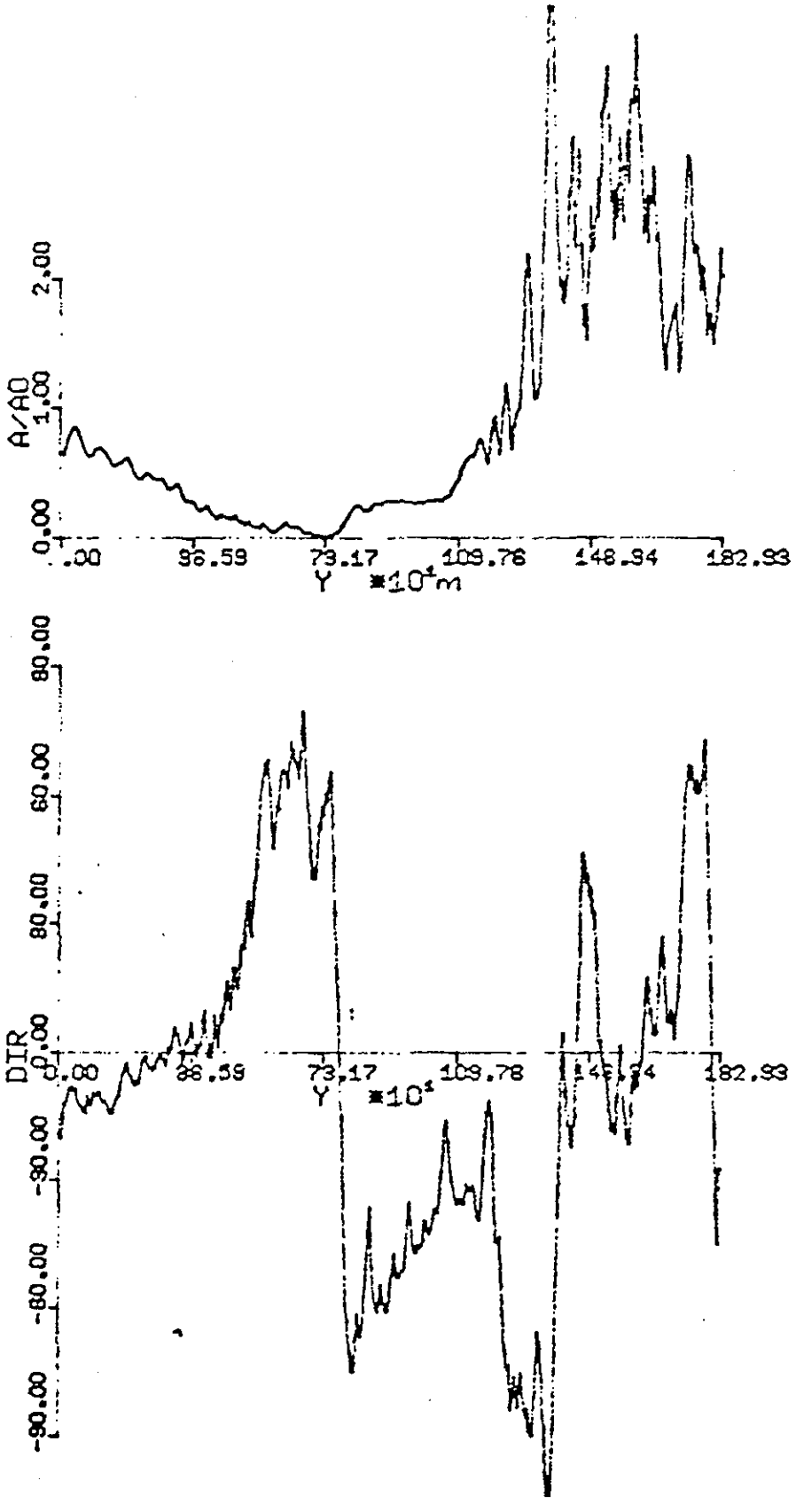

Figure 2-16. Wave height and direction from Pine Island to Black Rock for waves from the southwest with the containment structure in place at high water.

and directional variability which appear in these portions of the figures should be disregarded.

Under prototype conditions, it is reasonable to expect negligible reflection from the dikes based on the use of rubble-mound construction as proposed in the present conceptual design (COE, 1983). Waves along the windward edge of the grid should therefore remain unaffected by the presence of the structure. Accordingly, the numerical problems experienced with the model in this portion of the grid does not affect information of any significant interest. Moreover, because of the forward-scattering properties of the model, the distortion produced at the lateral boundaries does not propagate into the central portion of the grid where genuine diffraction effects occur; i.e., in the shadow zone immediately shoreward of the structure. The results obtained within this essential region of the model grid remain valid in all cases. It is possible to eliminate this problem by expanding the width of the grid sufficiently to remove the edge distortion beyond the area surrounding the DMCF. However, this approach would require a large increase in computational effort without providing any real benefit.

The important aspect of the model results is the prediction of a triangular shadow zone in the area of Pine Island Channel extending shoreward of the structure. The model confirms that the effect extends over a broad area of the channel and onto the shoreline near Avery Point. The apex of the zone is marked by a rapid change in wave direction from large positive to negative angles with increasing distance along the transect from east to west. This corresponds to the transition from the diffraction pattern produced at the eastern end of the structure to the pattern produced at the western end. The position of this point shifts in response to changes in the direction of wave approach.

The dimensions of the shadow zone also change in response to wave direction, because of changes in the effective cross-section of the structure from different angles of approach. Most importantly, the nature of this effect is in direct contrast to the pattern of wave amplification in the vicinity of Avery Point produced by the existing bathymetry.

A second dike configuration, indicating the option for expanding the area of the DMCF to the west over Frank and New London Ledges is outlined in Figure 2-1 (dashed line). This design has not been modeled since it was apparent that the resulting shadow zone would simply be widened, but remain the same in all other essential respects. Similarly, the diffraction pattern would not be affected by alterations in the lay-out of the dikes from that shown in Figure 2-1, provided that the overall horizontal dimensions of the structure remain roughly comparable with the dimensions of the shoal as defined by the 18-ft depth contour. On this basis, the above series of model runs is considered sufficient to represent a reasonable range design alternatives for the purposes of environmental assessment.

2.2.2 Potential Impacts on Physical and Chemical Characteristics of the Aquatic Ecosystem

The following sub-sections examine potential impacts in accordance with the categories define by the EPA 404 guidelines.

Substrate

Long-term changes in substrate characteristics in the area surrounding the DMCF are directly related to changes in the local wave field. As predicted in the modeling runs, the structure will provide shelter to a large portion of Pine Island Channel

and to the shoreline in the immediate vicinity of Avery Point. These areas presently experience amplified wave heights over a range of commonly occurring storm conditions.

The effect on the channel substrate will be to reduce the intermittent scouring action due to storm waves and permit the accumulation of finer grained sediments. The channel bed is presently armored with shingle, indicating the effectiveness of scouring under existing conditions. Tidal currents throughout the area will remain unaffected and will continue to transport sediments below a limiting grain size. A quantitative calculation of this limit is not possible due to the lack of near-bottom current measurements. As a rough estimate, it is considered likely that the tidal currents are capable of transporting silt and fine sand fractions, but that the reduction in wave energy will allow the deposition of medium and coarse sand to occur on a continuing basis, where this now occurs only during intervals between storm events. The supply of such sediment fractions is almost certainly low enough that the rate of deposition will not present a shoaling problem of significance to navigation. Shoaling of the smaller inlet further east leading to the anchorage at Jupiter Point might be of greater concern, except that the shadow zone does not effectively extend into this area. It also remains directly exposed to storm waves approaching from the south.

The second effect will be to dissipate the storm wave attack on the Avery Point shoreline and so reduce the rate of erosion presently experienced by this headland. It is presumed that this erosion process is not a significant source of sediment in the overall budget for littoral material along the Groton shoreline. Accordingly, the reduction in erosion should not have the effect of interrupting or significantly reducing the supply of sediment

to neighboring beaches. In particular, Shennecossett Beach should remain unaffected. Also, the shadow zone does not extend to this section of the shoreline and the beach remains directly exposed to waves from the southwest. Consequently, the local wave climate along the beach and resulting sediment transport processes should not be impacted.

Suspended Particulates/Turbidity

Suspended particulates and turbidity of the water will increase temporarily as a result of construction activities; however, the severity of the impact can be minimized with appropriate construction practices. The nature of such impacts is considered minor, being comparable with the range of natural background variability of the water column. The effect on the biota is further discussed in the following section. It is presumed that the dike will be properly designed to eliminate the possibility of wash-out of disposed dredged materials. Also, it is presumed that the operation of barging these materials to the site and transferring them to the structure will be performed with reasonable precautions to avoid spillage.

Water

Secondary water quality impacts related to the temporary increase in suspended particulates may occur during the period of construction, but with minor impact. There is no continuing discharge associated with the DMCF and, consequently, no permanent water quality impacts of concern beyond the construction period.

Current Patterns and Water Circulation

The DMCF will have a negligible effect on current patterns and water circulation. The present shoal at Black Ledge already exerts topographic control of the currents in the Pine Island Channel area. The DMCF will slightly modify the currents in the immediate vicinity of the dikes, but this effect is not consider to be of any environmental significance.

Normal Water Fluctuations

The DMCF will have a negligible impact on stillwater level fluctuations.

Salinity Gradients

The DMCF will have a negligible impact on salinity gradients.

2.2.3 Potential Impacts on Biological Characteristics of the Aquatic Ecosystem

Threatened and Endangered Species

No species with special state or federal status are known to occur in the vicinity of Black Ledge (see Beccasio et al., 1980).

Fish, Crustaceans, Molluscs, and Other Aquatic Organisms in the Food Chain

The DMCF currently envisioned for the Black Ledge site will cover an area approximately 160 acres in size. The structure will encompass most of the rocky bottom area of the Ledge, and much of the adjacent sand-and-gravel bottom area, particularly

the area lying immediately south of the Ledge. Some rocky bottom will remain along the northern portion of Black Ledge adjacent to Pine Island Channel.

The impacts to the aquatic biota can be divided among three categories. First are those impacts which will result from the destruction of natural habitat on the Ledge and in immediately adjacent areas. This impact will be mitigated to some extent by the creation of new habitat along the dikes of the facility. Second are those impacts to areas nearby the proposed structure where changes in the sedimentary environment might occur. Finally, construction-related impacts such as locally increased turbidity can have effects on the resident biota, effects which are confined to the construction-phase itself and, therefore, relatively short-lived.

The loss of bottom habitat caused by the location of a DMCF at the Black Ledge site will affect most of the rocky area of the Ledge and a larger area of bottom consisting primarily of sand and gravel. The information reviewed in subsection 2.1.2 indicates that the proposed action will destroy the existing mussel/algal community in the rocky area of the Ledge, a community which supports diverse macrofauna including a variety of amphipod crustaceans and gastropod molluscs. Information on the fish resources of Black Ledge is not available, but other rocky bottoms in northeast coastal areas are known to support a variety of fish species such as tautog, cunner, sculpins, radiated shanny, etc., and it is likely that a similar fish fauna is found here. The construction of the facility should not result in the direct destruction of this fish community, but indirectly will affect it by eliminating the physical habitat and the hard-bottom macrofauna (e.g., amphipods) on which it depends in part for food. However, the dike around the structure will

hard-bottom area (1.5 linear miles), the subtidal and intertidal portions of which will, in time, come to support a hard-bottom community likely to be very similar to that now found on the Ledge. Thus, the reduction in the hard-bottom community will be mitigated to some extent.

The elimination of the sand and gravel area south of the Ledge will, however, result in a permanent loss of this habitat type. The resident macrofuna in this area appear to be dominated primarily by amphipods, including Leptocheirus pinguis, Ampelisca spp., and Unciola irrorata. These and other macrofaunal resources will be lost to the bottom-feeding fish community which will therefore suffer a net reduction in its feeding habitat.

The preceding subsection on physical impacts of the DMCF proposed for the Black Ledge site stated that a large reduction in the energy of the wave environment is likely to occur in the "shadow" of the structure, i.e., north of the Ledge in Pine Island Channel and the adjacent shore area. At present, the Ledge appears to amplify waves reaching these areas contributing to a high-energy environment. Outside of the Ledge itself, the coarsest sediments encountered during the present study were at stations located in the Pine Island Channel. It is likely that wave energy contributes to the scouring of this area, so that a reduction in wave energy may result in an increase in the fraction of finer sediments that would accumulate. In this case, one would expect that the present macrofaunal community characterized by relatively low dominance and density would tend to shift towards that currently found in the sand and gravel environment south of the Ledge where fairly high densities and dominance by amphipods are found. Thus, some of the sand-and-gravel community eliminated south of the Ledge might be returned in the area just north of the Ledge, at the expense of the coarse gravel community

that currently exists in this area. The wave modeling analysis suggests that similar shifts in the sedimentary regime are not expected elsewhere in the study area.

Construction-related impacts to aquatic biota include temporary increases in turbidity and dissolved nutrients (nitrogen, phosphorous) and possible decreases in dissolved oxygen levels. These changes have the potential for disturbing phytoplankton, zooplankton, fish and macrofauna in the immediate vicinity of the construction site. Such disturbances would be predominantly local and short-term. Consequently, they are not regarded as being significant.

Other Wildlife

It is likely that various terns, gulls and other marine birds occur in the general Black Ledge area, but no bird species is known to be uniquely associated with or in other ways dependent on the Ledge. Moreover, there are no reports of marine mammals in this area. In that the construction of the DMCF will result in an artificial island, the possibility exists that various bird species will come to make heavier use of the area than at present.

3. PENFIELD REEF SITE

3.1 DESCRIPTION OF THE EXISTING ENVIRONMENT

3.1.1 Physical Environment

Penfield Reef is comprised of the eroded remnants of an offshore island and a tombolo extending roughly one mile west to the shoreline at Shoal Point. The tombolo is exposed at low water and provides shelter to Fairfield Beach and Black Rock Harbor to the north. The mean tidal range at Black Rock Harbor is 6.9 ft., and the spring range increases to 7.9 ft (NOAA, 1982a). This range is sufficient to submerge the tombolo during periods of high tide over the majority of its length and so allow storm waves to reach the shallow embayment fronting Fairfield Beach. The seaward side of the tombolo is fronted by a terrace of hard sand extending roughly 2,000 ft offshore to the 6-ft depth contour (MLW). This terrace offers effective wave protection so that storm waves which reach the crest of the tombolo and reform on the back side are substantially reduced. Extreme storm conditions are likely to scour the terrace sediment and produce washover to the Fairfield Beach embayment. The crest itself is armored with coarse gravel and cobble, evidence of the repeated agitation provided by breaking waves during high tides. Under less extreme conditions, the shallow, mildly sloping profile of the terrace produces a wide surf zone characterized by spilling breakers. In turn, this implies a broad alongshore current system and an effective mechanism for sediment transport over the width of the terrace.

In order to provide a more detailed description of the wave characteristics in the immediate vicinity of the reef, the refraction model was used to simulate the wave fields produced under various storm conditions. Results were obtained for waves approaching from the southeast, south and southwest with offshore heights of 6.6 ft (2.0 m). The resulting wave heights and directions are presented in Figures 3-1, 3-2, and 3-3 for the three respective cases. A tidal elevation corresponding to mean high water is assumed in order to allow unbroken waves to propagate over the width of the terrace to the approximate crest of the tombolo. As might be expected, the shoal formations at the eastern end of the tombolo act as a focal point for waves from the south and southeast. Waves from the southwest are more evenly distributed in height over the length of the tombolo. Also, the south and southeasterly approaches produce a wave angle relative to the axis of the tombolo which would produce westerly littoral drift. The southwesterly appoach produces a normal wave attack, implying minimal longshore transport. These results are consistent with observations of a predominant westerly direction of the littoral drift in the general area and support the concept of a sacrificial beach of clean spoil material connecting the shoreline and the diked outer island to supply sediment to the shoreline west of the reef.

The local area where the tombolo joins the shoreline at Shoal Point is indicated to be a region of moderate defocusing in all three model runs. This is consistent with the concave form of the 6-ft depth contour, suggesting that this section of the shoreline may be an area of reduced transport and perhaps intermittent deposition. The model indicates that the defocusing effect is sufficient to produce only a modest reduction in the height of storm waves at high tide, so that effective scouring and alongshore transport is expected to occur under such

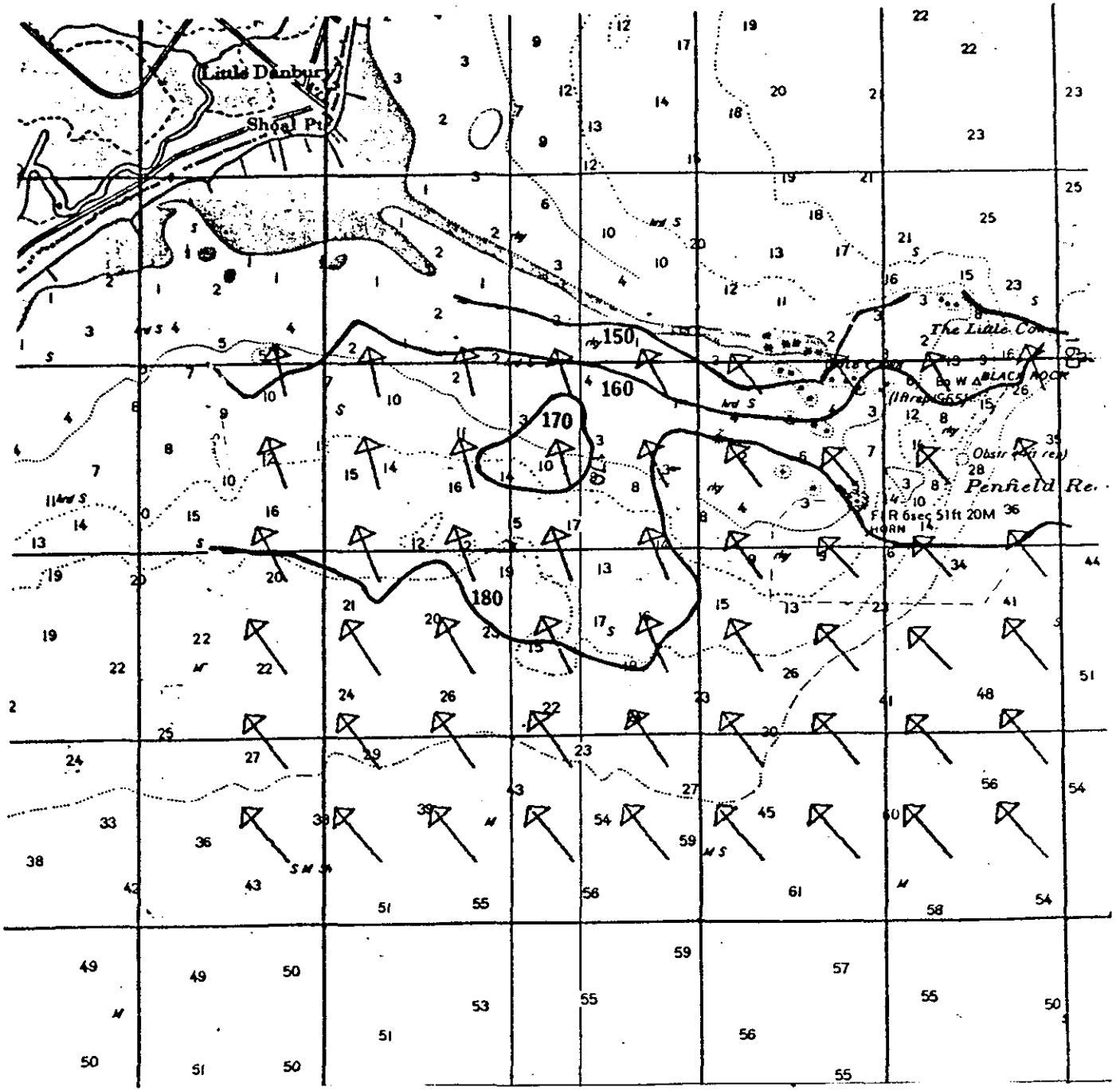

Figure 3-1. Model wave height and direction for waves from the southeast at Penfield Reef. The wave height contours are labeled in centimeters and the length of the wave vectors is proportional to the local wavelength.

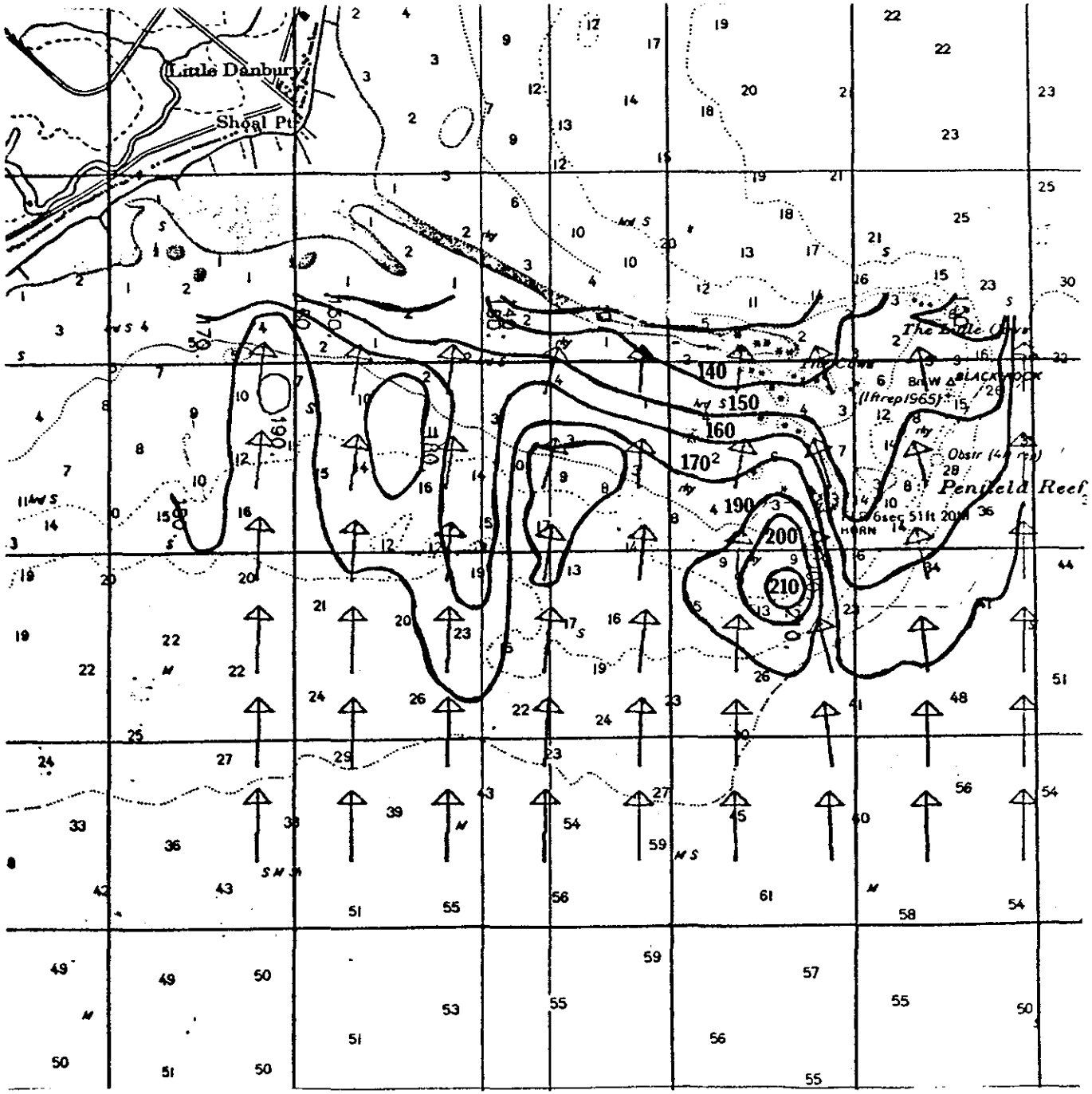

Figure 3-2. Model wave height and direction for waves from the south at Penfield Reef. The wave height contours are labeled in centimeters and the length of the wave vectors is proportional to the local wavelength.

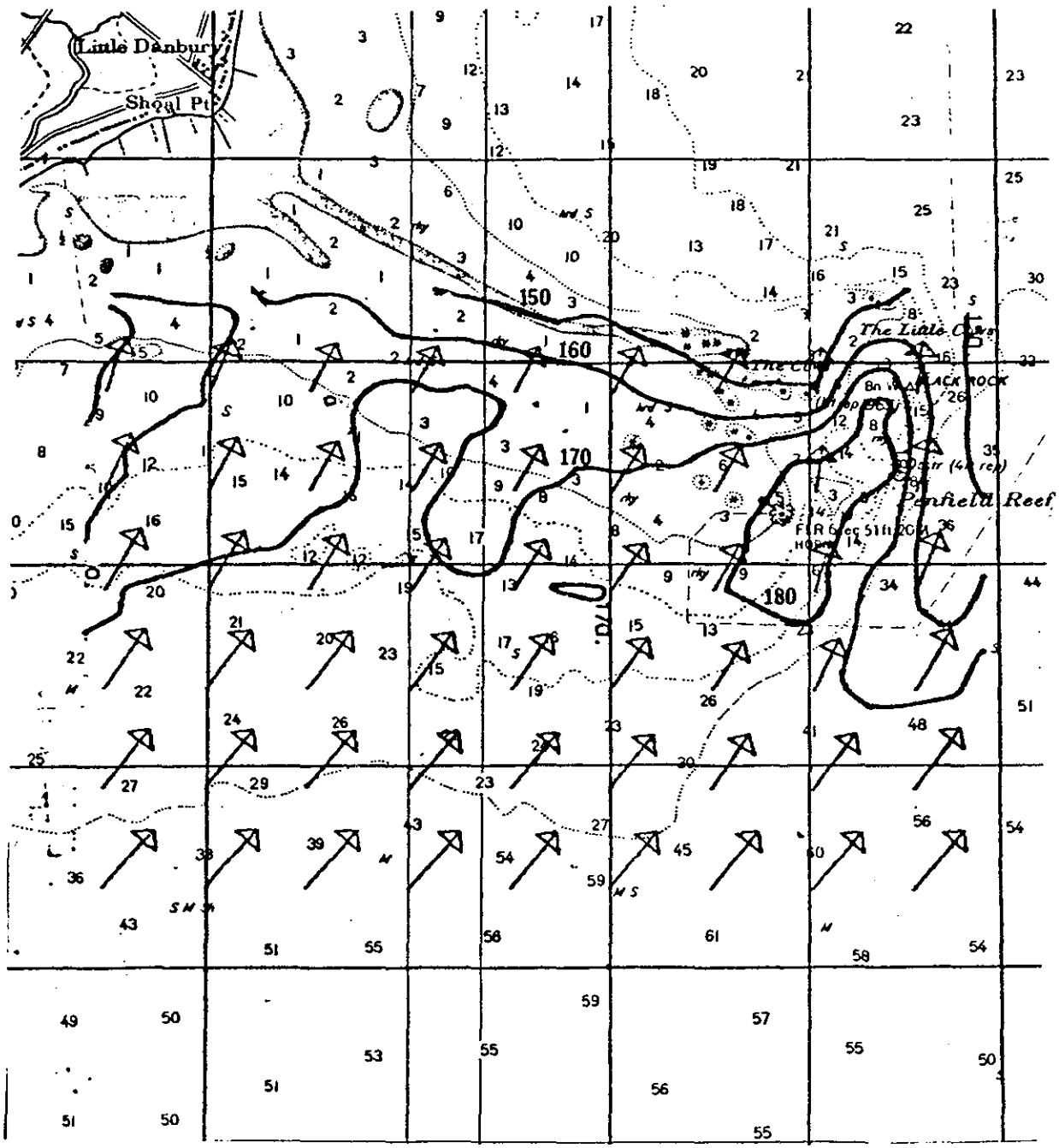

Figure 3-3. Model wave height and direction for waves from the southwest at Penfield Reef. The wave height contours are labeled in centimeters and the length of the wave vectors is proportional to the local wavelength.

conditions. Nevertheless, this does not appear to be a relatively low energy environment in comparison with sections further east along the reef.

The patterns of wave heights and directions within the deep-water approach to Black Rock Harbor north of the reef, especially in the immediate vicinity of the shoal formations, are likely to be affected by diffraction. The refraction model is unable to account for this process so that the results are strictly valid only for the offshore areas fronting the reef system to the south and east. This limitation was considered acceptable because these are the high-energy areas where wave impacts are most likely to be significant. Also, the distance is considerable from the shoals to points along the northerly shoreline off Fairfield Beach. Diffraction effects are most likely to be limited to a fraction of these length scales and so may be considered as localized effects. The mild bottom slope, concave planform, and north-south alongshore alignment of the Fairfield Beach embayment implies that the wave energy will be substantially reduced as it propagates toward the shoreline. An attempt at detailed modeling of this low-energy area was not considered justified within the scope of the present study. If significant questions concerned with local effects in this area do arise at a later time, the refraction-diffraction model could then be employed to provide an accurate means of impact assessment.

A second limitation of the model is that the refraction analysis is valid only to the limit of the breaker line. Inshore of this boundary, e.g., within the surf zone, the wave processes become too complex to model accurately. With the assumption of high-tide conditions, the breaker line is moved inshore virtually to the crest of the tombolo so that the model provides valid results over at least the majority of the area of interest.

3.1.2 Biological Environment

As is the case for Black Ledge, the Penfield Reef site was the subject of an earlier biological reconnaisance survey that involved sampling of both hard-bottom on the shoals at the eastern end of the reef system and in soft-bottom areas removed from the Reef. The results of this survey are reported in NAI (1982) and will be summarized below before presenting the results of the present study.

Station locations for the NAI (1982) survey, conducted during late summer 1982, are plotted in Figure 3-4. Destructive samples (diver collections) were taken in hard-bottom areas and grab samples in nominally soft-bottom areas. However, the grab was unable to penetrate the bottom at Stations 3, 4, 7, 9 and 11, so that soft-bottom macrofaunal data are available from only 11 of the 16 stations where sampling was attempted.

The hard-bottom macrofaunal and algal communities of the shoals were found to be extremely rich; this area supported some 122 species of benthic invertebrates and 23 species of algae, at densities averaging upwards of 235,000 m^{-2}. The overwhelmingly dominant forms were the amphipods *Jassa falcata*, *Corophium* spp., and *Caprella penantis*. Together and in approximately equal proportions, these three taxa contributed about 83% of the total number of individuals recorded at the shoals stations. All are normal constituents of hard-bottom communities in northeast coastal environments, although *Corophium* is observed on soft bottoms as well and, like *Ampelisca*, is a tube dweller.

Compared to the hard-bottom stations, the soft-bottom areas sampled around Penfield Reef were rather depauperate: density

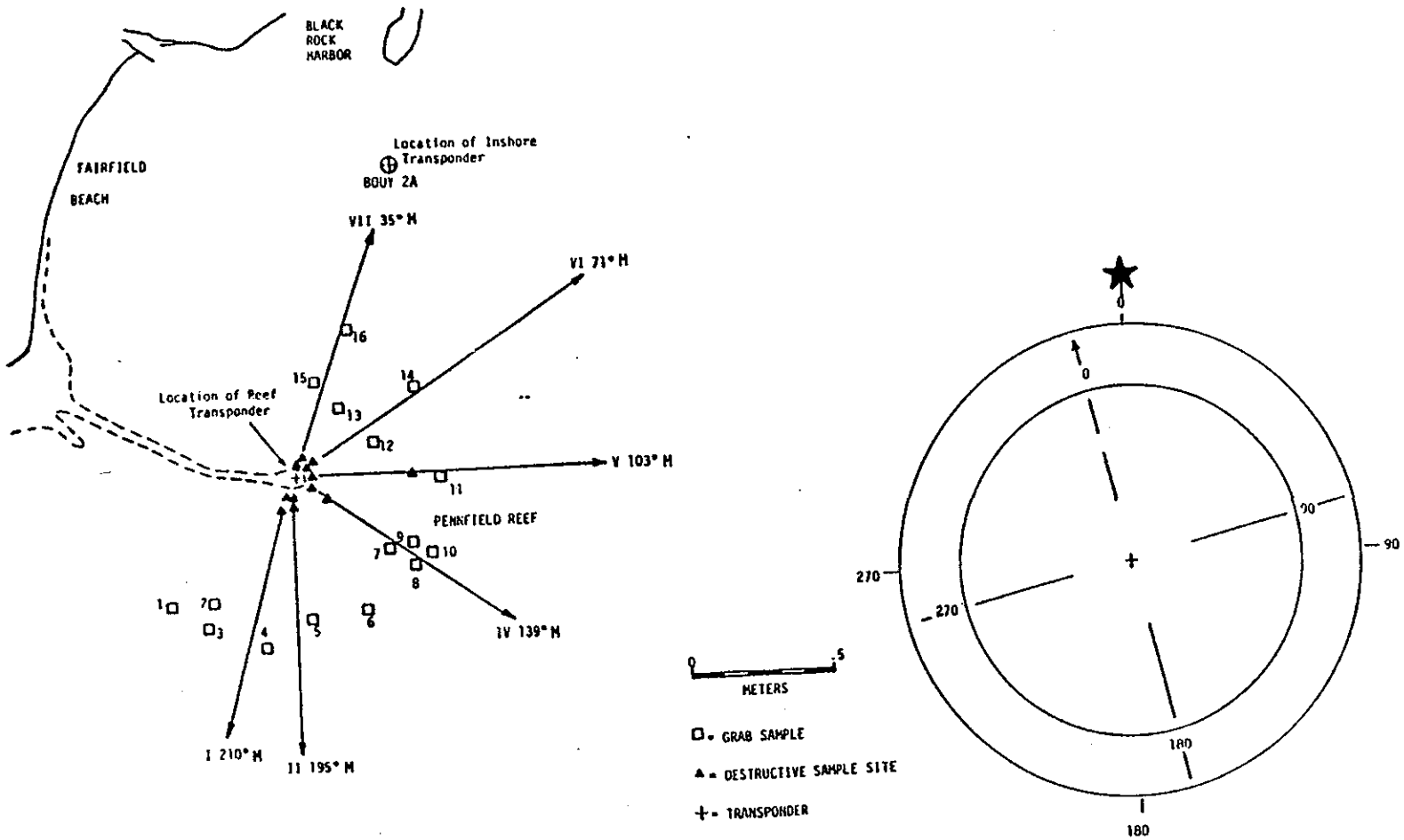

Figure 3-4. Transects and grab stations at Penfield Reef (from NAI, 1982).

averaged 1230 m^{-2}. Moreover, although 125 taxa were collected from the grab samples, many occurred at only one or several stations so that the mean number of taxa per station was 23; this compares with 42 at the Reef stations where 122 taxa were collected overall.

NAI (1982) reported that the grab samples produced a mixture of hard- and soft-substrate taxa. In general, soft-bottom forms contributed the dominant taxa at most stations, although these varied greatly among stations. The polychaetes Mediomastus sp., Spiophanes bombyx and Streblospio benedicti were among the dominants at several stations, while oligochaetes, the bivalve Mulinia lateralis and the gastropod Acteocina canaliculata were numerically important at two stations each. Hard-substrate forms such as the tube-building polychaete Sabellaria vulgaris, the caprellid amphipod Paracaprella tenuis, and the hydroid Hydractinia sp., were also among the numerically dominant organisms at two of the stations, but not to the exclusion of soft-bottom species.

The present study examined the soft-bottom fauna of the Penfield Reef area during July 1983. Station locations and substrate type are indicated in Figure 3-5. Sediment type showed low consistency from one grab to the next but, in general, sand-sized sediments were most often encountered.

A total of 112 macrofaunal taxa were collected in the study area, to which the polychaetes contributed 50 taxa (45% of the total), the crustaceans 30 (27%), and the molluscs 22 (20%).

Total mean density in the study area was 5516 m^{-2}, of which the 10 most abundant taxa accounted for 4900 m^{-2} or 89% (Table 3-1). All 10 can be regarded as primarily soft-substrate forms.

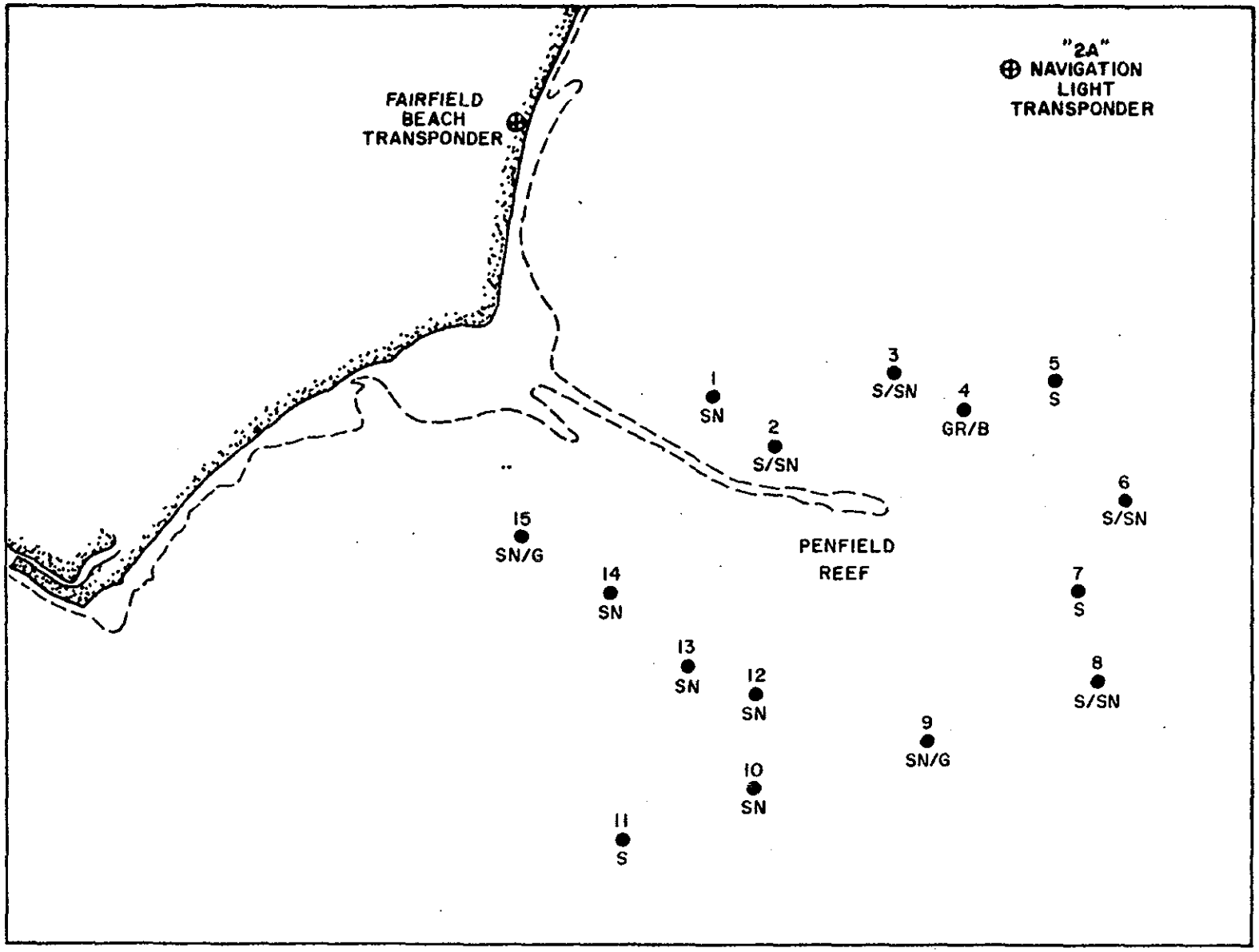

Figure 3-5. Station locations and sediment types at the Penfield Reef Site, July 1983. B: boulder; G: gravel; Sn: sand; S: silt.

Table 3-1. Ten numerically most important macrofaunal taxa at the Penfield Reef Site, July 1983. B: bivalve; P: polychaete.

		No./m^2	% Total Density
1.	*Mediomastus ambiseta* (P)	1454	26.4
2.	*Tellina agilis* (B)	980	17.8
3.	Archiannelida (P)	822	14.9
4.	*Nucula proxima* (B)	497	9.0
5.	*Yoldia limatula* (B)	317	5.7
6.	Oligochaeta	295	5.3
7.	*Tharyx acutus* (P)	256	4.6
8.	*Pitar morrhuanus* (B)	108	2.0
9.	*Polydora ligni* (P)	96	1.7
10.	*Spiophanes bombyx* (P)	75	1.4
	Total	4900	88.8

The capitellid polychaete Mediomastus ambiseta was the most frequently encountered organism in the study area followed by the bivalve Tellina agilis; both are deposit feeders. Archiannelids include several families of diminutive polychaetes adapted for life in the interstitial spaces of sandy bottoms (Fauchald, 1977); they, too, are deposit feeders and formed the third most abundant group recorded from the Penfield Reef site.

Figure 3-6 reveals that the three deposit-feeding taxa mentioned above contributed the dominant forms at most of the stations sampled: M. ambiseta was a dominant or co-dominant at 6 stations, T. agilis also at 6 stations, and archiannelids at 4 stations. The spatial separation of the dominant forms was less pronounced than at the Black Ledge site. In general, there appeared to be a trend for the archiannelid-dominanted stations to lie south of the Reef while Mediomastus-dominated stations lie north and east of the Reef. Archiannelids may be the better adapted forms for shifting-sand environments which suggests, on biological grounds, that the Sound side of the Reef is the more energetic environment. The co-dominance of the tube-building polychaete Spiophanes bombyx at two of these stations (10 and 12) also suggests this interpretation. In the Black Ledge study area, Spiophanes was best represented in the higher-energy sand and gravel environments and dominant at one of the gravel stations.

Additional information on the biological resources of the Penfield Reef environment was provided by the Fish and Wildlife Service, U.S. Department of the Interior, in a letter to the New

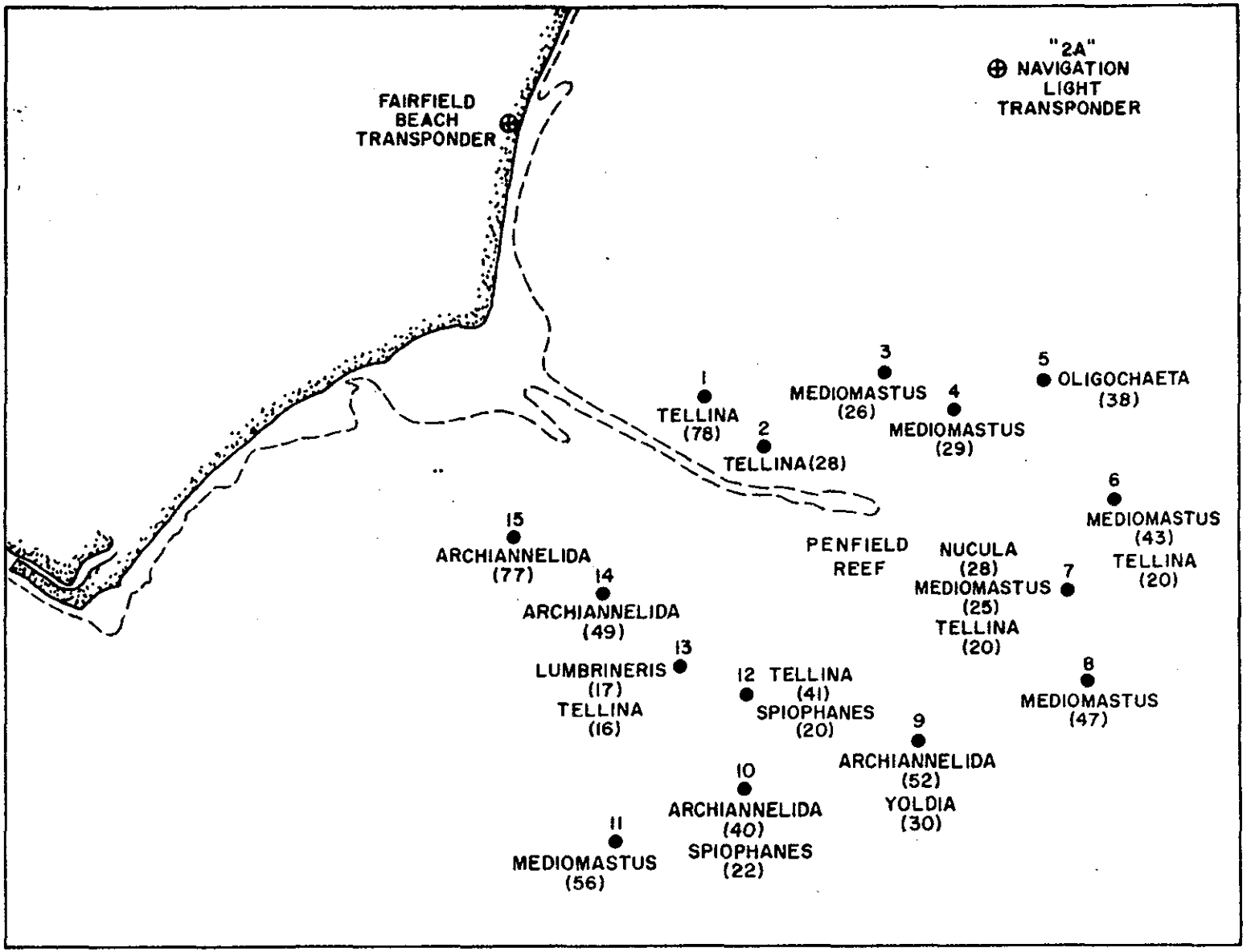

Figure 3-6. Dominant species of macrofauna at the Penfield Site, July 1983. Figures in parentheses indicate the percentage of total macrofaunal density contributed by dominant species at each station.

England Division of the Corps of Engineers (reproduced in COE, 1983). The relevant portion of that letter is quoted below:

> Penfield Shoals/Reef-- This site is located off of Shoal Point, Fairfield, Connecticut. Preliminary plans envision island creation with diking on four sides. The reef is approximately one-mile long and is one of the few areas along this part of the coast that has a significant amount of rocky-cobble bottom. It is a very productive area from a fish and wildlife standpoint. There is a large natural bed of oysters and hard clams that extends from the reef, east, to well below Pine Creek Point. The reef area also supports a large population of blue mussels. Immediately to the north and west of the reef there are leased shellfish beds. The rocky habitat around Penfield Light is a productive area for lobsters. Both shore-based and boat fishermen utilize the area. It is considered to be one of the better surf fishing spots in the State of Connecticut. Predominate fish species include striped bass, bluefish, weakfish, winter and summer flounder and Atlantic mackerel. This shoal area is also extensively utilized by waterfowl such as black ducks and Scaup and provides excellent feeding and resting habitat for a large variety of seabirds and shorebirds.

In summary, the Fish and Wildlife Service regards the Penfield Reef area as ecologically sensitive and important. Overall, the area can be described as supporting a rich and productive hard-bottom community which, in turn, is important as food and habitat for other larger crustaceans and fish. The soft (silt/sand) communities are less diverse and apparently less productive than Black Ledge, but similar to other soft-bottom areas in this general region of Long Island Sound.

3.2 POTENTIAL IMPACTS OF A DREDGED MATERIAL CONTAINMENT FACILITY

This section of the report provides a preliminary analysis of the impacts of a DMCF on the physical, chemical, and biological characteristics of Penfield Reef. The sub-sections correspond to the impact categories defined by the EPA 404 guidelines.

The conceptual design of the DMCF proposed for Penfield Reef (COE, 1983) consists of a diked containment structure aligned with the axis of the tombolo as shown in Figure 3-7. As in the case of the Black Ledge site, rubble-mound construction would be used for the dikes with a suitable cover of armor stone. Along the southern, inshore corner of the structure in the vicinity of Shoal Point, the toe of the dike would be surrounded with clean spoil material to serve as a sacrificial sand reservoir for supplying littoral material to the presently eroding stretches of shoreline to the west of the site.

As evident from Figure 3-7, the toe of the southern dike would not extensively encroach on the terrrace fronting the tombolo. In fact, it can be presumed that the stucture lies within the present limits of the surf zone, except perhaps during periods of high water when the breaker line may move inshore virtually to the crest of the reef. Also, in view of the rubble-mound construction, no wave reflection is anticipated from the face of the dike, so that the offshore wave characteristics (beyond the breaker line) computed by the model remain valid for the post-construction condition, as well as for the existing bathymetry. Provided that the dike does not extend further onto the terrace, the impact of the structure on the alongshore transport of sediment should be minor. The major impact of the structure on the wave regime is the elimination of wave energy

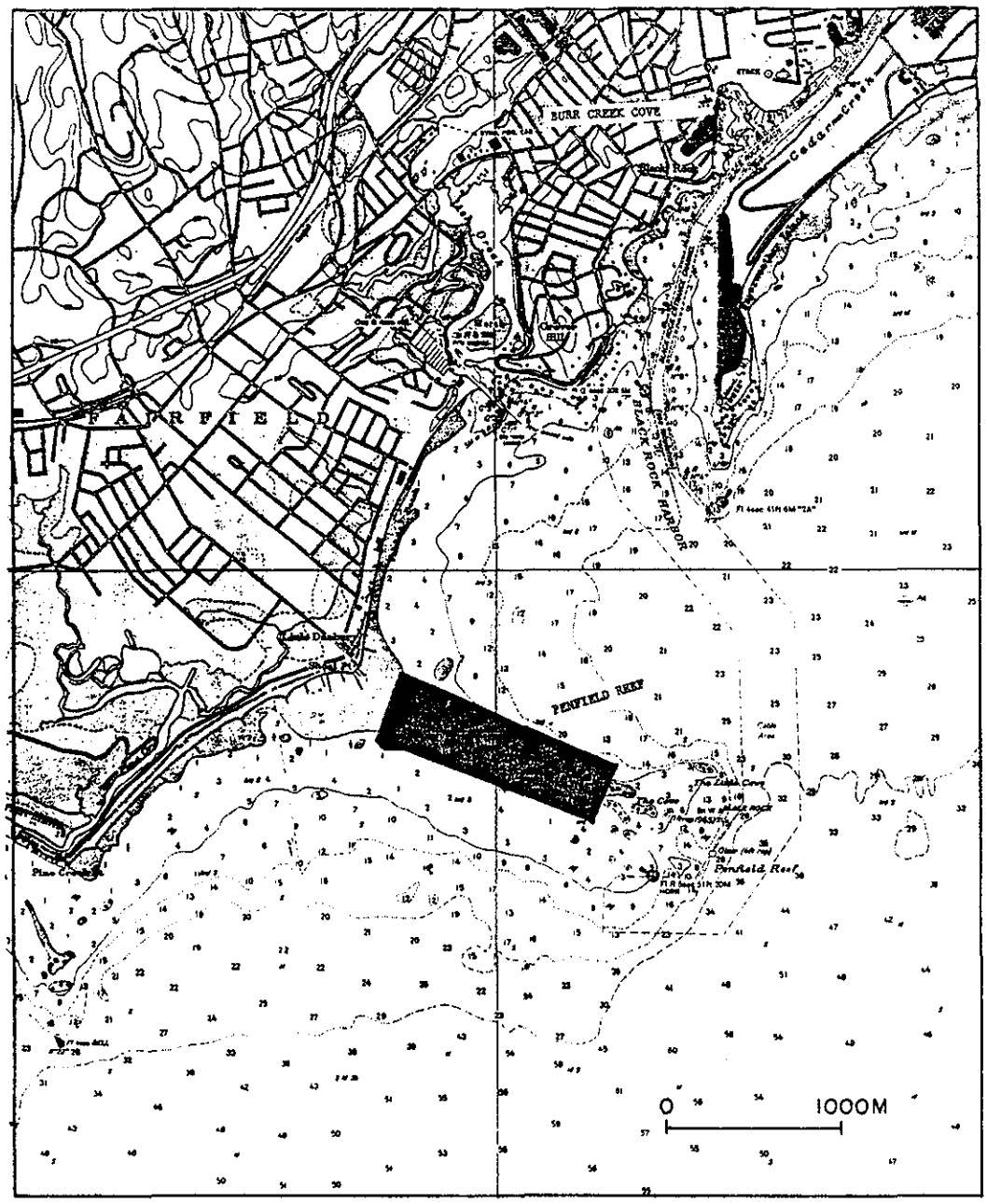

Figure 3-7. Location of the proposed containment facility for Penfield Reef (from COE, 1983).

propagation over the crest of the reef and into the embayment fronting Fairfield Beach. As noted previously, the refraction model is not capable of simulating this wave transmission process nor the complex propagation processes governing the wave field to the north of the reef.

3.2.1 Potential Impacts on the Physical and Chemical Characteristics of the Aquatic Ecosystem

Substrate

According to the lay-out shown in Figure 3-7, the DMCF will not impact the alongshore transport of sediment along the length of the tombolo. The spoil material proposed for the area fronting Shoal Point will be eroded and transported westward; however, the concave shape of the depth contours at this point and the resulting divergence of the wave vectors, implies that this is not an area of active erosion and that the removal of this material may be a gradual process. In turn, if this material is not provided, or periodically replenished, the reduced wave energy produced by the offshore bathymetry would not be expected to produce a serious erosion problem at the inshore end of the structure. Flanking of the structure at this point is not anticipated to be a serious design problem, nor lead to an interruption in the alongshore transport of sediment, except perhaps under extreme storm conditions.

The major impact of the DMCF will be the prevention of overwash to the northern side of the reef and the consequent decrease in the supply of sediment to this general area. This impact is not significant in terms of the stability of the Fairfield Beach shoreline, since the volume of overwash is comparatively minor in this context. However, the process is

signficant in a biological context and the nature of the impacts is discussed in detail in the following section.

Suspended Particulates/Turbidity

Suspended particulates and turbidity of the water may increase temporarily as a result of construction activities; however, as in the case of the Black Ledge site, this is considered a minor impact, comparable with the effects of natural variability in the water column. No persistent effects are anticipated.

Water Quality

Water quality impacts may occur during the period of construction; however, as in the case of suspended particulates, the effects are not of significant concern. There is no discharge associated with the DMCF and, consequently, no permanent water quality impacts of concern beyond the construction period.

Current Patterns and Water Circulation

The DMCF will have a negligible impact on current patterns and water circulation in the area offshore of the reef. The proposed structure will prevent storm wave transmission over the reef during periods of high tide, therby providing a signficant sheltering affect under these conditions. It is not anticipated to affect tidal currents or residual circulation to any signficant extent.

Normal Water Fluctuations

The DMCF will have a negligible impact on stillwater level fluctuations.

Salinity Gradients

The DMCF will have a negligible impact on salinity gradients.

3.2.2 Potential Impacts on Biological Characteristics of the Aquatic Ecosystem

Threatened and Endangered Species

No threatened or endangered species are known to occur in the Penfield Reef area (see Beccasio et al., 1980).

Fish, Crustaceans, Molluscs, and Other Aquatic Organisms in the Food Web

As was discussed in subsection 2.2.2, the potential impacts on aquatic biota of a DMCF can be divided into three categories: 1) direct impacts on resident biota at the site where the facility is to be built; 2) indirect impacts on biota in areas nearby the facility site that undergo a change in the sedimentary environment; and 3) construction-related effects such as increased turbidity, increased nutrients and lower dissolved oxygen levels which are generally localized, short-lived and therefore minor.

Because the subtidal hard-bottom environment of Penfield Shoals appears to be, at least seasonally, extremely productive of macrofaunal forms (e.g., amphipods) important in marine food

chains, construction in this area would cause direct impacts that would have to be regarded as severe. However, the proposed DMCF (as illustrated in Figure 3-7) would extend along the tombolo trending easterly towards the productive shoals area, but would stop short of encroaching on this area. Presumably, similarly productive rocky bottom would be lost in the areas immediately adjacent to the Reef, but this would be mitigated to some extent through the provision of new hard substrate by the DMCF structure. In any case, the highly productive environment of the Penfield Shoals area would be left primarily intact given the presently proposed configuration of the proposed DMCF.

The biological results of the present study suggest that the marine area south of the Reef was the somewhat more energetic environment than north of the Reef. It is likely that the presence of the proposed DMCF would intensify this trend, with finer sediments becoming more conspicuous north of the structure, leading to a greater preponderance in this area of deposit-feeding forms characteristic of silt and fine sand environments. This would tend further to differentiate the macrofaunal community of this area not only from that found south of the Reef but also that found east of the proposed facility and just north of the shoals. Such a change would not constitute a significant ecological impact, however.

Other Wildlife

The U.S. Fish and Wildlife Service has noted (see letter reproduced in COE, 1983) that Penfield Reef is utilized by waterfowl such as black ducks and scaup and provides feeding and resting habitat for a variety of seabirds and shorebirds. The construction of a DMCF in this area will no doubt compromise its habitat value for many of these species. However, in the

postconstruction phase, it is probable that at least some of the marine birds currently utilizing the area would return.

4. SHERWOOD ISLAND BORROW PIT SITE

4.1 DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1.1 Physical Environment

The physical conditions characterizing this area are described in detail in a study performed by the Corps of Engineers in connection with a beach restoration project (COE, 1981). This study includes hindcast wave data, graphic wave refraction analyses, and some drogue measurements reflecting the magnitude and direction of the alongshore current. Briefly, the shoreline west of Sherwood Point, known as West Beach, is exposed to storm waves approaching from the southeast quadrant, producing westward littoral drift and sediment transport. An extensive shoal formation surrounding Cockenoe Island limits the fetch to roughly two miles within the southwest quadrant. Tidal currents set predominantly westward on both flood and ebb cycles with speeds ranging up to 0.3 meters per second (0.6 knots). The mean and spring tidal ranges are 7.0 and 8.0 ft, as listed by NOAA at the mouth of the Saugatuck River two miles west of the site (NOAA, 1982a).

4.1.2 Biological Environment

No systematic benthic surveys have previously been conducted at the Sherwood Island Borrow Pit site as part of the Corps' Long Island Sound Dredged Material Containment Study. The Corps has stated that "tests indicate ... very little, if any, marine life exists in these very deep pits due to the anaerobic conditions"

(COE, 1983). The objectives of the present surveys conducted during July and September 1983 were to confirm the suspected anaerobic nature of the borrow pit or pits and, in general, to characterize better the existing macrofaunal community in the surrounding area.

Figure 4-1 shows station locations during the July cruise and bottom types encountered at that time. Silt was clearly the predominant sediment type, occasionally containing shell debris. Stations 4 and 10 were the deepest sampled within the nominal pit boundary, both at 40 feet. The surrounding bottom was generally in the 25-30 foot depth range (see Appendix B), so Stations 4 and 10 represent pit samples. Station 10 had silty sediments, but Station 4 consisted of detritus and rock in addition to silt.

The 30 grab samples collected in July at the Sherwood Island site produced a much smaller total number of species or taxa than collected in the 30 samples taken during the same period at each of the other two sites surveyed in this study: 49 versus 140 at Black Ledge and 112 at Penfield Reef. This is, at least partly, a consequence of the much more uniform sedimentary environment in the Borrow Pit area. Of the 49 taxa, polychaetes contributed 19 (39%), molluscs 16 (33%), and crustaceans 7 (14%).

Polychaetes dominated taxonomically, but molluscs dominated numerically. Of the 10 most abundant species in the study area (Table 4-1) molluscs contributed 6 and polychaetes 3. One species of filter-feeding bivalve, *Mulinia lateralis*, accounted for 55% of all individuals counted. The most abundant polychaete was a deposit-feeding species, the capitellid *Mediomastus ambiseta*. Together these two organisms contributed 76% of total macrofaunal density and dominated most of the stations in the

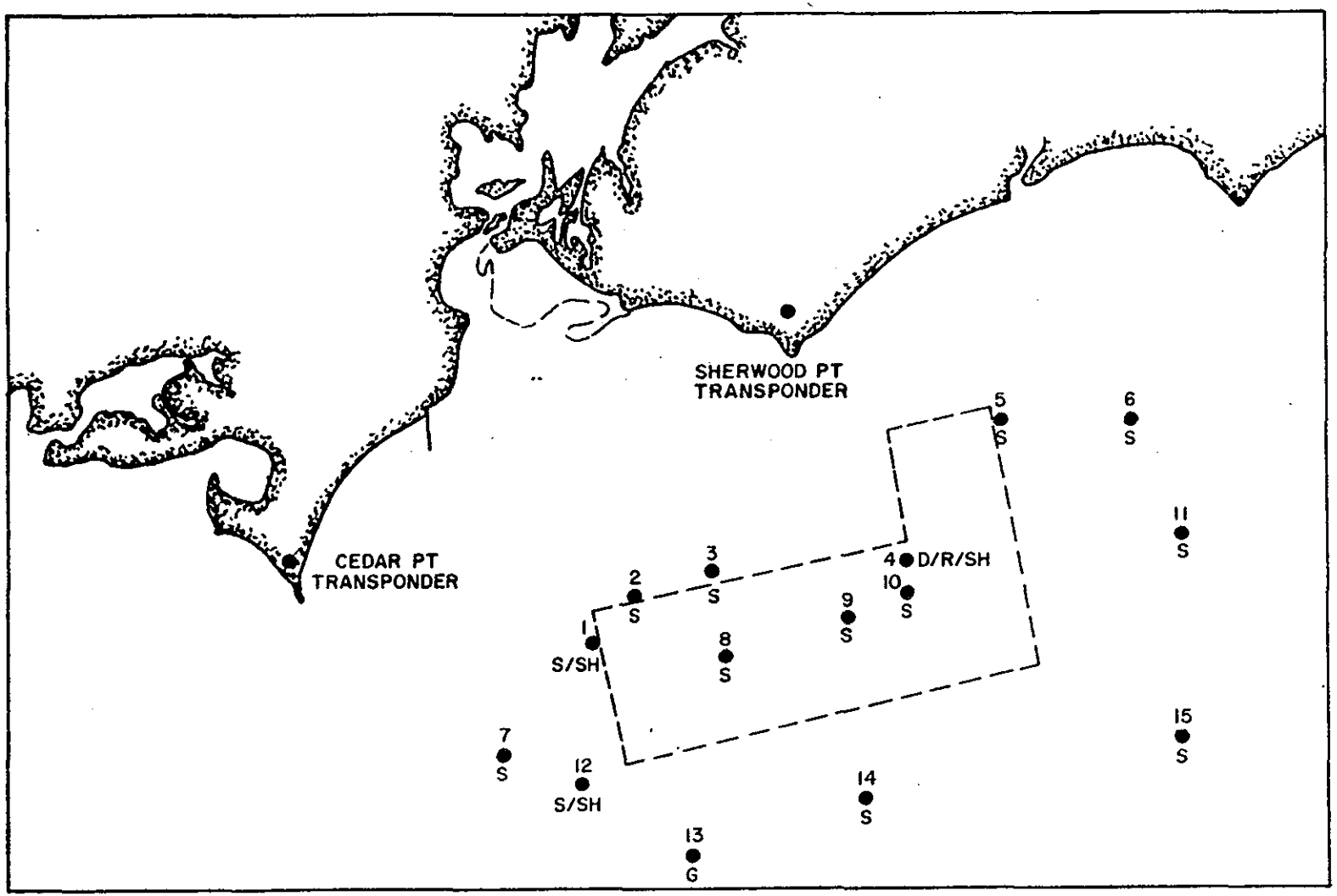

Figure 4-1. Station locations and sediment types at the Sherwood Island Borrow Pit Site, July 1983. D: detritus; G: gravel; R: rock; Sh: shell debris; S: silt.

Table 4-1. Ten numerically most important macrofaunal taxa at the Sherwood Island Borrow Pit Site, July 1983. B: bivalve; G: gastropod; P: polychaete.

		No./m^2	% Total Density
1.	*Mulinia lateralis* (B)	5822	55.4
2.	*Mediomastus ambiseta* (P)	2189	20.8
3.	Oligochaeta	635	6.0
4.	*Tellina agilis* (B)	402	3.8
5.	*Yolida limatula* (B)	316	3.0
6.	*Nucula proxima* (B)	277	2.6
7.	*Pectinaria gouldii* (P)	140	1.3
8.	*Nassarius trivittatus* (G)	114	1.1
9.	*Nephtys incisa* (P)	99	0.9
10.	*Cylichnella canaliculata* (G)	94	0.9
	Total	10,088	96.0

study area. This is illustrated in Figure 4-2. Mulinia is dominant at 7 stations; Mediomastus is dominant at 4 stations; and the two forms co-dominant at the remaining 4 stations. Other occasionally important taxa include oligochaetes and the bivalve Tellina agilis, both deposit feeders. Note that deposit-feeding is the primary trophic mode at the pit stations (4 and 10). At most other stations, the filter-feeding Mulinia is either the clear dominant or at least a co-dominant. Mulinia is regarded as an opportunistic bivalve and one that requires a reasonably stable bottom environment (i.e., low near-bottom turbidity) in order to prosper (Rhoads, 1974).

Although Stations 4 and 10 appeared to be distinguished from most other stations sampled by a preponderance of deposit feeders--Stations 7 and 9 were also dominated by deposit feeders--no strong trends with respect to density are apparent. Density in the pit was on the order of 4,000-5,000 m^{-2}, versus about 10,500 m^{-2} in the study area overall, but five other stations--all located outside of the nominal Borrow Pit site boundaries--had lower densities (see Appendix C for replicate data). Moreover, mean values for number of taxa, diversity, and evenness recorded for Stations 4 and 10 were somewhat higher than in the entire study area. The picture presented in July 1983, therefore, was one of fairly uniform environmental and biological conditions throughout the study area. The preponderance of an opportunistic species suggests an early successional stage, i.e., that the benthic ecosystem was generally immature. It is likely that the system is perturbed by seasonal storms.

One final observation made during the July cruise to the Sherwood Island Borrow Pit site is relevant: the area around Stations 4 and 10, i.e., in and around the pit, was being heavily fished for lobster.

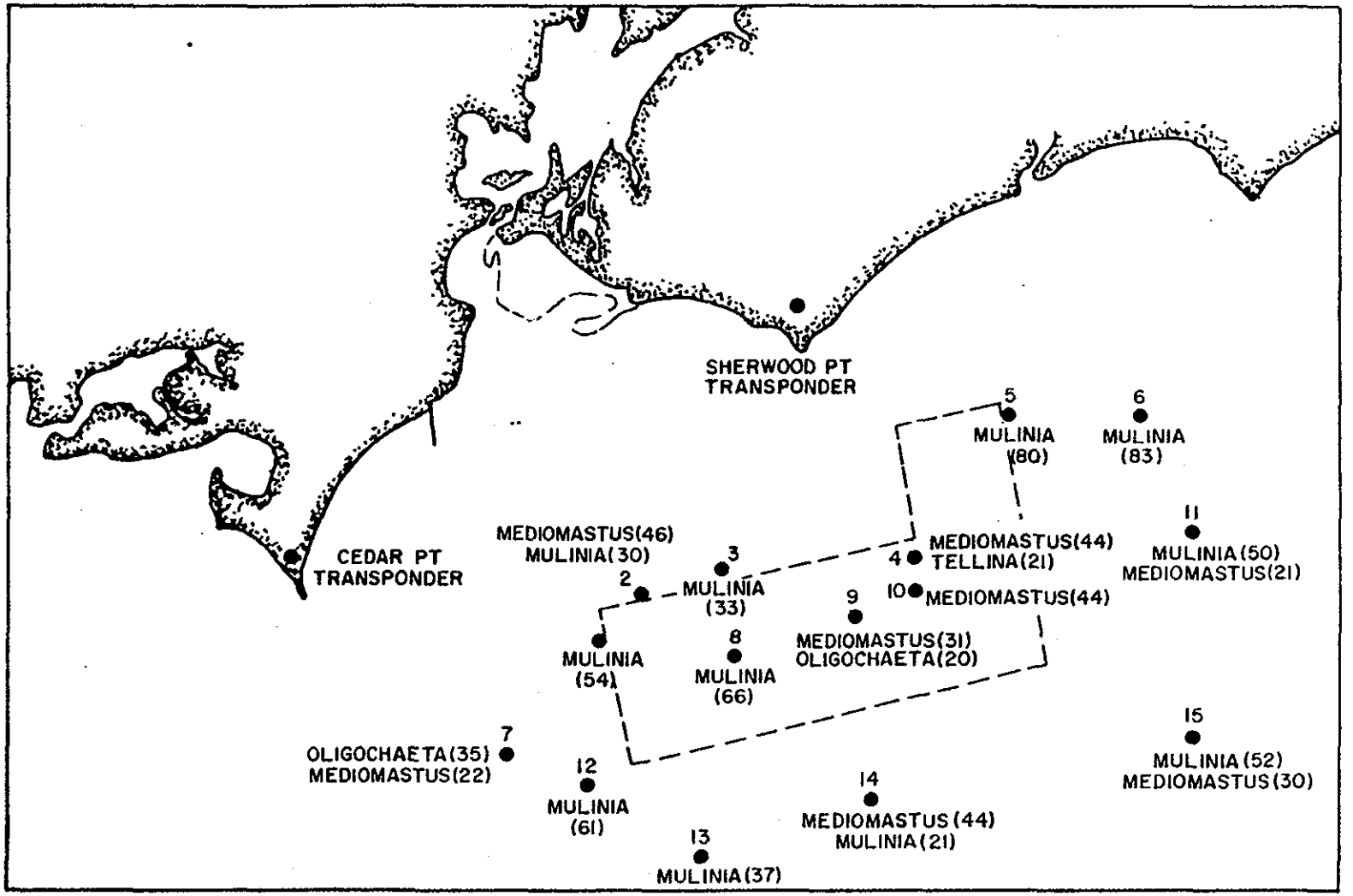

Figure 4-2. Dominant species of macrofauna at the Sherwood Island Borrow Site, July 1983. Figures in parentheses indicate the percentage of total macrofaunal density contributed by dominant species at each station.

In September, when the site was revisited, the lobster gear was gone. This may have been a partial consequence of the apparently hypoxic conditions of the pit environment. Station locations and bottom conditions during the September cruise are indicated in Figure 4-3. Silt was again the predominant sediment type, but many more samples contained shell debris. Malodorous samples were obtained from Stations 4 and 10, indicating anoxic conditions in the bottom sediments of the pit. Malodorous sediments were also retrieved at Station 14, which suggests that this station may also have been located in a relict pit, though one that is outside the nominal boundaries of the Borrow Pit site.

The total number of taxa recorded for the area had decreased slightly from July to 43. The polychaetes remained taxonomically dominant with 17 species (40%); molluscs contributed 12 species (28%) and the crustaceans 8 (19%).

Total macrofaunal density in the area had also decreased from July, to a mean of 4,096 m^{-2}. Density at the three stations (4, 10, and 14) yielding malodorous sediments were particularly low, averaging 694 m^{-2}. At Station 10 only 268 individuals per m^2 were recorded; these were dominated by an opportunistic polychaete species, Streblospio benedicti.

Other numerically important species in the study area are listed in Table 4-2. Although its density was down by half since the July survey, Mulinia lateralis increased its share of the total macrofauna from 55% to 71%. Figure 4-4 shows that Mulinia was the dominant at 13 of the 15 stations sampled. No Mulinia were found at Station 10, deep in the pit and dominated, as noted, by Streblospio, and only two specimens were collected at

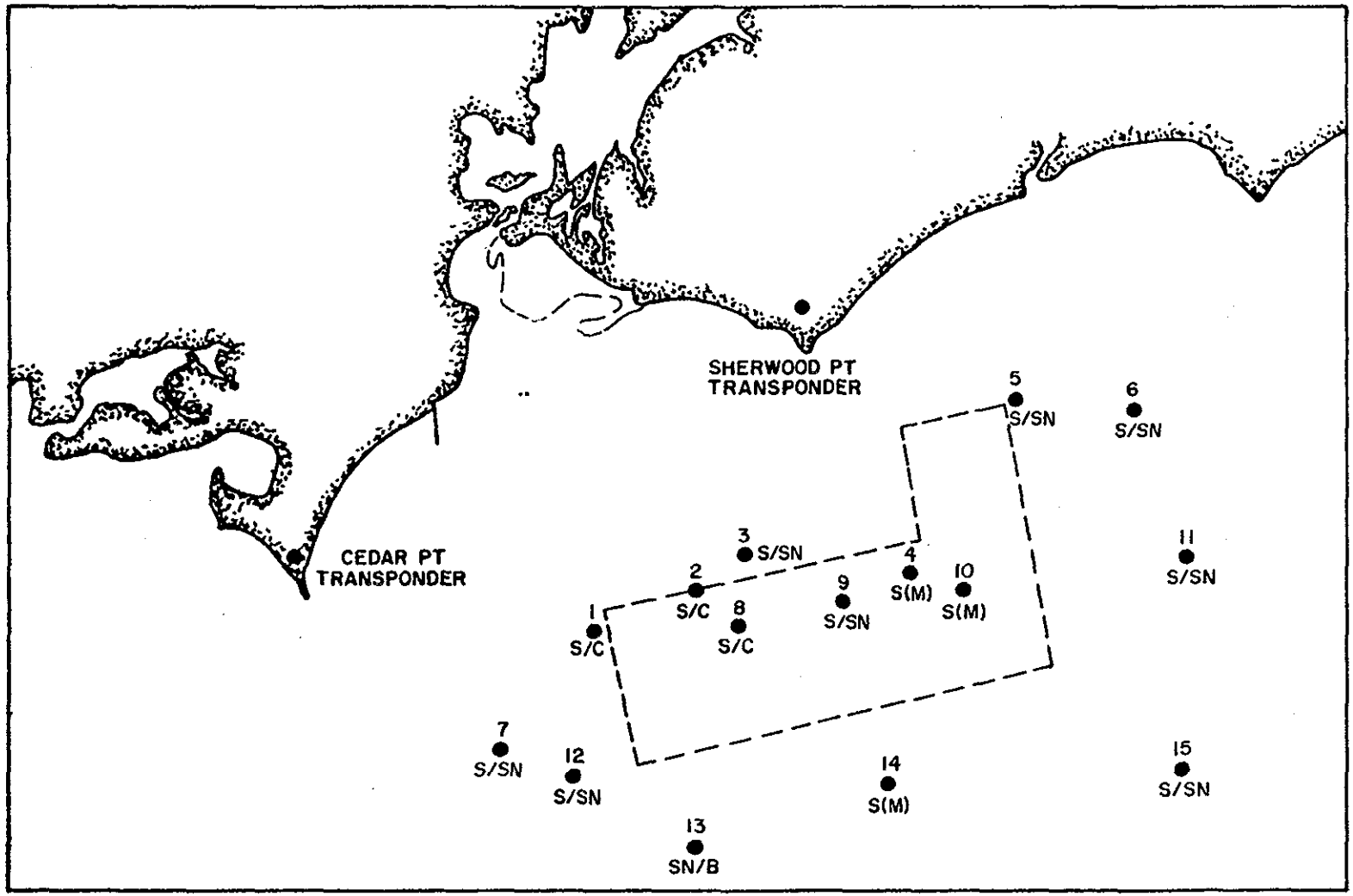

Figure 4-3. Station locations and sediment types at the Sherwood Island Borrow Site, September 1983. B: boulder; C: clay; (M): malodorous; Sn: sand; Sh: shell debris; S: silt.

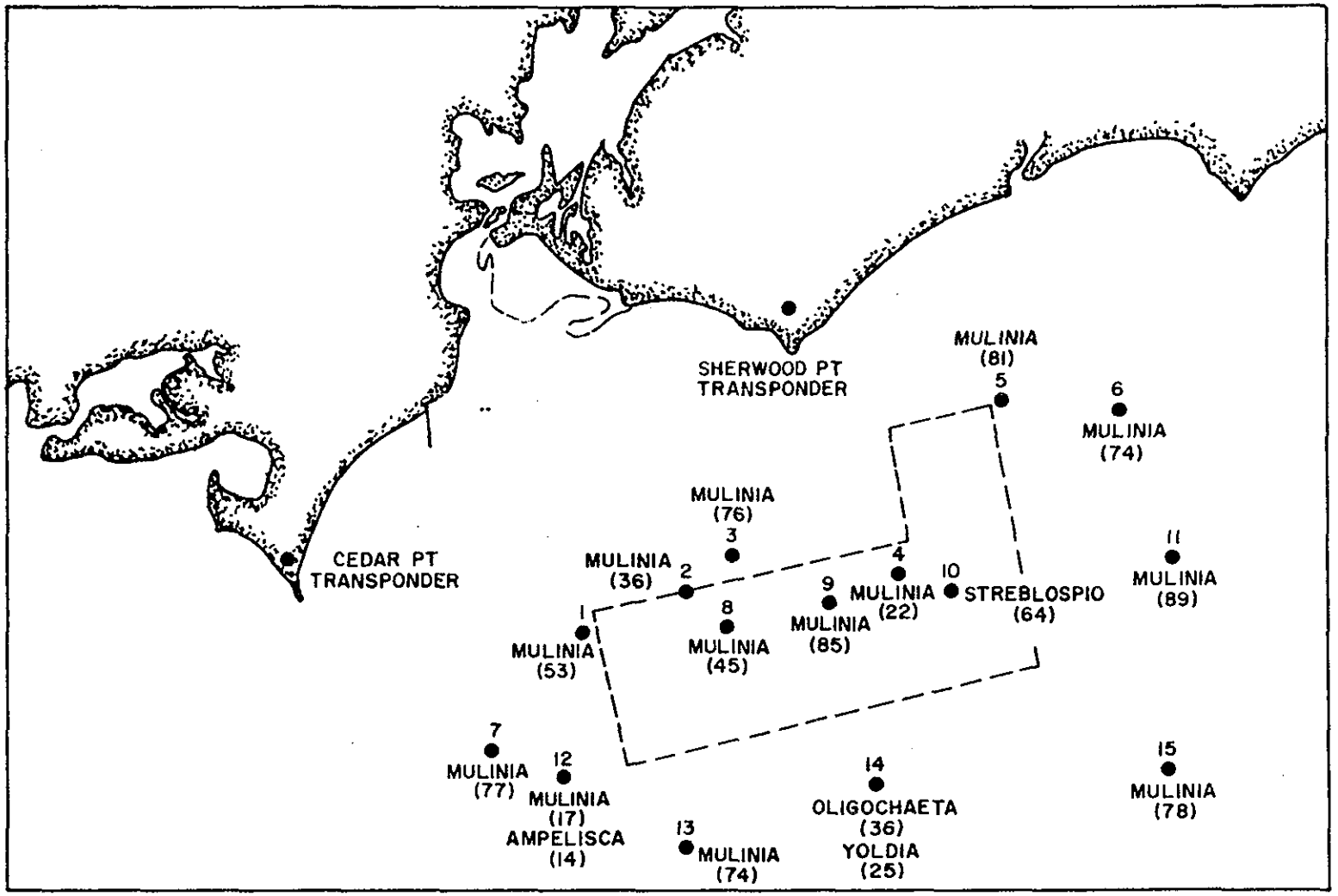

Figure 4-4. Dominant species of macrofauna at the Sherwood Island Borrow Pit Site, September 1983. Figures in parentheses indicate the percentage of total macrofaunal density contributed by dominant species at each station.

Table 4-2. Ten numerically most important macrofaunal taxa at the Sherwood Island Borrow Pit Site, September 1983. B: bivalve; G: gastropod; P: polychaete.

		No./m^2	% Total Density
1.	*Mulinia lateralis* (B)	2888	70.5
2.	*Nucula proxima* (B)	214	5.2
3.	*Cylichnella caniculata* (G)	143	3.5
4.	Oligochaeta	143	3.5
5.	*Nassarius trivittatus* (G)	114	2.8
6.	*Tellina agilis* (B)	79	1.9
7.	*Pectinaria gouildii* (P)	76	1.9
8.	*Streblospio benedicti* (P)	71	1.7
9.	*Yoldia limatula* (B)	60	1.5
10.	*Mediomastus ambiseta* (P)	48	1.2
	Total	3836	93.7

Station 14 where oligochaetes and the protobranch bivalve Yoldia limatula were co-dominants. Stations 10 and 14 were characterized by malodorous sediments, as was Station 4 where Mulinia was dominant, but only 13 specimens were taken.

In summary, the Sherwood Island Borrow Pit site appears to be a perturbed area characterized by a strong dominance of the macrofaunal community by opportunistic species. Primary sources of disturbance are likely to include seasonal storms and the progressive development during the warm months of hypoxic or anoxic conditions in the relict borrow pits. Nevertheless, during certain periods of the year, the site is capable of supporting a lobster fishery.

Additional information on the fishery resources in the general Sherwood Island area was contained in a letter from the U.S. Fish and Wildlife Service to the Corps of Engineers (see COE, 1983). This information is quoted below:

> Sherwood Point is the apex of a number of boundary lines marking shellfish lots (oyster and hard clam). While there are no leased shellfish beds within the hole area, it does contain a natural population of hard clams. There are 4 leased shellfish beds and one natural bed shoreward of the hole area and many more leased beds seaward of the area and to the west toward Cedar Point. There is also a significant amount of recreational clamming along the inshore area. This area has been certified as clean water by the State Health Department for the direct marketing of shellfish. Lobsters are found generally seaward of the hole, starting at about the 30-foot contour, and support both a commercial and recreational fishery. The general area supports a fairly strong sport fishery for winter flounder, bluefish, striped bass, scup, blackfish and weakfish.

4.2 POTENTIAL IMPACTS OF A DREDGED MATERIAL CONTAINMENT FACILITY

4.2.1 Potential Impacts on the Physical and Chemical Characteristics of the Aquatic Ecosystem

Substrate

According to a bathymetric survey performed by the Corps of Engineers in October of 1981, significant excavation appears to be limited to the extreme eastern portion of the project area (COE, 1981). Filling and capping of this relatively small area will produce negligible changes in wave and current characteristics over the general project area and the adjacent stretch of shoreline. However, the cap will be located in proximity to Sherwood Point which is a prominent headland and an apparent focal point for wave attack. The major environmental concern is that a possible concentration of wave energy over repeated storms events will erode the cap and disperse the contaminated fill beneath.

In order to examine this possibility, the refraction model was used to determine the nearshore wave heights and lengths. Using linear theory, an estimate of the near-bottom orbital velocity was then determined to gain an indication of the stability of the bottom material. Figure 4-5 presents the wave height distribution and wave vectors computed by the model for an offshore wave with a deepwater height of 2.0 meters approaching from the southeast. As noted previously, the fetch within the southwest quadrant is limited to roughly two miles, so that it is sufficient to consider the case of storm waves approaching from the southeast only. Figure 4-6 indicates the corresponding distribution of the near-bottom velocity in centimeters per

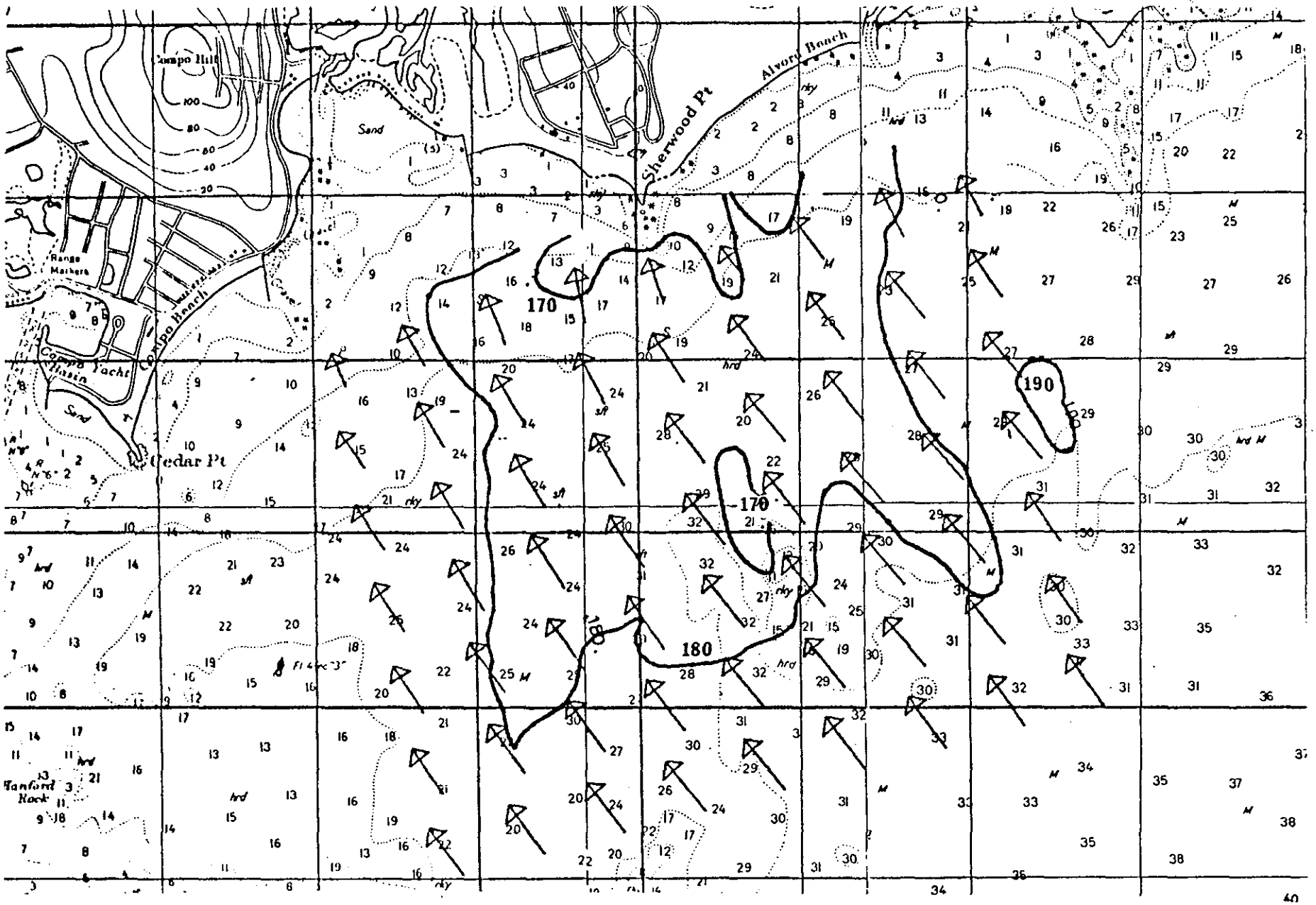

Figure 4-5. Model wave height and direction for waves from the southeast. The wave height contours are labeled in centimeters and the length of the wave vectors is proportional to the local wavelength.

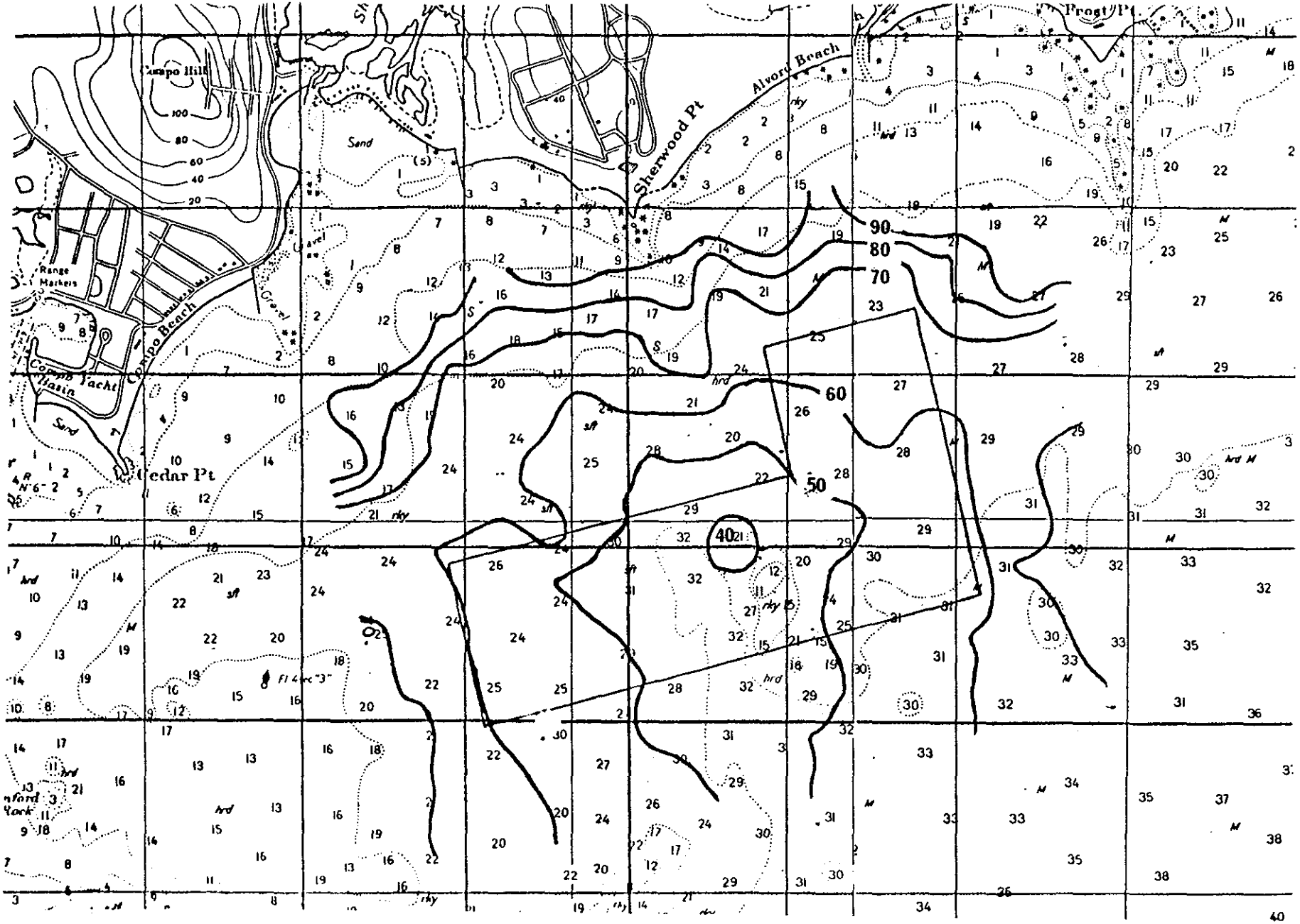

Figure 4-6. Contours of maximum near-bottom orbital velocities in units of cm/sec.

second. The possible refractive effects of the alongshore tidal current were also examined using an assumed alongshore current profile with a maximum velocity of 30 centimeters per second at a distance of 400 meters from the shoreline. The results obtained using the same offshore wave condition showed negligible differences with the previous results.

The relationship for the threshold velocity for sediment movement as a function of grain size, developed by Komar and Miller (1975) and Rance and Warren (1969), predicts that a grain size of roughly 2 to 3 mm or greater (i.e., coarse sand) is required for stability under the computed wave field. This is a preliminary result which suggests that a stable cap is feasible; it is not intended for design purposes since the deepwater wave height was not selected on a rigorous statistical basis.

Suspended Particulates/Turbidity

Suspended particulates and turbidity may increase during filling and capping activities if appropriate mitigative measures are not implemented. The sediment cap should be stable under modeled wave conditions, so no long-term change in suspended particulates and turbidity is predicted.

Water

Water quality impacts may occur during the placement of contaminated spoil material if appropriate mitigative measures are not implemented, as discussed more fully in the following section on biological impacts. With proper design there is no discharge associated with this disposal plan and, consequently, no permanent water quality impacts of concern beyond the placement of the cap material.

Current Patterns and Water Circulation

The alteration of the bathymetry can theoretically affect wave characteristics through shoaling and refraction processes. However, the dimensions of the borrow pit are sufficiently small that these effects will be limited to minor and localized perturbations of short period waves which will not produce significant impacts.

Normal Water Fluctuations

The disposal plan will have a negligible impact on stillwater level fluctuations.

Salinity Gradients

The disposal plan will have a negligible impact on salinity gradients.

4.2.2 Potential Impacts on Biological Characteristics of the Aquatic Ecosystem

Threatened and Endangered Species

No threatened or endangered species is known to occur in the Sherwood Island Borrow Pit area (see Beccasio et al., 1980).

Fish, Crustaceans, Molluscs and Other Aquatic Organisms in the Food Web

Of the three sites considered in the present study, the Sherwood Island Borrow Pit site appears to be the most perturbed area supporting the least dense and least diverse assemblage of

macrofauna. The pit area itself is particularly stressed, primarily through the development during late summer/early fall of hypoxic or anoxic conditions in the deeper portions. Although during certain times of the year lobsters congregate in this area and there are reported to be hard clam resources as well, in general the overall habitat value of the site can be rated as low. Therefore, the filling in and capping of the pits with dredged materials will not destroy an ecologically significant bottom area. Moreover, in the post-construction phase, the area should gradually return to an ecological state of development approximating or superior to that which currently prevails.

As the preceding subsection revealed, the proposed activity should result in no or only trivial changes in the hydrodynamic regime of the area. Consequently, no indirect effects of the activity via changes in nearby sedimentary environments are anticipated.

The primary potential source of impact to marine resources in the area would occur during the filling of the pits. Extensive hard clam and oyster beds lie in close proximity to the site. Highly turbid conditions and/or the suspension of contaminated sediments in the area could have detrimental effects on these resources. The possibility of such impacts occurring can be minimized through the use of various mitigation measures including the timing of spoils dumping.

Other Wildlife

No other wildlife resources of importance are known to occur in the Sherwood Island Borrow Pit area.

5. REFERENCES

Beccasio, A.D., G.H. Weissberg, A.E. Redfield, R.L., Frew, W.M. Levitan, J.E. Smith, and R.E. Godwin 1980. Atlantic coast ecological inventory. Biological Services Program, U.S. Fish and Wildlife Service, Washington, D.C.

Berkhoff, J.C.W. 1972. "Computation of Combined Refraction-Diffraction", Proceedings 13th International Conference on Coastal Engineering, Vancouver.

Corps of Engineers 1981. "Detailed Project Report and Environmental Assessment, Sherwood Island State Park", September.

Corps of Engineers 1983. Progress Report. Long Island Sound dredged material containment feasibility study. New England Division, Corps of Engineers, Waltham, MA.

Fauchald, K. 1977. The polychaete worms. Definitions and keys to the orders, families and genera. Natural history Museum of Los Angeles County, Science Series 28:1-190.

Kirby, J.T. and R.A. Dalrymple 1982. "Numerical Modeling of the Nearshore Region", Technical Report No. 11, Department of Civil Engineering, University of Delaware, June.

Kirby, J.T. and R.A. Dalrymple 1983. "Verification of a Parabolic Equation for Propagation of Weakly-Nonlinear Waves", submitted to Coastal Engineering.

Komar, P.D. and M.C. Miller 1975. Sediment threshold under oscillatory waves. Proc. 14th Conf. on Coast. Engrg., pp. 756-75.

McGrath, R.A., W.F. Grocki, D.C. Rhoads, J. Germano, and L. Boyer 1982. Environmental baseline data collections and site evaluations, Long Island Sound container disposal study, Black Ledge, Groton - New London Harbor, Connecticut. Taxon, Inc., Salem, MA.

NAI, 1982. Ecological surveys of Pennfield Reef and Milford Harbor. Normandeau Associates, Inc., Bedford, N.H.

National Oceanic and Atmospheric Administration 1982a. Tide Tables 1983: East Coast of North and South America, Department of Commerce.

National Oceanic and Atmospheric Administration 1982b. Tide Current Tables 1983: Atlantic Coast of North America, Department of Commerce.

Noda, E.K., Sonu, C.J., Rupert, V.C and J.I. Collins 1974. "Nearshore Circulations Under Sea Breeze Conditions and Wave-Current Interactions in the Surf Zone", Technical Report No. 4, Tetra Tech, Inc., February.

Phillips, O. 1966. The Dynamics of the Upper Ocean. Cambridge University Press, 1966.

Radder, A.C. 1979. "On the Parabolic Equation Method for Water-Wave Propagation", Journal of Fluid Mechanics, 95(1):159-176.

Rance, P.J. and N.F. Warren 1969. The threshold movement of coarse material in oscillatory flow. Proc. 11th Conf. on Coast. Engrg., pp.487-91.

Rhoads, D.C. 1974. Organism - sediment relations on the muddy seafloor. Oceanogr. Mar. Biol. Ann. Rev. 12:263-300.

Sanders, H.L. 1960. Benthic studies in Buzzards Bay III. The structure of the soft-bottom community Limnol. Oceanogr. 5:138-152.

APPENDIX A

Appendix A. Derivation and Application of the Parabolic Eqnation

The nonlinear equation governing the complex amplitudes A(x,y) of a monochromatic wavefield may be obtained through a simple two-step procedure. A more formal derivation may be found in Kirby and Dalrymple (1983a).

A hyperbolic equation governing the time dependent water surface elevation $\eta(x,y,t)$ in the linear mild-slope approximation may be written as (following Booij, 1981):

$$\frac{\partial^2 \eta}{\partial t^2} - \nabla \cdot (CC_g \nabla \eta) + \omega_o^{\,2}\left(1 - \frac{C_g}{C}\right)\eta = 0 \qquad (1)$$

where

$$\omega_o^{\,2} = gk \tanh kh$$

$$C = \omega_o / k$$

$$C_g = \frac{\partial \omega_o}{\partial k}$$

and ∇ is the horizontal gradient operator $\{\partial/\partial x,\ \partial/\partial y\}$. For the case of constant depth and, without loss of generality, propagation in the x-direction, Eq. (1) is satisfied by linear plane waves of the form

$$\eta = Ae^{i(kx-\omega_o t)} \quad ; \quad \text{A constant} \qquad (2)$$

We now assume a modified form of Eq. (1) containing an unknown nonlinear term $F(\eta)$, given by

$$\frac{\partial^2 \eta}{\partial t^2} - \nabla(CC_g \nabla \eta) + \omega_o^{\,2}\left(1 - \frac{C_g}{C}\right)\eta + F(\eta) = 0 \qquad (3)$$

In the constant depth case, this equation is to be satisfied exactly by the leading component of a nonlinear Stokes wave given by

$$\eta = Ae^{i(kw-\omega t)} \quad ; \quad A \text{ constant} \tag{4}$$

where ω and ω_o are related to $O(k|A|^2)$ by

$$\omega^2 = \omega_o{}^2(1 + C_g K'|A|^2/\omega_o) \tag{5}$$

Substituting Eq. (5) into Eq. (2) leads to the result

$$F(\eta) = (\omega^2 - \omega_o{}^2) = \omega_o C_g K'|A|^2\eta \tag{6}$$

where K' is given by

$$K' = k^3\left(\frac{C}{C_g}\right)\frac{\cosh 4kh + 8 - 2\tanh^2 kh}{8\sinh^4 kh} \tag{7}$$

We now take the alternate viewpoint that the wave is allowed to travel at small angles to the x-direction in a region of variable depth, and that the wave frequency ω_o is specified (leading to second order corrections to the wavenumber k). Then, η may be written as

$$\eta = A'(x,y)e^{i(\int^x kdx - \omega_o t)} \quad ; \quad |A'| = |A| \tag{8}$$

where A' must absorb the effects of angle of propagation and nonlinearity. Substituting Eq. (8) into Eq. (3) with $F(\eta)$ given by Eq. (6) leads to a parabolic-elliptic model including diffraction effects in the x-direction, given by

$$2ikCC_g A'_x + i(kCC_g)_x A' + \nabla(CC_g\nabla A') - kCC_g K'|A'|^2 A' = 0 \tag{9}$$

Assuming that A' varies more slowly in the x-direction than the y-direction, since the principal variation appears in the phase $(\int^x kdx - \omega_o t)$, and introducing the phase shift

$$A' = Ae^{i(k_o x - \int^x k(x)dx)} \tag{10}$$

gives

$$2ikCC_gA_x + 2k(k-k_o)CC_gA + i(kCC_g)_xA$$

$$+ (CC_gA_y)_y - k(CC_g)K'|A|^2A = 0 \qquad (11)$$

which is the form of the model used for the present calculations.

The parabolic model may be solved in a forward-marching (in x) procedure in analogy to the heat-transfer equation. After discretizing a domain $\{0 \le x \le x_{max},\ 0 \le y \le y_{max}\}$ by a finite-difference grid, initial conditions $A(x=0,y)$ are specified, and the problem then requires lateral boundary conditions at $y=0,y_{max}$ for each value of x; these are discussed below. Solutions are obtained efficiently by the Crank-Nicholson implicit scheme. Iteration is required to estimate the factor $|A|^2$ in the nonlinear term at the updated positions of x; here, we use an explicit intermediate step in order to obtain an estimate of A at the updated x. In the event that linear results are to be obtained, the cubic term is dropped and the Crank-Nicholson scheme proceeds without iteration.

In the event that the ratio of wave height to water depth becomes too large, wave breaking occurs and wave energy is lost to friction and turbulence. Breaking is implemented in the present model by the addition of a dissipation term to Eq. (11), which is modified to

$$2ikCC_gA_x = 2k(k-k_o)CC_gA + ikCwA + i(kCC_g)_xA$$

$$+ (CC_gA_y)_y - k(CC_g)K'|A|^2A = 0 \qquad (12)$$

The dissipation coefficient w for breaking is specified according to the model of Dally (1980), and its implementation in the refraction-diffraction model has been discussed by Kirby (1983). w is specified by

$$w = \frac{K}{h} C_g \left\{ 1 - \frac{\gamma^2 h^2}{4|A|^2} \right\}$$

where K is the ratio of wave height to water depth at breaking (taken = 0.78) and γh represents a "stable" wave height representing the asymptotic value reached by a wave after breaking. A value of $\gamma = 0.4$ is used in the present calculations.

Computations for Dredge Spoil Island

The inclusion of an island is treated with a "thin film" analog. Using this mechanism, the model considers that there is water in all grid points; however, at the island, the water depth is fixed at a very small value, say ε. The wave breaking included in the wave propagation model forces the wave height in the thin film region to be smaller than ε, and hence the energy in the "waves" which propagate over the island is proportional to ε^2, which is negligible.

An island has a finite slope (typically 1:2 or 1:3). This slope causes wave reflection and wave breaking, the amount of each depending on the incident wave angle and steepness. The thin film model does not alter this process, except at the first ε grid as encountered by the wave, where again an ε^2 amount of energy is allowed to propagate into the island.

References

Berkhoff, J. C. W., Booij, N., and Radder, A. C., 1982, "Verification of Numerical Wave Propagation Models for Simple Harmonic Linear Waves," Coastal Engineering, 6, 255-279.

Booij, N., 1981, "Gravity Waves on Water with Non-uniform Depth and Current," Dept. of Civil Eng., Delft Univ. Tech., Rept. 81-1.

Dally, W. R., 1980, "A Numerical Model for Beach Profile Evolution," M.S. Thesis, Dept. of Civil Eng., University of Delaware.

Kirby, J. T., 1983, "Propagation of Weakly-nonlinear Surface Water Waves in Regions with Varying Depth and Current," Rept. CE-83-37, Dept. of Civil Eng., University of Delaware.

Kirby, J. T., and Dalrymple, R. A., 1983a, "A Parabolic Equation for the Combined Refraction and Diffraction of Stokes Waves by Mildly Varying Topography," J. Fluid Mech., in press.

Kirby, J. T., and Dalrymple, R. A., 1983b, "Verification of a Parabolic Equation for the Combined Refraction-Diffraction of Weakly-Nonlinear Waves," in press, Coastal Engineering.

Radder, A. C., 1979, "On the Parabolic Equation Method for Water-Wave Propagation," J. Fluid Mech., 95(1), 159-176.

APPENDIX B

Accurate positioning of sampling stations for the benthic survey was accomplished with the Motorola Mini-Ranger III navigation system. This system displays ranges from two remote reference stations with an acccurcy of ± meters.

At each site, two transponder stations were located at existing landmarks which appear on the navigation charts. Sites were selected that afforded reasonable security and could be easily relocated for future surveys.

At Black Ledge, reference stations were located at the Avery Point Lighthouse and at Quinipeag Rocks. At the Sherwood site, transponders were located at Sherwood Island State Park Headquarters and at the cannons on Cedar Point. At Penfield Reef, transponders were positioned at the "2A" navigation beacon and at the Fairfield Beach House. Transponder locations for the three sites are shown in Figures 2.1.2-2, 3.1.2-2, and 4.1.2-1, respectively.

In tables B1, B2 and B3, range information for the sampling stations, as well as times of sampling and depths are reported.

Table B1. Black Ledge Site - 7/22/83

Transponder Location: Code 3 Quinipeag Rocks; Code 4 Avery Point Lighthouse

Station	Replicate	Time	Code 3 Range (m)	Code 4 Range (m)	Depth (ft)*
1	A	1028	1363	1271	25
	B	1046	1385	1249	25
2	A	0940	1124	1848	29
	B	0943	1109	1855	29
3	A	1410	2524	1892	37
	B	1420	2526	1903	37
4	A	1003	1870	1664	31
	B	1007	1846	1682	31
5	A	1340	3339	2332	41
	B	1345	3348	2300	41
6	A	1357	2443	1265	22
	B	1400	2426	1263	22
7	A	1340	2774	1419	27
	B	1345	2845	1450	27
8	A	1300	3210	1510	30
	B	1310	3199	1460	30
9	A	1215	2733	1097	23
	B	1217	2719	1120	23
10	A	1235	2566	761	23
	B	1250	2616	764	23
11	A	1145	2280	739	22
	B	1152	2269	716	22
12	A	1125	2073	618	22
	B	1135	2036	600	22
13	A	1100	1648	781	20
	B	1107	1693	792	20

Table B1. Black Ledge Site - 7/22/83 (con.t)

Transponder Location	Code 3	Quinipeag Rocks
	Code 4	Avery Point Lighthouse

Station	Replicate	Time	Code 3 Range (m)	Code 4 Range (m)	Depth (ft)*
14	A	0854	1068	1245	28
	B	0911	1029	1238	28
15	A	1015	1610	1301	24
	B	1020	1624	1316	24

*Due to fath. failure, depths were measured only at Station 2 and 14; depths at other stations were undetermined from nautical chart.

Table B2. Penfield Reef Site - 7/22/83

Transponder 2 Navigation Beacon
Transponder 4 Fairfield Beach House

Station	Replicate	Time	Code 2 Range (m)	Code 4 Range (m)	Depth (ft)
1	A	0915	1757	1334	18
	B	0925	1848	1371	15
2	A	0938	1765	1627	17
	B	0930	1758	1637	17
3	A	0940	1231	1802	27
	B	0941	1218	1796	26.5
4	A	0952	1330	2123	29
	B	1008	1340	2121	29
5	A	1015	1215	2383	30
	B	1017	1209	2394	30.5
6	A	1017	1786	2838	36
	B	1034	1781	2842	36
7	A	1042	2083	2875	40
	B	1046	2086	2875	40
8	A	1100	2424	3222	46
	B	1056	2423	3179	46
9	A	1115	2706	2901	35
	B	1120	2710	2894	34
10	A	1131	2996	2728	26
	B	1142	2973	2746	26
11	A	1205	3415	2855	36
	B	1216	3384	2841	36
12	A	1251	2645	2436	20
	B	1252	2634	2448	18
13	A	1300	2666	2178	20
	B	1330	2672	2196	19
14	A	1347	2599	1860	15
	B	1348	2581	1844	14
15	A	1355	2697	1564	14
	B	1402	2714	1675	12

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
SEDIMENT TYPE	SILT		SILT/CLAY		SILT	SILT	SILT/CLAY		SILT		SILT/GRAVEL		SAND/GRAVEL		SILT/SAND
ORBINIIDAE															
HAPLOSCOLOPLOS ACUTUS	1		3	3	13	3		2	2	1					
SCOLOPLOS FRAGILIS															1
PARAONIDAE															
ARICIDEA CATHERINAE		66	25	87	1		55	68			1	36	4		5
PARADONEIS LYRA															
PARAONIS GRACILIS		3	1	4	2		1	1							
PHYLLODOCIDAE															
EUMIDA SANGUINEA											1	2			
PHYLLODOCE ARENAE															
PHYLLODOCE MUCOSA		1			2	4	1	2			13	4	2		1
PILARGIIDAE															
SIGAMBRA TENTACULATA			1		2			1	1						
POLYNOIDAE															
HARMOTHOE EXTENUATA					1	5					5	4			2
HARMOTHOE IMBRICATA								2							
LEPIDONOTUS SQUAMATUS												1			
SABELLIDAE															
EUCHONE ELEGANS															
EUCHONE INCOLOR															
LAONOME KROYERI		1			2		7	6							
SERPULIDAE															
SPIRORBIS SP.											103				
SIGALIONIDAE															
PHOLOE MINUTA		11	10	8	21	22	21	11		8		4	4	8	13
SPIONIDAE															
LAONICE CIRRATA		8		1	1										
POLYDORA CAULLERYI					1						16	29	4	4	
POLYDORA LIGNI			3	7										1	
POLYDORA QUADRILOBATA						2	3						1		
POLYDORA SOCIALIS											3	1	1		
PRIONOSPIO STEENSTRUPI		3	11	11	9	7	10	2			2	2	29	19	25
SPIOPHANES BOMBYX	1		2	2								1	3	2	5
SPIO FILICORNIS											3	3		1	
SPIO SETOSA												1			
STREBLOSPIO BENEDICTI															
SYLLIDAE															
EXOGENE HEBES											26	67	29	6	2
PARAPIONOSYLLIS LONGOCIRRATA												3			
SYLLIDAE SP.															
TEREBELLIDAE															
NICOLEA VENUSTULA												1			
POLYCIRRUS EXIMUS			4					1			14	22		1	
TEREBELLIDAE SP. FRAG.															
TROCHOCHAETIDAE															
TROCHOCHAETA MULTISETOSA			1												

Table B3. Sherwood Island Site (CRUISE #2)

Transponder Location: Code 2 Sherwood Point; Code 3 Cedar Point

Station	Replicate	Time	Code 2 Range (m)	Code 3 Range (m)	Depth (ft)
1	A	1017	1410	1180	26
	B	1022	1216	1216	25
2	A	1032	1085	1532	26
	B	1038	1220	1536	26
3	A	1042	899	1701	26
	B	1047	905	1711	24
4	A	1105	1030	2398	39
	B	1107	1019	2383	39
5	A	1117	918	2804	22
	B	1118	911	2809	22
6	A	1120	1274	3283	20
	B	1131	1254	3273	19
7	A	1305	1939	1039	27
	B	1308	1942	1018	26
8	A	1327	1152	1713	28
	B	1329	1116	1702	28
9	A	1341	1086	2107	32
	B	1345	1063	2125	32
10	A	1355	1156	2519	44
	B	1358	1120	2465	42
11	A	1144	1679	3395	30
	B	1147	1675	391	30
12	A	1246	1879	1323	27
	B	1248	1870	1309	27
13	A	1231	1990	1850	27
	B	1232	1984	1841	27
14	A	1215	1736	2414	33
	B	1216	1713	2400	33
15	A	1200	2185	3456	32
	B	1205	2192	3446	32

APPENDIX C

A 523 cm^2 PONAR grab was used to collect two replicate samples at each of the 15 stations at each site. Immediately following collection, each grab sample was washed through a 500-micron sieve in the field. The material retained on the above sieve was carefully washed into appropriately-sized sample containers and fixed with formaldehyde buffered with borax. Rose bengal stain was added to the sample to facilitate later sorting efforts.

Station data was transcribed onto field log sheets simultaneously with the field collection effort. The data included site designation, station coordinates, station number, replicate number, depth, sediment type, field conditions, and the date. Sediment type was based on a visual classification of the sediment observed in each sample, such as gravel, sand, silt, clay or appropriate mixtures.

A sample tag was placed into each sample container in order to facilitate the identification of the sample. Information on the tag included the site designation, station number, date, and replicate number.

Sample Processing

Samples returned to the laboratory from Black Ledge, Penfield Reef, and Sherwood Island Borrow Pit were logged into the laboratory work-order book which is used to track the samples through the laboratory work phase. Standard laboratory analysis procedures were followed in the effort to process these samples. Within 24 hours after fixation in formalin, the samples were

rewashed to remove the formalin and transferred to a 70% ethanol-5% glycerin mixture for preservation. In turn, as each sample was assigned for sorting, drained of alcohol and rewashed through through a 500-micron sieve. The material retained on the sieve was examined in its entirety under a dissecting microscope and all macrofauna were removed as seen by a laboratory technician. The processed sample then went to a research biologist who was responsible for identifying the macrofauna to the lowest possible and practical level which, in most cases, was to species. Following identification, each species was counted and the data transcribed onto a laboratory data form. All species were maintained in individual glass vials for future reference and verification.

Data Analysis

The information written on the laboratory forms was used to develop a phylogentic tabulation of the species and their numbers found at each station. the data were used to conduct statistical analyses including the diversity indices Shannon-Weaver and Margalef, and evenness and species redundancy. Averages for two replicates were used to rank the species by abundance per station along with the respective percent composition. and the estimated number of a species per square meter. Data tables are presented in the following subsection.

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION SEDIMENT TYPE	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
	SILT		SILT/CLAY		SILT	SILT	SILT/CLAY		SILT		SAND/GRAVEL		SAND/GRAVEL		SILT/SAND
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA			1		1		1			1	3	6	4	4	2
ASABELLIDES OCULATA													1		
ARABELLIDAE															
DHILONERIS MAGNA									1	2			1		
CAPITELLIDAE															
CAPITELLA CAPITATA											6	14		1	
MEDIOMASTUS AMBISETA		2	1	2	6	1		1						1	2
CIRRATULIDAE															
CAULLERIELLA KILLERIENSIS															
THARYX ACUTUS			2			4	2				5	7	5	4	9
THARYX ANNULOSUS		73	6	10	15	8	6	27		1	1	12	12	42	33
CIRRHATULIS GRANDIS															
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS															
COSSURIDAE															
COSSURA LONGOCIRRATA								1							
DORVILLEIDAE															
PROTODORVILLEA KEFERSTEINI												3			
SCHISTOMERINGOS CAECA															
EUNICIDAE															
MARPHYSA BELLI															
FLABELLIGERIDAE															
PHERUSA AFFINIS				1	1			1				1		1	
GLYCERIDAE															
GLYCERA DIBRANCHIATA													1	1	
GONIADIDAE															
GONIADELLA GRACILIS											1				
LUMBRINERIDAE															
LUMBRINERIS IMPATIENS		17	10	8	17	17	5	13					4	14	4
LUMBRINERIS TENUIS												2			
NINOE NIGRIPES		2	2	3	5		3	1	1	1				1	3
MALDANIDAE															
ASYCHIS ELONGATA		4	1	3	2		3	3							
CLYMENELLA TORQUATA		2		3	4	2	3	6					5	1	9
EUCLYMENE ZONALIS		5	7	1	1	2	5	8	1				2	1	4
MALDANIDAE SP. JUV.			4												
NEPHTYIDAE															
AGLAOPHAMUS CIRCINATA												3	5	3	1
NEPHTYS INCISA		18	11	10	23	12	31	26	7	5					2
NEPHTYS PICTA												2	7		
NEPHTYIDAE SP. JUV.								1			9	6			
NEREIDAE															
NEREIS SP. JUV.															
NEREIS SUCCINEA														1	
OPHELIIDAE															
AMMOTRYPANE AULOGASTER															3

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
SEDIMENT TYPE	SILT		SILT/CLAY		SILT	SILT	SILT/CLAY		SILT		SILT/GRAVEL		SAND/GRAVEL		SILT/SAND
ORBINIIDAE															
HAPLOSCOLOPLOS ACUTUS	1		3	3	13	3		2	2	1					
SCOLOPLOS FRAGILIS															1
PARAONIDAE															
ARICIDEA CATHERINAE		66	25	87	1		55	68			1	36	4		5
PARADONEIS LYRA															
PARAONIS GRACILIS		3	1	4	2		1	1							
PHYLLODOCIDAE															
EUMIDA SANGUINEA											1	2			
PHYLLODOCE ARENAE															
PHYLLODOCE MUCOSA		1			2	4	1	2			13	4	2		1
PILARGIIDAE															
SIGAMBRA TENTACULATA			1		2			1	1						
POLYNOIDAE															
HARMOTHOE EXTENUATA					1	5					5	4			2
HARMOTHOE IMBRICATA								2							
LEPIDONOTUS SQUAMATUS												1			
SABELLIDAE															
EUCHONE ELEGANS															
EUCHONE INCOLOR															
LAONOME KROYERI		1			2		7	6							
SERPULIDAE															
SPIRORBIS SP.											103				
SIGALIONIDAE															
PHOLOE MINUTA		11	10	8	21	22	21	11		8		4	4	8	13
SPIONIDAE															
LAONICE CIRRATA		8		1	1										
POLYDORA CAULLERYI					1						16	29	4	4	
POLYDORA LIGNI			3	7										1	
POLYDORA QUADRILOBATA						2	3						1		
POLYDORA SOCIALIS											3	1	1		
PRIONOSPIO STEENSTRUPI		3	11	11	9	7	10	2			2	2	29	19	25
SPIOPHANES BOMBYX	1		2	2								1	3	2	5
SPIO FILICORNIS											3	3		1	
SPIO SETOSA												1			
STREBLOSPIO BENEDICTI															
SYLLIDAE															
EXOGENE HEBES											26	67	29	6	2
PARAPIONOSYLLIS LONGOCIRRATA												3			
SYLLIDAE SP.															
TEREBELLIDAE															
NICOLEA VENUSTULA												1			
POLYCIRRUS EXIMUS			4					1			14	22		1	
TEREBELLIDAE SP. FRAG.															
TROCHOCHAETIDAE															
TROCHOCHAETA MULTISETOSA			1												

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION SEDIMENT TYPE	1-A SILT	1-B	2-A SILT/CLAY	2-B	3-A SILT	3-B SILT	4-A SILT/CLAY	4-B	5-A SILT	5-B	6-A SAND/GRAVEL	6-B	7-A SAND/GRAVEL	7-B	8-A SILT/SAND
CRUSTACEA															
AMPHIPODA															
AMPELISCA ABDITA		10	6	9	944	283	102	67	236	22	3	4	43	86	1490
AMPELISCA SP. JUV.															
AMPELISCA VADORUM															
AMPELISCA VERILLI														1	
GAMMARUS SP.					2										
CALLIOPIUS LAEVISCULUS															
CERAPUS TUBULARIS					1										
COROPHIUM ACHERUSICUM											10				
COROPHIUM TUBERCULATUM															
DYOPEDOS MONACANTHUS									1						
LEPTOCHEIRUS PINGUIS		3	5		5	239	7	95	16	85	479	331	607	64	225
MICRODEUTOPES ANOMALUS															
MICRODEUTOPES GRYLLOTALPA															1
PARAMETOPELLA CYPRIS															
PHOTIS MACROCOXA						2	1	2							
PHOXOCEPHALUS HOLBOLLI											6	9	1		
PONTOGENEIA INERMIS															
RHEPOXYNUS EPISTOMUS											1				
STENOTHOE MINUTA					1		1								
UNCIOLA INERMIS											5	5			
UNCIOLA IRRORATA	1	4	1	5	3	1		3	3		1		18		49
UNCIOLA SP. JUV.						4									
CAPRELLIDA													6		
CAPRELLIDAE SP. JUV.															
CUMACEA											1	5	1		1
OXYUROSTYLIS SMITHI	1							2							
DECOPODA															
CANCER IRRORATUS					1										
CRANGON SEPTEMSPINOSA					1				1	4		2		1	2
PAGURUS SP. JUV.					1							1	3	1	2
ISOPODA													1		
EDOTEA TRILOBA		2													
ERISCHONELLA FILIFORMIS															
ERISCHONELLA SP.															
ERISCHONELLA SP. JUV.															
IDOTEA PHOSPHOREA															
PTILANTHURA TENUIS			1					9			1				
OSTRACODA		21					26	41		1	1		2		
TANAIDACEA											20				
TANAISSIS LILJEBOROI												12			

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION SEDIMENT TYPE	1-A SILT	1-B	2-A SILT/CLAY	2-B	3-A SILT	3-B SILT	4-A SILT/CLAY	4-B	5-A SILT	5-B	6-A SAND/GRAVEL	6-B	7-A SAND/GRAVEL	7-B	8-A SILT/SAND
ARCHIANNELIDA											2	8	2		
NEMATODA											3		19		3
OLIGOCHAETA	1	2	3	6							3	25	7		
RHYNCOCOELA			3	1		2				2	4	5	1		1
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA												1			
CREPIDULA SP.JUV.															
CYLICHNELLA CANALICULATA		1	2												
GASTROPODA SP.															
LUNATIA TRISERIATA				1		1									
MITHELLA LUNATA							1								
NASSARIUS TRIVITTATUS			1												
TURBONILLA INTERRUPTA		10	5	3				3							
PELECYPODA															
ARCTICA ISLANDICA		1						1							
ASTARTE UNDATA					3				4	1					2
MYSELLA PLANULATA															
CERASTODERMA PINNULATUM												3	2		2
CRENELLA GLANDULA															
CYCLOCARDIA BOREALIS						4						1			3
ENSIS DIRECTUS				4			1	2						1	3
HIATELLA ARCTICA												2			
LYONSIA HYALINA		2					2								
LYONSIA SP. JUV.		19		2			2	9					6		
MERCENARIA MERCENARIA			1	1			1	1							
MODIOLUS MODIOLUS												1			
MULINIA LATERALIS															
MUSCULUS DISCORS					1							1			
MYTILUS EDULIS															
NUCULA DELPHINODONTA		4			26	9	7	6	1						
NUCULA PROXIMA		291	619	749	36	16	385	314	2	1					
PANDORA INORNATA			1												
PERIPLOMA PAPYRATIUM															
PITAR MORRHUANUS		1	1	1											
TELLINA AGILIS			1	7	11	4	6	4				15	14	2	11
YOLDIA LIMATULA		6	1	3	1		2	3							
YOLDIA SP. JUV.		5	2	9			1	4							
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.															
EDWARDSIA ELEGANS					1		1	1							
EDWARDSIA SP.		2													
HYDROZOA													P		
EUDENDRIUM CARNEUM															

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

STATION	1-A	1-B	2-A	2-B	3-A	3-D	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
SEDIMENT TYPE	SILT		SILT/CLAY		SILT	SILT	SILT/CLAY		SILT		SAND/GRAVEL		SAND/GRAVEL		SILT/SAND
ECHINODERMATA															
HOLOTHUROIDEA															
PENTAMERA PULCHERRIMA												1			
ECTOPROCTA															
CRISIA EBURNEA											P				
TUBULIPORA SP..											P				
BOWERBANKIA SP.											P				
MEMBRANIPORA SP.															
ELECTRA PILOSA											P				
ELECTRA SP.											P				
CRYPTOSULA SP.															
SCHIZOPORELLA UNICORNIS											P				
CONOPEUM SP.											P				
DISPORELLA HISPIDA											P				
MICROPORELLA SP.															
CRIBRILINA PUNCTATA											P				
CRIBRILINA ANNULATA											P				
BUGULA TURRITA											P				
CALLOPORA AURITA											P				
HIPPOTHOA HYALINA											P				
PHORONIDA															
PHORONIS ARCHITECTA				1	5		2				2		1		2
UROCHORDATA															
MOLGULA ARENATA					2										

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	8-B	9-A	9-B	10-A	10-B	11-A	11-B	12-A	12-B	13-A	13-B	14-A	14-B	15-A	15-B
SEDIMENT TYPE	SILT/SAND	SAND/GRAVEL		GRAVEL		GRAVEL		GRAVEL		GRAVEL	GRAVEL	SILT/CLAY		SILT	
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA	1	6	1	6	4	4	3	2		5					
ASABELLIDES OCULATA															
ARABELLIDAE															
DRILONERIS MAGNA	1				1										
CAPITELLIDAE															
CAPITELLA CAPITATA			1			1	2	1		8					
MEDIOMASTUS AMBISETA	2	2									18				
CIRRATULIDAE															
CAULLERIELLA KILLERIENSIS				2	2	1	1								
THARYX ACUTUS		16	4	8	4	3				18	11	2			
THARYX ANNULOSUS	27	5	2	8	10	4	1		13	19	19			9	9
CIRRATULIS GRANDIS										48					
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS	2	2	1				1								
COSSURIDAE															
COSSURA LONGOCIRRATA															
DORVILLEIDAE															
PROTODORVILLEA KEFERSTEINI				6						8					
SCHISTOMERINGOS CAECA			1			3									1
EUNICIDAE															
MARPHYSA BELLI								1							
FLABELLIGERIDAE															
PHERUSA AFFINIS									2	2					
GLYCERIDAE															
GLYCERA DIBRANCHIATA			1		1										
GONIADIDAE															
GONIADELLA GRACILIS					1	2									
LUMBRINERIDAE															
LUMBRINERIS IMPATIENS	2	2							22	1		2	3	6	14
LUMBRINERIS TENUIS				2	5			1							
NINOE NIGRIPES	1											1	2	1	2
MALDANIDAE															
ASYCHIS ELONGATA												1		2	2
CLYMENELLA TORQUATA		2							1			13	12	5	2
EUCLYMENE ZONALIS	6	3	1	1	1				3	2		1		1	3
MALDANIDAE SP. JUV.												15	5		
NEPHTYIDAE															
AGLAOPHAMUS CIRCINATA		2					1	2							
NEPHTYS INCISA			1						17			28		18	23
NEPHTYS PICTA		7		2	2	13	4				6				
NEPHTYIDAE SP. JUV.					3		3								
NEREIDAE															
NEREIS SP. JUV.			1	1											
NEREIS SUCCINEA					1		1								
OPHELIIDAE															
AMMOTRYPANE AULOGASTER															

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION SEDIMENT TYPE	8-B SILT/SAND	9-A SAND/GRAVEL	9-B	10-A GRAVEL	10-B	11-A GRAVEL	11-B	12-A GRAVEL	12-B	13-A GRAVEL	13-B GRAVEL	14-A SILT/CLAY	14-B	15-A SILT	15-B
ORBINIIDAE															
HAPLOSCOLOPLOS ACUTUS												22			2
SCOLOPLOS FRAGILIS											1				
PARAONIDAE															
ARICIDEA CATHERINAE	2	1	10				1			1		72		7	2
PARADONEIS LYRA				12	13	5									
PARAONIS GRACILIS												2			3
PHYLLODOCIDAE															
EUMIDA SANGUINEA				1	1	1				1					
PHYLLODOCE ARENAE			1												
PHYLLODOCE MUCOSA	2	3		1		3	1	1		4					
PILARGIIDAE															
SIGAMBRA TENTACULATA															
POLYNOIDAE															
HARMOTHOE EXTENUATA		6		8	2	7		5	2	6					
HARMOTHOE IMBRICATA										3					
LEPIDONOTUS SQUAMATUS									1	1					
SABELLIDAE															
EUCHONE ELEGANS		1													
EUCHONE INCOLOR			1											1	
LAONOME KROYERI									2					2	1
SERPULIDAE															
SPIRORBIS SP.															
SIGALIONIDAE															
PHOLOE MINUTA	15	1	3		2				1	14		10		26	7
SPIONIDAE															
LAONICE CIRRATA															
POLYDORA CAULLERYI			3	17	23	1	2	18		10					
POLYDORA LIGNI												3		1	
POLYDORA QUADRILOBATA		1			1		9	2						4	
POLYDORA SOCIALIS				2	1		1	1							1
PRIONOSPIO STEENSTRUPI	12	11	10	4	2			1	1	14		18	1	4	5
SPIOPHANES BOMBYX	5	10	6	10	1		5	1		2	75	2			
SPIO FILICORNIS				3		2				1					
SPIO SETOSA				1	2	2	1				1				
STREBLOSPIO BENEDICTI											2				
SYLLIDAE															
EXOGENE HEBES	1	11	20	41	28	36		13		13					
PARAPIONOSYLLIS LONGOCIRRATA		4	4	1	4	2				3					
SYLLIDAE SP.										1					
TEREBELLIDAE															
NICOLEA VENUSTULA		1		1	2	2									
POLYCIRRUS EXIMUS		2	5	5	14	9	9	10		6		4	1		
TEREBELLIDAE SP. JUV.															
TROCHOCHAETIDAE															
TROCHOCHATAETA MULTISETOSA															

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION SEDIMENT TYPE	8-B SILT/SAND	9-A SAND/GRAVEL	9-B	10-A GRAVEL	10-B	11-A GRAVEL	11-B	12-A GRAVEL	12-B	13-A GRAVEL	13-B GRAVEL	14-A SILT/CLAY	14-B	15-A SILT	15-B
CRUSTACEA															
AMPHIPODA															
AMPELISCA ABDITA	222			2	10	2		1		2		28		12	
AMPELISCA SP. JUV.											2				
AMPELISCA VADORUM					1										
AMPELISCA VERRILLI	6														
GAMMARUS SP.															
CALLIOPIUS LAEVISCULUS							1								
CERAPUS TUBULARIS															
CORophium ACHERUSICUM	1	1		2		5				20					
CORophium TUBERCULATUM							3								
DYOPEDOS MONACANTHUS															
LEPTOCHEIRUS PINGUIS	31	23	34	16	23		51	151	106	70		15		4	
MICRODEUTOPES ANOMALUS		6													
MICRODEUTOPES GRYLLOTALPA	1														
PARAMETOPELLA CYPRIS		1		1											
PHOTIS MACROCOXA															
PHOXOCEPHALUS HOLBOLLI		3		2	6	14	3	4	1	4				1	
PONTOGENEIA INERMIS						5									
RHEPOXYNUS EPISTOMUS						1	1								
STENOTHOE MINUTA				1											
UNCIOLA INERMIS				5	8	10	1	1							
UNCIOLA IRRORATA	20			3	3							7		2	1
UNCIOLA SP. FRAG.					3										
UNCIOLA SP. JUV.															
CAPRELLIDA						14	13								
CAPRELLIDAE SP. JUV.				4	1										
CUMACEA															
OXYUROSTYLIS SMITHI															
DECOPODA						4				3					
CANCER IRRORATUS		2		1	1			2			1	1			1
CRANGON SEPTEMSPINOSA			2											1	
PAGURUS SP. JUV.					1										
ISOPODA															
EDOTEA TRILOBA									1						
ERISCHONELLA FILIFORMIS							1								
ERISCHONELLA SP.							2								
ERISCHONELLA SP. JUV.							3								
IDOTEA PHOSPHOREA												1			1
PTILANTHURA TENUIS		1	1												13
OSTRACODA		1													
TANAIDACEA						8				1					
TANAISSIS LILJEBORGI		1	3	7											

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	8-B	9-A	9-B	10-A	10-B	11-A	11-B	12-A	12-B	13-A	13-B	14-A	14-B	15-A	15-B
SEDIMENT TYPE	SILT/SAND	SAND/GRAVEL		GRAVEL		GRAVEL		GRAVEL		GRAVEL	GRAVEL	SILT/CLAY		SILT	
ARCHIANNELIDA		6		13	41	54	54	9							
NEMATODA	1	7		7		9	2	4		15					
OLIGOCHAETA		10		37	25	66	19	19		8	11				
RHYNCOCOELA	1	13						1	9		1				
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA		2		1		1				1					
CREPIDULA SP.JUV.					8										
CYLICHNELLA CANALICULATA															
GASTROPODA SP.															
LUNATIA TRISERIATA															
MITRELLA LUNATA		1			3				5						
NASSARIUS TRIVITTATUS				1											
TURBONILLA INTERRUPTA												8		5	
PELECYPODA															
ARCTICA ISLANDICA		1													
ASTARTE UNDATA	1											1			
MYSELLA PLANULATA									1						
CERASTODERMA PINNULATUM	1	1		1	1	1								1	
CRENELLA GLANDULA				1	2										
CYCLOCARDIA BOREALIS				6	3	1				1					
ENSIS DIRECTUS		1		5	3						1	2			1
HIATELLA ARCTICA									1	1					
LYONSIA HYALINA						1									
LYONSIA SP. JUV.		2		2	2									1	11
MERCENARIA MERCENARIA												1			1
MODIOLUS MODIOLUS										1					
MULINIA LATERALIS											7				
MUSCULUS DISCORS		1			7	2			1	2					
MYTILUS EDULIS															
NUCULA DELPHINODONTA												14		14	21
NUCULA PROXIMA			2	1					1			57		457	3498
PANDORA INORNATA															
PERIPLOMA PAPYRATIUM														1	1
PITAR MORRHUANUS															
TELLINA AGILIS		11	14	5	7	1			1	1	84				4
YOLDIA LIMATULA											2	3			2
YOLDIA SP. JUV.											2	3		1	2
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.															
EDWARDSIA ELEGANS												1			3
EDWARDSIA SP.													1		
HYDROZOA															
EUDENDRIUM CARNEUM															

Table C.2.1-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Black Ledge study site, July 1983.

STATION	8-B	9-A	9-B	10-A	10-B	11-A	11-B	12-A	12-B	13-A	13-B	14-A	14-B	15-A	15-B
SEDIMENT TYPE	SILT/SAND	SAND/GRAVEL		GRAVEL		GRAVEL		GRAVEL		GRAVEL	GRAVEL	SILT/CLAY		SILT	
ECHINODERMATA															
HOLOTHUROIDEA															
PENTAMERA PULCHERRIMA															
ECTOPROCTA															
CRISIA EBURNEA															
TUBULIPORA SP.						P	P			P					
BOWERBANKIA SP.						P									
MEMBRANIPORA SP.					P										
ELECTRA PILOSA					P					P					
ELECTRA SP.															
CRYPTOSULA SP.					P	P									
SCHIZOPORELLA UNICORNIS															
CONOPEUM SP.															
DISPORELLA HISPIDA							P	P							
MICROPORELLA SP.								P							
CRIBRILINA PUNCTATA		P													
CRIBRILINA ANNULATA		P						P							
BUGULA TURRITA						P	P	P		P					
CALLOPORA AURITA		P						P		P					
HIPPOTHOA HYALINA															
PHORONIDA															
PHORONIS ARCHITECTA	2	2													
UROCHORDATA															
MOLGULA ARENATA												1		1	

Table C.2.1-3. Mean number of individuals per species per square meter at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA		10	6	10	10	86	76	29	67	95	67	19	48		
ASABELLIDES OCULATA							10								
ARABELLIDAE															
DRILONERIS MAGNA					19		10	10		10					
CAPITELLIDAE															
CAPITELLA CAPITATA						191	10		10		29	10	76		
MEDIOMASTUS AMBISETA	19	29	107	10			10	19	19				172		
CIRRATULIDAE															
CAULLERIELLA KILLERIENSIS										38	19				
THARYX ACUTUS		19	191	19		115	86	86	191	115	29	458	277	19	
THARYX ANNULOSUS	697	153	273	315	10	124	516	573	67	172	48	143	181	181	172
CIRRATULIS GRANDIS												458			
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS								38	29		10				
COSSURIDAE															
COSSURA LONGOCIRRATA			95	10											
DORVILLEIDAE															
PROTODORVILLEA KEFERSTEINI						29				57			76		10
SCHISTOMERINGOS CAECA									10		29				
EUNICIDAE															
MARPHYSA BELLI												10			
FLABELLIGERIDAE															
PHERUSA AFFINIS		10	6	10		10	10					19	19		
GLYCERIDAE															
GLYCERA DIBRANCHIATA									10	10					
GONIADIDAE															
GONIADELLA GRACILIS										10	19				
LUMBRINERIDAE															
LUMBRINERIS IMPATIENS	163	172	23	95			172	57	19			210	10	48	191
LUMBRINERIS TENUIS						19				67		10			
NINOE NIGRIPES	19	49	31	38	10		10	38						29	29
MALDANIDAE															
ASYCHIS ELONGATA	38	38	19	57										10	38
CLYMENELLA TORQUATA	19	29	38	86			57	86	19			10		239	67
EUCLYMENE ZONALIS	48	76	19	124			29	95	29	19		29	19	10	38
MALDANIDAE SP. JUV.		38												191	
NEPHTYIDAE															
AGLAOPHAMUS CIRCINATA						29	76	10	19		10	10			
NEPHTYS INCISA	172	201	401	544	115			19	10			162		276	497
NEPHTYS PICTA						19	68			38	181		57		
NEPHTYIDAE SP. JUV.				10		124				29	29				
NEREIDAE															
NEREIS SP. JUV.									10	10					
NEREIS SUCCINEA							10		10	19	10				
OPHELIIDAE															
AMMOTRYPANE AULOGASTER								29							

Table C.2.1-3. Mean number of individuals per species per square meter at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ORBINIIDAE															
HAPLOSCOLOPLOS ACUTUS	10	57	102	19	29									210	19
SCOLOPLOS FRAGILIS								10					10		
PARAONIDAE															
ARICIDEA CATHERINAE	630	1070	315	1175		353	38	67	105		10		10	688	86
PARADONEIS LYRA										239	48				
PARAONIS GRACILIS	29	29	12	19										19	29
PHYLLODOCIDAE															
EUMIDA SANGUINEA						29				19	10		10		
PHYLLODOCE ARENAE									10						
PHYLLODOCE MUCOSA	10					162	19	29	29	10	38	10	38		
PILARGIIDAE															
SIGAMBRA TENTACULATA		10	12	10	10										
POLYNOIDAE															
HARMOTHOE EXTENUATA			38			86		19	57	95	67	67	57		
HARMOTHOE IMBRICATA				19									29		
LEPIDONOTUS SQUAMATUS						10						10	10		
SABELLIDAE															
EUCHONE ELEGANS									10						
EUCHONE INCOLOR									10						10
LAONOME KROYERI	10		12	115								19			29
SERPULIDAE															
SPIRORBIS SP.						984									
SIGALIONIDAE															
PHOLOE MINUTA	105	172	439	306	76	38	115	363	38	19		10	134	96	315
SPIONIDAE															
LAONICE CIRRATA	76	10	48												
POLYDORA CAULLERYI			6			430	76		10	382	29	172	96		
POLYDORA LIGNI		95					10							29	10
POLYDORA QUADRILOBATA				48			10		10	10	86	19			38
POLYDORA SOCIALIS						38	10			29	19				10
PRIONOSPIO STEENSTRUPI	29	210	430	162	19	38	458	353	201	57		19		181	86
SPIOPHANES BOMBYX	10	38				10	48	95	153	105	48	10	735	19	
SPIO FILICORNIS						57	10			29	19		10		
SPIO SETOSA						10				29	29		10		
STREBLOSPIO BENEDICTI													19		
SYLLIDAE															
EXOGENE HEBES						888	334	29	296	659	344	124	29		
PARAPIONOSYLLIS LONGOCIRRATA						29			76	48	19				
SYLLIDAE SP.													10		
TEREBELLIDAE															
NICOLEA VENUSTULA						10			10	29	19				
POLYCIRRUS EXIMUS		38		10		344	10		67	181	172	95	57	48	
TEREBELLIDAE SP. FRAG.								10							
TROCHOCHAETIDAE															
TROCHOCHAETA MULTISETOSA		10													

Table C.2.1-3. Mean number of individuals per species per square meter at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CRUSTACEA															
AMPHIPODA															
AMPELISCA ABDITA	10	144	409	1024	2464	67	1232	16350		115	19	10	19		
AMPELISCA SP. JUV.													19		
AMPELISCA MACROCEPHALA							10								
AMPELISCA VADORUM			6												
AMPELISCA VERILLI								57		10					
AMPHIPODA SP.			12												
CALLIOPIUS LAEVISCULUS											10				
CERAPUS TUBULARIS			6												
COROPHIUM ACHERUSICUM						95		10	10	19	48		20		
COROPHIUM TUBERCULATUM											29				
DYOPEDOS MONACANTHUS					10										
LEPTOCHEIRUS PINGUIS	29	48	1547	974	959	7736	6418	2445	544	353	487	2454	.669	143	38
MICRODEUTOPES ANOMALUS															
MICRODEUTOPES GRYLLOTALPA								10							
PARAMETOPELLA CYPHIS								10	10	10					
PHOTIS MACROCOXA			12	29											
PHOXOCEPHALUS HOLBOLLI						143	10		29	57	162	48	28		10
PONTOGENEIA INERMIS											48				
RHEPOXYNUS EPISTOMUS						10					19				
STENOTHOE MINUTA			6	10						10	29				
UNCIOLA INERMIS						95				124	105	10			
UNCIOLA IRRORATA	48	57		29	29	10	172	659		57				67	29
UNCIOLA SP. FRAG.										29					
UNCIOLA SP. JUV.			25				57								
CAPRELLIDA															
CAPRELLIDAE SP. JUV.						57	10	10		48	258				
CUMACEA															
OXYUROSTYLIS SMITHI	10			19											
DECOPODA															
CANCER IRRORATUS			6			19	10	19	19	19	38		29		
CRANGON SEPTEMSPINOSA			6			10	38	19	19			19	10		10
PAGURUS SP. JUV.			6				10			10					10
ISOPODA															
EDOTEA TRILOBA	19									29					
ERISCHONELLA FILIFORMIS												10			
ERISCHONELLA SP.											10				
ERISCHONELLA SP. JUV.											19				
IDOTEA PHOSPHOREA						10					29				
PTILANTHURA TENUIS		10				10	19		19					10	10
OSTRACODA	201		573	640	29	29			10						124
TANAIDACEA															
TANAISSIS LILJEBORGI						115			38	67	26		6		

Table C.2.1-3 Mean number of individuals per species per square meter at each sampling station, Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ANCHIANNELIDA						95	19		76	516	1031	86			
NEMATODA						29	86	38	86	67	105	38	144		
OLIGOCHAETA	29	86	407			267	67		95	592	812	76	181		
RHYNCOCOELA		38	12	10	10	86	10	19	29			95	19		
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA						10			19	10	10		10		
CREPIDULA SP.JUV.										76					
CYLICHNELLA CANALICULATA	10	19													
GASTROPODA SP.								10							
LUNATIA TRISERIATA		10	6												
MITRELLA LUNATA				10					10	29		48			
NASSARIUS TRIVITTATUS		10								10	10				
TURBONILLA INTERRUPTA	95	76		29										76	48
PELECYPODA															
ARCTICA ISLANDICA	10		6	10					10						
ASTARTE UNDATA			10		48			29						10	
MYSELLA PLANULATA								29				10			
CERASTODERMA PINNULATUM				10		29	19	29	10	19	10				10
CRENELLA GLANDULA										29					
CYCLOCARDIA BOREALIS			76			10		29		86					
ENSIS DIRECTUS		38		29			10	29	10	76			10	19	10
HIATELLA ARCTICA						19						10	10		
LYONSIA HYALINA	19			10							10				
LYONSIA SP. JUV.	162	19		105			57		19	38					115
MERCENARIA MERCENARIA		19		10										10	10
MODIOLUS MODIOLUS						10									
MULINIA LATERLAIS													67		
MUSCULUS DISCORS			6			10			10	67	19	10	19		
MYTILUS EDULIS			6												
NUCULA DELPHINODONTA	38		222	124	10									134	334
NUCULA PROXIMA	2789	13064	361	6800	29				19	10		10		554	37770
PANDORA INORNATA		10													
PERIPLOMA PAPYRATIUM															19
PITAR MORRHUANUS	10	19													
TELLINA AGILIS		76	172	95	19	143	152	105	105	115	10	10	812		38
YOLDIA LIMATULA	57	38	19	48									19	29	19
YOLDIA SP. JUV.	48	105	6	48									19	29	29
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.															
EDWARDSIA ELEGANS				19										10	29
EDWARDSIA SP.	19													10	
HYDROZOA															
EUDENDRIUM CARNEUM															
ECHINODERMATA															
HOLOTHUROIDEA															
PENTAMERA PULCHERRIMA						10			10						
PHORONIDA															
PHORONIS ARCHITECTA		10	31	19		19	10	38	19						
UROCHORDATA															
MOLGULA ARENATA			10										10		10

Table C.2.1-4. Relative frequency of individual species at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA		0.06	0.04	0.07	0.25	0.64	0.71	0.13	2.30	1.80	1.40	0.41	1.00		
ASABELLIDES OCULATA							0.09								
ARABELLIDAE															
DRILONERIS MAGNA					0.49		0.09	0.05		0.19					
CAPITELLIDAE															
CAPITELLA CAPITATA						1.40	0.09		0.34		0.60	0.22	1.60		
MEDIOMASTUS AMBISETA	0.30	0.18	0.78	0.07			0.09	0.09	0.65				3.60		
CIRRATULIDAE															
CAULLERIELLA KILLERIENSIS										0.71	0.40				
THARYX ACUTUS		0.12	1.40	0.14		0.85	0.80	0.39	6.50	2.20	0.60		5.80	0.55	
THARYX ANNULOSUS	2.00	0.93	2.00	2.20	0.25	0.92	4.80	2.60	2.30	3.20	1.00	3.10	3.80	5.20	0.45
CIRRATULIS GRANDIS												9.00			
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS								0.17	1.00		0.21				
COSSURIDAE															
COSSURA LONGOCIRRATA			0.69	0.07											
DORVILLEIDAE															
PROTODORVILLEA KEFERSTEINI						0.21				1.10			1.60		0.03
SCHISTOMERINGOS CAECA									0.34		0.60				
EUNICIDAE															
MARPHYSA BELLI												0.22			
FLABELLIGERIDAE															
PHERUSA AFFINIS		0.06	0.04	0.07		0.07	0.09					0.41	0.40		
GLYCERIDAE															
GLYCERA DIBRANCHIATA									0.34	0.19					
GONIADIDAE															
GONIADELLA GRACILIS										0.19	0.40				
LUMBRINERIDAE															
LUMBRINERIS IMPATIENS	2.80	1.00	0.17	0.68			1.60	0.26	0.65			4.60	0.20	1.40	0.50
LUMBRINERIS TENUIS						0.07				1.30		0.22			
NINOE NIGRIPES	0.30	0.29	0.23	0.27	0.25		0.09	0.39						0.84	0.08
MALDANIDAE															
ASYCHIS ELONGATA	0.70	0.23	0.14	0.40										0.29	0.10
CLYMENELLA TORQUATA	0.30	0.18	0.28	0.61			0.53	0.39	0.65			0.22		6.90	0.17
EUCLYMENE ZONALIS	0.80	0.46	0.14	0.88			0.27	0.43	1.00	0.36		0.63	0.40	0.29	0.10
MALDANIDAE SP. JUV.		0.23												5.50	
NEPHTYIDAE															
AGLAOPHAMUS CIRCINATA						0.14	0.71	0.05	0.65		0.21	0.22			
NEPHTYS INCISA	2.90	1.20	2.90	3.90	2.90			0.09	0.34			3.50		7.90	1.30
NEPHTYS PICTA						0.2	0.63			0.71	3.41		1.20		
NEPHTYIDAE SP. JUV.				0.07		0.92				0.55	0.60				
NEREIDAE															
NEREIS SP. JUV.									0.34	0.19					
NEREIS SUCCINEA							0.09		0.34	0.36	0.21				
OPHELIIDAE															
AMMOTRYPANE AULOGASTER								0.13							

Table C.2.1-4. Relative frequency of individual species at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ORBINIIDAE															
HAPLOSCOLOPLOS ACUTUS	0.17	0.35	0.75	0.14	0.73			0.05						6.10	0.05
SCOLOPLOS ARMIGER													0.20		
PARAONIDAE															
AMICIDEA CATHERINAE	10.90	6.50	2.30	8.50		2.60	0.35	0.30	3.60		0.21		0.20	19.80	0.22
PARADONEIS LYRA										4.50	1.00				
PARAONIS GRACILIS	0.50	0.17	0.09	0.14										0.55	0.08
PHYLLODOCIDAE															
EUMIDA SANGUINEA						0.21				0.36	0.21		0.20		
PHYLLODOCE ARENAE									0.34						
PHYLLODOCE MUCOSA	0.17					0.75	0.18	0.13	1.00	0.19	0.80	0.22	0.80		
PILARGIIDAE															
SIGAMBRA TENTACULATA		0.06	0.09	0.07	0.25										
POLYNOIDAE															
HARMOTHOE EXTENUATA			0.29			0.64		0.09	1.20	1.80	1.40	1.50	1.10		
HARMOTHOE IMBRICATA				0.14									0.60		
LEPIDONOTUS SQUAMATUS						0.07						0.22	0.20		
SABELLIDAE															
EUCHONE ELEGANS									0.34						
EUCHONE INCOLOR									0.34						0.03
LAONOME KROYERI	0.17		0.09	0.82								0.41			0.08
SERPULIDAE															
SPIROBIS SP.						7.30									
SIGALIONIDAE															
PHOLOE MINUTA	1.80	1.00	3.20	2.20	1.90	0.28	1.10	1.60	1.90	0.36		0.22	2.80	2.70	0.82
SPIONIDAE															
LAONICE CIRRATA	1.30	0.06	0.35												
POLYDORA CAULLERYI			0.04			3.20	0.71		0.34	7.20	0.60	3.70	2.00		
POLYDORA LIGNI		0.58					0.09							0.84	0.03
POLYDORA QUADRILOBATA				0.34			0.09		0.34	0.19	1.80	0.41			0.10
POLYDORA SOCIALIS						0.28	0.09			0.55	0.40				0.03
PRIONOSPIO STEENSTRUPI	0.50	1.30	3.20	1.20	0.48	0.28	4.30	1.60	6.90	1.10		0.41	2.80	5.20	0.22
SPIOPHANES BOMBYX	0.17	0.23				0.07	0.45	0.43	5.20	2.20	1.00	0.22	15.7	0.55	
SPIO FILICORNIS						0.42	0.09			0.55	0.40		0.20		
SPIO SETOSA						0.07				0.55	0.60		0.20		
STREBLOSPIO BENEDICTI													0.40		
SYLLIDAE															
EXOGENE HEBES						6.60	3.10	0.13	10.10	12.40	7.10	2.70	2.60		
PARAPIONOSYLLIS LONGOCIRRATA						0.21			2.60	0.90	0.40		0.60		
SYLLIDAE SP.													0.20		
TEREBELLIDAE															
NICOLEA VENUSTULA						0.07			0.34	0.55	0.40				
POLYCIRRUS EXIMUS		0.23		0.07		2.50	0.09		2.30	3.40	3.50	2.10	1.20	1.40	
TEREBELLIDAE SP. FRAG.								0.05							
TROCHOCHAETIDAE															
TROCHOCHAETA MULTISETOSA		0.06													

Table C.2.1-4. Relative frequency of individual species at each sampling station at the Black ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CRUSTACEA															
AMPHIPODA															
AMPELISCA ABDITA	0.17	0.88	2.90	7.30	61.90	0.50	11.50	74.30		2.20	0.40	0.22	0.40		
AMPELISCA SP. JUV.													0.40		
AMPELISCA VADORUM			0.04							0.19					
AMPELISCA VERILLI							0.09	0.26							
GAMMARUS SP.			0.08												
CALLIOPIUS LAEVISCULUS															
CERAPUS TUBULARIS			0.04								0.21				
COROPHIUM ACHERUSICUM						0.70		0.05	0.34	0.36					
COROPHIUM TUBERCULATUM											1.00		3.80		
DYOPEDOS MONACANTHUS					0.25						0.60				
LEPTOCHEIRUS PINGUIS	0.50	0.29	11.30	6.90	24.30	7.20	59.90	11.10	18.60	6.60					
MICRODEUTOPES ANOMALUS									1.90		10.00	53.50	13.90	14.10	0.10
MICRODEUTOPES GRYLLOTALPA								0.05							
PARAMETOPELLA CYPRIS								0.05	0.34	0.19					
PHOTIS MACROCOXA			0.08	0.21											
PHOXOCEPHALUS HOLBOLLI						1.10	0.09		1.00	1.10					
PONTOGENEIA INERMIS											3.30	1.00 2	0.80		0.03
RHEPOXYNUS EPISTOMUS						0.07					1.00				
STENOTHOE MINUTA			0.04	0.07						0.19	0.40				
UNCIOLA INERMIS						0.70				2.20	0.60				
UNCIOLA IRRORATA	0.83	0.35		0.21	0.73	0.07	1.60	2.90		1.10	2.20	0.21			
UNCIOLA SP. FRAG.										0.55				1.90	0.08
UNCIOLA SP. JUV.			0.18				0.53								
CAPRELLIDA															
CAPRELLIDAE SP. JUV.						0.42	0.09	0.05		0.90					
CUMACEA											5.30				
OXYUROSTYLIS SMITHI	0.17			0.14											
DECOPODA															
CANCER IRRORATUS			0.04			0.14	0.09	0.09	0.65	0.36					
CRANGON SEPTEMSPINOSA			0.04		1.20	0.07	0.35	0.09	0.65		0.80		0.60		
PAGURUS SP. JUV.			0.04				0.09			0.19		0.41	0.20		0.03
ISOPODA															0.03
EDOTEA TRILOBA	0.35									0.55					
ERISCHONELLA FILIFORMIS															
ERISCHONELLA SP.												0.22			
ERISCHONELLA SP. JUV.											0.21				
IDOTEA PHOSPHOREA						0.07					0.40				
PTILANTHURA TENUIS		0.06				0.07	0.18		0.65		0.60				
OSTRACODA	3.50		4.20	4.60	0.73	0.21			0.34					0.36	0.03
TANAIDACEA															0.32
TANAISSIS LILJEBORGI						0.85			1.30	1.30					
											0.60		1.20		

Table C.2.1-4. Relative frequency of individual species at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ANCHIANNELIDA						0.70	0.18		2.60	9.60	21.20	1.90			
NEMATODA						0.21	0.80	0.17	2.90	1.20	2.20	0.82	3.00		
OLIGOCHAETA	0.50	0.52	2.90			1.90	0.63		3.20	11.10	16.70	1.70	3.80		
RHYNCOCOELA		0.23	0.09	0.07	0.25	0.27	0.09	0.09	1.00			2.10	0.40		
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA						0.07			0.65	0.19	0.21		0.20		
CREPIDULA SP.JUV.										1.40					
CYLICHNELLA CANALICULATA	0.17	0.12													
GASTROPODA SP.								0.05							
LUNATIA TRISERIATA		0.06	0.04												
MITRELLA LUNATA				0.07					0.34	0.55		1.00			
NASSARIUS TRIVITTATUS		0.06								0.19	0.21				
TURBONILLA INTERRUPTA	1.60	0.46		0.21										2.20	1.20
PELECYPODA															
ARCTICA ISLANDICA	0.17		0.04	0.07					0.34						
ASTARTE UNDATA			0.07		1.20			0.13						0.29	
MYSELLA PLANULATA								0.13				0.22			
CERASTODERMA PINNULATUM				0.07		0.21	0.18	0.13	0.34	0.36	0.21				0.03
CHEMELLA GLANDULA										0.55					
CYCLOCARDIA BOREALIS			0.56			0.07		0.13		1.60	0.21		0.20		
ENSIS DIRECTUS		0.23		0.21			0.09	0.13	0.34	1.40			0.20	0.55	0.03
HIATELLA ARCTICA						0.14						0.22	0.20		
LYONSIA HYALINA	0.53			0.07							0.21				
LYONSIA SP. JUV.	2.80	0.12		0.75			0.53		0.65	0.71					3.00
MERCENARIA MERCENARIA		0.12		0.07										0.29	0.03
MODIOLUS MODIOLUS						0.07							0.20		
MULINIA LATERALIS													1.40		
MUSCULUS DISCORS			0.04			0.07			0.34	1.30	0.40	0.22	0.40		
MYTILUS EDULIS			0.04												
NUCULA DELPHINODONTA	0.66		1.60	0.88	0.25									3.90	9.00
NUCULA PROXIMA	48.40	79.40	0.25	48.50	0.73				0.65	0.19		0.22		9.90	9.30
PANDORA INORNATA		0.06													
PERIPLOMA PAPYRATIUM															0.05
PITAR MORRHUANUS	0.17	0.12													
TELLINA AGILIS		0.46	1.30	0.68	0.48	1.10	1.40	0.47	3.60	2.20	0.21	0.22	16.90		0.10
YOLDIA LIMATULA	0.98	0.23	0.14	0.34									0.40	0.84	0.05
YOLDIA SP. JUV.	0.83	0.64	0.04	0.34									0.40	0.84	0.08
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.															
EDWARDSIA ELEGANS				0.14										0.29	0.08
EDWARDSIA SP.	0.33													0.29	
HYDROZOA															
EUDENDRIUM CARNEUM															
ECHINODERMATA															
HOLOTHUROIDEA															
PENTAMERA PULCHERRIMA						0.07			0.34						
PHORONIDA															
PHORONIS ARCHITECTA		0.06	0.23	0.14		0.14	0.09	0.17	0.65						0.03
UROCHORDATA															
MOLGULA ARENATA			0.07											0.29	0.03

Table C.2.1-5. Ranks of species by relative abundance at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA		19	22	19	8	14	10	12	10	10	11	15	15		
ASABELLIDES OCULATA							17								
ARABELLIDAE															
DRILONERIS MAGNA					7		17	14		20					
CAPITELLIDAE															
CAPITELLA CAPITATA						8	17		16		14	16	11		
MEDIOMASTUS AMBISETA	19	16	9	19			17	13	16				6		
CIRRATULIDAE															
CAULLERIELLA KILLERIENSIS										17	15				
THARYX ACUTUS		18	8	18		11	9	8	4	9	14		4	15	
THARYX ANNULOSUS	2	6	6	7	8	10	3	4	10	8	12	6	5	8	8
CIRRATULIS GRANDIS												2			
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS								11	14		16				
COSSURIDAE															
COSSURA LONGOCIRRATA			11	19											
DORVILLEIDAE															
PROTODORVILLEA KEFERSTEINI						19				15			11		15
SCHISTOMERINGOS CAECA									16		14				
EUNICIDAE															
MARPHYSA BELLI												16			
FLABELLIGERIDAE															
PHERUSA AFFINIS		19	22	19		21	17					15	18		
GLYCERIDAE															
GLYCERA DIBRANCHIATA									16	20					
GONIADIDAE															
GONIADELLA GRACILIS										20	15				
LUMBRINERIDAE															
LUMBRINERIS IMPATIENS	6	5	17	12			6	10	15			3	19	13	7
LUMBRINERIS TENUIS						21				13		16			
NINOE NIGRIPES	19	14	16	16	8		17	8						14	13
MALDANIDAE															
ASYCHIS ELONGATA	13	15	18	14										17	12
CLYMENELLA TORQUATA	19	16	14	13			12	8	15			16		5	11
EUCLYMENE ZONALIS	12	12	18	9			15	7	14	19		14	18	17	12
MALDANIDAE SP. JUV.		15												7	
NEPHTYIDAE															
AGLAOPHAMUS CIRCINATA						20	10	14	15		16	16			
NEPHTYS INCISA	5	4	4	6	3			13	16			5		4	4
NEPHTYS PICTA						19	11			17	7		13		
NEPHTYIDAE SP. JUV.				19		10				18	15				
NEREIDAE															
NEREIS SP. JUV.									16	20					
NEREIS SUCCINEA							17		16	19	16				
OPHELIIDAE															
AMMOTRYPANE AULOGASTER								12							

Table C.2.1-5. Ranks of species by relative abundance at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ORBINIIDAE															
HAPLOSCOLOPLOS ACUTUS	20	13	10	18	6			14						6	14
SCOLOPLOS FRAGILIS													19		
PARAONIDAE															
ARICIDEA CATHERINAE	3	2	5	2		5	14	9	6		16		19	1	10
PARADONEIS LYRA										6	12				
PARAONIS GRACILIS	16	17	19	18										5	13
PHYLLODOCIDAE															
EUMIDA SANGUINEA						19				19	16		19		
PHYLLODOCE ARENAE									16						
PHYLLODOCE MUCOSA	10					12	16	12	14	20	13	16	16		
PILARGIIDAE															
SIGAMBRA TENTACULATA		19	19	19	8										
POLYNOIDAE															
HARMOTHOE EXTENUATA			13			14		13	13	10	11	11	14		
HARMOTHOE IMBRICATA				18									17		
LEPIDONOTUS SQUAMATUS						21						16	19		
SABELLIDAE															
EUCHONE ELEGANS									16						
EUCHONE INCOLOR									16						15
LAONOME KROYERI	20		19	10								15			13
SERPULIDAE															
SPIRORBIS SP.						2									
SIGALIONIDAE															
PHOLOE MINUTA	7	5	4	7	4	17	8	5	11	19		16	8	10	6
SPIONIDAE															
LAONICE CIRRATA	9	19	12												
POLYDORA CAULLERYI			22			4	10		16	4	14	4	10		
POLYDORA LIGNI		10					17							14	15
POLYDORA QUADRILOBATA				15			17		16	20	10	15			12
POLYDORA SOCIALIS						17	17			18	15				15
PRIONOSPIO STEENSTRUPI	16	3	3	8	7	17	4	5	3	15		15	8	8	10
SPIOPHANES BOMBYX	20	15				21	13	7	5	9	12	16	2	15	
SPIO FILICORNIS						16	17			18	15		19		
SPIO SETOSA						21				18	14		19		
STREBLOSPIO BENEDICTI													18		
SYLLIDAE															
EXOGONE HEBES						3	5	12	2	1	4	7	9		
PARAPIONOSYLLIS LONGOCIRRATA						19			9	16	15		17		
SYLLIDAE SP.													19		
TEREBELLIDAE															
NICOLEA VENUSTULA						21			16	18	15				
POLYCIRRUS EXIMUS		15		19		6	17		10	7	6	8	13	13	
TEREBELLIDAE SP. FRAG.								14							
TROCHOCHAETIDAE															
TROCHOCHAETA MULTISETOSA		19													

Table C.2.1-5. Ranks of species by relative abundance at each sampling station at the Black Ledge study site, July 1983.

BLACK LEDGE STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CRUSTACEA															
AMPHIPODA															
AMPELISCA ABDITA	20	7	4	3	1	15	2	1		9	15	16	18		
AMPELISCA SP. JUV.													18		
AMPELISCA VADORUM			22							20					
AMPELISCA VERILLI							17	10							
GAMMARUS SP.			20												
CALLIOPIUS LAEVISCULUS															
CERAPUS TUBULARIS			22								16				
CORCPHIUM ACHERUSICUM						13		14	16	19					
CORCPHIUM TUBERCULATUM											12		5		
DYOPEDOS MONACANTHUS					8						14				
LEPTOCHEIRUS PINGUIS	16	14	1	4	2	1	1	2	1	5					
MICRODEUTOPES ANOMALUS									11		3	1	3	2	12
MICRODEUTOPES GRYLLOTALPA								14							
PARAMETOPELLA CYPRIS								14	16	20					
PHOTIS MACROCOXA			20	17											
PHOXOCEPHALUS HOLBOLLI						9	17		14	15					
PONTOGENEIA INERMIS											8	12	16		15
RHEPOXYNUS EPISTOMUS						21					12				
STENOTHOE MINUTA			22	19						20	15				
UNCIOLA INERMIS						13				9	14				
UNCIOLA IRRORATA	1	13		17	6	21	6	3		15	9	16			
UNCIOLA SP. FRAG.										18				12	13
UNCIOLA SP. JUV.			17				12								
CAPRELLIDA															
CAPRELLIDAE SP. JUV.						16	17	14		16					
CUMACEA											5				
OXYUROSTYLIS SMITHI	20			18											
DECOPODA															
CANCER IRRORATUS			22			20	17	13	15	19					
CRANGON SEPTEMSPINOSA			22		5	21	14	13	15		13		17		
PAGURUS SP. JUV.			22				17			20		15	19		15
ISOPODA															15
EDOTEA TRILOBA	7									18					
ERISCHONELLA FILIFORMIS															
ERISCHONELLA SP.												16			
ERISCHONELLA SP. JUV.											16				
IDOTEA PHOSPHOREA						21					15				
PTILANTHURA TENUIS		19				1	16		15		14				
OSTRACODA	4		2	5	6	19			16					16	15
TANAIDACEA															9
TANAISSIS LILJEBORGI						11			12	13					
											14		13		

Table C.2.1-5. Ranks of species by relative abundance at each sampling station at the Black Ledge study site, July 1983.

STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ANCHIANNELIDA						13	16		9	3	1	9			
NEMATODA						19	9	11	8	14	9	13	7		
OLIGOCHAETA	16	11	4			7	11		7	2	2	10	5		
RHYNCOCOELA		15	19	19	8	18	17	13	14			8	18		
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA						21			15	20	16		19		
CREPIDULA SP.JUV.										12					
CYLICHNELLA CANALICULATA	20	18													
GASTROPODA SP.								14							
LUNATIA TRISERIATA		19	22												
MITRELLA LUNATA				19	9				16	18		12			
NASSARIUS TRIVITTATUS		19								20	16				
TURBONILLA INTERRUPTA	8	12		17										11	5
PELECYPODA															
ARCTICA ISLANDICA	20		22	19					16						
ASTARTE UNDATA			21		5			12						17	
MYSELLA PLANULATA								12				16			
CERASTODERMA PINNULATUM				19		19	16	12	16	19	16				15
CRENELLA GLANDULA										18					
CYCLOCARDIA BOREALIS			11			21		12		11	16		19		
ENSIS DIRECTUS		15		17			17	12	16	12			19	15	15
HIATELLA ARCTICA						20						16	19		
LYONSIA HYALINA	15			19							16				
LYONSIA SP. JUV.	6	18		11			12		15	17					3
MERCENARIA MERCENARIA		18		19										17	15
MODIOLUS MODIOLUS						21							19		
MULINIA LATERALIS													12		
MUSCULUS DISCORS			22			21			16	13	15	16	18		
MYTILUS EDULIS			22												
NUCULA DELPHINODONTA	14		7	9	8									9	2
NUCULA PROXIMA	1	1	15	1	6				15	20		16		3	1
PANDORA INORNATA		19													
PERIPLOMA PAPYRATIUM															14
PITAR MORRHUANUS	20	18													
TELLINA AGILIS		12	8	12	7	9	7	6	6	9	16	16	1		12
YOLDIA LIMATULA	10	15	18	15									18	14	14
YOLDIA SP. JUV.	11	9	22	15									18	14	13
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.															
EDWARDSIA ELEGANS				18										17	13
EDWARDSIA SP.	18													17	7
HYDROZOA															
EUDENDRIUM CARNEUM															
ECHINODERMATA															
HOLOTHUROIDEA															
PENTAMERA PULCHERRIMA						14		13							
PHORONIDA															
PHORONIS ARCHITECTA		19	16	18		20	17	11	15						15
UROCHORDATA															
MOLGULA ARENATA														17	15

Table C.2.2-1. Faunal sample parameter summary for Penfield Reef Site. S = number of species or taxa; N = number of individuals/m^2; SR = species richness; H = Shannon-Weiner diversity index; J = evenness.

Station	S	N	SR	H	J
1-A	7	898	1.56	1.23	0.63
1-B	17	2,300	3.33	2.01	0.71
2-A	19	1,643	4.04	2.23	0.76
2-B	15	1,776	3.09	2.18	0.81
3-A	10	1,471	2.07	1.70	0.71
3-B	13	1,719	2.67	2.20	0.86
4-A	22	5,845	3.67	1.89	0.61
4-B	30	4,336	5.35	2.61	0.77
5-A	13	4,183	2.23	1.83	0.71
5-B	7	2,712	1.21	1.05	0.54
6-A	22	7,640	3.51	1.50	0.49
6-B	26	8,213	4.12	1.60	0.49
7-A	27	12,320	4.02	2.00	0.61
7-B	23	13,867	3.34	1.75	0.56
8-A	30	18,298	4.22	1.78	0.53
8-B	20	11,078	2.99	1.71	0.57
9-A	28	9,130	4.38	1.44	0.43
9-B	11	726	2.75	2.01	0.84
10-A	21	5,157	3.57	2.14	0.70
10-B	17	4,259	2.96	1.85	0.65
11-A	11	8,366	1.64	1.52	0.63
11-B	22	7,984	3.48	1.41	0.46
12-A	10	1,394	2.10	1.50	0.65
12-B	15	1,700	3.12	2.00	0.74
13-A	8	993	1.77	1.39	0.67
13-B	22	1,986	4.52	2.44	0.79
14-A	17	1,776	3.53	2.20	0.78
14-B	24	9,932	3.70	1.66	0.52
15-A	23	7,449	3.69	1.33	0.42
15-B	13	6,322	2.07	0.66	0.26
Mean	18	5,516	3.16	1.76	0.63
S.D.	6.8	4,468	0.99	0.42	0.14

Table C.2.2-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION SEDIMENT TYPE	1-A SAND	1-B	2-A SAND	2-B	3-A SILT/SAND	3-B SILT/SAND	4-A GRAVEL/BOULDER	4-B	5-A SILT	5-B	6-A SILT/SAND	6-B	7-A SILT	7-B	8-A SILT/SAND
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA			1				1	3				6	5	8	1
ASABELLIDES OCULTA															
CAPITELLIDAE															
MEDIOMASTUS AMBISETA					37	14	114	10	29	39	25	179	125	251	431
CIRRATULIDAE															
THARYX ACUTUS		7	7	2			17	14	1		4	15	10	2	6
THARYX ANNULOSUS															
CHAETOPTERIDAE															
SPIOCHAETOPTEROUS OCULATUS													1		
COSSURIDAE															
COSSURA LONGOCIRRATA										1					
DORVILLEIDAE															
DORVILLEA RUDOLPHI								1							
FLABELLIGERIDAE															
PHERUSA AFFINIS		1										1		1	
GLYCERIDAE															
GLYCERA DIBRANCHIATA								1				2	1	2	1
GONIADIDAE															
GONIADELLA GRACILIS															
LUMBRINERIDAE															
LUMBRINERIS FRAGILIS								1							
LUMBRINERIS SP.JUV.															
LUMBRINERIS TENUIS															
NINOE NIGRIPES															
MALDANIDAE															
EUCLYMENE ZONALIS		1						51				4	16		7
NEPHTYIDAE															
NEPHTYIDAE SP. JUV.															
NEPHTYS INCISA					7	12			17	10	7	4	4	6	4
NEPHTYS PICTA	4		1	10											
NEREIDAE															
NEREIS SP. JUV.															
NEREIS SUCCINEA		1					1					1	1		
NEREIS VIRENS	1														
ORBINIIDAE															
HAPLOSCOLOPLOS(=SCOLOPLOS)ACUTUS		1		3											
ORBINIIDAE SP.	1														
PARAONIDAE															
ARICIDEA CATHERINAE															
PECTINARIIDAE															
PECTINARIA GOULDII							2	2			4			2	6
PISIONIDAE															
PISIONE REMOTA															
PHYLLODOCIDAE															
ETEONE HETEROPODA															
ETEONE LACTEA	1													1	
EUMIDA SANGUINEA							3	8				2			
EUMIDA SP. JUV.		1													
PARANAITIS SPECIOSA							1						2		

Tab C.2.2-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION SEDIMENT TYPE	1-A SAND	1-B	2-A SAND	2-B	3-A SILT/SAND	3-B SILT/SAND	4-A GRAVEL/BOULDER	4-B	5-A SILT	5-B	6-A SILT/SAND	6-B	7-A SILT	7-B	8-A SILT/SAND
PHYLODOCE ARENAE															
PILARGIIDAE															
SIGAMBRA TENTACULATA															
POLYNOIDAE											1				
HARMOTHOE EXTENUATA								1							
HARMOTHOE IMBRICATA							7	2							
LEPIDONOTUS SQUAMATUS								1							
LEPIDONOTUS SUBLEVIS												1			
SABELLARIIDAE															
SABELLARIA VULGARIS BEAUFORTENSIS															
SCALIBREGMIDAE															
SCALIBREGMA INFLATUM															
SERPULIDAE															
SERPULIDAE SP.															
SIGALIONIDAE															
PHOLOE MINUTA															1
SPIONIDAE															
POLYDORA LIGNI		5					4				1	1			
PRIONOSPIO STEENSTRUPI			1				1	1				3			3
SPIOPHANES BOMBYX	3		4	8											
SPIO SETOSA															
STREBLOSPIO BENEDICTI			2					1				2		1	3
SYLLIDAE															
EXOGENE HEBES															
TEREBELLIDAE															
NICOLEA VENUSTULA															
POLYCIRRUS EXIMUS											2				
															6
ARCHIANNELIDA	2	29	26			8		21							
											1				
OLIGOCHAETA	5	2		16	20	20	31	16	105	86	44	1	15	41	5
RHYNCOCOELA		1		1				14			3	3	9	5	21
NEMATODA							3								
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA															
CREPIDULA SP. JUV.															
CYLICHNELLA(=CYLICHNA)CANALICULATA								39							
CYLICHNELLA(=CYLICHNA)ORYZA					1	2			26		4				
NASSARIUS TRIVITTATUS						3			2						
PELECYPODA		1	3	3	2	8		6			4	2	15	10	1
ASTARTE UNDATA															
ENSIS DIRECTUS			2	2				2							1
GEMMA GEMMA	6		6	17										2	
LYONSIA ARENOSA				2											
LYONSIA HYALINA													1		
LYONSIA SP. JUV.			1												
MERCENARIA MERCENARIA			1										4		3

Table C.2.2-2. Number of individuals per species for each PONAR grab ($0.0523m^2$) collected at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
SEDIMENT TYPE	SAND		SAND		SILT/SAND	SILT/SAND	GRAVEL/BOULDER		SILT		SILT/SAND		SILT		SILT/SAND
MULINIA LATERALIS			1	2	5	12			4	1					
MYA ARENARIA				4											
MYTILUS EDULIS		42				2	202	2			1			2	
NUCULA PROXIMA					2	1			2	1	1	1	182	223	188
PANDORA GOULDIANA			1	1									1		
PETRICOLA PHOLADIFORMIS		1						1				4		1	3
PITAR MORRHUANUS					3			1			11	14	21	6	25
TELLINA AGILIS	30	14	21	28	3	1	84	16	4		35	166	186	107	151
YOLDIA LIMATULA						6			21	4	20	2	26	30	63
YOLDIA SP.JUV.							3		11					8	15
ARTHROPODA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS														1	
ARTHROPODA (MANDIBULATA)															
AMPHIPODA															
AMPELISCA ABDITA											3		1		1
AMPELISCA MACROCEPHALA															
AMPELISCA SP. JUV.											2		5	5	3
AMPELISCA VERRILLI												1			
AMPELISCA VADORUM															
COROPHIUM BONELLI															
COROPHIUM TUBERCULATUM		8													
ELASMOPUS LEVIS															
ERICHTHONIUS RUBRICORNIS															
LEPTOCHEIRUS PINGUIS															1
MICRODEUTOPES GRYLLOTALPA							6	4							
MONOCULODES EDWARDSI			1												
PHOXOCEPHALUS HOLBOLLI															
UNCIOLA INNOMATA								1			1	3	6		2
UNCIOLA SP. FRAG.															
UNCIOLA SP. JUV.								3					2		
UNCIOLA SERRATA								6							
CUMACEA															
LEUCON AMERICANUS					1		2								
OXYUROSTYLIS SMITHI			4	9		1	2	2					1		
DECAPODA															
CANCER IRRORATUS					1		1					3			
CRANGON SEPTEMSPINOSA				1							1	1	3	1	1
LIBINIA SP. JUV.							1								
PAGURUS SP. JUV.								1					1		
PAGURUS LONGICARPUS											2	8			
PINNIXA SAYANNA								1						1	
RITHROPANOPEUS HARRISII							1								
ISOPODA															
EDOTEA TRILOBA															
PTILANTHURA TENUIS															3
OSTRACODA															
TANAIDACEA															
TANAISSIS LILJEBORGI															

Table C.2.2-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY															
STATION	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
SEDIMENT TYPE	SAND		SAND		SILT/SAND	SILT/SAND	GRAVEL/BOULDER		SILT		SILT/SAND		SILT		SILT/SAND
CNIDARIA															
CERIANTHEOPSIS AMERICANUS															
CLAVA LEPTOSTYLA (COLONY)					P							P	P		
ECHINODERMATA															
ASTERIIDAE SP. JUV.		3	1				1		1						
ASTERIAS FORBESII													1		
ECTOPROCTA															
MEMBRANIPORA SP.				P				P							
ALCYONIDIUM POLYOUM								P							
BOWERBANKIA SP.								P							
CONOPEUM SP.				P											
MICROPORELLA CILIATA															
CRYPTOSULA SP.								P							
CALLOPORA AURITA								P							
BUGULA TURRITA															
PHORONIDA															
PHORONIS ARCHITECTA															1
SIPUNCULIDA															
GOLFINGIA IMPROVISA															

Table C.2.2-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION SEDIMENT TYPE	8-B SILT/SAND	9-A SANDS/GRAVEL	9-B	10-A SAND	10-B	11-A SILT	11-B	12-A SAND	12-B	13-A SAND	13-B SAND	14-A SAND	14-B	15-A SAND/GRAVEL	15-B
POLYCHAETA															
AMPHARETIDAE															
AMPHARETEARCTICA		15		3	1			3	3		1				4
ASABELLIDES OCULTA	1														
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	294					227	274		1				1	2	
CIRRATULIDAE															
THARYX ACUTUS		6		2	5		5		1	4	1	9	5	10	2
THARYX ANNULOSUS	1										3				
CHAETOPTERIDAE															
SPIOCHAETOPTEROUS OCULATUS															
COSSURIDAE															
COSSURA LONGOCIRRATA															
DORVILLEIDAE															
DORVILLEA RUDOLPHI															
FLABELLIGERIDAE															
PHERUSA AFFINIS	3				1		1							1	
GLYCERIDAE															
GLYCERA DIBRANCHIATA		5		1				1						1	
GONIADIDAE															
GONIADELLA GRACILIS							1								
LUMBRINERIDAE															
LUMBRINERIS FRAGILIS	1														
LUMBRINERIS SP.JUV.											3				
LUMBRINERIS TENUIS											6				
NINOE NIGRIPES											2				
MALDANIDAE															
EUCLYMENE ZONALIS	6		1						2						
NEPHTYIDAE															
NEPHTYIDAE SP. JUV.															
NEPHTYS INCISA	7		1				4								
NEPHTYS PICTA		4	4	9	16		1					1	1	1	
NEREIDAE															
NEREIS SP. JUV.														1	
NEREIS SUCCINEA														1	
NEREIS VIRENS															
ORBINIIDAE															
HAPLOSCOLOPLOS(=SCOLOPLOS)ACUTUS									1			1			
ORBINIIDAE SP.															
PARAONIDAE															
ARICIDEA CATHERINAE											13				
PECTINARIIDAE															
PECTINARIA GOULDII												1	1		
PISIONIDAE															
PISIONE REMOTA															
PHYLLODOCIDAE															
ETEONE HETEROPODA													1		
ETEONE LACTEA															
EUMIDA SANGUINEA		3											2	2	
EUMIDA SP. JUV.															
PARANAITIS SPECIOSA															

Table C.2.2-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION SEDIMENT TYPE	8-B SILT/SAND	9-A SANDS/GRAVEL	9-B	10-A SAND	10-B	11-A SILT	11-B	12-A SAND	12-B	13-A SAND	13-B SAND	14-A SAND	14-B	15-A SAND/GRAVEL	15-B
PHYLLODOCE ARENAE		1		2							1				
PILARGIIDAE															
SIGAMBRA TENTACULATA															
POLYNOIDAE															
HARMOTHOE EXTENUATA															
HARMOTHOE IMBRICATA													1		
LEPIDONOTUS SQUAMATUS															
LEPIDONOTUS SUBLEVIS															
SABELLARIIDAE															
SABELLARIA VULGARIS BEAUVORTENSIS		1													
SCALIBREGMIDAE															
SCALIBREGMA INFLATUM				1											
SERPULIDAE															
SERPULIDAE SP.														1	
SIGALIONIDAE															
PHOLOE MINUTA															
SPIONIDAE															
POLYDORA LIGNI					1				13		2	7	62	41	14
PRIONOSPIO STEENSTRUPI	5	1	1		1		1								
SPIOPHANES BOMBYX		1	3	30	12		1	22	11	10	2	4	5		1
SPIO SETOSA		1	1							1		1	2	3	
STREBLOSPIO BENEDICTI	1			5			3		2			3		2	
SYLLIDAE															
EXOGENE HEBES											10				
TEREBELLIDAE															
NICOLEA VENUSTULA															
POLYCIRRUS EXIMUS											1				1
ARCHIANNELIDA	1	253	14	12	48				13	2	17		294	267	283
OLIGOCHAETA	19	1	1		5	31	11		4					3	
RHYNCOCOELA	5	1				5	7		1						
NEMATODA															
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA													1		
CREPIDULA SP. JUV.														2	
CYLICHNELLA(=CYLICHNA)CANALICULATA						3	5								
CYLICHNELLA(=CYLICHNA)ORYZA						2									
NASSARIUS TRIVITTATUS	8	7	3	17	3		13	2		1		1	2	3	
PELECYPODA															
ASTARTE UNDATA											1				
ENSIS DIRECTUS		1	3	1					1		1	9	30		1
GEMMAGEMMA													10		
LYONSIA ARENOSA													4		
LYONSIA HYALINA		2							1						
LYONSIA SP. JUV.				1								1	4		
MERCENARIA MERCENARIA							1								1

Table C.2.2-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION SEDIMENT TYPE	8-B SILT/SAND	9-A SANDS/GRAVEL	9-B	10-A SAND	10-B	11-A SILT	11-B	12-A SAND	12-B	13-A SAND	13-B SAND	14-A SAND	14-B	15-A SAND/GRAVEL	15-B
HOLIMIA LATERALIS				11		1	2			4		4	28		
MYA ARENARIA												4			
MYTILUS EDULIS						1						1			
NUCULA PROXIMA	85					51	2								
PANDORA GOULDIANA				46	52		1	5					3	1	
PETRICOLA PHOLADIFORMIS				1										6	
PITAR MORRHUANUS				37								1	1		1
TELLINA AGILIS	37	150		86	72		29	1		1		36	52	29	20
YOLDIA LIMATULA	58					28		34	33	29					
YOLDIA SP.JUV.	3					70	48								
						19									
ARTHROPODA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS															
ARTHROPODA (MANDIBULATA)															
AMPHIPODA															
AMPELISCA ABDITA		1													
AMPELISCA MACROCEPHALA					1										
AMPELISCA SP. JUV.		1													
AMPELISCA VERRILLI				1					2						
AMPELISCA VADORUM		1													
CORONIUM BONELLI						1					2				
CORONIUM TUBERCULATUM														5	
ELASMOPUS LEVIS														1	
ERICHTHONIUS RUBRICORNIS											1				
LEPTOCHEIRUS PINGUIS	1										14				
MICRODEUTOPES GRYLLOTALPA															
MONOCULODES EDWARDSI															
PHOXOCEPHALUS HOLBOLLI											3				
UNCIOLA IRRORATA	2		1		1		5				2				
UNCIOLA SP. PRAO.							1								
UNCIOLA SP. JUV.			3		1										
UNCIOLA SERRATA															
CUMACEA															
LEUCON AMERICANUS				2											
OXYUROSTYLIS SMITHI		2										4	2		
DECAPODA															
CANCER IRRORATUS		1						3							
CRANGON SEPTEMSPINOSA	4	6			2									1	
LIBINIA SP. JUV.							2	1				1			
PAGURUS SP. JUV.		5													
PAGURUS LONGICARPUS	1	1	1		1										
PINNIXA SAYANNA															
RITHROPANOPEUS HARRISII															
ISOPODA															
EDOTEA TRILOBA													1		
PTILANTHURA TENUIS											1				
OSTRACODA															
TANAIDACEA															
TANAISSIS LILJEBORGI											7				

Table C.2.2-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION SEDIMENT TYPE	8-B SILT/SAND	9-A SANDS/GRAVEL	9-B	10-A SAND	10-B	11-A SILT	11-B	12-A SAND	12-B	13-A SAND	13-B SAND	14-A SAND	14-B	15-A SAND/GRAVEL	15-B
CNIDARIA															
ANTHOZOA															
CERIANTHEOPSIS AMERICANUS															
CLAVA LEPTOSTYLA (COLONY)	P	P	P												
ECHINODERMATA															
ASTERIIDAE SP. JUV.		2									7	14	6	1	
ASTERIAS FORBESII			2												
ECTOPROCTA															
MEMBRANIPORA SP.		P	P												
ALCYONIDIUM POLYOUM		P	P												
BOWERBANKIA SP.		P	P												
CONOPEUM SP.			P												
MICROPORELLA CILIATA		P													
CRYPTOSULA SP.			P												
CALLOPORA AURITA			P												
BUGULA TURRITA			P												
PHORONIDA															
PHORONIS ARCHITECTA															
SIPUNCULIDA															
GOLFINGIA IMPROVISA											1				

Table C.2.2-3. Mean number of individuals per species per square meter at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA		10		38		57	124	10	143	38		57	10		38
ASABELLIDES OCULTA								10							
CAPITELLIDAE															
MEDIOMASTUS AMBISETA			487	1184	649	4145	3590	6924			4785	10		10	19
CIRRATULIDAE															
THARYX ACUTUS	67	86		296	10	1825	1156	57	57	67	48	10	48	134	115
THARYX ANNULOSUS								10					29		
CHAETOPTERIDAE															
SPIOCHAETOPTEROUS OCULATUS							10								
COSSURIDAE															
COSSURA LONGOCIRRATA					10										
DORVILLEIDAE															
DORVILLEA RUDOLPHI					10										
FLABELLIGERIDAE															
PHERUSA AFFINIS	10					10		38		10	10				10
GLYCERIDAE															
GLYCERA DIBRANCHIATA					10	19	29	10	48	10		10			10
GONIADIDAE															
GONIADELLA GRACILIS											10				
LUMBRINERIDAE															
LUMBRINERIS FRAGILIS					10			10							
LUMBRINERIS SP.JUV.													297		
LUMBRINERIS TENUIS													57		
NINOE NIGRIPES													19		
MALDANIDAE															
EUCLYMENE ZONALIS	10				487	38	153	67	57	10		19			
NEPHTYIDAE															
NEPHTYIDAE SP. JUV.															10
NEPHTYS INCISA			181		258	105	96	105		10	38				
NEPHTYS PICTA	38	105							76	239		10		19	10
NEREIDAE															
NEREIS SP. JUV.															10
NEREIS SUCCINEA	10			10		10	10								10
NEREIS VIRENS	10														
ORBINIIDAE															
HAPLOSCOLOPLOS(=SCOLOPLOS)ACUTUS	10	29											10	10	
ORBINIIDAE SP.	10														
PARAONIDAE															
ARICIDEA CATHERINAE													124		
PECTINARIIDAE															
PECTINARIA GOULDII					38	38	19	57						10	10

Table C.2.2-3. Mean number of individuals per species per square meter at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY

STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PISIONIDAE															
PISIONE REMOTA															
PHYLLODOCIDAE															
ETEONE HETEROPODA															
ETEONE LACTEA															
EUMIDA SANGUINEA	10														
EUMIDA SP. JUV.											10				
PARANAITIS SPECIOSA	10			105			10								
PHYLLODOCE ARENAE						19									
PILARGIIDAE															
SIGAMBRA TENTACULATA				10					29					10	
POLYNOIDAE							19								
HARMOTHOE EXTENUATA														19	19
HARMOTHOE IMBRICATA									10						
LEPIDONOTUS SQUAMATUS						10				19					
LEPIDONOTUS SUBLEVIS				10									10		
SABELLARIIDAE				86											
SABELLARIA VULGARIS				10											
SCALIBREGMIDAE															
SCALIBREGMA INFLATUM						10									
SERPULIDAE															
SERPULIDAE SP.									10						
SIGALIONIDAE															
PHOLOE MINUTA															
SPIONIDAE										10					
POLYDORA LIGNI															
PRIONOSPIO STEENSTRUPI	48														
SPIOPHANES BOMBYX		10		38			10								10
SPIO SETOSA	29	115		19		19									
STREBLOSPIO BENEDICTI						29									
SYLLIDAE							76		19	10					
EXOGENE HEBES		19							38	10	10	124	19	657	525
TEREBELLIDAE						19	10	38	19	401	10	315	115	86	10
NICOLEA VENUSTULA										48	29	19	10	29	29
POLYCIRRUS EXIMUS					19									29	19
								57					96		
													10		10

Table C.2.2-3. Mean number of individuals per species per square meter at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ARTHROPODA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS							10								
ARTHROPODA (MANDIBULATA)															
AMPHIPODA															
AMPELISCA ABDITA						29	10	10	10						
AMPELISCA SP. JUV.						19	96	29	10			19			
AMPELISCA MACROCEPHALA										19					
AMPELISCA VERRILLI						10									
AMPELISCA VADORUM									10						
COROPHIUM ASCHERUSICUM													19		
COROPHIUM TUBERCULATUM	77														48
ELASMOPUS LEVIS															10
ERICHTHONIUS RUBRICORNIS													10		
LEPTOCHEIRUS PINGUIS								10					134		
MICRODEUTOPES GRYLLOTALPA				96											
MONOCULODES EDWARDSI		10													
PHOXOCEPHALUS HOLBOLLI													29		
UNCIOLA IRRORATA				10		38	47	19	10	10	48		19		
UNCIOLA SP. FRAG.											10				
UNCIOLA SP. JUV.				29			19		29	10					
UNCIOLA SERRATA				57											
CUMACEA															
LEUCON AMERICANUS				19						19					
OXYUROSTYLIS SMITHI		124	10	38			10		19			29		57	
DECAPODA															
CANCER IRRORATUS			10	10		29			10						10
CRANGON SEPTEMSPINOSA		10				19	38	48	57	19	19	19			
LIBINIA SP. JUV.				10											
PAGURUS SP. JUV.				10			10		48					10	
PAGURUS LONGICARPUS						96		19	19	10					
PINNIXA SAYANNA				10			10								
RITHROPANOPEUS HARRISII				10											
ISOPODA															
EDOTEA TRILOBA														10	
PTILANTHURA TENUIS													10		
OSTRACODA								29							
TANAIDACEA															
TANAISSIS LILJEBORGI													67		
CNIDARIA															
CERIANTHEOPSIS AMERICANUS								10							
CLAVA LEPTOSTYLA (COLONY)															
ECHINODERMATA															
ASTERIIDAE SP. JUV.	29	10		10	10				19					201	67
ASTERIAS FORBESII							10		19						
PHORONIDA															
PHORONIS ARCHITECTA								10							
SIPUNCULIDA															
GOLFINGIA IMPROVISA													10		

Tabl).2.2-3. Mean number of individuals per species per square meter at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ANCHIANNELIDA	296	248	76	201		10		10	2550	573		124	182	2808	5253
OLIGOCHAETA	48	19	344	449	1824	430	535	229	19	48	401	38		29	
RHYNCOCOELA	10	10		134		57	134	248	10		115	10			
NEMATODA					288										
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA															
CREPIDULA SP. JUV.														10	
CYLICHNELLA(=CYLICHNA)CANALICULATA			287		373										19
CYLICHNELLA(=CYLICHNA)ORYZA			29		248	38					77				
NASSARIUS TRIVITTATUS	10	57	96		19						19				
PELECYPODA					57	57	239	86	96	191	124	19	10	29	29
ASTARTE UNDATA															
ENSIS DIRECTUS													10		
GEMMA GEMMA		38					19	10	38	10		10		372	10
LYONSIA ARENOSA	57	220		19										95	
LYONSIA HYALINA		19												38	
LYONSIA SP. JUV.							10		19			10			
MENCENARIA MENCENARIA		10												48	
MULINIA LATERALIS		10					19	29			10				10
MYA ARENARIA		29	162		48						29		38	306	
MYTILUS EDULIS	401	38												38	
NUCULA PROXIMA			19	210			19				10				
PANDORA GOULDIANA			29		29	19	3963	2607			806				
PETRICOLA PHOLADIFORMIS		10					10				10	48		29	10
PITAR MORRHUANUS	10					38	10	10							57
TELLINA AGILIS			29	10		239	334	688			277	10	10	19	10
YOLDIA LIMATULA	4202	478	38	955	38	1920	2798	1795			267	640	277	821	468
YOLDIA SP.JUV.			57		239	210	535	1156	1433		1127				
				29	105		76	172			182				

Table C.2.2-4. Relative frequency of individual species at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA		0.60		0.90		0.60	0.90	0.07	2.90	2.10		3.70	0.60		0.60
ASABELLIDES OCULTA								0.07							
CAPITELLIDAE															
MEDIOMASTUS AMBISETA			26.40	28.80	13.60	43.00	25.30	47.10			56.40	0.60		0.20	0.30
CIRRATULIDAE															
THARYX ACUTUS	1.20	4.90		7.20	0.20	19.00	8.10	0.39	1.20	3.70	0.60	0.60	2.70	2.30	1.70
THARYX ANNULOSUS								0.07					1.60		
CHAETOPTERIDAE															
SPIOCHAETOPTEROUS OCULATUS							0.07								
COSSURIDAE															
COSSURA LONGOCIRRATA					0.20										
DONVILLEIDAE															
DONVILLEA RUDOLPHI					0.20										
FLABELLIGERIDAE															
PHERUSA AFFINIS	0.20					0.10		0.26		0.60	0.10				0.10
GLYCERIDAE															
GLYCERA DIBRANCHIATA					0.20	0.20	0.20	0.07	0.97	0.60		0.60			0.10
GONIADIDAE															
GONIADELLA GRACILIS											0.10				
LUMBRINERIDAE															
LUMBRINERIS FRAGILIS					0.20			0.07							
LUMBRINERIS SP.JUV.													16.70		
LUMBRINERIS TENUIS													3.20		
NINOE NIGRIPES													1.10		
MALDANIDAE															
EUCLYMENE ZONALIS	0.20				10.20	0.40	1.10	0.70	1.20	0.60		1.20			
NEPHTYIDAE															
NEPHTYIDAE SP. JUV.															0.10
NEPHTYS INCISA			9.80		5.40	1.10	1.80	0.70		0.60	0.40				
NEPHTYS PICTA	0.70	6.10							1.50	11.60		0.60		0.30	0.10
NEREIDAE															
NEREIS SP. JUV.															0.10
NEREIS SUCCINEA	0.20			0.24		0.10	0.07								0.10
NEREIS VIRENS	0.20														
ORBINIIDAE															
NAPLOSCOLOPLOS(=SCOLOPLOS)ACUTUS	0.20	1.70											0.60	0.20	
ORBINIIDAE SP.	0.20														
PARAONIDAE															
ARICIDEA CATHERINAE													7.00		
PECTINARIIDAE															
PECTINARIA GOULDII					0.80	0.40	0.10	0.39						0.20	0.10

Table C.2.2-4. Relative frequency of individual species at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PISIONIDAE															
PISIONE REMOTA											0.10				
PHYLLODOCIDAE															
ETEONE HETEROPODA							0.07							0.20	
ETEONE LACTEA	0.20														
EUMIDA SANGUINEA				2.60		0.20			0.50					0.30	0.30
EUMIDA SP. JUV.	0.20														
PARANAITIS SPECIOSA				0.24			0.10								
PHYLLODOCE ARENAE									0.20	1.00			0.60		
PILARGIIDAE															
SIGAMBRA TENTACULATA						0.10									
POLYNOIDAE															
HARMOTHOE EXTENUATA				0.24											
HARMOTHOE IMBRICATA				2.10											
LEPIDONOTUS SQUAMATUS				0.24											
LEPIDONOTUS SUBLEVIS						0.10									
SABELLARIIDAE															
SABELLARIA VULGARIS									0.20						
SCALIBREGMIDAE															
SCALIBREGMA INFLATUM										0.60					
SERPULIDAE															
SERPULIDAE SP.															0.10
SIGALIONIDAE															
PHOLOE MINUTA								0.07							
SPIONIDAE															
POLYDORA LIGNI	0.90			0.80		0.20				0.60		8.00	1.10	12.00	7.60
PRIONOSPIO STEENSTRUPI		0.60		0.50		3.00		0.50	0.40	0.60	0.10				
SPIOPHANES BOMBYX	0.50	6.70							0.80	22.40	0.10	20.30	6.50	1.50	0.10
SPIO SETOSA									0.40				0.60	0.50	0.40
STREBLOSPIO BENEDICTI		1.10				0.20	0.07	0.30		2.60	0.30	1.20		0.50	0.30
SYLLIDAE															
EXOGENE HEBES													5.40		
TEREBELLIDAE															
NICOLEA VENUSTULA						0.20									
POLYCIRRUS EXIMUS								0.40					0.60		0.10

Table C.2.2-4. Relative frequency of individual species at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ARTHROPODA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS							0.07								
ARTHROPODA (MANDIBULATA)															
AMPHIPODA															
AMPELISCA ABDITA						0.30	0.07	0.07	0.20						
AMPELISCA SP. JUV.						0.20	0.80	0.20	0.20			1.20			
AMPELISCA MACROCEPHALA										1.00					
AMPELISCA VERRILLI						0.10									
AMPELISCA VADORUM									0.20						
CORONHIUM ASCHERUSICUM													1.10		
CORONHIUM TUBERCULATUM	1.40														0.70
ELASMOPUS LEVIS															0.10
ERICHTHONIUS RUBRICORNIS													1.00		
LEPTOCHEIRUS PINQUIS								0.07					7.50		
MICRODEUTOPES GRYLLOTALPA				2.30											
MONOCULODES EDWARDSI		0.60													
PHOXOCEPHALUS HOLBOLLI													1.60		
UNCIOLA IRRORATA				0.20		0.40	0.40	0.10	0.20	0.60	0.60		1.10		
UNCIOLA SP. FRAG.											0.10				
UNCIOLA SP. JUV.				0.70			0.20		0.50	0.60					
UNCIOLA SERRATA				3.10											
CUMACEA															
LEUCON AMERICANUS				0.50						1.00					
OXYUROSTYLIS SMITHI		7.20	0.50	0.90			0.07		0.40			1.70		1.00	
DECAPODA															
CANCER IRRORATUS			0.50	0.20		0.30			0.20						0.10
CRANGON SEPTEMSPINOSA		0.60				0.20	0.30	0.30	1.20	1.00	0.20	1.20			
LIBINIA SP. JUV.				0.20											
PAGURUS SP. JUV.				0.20			0.07		1.00					0.20	
PAGURUS LONGICARPUS						1.00		0.07	0.40	0.60					
PINNIXA SAYANNA				0.20			0.07								
RITHROPANOPEUS HARRISII				0.20											
ISOPODA															
EDOTEA TRILOBA														0.20	
PTILANTHURA TENUIS													0.60		
OSTRACODA								0.20							
TANAIDACEA															
TANAISSIS LILJEBORGI													3.80		
CNIDARIA															
CERIANTHEOPSIS AMERICANUS								0.07							
CLAVA LEPTOSTYLA (COLONY)															
ECHINODERMATA															
ASTERIIDAE SP. JUV.	0.50	0.60		0.20	0.20				0.40					3.50	1.00
ASTERIAS FORBESII							0.07		0.40						
PHORONIDA															
PHORONIS ARCHITECTA								0.07							
SIPUNCULIDA															
GOLFINGIA IMPROVISA													0.60		

Table C.2.4-4. Relative frequency of individual species at each sampling station at the Penfield Reef study site, September 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ARCHIANNELIDA	5.50	14.40	4.10	5.10		0.10		0.07	51.50	40.00		8.0	10.3	49.2	76.5
OLIGOCHAETA	0.90	1.10	18.60	11.00	38.30	4.50	3.80	1.50	0.40	2.60	4.70	2.50		0.50	
RHYNCOCOELA	0.20	0.60		3.30		0.60	0.90	1.70	0.20		1.40	0.60			
NEMATODA					6.10										
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA														0.20	
CREPIDULA SP. JUV.					7.80										0.30
CYLICHNELLA(=CYLICHNA)CANALICULATA			15.50		5.20	0.40					0.90				
CYLICHNELLA(=CYLICHNA)ORYZA			1.60		0.40						0.20				
NASSARIUS TRIVITTATUS	0.20	3.30	5.20		1.20	0.60	1.70	0.60	1.90	10.70	1.50	1.20	0.60	0.50	0.40
PELECYPODA															
ASTARTE UNDATA													0.60		
ENSIS DIRECTUS		2.20					0.10	0.07	0.80	0.60		0.60		7.40	0.10
GEMMA GEMMA	1.10	12.80		0.50										4.80	
LYONSIA ARENOSA		1.10												0.60	
LYONSIA HYALINA							0.07		0.40			0.60			
LYONSIA SP. JUV.		0.60												0.80	
MERCENARIA MERCENARIA		0.60					0.10	0.20			0.10				0.10
MULINIA LATERALIS		1.70	8.70		1.00						0.30		2.10	5.60	
MYA ARENARIA		2.20												0.60	
MYTILUS EDULIS	7.4		1.00	5.10			0.10				0.10				
NUCULA PROXIMA			1.60		0.60	0.20	27.90	17.70			9.50				
PANDORA GOULDIANA		1.20					0.07				0.10	3.10		0.50	0.10
PETRICOLA PHOLADIFORMIS	0.20					0.40	0.07	0.20							0.80
PITAR MORRHUANUS			1.60	0.20		2.50	2.30	5.70			3.30	0.60	0.60	0.30	0.10
TELLINA AGILIS	77.90	27.70	2.00	23.20	0.80	19.90	19.70	12.20			3.20	41.30	15.60	14.80	7.80
YOLDIA LIMATULA			3.10		5.00	2.20	3.80	7.90	30.00		13.30				
YOLDIA SP.JUV.				0.70	2.20		0.50	1.20			2.10				

Table C.2.2-5. Ranks of species by relative abundance at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA		16		12		9	11	24	3	8		5	18		8
ASABELLIDES OCULTA								24							
CAPITELLIDAE															
MEDIOMASTUS AMBISETA			1	1	2	1	2	1			1	14		22	11
CIRRATULIDAE															
THARYX ACUTUS	5	7		4	16	3	4	13	6	5	11	14	10	7	4
THARYX ANNULOSUS								24					12		
CHAETOPTERIDAE															
SPIOCHAETOPTEROUS OCULATUS							24								
COSSURIDAE															
COSSURA LONGOCIRRATA					16										
DORVILLEIDAE															
DORVILLEA RUDOLPHI					16										
FLABELLIGERIDAE															
PHERUSA AFFINIS	12					28		17		13	18				15
GLYCERIDAE															
GLYCERA DIBRANCHIATA					16	20	17	24	9	13		14			15
GONIADIDAE															
GONIADELLA GRACILIS											18				
LUMBRINERIDAE															
LUMBRINERIS FRAGILIS					16			24					1		
LUMBRINERIS SP.JUV.													9		
LUMBRINERIS TENUIS													14		
NINOE NIGRIPES															
MALDANIDAE															
EUCLYMENE ZONALIS	12				3	12	9	12	6	13		9			
NEPHTYIDAE															
NEPHTYIDAE SP. JUV.															15
NEPHTYS INCISA			4		6	7	12	9		13	13				
NEPHTYS PICTA	9	6							5	3		14		19	15
NEREIDAE															
NEREIS SP. JUV.															15
NEREIS SUCCINEA	12			20		28	24								15
NEREIS VIRENS	12														
ORBINIIDAE															
HAPLOSCOLOPLOS(=SCOLOPLOS)ACUTUS	12	11											18	22	
ORBINIIDAE SP.	12														
PARAONIDAE															
ARICIDEA CATHERINAE													5		
PECTINARIIDAE															
PECTINARIA GOULDII					12	12	18	13						22	15

Table C.2.2-5. Ranks of species by relative abundance at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PISIONIDAE															
PISIONE REMOTA											18				
PHYLLODOCIDAE															
ETEONE HETEROPODA							24							22	
ETEONE LACTEA	12														
EUMIDA SANGUINEA				8		20			13					19	11
EUMIDA SP. JUV.	12														
PARANAITIS SPECIOSA				20			18								
PHYLLODOCE ARENAE									23	9			18		
PILARGIIDAE															
SIGAMBRA TENTACULATA						28									
POLYNOIDAE															
HARMOTHOE EXTENUATA				20											
HARMOTHOE IMBRICATA				10											
LEPIDONOTUS SQUAMATUS				20											
LEPIDONOTUS SUBLEVIS						28									
SABELLARIIDAE															
SABELLARIA VULGARIS									23						
SCALIBREGMIDAE															
SCALIBREGMA INFLATUM										13					
SERPULIDAE															
SERPULIDAE SP.															15
SIGALIONIDAE															
PHOLOE MINUTA								24							
SPIONIDAE															
POLYDORA LIGNI	7			12		20				13		3	14	3	2
PRIONOSPIO STEENSTRUPI		16		17		17		11	15	13	18				
SPIOPHANES BOMBYX	10	5							11	2	18	2	6	9	15
SPIO SETOSA									15				18	14	9
STREBLOSPIO BENEDICTI		13				20	24	17		6	14	9		14	11
SYLLIDAE															
EXOGENE HEBES													7		
TEREBELLIDAE															
NICOLEA VENUSTULA						20									
POLYCIRRUS EXIMUS								13					18		15

Table C.2.2-5. Ranks of species by relative abundance at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ARTHROPODA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS							24								
ARTHROPODA (MANDIBULATA)															
AMPHIPODA															
AMPELISCA ABDITA						17	24	24	23						
AMPELISCA SP. JUV.						20	12	19	23			9			
AMPELISCA MACROCEPHALA										9					
AMPELISCA VERRILLI						28									
AMPELISCA VADORUM									23						
COROPHIUM ASCHERUSICUM													14		
COROPHIUM TUBERCULATUM	4														7
ELASMOPUS LEVIS															15
ERICHTHONIUS RUBRICORNIS													16		
LEPTOCHEIRUS PINGUIS								24					4		
MICRODEUTOPES GRYLLOTALPA				9											
MONOCULODES EDWARDSI		16													
PHOXOCEPHALUS HOLBOLLI													12		
UNCIOLA IRRORATA				20		12	15	22	23	13	11		14		
UNCIOLA SP. FRAG.											18				
UNCIOLA SP. JUV.				15			18		13	13					
UNCIOLA SERRATA				11											
CUMACEA															
LEUCON AMERICANUS				17						9					
OXYUROSTYLIS SMITHI		4	14	12			24		15			8		10	
DECAPODA															
CANCER IRRORATUS			14	20		17			23						15
CRANGON SEPTEMSPINOSA		16				20	16	16	6	9	16	9			
LIBINIA SP. JUV.				20											
PAGURUS SP. JUV.				20			24		9					22	
PAGURUS LONGICARPUS						8		22	15	13					
PINNIXA SAYANNA				20			24								
RITHROPANOPEUS HARRISII				20											
ISOPODA															
EDOTEA TRILOBA														22	
PTILANTHURA TENUIS													18		
OSTRACODA								19							
TANAIDACEA															
TANAISSIS LILJEBORGI													8		
CNIDARIA															
CERIANTHEOPSIS AMERICANUS								24							
CLAVA LEPTOSTYLA (COLONY)															
ECHINODERMATA															
ASTERIIDAE SP. JUV.	10	16		20	16				15					6	5
ASTERIAS FORBESII							24		15						
PHORONIDA															
PHORONIS ARCHITECTA								24							
SIPUNCULIDA															
GOLFINGIA IMPROVISA													18		

Ta C.2.2-5. Ranks of species by relative abundance at each sampling station at the Penfield Reef study site, July 1983.

PENFIELD REEF STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ARCHIANNELIDA	3	2	7	6		28		24	1	1		3	3	1	1
OLIGOCHAETA	7	13	2	3	1	4	5	7	15	6	4	7		14	
RHYNCOCOELA	12	16		7		9	10	6	23		9	14			
NEMATODA					5										
MOLLUSCA															
GASTROPODA															
CREPIDULA FORNICATA														22	
CREPIDULA SP. JUV.					4										11
CYLICHNELLA(=CYLICHNA)CANALICULATA			3		7	12					10				
CYLICHNELLA(=CYLICHNA)ORYZA			10		15						16				
NASSARIUS TRIVITTATUS	12	8	6		10	9	8	10	4	4	8	9	18	14	9
PELECYPODA															
ASTARTE UNDATA													18		
ENSIS DIRECTUS		9					18	24	11	13		14		4	15
GEMMA GEMMA	6	3		17										8	
LYONSIA ANENOSA		13												12	
LYONSIA HYALINA							24		15			14			
LYONSIA SP. JUV.		16												11	
MERCENARIA MERCENARIA		16					18	19			18				15
MULINIA LATERALIS		11	5		11						14		11	5	
MYA ARENARIA		9												12	
MYTILUS EDULIS	2		13	5			18				18				
NUCULA PROXIMA			10		14	20	1	2			3				
PANDORA GOULDIANA		16					24				18	6		14	15
PETRICOLA PHOLADIFORMIS	12					12	24	24							6
PITAR MORRHUANUS			10	20		5	7	5			5	14	18	19	15
TELLINA AGILIS	1	1	9	2	12	2	3	3			6	1	2	2	3
YOLDIA LIMATULA			8		8	6	5	4	2		2				
YOLDIA SP.JUV.				15	9		14	8			7				

Table C.2.3-1. Faunal sample parameter summary for Sherwood Island Borrow Pit Site (July 1983). S = number of species or taxa; N = number of individuals/m^2; SR = species richness; H = Shannon-Weiner diversity index; J = evenness.

Station	S	N	SR	H	J
1-B	23	26,683	3.04	1.44	0.46
1-C	22	28,306	2.88	1.76	0.57
2-A	18	12,300	2.63	1.63	0.57
2-B	21	8,442	3.28	1.66	0.55
3-A	11	5,444	1.77	0.85	0.36
3-B	11	2,292	2.09	1.06	0.44
4-A	22	4,794	3.80	2.08	0.67
4-B	18	5,424	3.01	1.62	0.56
5-A	14	12,014	2.02	0.73	0.28
5-B	21	12,530	3.08	0.96	0.32
6-A	21	31,782	2.70	0.77	0.25
6-B	25	32,814	3.22	0.74	0.23
7-A	13	4,355	2.21	1.71	0.67
7-B	14	2,388	2.69	2.03	0.77
8-A	14	6,074	2.26	1.23	0.47
8-B	19	10,276	2.86	1.28	0.43
9-A	26	10,505	3.96	2.27	0.70
9-B	16	2,750	3.02	2.20	0.80
10-A	19	4,794	3.26	1.68	0.57
10-B	19	4,068	3.36	2.00	0.68
11-A	18	14,478	2.56	1.54	0.53
11-B	26	13,809	3.80	1.56	0.48
12-A	19	4,813	3.26	1.21	0.41
12-B	13	2,445	2.47	1.71	0.67
13-A	5	1,146	0.98	0.73	0.28
13-B	13	1,834	2.63	2.11	0.82
14-A	3	96	1.24	0.95	0.87
14-B	12	2,846	2.20	1.78	0.72
15-A	20	23,207	2.68	1.49	0.50
15-B	21	22,404	2.83	1.28	0.42
Mean	17	10,504	2.73	1.47	0.54
S.D.	5.6	9,665	0.69	0.47	0.18

Table C.2.3-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
SEDIMENT TYPE	SILT/SHELL		SILT		SILT	SILT	DETRITUS/ROCK/SHELL		SILT		SILT		SILT		SILT
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA	1	5	1				2	1		1		2			
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	251	253	239	145		1	86	147	35	42	84	119	39	38	39
CIRRATULIDAE															
THARYX ACUTUS	8	12	3	1			3	2	2	5	2	7	2		1
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS															
COSSURIDAE															
COSSURA LONGOCIRRATA			1	2						2	1	3			
FLABELLIGERIDAE															
PHERUSA AFFINIS	1	2		1											
GLYCERIDAE															
GLYCERA DIBRANCHIATA							1				2	1			
MALDANIDAE															
EUCLYMENE ZONALIS	4	1					3	1				2			
NEPHTYIDAE															
NEPHTYS INCISA	12	17	3	6	10	10	1	1	4	6	5	4	6	8	3
NEREIDAE															
NEREIS SUCCINEA							5								
PECTINARIIDAE															
PECTINARIA GOULDII	29	19	16	11	4	1	8	5		2	1	1	13	10	2
PHYLLODOCIDAE															
ETEONE HETEROPODA															
PARANAITIS SPECIOSA				1			2	2						1	
PILARGIIDAE															
SIGAMBRA TENTACULATA	12	1	2							1			4	1	
SABELLARIIDAE															
SABELLARIA VULGARIS							2	1							
SPIONIDAE															
POLYDORA LIGNI	21	18	39	21			1	1					1		
PRIONOSPIO STEENSTRUPI	2	3		3				1		1					
STREBLOSPIO BENEDICTI							22	27							
TEREBELLIDAE															
POLYCIRRUS EXIMUS															
NEMATODA															
OLIGOCHAETA	51	173	92		15	1	3		9	37	12	4	106	19	11
RHYNCOCOELA										7	2				
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANALICULATA	18	9		3	6	3				8	14	12	1	2	1
CYLICHNELLA ORYZA	2	6			1							1	2		
GASTROPODA SP.			2						2	2	12	9			
NASSARIUS TRIVITTATUS	5	5	4	4	2			3	17	3	10	26		1	7
TURBONILLA INTERRUPTA															

Table C.2.3-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY															
STATION	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
SEDIMENT TYPE	SILT/SHELL		SILT		SILT	SILT	DETRITUS/ROCK/SHELL		SILT		SILT		SILT		SILT
PELECYPODA															
ENSIS DIRECTUS				1								1			
LYONSIA HYALINA	1	3	1	2		1			3	6					
LYONSIA SP. FRAG.										1	1409	1395	33	27	219
MERCENARIA MERCENARIA	1								539	492	13	23	7	6	
MULINIA LATERALIS	849	701	213	193	232	88			6	8					
NUCULA PROXIMA	77	72	11	10	7	4					1	6			
PANDORA INORNATA	1										18	7			
PETRICOLA PHOLADIFORMIS	2					2	25	14			45	49	10	4	
PITAR MORRHUANUS	9	33	2		1	1	1	1	2	2	25	28	4	4	
TELLINA AGILIS		127	4	11	3		56	54	6	14	4	6			
YOLDIA LIMATULA	11	5	14	12	4	6	20	16	2	15					
YOLDIA SP. JUV.	3						5								
CRUSTACEA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS															
CRUSTACEA (MANDIBULATA)														3	5
AMPHIPODA														1	
AMPELISCA ABDITA	9		1	4			1	1		1					
AMPELISCA VADORUM							1								
LEPTOCHEIRUS PINGUIS															
CIRRIPEDIA															
BALANUS CRENATUS															
CUMACEA											1				
LEUCON AMERICANUS				2											
OXYUROSTYLIS SMITHI	3	2		8							1	7			2
DECAPODA															
CRANGON SEPTEMSPINOSA	14	15		1			1		1						
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.												3			
CLAVA LEPTOSTYLA															
ECHINODERMATA															
ASTERIIDAE SP. JUV.							2								
PHORONIDA											2	2			1
PHORONIS ARCHITECTA						2									

Table C.2.3-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION SEDIMENT TYPE	8-B SILT	9-A SILT	9-B	10-A SILT	10-B	11-A SILT	11-B	12-A SILT/SHELL	12-B	13-A GRAVEL	13-B GRAVEL	14-A SILT	14-B	15-A SILT	15-B
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA					2		1	1	1						1
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	108	172	41	130	84	193	116	15	5		25	3	64	283	443
CIRRATULIDAE															
THARYX ACUTUS		2			2		1		1						
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS						1	1								
COSSURIDAE															
COSSURA LONGOCIRRATA		1				2									
FLABELLIGERIDAE															
PHERUSA AFFINIS							3	1							2
GLYCERIDAE															
GLYCERA DIBRANCHIATA		2			1						1				
MALDANIDAE															
EUCLYMENE ZONALIS															
NEPHTYIDAE															
NEPHTYS INCISA	4	2	5	1	4	6	5	9	5	1	8		2	6	3
NEREIDAE															
NEREIS SUCCINEA															
PECTINARIIDAE															
PECTINARIA GOULDII	8	21	1	1	1	1	7	4	10		1	1	8	7	25
PHYLLODOCIDAE															
ETEONE HETEROPODA				1											
PARANAITIS SPECIOSA															
PILARGIIDAE															
SIGAMBRA TENTACULATA		2	1	1				1	1	6				3	1
SABELLARIIDAE															
SABELLARIA VULGARIS															
SPIONIDAE															
POLYDORA LIGNI	1	10		1				1			5		7		1
PRIONOSPIO STEENSTRUPI															1
STREBLOSPIO BENEDICTI				2	2		2								
TEREBELLIDAE															
POLYCIRRUS EXIMUS		1													
NEMATODA										1					
OLIGOCHAETA	17	114	23	26	26	135	15	11	49		6		16	18	1
RHYNCOCOELA	4	2		1		2	4							14	
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANALICULATA		10	6		1	1	5	1	1		23		3	17	2
CYLICHNELLA ORYZA		7	1					2	1				1	6	2
GASTROPODA SP.	2	2		2			2				2			8	2
NASSARIUS TRIVITTATUS	6	4	12	7	29		5	3	6		8		1	8	3
TURBONILLA INTERRUPTA															

Table C.2.3-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	8-B	9-A	9-B	10-A	10-B	11-A	11-B	12-A	12-B	13-A	13-B	14-A	14-B	15-A	15-B
SEDIMENT TYPE	SILT	SILT		SILT		SILT		SILT		GRAVEL	GRAVEL	SILT		SILT	
PELECYPODA															
ENSIS DIRECTUS								1							
LYONSIA HYALINA	1		1				5	4						2	2
LYONSIA SP. FRAG.															
MERCENARIA MERCENARIA					1	1									
MULINIA LATERALIS	346	81	14	1		331	413	190	41	48	10	1	31	681	566
NUCULA PROXIMA	4	30	7		2	22	30	2					5	50	27
PANDORA INORNATA							1								
PETRICOLA PHOLADIFORMIS	1	1				1								6	
PITAR MORRHUANUS	4	17	3	1	2	1	1	1			3		3	8	2
TELLINA AGILIS	12	51	20	35	20	9	10	4	2	4				20	16
YOLDIA LIMATULA	13	5	6	24	21	36	78		5		3		8	60	55
YOLDIA SP. JUV.		3		5		9	11	1						13	15
CRUSTACEA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS		1			1										
CRUSTACEA (MANDIBULATA)															
AMPHIPODA															
AMPELISCA ABDITA		6	2				1	1						2	
AMPELISCA VADORUM						1		1							
LEPTOCHEIRUS PINGUIS															
CIRRIPEDIA															
BALANUS CRENATUS															
CUMACEA															
LEUCON AMERICANUS	1	1	1		2		1								
OXYUROSTYLIS SMITHI		1		1	2										
DECAPODA															
CRANGON SEPTEMSPINOSA	2	2		10	10		1	3			1			3	3
CNIDARIA															
ANTHOZOA															
CERIANTHIDAESP.JUV.				1								P			
CLAVA LEPTOSTYLA															
ECHINODERMATA															
ASTERIIDAE SP. JUV.															
PHORONIDA															
PHORONIS ARCHITECTA	3					2	4								

Table C.2,3-3. Mean number of individuals per species per square meter at each sampling station at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA	57	10		29	10	19				19	10	19			10
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	4813	5950	10	2225	735	1914	735	1404	2034	2034	2951	191	239	640	6933
CIRRATULIDAE															
THARYX ACUTUS	191	38		48	67	86	19	10	19	19	10	10			
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS											19				
COSSURIDAE															
COSSURA LONGOCIRRATA		29			19	38			10		19				
FLABELLIGERIDAE															
PHERUSA AFFINIS	29	10									29	10			19
GLYCERIDAE															
GLYCERA DIBRANCHIATA				10		29			19	10			10		
MALDANIDAE															
EUCLYMENE ZONALIS	48			38		19									
NEPHTYIDAE															
NEPHTYS INCISA	277	86	191	10	96	86	134	67	67	48	105	124	86	19	86
NEREIDAE															
NEREIS SUCCINEA				48											
PECTINARIIDAE															
PECTINARIA GOULDII	458	258	48	124	19	19	239	96	210	19	76	134	10	86	306
PHYLLODOCIDAE															
ETEONE HETEROPODA										10					
PARANAITIS SPECIOSA		10		38			10								
PILARGIIDAE															
SIGAMBRA TENTACULATA	124	19			10		48		29	10		19	57		38
SABELLARIIDAE															
SABELLARIA VULGARIS				29											
SPIONIDAE															
POLYDORA LIGNI	373	573		19			10	10	96	10		10	48	67	10
PRIONOSPIO STEENSTRUPI	48	29		10	10										10
STREBLOSPIO BENEDICTI				468						38	19				
TEREBELLIDAE															
POLYCIRRUS EXIMUS									10						
NEMATODA															
OLIGOCHAETA	2139	879	153	86	439	153	1194	267	1308	497	1433	573	67	153	181
RHYNCOCOELA					67	19		38	19	10	57				134
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANALICULATA	258	29	86		76	248	29	10	153	10	57	19	220	29	181
CYLICHNELLA ORYZA	57		10			10	19		76			29		10	76
GASTROPODA SP.		19			38	201		19	19	10	19		19		96
NASSARIUS TRIVITTATUS	95	76	19	29	191	344	10	124	153	344	48	86	76	10	105
TURBONILLA INTERRUPTA															

Table C.2.3-3. Mean number of individuals per species per square meter at each sampling station at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PELECYPODA															
ENSIS DIRECTUS		10									10				
LYONSIA HYALINA	38	29	10		86	10		10	10		86				38
LYONSIA SP. FRAG.															
MERCENARIA MERCENARIA	10				19					10					
MULINEA LATERALIS	14802	3877	3056		9846	26778	573	5396	907	10	7105	2206	554	306	11909
NUCULA PROXIMA	1443	201	201		134	344	124	38	353	19	497	19		48	735
PANDORA INORNATA	10										10				
PETRICOLAPHOLADIFORMIS	19		19	373		67		10			10				57
PITAR MORRHUANUS	401	19	19	19	38	229		67	191	29	19	10	29	29	96
TELLINA AGILIS	1213	143	29	1050	191	898	134	191	678	735	344	37	38		344
YOLDIA LIMATULA	153	248	96	342	162	506	76	277	105	430	1089	48	29	76	1098
YOLDIA SP. JUV.	29			48		96			29	48	191	10			267
CRUSTACEA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS									10	10					
CRUSTACEA (MANDIBULATA)															
AMPHIPODA															
AMPELISCA ABDITA	86	48			10		29	48	76		10	10			19
AMPELISCA VADORUM							10				10	10			
LEPTOCHEIRUS PINGUIS				10											
CIRRIPEDIA															
BALANUS CRENATUS															
CUMACEA															
LEUCON AMERICANUS		19						10	19	19	10				
OXYUROSTYLIS SMITHI	48	76				10			10	29					
DECAPODA															
CRANGON SEPTEMSPINOSA	277	10			10	76		38	19	191	10	29	10		57
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.										10					
CLAVA LEPTOSTYLA															
ECHINODERMATA															
ASTERIIDAE SP. JUV.				19		29									
PHORONIDA															
PHORONIS ARCHITECTA			19			38		38			57				

Table C.2.3-5. Ranks of species by relative abundance at each sampling station at the Sherwood Borrow Pit study site, July 1983

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA	16	15		11	14	17				11	15	10			17
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	2	1	10	1	2	2	2	2	1	1	2	3	2	1	2
CIRRATULIDAE															
THARYX ACUTUS	11	12		9	10	12	10	12	14	11	15	11			
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS											14				
COSSURIDAE															
COSSURA LONGOCIRRATA		13			13	15			15		14				
FLABELLIGERIDAE															
PHERUSA AFFINIS	19	15									13	11			16
GLYCERIDAE															
GLYCERA DIBRANCHIATA				13		16			15	12			12		
MALDANIDAE															
EUCLYMENE ZONALIS	17			10		17									
NEPHTYIDAE															
NEPHTYS INCISA	9	9	3	13	7	12	5	8	12	7	8	5	4	9	12
NEREIDAE															
NEREIS SUCCINEA				9											
PECTINARIIDAE															
PECTINARIA GOULDII	6	9	7	6	13	17	4	7	6	11	10	4	12	4	6
PHYLLODOCIDAE															
ETEONE HETEROPODA										12					
PARANAITIS SPECIOSA		15		10			11								
PILARGIIDAE															
SIGAMBRA BASSI	13	14			14		8		1	12		10	7		15
SABELLARIIDAE															
SABELLARIA VULGARIS				11											
SPIONIDAE															
POLYDORA LIGNI	8	5		12			11	12	10	12		11	8	6	17
PRIONOSPIO STEENSTRUPI	17	13		13	14										17
STREBLOSPIO BENEDICTI				3						9	14				
TEREBELLIDAE															
POLYCIRRUS EXIMUS									15						
NEMATODA															
OLIGOCHAETA	8	3	4	8	3	10	1	4	2	3	3	2	6	3	8
RHYNCOCOELA					11	17		10	14	12	11				9
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANALICULATA	10	13	6		9	6	9	12	8	12	11	10	3	8	8
CYLICHNELLA ORYZA	16		10			18	10		11			9		10	13
GASTROPODA SP.		14			12	9		11	14	12	14		11		11
NASSARIUS TRIVITTATUS	14	10	9	11	4	8	11	6	8	5	12	6	5	10	10
TURBONILLA INTERRUPTA															

Table C.2.3-5. Ranks of species by relative abundance at each sampling station at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PELECYPODA															
ENSIS DIRECTUS															
LYONSIA HYALINA		15													
LYONSIA SP. FRAG.	18	13	10		8	8		12	15		15				
MENCENARIA MENCENARIA											9				15
MULINIA LATERALIS	21				13					12					
NUCULA PROXIMA	1	2	1		1	1	3	1	3	12					
PANDORA INORNATA	4	7	2		6	8	6	10	5	12	1	1	1	2	1
PETRICOLA PHOLADIFORMIS											5	10		7	4
PITAR MORRHUANUS	21		9	4		???		????			15				
TELLINA AGILIS	7	14	9	12	12	7		8	7	10	15				14
YOLDIA LIMATULA	5	8	8	2	4	3	5	5	4	2	14	11	10	8	11
YOLDIA SP. JUV.	12	6	5	5	5	6	7	3	9	4	6	7	0		5
	29			9		11			13	8	4	8	10	5	3
CRUSTACEA (CHELICERATA)											7	11			7
MERISTOMATA															
LIMULUS POLYPHEMUS															
CRUSTACEA (MANDIBULATA)															
AMPHIPODA									15	12					
AMPELISCA ABDITA															
AMPELISCA VADORUM	15	11			14		9	9	11		15	11			16
LEPTOCHEIRUS PINQUIS							11				15	11			
CIRRIPEDIA				13											
BALANUS CRENATUS															
CUMACEA															
LEUCON AMERICANUS															
OXYUROSTYLIS SMITHI		14						12	14	11	15				
DECAPODA	17	10				18			15	10					
CRANGON SEPTEMSPINOSA	9	15			14	13		10	14	6	15	9	12		14
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.															
CLAVA LEPTOSTYLA										12					
ECHINODERMATA															
ASTERIIDAE SP. JUV.				12		16									
PHORONIDA															
PHORONIS ARCHITECTA			9			15		10			11				

Table C.2.3-4. Relative frequency of individual species at each sampling station at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
AMPHARETIDAE															
AMPHARETE ARCTICA	0.21	0.07		0.56	0.08	0.60				0.41	0.07	0.53			0.04
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	17.51	46.40	0.24	43.60	6.00	6.00	21.70	17.20	30.70	43.90	20.60	5.30	16.02	43.500	30.40
CIRRATULIDAE															
THARYX ACUTUS	0.69	0.03		0.98	0.54	0.27	0.56	0.12	0.29	0.41	0.07	0.26			
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS											0.13				
COSSURIDAE															
COSSURA LONGOCIRRATA			0.22		0.16	0.12			0.14		0.13				
FLABELLIGERIDAE															
PHERUSA AFFINIS	0.10	0.07									0.20	0.26			0.08
GLYCERIDAE															
GLYCERA DIBRANCHIATA				0.19		0.09			0.14	0.22			0.67		
MALDANIDAE															
EUCLYMENE ZONALIS	0.17			0.74		0.06									
NEPHTYIDAE															
NEPHTYS INCISA	1.01	0.67	4.80	0.19	0.78	0.27	3.90	0.82	1.00	1.10	0.73	3.40	5.76	1.30	0.38
NEREIDAE															
NEREIS SUCCINEA				0.93											
PECTINARIIDAE															
PECTINARIA GOULDII	1.67	2.00	1.20	2.40	0.16	0.06	7.00	1.20	3.20	0.41	0.53	3.70	0.67	5.80	1.30
PHYLLODOCIDAE															
ETEONE HETEROPODA										0.22					
PARANAITIS SPECIOSA		0.70		0.74			0.28								
PILARGIIDAE															
SIGAMBRA TENTACULATA	0.45	0.15			0.80		1.40		0.43	0.22		0.52	3.82		0.17
SABELLARIIDAE															
SABELLARIA VULGARIS				0.56											
SPIONIDAE															
POLYDORA LIGNI	1.36	4.50		0.37			0.28	0.12	1.40	0.22		0.26	3.22	4.50	0.04
PRIONOSPIO STEENSTRUPI	0.17	0.22		0.19	0.80										0.04
STREBLOSPIO BENEDICTI				9.20						0.82	0.13				
TEREBELLIDAE															
POLYCIRRUS EXIMUS									0.14						
NEMATODA															
OLIGOCHAETA	7.78	6.90	3.90	1.70	3.60	0.47	35.20	3.20	19.70	10.70	10.00	15.80	4.49	10.40	0.80
RHYNCOCOELA					0.54	0.06		0.47	0.29	0.22	0.40				0.59
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANALICULATA	0.94	0.22	2.20		0.62	0.78	0.85	0.12	2.30	0.22	0.40	0.53	14.75	1.90	0.80
CYLICHNELLA ORYZA	0.21		0.24			0.03	0.56		1.20			0.79		0.65	0.34
GASTROPODA SP.		0.15			0.31	0.62		0.23	0.29	0.22	0.13		1.27		0.42
NASSARIUS TRIVITTATUS	0.35	0.60	0.48	0.56	1.60	1.10	0.28	1.50	2.30	7.40	0.33	2.40	5.09	0.65	0.46
TURBONILLA INTERRUPTA															

Table C.2.3-4. Relative frequency of individual species at each sampling station at the Sherwood Borrow Pit study site, July 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PELECYPODA															
ENSIS DIRECTUS		0.07									0.07				
LYONSIA HYALINA	0.14	0.22	0.24		0.70	0.03		0.12	0.14		0.60				0.17
LYONSIA SP. FRAG.															
MERCENARIA MERCENARIA	0.14				0.16					0.22					
MULINIA LATERALIS	53.84	30.20	77.10		80.20	82.90	16.90	66.00	13.70	0.22	49.70	60.90	37.13	20.80	52.20
NUCULA PROXIMA	5.25	1.60	5.10		1.10	1.10	3.70	0.47	5.30	0.41	3.50	0.53		3.20	3.20
PANDORA INORNATA											0.07				
PETRICOLA PHOLADIFORMIS	0.07		0.48	7.30		0.21		0.12			0.07				0.25
PITAR MORRHUANUS	1.46	0.15	0.48	0.37	0.31	0.71		0.82	2.90	0.63	0.13	0.26	1.94	1.90	0.42
TELLINA AGILIS	4.41	1.10	0.73	20.60	1.60	2.80	3.90	2.30	10.20	15.90	2.40	1.60	2.55		1.50
YOLDIA LIMATULA	0.56	1.90	2.40	6.70	1.30	1.60	2.30	3.40	1.60	9.30	7.60	1.30	1.94	5.20	4.80
YOLDIA SP. JUV.	0.10			0.93		0.30			0.43	1.00	1.30	0.26			1.20
CRUSTACEA (CHELICERATA)															
MERISTOMATA															
LIMULUS POLYPHEMUS									0.14	0.22					
CRUSTACEA (MANDIBULATA)															
AMPHIPODA															
AMPELISCA ABDITA	0.31	0.38			0.08		0.85	0.58	1.20		0.07	0.26			0.08
AMPELISCA VADORUM							0.28				0.07	0.26			
LEPTOCHEIRUS PINGUIS				0.19											
CIRRIPEDIA															
BALANUS CRENATUS															
CUMACEA															
LEUCON AMERICANUS		0.15						0.12	0.29	0.41	0.07				
OXYUROSTYLIS SMITHI	0.17	0.59				0.30			0.14	0.63					
DECAPODA															
CRANGON SEPTEMSPINOSA	1.01	0.07			0.08	0.24		0.47	0.29	4.40	0.07	0.79	0.67		0.25
CNIDARIA															
ANTHOZOA															
CERIANTHIDAE SP. JUV.										0.22					
CLAVA LEPTOSTYLA															
ECHINODERMATA															
ASTERIIDAE SP. JUV.				0.37		0.09									
PHORONIDA															
PHORONIS ARCHITECTA			0.48			0.12		0.47			0.40				

Table C.2.4-1. Faunal sample parameter summary for second sampling of Sherwood Borrow Pit site (September 1983). S = number of species/taxa; SR = species richness; N = number of individuals/m^2; H = Shannon-Wiener diversity; J = evenness.

Station	S	SR	N	H	J
1-A	16	2.80	4087	2.08	0.75
1-B	23	3.88	5577	1.82	0.58
2-A	14	2.48	3629	1.84	0.70
2-B	11	2.40	1222	1.95	0.81
3-A	10	1.52	7220	0.97	0.42
3-B	9	1.31	8404	0.77	0.35
4-A	15	3.18	1566	2.12	0.78
4-B	9	2.22	707	1.89	0.86
5-A	13	2.09	5978	0.82	0.32
5-B	15	2.47	5577	0.94	0.35
6-A	10	1.58	5654	0.65	0.28
6-B	13	2.47	2464	1.81	0.71
7-A	13	2.72	1566	1.87	0.73
7-B	14	2.17	7736	0.74	0.28
8-A	14	2.50	3438	1.38	0.52
8-A	18	3.48	2521	2.43	0.84
9-A	12	1.65	14860	0.72	0.29
9-B	13	2.20	4469	0.74	0.29
10-A	5	1.82	172	1.43	0.89
10-B	4	1.02	363	0.85	0.62
11-A	9	1.44	4947	0.63	0.28
11-B	7	1.08	5023	0.39	0.20
12-A	15	3.18	1566	2.34	0.88
12-B	10	2.23	993	1.89	0.82
13-A	10	1.63	4832	0.86	0.37
13-B	13	2.26	3839	1.27	0.50
14-A	11	2.54	974	1.72	0.72
14-B	7	2.00	382	1.44	0.74
15-A	7	1.14	3763	0.75	0.39
15-B	9	1.29	9359	0.72	0.33
Mean	12	2.16	4096	1.33	0.55
S.D.	4.0	0.72	3244	0.60	0.23

Table C.2.4-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION SEDIMENT TYPE	1-A SILT/CLAY	1-B SILT/CLAY	2-A SILT/CLAY	2-B	3-A SILT/SAND	3-B SILT/SAND	4-A SILT ODIFEROUS	4-B	5-A SILT MULINIA	5-B SHELLHASH	6-A SILT MULINIA	6-B SHELLHASH	7-A SILT SHELLHASH	7-B	8-A SILT/CLAY
POLYCHAETA															
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	9	11		16	1		1		4	5				1	13
CIRRATULIDAE															
THARYX ACUTUS		1			2		2				1	1			1
THARYX ANNULOSUS		1													
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATA		2													
COSSURIDAE															
COSSURA LONGOCIRRATA						1					1				3
FLABELLIGERIDAE															
PHERUSA AFFINIS		1													
GLYCERIDAE															
GLYCERA AMERICANA	2	1								1					
MALDANIDAE															
EUCLYMENE ZONALIS			1												
NEPHTYIDAE															
NEPHTYS INCISA		3	2	5		3	2	2	2			2	2	2	3
NERIIDAE															
NEREIS SUCCINEA															
PECTINERIIDAE															
PECTINARIA GOULDII	21	7	14	7	4		1	2	2	5	3	5	3	10	6
PILARGIIDAE															
SIGAMBRA TENTACULATA		1								3		1		1	
PHYLLODOCIDAE															
ETEONE SP. JUV.	2	2							3		2				
PHYLLODOCE ARENAE															
PHYLLODOCIDAE SP. JUV.										3					
POLYNOIDAE															
LEPIDONOTUS SQUAMATUS			1												
SPIONIDAE															
STREBLOSPIO BENEDICTI		2		2	18		6	13		3	1		1		
NEMATODA	1						1								
OLIGOCHAETA	13	4	7	2	1	31	18		14	23	7	6		3	17
PLATYHELMINTHES															
TURBELLARIA SP.	3	4	20	20					3	2			2		
RHYCOCOELA	3			2											1
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANICULATA	3	7	4	1	74	29		1					3	1	1
CYLICHNELLA ORYZA		3			4	3							3		
GASTROPODA SP. JUV.	7	7	1		1		2	4	1	1			1	1	2
NASSARIUS TRIVITTATUS	21	14	16	3			9	2	2	7		18	3		8

Table C.2.4-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Sherwood Borrow Pit study site, September 1983.

STATION	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	5-A	5-B	6-A	6-B	7-A	7-B	8-A
SEDIMENT TYPE	SILT/CLAY		SILT/CLAY		SILT/SAND	SILT/SAND	SILT ODIFEROUS		SILT MULINIA SHELLHASH		SILT MULINIA SHELLHASH		SILT SHELLHASH		SILT/CLAY
PELECYPODA															
LYONSIA SP. JUV.															
MENCENARIA MENCENARIA										1					
MULINIA LATERALIS	87	171	91		265	357	26		261	232	255	58	31	343	118
NUCULA PROXIMA	21	15	16			10		2	6	4	14	11	23	19	
PANDORA GOULDIANA															
PITAR MARRHUANUS		4	3						3			1	2	1	2
TELLINA AGILIS	3	11	7	1	8	5	3		4		9	17	6	5	3
YOLDIA LIMATULA	9	15	7	5			3	7	8		3	3	2	4	
CRUSTACEA															
AMPHIPODA															
AMPELLISCA ABDITA	9	5					2					5		12	
AMPELLISCA SP. JUV.															
CUMACEA															
LEUCON AMERICANUS							5	4							
OXYURUSTYLIS SMITHI							1								
DECAPODA															
CANCER IRRORATUS										1					
CRANGON SEPTEMSPINOSA												1			
OVALIPES OCELLATUS														2	
PINNIXA SAYANA															
ECHINODERMATA															
ASTEROIDEA															
ASTERIIDAE SP. JUV.						1									
PHORONIDA															
PHORONIS ARCHITECTA										1					2

Table C.2.4-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY	8-B	9-A	9-B	10-A	10-B	11-A	11-B	12-A	12-B	13-A	13-B	14-A	14-B	15-A	15-B
STATION															
SEDIMENT TYPE	SILT/CLAY	SILT SHELLHASH		SILT ODIFEROUS		SILT MULINIA SHELLHASH		SILT MULINIA SHELLHASH		SAND/ROCK	SAND/ROCK	SILT ODIFEROUS		SILT MULINIA SHELLHASH	
POLYCHAETA															
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	11									9	11	1			
CIRRATULIDAE															
THARYX ACUTUS															
THARYX ANNULOSUS															
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATUS								2							
COSSURIDAE															
COSSURA LONGOCIRRATA										1	2	1		1	1
FLABELLIGERIDAE															
PHERUSA AFFINIS															
GLYCERIDAE															
GLYCERA AMERICANA			1												
MALDANIDAE															
EUCLYMENE ZONALIS															
NEPHTYIDAE															
NEPHTYS INCISA	4	4	1		2		2	6	1	3	2		1		
NERIIDAE															
NEREIS SUCCINEA											1				
PECTINERIIDAE															
PECTINARIA GOULDII	13	2						10	4	1	1				
PILARGIIDAE															
SIGAMBRA TENTACULATA	1		1					2				6			
PHYLLODOCIDAE															
ETEONE SP. JUV.											1		1		
PHYLLODOCE ARENAE				1											
PHYLLODOCIDAE SP. JUV.															
POLYNOIDAE															
LEPIDONOTUS SQUAMATUS								1							
SPIONIDAE															
STREBLOSPIO BENEDICTI	3	4	1	4	14	2	2			16	18	1			
NEMATODA															
OLIGOCHAETA	4	14	4			1	1	16		3	2	25	1	5	2
PLATYHELMINTHES															
TURBELLARIA SP.	2		1			1									
RHYCOCOELA	3													1	1
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANICULATA	1	37	11			1		8	6	13	19		3		1
CYLICHNELLA ORYZA		2													
GASTROPODA SP. JUV.	2	22	1					11							
NASSARIUS TRIVITTATUS	23	3		2		17			3		2	3	2	2	19

Table C.2.4-2. Number of individuals per species for each PONAR grab (0.0523 m^2) collected at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	8-B	9-A	9-B	10-A	10-B	11-A	11-B	12-A	12-B	13-A	13-B	14-A	14-B	15-A	15-B
SEDIMENT TYPE	SILT/CLAY	SILT SHELLHASH		SILT ODIFEROUS		SILT MULINIA SHELLHASH		SILT MULINIA SHELLHASH		SAND/ROCK	SAND/ROCK	SILT ODIFEROUS		SILT MULINIA SHELLHASH	
PELECYPODA															
LYONSIA SP. JUV.		4													
MERCENARIA MERCENARIA						221	241	4	19	202	134	2		154	381
MOLINIA LATERALIS	23	662	198			13	14	7	3			1		30	81
NUCULA PROXIMA	22	15	9											4	3
PANDORA GOULDIANA						1							1		
PITAR MARRHUANUS	2						2	2	4	4	7	3			1
TELLINA AGILIS	7	9	3					1	1			7	11		
YOLDIA LIMATULA	4		2		2										
CRUSTACEA															
AMPHIPODA															
AMPELLISCA ABDITA	6							9	10		1				
AMPELLISCA SP. JUV.					1										
CUMACEA															
LEUCON AMERICANUS				1								1			
OXYUROSTYLIS SMITHI				1				1							
DECAPODA															
CANCER IRRORATUS							1								
CRANGON SEPTEMSPINOSA															
OVALIPES OCELLATUS									1	1					
PINNIXA SAYANA			1												
ECHINODERMATA															
ASTEROIDEA															
ASTERIIDAE SP. JUV.															
PHORONIDA															
PHORONIS ARCHITECTA	1					2		2							

Table C.2.4-3. Mean number of individuals per species per square meter at each sampling station at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	19	153	10	10	85		19	229					191	10	
CIRRATULIDAE															
THARYX ACUTUS	10		19	19		19		10							
THARYX ANNULOSUS	10														
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATA	19											19			
COSSURIDAE															
COSSURA LONGOCIRRATA			10			10		29					29	10	19
FLABELLIGERIDAE															
PHERUSA AFFINIS	10														
GLYCERIDAE															
GLYCERA AMERICANA	29				10				10						
MALDANIDAE															
EUCLYMENE ZONALIS		10													
NEPHTYIDAE															
NEPHTYS INCISA	29	69	29	38	19	19	38	67	48	19	19	67	48	10	
NERIIDAE															
NEREIS SUCCINEA													10		
PECTINARIIDAE															
PECTINARIA GOULDII	267	201	38	29	67	76	124	181	19			134	10		
PILARGIIDAE															
SIGAMBRA TENTACULATA	10				29	10	10	10	10			19		57	
PHYLLODOCIDAE															
ETEONE SP. JUV.	38				29	19							10	10	
PHYLLODOCE ARENAE										10					
PHYLLODOCIDAE SP. JUV.					29										
POLYNOIDAE															
LEPIDONOTUS SQUAMATUS		10										10			
SPIONIDAE															
STREBLOSPIO BENEDICTI	19	19	38	181	29	10	10	29	48	172	38		325	10	
NEMATODA	10			10											
OLIGOCHAETA	162	86	306	172	353	124	29	201	172		19	153	48	248	67
PLATYHELMINTHES															
TURBELLARIA SP.	67	382			48		19	19	10		10				
RHYCOCOELA	29	19						38							19
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANICULATA	96	48	984	10			38	19	458		10	134	306	29	10
CYLICHNELLA ORYZA	29		67				29		19						
GASTROPODA SP. JUV.	134	10	10	57	19		19	38	220			105			
NASSARIUS TRIVITTATUS	334	181		105	86	172	29	296	29	19	162	29	19	48	201

Table C.2.4-3. Mean number of individuals per species per square meter at each sampling station at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PELECYPODA															
LYONSIA SP. JUV.									38						
MERCENARIA MERCENARIA					10										
MULINIA LATERALIS	2464	869	5940	248	4708	2989	3572	1347	8213		4412	220	3209	19	5109
NUCULA PROXIMA	344	153	96	19	96	239	401	210	229		258	96		10	1060
PANDORA GOULDIANA															67
PITAR MARRHUANUS	34	29			29	10	29	38			10			10	
TELLINA AGILIS	134	76	124	29	38	248	105	95	115		19	57	105	29	10
YOLDIA LIMATULA	229	115		96	76	57	57	38	19	19		19		172	
CRUSTACEA															
AMPHIPODA															
AMPELLISCA ABDITA	134			19		48	115	57				181	10		
AMPELLISCA SP. JUV.										10					
CUMACEA															
LEUCON AMERICANUS				86						10					
OXYUROSTYLIS SMITHI				10						10			10		
DECAPODA												10			
CANCER IRRORATUS											10				
CRANGON SEPTEMSPINOSA					10	10	19								
OVALIPES OCELLATUS												10			
PINNIXA SAYANA									10				10		
ECHINODERMATA															
ASTEROIDEA															
ASTERIIDAE SP. JUV.			10												
PHORONIDA															
PHORONIS ARCHITECTA					10						19	19			

Table C.2.4-4. Relative frequency of individual species at each sampling station at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	0.41	6.30	0.13	0.88	1.47		0.41	7.68					4.41	1.47	
CIRRATULIDAE															
THARYX ACUTUS	0.21		0.24	1.67		0.47		0.34							
THARYX ANNULOSUS	0.21														
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATA	0.41											1.48			
COSSURIDAE															
COSSURA LONGOCIRRATA			0.13			0.25		0.97					0.67	1.47	0.29
FLABELLIGERIDAE															
FHERUSA AFFINIS	0.21														
GLYCERIDAE															
GLYCERA AMERICANA	0.62				0.17				0.10						
MALDANIDAE															
EUCLYMENE ZONALIS		0.41													
NEPHTYIDAE															
NEPHTYS INCISA	0.62	2.84	0.37	3.34	0.33	0.47	0.82	2.25	0.50	7.06	0.38	5.23	1.11	1.47	
NERIIDAE															
NEREIS SUCCINEA													0.23		
PECTINERIIDAE															
PECTINARIA GOULDII	5.72	8.27	0.49	2.55	1.16	1.87	2.66	6.07	0.20			10.45	0.23		
PILARGIIDAE															
SIGAMBRA TENTACULATA	0.21				0.50	0.25	0.21	0.34	0.10			1.48		8.36	
PHYLLODOCIDAE															
ETEONE SP. JUV.	0.81				0.50	0.47							0.23	1.47	
PHYLLODOCE ARENAE										3.72					
PHYLLODOCIDAE SP. JUV.					0.50										
POLYNOIDAE															
LEPIDONOTUS SQUAMATUS		0.41										0.78			
SPIONIDAE															
STREBLOSPIO BENEDICTI	0.41	0.78	2.20	15.91	0.50	0.25	0.21	0.97	0.50	63.94	0.76		7.51	1.47	
NEMATODA	0.21			0.88											
OLIGOCHAETA	3.47	3.54	3.92	15.11	6.11	3.05	0.62	6.74	1.78		0.38	11.93	1.11	36.36	1.02
PLATYHELMINTHES															
TURBELLARIA SP.	1.44	15.72			0.83		0.41	0.64	0.10		0.20				
RHYCOCOELA	0.62	0.78						1.28							0.29
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANICULATA	2.06	1.98	12.59	0.88			0.82	0.64	4.74		0.20	10.45	7.07	4.25	0.15
CYLICHNELLA ORYZA	0.62		0.86				0.62		0.20						
GASTROPODA SP. JUV.	2.87	0.41	0.13	5.01	0.33		0.41	1.28	2.28			8.19			
NASSARIUS TRIVITTATUS	7.16	7.45		9.23	1.49	4.24	0.62	9.93	0.30	7.06	3.25	2.26	0.44	7.04	3.06

Table C.2.4-4. Relative frequency of individual species at each sampling station at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PELECYPODA															
LYONSIA SP. JUV.															
MERCENARIA MERCENARIA					0.17				0.39						
MULINIA LATERALIS	52.83	35.76	76.01	21.79	81.45	73.62	76.62	45.20	84.96		88.49	17.16	74.11	2.79	77.86
NUCULA PROXIMA	7.38	6.30	1.23	1.67	1.66	5.89	8.60	7.05	2.37		5.17	7.49		1.47	16.15
PANDORA GOULDIANA															1.02
PITAR MARRHUANUS	0.81	1.19			0.50	0.25	0.62	1.28			0.20			1.47	
TELLINA AGILIS	2.87	3.13	1.59	2.55	0.66	6.11	2.25	3.19	1.19		0.38	4.45	2.42	4.25	0.15
YOLDIA LIMATULA	4.91	4.73		8.44	1.31	1.40	1.22	1.28	0.20	7.06		1.48		25.22	
CRUSTACEA															
AMPHIPODA															
AMPELLISCA ABDITA	2.87			1.67		1.18	2.47	1.91				14.12	0.23		
AMPELLISCA SP. JUV.										3.72					
CUMACEA															
LEUCON AMERICANUS				7.56						3.72				1.47	
OXYUROSTYLIS SMITHI				0.88						3.72		0.78			
DECAPODA															
CANCER IRRORATUS											0.20				
CRANGON SEPTEMSPINOSA					0.17	0.25	0.41								
OVALIPES OCELLATUS												0.78			
PINNIXA SAYANA									0.10				0.23		
ECHINODERMATA															
ASTEROIDEA															
ASTERIIDAE SP. JUV.			0.13												
PHORONIDA															
PHORONIS ARCHITECTA					0.17			0.97			0.38	1.48			

Table C.2.4.5. Ranks of species by relative abundance at each sampling station at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POLYCHAETA															
CAPITELLIDAE															
MEDIOMASTUS AMBISETA	18	5	11	14	5		13	3					4	8	
CIRRATULIDAE															
THARYX ACUTUS	21		10	11		9		19							
THARYX ANNULOSUS	21														
CHAETOPTERIDAE															
SPIOCHAETOPTERUS OCULATA	18											11			
COSSURIDAE															
COSSURA LONGOCIRRATA			11			12		14					8	8	6
FLABELLIGERIDAE															
PHERUSA AFFINIS	21														
GLYCERIDAE															
GLYCERA AMERICANA	14				17				14						
MALDANIDAE															
EUCLYMENE ZONALIS		16													
NEPHTYIDAE															
NEPHTYS INCISA	14	10	9	8	15	9	7	8	7	2	5	8	6	8	
NERIIDAE															
NEREIS SUCCINEA													10		
PECTINERIIDAE															
PECTINARIA GOULDII	4	3	8	9	7	6	3	6	11			4	10		
PILARGIIDAE															
SIGAMBRA TENTACULATA	21				10	12	18	19	14			11		3	
PHYLLODOCIDAE															
ETEONE SP. JUV.	12				10	9							10	8	
PHYLLODOCE ARENAE										5					
PHYLLODOCIDAE SP. JUV.					10										
POLYNOIDAE															
LEPIDONOTUS SQUAMATUS		14										15			
SPIONIDAE															
STREBLOSPIO BENEDICTI	18	12	4	2	10	12	17	14	7	1	4		2	8	
NEMATODA	21			14											
OLIGOCHAETA	6	7	3	3	2	5	9	5	5		5	3	6	1	4
PLATYHELMINTHES															
TURBELLARIA SP.	11	2			8		13	17	14		9				
RHYCOCOELA	14	12						10							6
MOLLUSCA															
GASTROPODA															
CYLICHNELLA CANICULATA	10	10	2	14			8	17	2		9	4	3	5	8
CYLICHNELLA ORYZA	14		7				10		11						
GASTROPODA SP. JUV.	7	14	11	7	15		13	10	4			6			
NASSARIUS TRIVITTATUS	3	4		4	4	4	11	2	10	2	3	10	9	4	3

Table C.2.4.5. Ranks of species by relative abundance at each sampling station at the Sherwood Borrow Pit study site, September 1983.

SHERWOOD ISLAND BORROW PIT STUDY STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PELECYPODA															
LYONSIA SP. JUV.									9						
MERCENARIA MERCENARIA					17										
MULINIA LATERALIS	1	1	1	1	1	1	1	1	1		1	1	1	7	1
NUCULA PROXIMA	2	5	6	11	3	3	2	4	3		2	7		8	2
PANDORA GOULDIANA															4
PITAR MARRHUANUS	13	11			10	12	12	10			9			8	
TELLINA AGILIS	7	8	5	9	9	2	5	7	6		5	9	5	5	8
YOLDIA LIMATULA	5	6		5	6	7	6	10	11	2		11		2	
CRUSTACEA															
AMPHIPODA															
AMPELLISCA ABDITA	7			11		8	4	9				2	10		
AMPELLISCA SP. JUV.										5					
CUMACEA															
LEUCON AMERICANUS				6						5				8	
OXYUROSTYLIS SMITHI				14						5		15			
DECAPODA															
CANCER IRRORATUS											9				
CRANGON SEPTEMSPINOSA					17	12	13								
OVALIPES OCELLATUS												15			
PINNIXA SAYANA									14				10		
ECHINODERMATA															
ASTEROIDEA															
ASTERIIDAE SP. JUV.			11												
PHORONIDA															
PHORONIS ARCHITECTA					17			14			5	11			

RESULTS OF BENTHIC SAMPLING

FROM THE MAMARONECK HARBOR

NEW YORK

Submitted to

NEW ENGLAND DIVISION
ARMY CORPS OF ENGINEERS
424 Trapelo Road
Waltham, MA

Submitted by

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P-151

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1.0 INTRODUCTION

NAI conducted a field survey of three sites in Mamaroneck Harbor: Hen Island, Black Tom and Scotch Caps. Each of these sites is made up of rocky outcroppings and ledges, supporting a productive hard substrate community. Sport and commercial fishing occurs in the area with lobsters, blue crabs, flounder, tautog, black sea bass and porgy being species of interest.

This baseline survey was undertaken to provide information on benthic populations and habitat types characterizing these sites. The information will allow a preliminary evaluation of impacts of a containment facility on the aquatic ecosystems in the harbor.

This report presents the methods, field data, mini-ranger station locations, and the results of the laboratory analysis.

2.0 METHODOLOGY

2.1 FIELD

Three Motorola Mini-Ranger transponders were used to locate stations around each of the three areas of interest (Table 2-1; Figure 2-1). The transponder locations are presented in Table 2-2 along with the general sediment type and water depth. Stations were located as close to the three sites as possible; presence of hard substrate determined the distance.

Ten grab samples were taken in the area surrounding each of the survey sites, Hen Island, Black Tom and Scotch caps, with a 523 cm sq Ponar grab equipped with venting screens to eliminate the bow-wave effect. Samples were sieved through a 0.5 mm screen and the residues were preserved in 10% buffered formalin. Observations regarding sediment type were made to document substrate type.

2.2 LABORATORY PROCESSING

Benthic faunal samples were received in the laboratory and logged into the sample tracking system to maintain accountability throughout the process. Benthic soft substrate animals were sorted from the substrate using a dissecting scope. Samples containing medium to coarse sands or shell hash were elutriated to remove the soft-bodied organisms. Samples were stained with Rose Bengal to assist with sorting.

Taxonomists identified all animals to the lowest possible taxonomic level. Data were recorded on data sheets, coded for the computer and sent to the NAI data center; colonial animals were recorded as present.

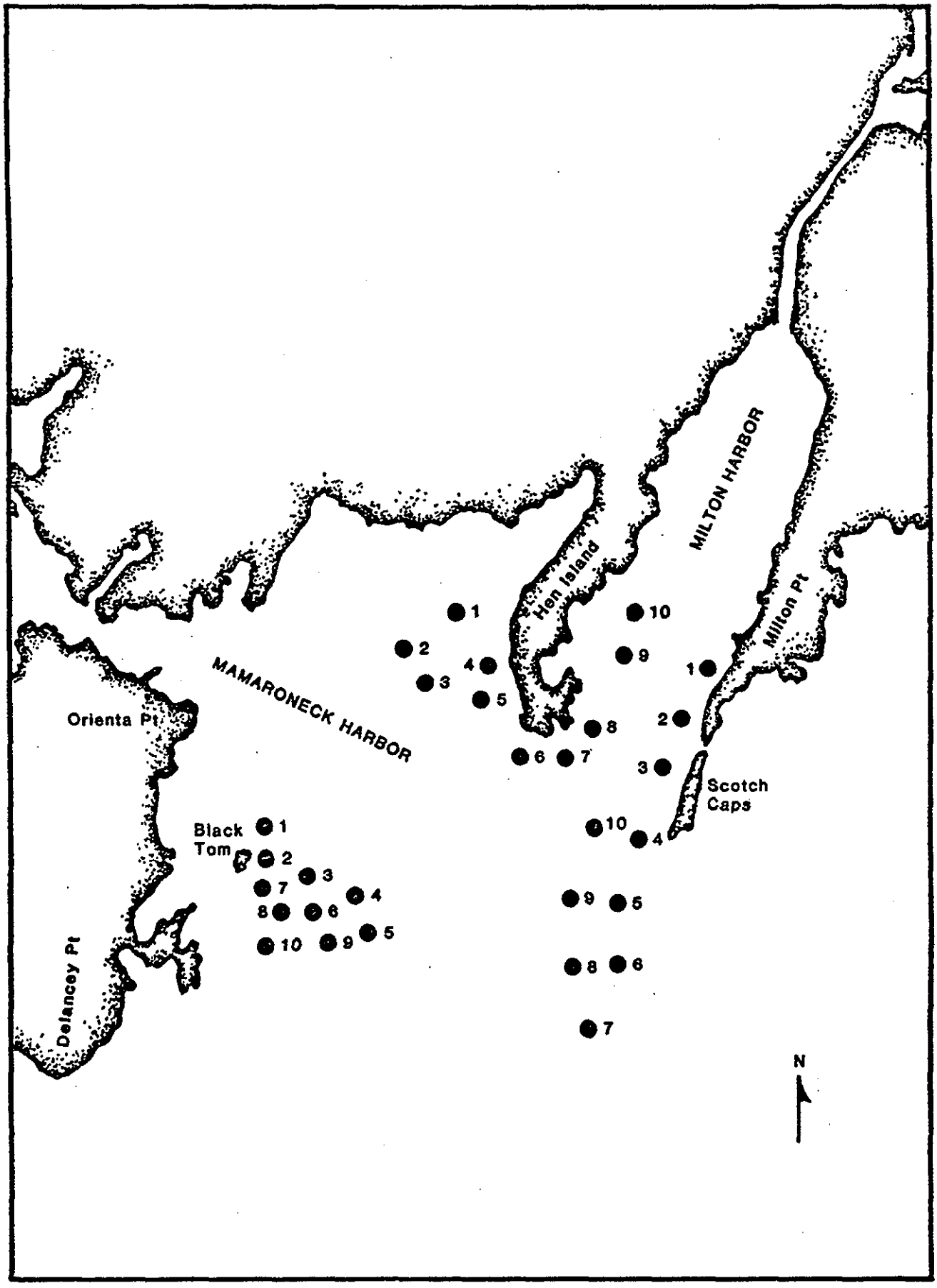

Figure 1. Station Locations for Benthic Sampling in Mamaroneck Harbor Mamaroneck Harbor Study 1984.

All of the samples were processed in accordance with the standard NAI Quality Control (QC) Procedure outlined in the Piscataqua Marine Laboratory Technical Procedures Manual. As part of this procedure, 10% of all samples were re-sorted, re-identified and re-counted to ensure the accuracy and reliability of the laboratory work.

TABLE 2-1. LOCATION AND COMPASS HEADINGS FOR TRANSPONDERS. MAMARONECK HARBOR STUDY, 1984.

TRANSPONDER #	COMPASS HEADING	COMMENTS ON POSITION
1	120°	Orienta Point Yacht Club, on the outer left-hand corner of the large pier facing outer red nun marking Mamaroneck Harbor
3	296°	American Yacht Club Flagpole, Rye (at Milton Pt.), facing the tip of Hen Island
4	208°	American Yacht Club Flagpole, Rye, facing the tip of the last island of Scotch Caps

TABLE 2-2. MINI-RANGER TRANSPONDER READINGS (DEPTH AND BOTTOM TYPE) FOR MAMARONECK HARBOR SAMPLING STATIONS. MAMARONECK HARBOR STUDY, 1984.

		TRANSPONDER READINGS				
AREA	STATION	#1	#2	#3	DEPTH	BOTTOM TYPE
Black Tom	1	487	1790		20	mud
	2	436	1843		21	mud
	3	538	1781		21	mud
	4	685	1673		21	mud
	5	783	1660		21	mud
	6	523	1893		21	mud
	7	491	1933		21	mud
	8	572	1907		21	mud
	9	822	1847		25	mud
	10	739	2006		26	mud
Hen Island	1	1214	1063		16	mud
	2	1008	1283		16	mud
	3	975	1266		18	mud
	4	1176	1048		17	mud
	5	1251	985		19	mud
	6	1304	967		20	mud
	7	1475	791		20	mud
	8	1592	629		18	mud
	9	1746	485		16	mud
	10	1850	459		18	mud
Scotch Caps	1	1912	323		18	mud
	2	1840	446		18	mud
	3	1767	637		16	mud
	4	1763	843		18	mud
	5	1738		1093	18	mixed*
	6	1828		1218	27	mixed*
	7	1657		1260	26	mixed*
	8	1600	1076		28	mud
	9	1598	872		24	mud
	10	1605	728		20	mud

*fine sand, coarse sand, gravel

3.0 RESULTS

Table 3-1 presents the number of individuals per square meter and the total number of taxa collected at each station. Table 3-2 gives Margalef's and Shannon-Weaver diversity and redundancy measure for each sampling station. A listing of species by station and a mean for each sample site (Black Tom, Scotch Caps, Hen Island) is presented in Table 3-3. The percent composition of each sample is shown in Table 3-4. The colonial taxa are indicated by a P for presence.

TABLE 3-1.
NUMBER OF TAXA AND NUMBER OF INDIVIDUALS PER STATION
IN MAMARONECK HARBOR. MAMARONECK HARBOR STUDIES, 1984.

		NO. IND.	NO. TAXA
BLACK TOM	1	1026	11
	2	1102	14
	3	1805	14
	4	760	22
	5	988	17
	6	323	11
	7	1216	19
	8	931	14
	9	836	19
	10	1520	21
	ALL	1051	56
SCOTCH CAP	1	3762	33
	2	3344	24
	3	3344	28
	4	47196	26
	5	6118	40
	6	6878	27
	7	4636	19
	8	4997	27
	9	3895	29
	10	4693	35
	ALL	8886	90
HEN Island	1	399	4
	2	1843	22
	3	3990	35
	4	2299	23
	5	570	7
	6	2318	21
	7	1862	30
	8	2717	26
	9	6099	28
	10	2242	27
	ALL	2434	68
ALL	1	1729	36
	2	2096	41
	3	3046	49
	4	16752	50
	5	2559	51
	6	3173	42
	7	2571	46
	8	2882	45
	9	3610	46
	10	2818	51
	ALL	4124	116

TABLE 3-2.

MARGALEF DIVERSITY (H BAR) AND REDUNDANCY AND SHANNON-WEAVER DIVERSITY (H PRIME) AND EVENNESS FOR THE MAMARONECK HARBOR STATIONS. MAMARONECK HARBOR STUDIES, 1984.

SAMPLES	HBAR DIVERSITY	RBAR REDUNDANCY	HPRIME DIVERSITY	HPRIME EVENNESS
BLACK TOM 1	1.73865	0.65019	2.05165	0.59306
BLACK TOM 2	1.94628	0.58292	2.28318	0.63688
BLACK TOM 3	1.75257	0.66293	1.99307	0.52348
BLACK TOM 4	2.39547	0.64141	2.98529	0.74632
BLACK TOM 5	1.21965	0.87021	1.49126	0.44892
BLACK TOM 6	1.85020	0.61886	2.46090	0.82030
BLACK TOM 7	2.21734	0.56113	2.59414	0.66399
BLACK TOM 8	1.27909	0.91406	1.58400	0.45788
BLACK TOM 9	2.28305	0.26522	2.63957	0.83269
BLACK TOM 10	2.10587	0.63564	2.44539	0.59827
HEN ISL. 1	0.61725	1.00000	0.81810	0.40905
HEN ISL. 2	2.45132	0.51970	2.77937	0.65429
HEN ISL. 3	3.65862	0.25300	3.95639	0.80629
HEN ISL. 4	2.56121	0.47796	2.84875	0.65914
HEN ISL. 5	1.36822	0.71021	1.69227	0.60280
HEN ISL. 6	2.64396	0.40797	2.92555	0.70158
HEN ISL. 7	2.59237	0.55395	2.98637	0.66018
HEN ISL. 8	3.04632	0.34001	3.36063	0.75360
HEN ISL. 9	1.79511	0.68114	1.93835	0.42276
HEN ISL. 10	2.12820	0.67205	2.44289	0.54780
SCOTCH CAP 1	2.48355	0.49941	2.70890	0.60745
SCOTCH CAP 2	1.64170	0.67599	1.80941	0.45235
SCOTCH CAP 3	2.46518	0.52726	2.72285	0.60193
SCOTCH CAP 4	0.75126	0.85137	0.77180	0.17062
SCOTCH CAP 5	2.47220	0.58047	2.67144	0.52959
SCOTCH CAP 6	1.25853	0.76180	1.34805	0.32328
SCOTCH CAP 7	1.80773	0.60168	1.93592	0.48398
SCOTCH CAP 8	2.04985	0.60565	2.21041	0.49567
SCOTCH CAP 9	2.71770	0.44181	2.94757	0.65160
SCOTCH CAP10	3.25654	0.35222	3.49548	0.71953

TABLE 3-3.
DENSITY (PER METER SQUARED) OR PRESENCE OF COLONIAL SPECIES COLLECTED IN MAMARONECK HARBOR. MAMARONECK HARBOR STUDIES, 1984.

		1	2	3	4	5	6	7	8	9	10	ALL
BLACK TOM	ARCHIANNELIDA	19			38					133	19	21
	OLIGOCHAETA	627	646	1159	361	760	133	627	703	266	874	616
	MEDIOMASTUS AMBISETA	152	95	228	19	19	76	152		95	171	101
	CIRRATULIDAE	19	76	19	19			19	19		38	21
	STREBLOSPIO BENEDICTI	57	38	152	57	19	19	76	19	152	76	67
	TELLINA AGILIS	19	19	38	19	19	19	19	19		114	29
	CAULLERIELLA SP. B	19		19					19		19	8
	NASSARIUS TRIVITTATUS	19	57	38	19		19				19	17
	ACTEOCINA CANALICULATA	57	19	19				19	57			17
	NUCULA PROXIMA					19	19	114				15
	LEUCON AMERICANUS		19							19	19	6
	MYTILIDAE		76	19	38	38	19	38		19		25
	SCOLOPLOS SP.			38								4
	RHYNCHOCOELA								19			2
	MERCENARIA MERCENARIA							19				2
	TURBELLARIA		19		19				19	19		8
	ETEONE SP.				19							2
	GASTROPODA							19			19	4
	NEOMYSIS AMERICANA									114	19	13
	MULINIA LATERALIS			19	38	38				19		11
	AMPELISCA ABDITA								19			2
	NEPHTYS INCISA	19	19		38			19	19		38	15
	CISTENA GOULDII			19								2
	YOLDIA LIMATULA					19						2
	MYA ARENARIA							19			19	4
	OXYUROSTYLIS SMITHI				19			38				6
	SPIOCHAETOPTERUS OCULATUS			19								2
	PAGURUS LONGICARPUS										19	2
	ANTINOELLA SARSI								19			2
	ASABELLIDES OCULATA						19					2
	ANOMIA SP.					38						4
	TURTONIA MINUTA							19				2
	COROPHIUM INSIDIOSUM					19						2
	NAINERIS QUADRICUSPIDA				19							2
	MYSELLA PLANULATA							19				2
	JASSA FALCATA		19								19	4
	LUMBRINERIS SP.										19	2
	NINOE NIGRIPES										19	2
	COSSURA CF. SOYERI			19								2
	UNCIOLA SP.				19							2
	PHOTIDAE				19							2

TABLE 3-3 CONTINUED.

		1	2	3	4	5	6	7	8	9	10	ALL
BLACK TOM	SIPUNCULA	19										2
	PORIFERA A				P	P	P			P		P
	CLIONA CELATA									P		P
	EUDENDRIUM DISPAR				P					P		P
	EUDENDRIUM SP.							P	P	P	P	P
	CAMPANULARIDAE							P		P		P
	OBELIA DICHOTOMA					P					P	P
	SERTULARIA CUPRESSINA				P	P		P	P	P	P	P
	SERTULARIA LATIUSCULA		P		P	P	P			P		P
	SYMPLECTOSCYPHUS TRICUSPIDATUS					P						P
	FLUSTRELLIDRA HISPIDA									P		P
	AEVERRILLIA ARMATA		P		P	P	P	P	P	P	P	P
	ELECTRA PILOSA				P							P
	CRYPTOSULA PALLASIANA					P						P
	CORIELLA STOLONATA									P		P
	ALL	1026	1102	1805	760	988	323	1216	931	836	1520	1051

TABLE 3-3.
DENSITY (PER METER SQUARED) OR PRESENCE OF COLONIAL SPECIES COLLECTED
IN MAMARONECK HARBOR. MAMARONECK HARBOR STUDIES, 1984.

		1	2	3	4	5	6	7	8	9	10	ALL
SCOTCH CAP	ARCHIANNELIDA	38	133	152	42009	171	5263	2945	532	19	114	5138
	OLIGOCHAETA	2109	152	1938	171	627	114	95	3173	1862	1254	1150
	MEDIOMASTUS AMBISETA	19	57	76		3591	988	779	152	456	779	690
	CIRRATULIDAE	266		95	3116	152		38	171	190	38	407
	SABELLARIA VULGARIS		2394		247	38	19				665	336
	STREBLOSPIO BENEDICTI	19	19	38	38	95		19	209	342	19	80
	TELLINA AGILIS	228	38	19	190	38	57			57	494	112
	CAULLERIELLA SP. B	114		57	323	19			76	152	114	86
	NASSARIUS TRIVITTATUS	152	76	95	38		76	266	19	95	133	95
	ACTEOCINA CANALICULATA	152		133						57	19	36
	ETEONE HETEROPODA	57		38		171	19		95		114	49
	NUCULA PROXIMA	95		114					76	57		34
	LEUCON AMERICANUS	57		114	19				19	76	19	30
	GYPTIS VITTATA	19	19							19		6
	EXOGONE DISPAR				190	190			228		19	63
	MYTILIDAE	76	19	19						95	38	25
	HETEROMASTUS FILIFORMIS		19			38					209	27
	SCOLOPLOS SP.	19		76							76	17
	TELLINIDAE			133		19		152	38	152		49
	NEREIS SUCCINEA		247			57					38	34
	RHYNCHOCOELA		57		152	114	38				38	40
	EUMIDA SANGUINEA		19		190	247	19		19			49
	MICROPHTHALMUS SCZELKOWII		38								19	6
	MERCENARIA MERCENARIA								19		266	29
	RICTAXIS PUNCTOSTRIATUS	95									19	11
	TURBELLARIA				209	19			19	38		29
	ETEONE SP.	19				38					19	8
	MACOMA TENTA			38		38	19	95	19	38		25
	GASTROPODA			57		19	19	19		38		15
	NEOMYSIS AMERICANA	19		38	19			19				10
	MULINIA LATERALIS	57		19						38		11
	NEPHTYS INCISA								38			4
	SCOLOPLOS ROBUSTUS			19							38	6
	GLYCERA AMERICANA		38			38						8
	CISTENA GOULDII									19		2
	NEPHTYS PICTA				57		19	76				15
	YOLDIA LIMATULA									38		4
	SPIOPHANES BOMBYX				38	19		57			19	13
	AMPHARETIDAE				19		76	19	19			13

TABLE 3-3 CONTINUED.

		1	2	3	4	5	6	7	8	9	10	ALL
SCOTCH CAP	MYA ARENARIA										38	4
	MYSIDACEA			19							19	4
	PAGURUS SP.			38		38			19			10
	GLYCERA DIBRANCHIATA			19	76		19					11
	OXYUROSTYLIS SMITHI							19	19	19		6
	SPIOCHAETOPTERUS OCULATUS									19		2
	ODOSTOMIA DEALBATA	76								19		10
	XANTHIDAE					95						10
	PAGURUS LONGICARPUS	19			19							4
	ANTINOELLA SARSI					19	19					4
	AUTOLYTUS SP.					57						6
	PROTODORVILLEA GASPEENSIS						57					6
	ARICIDEA CATHERINAE				19						38	6
	ASABELLIDES OCULATA								19		19	4
	TURTONIA MINUTA		19									2
	COROPHIUM INSIDIOSUM							19				2
	PARACAPRELLA TENUIS	57										6
	PARANAITIS SPECIOSA					38						4
	ANCISTROSYLLIS GROENLANDICA						19	19				4
	EXOGONE VERUGERA				19	19						4
	PARAPIONOSYLLIS LONGICIRRATA						38					4
	POLYDORA LIGNI				19							2
	ANTHOZOA					19						2
	SPHAEROSYLLIS ERINACEUS					19						2
	SCHISTOMERINGOS CAECA				19							2
	MALDANIDAE								19			2
	SABELLA MICROPHTHALMA					19						2
	HYDROIDES DIANTHUS					19						2
	DORIDELLA OBSCURA					19						2
	GEMMA GEMMA										19	2
	LYONSIA SP.					19						2
	PORIFERA A	P	P			P	P		P	P	P	P
	POLYMASTIA ROBUSTA	P										P
	CLIONA CELATA									P		P
	CLIONA LOBATA										P	P
	CAMPANULARIDAE		P	P			P		P	P		P
	CAMPANULARIA SP.	P										P
	OBELIA DICHOTOMA	P					P					P
	SERTULARIA CUPRESSINA	P	P	P		P	P			P		P
	SERTULARIA LATIUSCULA			P			P		P	P		P
	SERTULARIA SP.	P										P

TABLE 3-3 CONTINUED.

		1	2	3	4	5	6	7	8	9	10	ALL
SCOTCH CAP	SYMPLECTOSCYPHUS TRICUSPIDATUS	P				P						P
	ALCYONIDIUM PARASITICUM		P		P	P	P	P			P	P
	AEVERRILLIA ARMATA	P	P	P		P	P		P	P	P	P
	CONOPEUM RETICULUM		P									P
	CONOPEUM TENUISSIMUM		P		P	P	P	P	P		P	P
	CALLOPORA AURITA	P										P
	CRIBRILINA ANNULATA					P	P					P
	CRIBRILINA PUNCTATA				P							P
	CRYPTOSULA PALLASIANA	P	P					P			P	P
	CORIELLA STOLONATA	P		P								P
	ALL	3762	3344	3344	47196	6118	6878	4636	4997	3895	4693	8886

TABLE 3-3.
DENSITY (PER METER SQUARED) OR PRESENCE OF COLONIAL SPECIES COLLECTED IN MAMARONECK HARBOR. MAMARONECK HARBOR STUDIES, 1984.

		1	2	3	4	5	6	7	8	9	10	ALL
HEN Isl.	ARCHIANNELIDA			247			19	19	57	19		36
	OLIGOCHAETA	342	646	646	779	380	969	950	1083	4275	1425	1150
	MEDIOMASTUS AMBISETA		171	76	57		19	19	285	646	95	137
	CIRRATULIDAE		19	114	19	19	57	114	95	76	38	55
	SABELLARIA VULGARIS			19								2
	STREBLOSPIO BENEDICTI		589		19			38	133	76	57	91
	TELLINA AGILIS		38	608	19		57	19		114		86
	CAULLERIELLA SP. B			494	19	38	76	57	133	76	19	91
	NASSARIUS TRIVITTATUS		57	152		76	57	19	95	38	95	59
	ACTEOCINA CANALICULATA			38	418	19	342	19				84
	ETEONE HETEROPODA		38	38		19		76	171	190	76	61
	NUCULA PROXIMA			361	76		38	19		19		51
	LEUCON AMERICANUS		19	19	38		133	95	19	133	38	49
	GYPTIS VITTATA			95	570		19	76		19		78
	EXOGONE DISPAR								19		19	4
	MYTILIDAE	19	19	38	57					19		15
	HETEROMASTUS FILIFORMIS		19	209					38	19		29
	SCOLOPLOS SP.		57	76	19		19	19	76	38	19	32
	TELLINIDAE										38	4
	NEREIS SUCCINEA	19		19					19	57	57	17
	RHYNCHOCOELA				19			19	38			8
	MICROPHTHALMUS SCZELKOWII			304				76				38
	MERCENARIA MERCENARIA			19						95	19	13
	RICTAXIS PUNCTOSTRIATUS						304					30
	ETEONE SP.			19	19				76	38	76	23
	MACOMA TENTA				19		19	19		19		8
	GASTROPODA		19	19			57	19				11
	NEOMYSIS AMERICANA								38		38	8
	MULINIA LATERALIS			19			19	19				6
	AMPELISCA ABDITA							114	133	19		27
	NEPHTYS INCISA	19			19							4
	SCOLOPLOS ROBUSTUS		19					19	57	57	19	17
	GLYCERA AMERICANA		19	95					19			13
	CISTENA GOULDII			95	19						19	13
	CYLICHNA ORYZA				76		95					17
	YOLDIA LIMATULA			38		19			19		19	10
	MYA ARENARIA			57								6
	MYSIDACEA								76		19	10
	PAGURUS SP.							19			19	4

TABLE 3-3 CONTINUED.

		1	2	3	4	5	6	7	8	9	10	ALL
HEN Isl.	SPIOCHAETOPTERUS OCULATUS			19					38			6
	PAGURUS LONGICARPUS										19	2
	ANOMIA SP.										19	2
	TURTONIA MINUTA			19								2
	COROPHIUM INSIDIOSUM		19									2
	EXOGONE HEBES		38									4
	NAINERIS QUADRICUSPIDA			19								2
	POLYDORA LIGNI									19		2
	MYSELLA PLANULATA							19				2
	ENSIS DIRECTUS		19							19		4
	PYGOSPIO ELEGANS		19									2
	CAPITELLIDAE				19							2
	CAPITELLA CAPITATA		19									2
	ASYCHIS ELONGATA									19		2
	PITAR MORRHUANA				19							2
	PETRICOLA PHOLADIFORMIS			19								2
	ASTERIAS VULGARIS						19					2
	PORIFERA A			P	P			P			P	P
	CLIONA CELATA						P				P	P
	EUDENDRIUM SP.			P					P	P		P
	OBELIA DICHOTOMA							P		P		P
	OPERCULARELLA LACERATA		P	P								P
	SERTULARIA CUPRESSINA		P		P		P	P	P	P	P	P
	SERTULARIA SP.			P								P
	ALCYONIDIUM PARASITICUM							P				P
	AEVERRILLIA ARMATA		P		P		P	P	P	P	P	P
	CRIBRILINA PUNCTATA							P				P
	CRYPTOSULA PALLASIANA			P				P			P	P
	CORIELLA STOLONATA								P			P
	ALL	399	1843	3990	2299	570	2318	1862	2717	6099	2242	2434

TABLE 3-4.
PERCENT COMPOSITION FOR SPECIES PRESENT IN MAMARONECK HARBOR SAMPLES. MAMARONECK HARBOR STUDIES, 1984.

		1	2	3	4	5	6	7	8	9	10	ALL
BLACK TOM	ARCHIANNELIDA	1.9			5.0					15.9	1.2	2.0
	OLIGOCHAETA	61.1	58.6	64.2	47.5	76.9	41.2	51.6	75.5	31.8	57.5	58.6
	MEDIOMASTUS AMBISETA	14.8	8.6	12.6	2.5	1.9	23.5	12.5		11.4	11.2	9.6
	CIRRATULIDAE	1.9	6.9	1.1	2.5			1.6	2.0		2.5	2.0
	STREBLOSPIO BENEDICTI	5.6	3.4	8.4	7.5	1.9	5.9	6.3	2.0	18.2	5.0	6.3
	TELLINA AGILIS	1.9	1.7	2.1	2.5	1.9	5.9	1.6	2.0		7.5	2.7
	CAULLERIELLA SP. B	1.9		1.1					2.0		1.2	0.7
	NASSARIUS TRIVITTATUS	1.9	5.2	2.1	2.5		5.9				1.2	1.6
	ACTEOCINA CANALICULATA	5.6	1.7	1.1				1.6	6.1			1.6
	NUCULA PROXIMA					1.9	5.9	9.4				1.4
	LEUCON AMERICANUS		1.7							2.3	1.2	0.5
	MYTILIDAE		6.9	1.1	5.0	3.8	5.9	3.1		2.3		2.4
	SCOLOPLOS SP.			2.1								0.4
	RHYNCHOCOELA								2.0			0.2
	MERCENARIA MERCENARIA							1.6				0.2
	TURBELLARIA		1.7		2.5				2.0	2.3		0.7
	ETEONE SP.				2.5							0.2
	GASTROPODA							1.6			1.2	0.4
	NEOMYSIS AMERICANA									13.6	1.2	1.3
	MULINIA LATERALIS			1.1	5.0	3.8				2.3		1.1
	AMPELISCA ABDITA								2.0			0.2
	NEPHTYS INCISA	1.9	1.7		5.0			1.6	2.0		2.5	1.4
	CISTENA GOULDII			1.1								0.2
	YOLDIA LIMATULA					1.9						0.2
	MYA ARENARIA							1.6			1.2	0.4
	OXYUROSTYLIS SMITHI				2.5			3.1				0.5
	SPIOCHAETOPTERUS OCULATUS			1.1								0.2
	PAGURUS LONGICARPUS										1.2	0.2
	ANTINOELLA SARSI								2.0			0.2
	ASABELLIDES OCULATA						5.9					0.2
	ANOMIA SP.					3.8						0.4
	TURTONIA MINUTA							1.6				0.2
	COROPHIUM INSIDIOSUM					1.9						0.2
	NAINERIS QUADRICUSPIDA				2.5							0.2
	MYSELLA PLANULATA							1.6				0.2
	JASSA FALCATA		1.7								1.2	0.4
	LUMBRINERIS SP.										1.2	0.2
	NINOE NIGRIPES										1.2	0.2
	COSSURA CF. SOYERI			1.1								0.2
	UNCIOLA SP.				2.5							0.2
	PHOTIDAE				2.5							0.2
	SIPUNCULA	1.9										0.2

TABLE 3-4 CONTINUED

		1	2	3	4	5	6	7	8	9	10	ALL
BLACK TOM	PORIFERA A				P	P	P			P		P
	CLIONA CELATA									P		P
	EUDENDRIUM DISPAR				P					P		P
	EUDENDRIUM SP.							P	P	P	P	P
	CAMPANULARIDAE							P		P		P
	OBELIA DICHOTOMA					P					P	P
	SERTULARIA CUPRESSINA				P	P		P	P	P	P	P
	SERTULARIA LATIUSCULA		P		P	P	P			P		P
	SYMPLECTOSCYPHUS TRICUSPIDATUS					P						P
	FLUSTRELLIDRA HISPIDA									P		P
	AEVERRILLIA ARMATA		P		P	P	P	P	P	P	P	P
	ELECTRA PILOSA				P							P
	CRYPTOSULA PALLASIANA					P						P
	CORIELLA STOLONATA									P		P
	ALL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 3-4.
PERCENT COMPOSITION FOR SPECIES PRESENT IN MAMARONECK HARBOR SAMPLES. MAMARONECK HARBOR STUDIES, 1984.

		1	2	3	4	5	6	7	8	9	10	ALL
SCOTCH CAP	ARCHIANNELIDA	1.0	4.0	4.5	89.0	2.8	76.5	63.5	10.6	0.5	2.4	57.8
	OLIGOCHAETA	56.1	4.5	58.0	0.4	10.2	1.7	2.0	63.5	47.8	26.7	12.9
	MEDIOMASTUS AMBISETA	0.5	1.7	2.3		58.7	14.4	16.8	3.0	11.7	16.6	7.8
	CIRRATULIDAE	7.1		2.8	6.6	2.5		0.8	3.4	4.9	0.8	4.6
	SABELLARIA VULGARIS		71.6		0.5	0.6	0.3				14.2	3.8
	STREBLOSPIO BENEDICTI	0.5	0.6	1.1	0.1	1.6		0.4	4.2	8.8	0.4	0.9
	TELLINA AGILIS	6.1	1.1	0.6	0.4	0.6	0.8			1.5	10.5	1.3
	CAULLERIELLA SP. B	3.0		1.7	0.7	0.3			1.5	3.9	2.4	1.0
	NASSARIUS TRIVITTATUS	4.0	2.3	2.8	0.1		1.1	5.7	0.4	2.4	2.8	1.1
	ACTEOCINA CANALICULATA	4.0		4.0						1.5	0.4	0.4
	ETEONE HETEROPODA	1.5		1.1		2.8	0.3		1.9		2.4	0.6
	NUCULA PROXIMA	2.5		3.4					1.5	1.5		0.4
	LEUCON AMERICANUS	1.5		3.4	<0.1				0.4	2.0	0.4	0.3
	GYPTIS VITTATA	0.5	0.6							0.5		0.1
	EXOGONE DISPAR				0.4	3.1			4.6		0.4	0.7
	MYTILIDAE	2.0	0.6	0.6						2.4	0.8	0.3
	HETEROMASTUS FILIFORMIS		0.6			0.6					4.5	0.3
	SCOLOPLOS SP.	0.5		2.3							1.6	0.2
	TELLINIDAE			4.0		0.3		3.3	0.8	3.9		0.6
	NEREIS SUCCINEA		7.4			0.9					0.8	0.4
	RHYNCHOCOELA		1.7		0.3	1.9	0.6				0.8	0.4
	EUMIDA SANGUINEA		0.6		0.4	4.0	0.3		0.4			0.6
	MICROPHTHALMUS SCZELKOWII		1.1								0.4	0.1
	MERCENARIA MERCENARIA								0.4		5.7	0.3
	RICTAXIS PUNCTOSTRIATUS	2.5									0.4	0.1
	TURBELLARIA				0.4	0.3			0.4	1.0		0.3
	ETEONE SP.	0.5				0.6					0.4	0.1
	MACOMA TENTA			1.1		0.6	0.3	2.0	0.4	1.0		0.3
	GASTROPODA			1.7		0.3	0.3	0.4		1.0		0.2
	NEOMYSIS AMERICANA	0.5		1.1	<0.1			0.4				0.1
	MULINIA LATERALIS	1.5		0.6						1.0		0.1
	NEPHTYS INCISA								0.8			<0.1
	SCOLOPLOS ROBUSTUS			0.6							0.8	0.1
	GLYCERA AMERICANA		1.1			0.6						0.1
	CISTENA GOULDII									0.5		<0.1
	NEPHTYS PICTA				0.1		0.3	1.6				0.2
	YOLDIA LIMATULA									1.0		<0.1
	SPIOPHANES BOMBYX				0.1	0.3		1.2			0.4	0.1
	AMPHARETIDAE				<0.1		1.1	0.4	0.4			0.1
	MYA ARENARIA										0.8	<0.1
	MYSIDACEA			0.6							0.4	<0.1

TABLE 3-4 CONTINUED.

		1	2	3	4	5	6	7	8	9	10	ALL
SCOTCH CAP	PAGURUS SP.			1.1		0.6			0.4			0.1
	GLYCERA DIBRANCHIATA			0.6	0.2		0.3					0.1
	OXYUROSTYLIS SMITHI							0.4	0.4	0.5		0.1
	SPIOCHAETOPTERUS OCULATUS									0.5		<0.1
	ODOSTOMIA DEALBATA	2.0								0.5		0.1
	XANTHIDAE					1.6						0.1
	PAGURUS LONGICARPUS	0.5			<0.1							<0.1
	ANTINOELLA SARSI					0.3	0.3					<0.1
	AUTOLYTUS SP.					0.9						0.1
	PROTODORVILLEA GASPEENSIS						0.8					0.1
	ARICIDEA CATHERINAE				<0.1						0.8	0.1
	ASABELLIDES OCULATA								0.4		0.4	<0.1
	TURTONIA MINUTA		0.6									<0.1
	COROPHIUM INSIDIOSUM							0.4				<0.1
	PARACAPRELLA TENUIS	1.5										0.1
	PARANAITIS SPECIOSA					0.6						<0.1
	ANCISTROSYLLIS GROENLANDICA						0.3	0.4				<0.1
	EXOGONE VERUGERA				<0.1	0.3						<0.1
	PARAPIONOSYLLIS LONGICIRRATA						0.6					<0.1
	POLYDORA LIGNI				<0.1							<0.1
	ANTHOZOA					0.3						<0.1
	SPHAEROSYLLIS ERINACEUS					0.3						<0.1
	SCHISTOMERINGOS CAECA				<0.1							<0.1
	MALDANIDAE								0.4			<0.1
	SABELLA MICROPHTHALMA					0.3						<0.1
	HYDROIDES DIANTHUS					0.3						<0.1
	DORIDELLA OBSCURA					0.3						<0.1
	GEMMA GEMMA										0.4	<0.1
	LYONSIA SP.					0.3						<0.1
	PORIFERA A	P	P			P	P		P	P	P	P
	POLYMASTIA ROBUSTA	P										P
	CLIONA CELATA									P		P
	CLIONA LOBATA										P	P
	CAMPANULARIDAE		P	P			P		P	P		P
	CAMPANULARIA SP.	P										P
	OBELIA DICHOTOMA	P					P					P
	SERTULARIA CUPRESSINA	P	P	P		P	P			P		P
	SERTULARIA LATIUSCULA			P			P		P	P		P
	SERTULARIA SP.	P										P
	SYMPLECTOSCYPHUS TRICUSPIDATUS	P				P						P
	ALCYONIDIUM PARASITICUM		P		P	P	P	P			P	P
	AEVERRILLIA ARMATA	P	P	P		P	P		P	P	P	P
	CONOPEUM RETICULUM		P									P

TABLE 3-4 CONTINUED.

		1	2	3	4	5	6	7	8	9	10	ALL
SCOTCH CAP	CONOPEUM TENUISSIMUM		P		P	P	P	P	P		P	P
	CALLOPORA AURITA	P										P
	CRIBRILINA ANNULATA					P	P					P
	CRIBRILINA PUNCTATA				P							P
	CRYPTOSULA PALLASIANA	P	P					P			P	P
	CORIELLA STOLONATA	P		P								P
	ALL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 3-4.
PERCENT COMPOSITION FOR SPECIES PRESENT IN MAMARONECK HARBOR SAMPLES. MAMARONECK HARBOR STUDIES, 1984.

		1	2	3	4	5	6	7	8	9	10	ALL
HEN Isl.	ARCHIANNELIDA			6.2			0.8	1.0	2.1	0.3		1.5
	OLIGOCHAETA	85.7	35.1	16.2	33.9	66.7	41.8	51.0	39.9	70.1	63.6	47.2
	MEDIOMASTUS AMBISETA		9.3	1.9	2.5		0.8	1.0	10.5	10.6	4.2	5.6
	CIRRATULIDAE		1.0	2.9	0.8	3.3	2.5	6.1	3.5	1.2	1.7	2.3
	SABELLARIA VULGARIS			0.5								0.1
	STREBLOSPIO BENEDICTI		32.0		0.8			2.0	4.9	1.2	2.5	3.7
	TELLINA AGILIS		2.1	15.2	0.8		2.5	1.0		1.9		3.5
	CAULLERIELLA SP. B			12.4	0.8	6.7	3.3	3.1	4.9	1.2	0.8	3.7
	NASSARIUS TRIVITTATUS		3.1	3.8		13.3	2.5	1.0	3.5	0.6	4.2	2.4
	ACTEOCINA CANALICULATA			1.0	18.2	3.3	14.8	1.0				3.4
	ETEONE HETEROPODA		2.1	1.0		3.3		4.1	6.3	3.1	3.4	2.5
	NUCULA PROXIMA			9.0	3.3		1.6	1.0		0.3		2.1
	LEUCON AMERICANUS		1.0	0.5	1.7		5.7	5.1	0.7	2.2	1.7	2.0
	GYPTIS VITTATA			2.4	24.8		0.8	4.1		0.3		3.2
	EXOGONE DISPAR								0.7		0.8	0.2
	MYTILIDAE	4.8	1.0	1.0	2.5					0.3		0.6
	HETEROMASTUS FILIFORMIS		1.0	5.2					1.4	0.3		1.2
	SCOLOPLOS SP.		3.1	1.9	0.8		0.8	1.0	2.8	0.6	0.8	1.3
	TELLINIDAE										1.7	0.2
	NEREIS SUCCINEA	4.8		0.5					0.7	0.9	2.5	0.7
	RHYNCHOCOELA				0.8			1.0	1.4			0.3
	MICROPHTHALMUS SCZELKOWII			7.6				4.1				1.6
	MERCENARIA MERCENARIA			0.5						1.6	0.8	0.5
	RICTAXIS PUNCTOSTRIATUS						13.1					1.2
	ETEONE SP.			0.5	0.8				2.8	0.6	3.4	0.9
	MACOMA TENTA				0.8		0.8	1.0		0.3		0.3
	GASTROPODA		1.0	0.5			2.5	1.0				0.5
	NEOMYSIS AMERICANA								1.4		1.7	0.3
	MULINIA LATERALIS			0.5			0.8	1.0				0.2
	AMPELISCA ABDITA							6.1	4.9	0.3		1.1
	NEPHTYS INCISA	4.8			0.8							0.2
	SCOLOPLOS ROBUSTUS		1.0					1.0	2.1	0.9	0.8	0.7
	GLYCERA AMERICANA		1.0	2.4					0.7			0.5
	CISTENA GOULDII			2.4	0.8						0.8	0.5
	CYLICHNA ORYZA				3.3		4.1					0.7
	YOLDIA LIMATULA			1.0		3.3			0.7		0.8	0.4
	MYA ARENARIA			1.4								0.2
	MYSIDACEA								2.8		0.8	0.4
	PAGURUS SP.							1.0			0.8	0.2
	SPIOCHAETOPTERUS OCULATUS			0.5					1.4			0.2
	PAGURUS LONGICARPUS										0.8	0.1
	ANOMIA SP.										0.8	0.1

TABLE 3-4 CONTINUED.

		1	2	3	4	5	6	7	8	9	10	ALL
HEN Isl.	TURTONIA MINUTA			0.5								0.1
	COROPHIUM INSIDIOSUM		1.0									0.1
	EXOGONE HEBES		2.1									0.2
	NAINERIS QUADRICUSPIDA			0.5								0.1
	POLYDORA LIGNI									0.3		0.1
	MYSELLA PLANULATA							1.0				0.1
	ENSIS DIRECTUS		1.0							0.3		0.2
	PYGOSPIO ELEGANS		1.0									0.1
	CAPITELLIDAE				0.8							0.1
	CAPITELLA CAPITATA		1.0									0.1
	ASYCHIS ELONGATA									0.3		0.1
	PITAR MORRHUANA				0.8							0.1
	PETRICOLA PHOLADIFORMIS			0.5								0.1
	ASTERIAS VULGARIS						0.8					0.1
	PORIFERA A			P	P			P			P	P
	CLIONA CELATA						P				P	P
	EUDENDRIUM SP.			P					P	P		P
	OBELIA DICHOTOMA							P		P		P
	OPERCULARELLA LACERATA		P	P								P
	SERTULARIA CUPRESSINA		P		P		P	P	P	P	P	P
	SERTULARIA SP.			P								P
	ALCYONIDIUM PARASITICUM							P				P
	AEVERRILLIA ARMATA		P		P		P	P	P	P	P	P
	CRIBRILINA PUNCTATA							P				P
	CRYPTOSULA PALLASIANA			P				P			P	P
	CORIELLA STOLONATA								P			P
	ALL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
P.O. Box 1518
Concord, New Hampshire 03301

OCT 1 1 1980

New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

We have reviewed your Long Island Sound Interim Report on dredged material containment. The following comments are intended to aid your planning process during the Stage 2 studies.

The report is primarily concerned with containments to create shoreline land extensions. Only publicly-owned shoreline was investigated for potential containment facilities. This represents only about five percent of the Long Island Sound shoreline. We are in agreement with the suggestion in paragraph 5.10 (p. 5.5) that Stage 2 planning should consider privately owned shorefront for potential shoreline extension containment sites.

Paragraph 4.39 (p. 4-17) states that "Confined disposal is not considered to be compatible with existing wetlands, and these areas are excluded from further consideration." We believe opportunities may exist to enlarge wetlands through carefully designed projects and agree with your August 1, 1980, cover letter recommending areas be investigated for potential containment sites that would protect and enlarge existing wetlands.

Paragraph 4.38 (p. 4-17) states that significant concentrations of shellfish beds, lobster beds, crab habitats, waterfowl feeding/nesting, and finfish spawning/migration areas were eliminated from further consideration in order to minimize potential environmental conflicts. We suggest that significant shorebird concentration/feeding areas be added to this list since they normally denote areas that are highly productive from a biological standpoint.

Based on the preliminary siting analysis, the two (2) best available containment areas on public lands were selected and are discussed in paragraphs 4.74-4.92 (pages 4-71 -- 4-79).

The number one site in Connecticut, Bayview Park #3-69 (Long Wharf area), is located in New Haven Harbor. Paragraph 4.85 (p. 4-76) states that "The lack of piers for small boat use due to the tidal flat location would make the containment dike an ideal small boat facility. - - - The containment site might benefit the surrounding community by creating new recreational area on unused and unnavigable waters." We contend that

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this 225-acre area is not "unused." It is a tidal flat, highly productive from a biological standpoint, and is a significant shorebird concentration/feeding area. We would not condone the use of this area for a containment facility.

The number one site in New York, State Maritime College #2-6, is located on the northeastern side of Throgs Neck. Paragraph 4.87 (p. 4-77) states that "The scarcity of industrial lands makes the development of light industry conceivable for containment area reuse. The potential use of the site for industrial purposes would also help improve employment opportunities in this highly urbanized region." This 100-acre potential containment area is located in relatively shallow water and supports a rather diverse biological community. We cannot condone distruction of this shallow water area in the interest of creating an area for light industrial use.

While the report does consider ecological factors in the preliminary siting analysis (Section 4), it does not adequately consider the potential reuse of containment sites as ecological areas. Rather, it stresses the reuse of containment areas for industrial, commercial and recreational uses. We believe that greater emphasis should be put on creating beneficial natural environments such as wetlands and shore and sea bird resting/feeding areas.

Your Stage 2 studies should be expanded beyond a search for alternate disposal sites. You should also determine the sources of the sediment that require frequent maintenance dredging and identify measures to reduce the volume of sediment to be placed in a containment. We encourage you to identify beneficial uses of spoil and waste materials, to investigate alternate spoil disposal, and to develop a long-range coordinated dredging program for Long Island Sound.

We suggest that the following be added to the overall scope and planning objectives for this project.

- To investigate private as well as public shorefront areas for potential containment areas.

- To emphasize creation of fish and wildlife habitat, especially wetlands at containment structures that may be proposed as a part of the overall plan for spoil management.

- To determine the source of sediments that collect in channels and anchorages, and to search for measures to reduce deposition of sediment.

We are very much concerned with finding improved disposal procedures since existing practices usually result in adverse impacts on fish and wildlife resources. Our support and interest in your study is based on the belief that dredge material can and should be used to benefit the natural environment.

Sincerely yours,

Gordon E. Beckett

Gordon E. Beckett
Supervisor

United States Department of the Interior

FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
P.O. BOX 1518
CONCORD, NEW HAMPSHIRE 03301

OCT 15 1982

Colonel Carl B. Sciple
Division Engineer
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254

Dear Colonel Sciple:

This planning aid letter is intended to aid your study planning efforts for the Long Island Sound Dredged Material Disposal Container Study, Connecticut and New York. It has been prepared under authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

Mr. Ignazio's letter of July 12, 1982, requested that we conduct a preliminary ecological feasibility analysis of the fourteen (14) sites identified as possible dredge material containment disposal areas. This planning aid letter provides a brief environmental description and an environmental sensitivity ranking of the fourteen sites.

In the majority of cases detailed site development plans concerning the size, method of construction, amount and kind of fill, and potential use have not been identified. As a result, it is inappropriate at this time to determine the site specific environmental impacts of such development. In addition, detailed site specific environmental data are not available for the vast majority of the sites. Therefore, professional judgments and opinions were important in characterizing each site's environmental sensitivities to dredge material container development.

Representatives from the National Marine Fisheries Service, Marine Regional Headquarters and Wildlife Unit of the Connecticut Department of Environmental Protection, Aquaculture Division of the Connecticut Department of Agriculture, and the New York Department of Environmental Conservation contributed their technical expertise and judgment to this Service's evaluation of the fourteen sites. This letter does not represent the official views of those participating agencies concerning the ultimate development of any of these sites for dredge material containment disposal areas. However, it does serve to delineate the evaluated sites into sensitivity groups ranging from the least to the most sensitive from an environmental standpoint.

The following is a brief environmental description of the fourteen sites:

Flushing Bay - This 360-acre site designated for dredged material disposed is a highly stressed area located adjacent to LaGuardia Airport, Long Island, New York. Anaerobic conditions usually occur in this area during the summer

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months and restricts utilization of the area by finfish and shellfish. However, blue fish and other species do utilize this area to some extent and blue crabs are active scavengers of this area during seasons when dissolved oxygen is not a limiting factor.

The Flushing Bay area is considered a critical area for overwintering waterfowl by the New York State Department of Environmental Conservation. Waterfowl that overwinter here are Black ducks, Canada geese, Brant, Red-Breasted mergansers, Mallards and American golden-eye. A large variety of shorebirds and seabirds also utilize the general area of the site. Areas near Flushing Bay, such as North Brother's and South Brother's Island, support nesting colonies of Cattle egrets and Snowy egrets.

An extension from the south edge of LaGuardia, which was recently built, provided conditions for a saltmarsh to grow west of this spit. The area designated for container development is of the same character and could be used to produce a saltmarsh which would be an aid to water quality in the area.

Scotch Caps - This site is located on the east side of Milton Harbor near Mamaroneck, New York. The rock outcroppings, ledges and reef structures associated with this site provide excellent habitat for such organisms as rock weed, blue and ribbed mussels, barnacles, and other benthic invertebrates which contribute to the overall productivity of this area. It is considered to be excellent lobster habitat and does support a commercial fishery. This area also supports a considerable oyster population, especially on the western side.

The entire eastern edge supports an excellent striped bass fishery. Other finfish resources include cunner, winter flounder, tautog, black sea bass and porgy all of which are sought both commercially and recreationally.

Black Tom - This site is located on the western side of Mamaroneck Harbor, Mamaroneck, New York. The rock outcroppings, ledges and reef structures associated with this site are similar, though smaller in area, to Scotch Caps. It is a very productive area and has the same species association as Scotch Caps.

Hen Island - This site is located on the eastern edge of Mamaroneck Harbor, Mamaroneck, New York. Hen Island has a substantial salt marsh around it and is probably one of the best waterfowl and shorebird areas in Mamaroneck Harbor. It is also associated with a reef system and supports both blue and ribbed mussels, oysters, blue crabs and lobsters.

Hen Island is similar to Scotch Caps in that it has the same finfish resources and supports a productive striped bass fishery along its eastern shore.

Harbor Island Park - This site is located at the head of Mamaroneck Harbor and is a fully developed park with tennis courts, town beach, marina, etc. It receives near maximum recreational use and was not considered to be a spoil area. Therefore, this site received no further evaluation.

Sherwood Island: - This site is a barrow hole(s) located offshore of Sherwood's Island State Park in Westport, Connecticut. The preliminary plan is to

fill this hole(s) with Class II or Class III materials and cap it with Class I material. Sherwood Point is the apex of a number of boundary lines marking shellfish lots (oyster and hard clam). While there are no leased shellfish beds within the hole area, it does contain a natural population of hard clams. There are 4 leased shellfish beds and one natural bed shoreward of the hole area and many more leased beds seaward of the area and to the west toward Cedar Point. There is also a significant amount of recreational clamming along the inshore area. This area has been certified as clean water by the State Health Department for the direct marketing of shellfish. Lobsters are found generally seaward of the hole, starting at about the 30-foot contour, and support both a commercial and recreational fishery. The general area supports a fairly strong sport fishery for winter flounder, bluefish, striped bass, scup, blackfish and weakfish. While there is a fairly large population of Canada Geese in the general area their utilization of the immediate hole area is minimal.

This site was evaluated assuming that Class III materials would not be dumped in this productive shellfish area.

Yellow Mill Channel: - This man-made dredged channel is located in the upper reaches of Bridgeport Harbor and extends from Cooks Point to Crescent Avenue. The preliminary plan is to fill this area from about the I-95 overpass to Crescent Avenue and develop a "green" area-recreational park. Environmentally, Yellow Mill Channel is a severely stressed water body and under existing conditions is of low value to fish and wildlife resources. Local residents do fish the area and catch an occasional bluefish, tomcod or other species. Nearly every summer a die-off of menhaden occurs in this area due to poor water quality conditions. The area does receive moderate use by a variety of shorebirds. South of Yellow Mill Channel the water quality is still degraded, however, Bridgeport Harbor does support significant shellfish resources and there are both natural beds and leased grounds in this area. Finfish resources of the harbor area include menhaden, striped bass, Atlantic mackerel, winter and summer flounder, scup, tomcod, and bluefish. The most heavily used sport fishing areas are the Pleasure Beach Jetty and the Seaside Park area.

Pennfield Shoals/Reef - This site is located off of Shoal Point, Fairfield, Connecticut. Preliminary plans envision island creation with diking on four sides. The reef is approximately one-mile long and is one of the few areas along this part of the coast that has a significant amount of rocky-cobble bottom. It is a very productive area from a fish and wildlife standpoint. There is a large natural bed of oysters and hard clams that extends from the reef, east, to well below Pine Creek Point. The reef area also supports a large population of blue mussels. Immediately to the north and west of the reef there are leased shellfish beds. The rocky habitat around Pennfield Light is a productive area for lobsters. Both shore-based and boat fishermen utilize the area. It is considered to be one of the better surf fishing spots in the State of Connecticut. Predominate fish species include striped bass, bluefish, weakfish, winter and summer flounder and Atlantic mackerel. This shoal area is also extensively utilized by waterfowl such as Black ducks and Scaup and provides excellent feeding and resting habitat for a large variety of seabirds and shorebirds.

Milford Harbor - This site is located on the west side of the harbor entrance channel jetty at Milford, Connecticut. The preliminary plan is to create a relatively large rectangular shaped container extending from shore to the end of the jetty. This area is predominantly a large sand flat with a fringe of salt marsh along the shoreline. It does support a few soft-shelled clams and hard clams but it is not considered to be a very productive area. However, there are significant commercial oyster and hard clam grounds in the general vicinity, approximately 1500-feet off-shore. The general area of this proposed site is heavily utilized by a variety of shorebirds and receives moderate use by waterfowl. Sport fishing pressure is heavy, especially off the jetty which has excellent public access. The channel-ward side of the jetty receives the greatest fishing pressure and the predominate fish species caught are bluefish, striped bass, winter flounder, weakfish and tomcod.

Thames River - This site is located under the Gold Star Bridge on the west bank of the Thames River in New London, Connecticut. The preliminary plan for this area is to create a large square shaped container extending from Winthrop Point north under the Gold Star Bridge to the cable area and out to the bascule opening of the railroad bridge, nearly half the width of the Thames River. The container area supports both hard clams and oysters, however, the largest concentration of these shellfish occurs north of the site and are utilized for transplanting purposes. A moderate population of blue crabs also inhabits the container area. Immediately north of the proposed container site a large concentration of winter flounder occurs during the months of January, February and March and while not documented they probably spawn in this area. There is a new State-owned boat launching ramp under the Gold Star Bridge and it is heavily utilized by sport fishermen. The site area also receives heavy use from shore-based fishermen and it is one of the few places on the Thames River that has excellent access for this type of fishing. The predominate fish species caught in this area are winter flounder, bluefish, striped bass, scup, Atlantic mackrel and weakfish. The heaviest concentration of canvasback ducks in Connecticut occurs on the Thames River and they do utilize the site area along with Scaup and Black ducks. A large resident population of Mute swans inhabit the Thames and some of them regularly utilize the proposed container area.

Menunketesuch Island - This site is located east of the Patchogue River between Duck Island Roads and Westbrook Harbor. The preliminary plan consists of unconfined disposal of Class I and Class II materials to restore the northern end of the island and provide nesting habitat for Least terns. This area is open to harvesting of shellfish. There is a 266 acre shellfish bed (oysters, hard clams and surf clams) to the west of the island that is State-owned but has not been leased. To the east there are significant beds of soft-shelled clams, hard clams and oysters. There is a lobster fishery off of Duck Island that extends to the southern tip of Menunketesuch Island. While the immediate area of the site is shallow and sandy it does support a moderate sport fishery for bluefish, winter flounder, striped bass and weakfish. The general area is quite heavily utilized by a variety of seabirds and shorebirds but is not extensively used by waterfowl.

Guilford Harbor - This is an upland site located on the east bank of the West River near the Guilford Marina. The area is diked and has been previously

used for disposal of dredged materials. There are no significant fish and wildlife resources within the immediate disposal area. However, the West River is a very productive oyster area and also has soft-shell clams, blue mussels and blue crabs.

West Haven - This is an upland site located on the west bank of the West River between Interstate I-95 and the Penn Central New Haven Railroad tracks. The 10 1/2 acre site is diked and has been previously used for disposal of dredged material. There are no significant fish and wildlife resources within the immediate disposal area. However, there are leased shellfish beds at the mouth of the West River which are good seed oyster producing areas.

Mouth of Housatonic River - This site is located off of Milford Point behind the breakwater in Milford, Connecticut. We assume that the plan envisioned for this large triangular site is island creation. This area is quite productive from a fish and wildlife standpoint. The breakwater area supports a large population of blue mussels. There are natural beds of hard clams, oysters and soft-shell clams within the area of this proposed container. Directly to the east of the breakwater there are a large number of leased shellfish beds (oyster, hard clam) and the major portion of one of these beds lies within the container area. The mouth of the Housatonic River supports a very active sports fishery especially for such species as bluefish, striped bass and winter flounder. Fishing from the breakwater is severely limited since there is no public access, however, if such access were provided, this breakwater would become a very significant fishing area for shore-based fishermen. The proposed container site and adjacent lands provide excellent habitat for shorebirds. Milford Point is a Least tern nesting area. This point is privately owned and we understand that a portion of it is leased to the Audubon Society. The State-owned Nells Island area is heavily utilized by Black ducks, Mallards, and Canada geese. This general area is also considered to be a major resting area for hawks during the migration period.

The environmental sensitivities of the evaluated sites were rated using a technique from the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures, the calculation of Relative Value Indices (RVI). The calucation of RVI values is performed in three steps: 1) defining the perceived significance of RVI criteria; 2) rating each identified site against each criterion; and 3) transforming the perceived significance of each criterion and each site's rating into a RVI.

The RVI criteria used in this excercise are: 1) fishery resources; 2) wildlife resources, 3) water quality, 4) physical characteristics, and 5) development potential (See Table 1). The first step in RVI calculation involves the application of relative weights to each criterion to numerically define its perceived importance to the user. Pairwise comparisons are made in which each criterion is compared to every other criterion, and a decision is made about which criterion of any pair is more important. Values assigned to all pairs must be equal to 1. These comparisons can be easily made in a simple matrix and the relative weight of each criterion obtained as shown in Table 2.

The second step in RVI calculations involves rating each potential container site against each criterion. This does not involve a partitioning of values between two choices, but rather involves a judgment of what value between 0.1 and 1.0 (from Table 1) is most appropriate for each container site and criterion. These values are shown in Table 3.

Table 1. Relative Value Index Criteria for Evaluated Sites

Criteria	Definition	Range of Value
Fishery Resources	Finfish resources, shellfish resources, benthic organisms, etc.	0.1 low quality 1.0 high quality
Wildlife Resources	Waterfowl, shorebirds, songbirds, mammals, etc.	0.1 low quality 1.0 high quality
Water Quality		0.1 low quality 1.0 high quality
Physical Characteristics	Previous use of the area, amount of fill, upland/intertidal/subtidal area. Natural dynamics should be considered.	0.1 greatly disturbed 1.0 essentially undisturbed
Development Potential	Potential for developing habitat for fish & wildlife resources	0.1 easily managed or created 1.0 little or no possibility to manage or create

Table 2. Pairwise Comparison Matrix for Determining Relative Weights for each Ranking Criterion.[1/]

1. Study

Long Island Sound Dredged Material Disposal Container Study

2. Ranking criteria	3. Ranking criteria (1)	(2)	(3)	(4)	(5)	(6)	Dummy	4. Sum	6. Relative weight
(1) Fishery Resources	XXXXX	.50	.65	.80	.62		1.0	3.57	0.24
(2) Wildlife Resources	.50	XXXXX	.65	.80	.62		1.0	3.57	0.24
(3) Water Quality	.35	.35	XXXXX	.60	.42		1.0	2.72	0.18
(4) Physical Characteristics	.20	.20	.40	XXXXX	.42		1.0	2.22	0.15
(5) Development Potential	.38	.38	.58	.58	XXXXX		1.0	2.92	0.19
(6)						XXXXX	1.0		
Dummy criterion	0	0	0	0	0	0	XXXXX	0.0	0.00
								5. Total 15.00	7. Total weight 1.00

1/ Average values, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Connecticut Department of Environmental Protection, and the Aquaculture Division of the Connecticut Department of Agriculture.

Table 3. Determination of Relative Value Indices for each Evaluation Site.

1. Study
Long Island Sound Dredged Material Disposal Container Study

2. Evaluation site	3. Relative weight of ranking criteria						5. Relative value	6. Relati Value Inde
	1	2	3	4	5	6		
	0.24	0.24	0.18	0.15	0.19			
	4. Relative importance of each ranking criterion to each evaluation species.							
New York[1/]								
Flushing Bay	.30	.90	.27	.40	.50			
Product	.07	.22	.05	.06	.10		.50	.66
Scotch Caps	.80	.50	.70	.90	.87			
Product	.19	.12	.13	.14	.17		.75	.99
Black Tom	.80	.30	.70	1.0	.90			
Product	.19	.07	.13	.15	.17		.71	.93
Hen Island	.70	.67	.70	.73	.83			
Product	.17	.16	.13	.11	.16		.73	.96
Harbor Island Park	Fully developed park, not a disposal site							
Product							---	---
Connecticut[2/]								
Sherwood Island	.88	.30	1.00	.52	.20			
Product	.21	.07	.18	.09	.04		.59	.78
Yellow Mill Channel	.18	.28	.12	.10	.32			
Product	.04	.07	.02	.02	.06		.21	.28
Pennfield Shoals/ Reef	1.00	.72	.72	.72	.60			
Product	.24	.17	.13	.11	.11		.76	1.00

Table 3. Cont.

1. Study

2. Evaluation site	3. Relative weight of ranking criteria						5. Relative value	6. Relati Value Index
	1	2	3	4	5	6		
	0.24	0.24	0.18	0.15	0.19			
	4. Relative importance of each ranking criterion to each evaluation species.							
Milford Harbor	.75	.58	.68	.48	.38			
Product	.18	.14	.12	.07	.07		.58	.76
Thames River, Gold Star Bridge	.85	.60	.60	.35	.75			
Product	.20	.14	.11	.05	.14		.64	.84
Menunketesuch Island	.70	.38	.78	.68	.28			
Product	.17	.09	.14	.10	.05		.55	.72
Guilford Harbor	.10	.28	.10	.10	.20			
Product	.02	.07	.02	.02	.04		.17	.22
West Haven	.12	.22	.10	.10	.28			
Product	.03	.05	.02	.02	.05		.17	.22
Mouth Housatonic River	.90	.85	.70	.52	.42			
Product	.22	.20	.13	.08	.08		.71	.93

1/ Average values, National Marine Fisheries Service, U.S. Fish and Wildlife Service and New York Department of Environmental Conservation data as interpreted by USF&WS.

2/ Average values, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Connecticut Department of Environmental Protection, and the Aquaculture Division of the Connecticut Department of Agriculture.

The final step in RVI calculation involves multiplication of the relative weight of each criterion, determined in Step 1, by the value assigned each site in Step 2. All products for a site are then summed to obtain a relative value. This relative value is then divided by the highest relative value obtained for any site to determine each RVI. The relative values and RVI's for the evaluated sites are shown in Table 3. Sites with the lowest RVI's are the least sensitive and those with the highest RVI's are the most sensitive from an environmental standpoint.

In summary, Table 4 lists the evaluated sites and their RVI's in order of increasing environmental sensitivity. This list is broken into three groups representing the least environmentally sensitive (Group I), moderate environmentally sensitivity (Group II), and most environmentally sensitive (Group III).

Table 4. Environmental Sensitivity of Sites to Dredged Material Disposal Containment Development.

Site	RVI	
Guilford Harbor	.22	Group I
West Haven	.22	Least Sensitive
Yellow Mill Channel	.28	
Flushing Bay	.66	
Menunketesuch Island	.72	Group II
Milford Harbor	.76	Moderately
Sherwood Island	.78	Sensitive
Thames River, Gold Star Bridge	.84	
Mouth of Housatonic River	.93	Group III
Black Tom	.93	Most
Hen Island	.96	Sensitive
Scotch Caps	.99	
Pennfield Shoals/Reef	1.00	

We are very much concerned with finding improved disposal procedures since existing practices usually result in adverse impacts on fish and wildlife resources. Our support and interest in your study is based on the belief that dredge material can and should be used to benefit the natural environment and we plan to continue our coordination during further planning.

Sincerely yours,

Gordon E. Beckett

Gordon E. Beckett
Supervisor

United States Department of the Interior

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Colonel Carl B. Sciple
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New England Division
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JAN 9 1984

Dear Colonel Sciple:

This planning aid letter is intended to aid your study planning efforts for the Long Island Sound Dredged Material Containment Study, Connecticut and New York. It has been prepared under authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

The Long Island Sound Dredged Material Containment Feasibility Study Progress Report and accompanying Environmental Assessment summarize study progress including a compilation of the various site screenings and the detailed investigations of Clinton Harbor and Black Ledge. The Progress Report identified sixteen (16) sites that are currently being considered as possible sites for a dredged material containment facility (DMCF). However, we understand that two (2) of these sites, Yellow Mill Channel, Bridgeport, Connecticut, and Gold Star Bridge, New London, Connecticut, have recently been dropped from further consideration. In addition, the Flushing Bay site is currently being investigated by the New York District of the North Atlantic Division of the Corps of Engineers thereby eliminating the need for further study by your Division.

Our planning aid letter of October 15, 1982, provided comments on eight (8) of the thirteen (13) sites currently under investigation. This planning aid letter addresses the five (5) sites not previously reported on as well as updating our comments on the other eight (8) sites.

The following five (5) sites were not previously reported on in our October 15, 1982 letter. Two of these sites, Clinton Harbor and Black Ledge, are prototype studies which have received substantial investigation by private contractors and the Corps.

<u>Clinton Harbor, Clinton and Madison, CT</u> - The study site for this prototype marsh creation project abuts the existing sand berm and tidal marsh along the eastern edge of Hammonasset State Park west of the Federal navigation channel in Clinton Harbor. The containment facility would consist of approximately 100 acres of intertidal and subtidal habitat enclosed by a rock-faced retaining dike. It would be filled with about 1,000,000 cubic yards of

dredged material from Clinton Harbor. In its final form, the containment facility is proposed to be similar to the adjacent tidal marsh in that it would consist of channels for tidal movement and shallow subtidal areas, vegetated areas of Spartina alterniflora and Spartina patens and some unvegetated intertidal sand flats.

Your consultant reports indicate that the present biological habitat value of the area proposed for this DMCF is relatively low due to chronic physical disturbance. Virtually all of the bottom habitat consists of sandy sediments with less than five percent silt-clay. These sediments were found to be unstable and in a state of chronic minor, and periodic major, resuspension.

The area was determined to have high potential for biological enhancement through the establishment of a marsh on deposited spoils. Although it was recognized that benthic organisms in the study area are utilized as food by demersal fishes, primarily winter flounder, the low secondary production in the benthos indicates that any impacts to finfish via removal of this food resource would be minimal. Overall, the vast majority of estuarine fauna and flora will benefit from the broader contribution of the marsh to the estuary.

You conclude that, to date, no serious adverse impacts from the proposed project have been identified and that additional studies must be conducted to ensure that adverse impacts will not occur from effects which were outside the scope of the present study. The most significant of these is the potential for large-scale sediment alterations due to increased tidal velocities and diversion of wave energy to other areas of the harbor.

We are in general agreement with your assessment of existing resources and potential impacts. However, we believe that the oyster population at the southern end of the project should be preserved by an appropriate realignment of the container facility. Based on data to date, we believe that the proposed marsh creation project at Clinton Harbor affords the greatest potential for biological enhancement of any of the sites currently being considered in the Long Island Sound Dredged Material Containment Study.

Black Ledge, Groton, Connecticut - The study site for this prototype island creation project is a rocky shoal area located east of the New London channel, about 2,000 yards offshore of Avery Point, Groton, Connecticut. We understand that the proposed design for dredged material disposal at this site would be one of total containment within a four-sided rock dike. The total length of the exterior retaining dikes would be about 9,600 linear feet. These dikes, built in an average of 20 feet of water, would extend 13.5 feet above the mean low water line to prevent overtopping during storm events. This facility would be capable of storing about 7.5

million cubic yards of dredged material, most of which would be Class II and Class III materials. These materials would be capped with clean fill/topsoil, and it is assumed that the 125-acre island would serve as a controlled ecological education studies facility and ultimately be developed as a nature preserve; however, the overall management plan has yet to be developed.

Your studies indicate the bottom substrata in the Black Ledge vicinity fall into three general categories: rock, sand/gravel, and silt/clay with rock accounting for about 50 percent of the area that would be occupied by the proposed DMCF. On the ledge, the bottom consists of large angular boulders and the placement of these is such that crevices and small caves are abundant, providing a variety of microhabitats.

Your report states that the rock walls of the DMCF would provide an extremely large area for the re-establishment of a community similar to that which is presently found on Black Ledge. Allowing for side slope and an increase in colonizable area of 3X due to the numerous crevices between individual stones, the total new area available would be about 900,000 square feet. Approximately 50 percent (3,484,300 square feet) of the 160-acre area that would be occupied by the DMCF is hard bottom which presently supports Mytilus populations. Thus, you conclude that construction of the DMCF would remove about 75 percent of this community type from the existing ecosystem. However, the existing rock bottom is not flat and consists of angular boulders with many crevices and small caves. When this factor is considered, the resulting loss of the hard bottom community would be nearer to 90 percent. In addition, 80 acres of soft bottom habitat would be removed from the existing ecosystem.

Your report states that the proposed DMCF area "is reported to be a hazard to navigation of recreational boating and of minimum value for fishing and lobstering." We find nothing else in your environmental report on the extent or value of the finfish and lobster resources in the Black Ledge area. However, you state that with the DMCF "the open spaces between the rocks in the subtidal zone would also provide habitat space for lobsters and fish; this aspect has the potential of increasing the number of lobsters at Black Ledge as well as affecting and concentrating finfish." In view of the preceding paragraph, we question this statement and believe that the extent of the existing finfish and lobster resources should be more precisely known before a without and with the project comparison can be made.

Based on available data, we believe that construction of a DMCF at Black Ledge would result in a significant net environmental loss. However, the overall extent of these losses and any potential environmental benefits cannot be adequately addressed without additional environmental studies. If this prototype study is to continue, then additional benthic sampling must be conducted in the

northern area of the project as well as in the surrounding environs of Black Ledge; the existing finfish and lobster populations should be more clearly defined, and the recreational/commercial value of these resources documented; the potential change in tidal currents, wave patters and sediment transport/deposition must be investigated for impacts on biological communities as well as on shoreline erosion and navigation channel shoaling; and, the overall management plan for the completed DMCF should be more clearly defined.

Stratford Shoals Middle Ground, Stratford, CT - This area is located about 5.5 miles offshore of Stratford, Connecticut. The preliminary plan for this area is to build a large triangular island container, measuring between 700 and 1,200 yards on a side, centered around the existing navigation beacon. Stratford Shoals Middle Ground is a large reef/shoal area with high biological productivity. It is a major lobster producing area and is the center of the mid-Long Island Sound lobster fishery. It is considered to be one of the better fishing areas in Long Island Sound for both bottom and pelagic species, such as summer and winter flounder, blackfish, bluefish, striped bass and weakfish. In view of the major lobster and finfish resources, we cannot support development of a dredged material containment facility at Stratford Shoals Middle Ground. Therefore, we recommend that this site be dropped from further consideration as a containment facility.

Falkner/Goose Island, Guilford, CT - This island system consisting of Falkner Island, Goose Island, and several rock outcroppings is located about 2.5 miles offshore of Guilford, Connecticut. The preliminary plan for this area is to expand Goose Island into a relatively large diamond-shaped island of approximately 100 acres. Another possibility includes island creation in the shoal area between Falkner and Goose Islands. This entire area is considered to be productive habitat from a fish and wildlife standpoint. It is a productive area for lobsters and supports a significant lobster fishery. There are two leased shellfish beds in the immediate area that are utilized for cleansing oysters and hard clams. One of these beds abuts Goose Island. There are also natural beds of hard clams in this area. Most of the rock/reef habitat supports a large population of blue mussels. The area is a popular recreational fishing area and receives heavy fishing pressure especially for such species as winter flounder, striped bass and bluefish. Waterfowl, such as black ducks and scaup, utilize the area quite heavily during the winter period. In addition, the island areas provide important breeding habitat for both common and roseate terns. We believe that a large DMCF in this area would not be in the best interest of fish and wildlife resources. Therefore, we recommend that this site be dropped from further consideration as a containment facility.

Kelsey Point Breakwater, Clinton, CT - This site is located on the western edge of Duck Island Roads offshore of Kelsey Point, Clinton, Connecticut. The preliminary plan for this area is to utilize all or a portion of the eastern side of the breakwater as one leg of a triangular containment facility. The immediate area of the breakwater does support a lobster population, and there are some hard clams and oysters throughout this area. There are leased shellfish grounds to the immediate north, west and south of the breakwater. The area supports a modest recreational fishery for blackfish, bluefish, striped bass and winter flounder. If properly sized and situated, a containment facility at this site could possibly improve both lobster habitat and the recreational fishery. We believe that additional environmental studies are warranted in order to more accurately determine the overall biological productivity of this area and its environmental acceptability as a containment site.

The following eight sites were previously reported on in our October, 1982 letter. An attempt has been made to update our previous comments.

Guilford Harbor Disposal Area, Guilford, CT and I-95 Interchange, West Haven, CT

These two areas are actually upland sites previously utilized for disposal of dredged material. There are no significant fish and wildlife resources within these immediate disposal areas. We believe that the potential for disposal of additional dredged material at these sites merits further investigation.

Crab Island - Black Tom, Mamaroneck Harbor, NY - This site is located on the west side of the harbor between Delancey and Orienta Points. The preliminary plan for this area is to include Crab Island and Black Tom into a large triangular shoreline extension project measuring about 1,600 feet on a side.

The rock outcroppings, ledges and reef structures in this area provide excellent lobster habitat as well as areas for use by attaching benthic invertebrates which contribute to the overall productivity of this area. We do not believe that a large DMCF in this area would be in the best interest of fish and wildlife resources. Therefore, we recommend that this site be dropped from further consideration as a containment facility.

Housatonic River Breakwater, Milford, CT - This site is located on the east side of the breakwater off of Milford Point. This area is quite productive from a fish and wildlife standpoint and received a high environmental sensitivity rating in our planning aid letter of October, 1982. The environmental sensitivity of this site has yet to be fully documented by baseline environmental studies. However, based on data to date, we believe that develop-

ment of this site would not be in the best interests of fish and wildlife resources. Therefore, we recommend that this site be dropped from further consideration as a containment facility.

Menunketesuck Island, Westbrook, CT - This site is located east of the Patchogue River between Duck Island Roads and Westbrook Harbor. The preliminary plan consists of unconfined disposal of Class I and Class II materials to restore the northern end of the island and provide nesting habitat for Least terns. We understand that two restoration plans are possible: (1) total restoration, that is connecting the island to the mainland to form a penisula or (2) partial restoration to enlarge the island. The environmental sensitivity of this site was rated as moderate in our 1982 planning aid letter. We believe that additional environmental studies are warranted in order to more accurately determine the overall biological productivity of this area and its environmental acceptability as a containment site.

Sherwood Island Borrow Hole, Westport, CT - This site is a large borrow pit located offshore of Sherwood Island State Park. The preliminary plan is to fill this borrow hole with dredged material and cap with clean, coarse sand. It is thought that very little marine life exists in this borrow pit due to near anaerobic conditions. We understand that you are currently conducting additional biological surveys of this area to ascertain the extent of marine life in and near this borrow hole. If these surveys confirm the relative lack of biological productivity, this area would afford an excellent opportunity for environmental enhancement. This general area has been certified as clean water by the State Health Department for the direct marketing of shellfish, and there are many leased shellfish grounds surrounding the site; therefore, it is extremely important that the final results of borrow hole filling be compatible with adjacent areas. We believe that the use of Class I material for this project poses no hazard to shellfish resources. However, we have reservations about the use of Class II materials and the probability of permanently capping such material to retain the direct marketing status of shellfish. This aspect would need to be rigorously evaluated during the planning process. We would object to the placement of Class III materials in this area.

Penfield Shoals/Reef, Fairfield, CT - This site is located off of Shoal Point, Fairfield, Connecticut. The preliminary plan envisioned island creation in the reef area with diking on four sides. Our planning aid letter of October, 1982, indicated that this site is a very productive area from a fish and wildlife standpoint and in the preliminary environmental sensitivity analysis it was deemed to be the most sensitive of all the sites evaluated. Your preliminary baseline ecological survey of this site tends to confirm our initial evaluation. This survey concludes that the area around Penfield Reef is extremely productive and supports a very dense and diverse benthic community. Faunal

densities were generally higher than other north temperate hard substrate communities encountered. Diver observations indicate the presence of numerous epibenthic organisms and fish, further indicating the richness of the area. Subsequently, the siting was changed to a shoreline extension project that would straddle the sand bar leading out to the reef to -6 feet MLW. We understand that this site may serve as a prototype study for shallow water shoreline extensions and that additional baseline environmental studies are planned. In addition, the project's potential impact upon wave refraction/diffraction patterns and subsequent changes in the sediment erosion/deposit patterns will be investigated. We do not object to these further studies, however, we do have severe reservations about the ultimate environmental feasibility of this site. Therefore, we recommend that this site be dropped from further consideration as a containment facility.

Milford Harbor Jetty, Milford, CT - This site is located on the west side of the harbor entrance channel jetty and entails either (1) a marsh restoration project behind the existing jetty or (2) seward extension of the jetty by 1,000 feet with the new section serving as one side of a multi-celled containment facility. Your preliminary baseline environmental studies indicate that this area is predominantly hard-packed fine sand and the overall biomass is generally low. We believe that a marsh restoration project in this area would probably result in an overall net environmental benefit. However, additional studies will be required to document this assumption, and we encourage you to pursue studies in this area similar to those conducted for Clinton Harbor.

We are very much concerned with finding improved disposal procedures since existing practices usually result in adverse impacts on fish and wildlife resources. Our support and interest in your study is based on the belief that dredge material can and should be used to benefit the natural environment, and we plan to continue our coordination during further planning.

Sincerely yours,

Gordon E. Beckett

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MAY 23 1985

Colonel Carl B. Sciple
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Dear Colonel Sciple:

This is our Fish and Wildlife Report on the Long Island Sound Dredged Material Containment Study, Connecticut and New York. It has been prepared under authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

Your draft Feasibility Report indicates that over 300 potential containment sites were identified in the New York and Connecticut waters of Long Island Sound. Screening for technical and economic feasibility, environmental impacts and public acceptance severely reduced the number of sites and only five were identified for detailed invesitgation as prototype sites. The five sites, all in Connecticut, include: Black Ledge, Penfield Reef, Clinton Harbor, Milford Harbor, and Sherwood Island Borrow Hole. The findings of these detailed investigations are presented in the draft Feasibility Report.

The Black Ledge containment facility would store about 7.5 million cubic yards of dredged material and would create a 125 acre offshore island. Diking for the project would cost an estimated $40 million. The proposed facility would directly affect 150 acres of productive benthic habitat supporting a diversity of species and dense concentrations of blue mussels. Your study finds that the adverse environmental impacts and unfavorable economics currently make this site infeasible. We do not support development of a containment facility at this site for environmental reasons.

The Penfield Reef containment facility would be a shoreline extension project capable of storing about 4 million cubic yards of dredged material. Diking for the project would cost an estimated $8.6 million. The proposed facility would eliminate about 300 acres of productive bottom habitat supporting a dense and diverse benthic community. Your study finds that the project is not economically feasible and would result in negative environmental impacts. We regard potential environmental impacts as severe and do not support development of a containment facility at this site.

The Clinton Harbor containment proposal, a marsh creation project, could store up to one million cubic yards of dredged material and would expand the existing Hammonasset wetland areas. Your study finds that this containment facility is economically feasible and has high potential for biological

enhancement. However, the proposed facility abuts Hammonasset State Park and a portion of the Cedar Island spit which has been designated as a barrier beach under the Coastal Barrier Resources Act of 1982. The provisions of this legislation which restricts Federal participation and limits development activity in general would have to be addressed prior to further consideration of a containment facility at this site. We concur with your study findings.

The Milford Harbor containment facility was sited on the east side of the entrance channel as a shoreline extension project capable of storing about 270,000 cubic yards of dredged material. Your study finds that, based on sampling at nearby areas, this area is not particularly productive and major environmental impacts would not be expected. We believe that this containment facility could be developed as a marsh creation project but that additional site specific studies would be required in order to determine if environmental impacts are acceptable.

The Sherwood Island Borrow Hole is a large aqueous borrow pit that could hold/contain about 750,000 cubic yards of dredged material. Your study finds that the isolated nature of this area has generally resulted in an anoxic environment which supports a relatively low number of organisms. If the pit was filled and suitably capped the resulting environment would closely resemble that of the surrounding area which supports extensive hard clam and oyster beds. Use as a disposal area is a worthwhile consideration in the future. We are in general agreement with your study findings, however, we believe this area should be proposed for a site specific study.

Your draft Feasibility Report does not propose implementation of any project. The report concludes that under present conditions containment is not a feasible alternative and that critical factors including economics, environmental and public inputs rule out widespread reliance on containment for the disposal of dredged material in Long Island Sound. Although the study was able to identify potential sites for containment facility projects, current dredging and disposal operations are favored over containment alternatives not only on an economic and sometimes environmental basis but more specifically on cost sharing arrangements. Therefore, you have recommended no Federal interest at this time in the implementation of containment facilities for the disposal of dredged material in Long Island Sound.

We disagree with the conclusions of your feasbility study regarding containment of contaminated dredge material and beneficial uses of clean material in Long Island Sound. In our opinion, the practicality of utilizing confined disposal sites has been adequately demonstrated in the Great Lakes since the late 1950's. The major difference between study conditions in Long Island Sound and the Great Lakes is that people utilize the Great Lakes as a

source of drinking water and therefore are much more concerned about waste disposal practices in that system. We believe that Long Island Sound and the remainder of our coastal waters deserve the same level of protection as the Great Lakes since they are of major importance as food producing areas, have high ecological values including spawning and nursery areas for nearly all of our marine vertebrate and invertebrate species, provide migration pathways for fish and wildlife and contribute immense recreational and aesthetic values to man.

One of the major basic faults with the Long Island Sound study is the economic analysis which basically compares the existing open water disposal practice against confined and/or beneficial dredge material disposal practices. We believe a more appropriate economic analysis would be to compare alternative confined disposal sites against each other in a fashion similar to that done under P.L. 91-611 for the Great Lakes. The present analysis is deemed inappropriate in that it is skewed in favor of open water disposal since the appropriate monetary values have not or cannot be accurately predicted for the true environmental and societal costs for open water disposal of contaminated materials.

We are confident that many environmentally acceptable sites for confined disposal facilities exist in Long Island Sound. The proper conclusion of your feasibility study would be to actively pursue site specific studies for containment facilities within reasonable distances from the major commercial harbors in the Sound and elsewhere along the New England coast.

Sincerely yours,

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