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HYDROLOGY, SEDIMENTS, BENTHIC MACROFAUNA AND DEMERSAL FINFISH OF AN ALTERNATE DISPOSAL SITE (EAST HOLE IN BLOCK ISLAND SOUND) FOR THE THAMES RIVER (CONN.) DREDGING PROJECT.
FINAL REPORT

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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MIDDLE ATLANTIC COASTAL FISHERIES CENTER

Coastal
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OXFORD

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I. INTRODUCTION

This is the final report of the results of our baseline survey of Block Island Sound's "East Hole" depression, centered 4.5 miles south of Watch Hill Pt., Rhode Island (41°14'N, 71°51'W). This site is being considered as an alternate dredge spoil disposal site for the Thames River dredging project. Very few biological data exist for this area. Smith (1950) conducted a survey in 1949 in which he examined the benthic macrofauna and feeding habits of finfish in the northeast quarter of Block Island Sound. This study included one station in the East Hole area, but unfortunately the macrofauna was not completely identified, so his results have limited usefulness as a comparison with our macrofaunal results. Thus the U. S. Navy requested that the Middle Atlantic Coastal Fisheries Center (MACFC), of the National Marine Fisheries Service (NMFS) conduct a baseline survey of this site. The study was carried out under the terms of a proposal submitted to the U. S. Navy in February 1975 (NMFS, 1975a). Progress reports of the preliminary results for each of the two cruises called for in the proposal were submitted to the Navy in April 1975 (NMFS, 1975b) and September 1975 (NMFS, 1975c). This final report presents, analyzes and integrates all hydrological, sediment, benthic macrofauna, demersal finfish, and food web data collected during the two cruises as well as limited macrofauna data from a third macrofauna cruise, not specified in the proposal, undertaken in December 1975. The extra cruise was undertaken to provide additional data, on seasonal changes, needed for further insight into the macrofauna community.

II. METHODS

A. Station Location

Six stations were established for sampling of bottom waters, sediments and benthic macrofauna in the East Hole area (Fig. 1). Their locations were based on what was known of the currents and tidal drift (Riley, 1952; Williams, 1969; Hollman and Sandburg, 1972; Cook and Mc[illegible]ton, 1974; and Hollman, 1975) as well as the orientation of the depression. It is a general consensus among the above researchers that there is a two layer hydrological system in Block Island Sound. The upper layer flows out of Long Island Sound southeast past Montauk Pt.; the bottom layer moves in the opposite direction, with a general westward movement in the East Hole. Considering this westward bottom drift and the east-west axis of the East Hole, we established four macrofauna stations west of center of the proposed alternate dump site and one east. Stations 2, 3, 4, and 5 were positioned one nautical mile from center Station 1, with Stations 3 and 5 being at an angle of 30° from the east-west axis. Station 6 was positioned two nautical miles west of center (Fig. 1). Finfish stations (Fig. 2) were chosen near the six macrofauna stations considering the suitability of the bottom for trawling. Coordinates for all stations are listed in Table 1. The dates of the 1975 sampling cruises were: Cruise 1 - March 24-26 and April 22 (macrofauna Stations 4, 5, 6 only), Cruise 2 - July 7-8 (Finfish - July 29) and Cruise 3 - December 11, 1975.

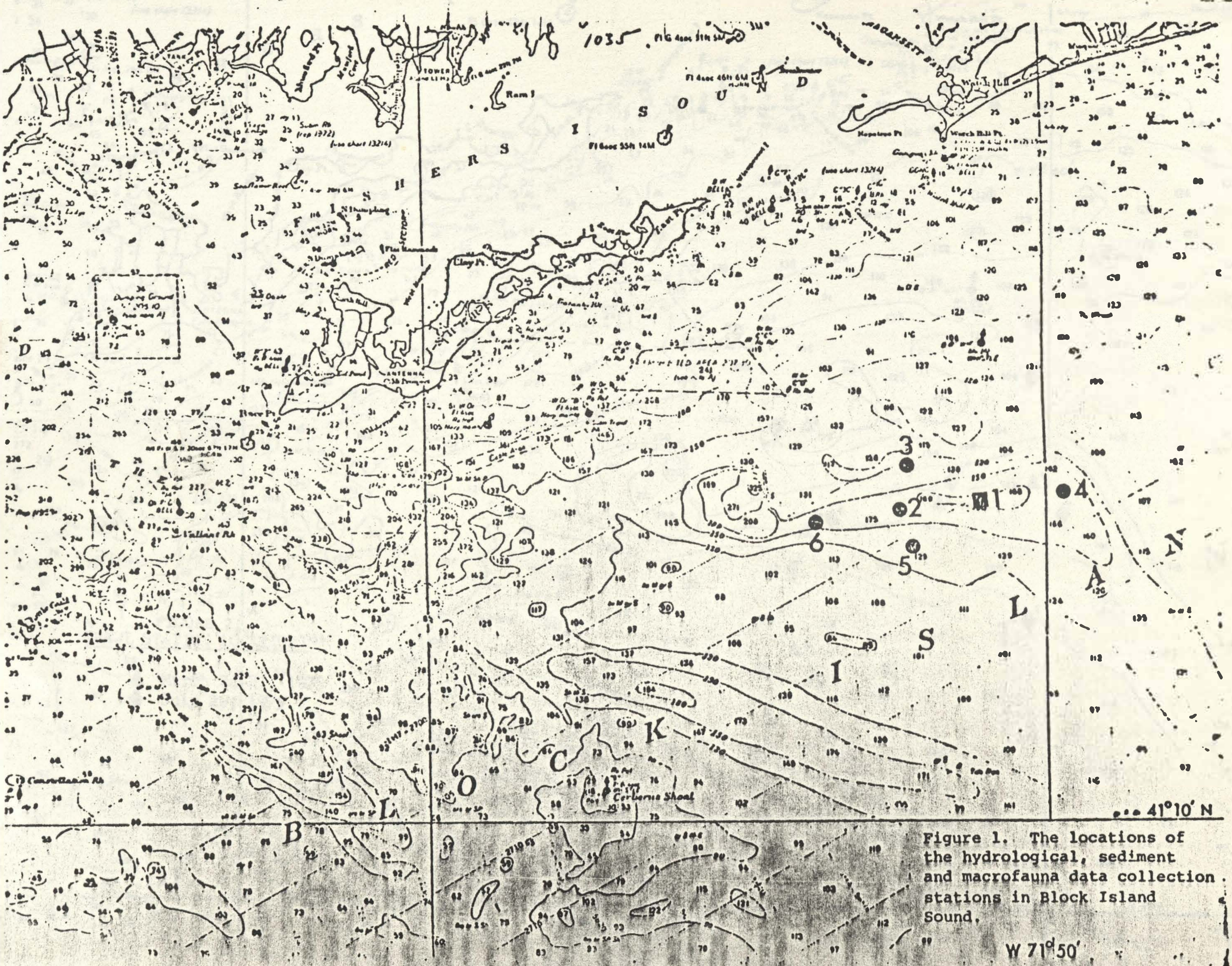

Figure 1. The locations of the hydrological, sediment and macrofauna data collection stations in Block Island Sound.

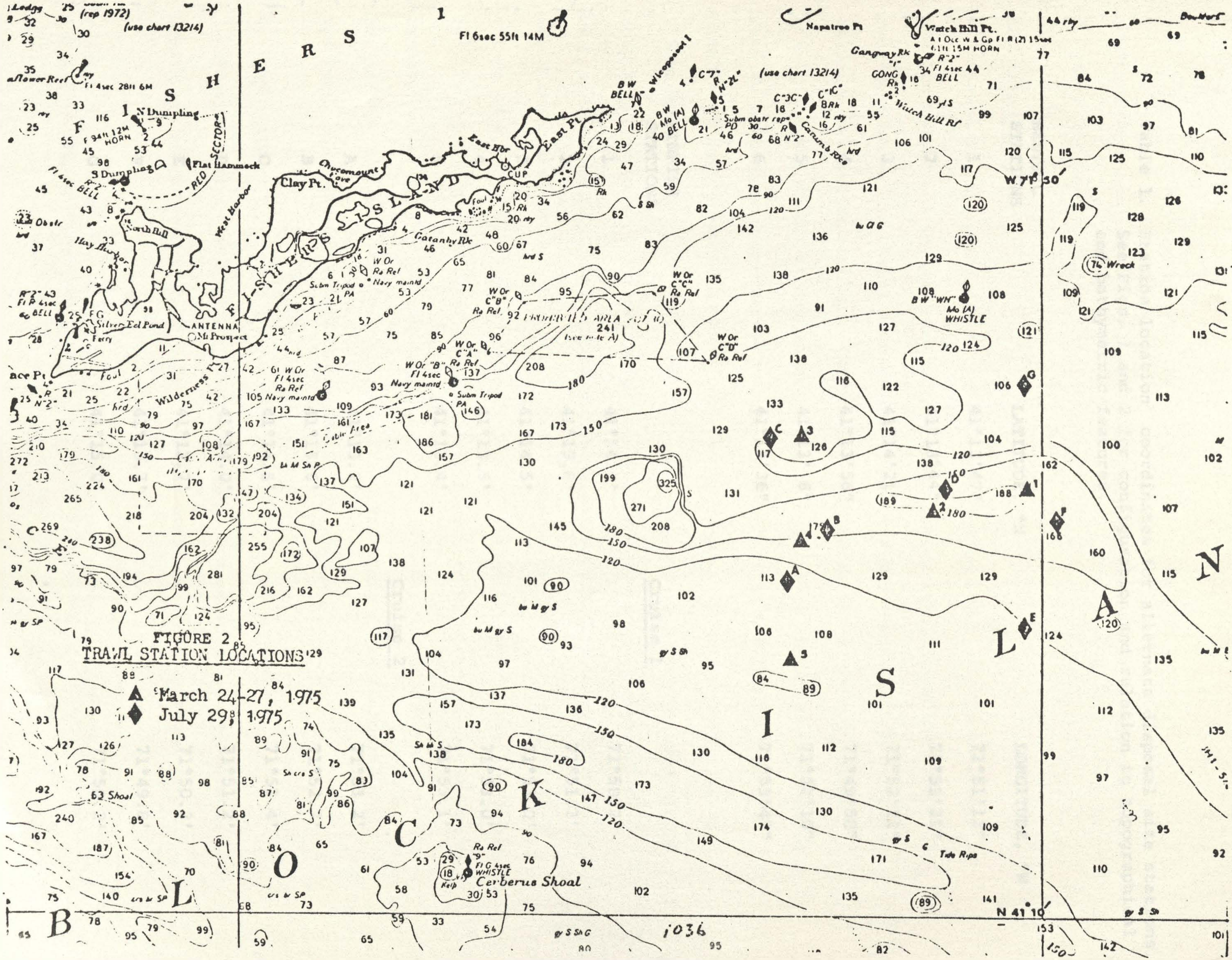

FIGURE 2
TRAWL STATION LOCATIONS

▲ March 24-27, 1975
◆ July 29, 1975

Table 1. Station location coordinates for alternate disposal site stations. See Figs. 1 and 2 for configuration and relation to topographical and bathymetric features.

BENTHIC STATIONS	LATITUDE, °N	LONGITUDE, °W
1	41°13'47"	71°51'13"
2	41°13°44"	71°52'31"
3	41°14'21"	71°52'21"
4	41°13'56"	71°49'50"
5	41°13' 8"	71°52'10"
6	41°13'36"	71°53'47"
FINFISH STATIONS		
	Cruise 1	
1	41°14.0'	71°50.2'
2	41°13.8'	71°51.3'
3	41°14.5'	71°53.0'
4	41°13.5'	71°53.0'
5	41°12.4'	71°53.1'
	Cruise 2	
A	41°13.2'	71°53.2'
B	41°13.6'	71°52.7'
C	41°14.5'	71°53.4'
D	41°14.0'	71°51.2'
E	41°12.7'	71°50.2'
F	41°13.7'	71°49.8'
G	41°15.0'	71°50.2'

Stations were located during each cruise by the combined use of Loran A and C, radar and depth recorder.

B. Water Column

Niskin bottles were used to collect near-bottom water samples at every station on each of the cruises for dissolved oxygen (macrofauna stations only) and salinity. Water samples were also collected by bucket for surface salinity at finfish stations. Salinities were measured in the laboratory with a Beckman RS-7C* induction salinometer. Dissolved oxygen concentrations were determined on board survey vessel using the azide modification of the Winkler titration method (Amer. Publ. Health Assoc., 1965) and substituting 0.25N phenylarsene oxide (Hach Chemical Co., Ames, Iowa*) for the less stable sodium thiosulfate. Sediment temperatures were measured by insertion of a mercury thermometer directly into the sediment contained in a grab sample, immediately upon being brought on board. Temperature profiles of the water column were also collected using expendable Bathythermographs (XBT) (Sippican Corp.*), on the finfish cruises; bucket thermometers were used to obtain surface temperatures. Physical Oceanography was studied under a subcontract to Dr. Rudolph Hollman, New York Ocean Science Laboratory (NYOSL), Montauk, New York, and his methods are presented in Appendix A.

C. Sediments

Plastic coring tubes, 35 mm in diameter, were used to obtain a sediment subsample approximately 8 cm deep from each grab sample. Two cores per

* Mention of commercial products by name does not imply endorsement by the National Marine Fisheries Service or the U. S. Government.

station were analyzed for grain size distribution, organic material and calcium carbonate under a subcontract to Dr. James Parks, Lehigh University, Bethlehem, Pennsylvania. Mean and median grain size diameters, sorting index, graphic skewness and kurtosis were determined from the percentages, by weight, of sediments retained on each of ten standard sieve sizes. Organic material content was determined by oxidizing the sample with hydrogen peroxide (H_2O_2) and measuring sample weight change; this method does not determine the nature of the organic material. Calcium carbonate content was determined by treating the sample with dilute hydrochloric acid (H Cl) and also measuring weight change.

Two other sediment cores were collected per station, on the first cruise, for analysis of heavy metal concentration. This work was done by personnel of Environmental Chemistry Investigation, MACFC, NMFS, Milford, Connecticut using atomic absorption spectroscopy. Sediments were analyzed for the following trace metals: silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn). In July, sediments were also collected by NYOSL for separate analysis of these metals, as well as iron (Fe) and mercury (Hg) using the same method.

D. Benthic Macrofauna

At each station, for each of the first two cruises, ten replicate 0.1 m^2 Smith-McIntyre grabs were collected; five replicates were collected during the third cruise. In the field, each grab sample was washed through a 1 mm mesh screen and the material retained was placed in a jar and preserved with a 10% solution of formalin in seawater. In the laboratory the samples were rewashed and transferred to a 70% ethanol solution with glycerine added to retard evaporation. For Cruises 1 and 2, five of the ten replicate samples per station were randomly selected and sorted; the organisms found were separated, speciated and enumerated. The identifications were verified by by an experienced taxonomist. The macrofauna data were analyzed to estimate means and variance for four population parameters: 1) total number of individuals (N), 2) total number of species (S), 3) species diversity $H' \cong -\sum \frac{n_i}{N} \ln \frac{n_i}{N}$ (Shannon and Weaver, 1963), where N is the total number of individuals in the sample and n_i is the number in the i^{th} species, and 4) equitability $J' = H'/H\ max \cong H'/\ln S$ (Pielou, 1966). Equitability is a measure of the evenness of distribution of individuals among species.

E. Finfish

At each finfish station, a 3/4 #36 Yankee otter trawl, with a 54 ft. sweep, was towed at a speed of 3.5 knots for 15 minutes. The trawl was fished at a 3:1 scope of wire to depth and was rigged with 500 pound rectangular doors with 9 fathom ground cables. The trawl was lined with 1/2 inch (stretched) mesh netting in such a manner that smaller fish could be captured. All species caught were identified, sorted by species, weighed and measured according to established groundfish survey procedures (Grosslein, 1969).

F. Food Webs

During the second finfish cruise (July 29, 1975) stomachs of 73 specimens of six species of demersal fish were removed to examine the importance of benthic macrofauna in their diet. We removed each stomach as soon as possible after the trawls were emptied and placed each stomach in an individual gauze bag or jar and preserved it with approximately 10% formalin. In the laboratory we opened the stomachs and identified, enumerated and determined volumes of the contents; the contents of the intestine were not included.

III. RESULTS AND DISCUSSION

A. Water Column

The chemical and physical data collected during the macrofauna sampling for all cruises are presented in Table 2A; the data from the finfish cruises are presented in Table 2B. Based on these data and the results of other studies (Williams, 1969; Nalwalk et al., 1972; Hollman, 1975) it appears that the bottom waters in the East Hole have an average salinity of about 31.5 o/oo, with a range of less than 1 o/oo. Bottom temperatures appear to range from about 3 to 16°C for the year with the coldest temperatures being found in early March and warmest in September. Our temperature measurements appear to agree with this pattern (Table 2). The discrepancy between the bottom temperatures in Table 2A and 2B is due to differences in sampling dates for macrofauna and finfish cruises. We found the bottom dissolved oxygen values to be relatively high throughout the year, with means of 7.9 mg/l (92% saturation) in July and 9.7 mg/l (98% saturation) in April. NYOSL's results are presented in Appendix A, and are in general agreement with our results.

B. Sediments

1. Grain size distributions -

The results of grain size analyses of the sediments of the East Hole are presented in Table 3. Our findings were combined with those of Savard (1966) and the U. S. Army Corps of Engineers (Northeast

Table 2. Temperature, salinity and dissolved oxygen of water column for all cruises.

A. MACROFAUNA STATIONS

Cruise	Station	Bottom Salinity (°/oo)	Bottom Temp. (°)	Dissolved Oxygen mg/L.	Dissolved Oxygen % Saturation
I	4	31.87	7.0	9.7	98.48
I	5	31.77	6.5	9.6	96.00
I	6	31.57	6.5	10.0	99.30
II	1	31.89	13.6	8.0	91.85
II	2	31.93	13.6	7.85	90.13
II	3	31.84	14.0	7.9	92.94
II	4	31.93	13.65	7.9	91.12
II	5	31.56	13.7	8.0	92.59
II	6	31.78	14.0	7.9	92.94

B. FINFISH STATIONS

Cruise	Station	Surface Salinity (°/oo)	Bottom Salinity (°/oo)	Surface Temp. (°C)	Bottom Temperature (°C)
I	1	-	-	4.7	4.3
I	2	-	-	4.5	4.3
I	3	-	-	4.6	4.4
I	4	-	-	4.7	4.4
I	5	-	-	4.6	4.5
II	A	30.89	32.12	18.7	15.4
II	B	31.35	31.24	18.9	-
II	C	31.23	32.30	19.5	15.4
II	D	31.20	32.41	18.7	15.4
II	E	31.20	32.22	18.9	15.4
II	F	31.06	32.29	19.4	14.9
II	G	29.95	32.40	20.1	14.6

Table 3. Sediments of East Hole Stations 1 through 6, two cores each from spring and summer sampling.

Sample Cruise	Sta.	Dia. in mm Mean	Med.	Sort. Index	Graphic Skew.	Kurt.	Percent weight retained on mesh sizes (mm) 4.0	2.0	1.0	0.5	.25	.125	.063	.016	.004	Clay
Mar. -	1	.056	.101	2.00	.636	0.98	0.0	0.0	0.0	0.1	1.8	39.9	18.3	20.5	11.7	7.7
Mar. -	1	.096	.155	2.04	.566	1.09	0.0	0.0	0.2	1.3	26.0	32.0	11.5	15.0	8.2	5.7
Jul. -	1	.097	.185	2.48	.554	0.94	0.0	1.3	1.2	4.4	33.4	21.5	5.5	14.7	10.8	7.3
Jul. -	1	.101	.155	2.21	.493	1.06	0.0	0.2	1.1	3.1	26.9	27.7	10.2	16.5	7.3	6.8
Mar. -	2	.052	.097	2.09	.626	0.90	0.0	0.0	0.0	0.1	1.4	41.7	11.9	23.1	13.4	8.4
Mar. -	2	.060	.107	1.93	.666	1.04	0.0	0.0	0.0	0.2	1.7	41.5	19.4	19.3	10.6	7.3
Jul. -	2	.070	.120	1.77	.641	1.10	0.0	0.3	0.8	1.7	2.7	42.9	18.3	17.8	10.9	4.5
Jul. -	2	.053	.092	2.07	.551	0.99	0.0	0.0	0.9	2.1	2.5	32.4	18.9	23.0	12.5	7.7
Mar. -	3	.221	.293	1.82	.446	1.73	0.0	1.0	4.3	12.8	39.0	21.5	5.8	8.3	4.6	2.7
Mar. -	3	.185	.306	2.71	.367	1.62	2.3	7.1	4.6	11.6	31.6	15.5	4.2	10.9	7.4	4.8
Jul. -	3	.141	.230	2.72	.377	0.90	0.0	3.8	7.2	14.7	22.7	13.6	3.4	19.5	9.7	5.6
Jul. -	3	.138	.210	2.72	.315	0.87	0.0	4.3	7.5	14.6	20.1	14.0	3.9	20.2	10.6	4.9
Apr. -	4	.078	.142	2.19	.585	1.10	0.0	0.1	0.5	3.4	12.5	40.9	10.3	15.1	9.9	7.3
Apr. -	4	.095	.150	2.27	.440	1.43	0.0	0.4	2.0	5.9	13.5	44.1	7.2	11.5	9.6	5.9
Jul. -	4	.068	.132	2.15	.664	0.97	0.0	0.0	0.3	0.9	6.6	46.0	8.1	19.2	10.9	8.1
Jul. -	4	.078	.136	1.94	.648	1.05	0.0	0.0	0.1	0.6	7.1	48.7	10.8	16.9	10.1	5.8
Apr. -	5	.086	.133	1.74	.574	1.15	0.0	0.0	0.0	0.7	9.5	44.7	15.3	17.8	8.7	3.3
Apr. -	5	.074	.126	1.90	.646	1.14	0.0	0.1	0.1	0.4	5.6	44.3	17.0	16.8	9.5	6.3
Jul. -	5	.064	.107	1.89	.595	1.20	0.0	0.1	0.7	1.3	4.9	30.9	28.1	17.6	10.0	6.5
Jul. -	5	.073	.120	1.83	.610	1.26	0.0	0.0	1.0	2.1	3.4	41.5	20.7	16.7	9.0	5.6
Apr. -	6	.035	.045	2.18	.304	0.83	0.0	0.0	0.0	0.1	0.6	28.5	13.7	30.4	16.1	10.7
Apr. -	6	.148	.218	2.31	.400	1.62	1.4	0.4	4.6	11.4	25.8	27.8	6.0	11.1	6.9	4.7
Jul. -	6	.408	.807	3.76	.398	0.71	25.3	14.9	7.4	7.7	9.5	6.1	1.9	11.6	9.6	6.0
Jul. -	6	.248	.332	3.30	.243	0.72	0.0	26.2	9.4	7.4	15.0	9.6	3.8	13.6	9.9	5.1

Division, Waltham, Massachusetts, unpublished data) to develop a detailed classification of the sediments of the East Hole area.

Savard sampled the sediments at 84 stations in Block Island Sound; four of these stations (S-23, 26, 27 and 36 in Figure 3) were in the East Hole area. Savard's thesis included a historical review of Block Island Sound sediments. He felt that these sediments consist mainly of reworked subaqueous glacial deposits and postglacial material derived from adjacent land areas and considered the present sediment distribution to be due primarily to strong tidal currents. He concluded that Long Island Sound, the Great Salt Pond near Charleston, Rhode Island, and other smaller ponds and bays surrounding Block Island Sound trap most sediment and there is little surface drainage from adjacent land areas. Also, most fine sediments entering Block Island Sound must be swept out to the continental shelf by strong tidal currents. He considered the East Hole to be a submerged valley leading west to the deeper West Hole (which he thought was probably a glacial kettle) and southeast to the Block Island Channel.

The Corps of Engineers sampled 21 stations (PE 17-37) in the East Hole (Figure 3) and reported that "the bottom throughout appeared smooth and continuous without significant changes in slope, except for some small terraces on the southern margin of the depression." They agreed with Savard that the area had not received any significant amounts of sediment since the flooding at the end of the last glacial period.

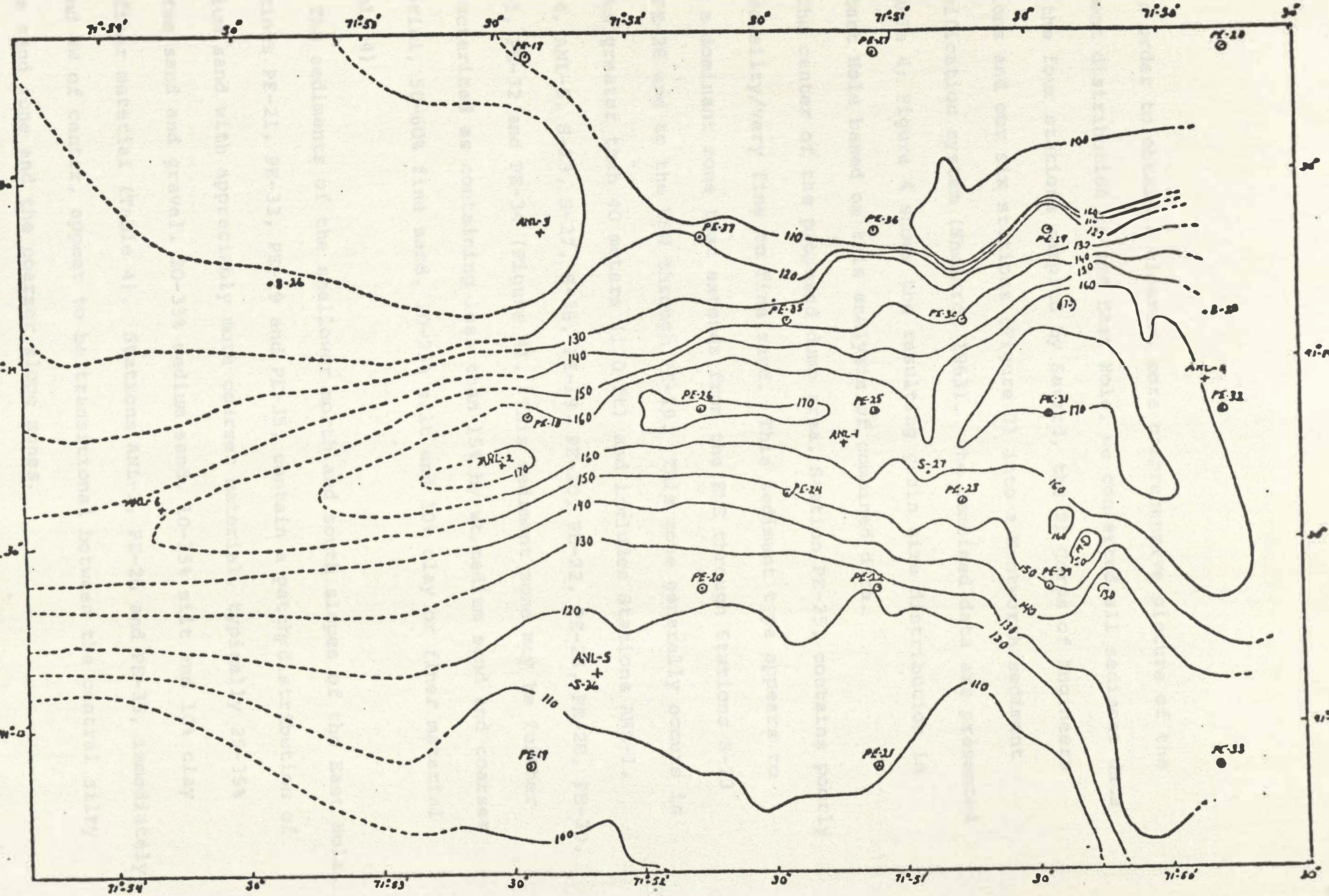

FIGURE 3. Station locations used to examine sediment distribution and bathymetry (based on Cook and Morton, 1974) - the dotted contours represent extrapolation of Cook and Morton's data and National Ocean Survey Chart 13209 (Nov., 1974). PE-25 and ANL-1 are located near the center of survey area.

In order to obtain a clearer, more comprehensive picture of the sediment distribution in the East Hole, we converted all sediment data from the four stations sampled by Savard, the 21 Corps of Engineers stations and our six stations (Figure 3) into a Wentworth sediment classification system (Shepard, 1963). The combined data are presented in Table 4; Figure 4 shows the resulting grain size distribution in the East Hole based on this analysis of combined data.

The center of the proposed dump area, Station PE-25, contains poorly sorted silty/very fine to fine sand. This sediment type appears to form a dominant zone that extends from the ENE through Stations S-23 and PE-28 and to the WSW through PE-19. This zone generally occurs in depths greater than 40 meters (120 ft) and includes Stations ANL-1, ANL-4, ANL-5, S-23, S-27, S-36, PE-19, PE-20, PE-22, PE-25, PE-28, PE-30, PE-31, PE-32 and PE-34 (Figure 4). This sediment zone may be further characterized as containing less than 15%, by wt, medium sand and coarser material, 50-60% fine sand, 10-25% silt and 10% clay or finer material (Table 4).

The sediments of the shallower north and south slopes of the East Hole, Stations PE-21, PE-33, PE-29 and PE-35, contain a patchy distribution of medium sand with appreciably more coarser material, typically 25-35% coarse sand and gravel, 20-35% medium sand, 10-15% silt and 10% clay or finer material (Table 4). Stations ANL-1, PE-26 and PE-35, immediately W and NW of center, appear to be transitional between the central silty fine sand zone and the coarser slope zones.

TABLE 4. Characterization of "East Hole" sediments; grain size analysis according to Wentworth (Shepard, 1963), % by wt.

Station	Water Depth (m)	Sample Depth (cm)	Sediment Type	% Gravel >4.0 mm	V. Coarse Sand >2.0	Coarse Sand >1.0	Medium Sand >0.5	Fine Sand >.25	V. Fine Sand >.125	Silts >.004	Clay and Finer <.004 mm
PE-17	37	30	silty med-fine sand	8	7	10	20	30	10	15	-
PE-18	46	54	clay	0	0	0	0	0	0	14	86
PE-19	33	30	silty very fine sand	2	2	1	5	40	32	12	12
PE-20	39	35	silty fine sand	2	2	5	9	31	25	15	12
PE-21	34	57	med-fine sand	3	10	17	23	22	8	9	9
PE-22	39	46	med-fine sand	3	8	13	19	26	15	8	9
PE-23	49	75	silty fine sand	1	2	5	10	42	16	10	14
PE-24	45	75	silty fine sand	0	1	1	2	38	30	15	14
PE-25	50	35	clayey	5	5	5	6	25	21	14	18
PE-26	52	39	silty med-fine sand	1	1	3	28	30	12	17	8
PE-27	35	39	fine sandy silt	1	2	9	11	13	14	42	8
PE-28	32	27	silty fine sand	0	1	2	10	40	20	15	12
PE-29	39	66	silty med sand	3	4	17	36	14	6	13	7
PE-30	46	25	silty med-fine sand	2	2	6	17	34	9	18	10
PE-31	53	30	silty very fine sand	0	0	1	2	38	34	14	11
PE-32	45	53	silty fine sand	0	1	2	15	48	6	12	11
PE-33	38	30	silty gravelly sand	13	9	13	18	12	10	16	9

BLE 4. (continued)

ation	Water Depth (m)	Sample Depth (cm)	Sediment Type	% Gravel >4.0mm	V. Coarse Sand >2.0	Coarse Sand >1.0	Medium Sand >0.5	Fine Sand >.25	V. Fine Sand >.125	Silts >.004	Clay and Finer <.004mm
E-34	46	65	silty fine sand	2	4	7	9	27	20	16	16
PE-35	44	25	med-fine sand	0	2	6	40	29	7	10	6
PE-36	32	50	medium sand	3	5	17	30	12	9	10	5
PE-37	36	3	sandy silt	3	4	10	16	10	8	36	9
ANL-1*	53	8	med-fine sand	0	0	3	27	28	13	26	6
ANL-2*	53	8	silty fine sand	0	0	1	2	39	16	33	7
ANL-3*	33	8	med-fine to silty medium sand	4	5	13	30	17	4	21	5
ANL-4*	50	8	silty fine to fine sand	0	1	3	11	44	8	26	7
ANL-5*	39	8	silty fine sand	0	0	1	6	41	19	28	5
ANL-6*	53	8	silty med-fine sand to mixed sandy gravel	14	5	5	15	22	6	26	7
S-23	45	10	silty fine sand	0	←		79		→	17	3
S-26	36	10	gravelly coarse sand	20	←		73		→	6	1
S-27	47	10	silty fine sand	0	←		75		→	19	4
S-36	37	10	silty fine sand	0	←		82		→	14	1

-means of analysis of four samples (two from March-April sampling, two from July sampling) see Table 3.
E - data from U. S. Army Corps of Engineers (1975).
NL - present survey
 - Savard (1966).

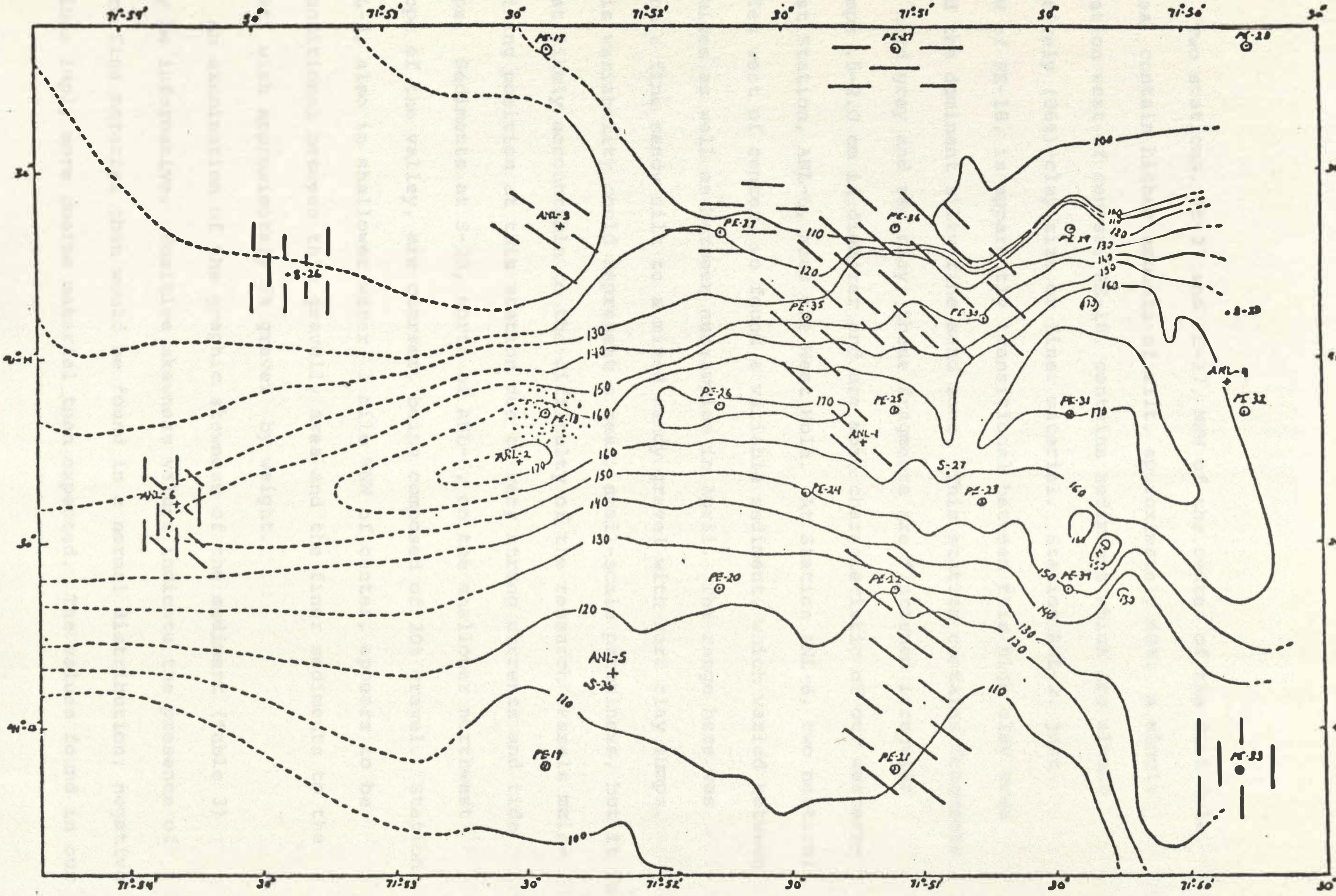

FIGURE 4. Sediment type distribution in the East Hole, based on Table 4. coarse sand and/or gravel; medium sand; sandy silt; silty clay; all other stations are silty fine sand.

Two stations, PE-27 and PE-37, NNW of the center of the East Hole area contain higher amounts of silt, approximately 40%. A single station west of center, PE-18, contains sediments which are almost entirely (86%) clay size or finer material. Station ANL-2, just SSW of PE-18, is apparently transitional between this high clay area and the dominant silty fine sand zone. This station contains fragments of hard grey and red clay; these fragments are flattened irregular lumps .5-2.0 cm in diameter and are more characteristic of our western-most Station, ANL-6, near the West Hole. At Station ANL-6, two nautical miles west of center, we found a variable sediment, which varied between cruises as well as between subsamples in April. The range here was from a fine sandy silt to a mixed sandy gravel with hard clay lumps. This variability could represent a real, small-scale patchiness, but it is most likely accountable to the difficulty of the research vessels maintaining position at this station due to very strong currents and tide rips. Sediments at S-26, north of ANL-6, on the shallower northwest slope of the valley, are coarser, being composed of 20% gravel. Station ANL-3, also in shallower water, 1 mile WNW of center, appears to be transitional between this gravelly area and the finer sediments to the east, with approximately 5% gravel by weight.

An examination of the graphic skewness of the sediment (Table 3) may be informative. Positive skewness values indicate the presence of more fine material than would be found in a normal distribution; negative values imply more coarse material than expected. The values found in our analysis were all positive and ranged between .243 and .666. Duane (1964) considers positive skewness to be an indicator of a depositional environment. It must be pointed out, however, that the tubes of the tube building amphipods and polychaetes which are abundant here may play a role in sediment type. Pratt, et al. (1973) believe that in Rhode Island Sound the amphipod tubes covering large areas of the bottom could enhance the retention of fine sediment. Thus, the depositional nature of the sediments, indicated by analysis of skewness, may be at least partially related to biological activity.

In summary, the East Hole alternate dumpsite is dominated by silty fine sands, especially in the center of the depression; there is a patchy distribution of coarser and finer materials on the shallower slopes as well as in the western part of the depression. Also present in the western section were lumps of hard clay fragments; the origin of these fragments is unknown, but they could possibly have come from the West Hole, where erosional processes may be occurring. The East Hole sediments appear to be part of a silty zone, described by Savard (1966), that extends from the east side of the "RACE" to the channel between Block Island and the Rhode Island coast.

2. Carbonate and Oxidizable Organic Contents -

The results of the carbonate and oxidizable organics content analysis of sediment samples are presented in Table 5. The samples were generally low in organic material with all samples containing less than 2.25% total oxidizable organics. Organic material only exceeded 1.4% of

TABLE 5. Carbonate and organic material in sediments of East Hole; values are percent by wt of total sediment

Date	Sample Station	Core No.	% Oxid. Organics	% Carbonate
March 24-26	ANL-1	G6	0.49	6.58
"	ANL-2	G2	0.43	7.62
"	ANL-3	G2	0.11	5.92
April 22	ANL-4	G6	0.23	6.81
"	ANL-5	G1	0.35	6.20
"	ANL-6	G6	0.13	5.52
July 7-8	ANL-1	G3	0.78	6.81
"	ANL-1	G5	0.80	5.28
"	ANL-2	G3	1.13	5.52
"	ANL-2	G5	1.40	4.59
"	ANL-3	G2	0.65	7.83
"	ANL-3	G3	0.43	3.39
"	ANL-4	G1	1.07	4.71
"	ANL-4	G5	0.87	2.30
"	ANL-5	G2	0.23	5.37
"	ANL-5	G5	0.18	4.56
"	ANL-6	G1	0.12	2.04
"	ANL-6	G4	2.25	4.77

sediments, by weight, in one sample: 2.25% in one of two replicate cores collected from Station ANL-6 in July. The values for all March-April samples averaged 0.29% while the values for all July samples averaged 0.82%. The higher summer values may be reflective of material reaching the bottom after the spring plankton bloom. These values are comparable to or slightly lower than those found in the New London disposal area (NMFS, 1975d). East Hole organic material concentrations are also typical of much of southern and eastern Long Island Sound and are appreciably lower than levels (to 10%) measured in the westernmost part of Long Island Sound (NMFS, 1974).

Calcium carbonate contents of the sediments were relatively uniform averaging 6.44% in March-April and 4.76% in July. These values are quite low compared to the occasional values of greater than 30% found in the New London area (NMFS, 1975d) and other parts of Long Island Sound (NMFS, 1974).

3. Chemical Analysis of Sediments -

a. Heavy Metals

The results of our analysis of the heavy metal concentrations in sediments of three stations sampled in March (Table 6A) were presented in the second progress report (NMFS, 1975c) and is re-presented here for completeness. Other heavy metal data, analyzed by NYOSL (Dr. R. Hollman, NYOSL, Montauk, N. Y., unpublished) are presented in Table 6B. On the whole, concentrations were often below instrument detection limits and where measurable, were

TABLE 6. A) Metal concentrations in top 1 1/2 inches of sediment collected from three alternate dump site stations, from Cruise 1 (March 1975).

		Metal Concentrations (ppm, dry weight)[a]					
Station	Grab	Cd	Cr	Cu	Ni	Pb	Zn
1	2	ND[b]	11.5	ND	15.5	17.5	44.3
1	5	ND	ND	ND	ND	12.5	39.3
2	6	ND	15.8	12.0	18.5	22.5	53.5
2	4	ND	17.0	12.5	17.0	17.5	54.5
3	1	ND	ND	ND	ND	10.0	30.3
3	5	ND	ND	ND	ND	12.5	35.0

a. Values are the means of duplicate measurements.
b. ND - not detectable Detection limits - Cd = 2.5 Ni = 10.0
Cr = 11.0 Pb = 10.0
Cu = 10.0

B) Metal concentrations collected in June-July 1975 by NYOSL, concentration in ppm.

Station	Hg	Cd	Cr*	Cu	Ni	Pb	Zn	Fe
1	.03	< 2	-	8	< 9	< 20	35	10.7
2	.09	< 2	-	10	< 9	< 20	50	17.5
3	.14	< 2	-	11	< 9	< 20	33	13.9
4	.02	< 2	-	10	< 9	< 20	46	11.4
5	.03	< 2	-	10	< 9	< 20	46	11.0
6	.02	< 2	-	12	< 9	< 20	40	21.0

* not measured

relatively low, compared to concentrations found in Fisher's Island Sound and Gardiners Bay (NMFS, 1974). The values were slightly higher than concentrations found on the continental shelf south of Long Island (Carmody et al., 1973) but comparable to background levels in bedrock (Saila et al., 1972).

Heavy metal concentrations in the tissues of the ocean quahog, Artica islandica, collected from the East Hole area were measured (Dr. R. Hollman, NYOSL, Montauk, N. Y., unpublished). The means and range of values in ppm (dry weight) found in the tissues, collected in April, 1975, are: cadmium - 1.8 (0.8-3.4), copper - 31 (22-42), mercury - 0.4 (0.2-0.6), nickel - 18 (10-27), lead - 18 (6-25), and zinc - 183 (87-288). These values are presented here as reference background data.

b. C.O.D., Kjeldahl Nitrogen and Phosphate -

These parameters were also examined by NYOSL in July (Dr. R. Hollman, NYOSL, Montauk, N. Y., unpublished). They found the chemical oxygen demand (C.O.D.) of the East Hole sediments to range from 12,000 to 22,600 mg O/kg with an average value of 18,100 mg O/kg. Kjeldahl nitrogen analysis showed an average value of 700 mg N/kg and a range of 283 to 1,040 mg N/kg. Total phosphorous (PO_4) averaged 576.5 P/kg with a range of 467 to 699. Generally the higher values in each case were found at the deeper siltier stations, i. e. Stations 2, 4, 5. These concentrations are comparable to predisposal values found in the New London area.

C. Benthic Macrofauna

1. Species composition -

Macrofauna collection results are presented in Table 7. Generally, the benthic macrofauna in the East Hole is relatively uniform throughout our six stations and is numerically dominated by colonies of *Ampelisca agassizi,* a tube-dwelling amphipod crustacean, one centimeter in length. This species dominated all our collections, except two: the December sampling at Station 1 and July sampling at Station 4. In these two samplings, *Nucula proxima,* a small bivalve, was more abundant; overall it was second to *A. agassizi* in abundance among all East Hole macrofaunal species. Other abundant subdominants were *Leptocheirus pinguis*, *Unciola irrorata,* (also tube-dwelling amphipods), *Photis dentata* (a small amphipod) and two small polychaete annelids, *Spiophanes bombyx* and *Asychis elongata*. With the exception of *Leptocheirus,* which is considered a suspension feeder, all of the above species are deposit feeders, utilizing the organic material found within the sediment or found on the sediment surface. This ampeliscid dominated community is similar to a more widely distributed silty-sand fauna reported by Lee (1944) and Saila,et al. (1972) for adjacent areas and on the southern New England continental shelf (Wigley, 1968; Pratt, 1973).

Several other species, while not numerically abundant, are important because of their large size or possible commercial value: the ocean quahog, *Artica islandica,* and the tunicates, *Molgula* sp. and a thus far unidentified colonial species. *Arctica* was found throughout the

TABLE 7. Results of macrofauna collections: species list, station and seasonal occurrence. Values are means of five samples and one standard deviation, + indicates the occurrence of a species but in numbers that average less than one per grab.

SPECIES	Station	ANL-1			ANL-2			ANL-3			ANL-4			ANL-5			ANL-6		
	Cruise	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Cnidaria:																			
Cerianthus sp.				2															+
Edwardsia sp.				+		2						1			1			1	
Haloclava sp.																		+	
Rhynchocoela:																			
unident. sp.			+	+		+			+	+					+			+	+
Phoronida:																			
Phoronis architecta		+		+		+						1							
Mollusca:																			
Crepidula fornicata										1									
Crepidula plana																		+	
Lunatia heros										+							+		
Lunatia triserata						+		+	+									1	
Anachis lafresnayi						+				+									+
Mitrella dissimilis		5±4	3±3	1	1	2		5±5	2	8±3	1						2	2	3±2
Buccinum totteni																	+		
Nassarius trivittata					+					+	+								
Retusa canaliculata		+																	+
Cylichna alba						+													
Turbonilla sp.					+			+			+								
Turbonilla elegantula			1			3±4				1	2	+					+		+
Odostomia sommeri		+																	
Facelina bostoniensis								+		+									+
Nucula proxima		138±98	19±11	445±73	201±32	130±49		8±4	5±4	4±1	53±20	246±38		84±32	262±49		40±29	4±3	1
Nucula delphinodonta				1	1	+				+		1			1				
Yoldia limatula		1		+	+	2						2			1				
Mytilus edulis																	+		
Musculus corrugatus			1			1		+	+	+		+			+		+	+	
Mercenaria mercenaria				+															
Crenella decussata			1		+	+		1	1			+			+			+	+
Crenella glandula		+		+						+							+		
Astarte undata		4±5	3±1	8±4	1	3±3		9±6	5±3	7±4	2	3±2		1	2		3±4	2	4±2
Astarte borealis										+									+
Cyclocardia borealis		1		+	+			+		+	+							+	+
Onchidoris aspersa																	+		+

TABLE 7 (continued)

SPECIES	Station	ANL-1			ANL-2			ANL-3			ANL-4			ANL-5			ANL-6		
	Cruise	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Arctica islandica			1	+				+	1			+			+		1		
Lucinoma filosa						+													
Cerastoderma pinnulatum				+	1	1		+	1	+				+			1	+	+
Pitar morrhuana		1	+	9±1	2	5±4		+		+		5±6		1	1		3±3		
Spisula solidissima								1											
Tellina agilis		2	1	2	2	2		+	+	+	+	+		+	+		1	1	+
Ensis directus			+			+			+	+		+			1			1	+
Lyonsia hyalina		1	1		2	1		3±3	+		1			1	1		3±2	1	
Periploma fragilis		1	1	4±1		1		+	+	+	5±5	4±2		+	2		1		
Unident. sp. #1				+		+						1							
Anomia simplex										+									
Anomia sp.										+									
Sipunculoidea:																			
Unident. sp.											+			+				+	
Phascolion strombi		1								+									
Annelida:																			
Harmothoe extenuata			2	1	1	4±5			+	+		2						2	+
Hartmania moorei		3±3		4±3	3±2	3±4					1			1	1		+		+
Lucinne cirrota						+													
Pholoe minuta		1	1	1	1	1			+	+	2	1		1	+		1	1	+
Sthenelais limicola		+	1			1		+	+	+		+			1			2	+
Sthenelais boa										+									
Phyllodoce mucosa				+	+			1			+						1		+
Phyllodoce arenae		1	1	2		1		2		2	1						1	1	6±2
Phyllodoce maculata		+	1			1			+	+								1	+
Eteone flava										+	+								+
Eteone lactea				+						+									
Paranaites speciosa																	+		+
Nereis succinea								1	+								+		
Nereis grayi						+		1	2		1							+	2
Nereis zonata																			+
Aglaophamus circinatus		+	1			+		+	+		+			1			1	1	
Nephtys picta				2	+					2				1			2		1
Nephtys incisa		6±4	2	9±6	7±4	8±5		1	2		1	15±5		8±6	10±1		2	2	+
Glycera dibranchiata								+			1								
Glycera americana			+	+	+			3±3	+	2	2			+			1		
Nephtys bucera			+		1	1		+			1			1					1

TABLE 7. (continued)

SPECIES	Station / Cruise	ANL-1 I	ANL-1 II	ANL-1 III	ANL-2 I	ANL-2 II	ANL-2 III	ANL-3 I	ANL-3 II	ANL-3 III	ANL-4 I	ANL-4 II	ANL-4 III	ANL-5 I	ANL-5 II	ANL-5 III	ANL-6 I	ANL-6 II	ANL-6 III
lycera capitata								+		2									+
lycera robusta		+																	
lycera sp.		+																	
niadella gracilis									+	1								+	4±
niglycera gigantea			+						+	1		+			+			+	+
niada brunnea					+						+			+			1		
niada norvegia								1											
niada maculata										+									
urphysa belli																			+
rilonereis magna					+														
rilonereis longa		4±2	2	6±2	4±3	5±3		3±5	2	4±2	2	3±1		3±2	4±3		1	2	4±2
umbrinereis tenuis		4±3	6±3	5±2	2	6±4		11±6	11±9	24±5	4±2	3±1		1	3±1		10±8	8±3	36±5
umbrinereis fragilis					+				+	1								+	+
inoe nigripes			2	2		+						3±2		+	1			3±1	
tocirrus spiniferus															+				
rabella tricolor					3±5													+	
coloplos acutus		1	+	1	+	+			3±2	2	11±7	+		2	1		1	3±2	1
coloplos sp. #1				+	+														
raonida sp. #1		+																	
olydora socialis		1	1	+		1		1	+	1	2					2			
rionospio streenstrupi		+	+	1	1	1		2	1	8±5				1	+		2	2	14±
pio filicornis						1								1					+
lipes sp. #1						2±4			1			+							+
lipes squamata																			+
phanes bombyx		94±81	8±3	+	19±10	16±8		204±20	17±12		41±26	29±22		32±16	23±4		41±51	72±71	
phanes wigleyi						+													
eliospio benedicti								1 +											
branchiopterus oculata		+		4±1					+	5±4									4±
tryx annulosus		+	+	+					1	10±5							1		2
tryx acutus		1	4±5	+	1	1		12±12	1	7±5	8±4	1		1	1		3±3		6±3
ria villosa		1	1	+				+	+	2	+	+			+				1
terusa affinis		1 +	1	+	1	1		+	+	+		+			1		1	2	1
alitrema inflatum		1	4±3	3±3		1		10±3	5±2	32±14	6±4	2		1	1		1	3±1	31±5
bellaria vulgaris								2		+									+
dionastus ambisetae					1			+		+									
pitelliidae sp.								+											
tomastus latericius										+									+
elina acuminata		+	1		+	+		1	1	+				1	+			1	+
ychis elongata		8±2	21±12		7±5	3±4		48±28	20±14	56±33	9±10	1		+	+		3±4	71±25	112±47

TABLE 7 (continued)

SPECIES	Station	ANL-1			ANL-2			ANL-3			ANL-4			ANL-5			ANL-6		
	Cruise	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Clymenella torquata		+	27±9	2	2	9±18		6±9	1	8±5	33±15	1					40±36	10±2	4±[illegible]
Clymenella zonalis		2	13±10	2	1	6±5		6±3	7±6	10±5	4±5	1		1	1		60±101	4±4	23±[illegible]
Myriochele heeri		3±4			1	7±7			1			1						+	
Owenia fusiformis		5±3		2	7±4	9±3		+				2		1	1		7±9	1	+
Ampharete arctica		1	3±2	6±3	1	3±2		1	1	3±1	3±2	2		1	1		1	2	5±[illegible]
Asabellides oculata		6±5		2	1	3±2		3±1	4±1	2	3±2	2		3±3	2		3±2	3±3	2
Polycirrus sp. #1				+								+							+
Terebellides stroemi			+	1				+			+	2		+	1		++	+	
Chone infundibuliformis		1		1	+			1		1		7±5			2			1	4±[illegible]
Laonome sp. #1						+					1								+
Potamilla reniformis				1				1	+	5±5	+			+			+		+
Potamilla neglecta			1			2		2	1	+	1	10±6			1		2	+	+
Euchone rubocinata										+	+	+							
Nicolea venustula										+									
Sabella sp. #1				1								+							
Sabella sp. #2		+																	
Myxicola infundibulum					+														
Aphrodita hastate									+										
Aphrogenea sp. #1					+														
Paraonis gracilis				+	+			+									+		+
Aricidea jeffreysii										+							+		
Aricidea suesica																	+		
Autolytus sp.										+							1		
Exogone hebes										+									4±[illegible]
Exogene dispar										+									1
Exogene verugera								2		+									+
Crustacea:																			
Eudorella emarginata		16±10	11±3	7±4	17±9	27±12		11±3	3±2	2	14±7	8±5		12±1	6±4		10±5	4±2	6±[illegible]
Diastylis sculpta		4±3	3±2	2	4±2	3±2		3±3	+		6±3	3±2					2	1	4±[illegible]
Edotea triloba		++	+			+			+		+						1	1	2
Ptilanthura tricarina		++	2		+	+		2	1	1	1						2	1	4±[illegible]
Cirolana concharum			+								+			+				+	
Neomysis americana						+													
Eualus pusiolus			+																
Crangon septemspinosa			+	+		1									+			+	
Calocaris sp.			+							+									+
Pagurus longicarpus			1					+	+	+								+	

TABLE 7 (continued)

SPECIES	Station Cruise ANL-1 I	ANL-1 II	ANL-1 III	ANL-2 I	ANL-2 II	ANL-2 III	ANL-3 I	ANL-3 II	ANL-3 III	ANL-4 I	ANL-4 II	ANL-4 III	ANL-5 I	ANL-5 II	ANL-5 III	ANL-6 I	ANL-6 II	ANL-6 III
Cancer sp.		2	+		3±3		+	1	1	+	1			2		+	3±11	+
Pinnixia sayana			+															
Callinassa atlantica									+									
Libinia emarginata																		+
Ampelisca vadorum		12±10	2		1		10±19	35±24	71±39	35±51			+	+		19±36	4±2	101±23
Ampelisca agassizi	362±370	434±34	233±89	299±159	520±145		333±128	90±16	206±112	650±34	76±21		373±105	318±99		1341±1121	542±162	264±97
Byblis serrata	+	1					24±17	1	11±9	3±2						3±4	+	10±4
Corophium crassicorne		+					+			+							+	+
Corophium bonelli		+							+									
Erichthonius hunteri	5±9	1		2	2		1	2		+	1		+	4±2		1	1	+
Unciola irrorata	4±4	37±7	1	+	5±2		29±16	92±59	21±26		1		1	1		27±30	26±26	12±2
Unciola inermis								7±14	57±16							1		98±33
Orchomenella pinquis		+			+			1						+			+	
Orchomenella minuta	+						+	1	+							1	+	
Hippomedon serratus		+			+			+			+			+			+	
Photis macrocoxa	1	+		3±3	+		1			1	+		+			1		
Photis dentata	32±38	58±56	+	18±14	23±27		8±10	3±5	4±3	2	4±4		5±4	3±3		36±20	3±5	16±9
Leptocheirus pinguis	9±8	60±51	6±3	1	15±14		68±54	112±59	65±21	79±38	1		1	13±10		53±36	11±2	50±[illegible]
Ischyrocerus anguipes		+			+			+								+		
Phoxocephalus holbolli	1		+	1	1		+	+	+					+		1		[illegible]
Harpina propingua	2	6±2	2	1	4±2		17±37	2	+	7±5	1		2	3±4		2	+	[illegible]
Stenopleustes gracilis		+			+		+	+	+					1		+		
Dulichia monacantha	2	+	1	2	3±3		1	2		2	17±7		4±4	4±2		3±3	1	5±5
Casco bigelowi								+	+	1								
Eriopisa elongata							1			+								
Aeginina longicornis	+	5±3		1	17±22		1	+		2	2			4±2		3±3	3±3	+
Caprella grahami																2		
Echinodermata:																		
Holothuroidea sp. #1									+		3±2							+
Holothuroidea sp. #2											3±2			+				
Thyone sp.		+			+													
Caudina arenata										+								
Asterias forbesi					+				+		+					1		
Henricia sanguidenta		+					+	+									+	+
Amphiolus squamata	+	+		+				+	+		+					+		+
Ophiopholus oculeata																		+

TABLE 7 (continued)

SPECIES	Station / Cruise	ANL-1 I	ANL-1 II	ANL-1 III	ANL-2 I	ANL-2 II	ANL-2 III	ANL-3 I	ANL-3 II	ANL-3 III	ANL-4 I	ANL-4 II	ANL-4 III	ANL-5 I	ANL-5 II	ANL-5 III	ANL-6 I	ANL-6 II	ANL-6 III
Hemichordata:																			
Stereobalanus canadiensis		+	+	1	1	3±2						4±2		1	2		1		
Chordata:																			
Molgula sp.			1			2						17±14			3±2			+	
Unident. colonial sp.									+			+			+				

year, occurring in 60% of our spring samples and 90% of our summer and fall samples. Molgula was common in the July sampling at most stations, but was not located in the partial analysis of the December cruise. The colonial form was found in the summer and also in December.

There is evidence of seasonal fluctuations in the benthic fauna, although a detailed analysis of seasonality has not been undertaken. Some of the more obvious changes are: the apparent colonization of the area by the above-mentioned tunicates during the summer and an increased abundance of juvenile Cancer crabs in the summer collection, being the result of early summer settling of the pelagic larvae. Populations of these three species were found to be reduced or absent in the December and March samplings. From a cursory review of literature, e.g. Sanders (1956), it is known that many smaller organisms, especially polychaetes, have annual cycles in which large numbers of larvae settle in the spring and population are reduced in winter because of natural mortality. Further sampling of increased frequency would be necessary for us to detect these trends with any degree of accuracy.

The sole known previous study of the benthic fauna of the East Hole area for comparison is that of Smith (1950). His study emphasized the use of macrofauna as fish forage and he identified only the dominant species used as forage although all other species were separated and given code designations for future identification. He collected his benthic samples with a 2 ft Agassiz dredge, which has a different sampling bias than our Smith-McIntyre grab. Also, his analysis was based on biomass, rather than numbers, so his dominant species will not correspond directly to our dominants. However, we feel that some of his data and unpublished notes (Dr. F. E. Smith, Graduate School of Design, Harvard University, Cambridge, Massachusetts, personal communication) are useful in examining the stability of the benthic populations in the East Hole area.

Smith made four dredge collections between May and August, 1949 at his Station 1-C, identified as being approximately four miles SSW of Watch Hill, Rhode Island. This would place Station 1-C on the north slope of the East Hole area. Our treatment of Smith's data is based mostly on our examination of his unpublished notes and are presented in Table 8. His collection is presently deposited with the Peabody Museum, Yale University, New Haven, Connecticut; it is anticipated that his specimens will be completely identified at some future data.

An examination of this data indicates that most of the species found in our collections had similar distributions and abundances in 1949. The tube-dwelling amphipods (*Leptocheirus, Ampelisca, Unciola*) were abundant then as now, and *Molgula* was important, in terms of biomass, that summer as it was during our sampling. Although it would appear that *Leptocheirus* was more important than *Ampelisca* in 1949, it should be noted that Smith's data is based on biomass and *Leptocheirus* is generally a larger amphipod, which would account for the discrepancy in dominance. Smith's data will be discussed further in the food web section.

TABLE 8. A list of species collected by Smith (1950) at his Station 1-C with relative abundance (% of total, by wt); "+" indicate species present, but amounting to less than .1% of total. Smith's code for each species, identified or unidentified, is also listed.

Species	Code	Collections (1949) May	June I	June II	August
Parasabella microthalmia	A 1	+			
Parasabella sp.	A 2	+			
Phyllodoce catenula	A 5	+		+	+
Unident. polychaete	A 25	+			
Unident. polychaete	A 30	+			
Unident. polychaete	A 31	+			
Unident. polychaete	A 32	+			
Maldanidae	A 9		+	+	
Lumbrineridae	A 10		+		
Unident. polychaete	A 11		+		
Ampharete sp.	A 12		+		
Ampharete sp.	A 3			+	+
Leptodonotus squamatus	A 4				
Unident. polychaete	A 13			+	
Unident. polychaete	A 14			+	
Unident. polychaete	A 15			+	
Leptocheirus pinguis	AM 1	+	42	5	10
Byblis serrata	AM 2	5		+	
Ampelisca spinipes	AM 3	.6	.6	.6	
Unciola irrorata	AM 4	+	4	3	3
Erichthonius sp.	AM 6	+	+	2	+
Monoculodes edwardsi	AM 7	+			
Paraphoxus spinosus	AM 11	+		+	
Unident. amphipod	AM 13	+	2	+	
Aeginina longicornis	AM 12		+	+	2
Unident. amphipod	AM 16		+	+	
Photis sp.	AM 8		+	+	+
Stenopleustes smithiana	AM 5			+	
Ischyroceros anquipes	AM 9			+	
Corophium sp.	AM 17			+	
Ampelisca sp.	AM 18			+	
Ampelisca sp.	AM 19			+	
Edotea triloba	I 1	+	.8	+	
Unident. isopod	I 3	+			
Unident. cumacean	C 2	+	+	+	
Unident. cumacean	C 4	+			
Unident. cumacean	C 5	+			
Unident. cumacean	C 6	+			
Diastylis bispinosus	C 1		+	+	
Unident. cumacean	C 3			+	
Sipuncula	S 2	+			
Molgula sp.	T 2	41	2		
Unident. tunicate	T 1			+	
Neomysis americana	M 1	+	+	+	19

TABLE 8 (continued)

Species	Code	May	Collections (1949) June I	June II	August
Crangon septemspinosa	D 1	.5	5	.5	4
Pagurus longicarpus	D 4	+		+	
Unident. decapod	D 5			+	
Unident. decapod	D 11				+
Crucibulum striatum	G 1	4			
Nassarius trivittatus	G 5	18	.6	.8	
Polinices triseriata	G 8	+			
Polinices heros	G 9	+		+	
Pyramidella sp.	G 14		+		
Unident. gastropod	G 16		+		
Unident. gastropod	G 12			+	
Unident. gastropod	G 17			+	
Unident. pelecypod	P 14	+			
Astarte undata	P 2	+			
Astarte quadrans	P 3	12			
Anomia simplex	P 5	+			
Venericardita borealis	P 8	11	.9	+	
Lyonsia hyalina	P 10	+	.9	+	
Mulinia lateralis	P 11	.5			
Unident. pelecypod	P 15	+			
Unident. pelecypod	P 16	+			
Modiolaria substriata	P 1	+			
Cardium pinnulatum	P 7		+	+	+
Nucula proxima	P 13		+	+	
Crenella decusssata	P 12			+	
Asterias vulgaris	E 5	37		14	58
Amphipholis squamata	E 2	+		+	+
Echinarachnius parma	E 4			69	

2. Community Analysis -

Community structure analysis of the macrofauna, including numbers of individuals and species, Shannon and Weaver (1963) diversity, H', and equitability, J' (Pielou, 1966) is presented in Table 9. The average number of organisms per grab ranged from 417 to 1,759. The cumulative number of species per station ranged from 47 to 105 species, with the mean number of species per grab ranging from 24 to 53. These values are similar to those found by Saila, et al. (1972) in Rhode Island Sound. Mean number of species per grab are higher than values found in the New London area (NMFS, 1975d) and the remainder of Long Island Sound (NMFS, 1974).

The mean diversity (H') values ranged from 1.18 at Station 5 in April to 2.58 at Station 3 in December. The average diversity for all stations and cruises is 1.80. This value is relatively low (Saila et al., 1972; Boesch, 1972) and could be considered to be in the range of stressed or marginally polluted areas. We do not believe this condition should be inferred in this survey because the Shannon-Weaver index is strongly influenced by the equitability (J') or evenness of the distribution of abundance of individuals in a sample. The average J' value for all samples was 0.50. This is relatively low and indicates strong dominance, numerically, by one or a small number of species; most of our collections were dominated by two species, Ampelisca agassizi and Nucula proxima. Such dominance will depress H' even though the fauna may be diverse, i.e. a high number of species. Saila, et al. (1972)

TABLE 9. Community characteristics of the macrofauna; the values are the mean of five grab samples (with one SD) per station, for three sampling periods.

Station	Cruise	Mean No. org./grab	Total No. Species	Mean No. sp./grab	Mean H' Diversity	Mean J' Evenness
ANL 1	March	741 ± 335	65	32 ± 6	1.69 ± .32	0.49 ± 0.10
	July	781 ± 67	78	47 ± 4	1.90 ± .52	0.50 ± 0.06
	December	806 ± 80	76	39 ± 4	1.47 ± .09	0.40 ± 0.03
ANL 2	March	534 ± 212	60	31 ± 8	1.60 ± .12	0.48 ± 0.06
	July	879 ± 217	85	45 ± 9	1.76 ± .27	0.46 ± 0.06
ANL 3	March	876 ± 181	79	38 ± 5	2.09 ± .24	0.58 ± 0.05
	July	417 ± 137	73	35 ± 4	2.27 ± .20	0.65 ± 0.08
	December	677 ± 229	105	50 ± 8	2.58 ± .08	0.66 ± 0.03
ANL 4	April	1,018 ± 146	68	37 ± 6	1.56 ± .24	0.43 ± 0.06
	July	499 ± 128	61	36 ± 9	2.01 ± .26	0.56 ± 0.04
ANL 5	April	604 ± 114	47	24 ± 2	1.18 ± .19	0.37 ± 0.07
	July	699 ± 99	58	35 ± 2	1.52 ± .66	0.43 ± 0.01
ANL 6	April	1,759 ± 1,066	79	39 ± 5	1.45 ± .88	0.39 ± .23
	July	819 ± 162	74	40 ± 11	1.46 ± .35	0.40 ± 0.07
	December	874 ± 151	94	53 ± 6	2.53 ± .16	0.64 ± 0.05

also reported this situation in his study, where the dominance of <u>A. agassizi</u> suppressed H' to a level below 1.00, but yet the community wasn't considered by other appearances to be stressed. In these situations it is probably not meaningful to use H' as an index of community health. We do feel that H' is a valuable parameter in establishing a baseline against which change can be detected.

D. Demersal Finfish

Finfish species caught at each station, with their number and weight, are listed in Tables 10 and 11 for winter and summer tows respectively. In Figure 2, winter tows are indicated by triangles and are assigned numerals, summer tows are indicated by diamonds and are assigned letters.

The species catch composition of the winter sample, the summer sample, and those seen in both samples are shown below:

Winter Only	Both Summer & Winter	Summer Only
Cod	Little skate	Smooth dogfish
Longhorned sculpin	Alewife	Big skate
Sea raven	Silver hake	Blueback herring
Ocean pout	Red hake	American shad
	Winter flounder	Spotted hake
	Windowpane	Fourspot flounder
		Butterfish
		Bluefish
		Scup
		Weakfish
		Cunner
		Goosefish
		Lobster
		Loligo squid

Species which were captured only during the winter sampling period are those which prefer lower temperatures and as a result are to some extent

TABLE 10. Weights (pounds) and numbers of demersal species caught by otter trawl in Block Island Sound, March 24-27, 1975

Tow	1		2		3		4		5		Mean	
Finfish	Wt.	#	Wt.	#	Wt.	#	Wt.	#	Wt.	#	Wt.	#
Little skate, Raja erinacea	42	33	13	11	12	8	28	23	21	19	23.2	18.8
Alewife, Alosa pseudoharengus							.5	1			.1	.2
Atlantic cod, Gadus morhua			44	2			33	2			15.4	.8
Silver hake, Merluccius bilinearis	1	7	.5	1	1	2	.5	2			.6	2.4
Red hake, Urophycis chuss	20	28	9	13	3	7	4	9	2	19	7.6	15.2
Ocean pout, Macrozoarces americanus	13	12	7	7	6	6	12	2	6	5	6.6	6.4
Sea raven, Hemitripterus americanus	2	1									.4	.2
Longhorn sculpin, Myoxocephalus octodecemspinosus	2	5	3	7	3	8	7	15	1	2	3.2	7.4
Windowpane, Scophthalmus aquosus	6	25	8	21	3	6	3	7	1	5	4.22	12.8
Winter flounder, Pseudopleuronectes americanus	3	11	1	1	9	13	5	11	1	2	3.82	7.6
Total	89	122	85.5	63	37	50	82.0	72	32	52	325.5	359.0

Total # 359 ÷ 5 = 71.8
Total Wt. 325.5 ÷ 5 = 65.1

Invertebrates	1		2		3		4		5		Mean	
Rock crab, Cancer irroratus	1	22									.2	.4

1076

1077

TABLE 11. Weights (pounds) and numbers of finfish and invertebrates caught by otter trawl in Block Island Sound, July 29, 1975

Species	Tow	A		B		C		D		E		F		G		Mean	
		Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#
Finfish																	
Smooth dogfish, Mustelus canis		15	3	11	2	12	2			3	1					5.9	1.1
Big skate, Raja ocellata		5	1			11	1									2.3	.3
Little common skate, Raja erinacea		14	17	35	30	35	31	23	20	12	12	24	19	6	71	21.3	19.4
Blueback herring, Alosa aestivalis												1	2			.1	.3
American shad, Alosa sapidissima				2	1					.5	1	.5	1			.4	.4
Alewife, Alosa pseudoharengus												3	6			.4	.9
Silver hake, Merluccius bilinearis		4	7	7	10	1	4	7	14			13	18	.5	5	4.6	8.3
Red hake, Urophycis chuss		.5	1	7	72			2	17			9	49			2.6	19.9
Spotted hake, Urophycis regius								.5	1					.5	1	.1	.3
Fourspot flounder, Paralichthys oblongus						.5	1					.5	1				
Winter flounder, Pseudopleuronectes americanus		13	16	6	9	8	16	7	8	2	3	11	11	8	12	7.9	10.7
Windowpane, Scophthalmus aquosus		1	2	3	7	.5	3	1	4	.5	2	11	24	1	2	2.6	6.3
Butterfish, Poronotus triacanthus	.1	.5	6	.5	1	11	148	7	37	13	151	2	7	8	53	6.0	57.5
Bluefish, Pomatomus saltatrix		6	1	3	1											1.3	.3
Scup, Stenotomus chrysops		.5	1			.5	1			1	2			.5	5	.2	1.3
Weakfish, Cynoscion regalis		52	9	16	3			22	4	14	2	6	1			15.7	2.7
Cunner, Tautogolabrus adspersus										.5	1					.1	.1
Goosefish, Lophius americanus												24	1			3.4	.1
	Total	111.5	64	90.5	136	79.5	207	69.5	105	46.5	175	105.0	140	25.0	86	527.5	913.0

Sum of Means (wt.) - 75.1 lb.1
Sum of Means (nos.) = 130.31

Species	Tow	A		B		C		D		E		F		G		Mean	
		Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#
Invertebrates																	
Lobster, Homarus americanus		2	2	1	31	2	4	3	6	31	6	3	4	2	4	2.3	4.1
Jonah Crab, Cancer borealis														.5	1	.1	.1
Long finned squid, Loligo pealei	Total	11	72	71	50	81	77	8	54	7	47	6	36	10	54	8.1	55.7
		13	74	81	53	10	81	11	60	10	53	9	40	12.5	59	10.5	59.9

Sum of Means (wt.) = 10.5 lb.
Sum of Means (nos.) = 60

migratory. Adult cod are known to support a recreational fishery in Block Island Sound during the colder months. During the summer months, when the water temperature rises, the adult cod move into cooler waters, generally offshore. However, some adult cod probably remain in the deeper, cooler holes such as the East Hole and West Hole, since the temperature does remain marginally low enough (approximately 15°C as of July 29, 1975) to support cod. Bigelow and Schroeder (1953) stated that cod "are abundant at times in temperatures as high as 58°-59°F (16°C) on Nantucket Shoals."

All of those species that were captured during the summer only are migratory in varying degrees. Of these summer species, butterfish, weakfish, lobster and Loligo squid are particularly well represented in the samples. The butterfish and squid are important links in the food webs of species favored for commercial and sport purposes. Weakfish support a sport fishery in Block Island Sound. It is well known that lobster is an important commercial species. Cooper and Uzmann (1971) demonstrated the migration of deep-sea lobster into Block Island Sound from the edge of the continental shelf and have related this phenomenon to temperature orientation. They determined the optimum temperature range to be between 10.0°C and 17.5°C. The bottom temperatures observed in the East Hole area on July 29, 1975 ranged between 14.6°C and 15.5°C. These temperatures are within the optimum range for lobster as established by Cooper and Uzmann (1971). The bottom temperatures observed during the winter sampling period ranged between 4.3°C and 4.5°C. This is well below the optimum for lobster and probably results in the absence of deep-sea lobster during the colder months. It was expected that a few lobster representing the inshore, non-migratory, resident population would be seen during the winter sampling period. However, none were caught and this may be the result of a combination of sampling methods, including the necessity of not trawling over an excessively rough bottom, and the reduced winter population.

Considering depth and the proximity of the stations to one another, four of the summer stations are comparable with four of the winter stations and are paired as follows: 1 with F, 2 with D, 3 with C and 4 with A. Table 12 considers only these four pairs of tows; showing the weight and number of each species captured during the winter and summer series.

Examination of the mean catch per tow values presented in Table 12 indicates that those species which were captured during both sampling periods dominated both the summer and winter tows and appear to comprise a resident population. Little skates represented nearly half the catch (on a weight basis) per tow for both sampling periods. Approximately the same poundage per tow of little skates occurred during both sampling periods, but those caught during the winter weighed approximately 25% more individually than those caught during the summer sampling. Red hake displayed a similar trend, in the number of fish caught per season. But the winter red hake weighed approximately three times more, per individual, than the summer fish. Windowpane showed no appreciable difference in the average weight per animal, but were more numerous in the winter sample than the summer sample. Unlike little skate and red hake, the larger silver hake and winter flounder were observed during the summer months. Edwards (1965) and McCracken (1963)

Table 12. Comparison between winter (numbers) and summer (letters) tows. Weight in pounds (lbs.).

Species	TOW 1 Wt.	1 #	F Wt.t	F #	2 Wt.	2 #	D Wt.	D #	3 Wt.	3 #	C Wt.	C #	4 Wt.	4 #	A Wt.	A #	Wintert Tows Mean Wt.	Wintert Tows Mean No.	Summer Tows Mean Wt.	Summer Tows Mean No.
Smooth dogfish, Mustelus canist	-	-	-	-	-	-	-	-	-	-	12	2	-	-	15	3	-	-	6.75	1.25
Big skate, Raja ocellata	-	-	-	-	-	-	-	-	-	-	11	1	-	-	5	1	-	-	4.00	.5
Little common skate, (Raja erinacea)	42	33	24	19	13	11	23	30	12	8	35	28	23	33	14	17	23.75	18.75	24.00	24.25
Blueback herring, Alosa aestivalist	-	-	1t	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.25	.5
Shad, Alosa sapidissima	-	-	.5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.13	.25
Alewife, Alosa pseudoharengus	-	-	3	6	-	-	-	-	-	-	-	-	.5	1	-	-	.1	.25	.75	1.5
Silver hake, Merluccius bilinearist	1	7	13	18	.5	1t	7	14	1	2	1	4	.5	2	4	7	.75	3.0	6.25	10.75
Cod, Gadus morhua	-	-	-	-	44	2	-	-	-	-	-	-	33	2	-	-	19.25	1	-	-
Red hake, Urophycis chuss	20	38	9	49	9	13	2	17	3	7	-	-	4	9	.5	1	9.0	16.75	2.88	16.75
Spotted hake, Urophycis regius	-	-	-	-	-	-	.5	1	-	-	-	-	-	-	-	-	-	-	.13	.25
Fourspot flounder, Paralichthys oblongus	-	-	.5	1	-	-	-	-	-	-	.5	1	-	-	-	-	-	-	.25	.5
Winter flounder, Pseudopleuronectes americanus	3	11	11	11	1	1	7	8	9	13	8	16	5	11	13	16	4.5	9.0	9.75	12.75
Windowpane, Scophthalmus aquosus	6	25	10	24	8	21	1	4	3	6	.5	3	3	7	1	2	5.0	14.75	3.13	8.25
Butterfish, Poronotus triacanthus	-	-	2	7	-	-	7	37	-	-	11	148	-	-	.5	6	-	-	5.13	49.5
Bluefish, Pomatomus saltatrix	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	1	-	-	1.5	.25
Scup, Stenotomus chrysops	-	-	-	-	-	-	-	-	-	-	.5	1	-	-	.5	1	-	-	.25	.5
Long horned sculpin, Myoxocephalus octodecemspinosus	2	5	-	-	3	7	-	-	3	8	-	-	7	15	-	-	3.75	8.75	-	-
Sea raven, Hemitripterus americanus	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.5	.25	-	-
Weakfish, Cynoscion regalis	-	-	6	1	-	-	22	4	-	-	-	-	-	-	52	9	-	-	20	3.5
Cunner, Tautogolabrus adspersus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ocean pout, Macrozoarces americanus	13	12	-	-	7	7	-	-	6	6	-	-	1	2	-	-	6.75	6.75	-	-
Goosefish, Lophius americanus	-	-	24	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0	.25
Lobster, Homarus americanus	-	-	3	4	-	-	3	6	-	-	2	4	-	-	2	2	-	-	2.5	4.0
Jonah crab, Cancer borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rock crab, Cancer irroratus	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.25	.5	-	-
Long fined squid, Loligo pealei	-	-	6	36	-	-	8	54	-	-	8	77	-	-	11	72	-	-	8.25	59.75

concluded that the migrations of finfish are closely associated with seasonal temperature changes. The inshore-offshore migration of winter flounder was documented by McCracken (1963) and was found to be particularly prominent south of Cape Cod. McCracken correlated the migration of winter flounder with temperature. Our work in the East Hole (Table 2) demonstrates a relatively large difference between the winter and summer bottom temperatures (Nearly 11°C). Silver hake and winter flounder catches increased in the cooler waters of East Hole during the summer months.

Based upon existing literature and our observations in the East Hole and nearby coastal areas, it can be concluded that migrations of different species do occur in the study area and some species reside in the area throughout the year.

Edwards (1965) indicated that there are different "complexes" of species which may be found in Block Island Sound according to season. A gross examination of Tables 10 and 11 indicates that the species captured on our surveys generally agree with Edwards'. However, our knowledge of the areas, based on nearby coastal surveys and the work of Edwards (1965) and Smith (1950), would indicate the expected, but not observed, presence of spiny dogfish, yellowtail flounder and a larger number of goosefish in the winter catch, while the summer samples lacked black sea bass and the number of Cancer crabs that would also normally be expected. It cannot be determined whether these species were absent, or were present but not captured for one reason or another (low numbers, irregular distribution, sampling methods, etc.); but their historic presence is documented.

Table 13 represents observations taken by Smith (1950) while on a commercial trawler in the East Hole area. Smith's weight observations are not directly comparable with ours because his tow time was much longer and our lack of knowledge about the trawl size or how it was fished. His data do provide a simple historical view of the species in the area that is comparable with our recent data. The similarity of the species composition of the catches suggests the existence of a relatively stable community in the East Hole area.

Based on this study it is not possible to quantify either the value of the East Hole to the fisheries in Block Island Sound, or the effect of dredge spoil disposal on those species that utilize or pass through the East Hole. In order to achieve a statistically precise assessment further research including more intense surveys and a study of the historic and ongoing commercial and recreational fisheries would be required.

E. Food Web Studies

As a preliminary study of the interrelationship between the demersal finfish and the benthic macrofauna, six finfish species were separated from the trawl collections of July, 1975 for gut content analysis. These species were selected because of their known use of benthic organisms as food. Winter flounder, Pseudopleuronectes americanus, dominated our sample, with 47 specimens being examined. We also examined stomachs of ten windowpane flounder, Scophthalmus aquosus, ten red hake, Urophvcis chuss, two silver hake, Merluccius bilinearis, two weakfish, Cynoscion regalis, and two scup, Stenotomus chrysops.

TABLE 13. 1949 trawling results in the East Hole area (Smith, 1975)

Trawl date	May 7	June 2 Haul 1	June 2 Haul 2	August 9	
Duration of tow (hrs)	1.5	1.0	2.0	1.0	
Species	weight caught (lbs)				Total Wt.
Winter flounder, Pseudopleuronectes americanus	89	200	267	113	569
Little skate, Raja erinacea,s	111	33	50	200	394
Sea robin, Prionotus sp.	67	3	1	133	204
Goosefish, Lophius americanus		50	33	1 specimen no wt.	68+
Big skate, Raja ocellatus				67	67
Fourspot flounder, Paralichthys oblongus	22	1.8	2	22	47.8
Whiting, Merluccius bilinearis	44			2.8*	46.8
Windowpane, Scophthalmus aquosus	22		2	22	45
Summer flounder, Paralichthys dentatus		33			33
Eel pout, Macrozoarces americanus	22	9			31
Barn door skate, Raja laevis	10	10			20
Sculpin, Myoxocephalus?	11	2.1			13.1
Red hake, Urophycis chuss	2	3	1	2.8*	3.8
eel, Anguilla?	8				3
Menhaden, Brevoortia tyrannus		3			3
Toadfish, Opsanus tau		3			3
Dogfish sp.?			2 specimens no wt.		
Cod, Gadus morhua			1 specimen no wt.		
Clearnose skate, Raja eglanteria				1 specimen no wt.s	

*sRed hake and whiting were listed as combined for a total weight of 5.6 lbs for this tow.s

1. Winter flounder -

Eight (17%) of the winter flounder had empty stomachs; of those with food in their stomachs, 24 were females, 14 males and one immature. They ranged in size from 24 to 45 cm total length ($\bar{x}$ = 30 $\pm$ 5 cm). We found that these fish fed on 37 identifiable species of benthic fauna: 13 amphipods, 17 polychaetes, 2 decapods, and one each mysid, cumacean, bivalve, tunicate and sipunculoid species. Amphipods were the most important food items both numerically (88% of total numbers) and volumetrically (52% of total volume), with tube-dwelling species Leptocheirus pinguis, Ampelisca agassizi and Unciola irrorata dominant. Polychaetes contributed 7% of the total numbers, and 22% of total volume; only two species, Asabellides oculata and Ampharete arctica, were frequently consumed, although the large size of Ophioglycera gigantea made it significant volumetrically (18%). The remaining groups contributed 13% of total volume (10% by the sipunculoids) with the final 13% being fragments and unidentifiable material.

A breakdown of the stomach contents of the 39 winter flounder for those prey species which make up 1% or more by number or volume, of the total contents, is presented in Table 14. Other species found were: Clymenella torquata (P), Photis macrocoxa (A), Nucula proxima (B), Photis dentata (A), Dulichia monacantha (A), Lumbrineris tenuis (P), Neomysis americana (M), Harmothoe extenuata (P), Ophalina acuminata (P), Crangon septembspinsa (D), Ninoe nigripes (P), Chone infundibuliformis (P), Sthenelais limicola (P), Tharyx acutus (P), Pherusa affinis (P), Harpinia propinqua (A), Scoloplos acutus (P), Phyllodoce arenae (P), Eudorella emarginata (C), Spiophanes bombyx (P), Nephtys incisa (P), Corophium crassicorne (A), and Scalibregma inflatum (P).

TABLE 14. Volumes and numbers of forage species eaten by winter flounder

Prey Species	% Total Volume	% Total Numbers	% Stomach Occurrence
Leptocheirus pinguis (A)	42	42	69
Ophioglycera gigantea (P)	18	<1	15
Unidentifiable fragments	13	-	100
Sipuncula	10	33	10
Unciola sp. (A)	6	13	49
Ampelisca agassizi (A)	3	12	82
Asabellides oculata (P)	3	4	36
Molgula sp. (T)	2	<1	3
Cancer sp. (D)	1	3	28
Aeginina longicornis (A)	<1	11	41
Ampelisca vadorum (A)	<1	4	21
Erichthonius hunterii (A)	<1	1	23
Ampharete sp. (P)	<1	1	21
Byblis serrata (A)	<1	1	21

A = amphipod, P = polychaete, B = bivalve, M = mysid, D = decapod, T = tunicate, C = cumacean

Of the 37 species eaten by winter flounder, all were part of the infauna discussed in section C, with the exception of juvenile rock crabs, Cancer irroratus, sand shrimp, Crangon septemspinosa , and mysid, Neomysis americana. These three species are motile epifaunal components of the benthic community and were only a minor (approximately 1% of total volume) part of the flounder's diet. Smith (1950) found infaunal species made up 99.2% of the wet weight of the diet of the winter flounder he examined.

2. Windowpane flounder -

The windowpanes were between 15 and 33 cm in length ($\overline{x}$ = 26 cm). Five were males and five females, and all stomachs contained food. Analysis of the stomach contents indicated they prefer epifaunal species; Crangon septemspinosa (43% of total numbers and 37% of total volume) and Neomysis americana (25% of total numbers and 22% of total volume) were the dominant items. This importance of epifauna in windowpane's diet is consistent with the results of Moore (1947), Smith (1950), Richards (1963 a,b) and Hickey (1975), although these authors found Neomysis to be more important than Crangon. Beside Crangon and Neomysis, eleven other crustacean species were eaten, including eight amphipods and three other decapods. The complete results are summarized in Table 15.

3. Red hake -

Of the ten red hake examined, nine ranged between 20 and 24 cm ($\overline{x}$ = 21.5) and one fish was 49 cm. These fish fed only upon five species

TABLE 15. Numbers and volumes of species eaten by windowpane

Prey Species	% Total Nos.	% Total Vol.	% Stomach Occurrence
Crangon septemspinosa (D)	43	37	80
Neomysis americana (M)	25	22	80
Leptocheirus pinguis (A)	15	13	70
Aeginina longicornis (A)	8	7	20
Dulichia monacantha (A)	6	5	30
Dichelopandalus leptoceros (D)	6	5	20
Erichthonius hunterii (A)	3	3	30
Ampelisca agassizi (A)	3	3	30
Byblis serrata (A)	2	2	20
Gammarus sp. (A)	2	2	10
Unciola irrorata (A)	1	1	10
Cancer sp. (D)	1	1	10
Homarus americanus (juv.) (D)	1	1	10

D = decapod, M = mysid, A = amphipod

of crustaceans with 96% of the total number being Crangon; the other four species were amphipods. Again, although the sample size was small, the results are similar to the findings of Richards (1963 a,b); the complete results are summarized in Table 16.

4. Other species -

The two (38 and 46 cm) silver hake fed mainly on Crangon, but also consumed a polychaete (Nephtys sp.), and an unidentifiable fish. The two (62 and 67 cm) weakfish also fed on Crangon, but fish remains dominated the stomach contents; three other benthic invertebrates were also found: the large polychaete, Ophioglycera gigantea, a cancer crab and a small amphipod, Photis sp. One of the two (20-25 cm) scup stomachs examined contained 30 Ampelisca agassizi, the other 96 Leptocheirus pinguis and small numbers of Ampelisca, Crangon, Unciola, Neomysis, Byblis and Asabellides oculata. These results are consistent with what has been reported by other researchers on the diets and feeding of these species (Smith, 1950; Richards, 1963 a,b).

Although our sample size was small and only a few fish species were examined, our survey does indicate that demersal fish of the East Hole area are dependent on benthic invertebrates for food and that at least two commercially important species, winter flounder and scup, rely almost exclusively on the benthic macrofauna for forage.

The East Hole appears to be a rich source of forage for these and other demersal finfish. The silty-sand ampeliscid dominated faunal zone discussed in the macrofauna section of this report is considered by

TABLE 16. Numbers and volumes of species eaten by red hake

Prey Species	% Total Vol.	% Total Nos.	% Stomach Occurrence
Crangon septemspinosa (D)	99	96	100
Leptocheirus pinguis (A)	<1	2	30
Aeginina longicornis (A)	<1	1	20
Dulichia monacantha (A)	<1	<1	10
Ampelisca agassizi (A)	<1	<1	10

D = decapod, A = amphipod

Pratt (1973) to be one of the most important benthic faunal zones in terms of its ability to supply forage for demersal finfish. Lee's (1944) results support this contention; he found the abundance of winter flounder in Menemsha Bight, bordering Rhode Island Sound, corresponded closely to the abundance of Ampelisca and Clymenella in the bottom sediments. Because the distribution of faunal zones is not well-known in Block Island Sound, it is difficult to appraise the relative worth of the East Hole compared to other Block Island Sound areas in terms of its importance in supplying forage to valuable finfish. However, a rough estimate could be made if we can assume a close correlation between the productive ampeliscid dominated community and sandy sediments which contain approximately 10-25% silt. This assumption is valid if we accept Thorson's (1957) hypothesis that certain benthic assemblages exhibit preferences for particular sediments, which seems well supported in many studies.

Savard's (1966) sediment data indicate that silty sands cover a relatively small proportion of Block Island Sound (Figure 5). The majority of the Sound contains relatively clean sands, which are considered by Pratt (1973) to have the lowest productivity of the natural faunal zones found in southern New England. An examination of Smith's (1950) data also lends support to the importance of the East Hole as a foraging ground. His study included the Block Island Sound coast of Rhode Island from Watch Hill to Pt. Judith (a good part of the silty sand zone defined by Savard) where he reported 46.1% (by wt) of all food found in the

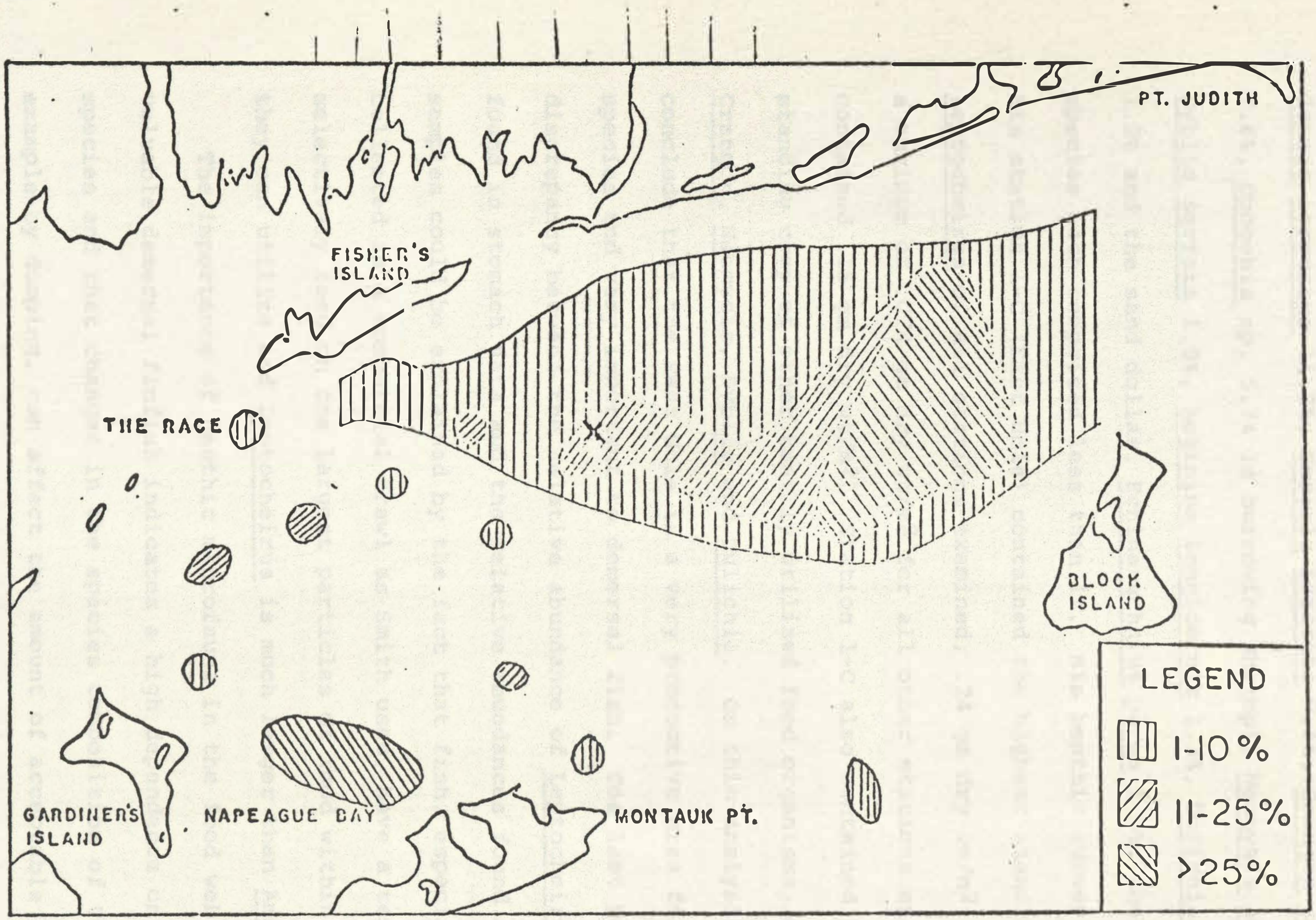

FIGURE 5. Distribution of silt in Block Island Sound, Savard (1966).
x - indicates the location of the center of the proposed East Hole Dump Site.

stomachs of the fish he collected were Leptocheirus pinguis, followed by Cancer irroratus 11.8%, Unciola irrorata 8.1%, Crangon septemspinosa 7.6%, Upogebia sp. 5.7% (a burrowing shrimp), Neomysis americana 4.2%, Byblis serrata 1.9%, Aeginina longicornis 1.3%, Dulichia monacantha 1.2% and the sand dollar, Echinarachnius parma 1.0%; the remaining species each comprised less than 1%. His benthic survey indicated that his station 1-C (East Hole) contained the highest standing crop of Leptocheirus of all stations examined, .24 gm dry wt/m^2, compared to a maximum of .074 gm dry wt/m^2 for all other stations except one, which contained .15 gm dry wt/m^2. Station 1-C also contained a significant standing crop of other heavily utilized food organisms, e.g. Unciola, Crangon, Neomysis, Byblis and Dulichia. On this analysis, we could conclude that the East Hole is a very productive area for benthic species and very important to demersal fish. One last point, the discrepancy between the relative abundance of Leptocheirus and Ampelisca found in stomach data and the relative abundances found in our macrofauna samples could be explained by the fact that fish, especially the size collected in a commercial trawl as Smith used, have a tendency to selectively feed on the largest particles of food within the size range they can utilize and Leptocheirus is much larger than Ampelisca.

The importance of benthic macrofauna in the food web supplying valuable demersal finfish indicates a high dependence on certain benthic species and that changes in the species composition of the fauna, for example by dumping, can affect the amount of acceptable forage available to fish in the area. In some cases an alternate diet could be readily adopted but in other cases, the lack of suitable forage may exclude certain species from the area, at least temporarily, or retard growth, fecundity and possibly recruitment. This could be very important to resident fish stocks which do not normally migrate outside of the immediate area. The preliminary food webs developed may also illustrate the possible paths of contaminants released by the spoil material.

IV. SUMMARY AND CONCLUSIONS

1. We found bottom water in the East Hole to have a narrow range of salinity (31.5 ± 1.0 ppt) during the year, the temperature range was 13°C (3-16°C) and the water was well oxygenated (a low of 90% saturation in July, 1975).
2. Hollman (Appendix A, this report) and Morton, et al. (1975) report the average bottom current drift to be to the WSW; Morton et al. also report the maximum bottom current velocity, either ebbing or flooding, to be about 40 cm/sec with the mean current velocity slightly higher than at the New London dumpsite; the friction velocity was less than 2.5 cm/sec, a value considered insufficient to erode Thames River dredge spoils.
3. Analyses of sediments, combined with Savard's (1966) and U. S. Army Corps of Engineers (1975) data indicate that the East Hole contains mostly silty sand (10-25% silt) with patches of finer and coarser materials being found mostly in the shallower north and south slopes of the depression.
4. The sediment heavy metal concentrations were found to be low. The carbonate and oxidizable organics in the sediment were also low

compared to values found in Long Island Sound.

5. The macrofauna of the East Hole was found to be dominated by populations of tube-dwelling amphipods, Ampelisca agassizi, Leptocheirus pinguis, and Unciola irrorata as well as a small bivalve, Nucula proxima. The majority of the 183 species found here are deposit feeders and appear to be part of a characteristic and productive silt sand fauna reported for adjacent areas and widespread off southern New England.
6. The demersal finfish were found to fall into three seasonal components: 1) a winter component dominated by cod, longhorn sculpin, and ocean pout, 2) a summer component dominated by butterfish, weakfish, bluefish and scup, and 3) a year-round resident population dominated by little skate, winter flounder, windowpane, and red hake. The average total biomass we caught per tow varied from 75.1 lbs (ranging from 25 to 111.5 lbs) in July to 65.1 lbs (ranging from 32 to 89 lbs) in March.
7. A preliminary survey of the occurrence of benthic macrofauna in the diets of demersal finfish indicated that winter flounder, and possibly scup, were almost entirely dependent on infauna for food, while the four other species studied depended on both infauna and motile epifauna.
8. From the data presented and Smith's (1950) study, it appears the East Hole may be a very productive source of forage for demersal finfish. Further studies would be necessary to confirm this.

V. ACKNOWLEDGEMENTS

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APPENDIX I

Report on the
Physical Oceanography of the
Alternate New London Dump Site Area
July, 1975

Submitted to

Sandy Hook Laboratory, Middle Atlantic Coastal
Fisheries Center, National Marine Fisheries Service
NOAA/U.S. Dept. Commerce
under Contract No. 03-5-043-305

by

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A. <u>Definitions:</u>

<u>u</u>: east/west velocity component in cm/sec

<u>v</u>: north/south velocity component in cm/sec

<u>R</u>: speed of the current in cm/sec,

$$R = [u^2 + v^2]^{1/2}$$

<u>θ</u>: direction of the current relative to geographic north,

$$\theta = \arctan v/u$$

<u>D(R)</u>: virtual distance in kilometers of a half-tidal cycle,

$$D(R) = \int_{1/2 \text{ tidal cycle}} R(t)\, dt$$

<u>t</u>: duration of half-tidal cycle in hours

<u>Beam Attenuation coefficient (β)</u>: sum of the absorption coefficient and total scattering coefficient and calculated from

$$\beta = (^{-1}/L) \ln (T/100)$$

where T is the beam transmittance in percent and L is the path length in centimeters.

<u>"Extinction" coefficient (k)</u>: is defined by the equation:

$$I(z) = I(z=0) \exp\{-kz\}$$

where I(z=0) is the total visible light energy (irradiance) incident to the air-sea interface, I(z), is the remaining light energy at the depth z (meters), and -k is the mean total "extinction" coefficient (m^{-1}) for the entire water column.

<u>"Transmission"</u>: the degree of daylight penetration in the water (transmission of downwelling irradiance over the visible spectrum) and calculated from:

$$\% \text{ Transmission} = [I(z)/I(z=0)] \times 100\%$$

B. Instrumentation

The current meters used in this study of the alternate dump site at East Hole included 2 General Oceanics Model 2010 film recording meters, one at the surface, and the second at mid-depth; the bottom current meter was a HYDRO-Products In-Situ current speed, direction, and temperature recording system, Model 502. Temperatures were measured by bathythermograph and surface bucket thermometer. Beam transmittance measurements were obtained with a HYDRO-Products Transmissometer.

C. Cruise Descriptions:

1. General

A total of 5 stations were selected for sampling at the East Hole, the designated alternate dump site in Block Island Sound:

a. Center Station (East Hole) 41°14'N; 71°51'W

b. Station N, 1/2 mile north 41°14.5'N; 71°51'W

c. Station S, 1/2 miles south 41°13.5'N; 71°51'W

d. Station E, 1/2 mile east 41°14'N; 71°50.3'W

e. Station W, 1/2 mile west 41°14'N; 71°51.6'W

2. Cruise 29 July 1975

A 3 current meter sub-surface array was installed at the Center Station at East Hole (Figure 1). Concurrent plankton tows were carried out in East Hole area. Navigation control was by visual bearings and by RADAR range and bearings.

3. Cruise 30 July 1975

Each station at the East Hole was sampled at 4 depths for water quality parameters and at 5m intervals for transmittance. The sample schedule was:

Stations	Current
C1, N1, E1, S1	Ebb flow
C2, N2, W1, S2	Slack water
C3, N3, W2, S3	Flood flow

Therefore, Station C, the center, was sampled 3 times during the day as was Station W and S. Station W (west) was sampled twice and the east station, E, once

4. Cruise 31 July 1975

The current meter array was retrieved during this cruise.

D. Results and Discussion

Average temperatures and salinities are tabulated in Table 1. Maximum variation in temperature at the center station, C, was 0.6°C and 0.8°/₀₀ in salinity; corresponding variations at the bottom were 0.1°C and 0.19°/₀₀. The maximum variation in both temperature and salinity occurred at Station S in the surface: 1.1°C and 0.16°/₀₀. Variations at the bottom at Station S were the same as Station C for temperature, 0.1°C, and only 0.08°/₀₀ in salinity. Station N is similar to Station C except that it is only half as deep.

The vertical temperature gradient varies from 4.8°C at Station N to 6.2°C at Station W (Table 1). These gradients are larger than the vertical gradients encountered at the dump site off New London, excepting the case of a freshwater lens originating from the Thames or from the Connecticut Rivers. In general, the high vertical gradients lead to a comparatively stable water column as can be seen in the change of density with depth.

The observed temperatures and salinities on 30 July agree with results observed in the past.

Beam transmittance (10 cm path length) and corresponding "attenuation" coefficients are tabulated in Table 2. The observations listed in this table, in general, are not significantly different from the background observations obtained at the dump site off New London.

Resultant current velocities over flood and ebb cycles are tabulated in Table 3. The averages for these 4 tidal cycles are tabulated in Tables 4a through 4c. The maximum speeds encountered, based on 15 minute averages, are tabulated in Table 5.

The moon was in quadrature on the 31st, and in apogee and on the equator on the 27th; therefore lower neap tides and correspondingly lower current speeds, as seen in Tables 3 and 4a. In other words, the tidal ranges during this period were unusually low, and therefore also the corresponding tidal velocities. For example, the predicted currents at The Race were 40% lower than the monthly average for July, and approximately 52% lower than the maximum flow.

The unusual net flow to the west (flood) at the surface in Table 5, and the unusual lower ebb flows (as compared to the floods) in Table 4a, can be attributed to the 3-foot Southeasterly swell due to extra-tropical storm "Blanche" that passed offshore the day before. Such a swell could produce a flow in the direction of propagation (NW) of approximately 10 cm/sec at 5 meters, thus enhancing the flood flow and inhibiting the ebb. The net result is therefore a net flow in the flood direction over the sampling period. A mild form of storm surge would also act in the same fashion.

The speed measuring system on the HYDRO-Products current meter on the bottom malfunctioned shortly after installation; we are trying to salvage what can be for inclusion in the next report.

Table 1 : Average Values of Temperature, Salinity and Resultant σ_t For Stations in the Alternate New London Dump Site, 30 July 1975.

Station	*N	Depth(m)	T(°C)	S(°/oo)	σ_t
C	3	0	20.4	30.63	21.36
		5	19.9	30.77	21.59
		10	19.2	30.91	21.88
		15	18.3	31.05	22.20
		20	16.8	31.20	22.67
		25	16.0	31.35	22.97
		30	15.5	31.50	23.19
		35	15.1	31.65	23.39
		40	14.8	31.78	23.56
		45	14.6	31.92	23.71
N	3	0	20.2	30.64	21.42
		5	19.5	30.73	21.66
		10	18.8	30.82	21.91
		15	17.8	30.97	22.26
		20	17.1	31.12	22.54
		25	15.9	31.60	23.18
		30	15.3	32.08	23.68
E	1	0	20.0	30.67	21.49
		5	19.6	30.63	21.56
		10	19.1	30.60	21.66
		15	18.3	30.86	22.06
		20	17.2	31.19	22.57
		25	16.4	31.52	23.01
		30	15.9	31.80	23.34
		35	15.0	31.88	23.59
		40	14.6	31.95	23.73
		45	14.4	32.02	23.83
S	3	0	20.6	30.71	21.37
		5	19.6	30.84	21.72
		10	18.9	30.98	22.00
		15	17.4	31.11	22.46
		20	16.7	31.36	22.82
		25	16.0	31.61	23.17
		30	15.1	31.86	23.56
		35	15.0	31.89	23.60
		40	14.9	31.91	23.64
		45	14.8	31.93	23.67
W	2	0	20.7	30.62	21.27
		5	19.6	30.75	21.65
		10	18.9	30.88	21.93
		15	17.7	31.00	22.31
		20	17.3	31.28	22.62
		25	16.0	31.56	23.13
		30	15.0	31.86	23.58
		35	14.8	31.93	23.67
		40	14.6	31.96	23.74
		45	14.5	32.00	23.79

* Number of Observations

Table 2 : Beam transmittance (T) and attenuation coefficient (β) as a function of depth and time for each station of the alternate New London Dump Site, 30 July 1975.

Station	C						S					
Time	0930		1125		1315		1032		1225		1412	
Depth (m)	T(%)	β(m^{-1})	T(%)	β(m^{-1})	T(%)	β(m^{-1})	T(%)	β(m^{-1})	T(%)	β(m^{-1})	T(%)	β(m^{-1})
1	92	0.83	85	1.63	82	1.99	94	0.62	85	1.63	82	1.99
5	89	1.16	83	1.86	81	2.11	86	1.51	90	1.05	82	1.99
10	86	1.51	82	1.99	80	2.23	82	1.99	85	1.63	79	2.36
15	85	1.63	81	2.11	79	2.36	81	2.11	82	1.99	78	2.49
20	84	1.74	80	2.23	78	2.49	81	2.11	81	2.11	78	2.49
25	84	1.74	80	2.23	77	2.61	80	2.23	80	2.23	76	2.74
30	84	1.74	80	2.23	76	2.74	80	2.23	80	2.23	75	2.88
35	84	1.74	80	2.23	74	3.01	79	2.36	76	2.74	71	3.43
40	84	1.74	79	2.36	73	3.15	79	2.36	74	3.01	71	3.43
45	83	1.86	78	2.49	74	3.01	78	2.42	73	3.15	70	3.57

Station	N						W				E	
Time	0950		1145		1335		1200		1350		1010	
Depth (m)	T(%)	β(m^{-1})	T(%)	β(m^{-1})	T(%)	β(m^{-1})	T(%)	β(m^{-1})	T(%)	β(m^{-1})	T(%)	β(m^{-1})
1	97	0.31	84	1.74	95	0.51	82	1.99	83	1.86	98	0.20
5	91	0.94	90	1.05	83	1.86	85	1.62	82	1.99	91	0.94
10	88	1.28	84	1.74	80	2.23	83	1.86	79	2.36	86	1.51
15	84	1.68	81	2.11	79	2.36	81	2.11	78	2.49	84	1.74
20	82	1.98	80	2.23	78	2.49	80	2.23	78	2.49	84	1.74
25	84	1.74	80	2.23	76	2.74	80	2.23	78	2.49	84	1.74
30	81	2.11	77	2.61	74	3.01	80	2.23	78	2.49	84	1.74
35							79	2.36	75	2.88	83	1.86
40							77	2.61	73	3.15	82	1.99
45							76	2.74			80	2.23

Table 3 : The Resultant Current Velocities at the Alternate Dump Site, Center Station (Half-Tidal Cycle).

Date	Cycle	Z (5)	Flood U (1)	Flood V (1)	Flood R (1)	Flood θ (2)	Flood D(R) (3)	Flood t (4)	Ebb U (1)	Ebb V (1)	Ebb R (1)	Ebb θ (2)	Ebb D(R) (3)	Ebb t (4)
29 VII 75	1	5.5	-34.7	-3.9	34.9	264	7.4	5.7*	19.7	7.7	21.2	69	5.3	6.2
30 VII 75	2	5.5	-32.0	-7.2	32.8	257	8.1	6.4	19.8	6.8	20.9	71	4.7	5.7
30 VII 75	3	5.5	-30.4	-6.3	31.0	258	8.4	6.9	24.1	10.8	26.4	66	5.8	5.7
31 VII 75	4	5.5	-27.9	-10.5	29.8	249	8.1	6.9	11.9	2.7	12.2	77	2.5	4.5
29 VII 75	1	27.0	-21.6	17.4	27.8	309	4.4	4.4*	28.0	2.1	28.1	86	7.8	6.9
30 VII 75	2	27.0	-18.4	17.2	25.2	313	5.0	5.4	30.9	2.4	31.0	86	7.8	6.4
30 VII 75	3	27.0	-20.1	15.9	25.6	308	5.0	5.4	32.0	-4.5	32.4	98	9.2	7.1
31 VII 75	4	27.0	-18.8	18.1	26.1	314	4.6	4.9	27.1	2.3	27.2	85	8.3	7.9

(1) Cm/Sec

(2) Degrees (Circular) Relative to Geographic North

(3) Kilometers

(4) Hours

(5) Depth from the Surface (Meters)

* Not a complete cycle

Table 4a: Average velocities for flood and ebb tidal cycles calculated from the half tidal cycle data.

	Flood		Ebb	
Depth(m)	R̄(cm/sec)	θ(°T)	R̄(cm/sec)	θ(°T)
5.5	32.0	257	20.1	70
27.0	26.1	311	29.5	89

Table 4b: Average effective distances and durations calculated from the half tidal cycle data.

	Flood		Ebb	
Depth(1)	D̄(R)(2)	t̄(3)	D̄(R)(2)	t̄(3)
5.5	8.0	6.5	4.6	5.5
27.0	4.8	5.0	8.3	7.1

(1) Meters (2) Kilometers (3) Hours

Table 4c: The net average tidal cycle flow for each depth calculated from the average velocities.

Depth(m)	R(cm/sec)	θ(°T)
5.5	6.2	270
27.0	10.1	029

Table 5 : The maximum observed speeds based on 15 minute averages.

		Flood		Ebb	
Date	Depth(m)	R(cm/sec)	θ(°T)	R(cm/sec)	θ(°T)
29 VII 75	5.5	54.2	273	38.5	066
	27.0	34.2	307	50.0	101
30 VII 75	5.5	53.4	257	38.9	063
	27.0	33.4	317	59.7	095

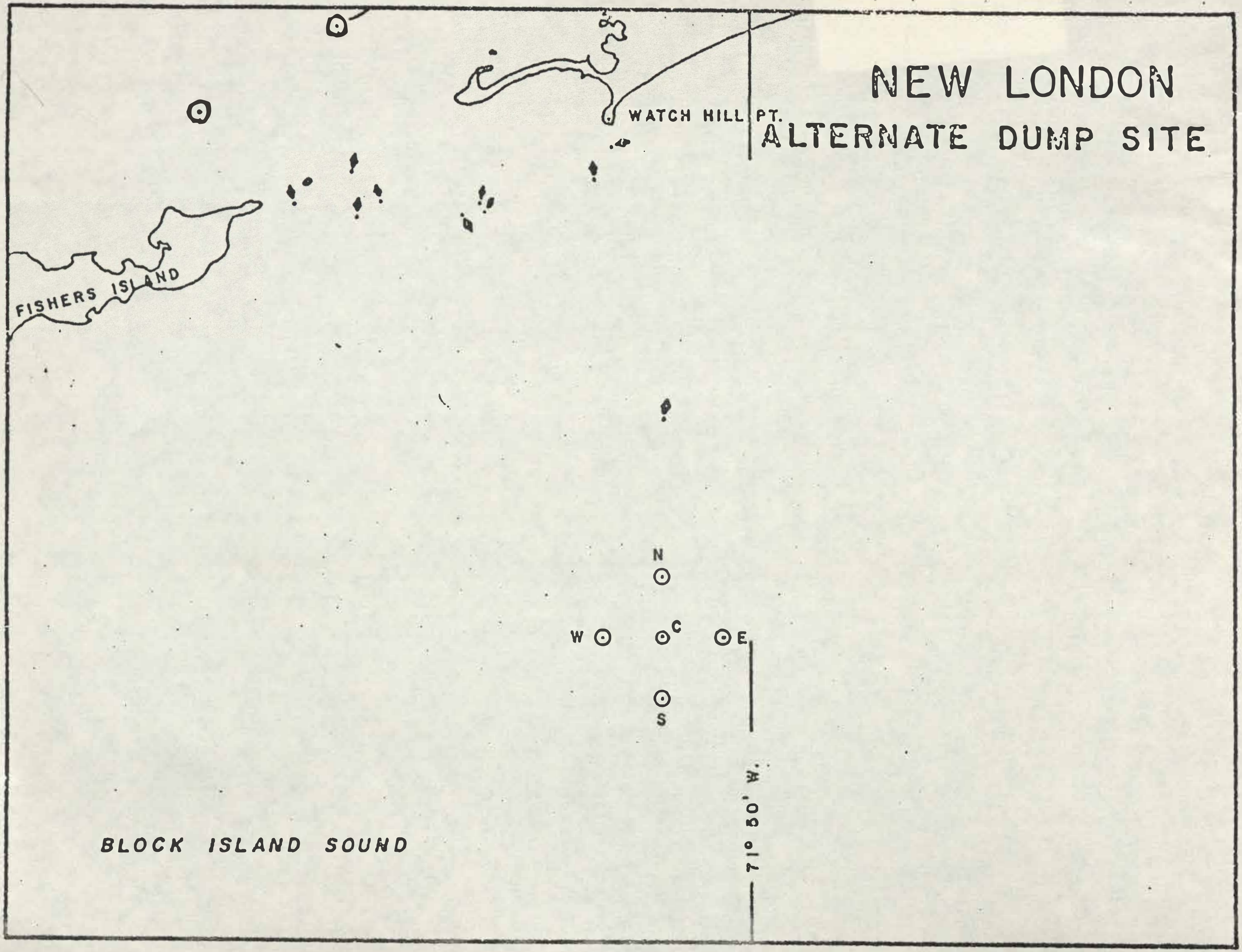

Figure 1: Station locations for the alternate dump site