DAMOS

DISPOSAL AREA MONITORING SYSTEM

ANNUAL DATA REPORT

PROCEEDINGS OF SYMPOSIUM
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VOL II
BIOLOGICAL OBSERVATIONS

NEW ENGLAND DIVISION
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VOLUME II

BIOLOGICAL OBSERVATIONS

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8.0 HEAVY METAL CONCENTRATIONS AND GONADAL DEVELOPMENT IN MYTILUS EDULIS AND MODIOLUS MODIOLUS

8.1 TRACE METAL BODY BURDENS IN MYTILUS EDULIS AND MODIOLUS MODIOLUS

(R.V. Grillo, J.K. Watson, E.M. Haddad, T.R. Ouellete, and S.Y. Feng)

8.1.1 Introduction

According to Bayne (1976a), pollutants are accumulated by marine organisms which contact contaminants in the water and sediment, or ingest others with their food. At concentrations above natural levels, trace metals may be considered as contaminants which can impose a stress upon marine oganisms. Concern has arisen regarding the deleterious effects of some metals on physiological and behavioral functions of commercially and ecologically important species of marine invertebrates. Many bivalves, being filter feeders, are well known bioconcentrators of trace metals. These animals may thus serve as a potential tool for monitoring temporal and spatial variations in ambient metal and other pollutant concentrations. In particular, the blue mussel, Mytilus edulis, is well suited for trace metal pollution studies due to its ubiquitous distribution and ability to function in a wide variety of temperature and salinity regimes (Bayne 1976b; Goldberg, 1975).

During the past seven years the Marine Science Institute has been engaged in the analysis of trace metals in tissues of natural and experimental populations of filter-feeding bivalves. In recent studies of the New London Disposal Site Project, we have shown that changes in the levels of some trace metals in the tissue probably reflect both anthropogenic activities and seasonal variations associated with physiological activities of the organism. This report presents the preliminary results of the trace metal concentrations found in two species of mussel which were deployed at major disposal and reference sites in New England coastal waters.

Our main goals during the first year of the DAMOS study have been to determine the variability of trace metal concentrations in the monitoring organisms at various sites and to develop effective field deployment and retrieval techniques for the mussel monitoring platforms. Since the first deployment of the experimental platforms in early 1978, 40 samples have been analyzed in triplicate for 10 metals through March 1979.

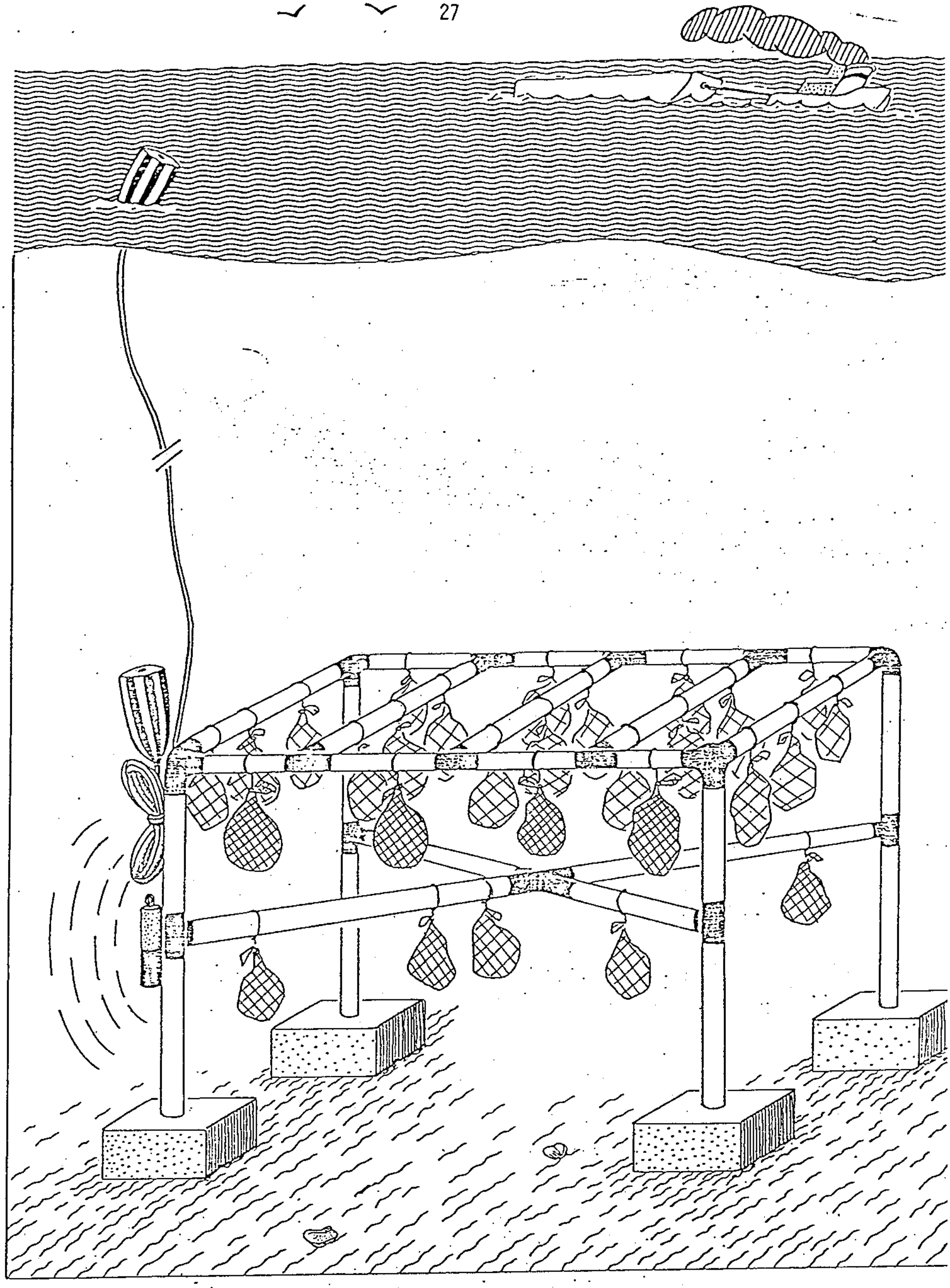
8.1.2 Materials and Methods

Although several species of filter-feeding bivalve molluscs are known to reflect changes in exposure of trace metals, specific criteria dictated the selection of organisms for this study. Organisms suitable for long-term trace metal monitoring should be robust, active through a major portion of the year, and of sufficient size and local abundance to permit frequent sampling. Accordingly, the horse mussel, *Modiolus modiolus*, and the blue mussel, *M. edulis*, were chosen for monitoring DAMOS sites located north and south of Cape Cod, respectively.

Ten replicate samples of *M. modiolus* were collected in August 1977 from natural populations near each of four northern disposal sites and analyzed for trace metals. Based on these preliminary observations, a single stock population with relatively low trace metal content was selected for each disposal area and designated as a reference population.

Populations of *M. edulis* at Latimer's Light, N.Y. and Newport, R.I. were selected as a reference stock for the southern New England sites. The former area was used to stock all Long Island Sound sites, while the latter supplied the Brenton Reef dumpsite platform.

Experimental stations were established at each of the dumpsites during the first five months of 1978. At the same time, large numbers of mussels were collected from the selected stock populations, placed in polyethylene mesh bags, attached to one meter tall PVC platforms, and deployed at corresponding disposal sites. A typical platform configuration is shown in Figure 8.1; corresponding disposal sites, reference areas, and deployment dates are listed in Table 8.1.1.



PVC PLATFORM USED FOR MUSSEL SAMPLING

FIGURE 8.1.1

Table 8.1.1 Deployment of the Mussel Monitors at the Northern and Southern New England Sites

A. *Modiolus modiolus*

Disposal Area	Reference Area	Date Deployed
Rockland	Drunkard's Ledge	5-12-78
Portland	Bulwark Shoals	5-14-78
--	Isle of Shoals	5-19-78
Boston Foul Ground	Halfway Rock	5-21-78
Boston Lightship	Halfway Rock	5-21-78

B. *Mytilus edulis*

Disposal Area	Reference Area	Date Deployed
Brenton Reef	Newport Outer Bridge	5-11-78
Cornfield Shoals	Off Cornfield Shoals Dumpsite	1-16-79
New Haven Dumpsite	Off New Haven Dumpsite	4-10-78
WLIS	--	4-10-78
Cable & Anchor Reef	--	4-10-78

All reference and experimental sites were sampled on a quarterly basis by divers from the Naval Underwater Systems Center and the Marine Sciences Institute of the University of Connecticut. In some instances, sampling was interrupted by adverse weather conditions or by the irretrievable loss of experimental platforms. Shellfish from individual bags were either refrigerated for trace metal analyses or shucked and fixed in buffered formalin for histological examination. Two or more subsamples, each consisting of four individual Modiolus or eight Mytilus from each station, were prepared for trace metal determination. Animals were cleaned, measured, shucked, weighed, and homogenized prior to lyophilization. A 0.8 g portion of each freeze-dried subsample was digested for 6 hours at 50°C with concentrated nitric acid and diluted to 50 ml with distilled deionized water. Each digested sample was passed through a pre-cleaned glass fiber filter to remove any refactory material and was then stored in an acid-cleaned polyethylene vial.

The samples were analyzed using flame atomic absorbtion spectrophotometry (Instrumentation Laboratory 151) for copper, zinc, and iron; flameless atomic absorption spectrophotometry (Perkin-Elmer 5000 and HGA-500 Furnace) for cadmium, chromium, nickel, lead, cobalt and vanadium, and cold vapor absorption spectrophotometry (Perkin-Elmer MAS-50 Mercury Aanlyzer) for mercury. Extreme care was taken during both the preparative and analytical stages to avoid trace metal contamination.

Results were corrected for blank values and calibrated by comparison with similarly prepared metal standards. The data were interpreted and plotted using a Hewlett-Packard System 45 computer and 9872A plotter. Detection limits of the analytical techniques and observed values of metals in a National Bureau of Standars reference materal are presented in Table 8.1.2.

The trace metal body burden data are presented graphically in Figures 8.1.2 - 8.1.8 as the mean concentration of trace metals in μg/g±2 standard deviations versus time. Chromium values for some samples have not been determined due to analytical difficulties.

Table 8.1.2 Analytical detection limits and results of analyses of NBS Standard Reference Material #1577 (Bovine Liver). All results are expressed in terms of ug/g.

	Cd	Co	Cu	Hg	Pb	Zn
Detection Limit	0.02	0.08	0.1	0.020	0.04	0.1
NBS Ref. Material #1577						
This Study	0.29	--	168	--	0.37	138
Certified Value	0.27±0.04	0.18*	193±10	0.016±0.002	34±0.08	130±13

* denotes non-certified value

8.1.3 Results and Discussion

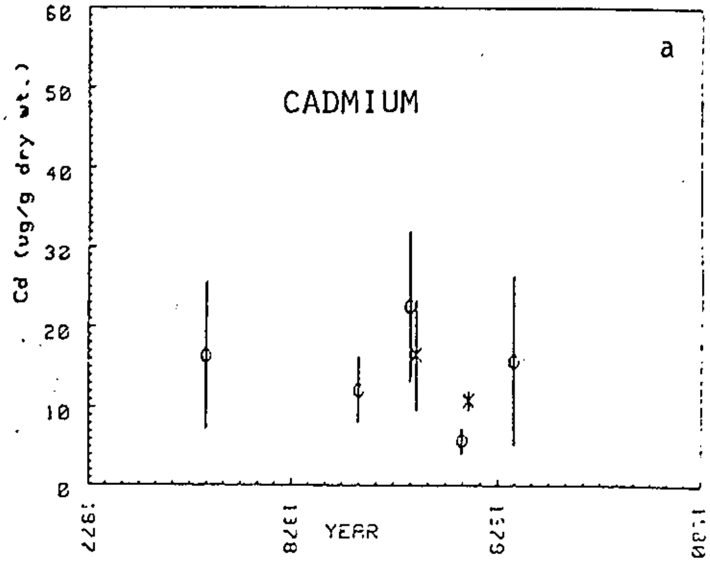
8.1.3.1 Northern New England

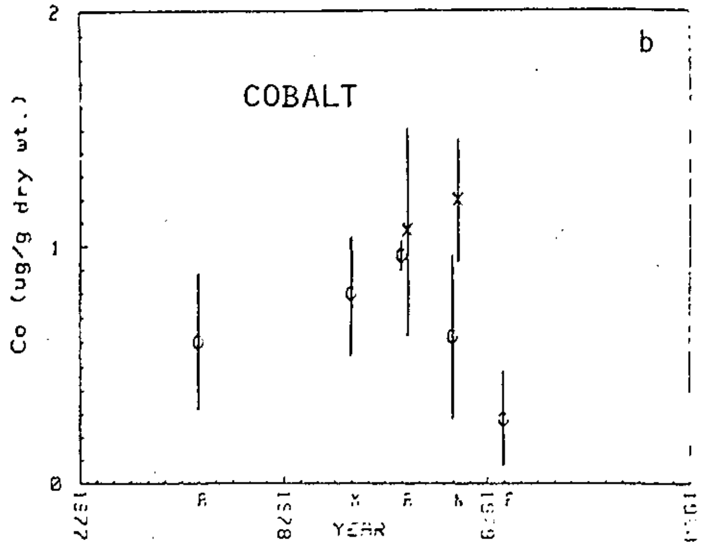
Figure 8.1.2 presents the trace metal concentration data from the Rockland disposal site and Drunkard's Ledge reference site. Cu concentrations in M. modiolus show little change with time at Drunkard's Ledge and are similar to Cu concentrations in mussels held at the disposal site (Fig. 8.1.2c) Pb, and to a lesser extent, Zn values exhibit a general downward trend at both the reference and dumpsite stations from May 1978 to February 1979 (Figs. 8.1.2e and 1).

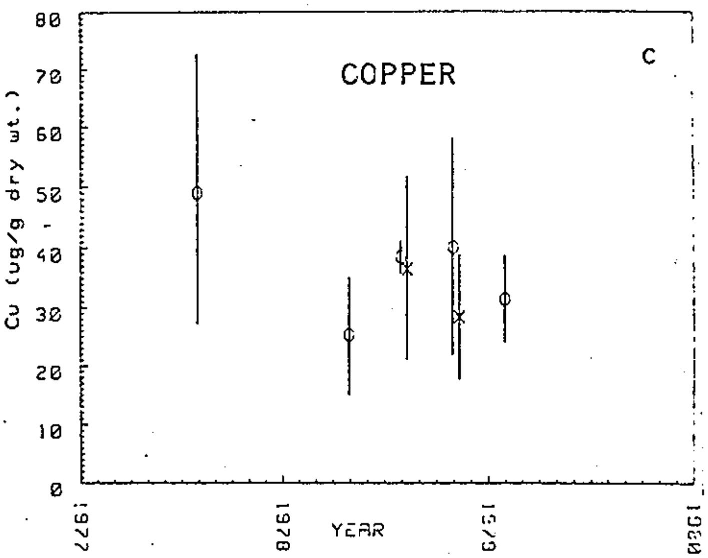
The levels of Cd, Co, Hg, Ni, and Fe in mussels from Drunkard's Ledge decreased from May through November 1978 (Figs. 8.1.2a,b,d,f, and g. In February 1979, Cd, Hg, Ni, and Fe values increased, while Co decreased. In August and November 1978, the concentrations of the preceding five metals in animals held at the Rockland dumpsite increased as compared with that of the animals collected from the natural reference station.

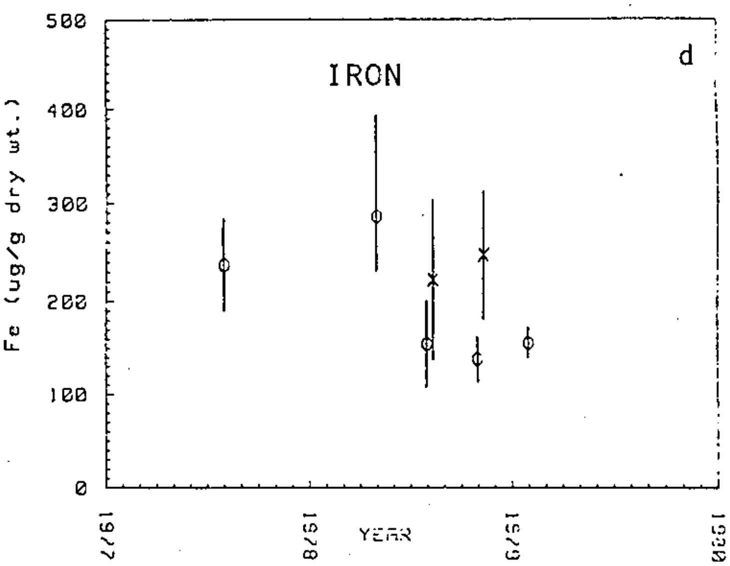
At Bulwark Shoals, the reference station for the Portland disposal site, either no change or a slight decrease in all metal concentrations occurred between August and March, 1979 Fig. 8.1.3). All metal concentrations for animals sampled from the Portland disposal site on August 1978 were less than or equal to those in mussels collected at Bulwark Shoals. During subsequent sampling dates in November and February 1978 levels of all metals, with the exception of Cd (Fig. 8.1.3a· were higher in mussels taken from the dumpsite than those sampled from the reference site.

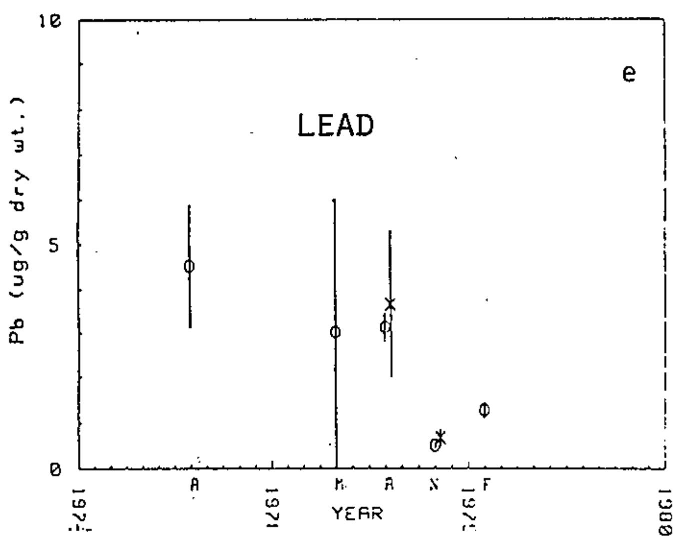
Overall, both the Rockland and Portland area exhibit a similar trend between their respective reference and disposal sites. From May 1978 to March 1979, the trace metal concentrations of the dumpsite mussels were higher than that of the reference site mussels. The Rockland disposal site, located on an old spoil pile, has not been used since 1974, while the Portland dumpsite is a newly designated disposal area yet to be utilized. It would appear that at Rockland the old spoil pile contributed to the observed increase in the body burden of metals in mussels. This argument, however, will not be able to





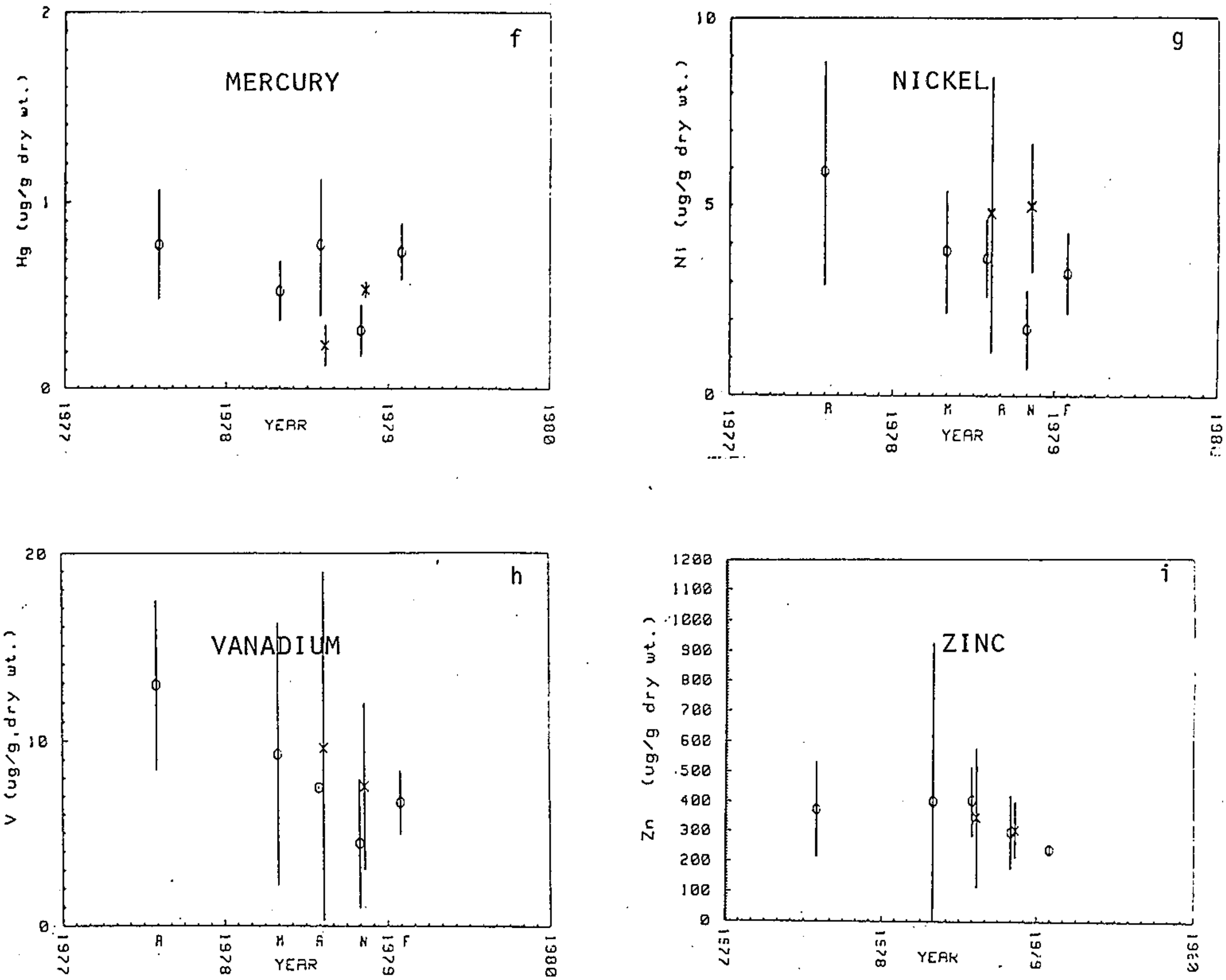






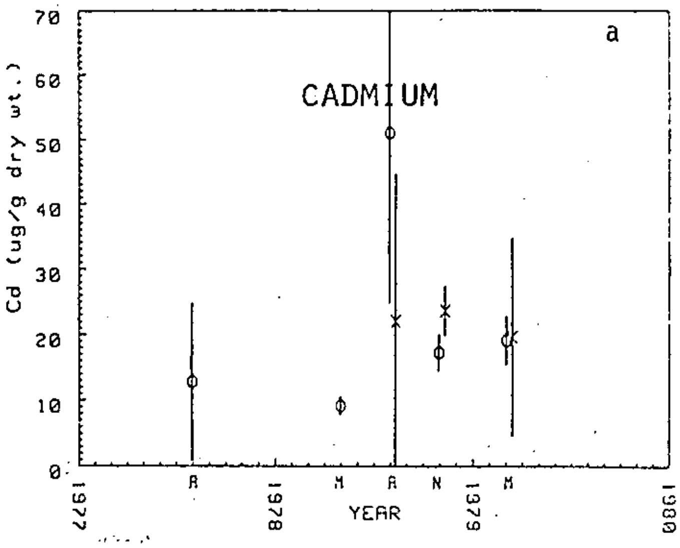
CONCENTRATION OF HEAVY METALS IN M. MODIOLUS FROM DRUNKARDS LEDGE (O) AND ROCKLAND DISPOSAL SITE (X)

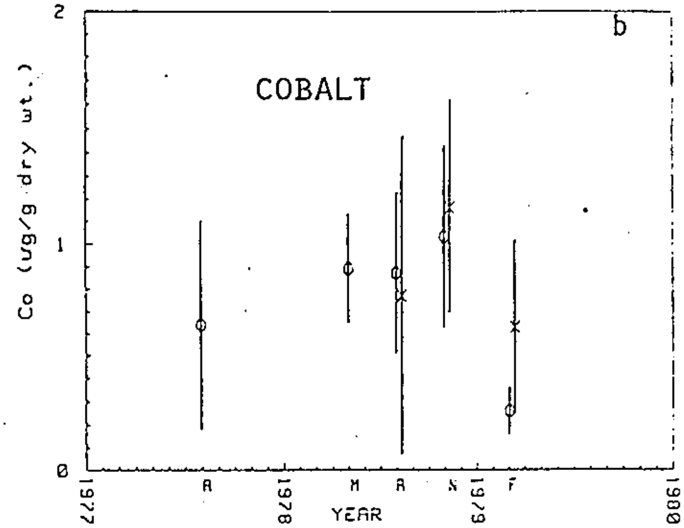
FIGURE 8.1.2

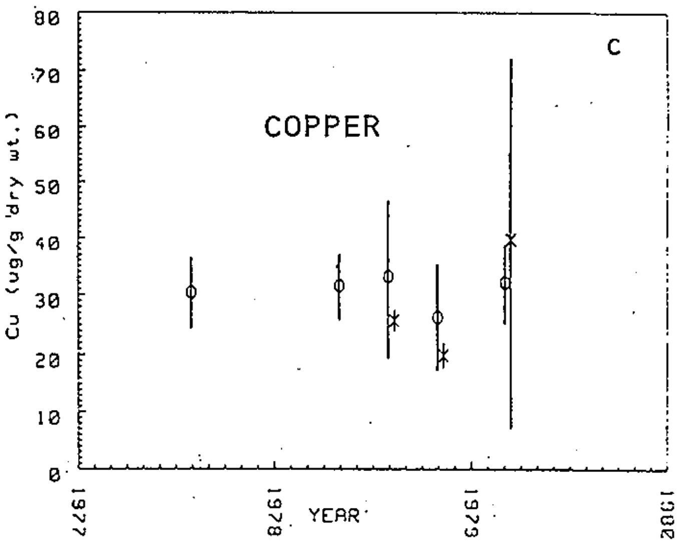


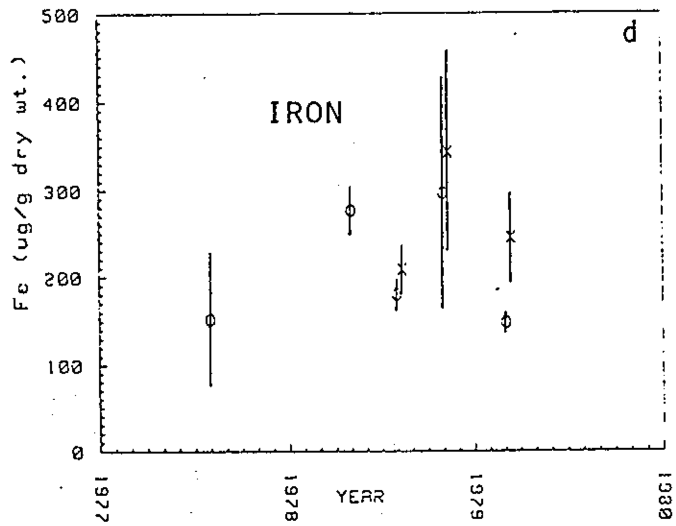
CONCENTRATION OF HEAVY METALS
IN M. MODIOLUS FROM
DRUNKARDS LEDGE (O) AND ROCKLAND
DISPOSAL SITE (X)

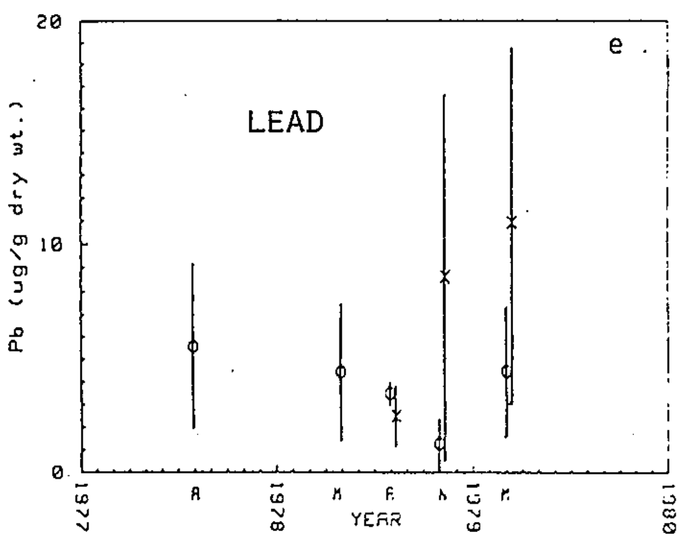
FIGURE 8.1.2





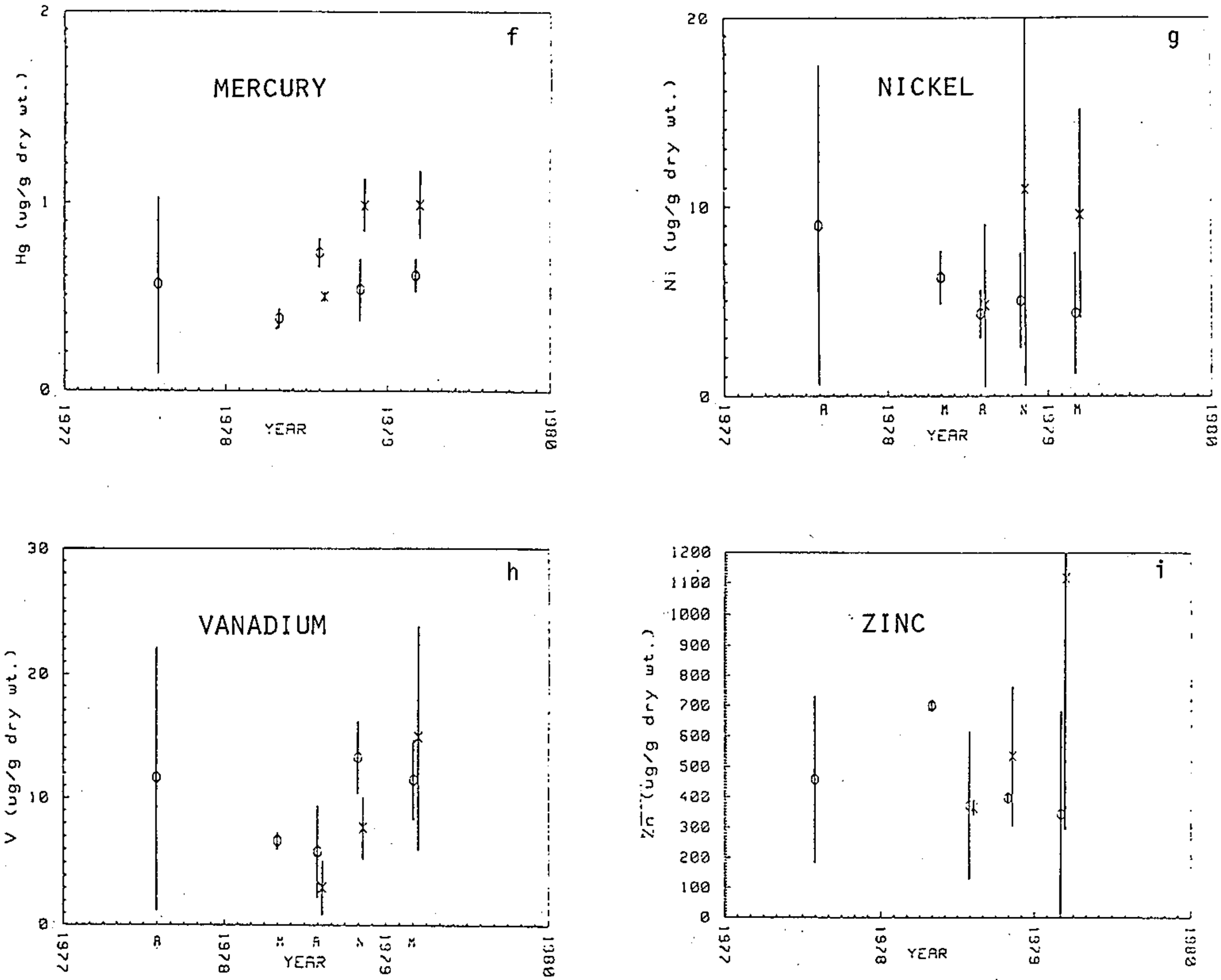






CONCENTRATION OF HEAVY METALS IN M. MODIOLUS FROM BULWARK SHOAL (O) AND PORTLAND DISPOSAL SITE (X)

FIGURE 8.1.3



CONCENTRATION OF HEAVY METALS
IN M. MODIOLUS FROM
BULWARK SHOAL (O)
AND PORTLAND DISPOSAL SITE (X)

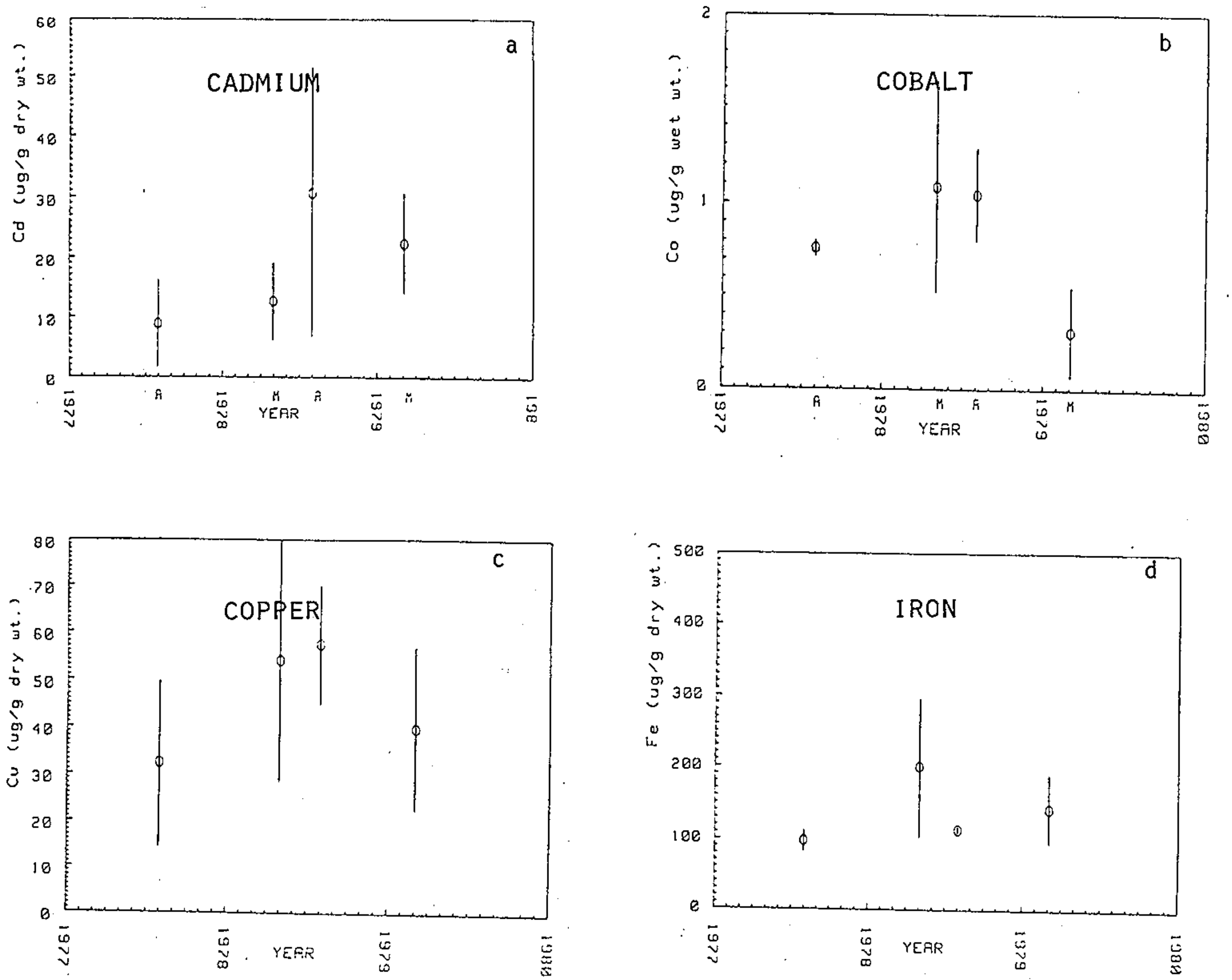
FIGURE 8.1.3

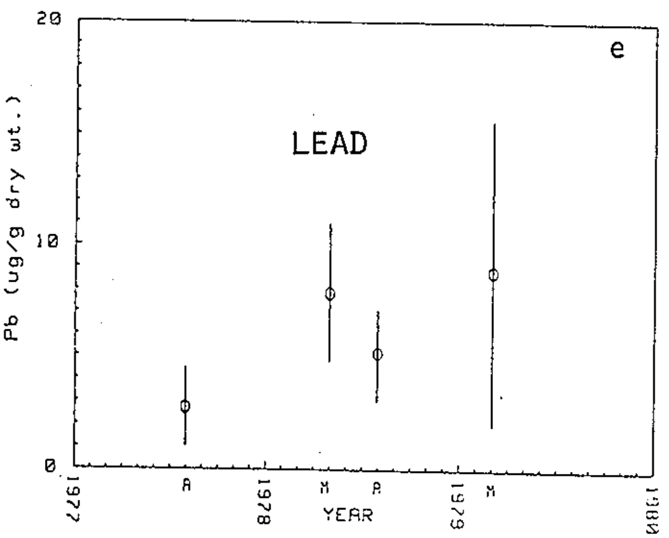
explain the higher level of metals in mussels at the Portland dispoal site; perhaps in this case the cause was not related to spoil dumping but to other factors, e.g., history of the site, depth, temperature, energy regime, geochemistry of the sediment, etc. These factors could dictate the availability of metals in the envrionment and alter the mussels' physiological response, and lead to the observed difference in trace metal body burdens between animals taken from the disposal and reference stations.

At the present time the Isles of Shoals Reference Site has no corresponding disposal area. From May 1978 to March 1979, concentrations of Cu, Ni, V, Pb, Zn, Cd, and Fe showed little variation (Fig. 8.1.4). Co, however, decreased from August 1978 to March 1979, while Hg increased (Figs. 8.1.4b & f.

The collection of samples from the Boston Foul Ground disposal site has been impeded by the repeated loss of the mussel platform. Samples collected at Halfway Rock, the reference site for the Boston Foul Ground, showed little change in metal concentrations from May through December 1978 (Figs. 8.1.5a-i. Mussels held at Boston Lightship, a secondary disposal site located approximately 2 km from the Foul Ground site, had metal concentrations which approximated those in animals at Halfway Rock from the December 1978 sample. The Boston Foul Ground Site was sampled on August 1978. With the exception of Fe and Hg (Figs. 8.1.5d & f, all metal concentrations in mussels at the Foul Ground were lower than those at Halfway Rock. Levels of Fe in mussels were higher at the Boston Foul Ground, while the Hg values were approximately the same at both the dumpsite and reference station.

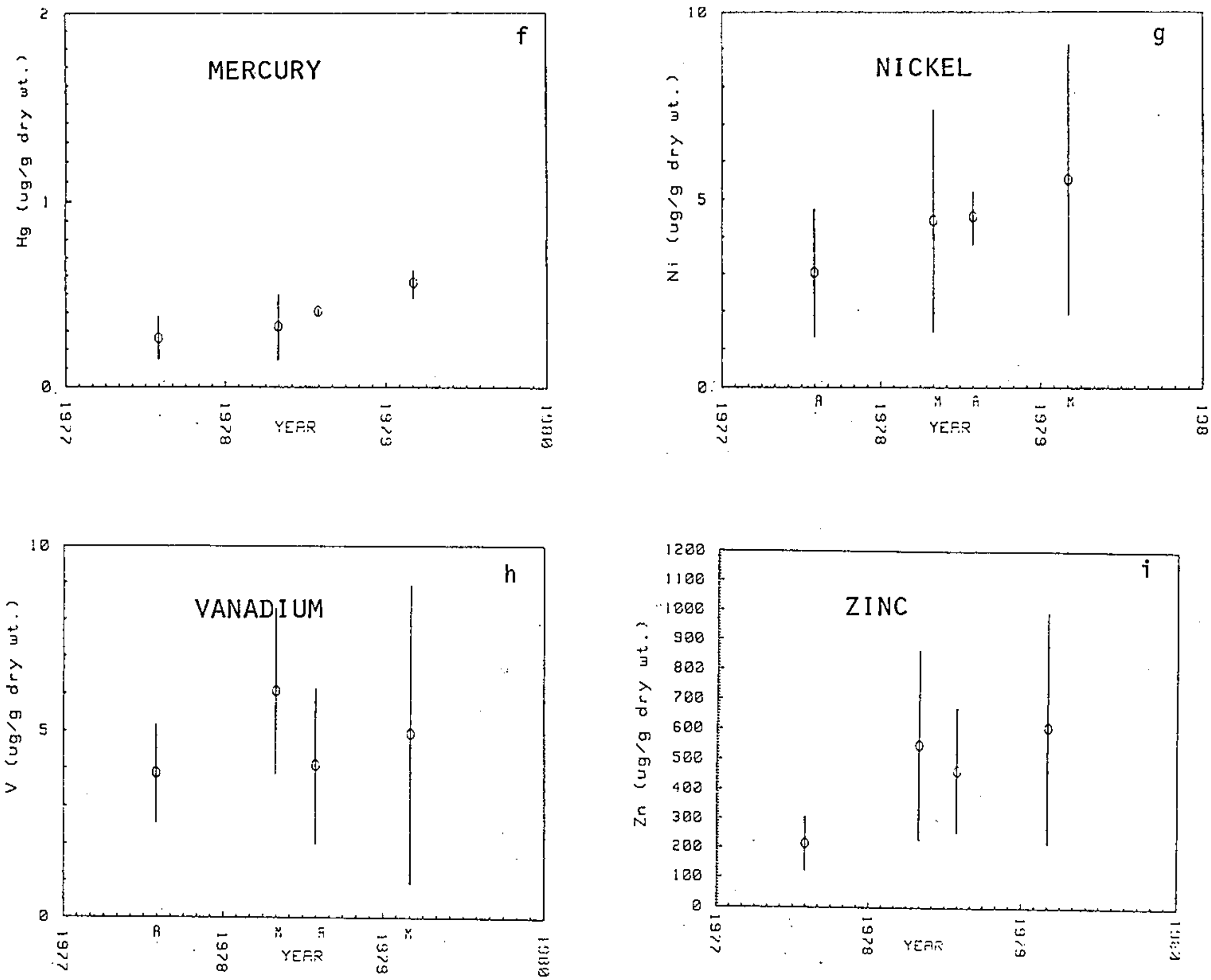
Data indicates that the reference population at Halfway Rock, being closer to terrestrial sources of pollution, is probably exposed to similar or higher concentrations of some trace metals than the mussels held at the offshore dumpsites. However, it is also possible that the same conditions may exist at the Massachusetts Bay sites as has been observed at both the Portland and Rockland sites. That is, for the first sampling of the dumpsite platform after its deployment, the trace metal concentrations are generally lower than or equal to those in mussels at the reference site. Subsequent samples taken from both the reference and dumpsite stations show increases of the dumpsite metal concentrations over those of the reference station.





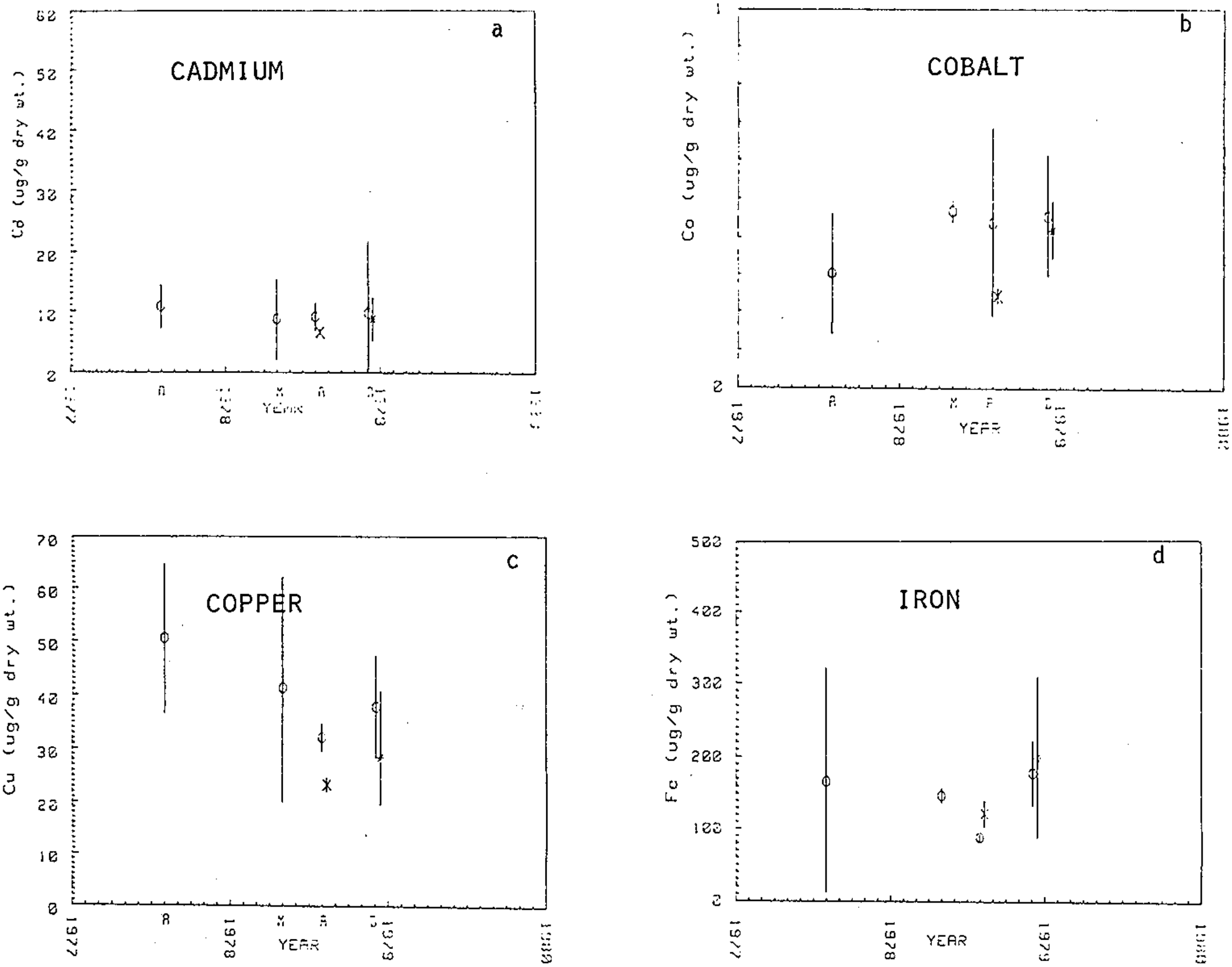
CONCENTRATION OF HEAVY METALS IN M. MODIOLUS FROM ISLE OF SHOALS (O)

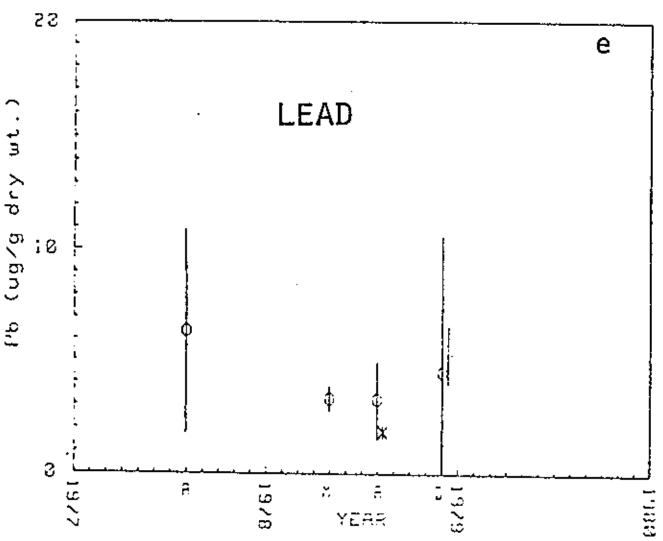
FIGURE 8.1.4



CONCENTRATION OF HEAVY METALS
IN M. MODIOLUS FROM
ISLE OF SHOALS (O)

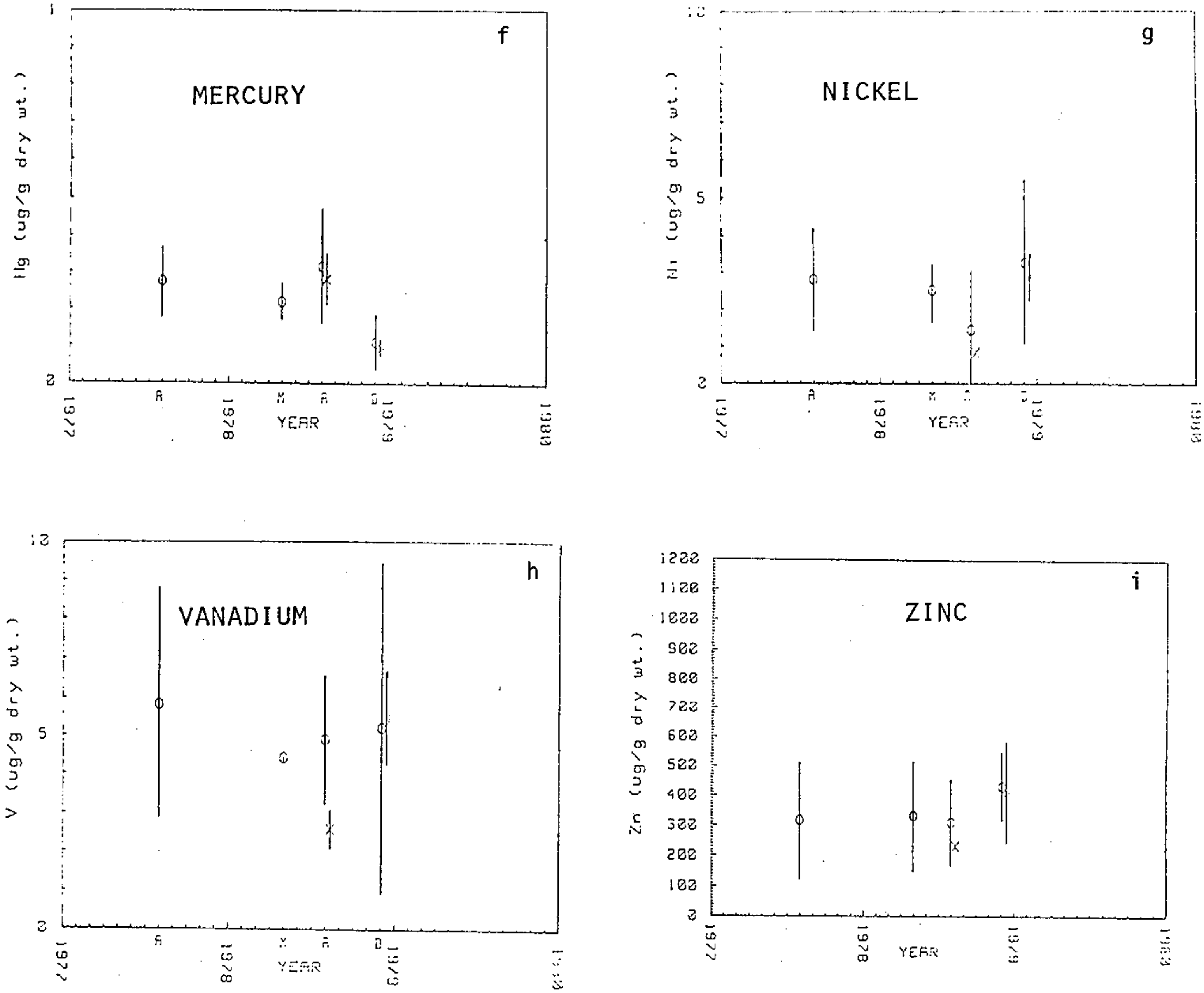
FIGURE 8.1.4





CONCENTRATION OF HEAVY METALS IN M. MODIOLUS FROM HALFWAY ROCK (O), BOSTON FOUL GROUND (X), AND BOSTON LIGHTSHIP (*)

FIGURE 8.1.5



CONCENTRATION OF HEAVY METALS
IN M. MODIOLUS FROM
HALFWAY ROCK (O), BOSTON FOUL GROUND (X)
AND BOSTON LIGHTSHIP (*)

FIGURE 8.1.5

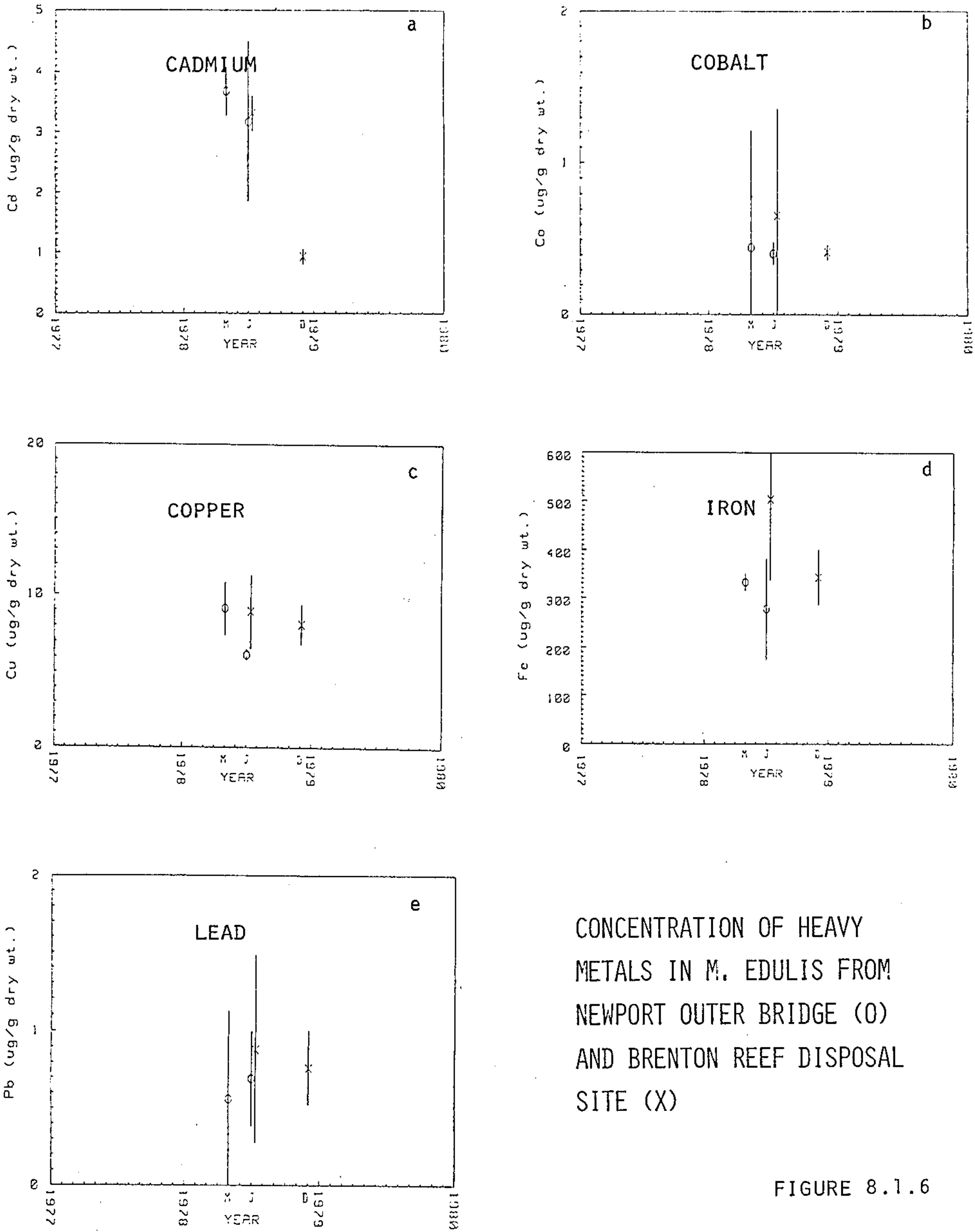
8.1.3.2 Southern New England

The trace metal data from M. edulis at the Newport Outer Bridge reference site and Brenton Reef disposal site are shown in Figure 8.1.6. Cu, Cd, V, Fe, and Hg concentrations decreased in mussels taken at the reference site from May to July 1978 (Figs. 6a,c,d,f,g,h), while Ni, Pb, and Zn increased (Figs. 8.1.6 e g & i). Metal concentrations in tissues from mussels taken at the dumpsite decreased from July to December 1978 for all metals except V which increased (Fig. 8.1.6 h) and Cu and Zn which remain constant (Figs. 8.1.6 c & i) . When the July Samples from the disposal and reference sites are compared, the concentrations of metals at the dumpsite are generally higher than at the reference site, with the exception of Ni and Zn (Figs 8.1.6 g & i).

M. edulis from Latimer's Light were used to stock all stations in Long Island Sound. Data have been collected from this station on a relatively uninterrupted basis provide information on naturally occurring seasonal trends of trace metals in tissues of this species (Figs. 8.1.7). For example, the concentrations of V, Ni, Co, and Pb deceased from January through August 1978, and then increased in October and December (Figs. 8.1.7 b,e,g and h). Cu and Hg, however, exhibited little seasonal change (Fig. 8.1.7).

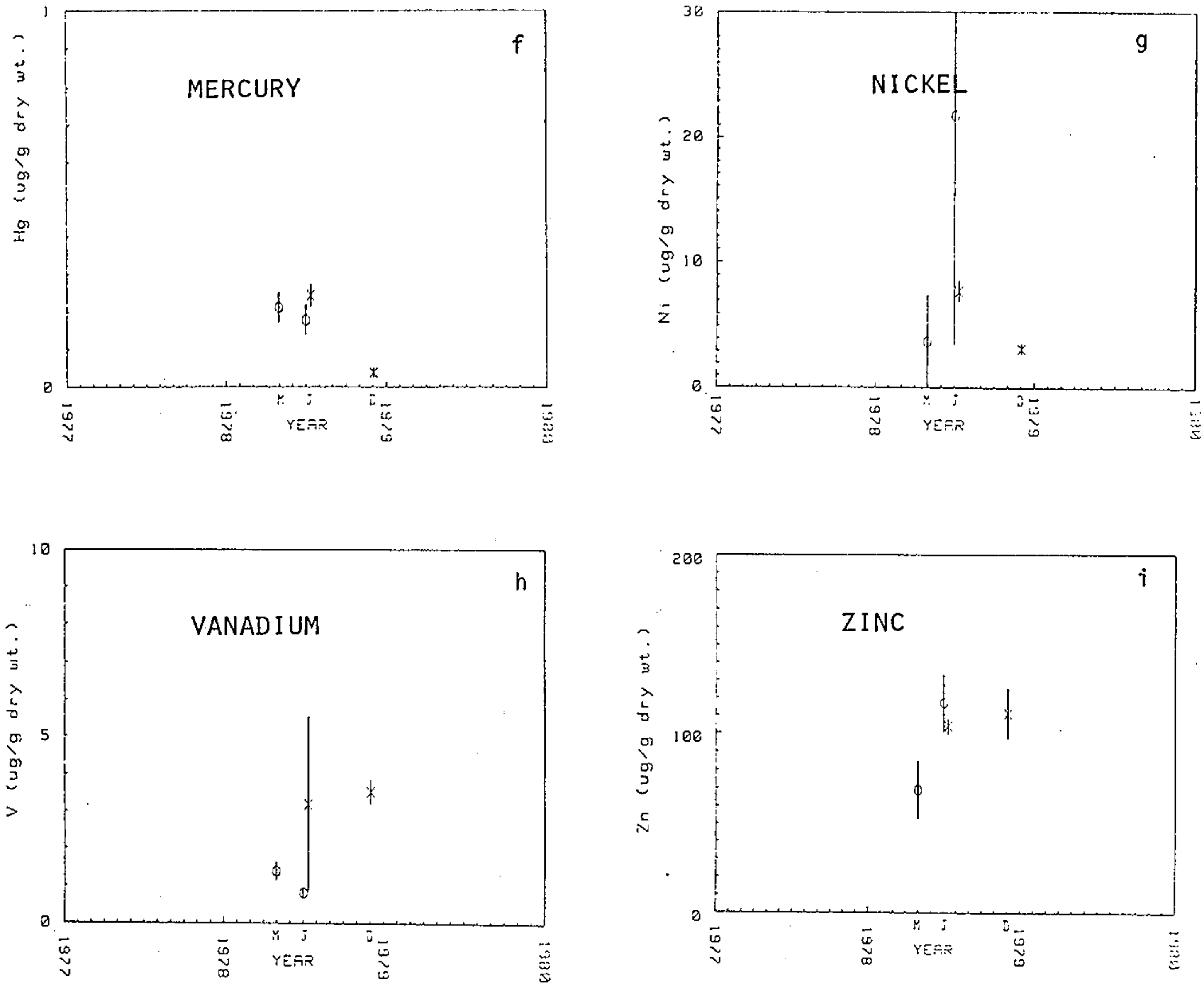
Concentrations of heavy metals in M. edulis at the Cornfield Shoals, New Haven, New Haven Reference, Western Long Island Sound, and Cable and Anchor Reef sites are all presented in Figures 8.1.8. At the Cornfield Shoals reference site, trace metal concentrations of Cu, Co, Hg, Pb, and Zn decreased from April to August 1978 (Figs. 8.1.8 b, d, e, f, and i) while V increased (Fig. 8.1.8h). There is no apparent change in tissue metal concentrations for Ni, Cd, and Cr. (Figs. 8.1.8 a, c and g.

At the New Haven sites, all metal concentrations in tissues taken from mussels at the dumpsite in July 1978 were significantly higher than those from tissues obtained at the reference site. As with the New Haven disposal site, the Cable and Anchor Reef and Western Long Island Sound disposal sites were



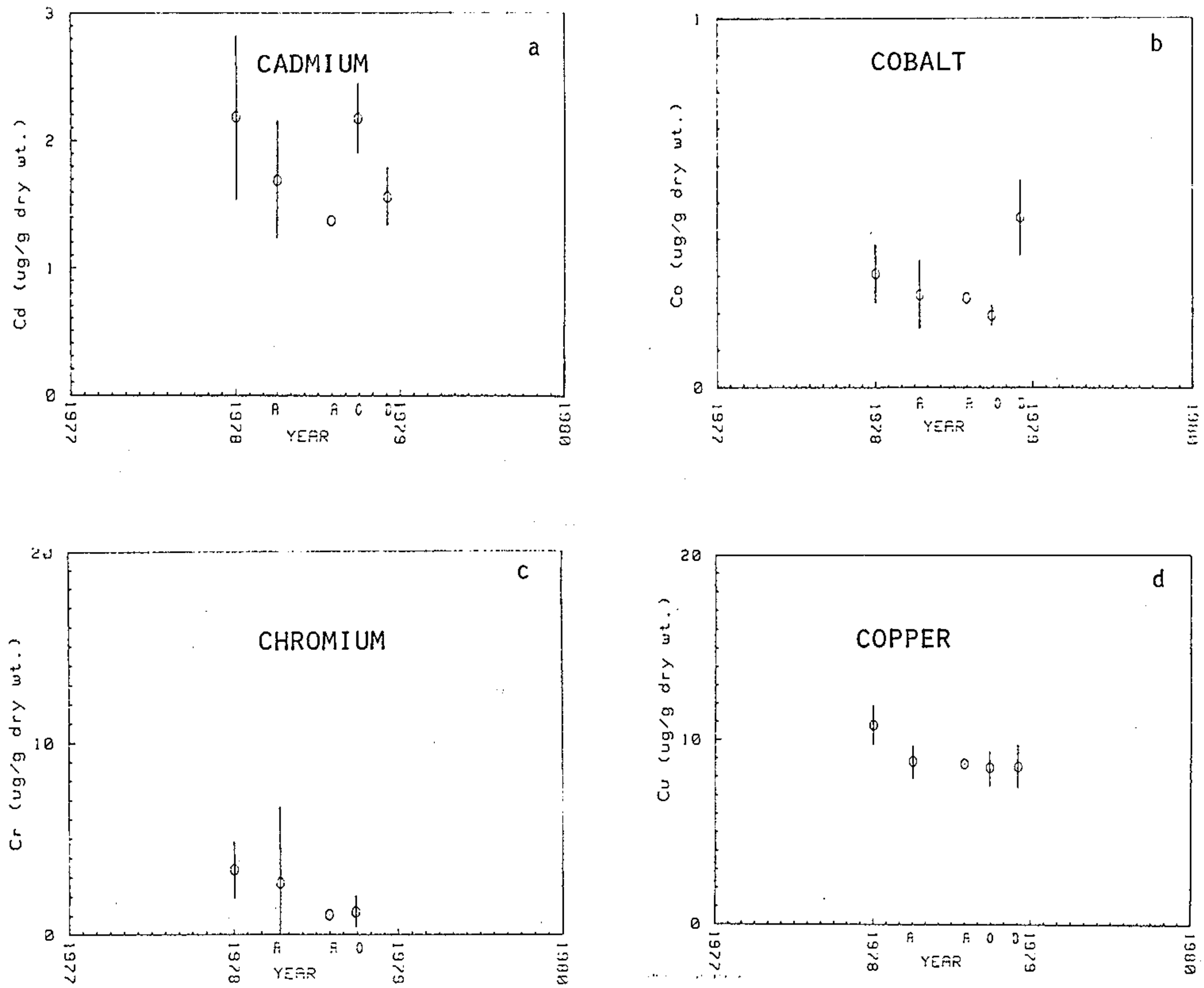
CONCENTRATION OF HEAVY METALS IN M. EDULIS FROM NEWPORT OUTER BRIDGE (O) AND BRENTON REEF DISPOSAL SITE (X)

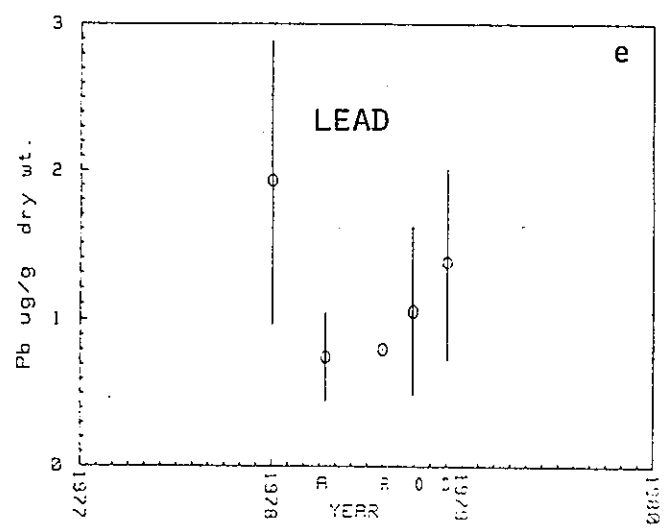
FIGURE 8.1.6



CONCENTRATION OF HEAVY METALS
IN M. EDULIS FROM
NEWPORT OUTER BRIDGE (O) AND
BRENTON REEF DISPOSAL SITE (X)

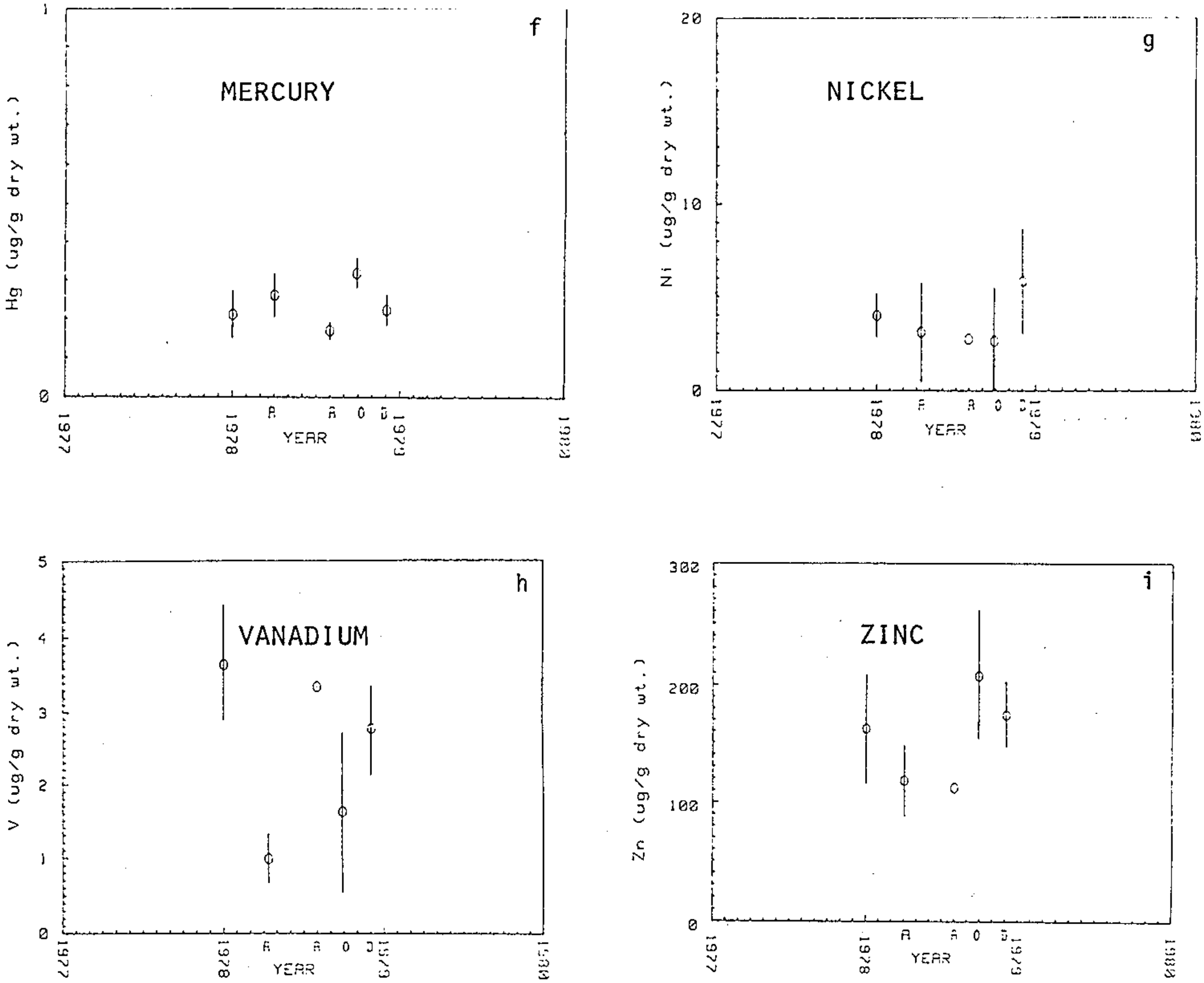
FIGURE 8.1.6





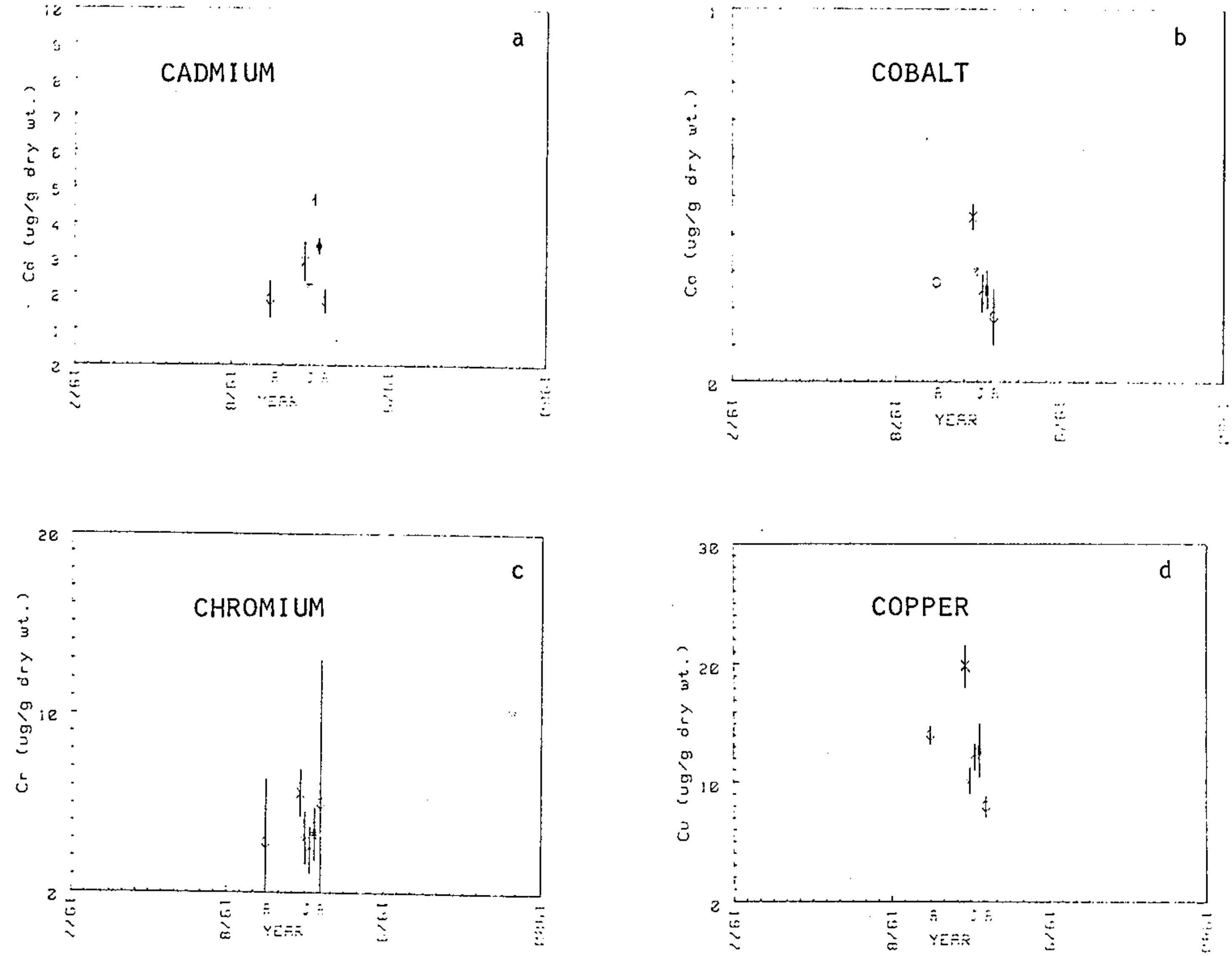
CONCENTRATION OF HEAVY METALS IN M. EDULIS FROM LATIMER'S LIGHT (O)

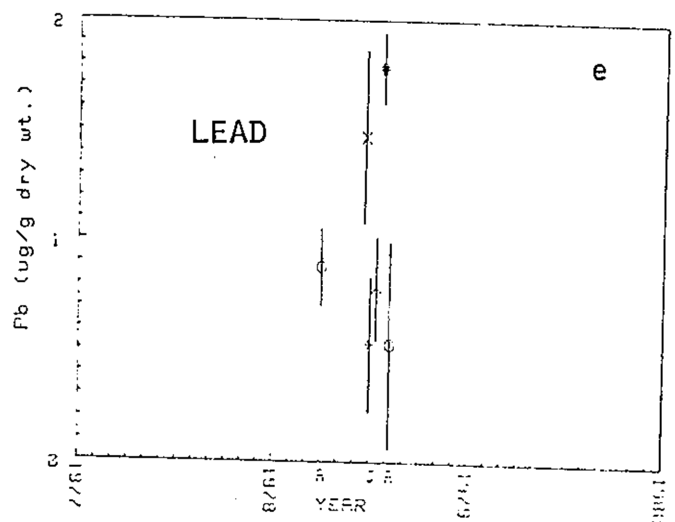
FIGURE 8.1.7



CONCENTRATION OF HEAVY METALS
IN M. EDULIS FROM
LATIMERS LIGHT (O)

FIGURE 8.1.7

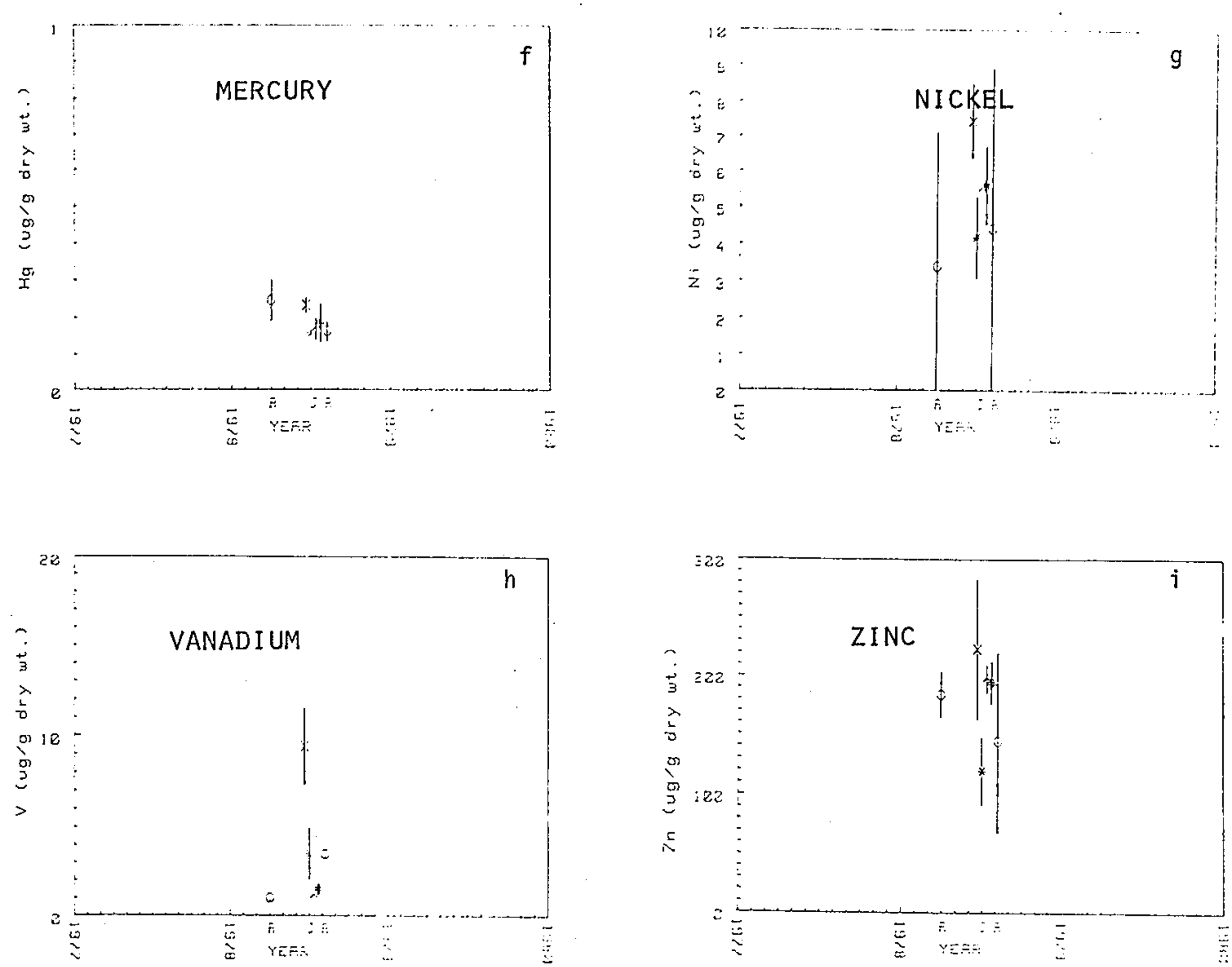




CONCENTRATION OF HEAVY METALS IN M. EDULIS FROM
CORNFIELD SHOALS (O)
NEW HAVEN DISPOSAL SITE (X)
NEW HAVEN REFERENCE (*)
WLIS DISPOSAL SITE (^)
CABLE & ANCHOR REEF (#)

new symbol for STNH N,S.

FIGURE 8.1.8



CONCENTRATION OF HEAVY METALS
IN M. EDULIS FROM
CORNFIELD SHOALS (O), NEW HAVEN
DISPOSAL SITE (X), NEW HAVEN REFERENCE (*)
WLIS DISPOSAL SITE (^) AND CABLE &
ANCHOR REEF (#)

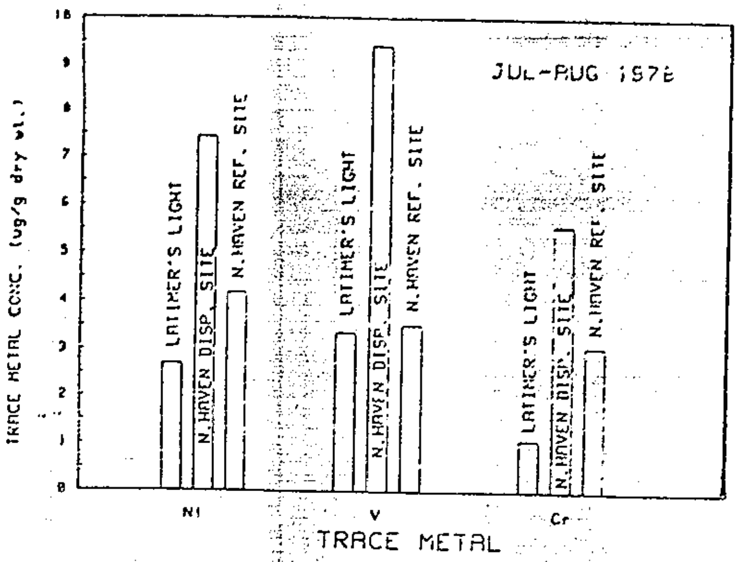
FIGURE 8.1.8

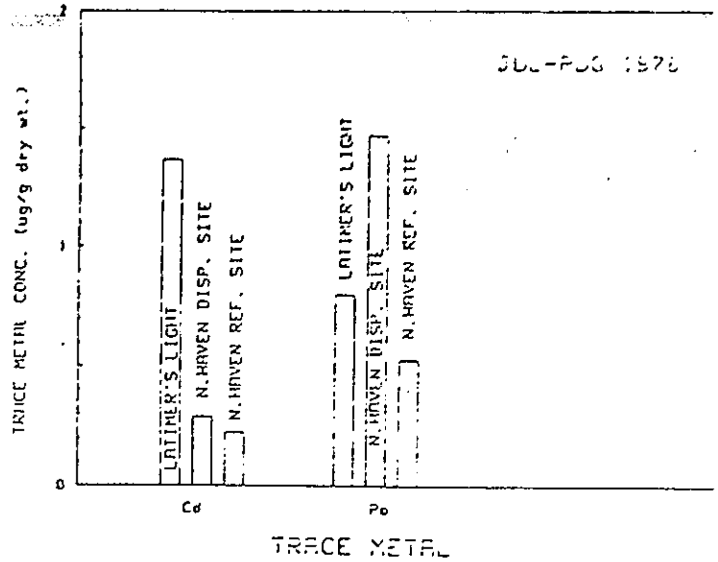
sampled only once, in July 1978. Mussels from both dumpsites had no significant differences between their metal concentrations, except Pb which was higher at Cable and Anchor Reef (Fig. 8.1.8e and Cd which had a higher concentration at the Western Long Island Sound disposal site (Fig. 8.1.8a

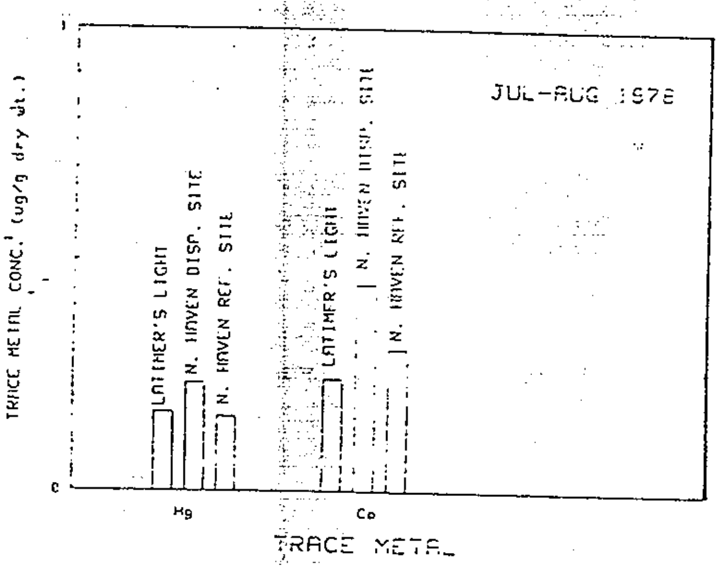
Since the New Haven disposal and reference sites are located in different types of local envirionemnt, the metal burdens of M. edulis from these two stations were compared with that in mussels taken from Latimer's Light for the same approximate date (July, 1978) in Figs. 8.1.9 a-e. Latimer's Light values are equal to or lower than those for the New Haven reference site for Cr, Cu, Co, Ni, V, Hg, and Zn. The Pb concentration in mussels from Latimer's Light is intermediate between the levels of the New Haven reference site and the New Haven disposal site. The concentration of Cd is higher at Latimer's Light than those found at both New Haven sites (Fig. 8.1.9-b). In general, metal concentrations in mussels taken from the New Haven disposal site are higher than those found in specimens collected at the nearby reference site.

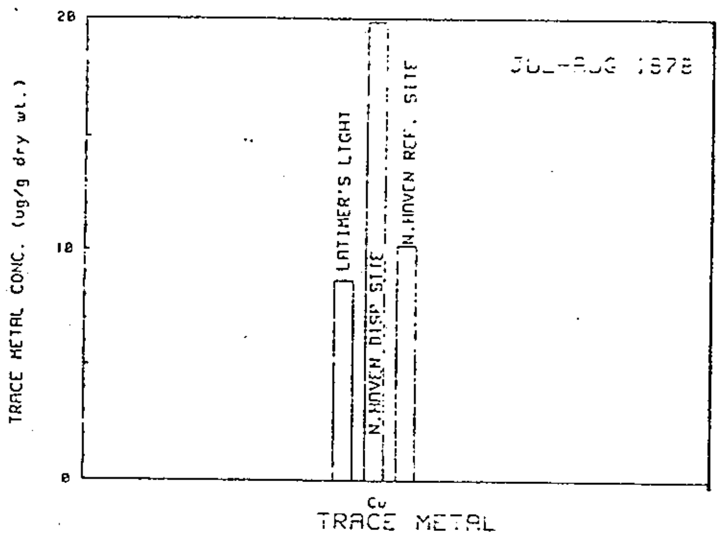
At the present time more data are needed to determine the significance of the dredging operations in Long Island Sound. However, patterns of metal uptake are emerging (e.g., Latimer's Light) and we are confident that changes associated with disposal activities can be elucidated, as shown in the data obtained from the New London Monitoring Project.

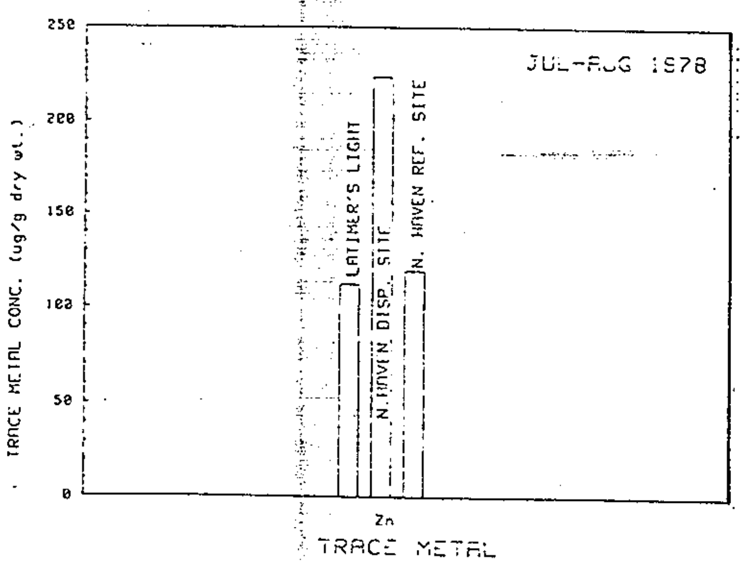
For the past two years, we have been monitoring an active disposal site in New London, Connecticut. Both the dumpsite and reference stations have been sampled on a monthly or bi-monthly basis, resulting in a more complete picture of the seasonal variations in tissue metal concentrations than we have to date for the DAMOS stations. The data for Hg, Cu, and Ni at one natural population reference site, North Dumpling, New York, and two dumpsite stations are shown in Figures 8.1.10,11, & 12. As we have seen in Latimer's Light data, a seasonal trend is observed for M. edulis at all three stations where metal concentrations are lowest during the summer months, and highest in the winter. This trend is of the least magnitude for Hg (Fig. 8.1.10 , more pronounced for Cu (Fig. 8.1.11 and most dramatic for Ni (Fig. 8.1.12 . For Ni, seasonal changes are most pronounced at dumpsite Station No. 1, which is closest to the dump buoy, and least evident at the North Dumpling reference station, located approximately 3 km east of the dumpsite.





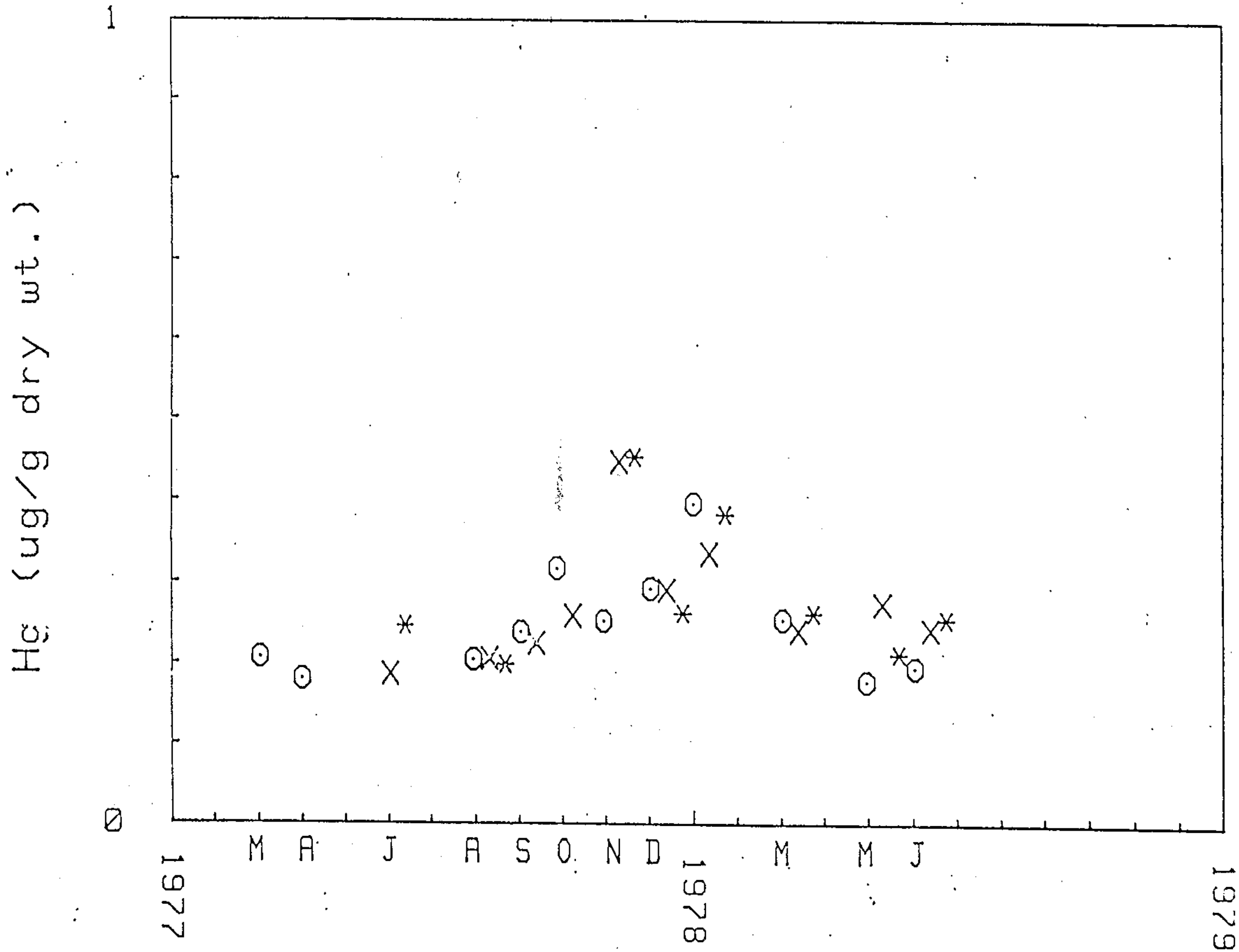






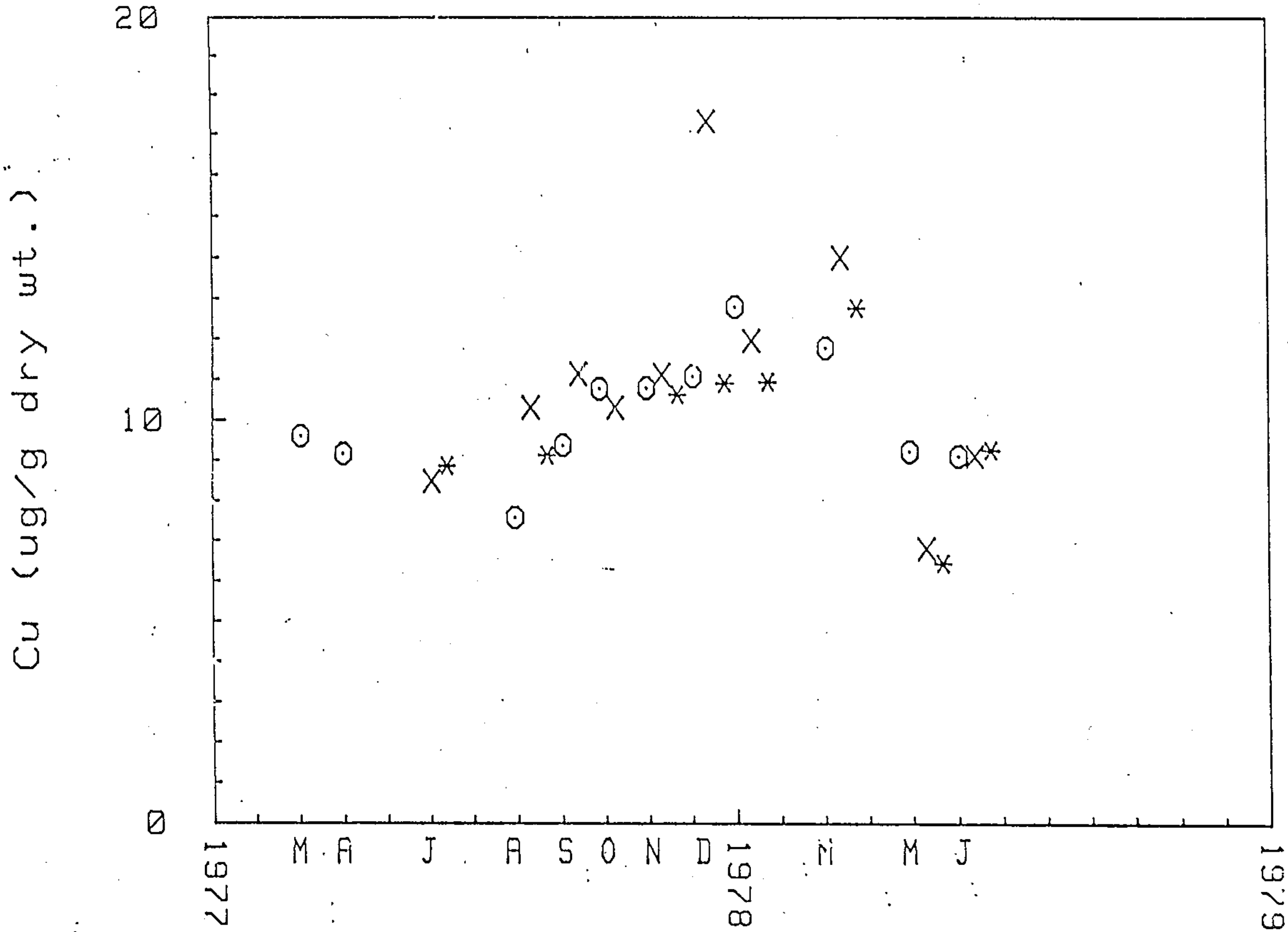
CONCENTRATION OF HEAVY METALS ± 2 STANDARD DEVIATIONS FROM LATIMER'S LIGHT, NEW HAVEN DISPOSAL SITE AND NEW HAVEN REFERENCE SITE

FIGURE 8.1.9



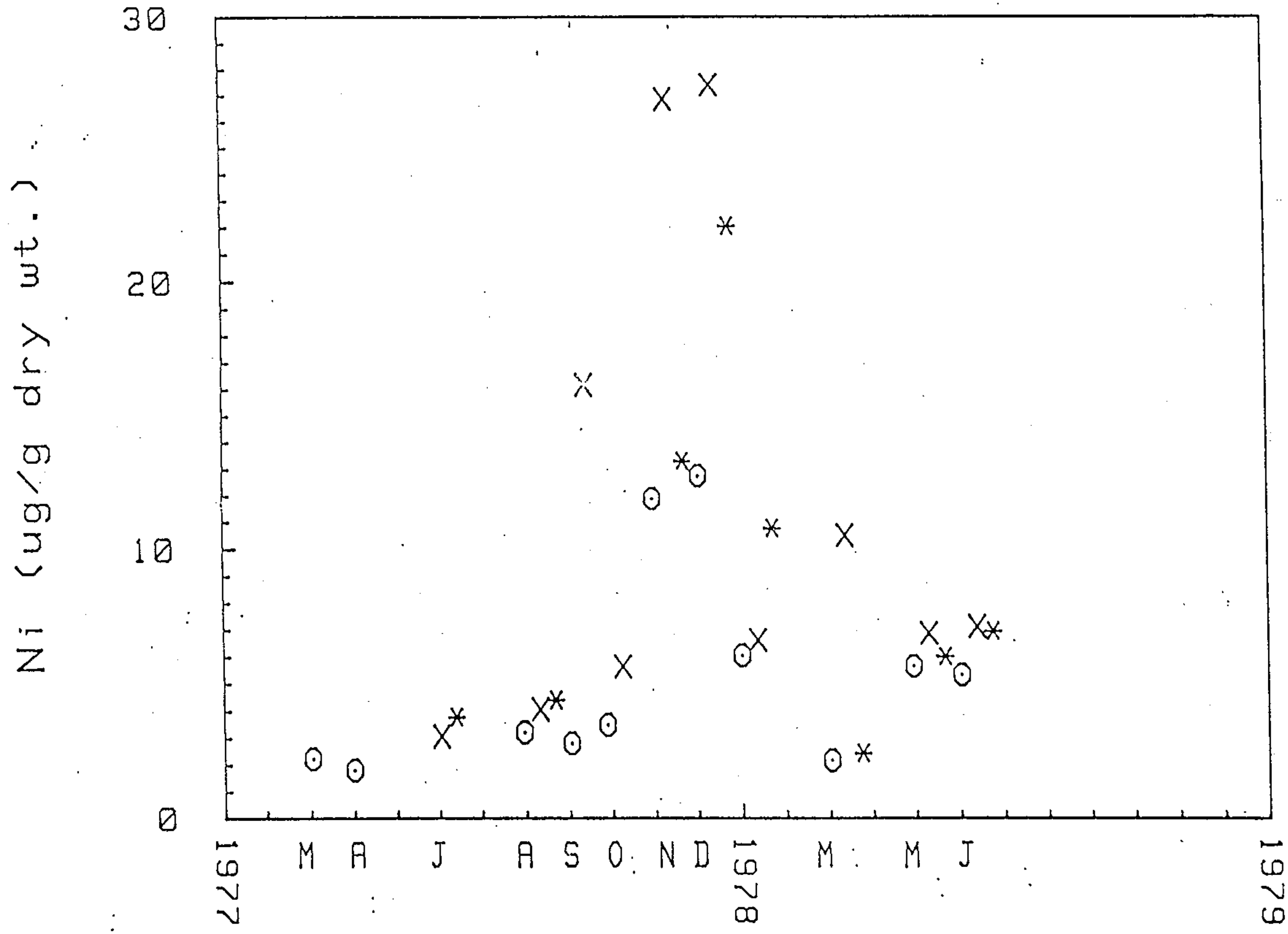
CONCENTRATION OF MERCURY IN M. EDULIS FROM NORTH DUMPLING (O)
DISPOSAL STATION #1 (X) AND DISPOSAL STATION #3 (*)
NEW LONDON DISPOSAL SITE

FIGURE 8.1.10



CONCENTRATION OF COPPER IN M. EDULIS FROM NORTH DUMPLING (O)
DISPOSAL STATION #1 AND (X) AND DISPOSAL STATION #3 (*)
NEW LONDON DISPOSAL SITE

FIGURE 8.1.11



CONCENTRATION OF NICKEL IN M. EDULIS FROM NORTH DUMPLING (O)
DISPOSAL STATION #1 (X) AND DISPOSAL STATION #3 (*)
NEW LONDON DISPOSAL SITE

FIGURE 8.1.12

When these metal data were correlated with other known parameters, a negative association of Ni concentration with monthly average water temperature data, and a positive association with the monthly average amount of dumped dredge soil was detected. This, coupled with the spatial differences among the three stations, suggests that the deposition of dredge spoils may have magnified a normal seasonal response in metal uptake by the species. As a worst case, if one assumes that the increase in Ni at all three stations is caused solely by the dredge spoil disposal, levels of the trace metal returned to pre-disposal levels within one month after the cessation of dredging. Since an increased frequency of sampling is planned for the DAMOS stations in the future, we feel that trends in tissue metal concentrations will serve as a reliable indicator for disposal activities, as demonstrated in the New London Project.

8.2 HISTOLOGICAL EXAMINATIONS OF GONADAL DEVELOPMENT IN *MYTILUS EDULIS* AND *MODIOLUS MODIOLUS* (R. Arimoto, E.M. Haddad and S.Y. Feng)

8.2.1 Introduction

In a study to determine whether trace metal body burdens are correlated with the fitness of shellfish populations, we have examined histological sections of gonads of the horse mussel, *Modiolus modiolus* and blue mussel, *Mytilus edulis* for pathological and subtle changes in tissue structure. Since the mussels were collected from natural (reference) populations and experimentally transplanted to dumpsites, we are ultimately studying the effects of dredge spoil disposal by comparing the reproductive fitness of one population in two environments. It must be emphasized that the tissue damage we have observed results from the stresses imposed by the environment *in toto*, and may not be attributable to any single factor.

Adult mussels (*M. edulis*) subjected to nutritive, thermal, or salinity stresses, produce eggs that differ from controls both in size and biochemical composition (Bayne, et al., 1978). The results we report here are an initial attempt to determine the effects of dredge spoil disposal on gametogenesis and fecundity of shellfish populations. This type of information is essential for assessing the impact of ocean dumping.

8.2.2 Materials and Methods

A description of the sampling regime was reported in section 8.1.1 of this report. The mussel samples used for histological analysis are shown in Tables 8.2.1 and 2.

Shellfish samples were fixed in either Bouin's solution or neutral (phosphate buffered) formalin. Sections were stained with hematoxylin and eosin. Samples were prepared for observation by the histology laboratory of the Department of Pathobiology, University of Connecticut.

Histological preparations were examined using a Millipore MC particle meeasurement computer system (Millipore Corp., Bedford, MA), interfaced with a Bausch and Lomb microscope, and a Setchell Carlson video monitor. This equipment was kindly loaned to us by Dr. Anthony Calabrese of the National Marine Fisheries Service in Milford, Connecticut.

For female specimens of both *M. edulis* and *M. modiolus*, the following measurments were made from each slide:

(1) number of eggs in each of 20 fields (each field = 57,909 um^2);
(2) area of one egg from each of the 20 fields, and
(3) area of the entire egg minus the area of the nucleus (cytoplastic area) for the same 20 eggs.

For male *M. modiolus* the number of sperm per field (field area = 9,822.9 um^2) was determined using the total particle count mode of the MC particle analyzer. The developmental condition of male *M. edulis* gonads were scored arbitrarily using a numerical system of 1 to 5 by estimating the area of the field occupied by sperm follicle. Animals with less than 20% of the area occupied were considered immature and scored as 1, those with 21-40% of the area occupied were scored as 2, those with 41-60% were scored as 3, animals with 61-80% of the area were scored as 4, and those with over 80% of the area occupied by sperm follicles were scored as 5.

Table 8.2.1 *M. modiolus* collected from northern New England for histological analysis

Site	Date	Number of Specimens: Female	Number of Specimens: Male
May 1978			
Drunkard's Ledge, ME	5/11/78	6	6
Bulwark Shoals, ME	5/14/78	4	5
Smuttynose Island, NH	5/19/78	5	7
Halfway Rock, MA	4/21/78	3	8
August 1978			
Portland, ME Dumpsite	8/05/78	2	3
Smuttynose Island, NH	8/05/78	0	4
Bulwark Shoals, ME	8/05/78	5	3
Drunkard's Ledge, ME	8/07/78	3	3
Rockland, ME	8/07/78	4	0
Halfway Rock, MA	8/08/78	1	0
Boston Foul Ground, MA	8/22/78	1	4
November/December 1978			
Drunkard's Ledge, ME	11/15/78	6	2
Rockland, ME Dumpsite	11/17/78	3	1
Bulwark Shoals, ME	11/19/78	5	3
Portland, ME Dumpsite	11/20/78	2	3
Boston Lightship, MA	12/06/78	0	4
February/March 1979			
Drunkard's Ledge, ME	2/28/79	3	6
Bulwark Shoals, ME	3/01/79	5	1
Portland, ME Dumpsite	3/03/78	4	4
Smuttynose Island, NH	3/05/79	3	5
	Total	65	72

Table 8.2.2 *M. edulis* collected from Long Island Sound for histological analysis

Site	Date	Number of Specimens Female	Male
January 1978			
Latimer's Light, NY	1/31/78	1	5
May 1978			
Outer Bridge, Newport, RI	5/11/78	1	9
July 1978			
Western Long Island Sound, (WLIS) Cage Station	7/16/78	3	3
Cable & Anchor Reef, Cable Station	7/27/78	2	7
New Haven, CT Dumpsite	10/27/78	0	2
New Haven, CT Reference Site	7/19/78	4	5
October 1978			
New Haven CT	10/27/78	0	2
Latimer's Light, NY	10/31/78	5	6
December 1978			
Latimer's Light, NY	12/01/78	1	8
Brenton Reef, RI, Cage	12/10/78	3	5
Latimer's Light, NY	12/27/78	3	4
January 1979			
Latimer's Light, NY	1/11/79	0	9
	Total	28	66

Photomicrographs of histological sections were taken using a Leitz Dialux-Pol microscope, Leitz Microsix - L exposure meter and a Leica MD camera (all manufactured by Ernst Leitz BMGH, Wetzlar Germany).

8.2.3 Results

Reproductive parameters of interest were compared for sites at which more than one specimen of mussel was taken. A one-way analysis of variance procedure was used.

Of the twenty analyses of variance performed on the M. modiolus data, three showed significant differences in reproductive parameters among collection sites. The May 1978 samples were significantly different in two measurements: the mean cytoplasmic area of the egg and the ratio of the total egg area to the cytoplasmic area of the egg (Table 8.2.3). The animals collected on this date were from reference populations only, thus no comparisons could be made between dumpsite populations and reference populations. The F-test of the August 1978 samples showed significant differences between collection sites for the ratio of total egg area to the cytoplasmic area of the egg.

It appears that the ratio is greater for the Portland dumpsite mussels than that of the Bulwark Shoals reference site animals. M. modiolus collected in November-December and February-March did not differ significantly in any of the reproductive parameters.

M. edulis collected from Long Island Sound have revealed significant differences in 3 of the 5 reproductive parameters examined (Table 8.2.4). The mussels differed in mean egg area, the ratio of total egg area to the cytoplasmic area of the egg, and in the subjective scoring of the male gonad.

To test for significant correlations between the reproductive parameters measured and amounts of trace metals in the specimens' tissues, a linear regression analysis was performed. M. modiolus collected in May 1978 had significant differences in mean cytoplasmic area of the eggs and also in ratio of total egg area to the cytoplasmic area of the egg. These parameters were

Table 8.2.3 Significant differences in reproductive parameters for *Modiolus modiolus* as measured by one-way analysis of variance

Stations Sampled in May 1978

Reproductive Parameter	Drunkard's Ledge	Bulwark Shoals	Smuttynose Island	Halfway Rock	F (df)
Cytoplasmic area (μm^2) of egg	3010 (378)	2635 (214)	2637 (310)	2197 (379)	4.20* (3.14)
Total area of egg / Cytoplasmic area of egg	1.32 (0.08)	1.36 (0.02)	1.49 (0.08)	1.47 (0.06)	7.37**(3.14)

Stations Sampled in August 1978

Reproductive Parameter	Drunkard's Ledge	Rockland Dumpsite	Bulwark Shoals	Portland Dumpsite	F (df)
Total area of egg / Cytoplasmic area of egg	1.28 (0.06)	1.35 (0.06)	1.24 (0.06)	1.42 (0.06)	5.29* (3.10)

Values in table are mean and (standard deviation).

*p<0.05

**p<0.01

Table 8.2.4 Significant differences in reproductive parameters for *Mytilus edulis* as measured by one-way analyses of variance

Stations Sampled in July 1978

Reproductive Parameter	WLIS Cage	Cable & Anchor Reef Cage	New Haven Dumpsite	New Haven Reference Site	F (df)
Egg area (μm^2)	1744 (252)	1866 (149)	1182 (197)	1522 (137)	8.80**(3.10)
Total area of egg / Cytoplasmic area of egg	1.43 (0.12)	1.42 (0.10)	1.13 (0.09)	1.26 (0.08)	8.72**(3.10)
Subjective score of male gonad	2.67 (0.58)	2.43 (0.98)	3.00 (1.00)	4.80 (0.45)	9.11**(3.14)

Values in table are mean and (standard deviation).
**$p<0.01$

found to be linearly correlated with the concentrations of Hg, Cr, V, and Fe in animals collected simultaneously (Table 8.2.5). The concentrations of Cr were negatively correlated with the mean cytoplasmic area of the eggs, while the concentrations of Hg and V were positively correlated with the parameters. The concentrations of Hg and Fe were both negatively correlated with the ratio of total egg area to the Cytoplasmic area of the egg. No significant correlation coefficient was found between trace metal concentrations and reproductive parameters of M. modiolus collected in August 1978.

M. edulis collected from Long Island Sound in July of 1978 showed a negative relationship between the concentrations of Co and V and both the mean egg area and the ratio of total egg area to the cytoplasmic area of the eggs (Table 8.2.6). Male M. edulis collected in July 1978 differed significantly in the subjective scoring of gonadal maturity. This parameter was significantly correlated with the concentration of Zn in animals collected simultaneously (Table 8.2.6).

Histological examinations of M. modiolus revealed no obvious histopathology in gonadal and associated tissues. Quantitative histological parameters, like egg dimensions, appear to be more sensitive in detecting subtle changes in the tissues than observational methods.

Blue mussels collected from Long Island Sound showed degenerative changes in gonadal tissue and generalized deterioration of Leydig and other tissues. The reproductive histopathology is illustrated in Plates A-J (Fig. 8.2.1). Animals from Western Long Island (WLIS) (Plates A and E) and Cable and Anchor Reef (Plates B and F) had normal tissues, although some animals did show heavy leukocytic infilitration of the Leydig tissue surrounding the gonads.

M. edulis gonadal tissue from specimens taken at the New Haven dumpsite exhibited a discernbile degernation when compared with tissue from animals taken at other collection sites. Pathological changes were evident in both sexes (Plates D, I, and J). Females had small eggs, many of which had no apparent nuclei; egg follicles were disrupted and frequently had few developing ova in the periphery (Plates I and J). Males showed the most obvious morphological alterations in the layers of spermatids surrounding the

Table 8.2.5 Summary of significant correlation coefficients for reproductive parameters vs. concentration of trace metals in <u>Modiolus modiolus</u>

Reproductive Parameter	Drunkard's Ledge	Bulwark Shoals	Smuttynose Island	Halfway Rock	r
	Stations Sampled in May 1978				
Egg cytoplasmic area (μm^2)	3010 (378)	2635 (214)	2637 (310)	2197 (379)	
Hg (μG/G)	0.529	0.378	0.262	0.218	0.90*
Cr (μG/G)	0.506	2.020	1.142	2.990	-0.94*
V (μG/G)	9.28	6.63	6.07	4.40	0.97**
Total egg area / Cytoplasmic area	1.32 (0.08)	1.36 (0.02)	1.49 (0.08)	1.47 (0.06)	
Hg (μG/G)	0.529	0.378	0.262	0.218	-0.94*
Fe (μG/G)	285	276	98	147	-0.98**

Mean and standard deviations (in parentheses) are given for reproductive parameters.

*$p<0.05$

**$p<0.01$

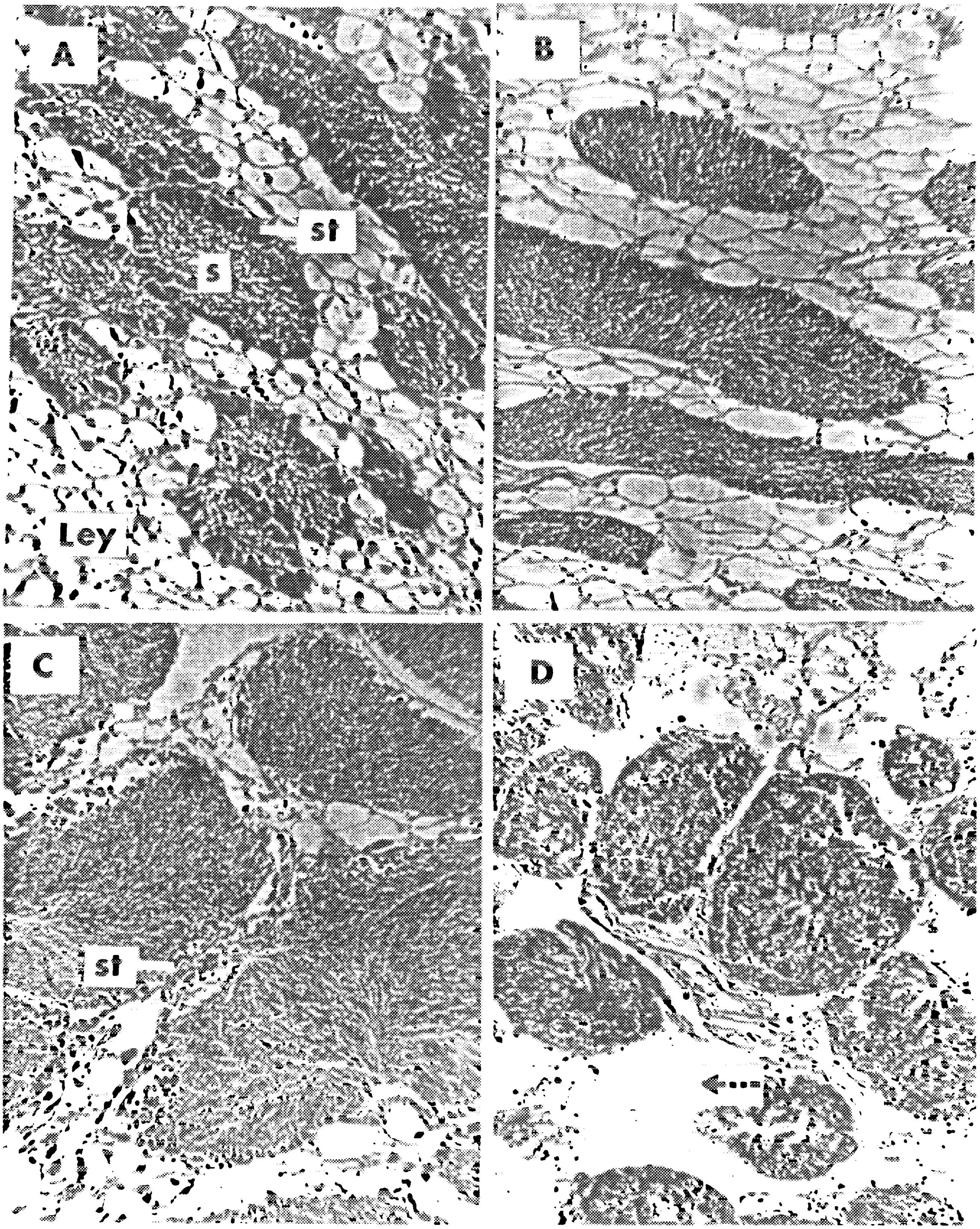
Table 8.2.6 Summary of significant correlation coefficients for reproductive parameters vs. concentration of trace metals in *Mytilus edulis*

Reproductive Parameter	Stations Sampled in July 1978: WLIS	CAR	New Haven Dumpsite	New Haven Reference Site	r
Egg area (um^2)	1744 (252)	1866 (149)	1182 (197)	1522 (137)	
Co (µG/G)	0.241	0.250	0.448	0.307	-0.97**
V (µG/G)	1.09	1.52	9.412	3.51	-0.96**
Total egg area / Cytoplasmic area	1.43 (0.12)	1.42 (0.10)	1.13 (0.09)	1.26 (0.08)	
Co (µG/G)	0.241	0.250	0.447	0.307	-0.96**
V (µG/G)	1.09	1.52	9.412	3.51	-0.95*
Subjective score of male gonad	2.67 (0.58)	1.43 (0.98)	3.00 (1.00)	4.80 (0.45)	
Zn (µG/G)	197	194	223	119	-0.87*

Mean and standard deviation (in parentheses) are given for reproductive parameters.

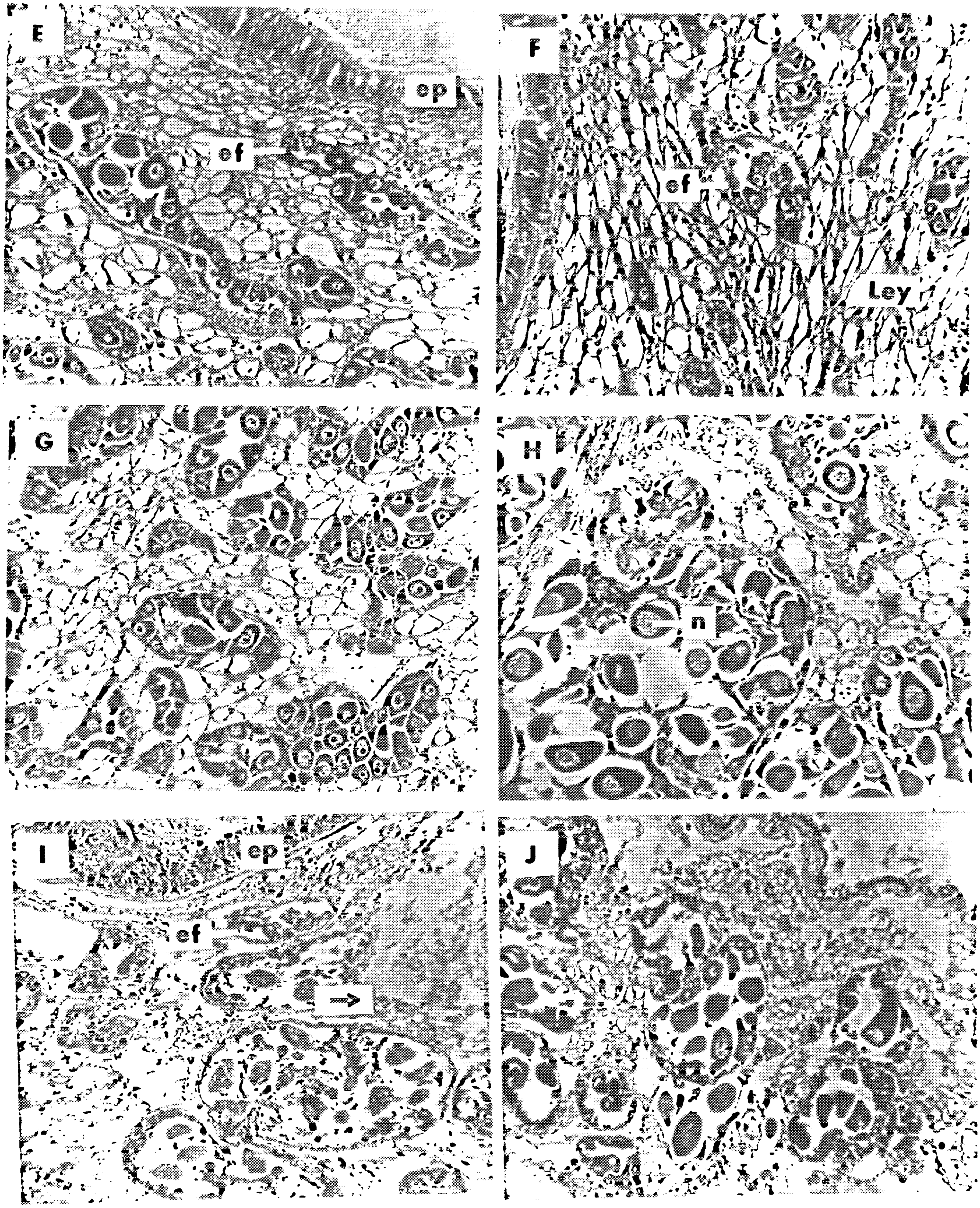
*p<0.05

**p<0.01



GONADAL TISSUE OF M. EDULIS SPECIMENS FROM LONG ISLAND SOUND

FIGURE 8.2.1



GONADAL TISSUE OF M. EDULIS SPECIMENS FROM LONG ISLAND SOUND

FIGURE 8.2.1(cont.)

spermatoza (Plate D). The spermatids of these animals appeared less densely and uniformly packed when compared with animals from other sites.

Tissues from animals taken from the New Haven reference sites (Plates C, G, and H) appeared intermediate in condition between the relatively healthy animals at the WLIS and Cable and Anchor Reef cages, and the animals from the New Haven dumpsite. Some areas of gonadal tissue appeared healthy (Plate G), while other areas showed some degeneration of Leydig tissue (Plate H). The spermatids of animals from the New Haven reference site were less uniformly packed than those of animals from the WLIS and Cable and Anchor Reef cages (Plate C).

This histopathology evident in the mussels from the New Haven dumpsite may have been caused, in part, by stresses other than those imposed by conditions at the dumpsite. For logistical reasons these animals were held in a flow-through tank at the University of Connecticut Marine Research Laboratory, Noank, Connecticut for approximately three months until they were deployed at the dumpsite. Furthermore, there is evidence that the platform was overturned during deployment. The animals used to stock the platform at the New Haven reference, WLIS, and Cable and Anchor Reef sites were held for a similar length of time, but deployed without problems.

8.2.4 Discussion

During the first year of monitoring the biological effects of dredge spoil disposal, we collected data that characterized our field experimental system. This information is required to determine the amount and type of data needed for subsequent analysis of changes in the system induced by the disposal of dredge materials. Preliminary histological examinations of mussels using a number of qualitative and quantitative criteria to evaluate changes in the mussels reproductive condition were reported herein. We feel that subtle effects of spoil disposal, which preceed large-scale changes in community structures, can be detected using this approach.

Histological examinations of *M. modiolus* which were collected from northern New England sites revealed no pathological response in reproductive tissues. A total of 169 slides were examined. Normal variations in gonadal development were observed, but no tissue damage was discerned. Small concentrations of undetermined composition were present in the kidney tissue of some individuals, but no attempt was made to quantify their extent or determine their effect on the animals.

The differences in reproductive parameters in horse mussel tissue in May, 1978 (Table 8.2.3) may not reflect pollutant effects. The May samples of M. modiolus were collected from reference sites only, and it is likely that the differences in the reproductive parameters were the result of normal physiological cycles. At that time of year, the increasing water temperatures may have affected the reproductive condition of the animals. The August 1978 M. modiolus samples were composed of animals from both reference sites and dumpsite platforms. The analysis showed a significant difference between the Bulwark Shoals reference site and the Portland dumpsite, but not between the other pair of stations. However, the Portland dumpsite has not yet been used for dredge spoil disposal, and the observed difference in the animals' tissues cannot be attributed to dredging operations.

The correlations between the reproductive parameters of M. modiolus and the tissue trace metal concentrations do not imply causative relationships. It is possible that the differences in the trace metal concentrations were associated with other factors that caused the observed differences in the reproductive condition of the mussels. To affirm a causative relationship, one must resort to controlled laboratory experimentation. Nevertheless, employing correlation analysis procedures is useful as a first step in seeking clues to cause and effect relationships.

Tissue sections of both sexes of M. edulis from the New Haven dumpsite platform showed degeneration of gonadal tissue. Males exhibited changes in the morphology of the spermaries, which consist of an outer layer of spermatids surrounding an inner portion containing mature spermatozoa. Females from the New Haven dumpsite had smaller eggs than those from the other sites, with many eggs lacking clearly defined nuclei. Deterioration of the peripheral area of the egg follicles was also observed in these animals. It should be emphasized that the samples showing the pathological signs were collected from the New Haven dumpsite before the most recent disposal operation began.

Pathological changes were also evident in other tissues of M. edulis collected at the New Haven dumpsite. Some sections showed pronounced deterioration of the Leydig tissue which stores glycogen and normally surrounds gonadal tissue. In other sections cut through gonad, no Leydig tissue was observed at all. Leukocytic infiltration which is a non-specific resonse to stress, was seen in tissues taken from animals at the New Haven dumpsite platform, but it was also noted in animals from the other Long Island Sound platforms.

Blue mussels from the New Haven dumpsite exhibited changes in certain parts of the digestive system. The columnar epithelium, surrounding the crystalline style and forming the digestive tubules, appeared abnormal. The normal close packing of cells along their long axes was distruped, with breaks apparent in the continuity of the layer. The digestive diverticula of mussels from the New Haven dumpsite also appeared degenerate, with cell boundaries indistinct.

Although tissue damage was evident in mussels from the New Haven dumpsite, the presence of food in their digestive lumina indicates that they were actively feeding shortly before they were collected. Thus, the animals may have been capable of recovery from their deteriorated condition if the environmental stresses were lessened. This question cannot be resolved because subsequent samples were not available for examination. On the following sampling cruise, it appeared that the New Haven dumpsite platform had been overturned and the experimental animals were dead.

The one-way analysis of variance procedures, comparing the quantitative measures of the reproductive condition of M. edulis from the Long Island Sound stations, confirmed the subjective differences in the microscopic appearance of the tissues. In the five anlaysis of variance tests performed, three parameters differed significantly ($P<0.05$) between stations. These parameters were: (1) mean egg area, (2) the ratio of the total area of the egg to the cytoplasmic area of the eggs, and (3) the subjective scoring of the male gonad.

Linear regressions of the rperoductive parameters of M. edulis from the Long Island Sound stations on the trace metal body burdens of animals collected simultaneously, indicated that the tissue concentration of cobalt was negatively correlated with both the mean area of the eggs and the ratio of the total area of the egg to the cytoplasmic area of the egg. These correlations suggest that high concentrations of cobalt may adversely affect the reproductive condition of M. edulis. However, as previously discussed, correlations between the trace metal body burdens and the reproductive parameters of the animals do not establish causality.

The criteria we have used to compare the reproductive condition of subsamples of the mussels to trace metal analyses appear to be sensitive to environmental changes. M. modiolus collected from New England did not differ in histological appearance. These animals differed in the quantitative measures of reporductive condition, but these differences were probably cuased by normal environmental cycles, and not by dredge spoil disposal.

M. edulis from the New Haven dumpsite platform differed from the animals at the other Long Island Sound platforms both histologically and also in the quantitative parameters measured. While these animals appeared injured, their deteriorated condition cannot be attributed to recent dredge spoil disposal since the samples were collected before the most recent dredging operations. It is possible that the animals were affected by smothering in previously deposited spoil or some other stress.

It is clear that, while we have observed changes in the reproductive condition of the mussels used in our monitoring program, we are not yet able to determine the causes of the changes with certainty, even though we have found that some of the differences are correlated with trace metal body burdens. The identification of the causes of observed differences in biological indicators, whether they can be associated with normal physiological activities of the organism or induced by extrinsic envrionmental stresses, remains one of the most complex, yet intriguing questions in our monitoring program.

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9.0

BENTHIC MACROFAUNA

ALBERT L. BROOKS

9.0 BENTHIC MACROFAUNA

9.1 INTRODUCTION

This is the second in a series of reports on the benthic biota at 11 dredge spoil disposal areas and 5 associated reference sites located between Rockland, Maine and Norwalk, Connecticut. The disposal site boundaries are given in the DAMOS Progress Report for FY 1977 presented to the New England Division, Corps of Engineers in January 1978, and the general characteristics (e.g., depth, energy regime, sediment character, history, etc.) of each site are presented in Section II of these proceedings. The basic objectives of the DAMOS benthos studies are:

(1) To monitor long-term changes in the benthic populations at active, relict or proposed dredge spoil disposal sites located between Rockland, Maine, and Norwalk, Connecticut, and

(2) To attempt to differentiate between natural population changes and changes which could reasonably be ascribed to envrionmental stress resulting from disposal operations.

9.2 METHODS AND MATERIALS

9.2.1 Sampling Effort and Schedule

Table 9.1 lists the DAMOS benthos sampling sites and dates of sampling. During 1977-78, with only two exceptions, three anchor dredge samples were collected from each site. The seasonal distribution of these samples was: winter-spring 1977-79 (47 samples), spring-summer 1978 (49 samples), and winter 1978 (24 samples).

Beginning in January 1979, the use of the anchor dredge was discontinued in favor of the Smith-McIntyre grab sampler. An additional 45 sediment samples (5 per site) were collected for benthos analysis. In addition to these regularly sampled stations, 20 more Smith-McIntyre grabs were obtained from the New Haven Dumping Grounds for a detailed study of the effects of the Stamford-New Haven dredge disposal and capping operations, underway during the spring of 1979. A total of 184 samples were collected for benthos analysis. Data were processed as described in the DAMOS Annual Data Report - 1978.

Table 9.1 Sites and dates of benthos sampling

	SITE	WINTER-SPRING COLLECTIONS 1977-78	SPRING-SUMMER COLLECTIONS 1978	WINTER COLLECTIONS 1978-79
1.	Rockland	12 Dec. 1977	11 May 1978	16 Nov. 1978
2.	Portland	15 Dec. 1977	18 May 1978	19 Nov. 1978
3.	Isle of Shoals	17 Dec. 1977	20 May 1978	8 Dec. 1978
4.	Boston Foul Ground	18 Dec. 1977	23 May 1978	6 Dec. 1978
5.	Boston Lightship	18 Dec. 1977	23 May 1978	6 Dec. 1978
6.	Brenton Reef Dump	25 Apr. 1978	3 Aug. 1978	11 Dec. 1978
7.	Brenton Reef Reference	19 Apr. 1978	3 Aug. 1978	11 Dec. 1978
8.	New London Dump	17 Apr. 1978	2 Aug. 1978	28 Jan. 1979
9.	New London Reference	17 Apr. 1978	2 Aug. 1978	28 Jan. 1979
10.	Cornfield Sh. Dump	31 Jan. 1978	31 July 1978	27 Jan. 1979
11.	Cornfield Sh. Reference	31 Jan. 1978	31 July 1978	27 Jan. 1979
12.	New Haven Dump	13 Apr. 1978	29 July 1978	19 Jan. 1979
13.	New Haven Reference	13 Apr. 1978	29 July 1978	26 Jan. 1979
14.	Cable & Anchor Dump	11 Apr. 1978	27 July 1978	23 Jan. 1979
15.	Western L.I. Sound Dump	12 Apr. 1978	27 July 1978	23 Jan. 1979
16.	Car & WLIS Reference	12 Apr. 1978	28 July 1978	23 Jan. 1979

Herein I compare the results of the analysis of the spring-summer 1978 collections with those of the winter-spring 1977-78 collections. Throughout this report the winter-spring 1977-78 collections will be referred to as "winter 1977"; spring-summer 1978 collections will be referred to as "summer 1978." Results from the analyses of the winter 1978-79 collections are not yet available.

9.2.2 Anchor dredge vs. Smith-McIntyre grab sampler

Reluctantly, the use of the anchor dredge was discontinued; it was done knowing that comparison of the early benthos collections with subsequent collections made with the Smith-McIntyre sampler would be difficult, at best. As stated in the DAMOS Annual Data Report-1978, the "sampling plan and sample analysis during the first year of this project as initially conceived were meant to be flexible and, to some degree, exploratory." The principal reason for the initial choice of the anchor dredge was the anticipation that sample-to-sample variability would be reduced as clumped aggregations of organisms were "integrated" during the passage of the dredge over an approximately 400-m sampling path. Unfortunately, high sample-to-sample variability persisted.

Dredge samples collected at the New London disposal site in March 1978 were compared with Smith-McIntyre grabs taken in March 1977 and March 1978. As Table 24 of the DAMOS Annual Data Report--1978 shows:

- The relative ability of the two samplers, to sample the species present at the site was approximately equal, though the species collected differed somewhat between sampling gears.
- The dredge collected only one-half the number of individuals that the Smith-McIntyre grab caught.

These factors, coupled with the greater potential for comparison of the DAMOS Smith-McIntyre samples with quantitative work of previous investigators at several of the disposal and reference sites, led to the decision to discontinue use of the anchor dredge.

9.3 RESULTS AND DISCUSSION

9.3.1 Benthic Biota -- Gulf of Maine Stations

A list of all species collected from the five stations in the Gulf of Maine, their frequency of occurrence, and total number of individuals in the 15 dredge samples is shown in Table 9.2. A total of 2,632 individuals representing 13 phyla and 136 species were collected (Table 9.3). Nine of these species constituted about 72 percent of the total number of individuals. Deposit-feeding annelids and molluscs were the most numerous animals.

The distribution of phyla, species, and number of individuals at each of the five sites is presented in Table 9.4. In the Gulf of Maine, greatest number of individuals were collected at the Isle of Shoals proposed dumpsite; fewest were found at the Boston Foul Ground site.

Data on the relative abundance of predominant species and the diversity of benthos at each disposal site in the Gulf of Maine is presented in Appendix 9.1. The format of these tables was recommended by Swartz (1978) for presentation of benthic data.

The information contained in this Appendix leads to the following general statements, which are essentially identical to the conclusions reached from results of the analyses of the winter collections of 1977-78.

- Sample-to-sample variability in number of individuals collected is high. The standard deviations in many cases exceed their means.
- With rare exceptions the coefficients of dispersion are greater than one, indicative of a highly clumped spatial distribution at each dump site.
- A few of the total number of species at a station often account for 80 percent or more of the total number of individuals collected.
- The mean diversity values ($\bar{H}'$) calculated for the Gulf of Maine stations were highest at Portland (3.30) and lowest (0.98) at the site off Rockland. At the Isle of Shoals, Boston Foul Ground and Boston Lightship sites these values range from 2.31 to 2.93.

Table 9.2 Species list and their occurrence in samples taken in the Gulf of Maine, summer 1978

	Species	Occurrence/ 15 Samples	No. Individuals
	Phylum PROTISTA		
1.	Foraminifera sp.	2	2
	Phylum CNIDARIA		
	Cl. Hydrozoa		
2.	*Calycella syringa*	2	2+
3.	*Campanularia* sp.	2	2+
4.	*Thuiaria* sp.	4	4+
	Cl. Anthozoa		
5.	*Cerianthus (borealis)*	1	1
6.	*Edwardsia (elegans)*	7	11
7.	*Halcampa duodecimcirrata*	1	1
	Phylum NEMATODA		
8.	NEMATODE sp.	3	4
	Phylum RHYNCHOCOELA		
9.	*Amphiporus* sp.	1	1
10.	*Cerebratulus* sp.	10	15
11.	*Lineus* sp.	1	1
12.	*Micrura* sp.	11	31
13.	RHYNCHOCOEL sp.	1	1
14.	*Tubulanus* sp.	2	2
	Phylum MOLLUSCA		
	Cl. Aplacophora		
15.	*Chaetoderma nitidulum*	8	14
	Cl. Gastropoda		
16.	*Admete couthouyi*	1	1
17.	*Alvania pelagica**	1*	2*
18.	*Bulbus smithii*	2	2
19.	*Crepidula convexa*	1	1
20.	*Cylichna alba*	1	1
21.	*Scaphander punctostriatus*	1	1
	Cl. Scaphopoda		
22.	*Dentalium occidentale*	1	1
	Cl. Pelecypoda		
23.	*Anomia simplex*	2	2
24.	*Arctica islandica*	2	3
25.	*Astarte subaequilatera*	1	2
26.	*Astarte (subaequilatera)*	1	3
27.	*Astarte undata*	3	7

**Alvania carinata* have all been changed to *A. pelagica* in Abbott (1954).

Table 9.2 (cont.)

	Species	Occurrence/ 15 Samples	No. Individuals
28.	Astarte (undata)	3	27
29.	Cerastoderma pinnulatum	3	10
30.	Corbula sp.	1	2
31.	Crenella decussata	1	1
32.	Cumingia tellinoides	1	2
33.	Cyclocardia borealis	2	36
34.	Nucula proxima	4	375
35.	Nucula tenuis	1	2
36.	Nuculana tenuisulcata	3	3
37.	Periploma fragile	2	2
38.	Periploma papyratium	2	5
39.	Thyasira (gouldii)	8	11
40.	Yoldia lucida	2	2
41.	Yoldia sapotilla	3	6
42.	Yoldia thraciaeformia	1	3
	Phylum ANNELIDA		
	Cl. Polychaeta		
43.	Ampharete arctica	2	2
44.	Ampharete (arctica)	15	315
45.	Amphicteis gunneri	3	5
46.	Amphitrite cirrata	1	1
47.	Aphrodita hastata	2	3
48.	Asychis elongata	1	1
49.	Chaetozone setosa	1	1
50.	Chone infundibuliformis	2	2
51.	CIRRATULID sp.	4	9
52.	Drilonereis magna	2	2
53.	Enipo gracilis	3	3
54.	Euclymene collaris	1	1
55.	Euclymene sp.	3	18
56.	Gattyana sp.	1	1
57.	Goniada maculata	10	40
58.	Harmanthoe extenuata	2	2
59.	Harmanthoe imbricata	2	2
60.	Hartmania moorei	2	3
61.	Heteromastus filiformis	4	14
62.	Laonice cirrata	6	8
63.	Lumbriclymene cylindricauda	2	2
64.	Lumbrineris fragilis	11	53
65.	Lumbrineris tenuis	4	8
66.	Maldane sarsi	9	646
67.	MALDANID sp.	1	1
68.	Melinna cristata	9	48
69.	Myriochele heeri	7	177
70.	Nephthys ciliata	1	1
71.	Nephthys incisa	13	33

Table 9.2 (cont.)

Species	Occurrence/ 15 Samples	No. Individuals
72. *Nephthys paradoxa*	2	2
73. *Nereis grayi*	1	2
74. *Nicomache lumbricalis*	3	8
75. *Ninoe nigripes*	14	46
76. *Notocirrus spiniferus*	1	1
77. *Notomastus latericeus*	6	16
78. *Ophelina aulogaster*	1	1
79. *Owenia fusiformis*	1	1
80. *Paraonis gracilis*	3	5
81. *Pectinana (gouldii)*	1	2
82. *Pherusa affinis*	2	2
83. *Pherusa plumosa*	3	4
84. *Pholoe minuta*	1	1
85. *Pista cristata*	5	7
86. *Polycirrus* sp.	2	8
87. *Polydora (ligni)*	2	2
88. *Polydora (socialis)*	1	1
89. *Potamilla neglecta*	1	1
90. *Potamilla reniformia*	2	6
91. *Praxillella gracilis*	9	38
92. *Prionospio malmgreni*	2	4
93. *Prionospio* sp.	2	6
94. *Proceraia (cornutus)*	1	1
95. *Rhodine loveni*	2	6
96. *Sabella crassicornis*	1	1
97. *Scalibregma inflatum*	3	5
98. *Scolecolepides viridis*	1	3
99. *Scoloplos acutus*	7	36
100. *Scoloplos armiger*	1	1
101. *Scoloplos robustus*	1	1
102. *Spio filicornis*	9	78
103. *Sternaspis scutata*	14	127
104. *Stebelosoma spiralis*	2	8
105. *Terebellides stroemi*	9	34
106. *Tharyx* sp.	7	7
107. *Theleppus cincinnatus*	2	2
108. *Trichobranchus glacialis*	5	6
Phylum SIPUNCULIDA		
109. *Phascolion strombi*	5	8
Phylum ARTHROPODA		
Cl. Crustacea		
O. Isopoda		
110. *Calathura branchiata*	3	7
O. Amphipoda		
111. *Ampelisca macrocephala*	2	2
112. *Byblis serrata*	1	1

Table 9.2 (cont.)

	Species	Occurrence/ 15 Samples	No. Individuals
113.	*Callipius laeviusculus*	1	1
114.	*Casco bigelowi*	1	4
115.	*Haploops tubicola*	7	65
116.	*Hippomedon propinquus*	1	1
117.	*Hippomedon serratus*	1	1
118.	*Leptocheirus pinguis*	3	3
119.	*Unciola irrorata*	3	6
120.	*Westwoodilla* sp.	1	1
	O. Decapoda		
121.	*Pagurus longicarpus*	1	1
	Phylum BRACHIOPODA		
122.	*Terebratulina septentrionalis*	1	1
	Phylum BRYOZOA		
123.	*Bowerbankia* sp.	1	1+
124.	*Membranipora tenuis*	1	1+
	Phylum ECHINODERMATA		
	Cl. Stelleroidea		
125.	*Amphipholis squamata*	1	1
126.	*Ctenodiscus crispatus*	5	8
127.	*Ophiura robusta*	2	5
128.	*Ophiura sarsi*	4	5
129.	*Ophiura* sp. (juv.)	2	2
130.	*Pedicellaster typicus*	2	2
131.	*Strongylocentrotus drobachiensis*	2	2
	Cl. Holothuroidea		
132.	*Cucumaria frondosa*	1	1
133.	*Molpadia oolitica*	2	2
134.	*Pentamera* sp.	1	1
	Phylum HEMICHORDATA		
135.	*Stereobalanus* canadensis	1	1
	Phylum CHORDATA		
136.	*Bostrichobranchus* (*pilularis*)	1	1

Table 9.3 Relative abundance of predominant species in summer 1978 samples taken in the Gulf of Maine.

Species	Phyla	Feeding Type	Occurrence 15 Samples	Total No. Individuals	Percent Totals	Cumulative Percent
1. *Maldane sarsi*	A	DF	9	646	24.5	24.5
2. *Nucula proxima*	M	DF	4	375	14.2	38.7
3. *Ampharete (arctica)*	A	DF	15	315	12.0	50.7
4. *Myriochele heeri*	A	DF	8	177	6.7	57.4
5. *Sternaspis scutata*	A	DF	14	127	4.8	62.2
6. *Spio filicornis*	A	DF	9	78	3.0	65.2
7. *Haploops tubicola*	Ar	SF	7	65	2.5	67.7
8. *Minoe nigripes*	A	P	14	56	2.1	69.8
9. *Lumbrineris fragilis*	A	P	11	53	2.0	71.8

A: Annelida
Ar: Arthropoda
M: Mollusca
DF: Deposit Feeder
SF: Suspension Feeder
P: Predator

Total No. Individuals (excluding *Foraminifera* sp. etc.)*: 2616

*Although *Foraminifera* sp. were counted and represented by a number rather than a"+", it was not felt that they warranted inclusion in a list of predominant species, so they were subtracted from the Total No. of Individuals before percentages were calculated. The same is true of Nematodes, Arachnoids, Copepods, Cladocerans and Ostracods. Due to their small size many more could have washed out during sieving, therefore the number counted does not accurately represent their presences at the disposal site.

Table 9.4 Distribution of benthos at five dumpsites in the Gulf of Maine, summer 1978.

Number of	ROCKLAND MAINE DUMPSITE			PORTLAND MAINE DUMPSITE			ISLE OF SHOALS DUMPSITE		
	#1	#2	#3	#1	#2	#3	#1	#2	#3
Species per Sample	13	19	11	35	48	49	32	28	35
Individuals per Sample	73	284	94	77	171	128	174	82	1070
Phyla per Station		5			10			8	
Species per Station		24			83			60	
Individuals per Station		451			376			1326	

Number of	BOSTON FOUL GROUND DUMPSITE			BOSTON LIGHTSHIP DUMPSITE		
Species per Sample	24	17	23	31	26	31
Individuals per Sample	52	102	54	81	81	109
Phyla per Station		6			9	
Species per Station		42			56	
Individuals per Station		208			271	

- The values for equitability or evenness of distribution of individuals among species are essentially the same at the Portland (.87), Boston Foul Ground (.86), and Boston Lightship (.87) sites, lower at the Isle of Shoals (.67) and Rockland (.38) sites.

A comparison of the mean number of individuals ($\bar{H}$), species ($\bar{S}$), diversity ($\bar{H}'$), and equitability ($\bar{J}'$) for winter 1978 collections (labelled "Dec. '77") and the summer 1978 collections (labelled "May '78") is presented in Table 9.5. Assuming that no significant difference exists between means with overlapping 95 percent confidence limits, the mean diversity for the Rockland site was significantly lower than that at the Portland, Boston Foul Ground, and Boston Lightship stations in 1978. Mean equitability at Rockland was significantly lower than at Portland or the Boston Lightship sites. No significant difference can be detected between any of the remaining means listed in Table 9.5.

9.3.2 Benthic biota-Rhode Island Sound Stations

The complete list of species, their frequency of occurrence, and number of individuals collected from the Brenton Reef dump and reference sites in summer 1978 is presented in Table 9.6. At these stations, 6,962 individuals of 9 phyla and 95 species were collected. Slightly more than 70 percent (i.e., 4,897) of the total number of individuals were comprised of the arthropod, Ampelisca agassizi, which was present in dense concentrations at the Brenton Reef reference station (Table 9.7). This amphipod was also predominant in samples taken in the winter of 1978. The number of phyla, species and individuals collected at the two sample sites in Rhode Island Sound is shown in Table 9.8. The relative abundance and diversity of predominant species collected at these stations are given in Appendix 9.2.

As reported for the winter 1978 collection, the most striking differences between the Rhode Island and Gulf of Maine sites are the absence of molluscs and the increased importance of arthropods at the Rhode Island Sound stations. The mean diversity ($\bar{H}'$) calculated for both winter 1977 and summer 1978 samples taken in Rhode Island was less than that for stations in the Gulf of Maine.

Table 9.5 Summary of species distribution at five dumpsites in the Gulf of Maine. The number of samples taken at each site and date are indicated by n. Mean number of individuals ($\bar{N}$), species ($\bar{S}$), diversity ($\bar{H}'$), and equitability ($\bar{J}'$), and the 95% C.I. of the means (in parentheses) are shown.

Station	n	Date	$\bar{N}$		$\bar{S}$		$\bar{H}'$		$\bar{J}'$	
Rockland	2	Dec 77	545.5	---	13.0	---	0.34	---	0.14	---
	3	May 78	150.3	(0-439.0)	14.3	(3.9-24.7)	0.98	(0.14-1.82)	0.38	(0.01-0.75)
Portland	3	Dec 77	229.0	(0.672.3)	40.7	(0-89.6)	3.05	(2.40-3.70)	0.86	(0.61-1.11)
	3	May 78	125.3	(8.3-242.3)	44.0	(24.6-63.4)	3.30	(2.95-3.65)	0.87	(0.77-0.97)
Isle of Shoals	4	Dec 77	204.3	(0-441.2)	38.8	(17.0-60.6)	2.98	(2.57-3.39)	0.83	(0.70-0.96)
	3	May 78	442.0	(0-1798.0)	31.7	(23.0-40.4)	2.31	(0.77-3.85)	0.67	(0.17-1.17)
Boston Foul Ground	3	Dec 77	59.7	(0-158.3)	20.0	(0-47.3)	2.36	(1.47-3.25)	0.80	(0.60-1.00)
	3	May 78	69.3	(0-139.6)	21.3	(11.9-30.7)	2.63	(1.91-3.35)	0.86	(0.74-0.98)
Boston Lightship	3	Dec 77	86.0	(0-243.3)	23.0	(0-53.3)	2.53	(0.96-4.10)	0.88	(0.81-0.95)
	3	May 78	90.3	(50.1-130.6)	29.3	(22.1-36.5)	2.93	(2.66-3.20)	0.87	(0.80-0.94)

Table 9.6 Species list and their occurrence in samples taken at Rhode Island Sound dumpsites, summer 1978.

	Species	Occurrence/ 6 Samples	No. Individuals
	Phylum PORIFERA		
1.	Haliclona sp.	1	1+
2.	Polymastia robusta	1	1+
	Phylum CNIDARIA		
	Cl. Hydroyoa		
3.	Campanularia (verticillata)	1	1+
4.	CAMPANULARIIDAE sp.	2	2+
5.	Halecium sp.	1	1+
6.	Thuiaria sp.	4	4+
	Cl. Anthozoa		
7.	Cerianthus (borealis)	3	6
8.	Edwardsia (elegans)	5	12
9.	Halcampa duodecimcirrata	1	2
	Phylum PLATYHELMINTHES		
10.	Platyhelminthes sp.	1	1
	Phylum RHYNCHOCOELA		
11.	Micrura sp.	5	14
12.	RHYNCHOCOEL sp.	1	1
	Phylum NEMATODA		
13.	NEMATODA sp.	4	12
	Phylum MOLLUSCA		
	Cl. Gastropoda		
14.	Nassarius trivittatus	2	2
15.	Arctica islandica	1	2
16.	Astarte borealis	1	1
17.	Astarte (undata)	1	2
18.	Nucula proxima	2	4
19.	Periploma fragile	2	8
20.	Pitar morrhuana	1	2
21.	Spisula solidissima	1	1
22.	Yoldia sapotilla	1	1
	Phylum ANNELIDA		
	Cl. Polychaeta		
23.	Aglaophamus circinata	2	3
24.	Ampharete arctica	5	104
25.	Ampharete (arctica)	4	250
26.	AMPHARETID sp.	1	1
27.	Asychis elongata	3	3
28.	Chone infundibuliformis	4	65
29.	CIRRATULID sp.	1	1

Table 9.6 (cont.)

	Species	Occurrence/ 6 Samples	No. Individuals
30.	*Cirriformia (grandis)*	2	4
31.	*Clymenella torquata*	3	4
32.	CLYMENELLINAE sp.	1	1
33.	*Drilonereis longa*	2	6
34.	*Eteone lactea*	3	5
35.	*Euchone elegans*	1	4
36.	FABRICIINAE sp.	2	3
37.	*Glycera dibranchiata*	1	1
38.	*Harmathoe extenuata*	2	2
39.	*Harmathoe imbricata*	2	2
40.	*Laonice cirrata*	1	2
41.	*Lumbrineris fragilis*	3	3
42.	*Lumbrineris tenuis*	6	12
43.	*Nephthys incisa*	5	64
44.	*Nephthys picta*	1	1
45.	*Nereis grayi*	1	1
46.	*Ninoe nigrippes*	6	91
47.	*Ophelina accuminata*	3	42
48.	*Ophioglycera gigantea*	1	1
49.	*Owenia fusiformis*	1	1
50.	*Paraonis gracilis*	3	4
51.	*Pherusa affinis*	4	23
52.	*Pholoe minuta*	3	4
53.	*Phyllodoce arenae*	1	1
54.	*Phyllodoce (mucosa)*	1	1
55.	*Prionospio (malmgreni)*	5	23
56.	*Scalibregma inflatum*	6	27
57.	*Scoloplos acutus*	3	18
58.	*Spio (filicornis)*	4	8
59.	*Spiophanes bombyx*	4	6
60.	*Sternaspis scutata*	1	3
61.	*Sthenelais limicola*	2	2
62.	*Terebellides stroemi*	1	1
63.	*Tharyx* sp.	1	1
	Phylum ARTHROPODA		
	Cl. Crustacea		
	Subcl. Copepoda		
64.	*Calanus* sp.	2	2
65.	*Centropages* sp.	3	5
	Subcl. Malacostraca		
	O. Cumacea		
66.	*Diastylis quadrispinosa*	5	10
67.	*Diastylis sculpta*	2	2
68.	*Eudorella truncatula*	3	166
69.	*Eudorella* sp.	1	1

Table 9.6 (cont.)

	Species	Occurrence/ 6 Samples	No. Individuals
70.	Leptocuma minor	1	1
	O. Isopoda		
71.	Cirolana polita	1	1
	O. Amphipoda		
72.	Aeginina longicornis	3	3
73.	Aeginina sp.	1	1
74.	Ampelisca abdita	3	27
75.	Ampelisca agassize	5	4897
76.	Ampelisca macrocephala	2	3
77.	Byblis serrata	4	12
78.	Erichthonius rubricornis	2	3
79.	Harpinia propinqua	3	228
80.	Hippomedon propinquis	3	5
81.	Hippomedon serratus	1	2
82.	Leptocheirus pinguis	6	200
83.	Photis dentata	3	3
84.	Phoxocephalus holbolli	4	7
85.	Trichophoxus epistomus	2	6
86.	Unciola inermis	1	1
87.	Unciola irrorata	6	482
	O. Decapoda		
88.	Axius serratus (juv.)	2	3
89.	Cancer borealis	1	1
90.	Crangon septemspinosa	1	1
	Phylum ECHINODERMATA		
	Cl. Stelleroidea		
91.	Echinarachnius parma	3	3

Table 9.7 Relative abundance of predominant species in summer 1978 samples taken in Rhode Island Sound.

Species	Phyla	Feeding Type	Occurrence 6 Samples	Total No. Individuals	Percent Totals	Cumulative Percent
1. *Ampelisca agassizi*	Ar	SF	5	4897	70.6	70.6
2. *Unciola irrorata*	Ar	DF	6	482	7.0	77.6
3. *Ampharete (arctica)*	A	DF	4	250	3.6	81.2
4. *Harpinia propinqua*	Ar	DF	3	228	3.3	84.5
5. *Leptocheirus pinquis*	Ar	DF	6	200	2.9	87.4
6. *Eudorella truncatula*	Ar	SF?	3	166	2.4	89.8

A: Annelida   Ar: Arthropoda
DF: Deposit Feeder   SF: Suspension Feeder

Total No. Individuals (excluding *Foraminifera* sp., etc*): 6933

*Although *Foraminifera* sp. were counted and represented by a number rather than a "+", it was not felt that they warranted inclusion in a list of predominant species, so they were subtracted from the Total No. of Individuals before percentages were calculated. The same is true of Nematodes, Arachnoids, Copepods, Cladocerans and Ostracods. Due to their small size many more could have washed out during sieving, therefore the number counted does not accurately represent their presences at the disposal site.

Table 9.8 Distribution of benthos summer 1978
Rhode Island Sound, Disposal Site

Number of	#1	#2	#3
Species per Sample	29	26	31
Individuals per Sample	155	206	177
Phyla per Station		9	
Species per Station		60	
Individuals per Station		538	

Table 9.9 Distribution of benthos at Rhode Island Sound
Reference Station

Number of	#1	#2	#3
Species per Sample	49	45	48
Individuals per Sample	2054	2309	2061
Phyla per Station		7	
Species per Station		72	
Individuals per Station		6424	

The lower diversity in Rhode Island is probably the result of a less stable environment and not indicative of increased stress caused by pollutants. The fact that the pollution-sensitive amphipod, Ampelisca agassizi, occurs in such high densities of the Brenton Reef reference site, supports this contention. Mean equitability values derived from "summer" 1978 collections at both the Rhode Island Sound sites, in contrast to "winter" 1977 samples, were lower than those reported for the same seasons at Gulf of Maine stations.

It appears, by examination of the confidence intervals in Table 9.9 that the mean number of undividuals and species at the Brenton Reef site were significantly fewer than those at the Reference site. Diversity and equitability values, however, were not significantly different.

9.3.3 Benthic Biota - Long Island Sound Stations

The total species list, their frequency of occurrence, and number of individuals in the 27 dredge samples collected at 9 stations in Long Island Sound is shown in Table 9.10. A summary of the more important aspects of Table 9.10 is presented in Table 9.11. From summer 1978 samples, 3,270 individual specimens of the benthos consisting of 12 phyla and 154 species were identified. In contrast to the predominantly deposit-feeding annelids, arthropods and molluscs of the northern sites, the predominant species in Long Island Sound are suspension-feeding molluscs. As was true for the winter 1978 collections, the inclusion of the edible mussel, Mytilus edulis, in the predominant species list is somewhat misleading since it was found at only one station, the New London Reference site, and was rarely taken in samples west of the Cornfield Shoals area. The total distribution of phyla, species, and individuals in summer 1978 collections from the nine sampling sites in Long Island Sound is given in Tables 9.12 and 9.13. Largest numbers of individuals were collected at the New Haven reference site; greatest number of species was found at the two New London sites. Lowest number of individuals were collected at the two Cornfield Shoals sites. The Cornfield Shoals reference site yielded the smallest number of species of any site sampled. Numeric density data for each of the nine Long Island Sound sampling sites are presented in

Table 9.10 Species list and their occurrence in samples taken in Long Island Sound, summer 1978.

	Species	Occurrence/ 27 Samples	No. Individuals
	Phylum PROTISTA		
1.	FORAMINIFERA sp. A	12	338
2.	FORAMINIFERA sp. B	4	12+
3.	FORAMINIFERA sp. C	1	1
	Phylum PORIFERA		
4.	*Cliona vastifica*	1	1+
5.	*Haliciona* sp.	2	2+
6.	PORIFERA sp.	1	1+
	Phylum CNIDARIA		
	Cl. Hydrozoa		
7.	*Calycella syringa*	7	7+
8.	*Campanularia (verticillata)*	1	1+
9.	CAMPANULARIIDAE sp.	5	5+
10.	*Clytia (coronata)*	1	1+
11.	*Clytia* sp.	1	1+
12.	*Eudendrium (vaginatim)*	1	1+
13.	*Eudendrium* sp.	2	2+
14.	*Garveia groenlandica*	1	1+
15.	*Gonothyraea (gracilis)*	5	5+
16.	*Halecium diminutivum*	3	3+
17.	*Halecium* sp.	4	4+
18.	*Hydractinia* sp.	2	2+
19.	*Stylactis hooperi*	3	5
20.	*Stylactis* sp.	2	4
21.	*Thuiaria (cupressina)*	3	3+
22.	*Thuiaria* sp.	8	8+
	Cl. Anthozoa		
23.	*Cerianthus (borealis)*	6	13
24.	*Edwardsia (elegans)*	1	1
25.	*Halcampa duodecimcirrata*	1	2
26.	*Halcampoides* sp.	1	1
27.	*Metridium senile*	1	1
	Phylum RHYNCHOCOELA		
28.	*Amphiporus* sp.	1	1
29.	*Cerebratulus* sp.	4	6
30.	*Micrura* sp.	5	9
31.	RHYNCHOCOEL sp.	4	4
	Phylum NEMATODA		
32.	NEMATODE sp.	7	75
	Phylum MOLLUSCA		
	Cl. Gastropoda		
33.	*Acteocina canaliculata*	1	3
34.	*Anachis lafresnayi*	2	6

Table 9.10 (cont.)

	Species	Occurrence/ 27 Samples	No. Individuals
35.	*Anachis* sp.	1	1
36.	*Buccinum undatum*	1	3
37.	*Crepidula fornicata*	2	3
38.	*Crepidula plana*	1	1
39.	*Cylichna* (*oryza*)	1	1
40.	*Lunatia heros*	2	3
41.	*Lunatia triseriata*	3	4
42.	*Mitrella lunata*	1	1
43.	*Nassarius trivittatus*	14	41
	Cl. Pelecypoda		
44.	*Anomia squamula*	2	3
45.	*Astarte* (*undata*)	5	14
46.	*Cerastoderma pinnulatum*	2	2
47.	*Cyclocardia borealis*	6	12
48.	*Dacrydium vitreum*	4	8
49.	*Ensis directus*	1	1
50.	*Lyonsia hyalina*	2	3
51.	*Macoma* tenta	1	2
52.	*Modiolus modiolus*	2	3
53.	*Mulinia lateralis*	11	478
54.	*Mytilus edulis*	2	187
55.	*Nucula proxima*	10	652
56.	*Periploma fragile*	1	1
57.	*Pitar morrhuana*	12	33
58.	*Solemya velum*	2	5
59.	*Solen viridis*	2	4
60.	*Tellina versicolor*	1	1
61.	*Yoldia limatula*	13	211
62.	*Yoldia sapotilla*	1	1
	Phylum ANNELIDA		
	Cl. Polychaeta		
63.	*Aglaophamus circinata*	1	1
64.	*Ampharete arctica*	8	22
65.	*Amphitrite johnstoni*	1	1
66.	*Ancistrosyllis* sp.	2	3
67.	*Asychis elongata*	1	1
68.	*Autolytus prolifer*	2	6
69.	*Autolytus* (*prolifer*)	2	7
70.	*Capitella capitata*	1	23
71.	CIRRATULID sp.	4	19
72.	*Cirriformia* (*grandis*)	1	1
73.	*Cirriformia* sp.	1	1
74.	*Clymenella torquata*	3	7
75.	*Clymenella zonalis*	3	16
76.	*Dodecaceria* (*concharum*)	1	1
77.	*Drilonereis longa*	2	2

Table 9.10 (cont.)

	Species	Occurrence/ 27 Samples	No. Individuals
78.	Euchone elegans	2	2
79.	Euclymene collaris	11	36
80.	Eulalia viridis	1	1
81.	Glycera americana	10	16
82.	Harmathoe extenuata	4	9
83.	Harmathoe imbricata	3	5
84.	Loimia medusa	2	3
85.	Lumbrineris fragilis	3	3
86.	Lumbrineris tenuis	7	26
87.	Mediomastus sp.	1	1
88.	Melinna cristata	3	15
89.	Nephthys bucera	1	3
90.	Nephthys caeca	2	2
91.	Nephthys incisa	20	268
92.	Ninoe nigripes	7	81
93.	Ophelina accuminata	1	1
94.	Owenia fusiformis	1	1
95.	Pectinaria (gouldii)	3	3
96.	Pherusa affinis	14	63
97.	Pholoe minuta	2	3
98.	Phyllodoce arenae	1	2
99.	Phyllodoce maculata	1	2
100.	Polycirrus sp.	2	2
101.	Polydora ligni	1	1
102.	Polydora sp.	1	1
103.	Potamilla reniformis	2	9
104.	Prionospio (malmgreni)	3	13
105.	Proceraea cornutus	3	6
106.	Sabellaria vulgaris	2	3
107.	Scalibregma inflatum	5	15
108.	Scoloplos acutus	1	1
109.	Spio (setosa)	1	1
110.	Spiophanes bombyx	1	1
111.	Sthenelais boa	1	1
112.	Syllis gracilis	1	1
113.	TEREBELLID sp.	2	2
114.	Tharyx sp.	1	2
	Phylum ARTHROPODA		
	Cl. Arachnoidea		
115.	Halcarus sp.	2	4
	Cl. Crustacea		
	Subcl. Branchiopoda		
116.	Evadne sp.	1	2
	Subcl. Ostracoda		
117.	OSTRACOD sp.	1	1
	Subcl. Copepoda		

Table 9.10 (cont.)

	Species	Occurrence/ 27 Samples	No. Individuals
118.	*Calanus* sp.	5	10
	Subcl. Malacostraca		
	O. Amphipoda		
119.	*Aeginina longicornis*	1	3
120.	*Ampelisca abdita*	1	1
121.	*Ampelisca vadorum*	7	149
122.	*Gammarus (annulatus)*	1	1
123.	*Leptocheirus pinguis*	8	22
124.	*Maera danae*	1	3
125.	*Parahaustorius (holmesi)*	1	4
126.	*Parahaustorius (longimerus)*	1	6
127.	*Paraphoxus spinosus*	1	1
128.	*Phoxocephalus holbolli*	1	1
129.	*Unciola irrorata*	8	45
130.	*Cancer irroratus*	6	7
131.	*Eurypanopeus depressus*	1	1
132.	*Libinia dubia*	1	1
133.	*Pagurus longicarpus*	7	22
	Phylum ENTOPROCTA		
134.	*Barentsia* sp.	1	1+
	Phylum BRYOZOA		
135.	*Aeverrillia armata*	2	2+
136.	*Aeverrillia setigera*	1	1+
137.	*Becellariella ciliata*	5	5+
138.	*Bicellariella* sp.	1	1+
139.	*Bowerbankia imbricata*	5	5+
140.	*Bugula simplex*	1	1+
141.	*Bugula turrita*	3	3+
142.	*Bugula* sp.	4	4+
143.	*Callopora aurita*	3	3+
144.	*Callopora craticula*	1	1+
145.	*Cribrilina punctata*	2	2+
146.	*Hippoporina* sp.	4	4+
147.	*Hippothoa hyalina*	1	1+
148.	*Membranipora tenuis*	2	2+
149.	*Microporella ciliata*	2	2+
150.	*Parasmittina* sp.	1	1+
151.	*Scruparia chelata*	2	2+
152.	*Tegella* sp.	1	1+
153.	*Triticella* sp.	3	3+
	Phylum ECHINODERMATA		
	Cl. Stelleroidea		
154.	*Amphipholis squamatus*	1	4
155.	*Asterias forbesi*	1	1

Table 9.10 (cont.)

Species	Occurrence/ 27 Samples	No. Individuals
Phylum CHORDATA		
Cl. Pisces		
O. Osteichthyes		
156. *Ammodytes americanus*	4	17

Table 9.11 Relative abundance of predominant species in summer 1978 samples taken in Long Island Sound.

Species	Phyla	Feeding Type	Occurrence 27 Samples	Total No. Individuals	Percent Totals	Cumulative Percent
1. Nucula proxima	M	SF	10	652	23.8	23.8
2. Mulinia lateralis	M	SF	11	478	17.5	41.3
3. Nephtys incisa	A	DF	20	262	9.6	50.9
4. Yoldia limatula	M	SF	13	211	7.7	58.6
5. Mytilus edulis	M	SF	2	187	6.8	65.4
6. Ampelisca vadorum	Ar	SF	7	149	5.4	70.8
7. Ninoe nigripes	A	P	7	81	3.0	73.8
8. Pherusa affinis	A	DF	14	63	2.3	76.1

A: Annelida Ar: Arthropoda M: Mollusca
DF: Deposit Feeder SF: Suspension Feeder P: Predator

Total No. Individuals (excluding Foraminifera sp. etc.)*: 2736

*See footnote - Table 9.3

Table 9.12 Distribution of benthos at six sites in eastern Long Island Sound, Summer 1978.

	NEW LONDON DUMPSITE			NEW LONDON REFERENCE			CORNFIELD SHOAL DUMPSITE		
	#1	#2	#3	#1	#2	#3	#1	#2	#3
Number of									
Species per Sample	46	55	49	46	38	51	20	7	0
Individuals per Sample	359	138	148	345	125	193	25	17	0
Phyla per Station		10			10			7	
Species per Station		86			80			24	
Individuals per Station		645			663			42	

	CORNFIELD SHOAL REFERENCE			NEW HAVEN DUMPSITE			NEW HAVEN REFERENCE		
	#1	#2	#3	#1	#2	#3	#1	#2	#3
Number of									
Species per Sample	4	3	0	17	11	7	11	13	19
Individuals per Sample	22	3	0	84	45	27	189	283	372
Phyla per Station		4			8			6	
Species per Station		6			26			27	
Individuals per Station		25			156			844	

Table 9.13 Distribution of benthos at three sites in western Long Island Sound, summer 1978.

	CABLE & ANCHOR REEF DUMPSITE			WESTERN L.I.S. DUMPSITE			CAR & WLIS REFERENCE		
Number of	#1	#2	#3	#1	#2	#3	#1	#2	#3
Species per Sample	9	10	13	5	4	6	10	8	8
Individuals per Sample	34	97	42	68	13	79	111	111	340
Phyla per Station		7			6			5	
Species per Station		22			9			15	
Individuals per Station		173			160			562	

Appendix 9.3. As has been the case for all stations so far examined, sample-to-sample variability is high with standard deviations frequently exceeding their respective means and, for the most part, a relatively small number of species comprising a large percentage of the total individuals collected. The mean value for diversity is highest at the New London reference site and lowest at the Cornfield Shoals reference site. Both the Cornfield Shoals dump site and Reference site are located in a very high-energy environment. This factor, combined with a rather coarse, sandy bottom probably restricts the establishment of many of the benthic species indigenous to sediments in the surrounding area. Values for equitability coefficients of dispersion indicate a clumped spatial distribution at all Long Island Sound sampling stations.

Tables 9.14 and 9.15 list $\bar{N}$, $\bar{S}$, $\bar{H}'$, and $\bar{J}'$ for stations in eastern and western Long Island Sound, respectively. The 95 percent confience intervals show that $\bar{S}$ is significantly greater at the New London dump and reference sites than at most of the other Long Island sites. No significant differences can be demonstrated between any of the other sites for the summer 1978 collections. A comparison of all means for winter, 1977 and summer 1978 collections are made for all stations in the following section.

9.3.4 Data Comparison - Winter-Spring 1977-78 with Spring-Summer 1978

A summary of the total distribution of benthic biola collected at all DAMOS stations during winter-spring 1977-78 and spring-summer 1978 sampling is shown in Table 9.16. Some striking similarities exist between the two data sets. The total number of phyla was the same. The total number of species collected in these two sampling periods differed by only four species. The total number of individuals collected from the winter-spring 1977-78 samples was 16,083; spring-summer 1978 collections yielded a total of 12,864 individuals. Seasonal difference can be attributed to the abundance of *A. agassizi*. The predominant species are members of three phyla, the annelids, molluscs, and arthropods. The overall percent composition of these three phyla is not greatly different for winter or summer.

Figure 9.1 shows how the percent of the total number of individuals in each of the three major phyla varies for all DAMOS sampling stations in winter

Table 9.14 Summary of species distribution of six sites in eastern Long Island Sound. The number of samples is indicated by n. Mean number of individuals ($\bar{N}$), species ($\bar{S}$), diversity ($\bar{H}'$), and equitability ($\bar{J}'$), and the 95% C.I. of these means (in parentheses) are shown.

Station	n	Date	$\bar{N}$		$\bar{S}$		$\bar{H}'$		$\bar{J}'$	
New London	3	Apr 78	284.3	(0-1323.6)	27.3	(0-77.2)	1.62	(0-3.31)	0.60	(0-1.27)
	3	Aug 78	215.0	(0-525.1)	50.0	(38.6-61.4)	2.80	(0.81-4.79)	0.72	(0.25-1.19)
N.L. Reference	3	Apr 78	167.0	(0-413.0)	39.7	(26.0-53.4)	2.62	(1.38-3.86)	0.71	(0.34-1.08)
	3	Aug 78	221.0	(0-500.7)	45.0	(28.6-61.4)	2.82	(1.48-4.16)	0.74	(0.37-1.11)
Cornfield Shoal	3	Jan 78	3.0	(0-9.6)	1.7	(0.3-3.1)	0.38	(0-1.25)	0.55	(0-1.82)
	3	Jul 78	14.0	(0-45.8)	9.0	(0-34.3)	1.50	(0-5.13)	0.59	(0-1.88)
C.S. Reference	3	Jan 78	29.7	(0-126.9)	6.7	(0-31.2)	0.94	(0-4.00)	0.51	(0-1.60)
	3	Jul 78	8.3	(0-37.9)	2.3	(0-7.5)	0.80	(0-2.54)	0.65	(0-2.40)
New Haven	3	Apr 78	157.0	(0-568.2)	18.7	(2.2-35.2)	2.04	(1.02-3.06)	0.71	(0.41-1.01)
	3	Jul 78	52.0	(0-124.3)	11.7	(0-24.1)	1.73	(0.79-2.67)	0.72	(0.50-0.94)
N.H. Reference	3	Apr 78	42.0	(4.9-79.1)	14.7	(10.9-18.5)	2.17	(1.33-1.01)	0.81	(0.51-1.11)
	3	Jul 78	281.3	(54.0-508.6)	14.3	(3.9-24.7)	1.06	(0.54-1.58)	0.40	(0.20-0.60)

Table 9.15 Summary of species distribution of three sites in western Long Island Sound. The number of samples is indicated by n. Mean number of individuals ($\bar{N}$), species (), diversity ($\bar{H}'$), and equitability ($\bar{J}'$), and the 95% C.I. of these means (in parentheses) are shown.

Station	n	Date	$\bar{N}$		$\bar{S}$		$\bar{H}'$		$\bar{J}'$	
Cable & Anchor Reef	3	Apr 78	15.0	(0-30.5)	5.0	(0-11.6)	1.01	(0-2.43)	0.65	(0.25-1.05)
	3	Jul 78	57.7	(0-142.9)	10.7	(5.5-15.9)	1.79	(1.04-2.54)	0.76	(0.54-0.98)
Western L.I. Sound	3	Apr 78	6.3	(0-17.5)	4.0	(0-9.0)	1.15	(0.16-2.14)	0.92	(0.65-1.19)
	3	Jul 78	53.3	(0-141.3)	5.0	(2.5-7.5)	0.97	(0.45-1.49)	0.62	(0.15-1.09)
C&AR and W.L.I.S.	3	Apr 78	26.3	(8.3-44.3)	6.0	(3.5-8.5)	1.06	(0.02-2.10)	0.58	(0.08-1.08)
Reference	3	Jul 78	187.3	(0-515.7)	8.7	(5.7-11.7)	1.09	(0-2.21)	0.50	(0-1.05)

Table 9.16 Data summary of benthos collected at DAMOS stations, 1977-78.

Total Number	Winter-Spring 1977-78	Spring-Summer 1978
Dredge Samples	47	48
Phyla	16	16
Species	274	278
Individuals	16,083	12,864
A. agassizi	8,081	4,897
Ind. (excluding *A. agassizi*)	8,002	7,967

Predominant species belong three Phyla:

	Percent of All Species	Percent of All Individuals
Annelida	32	28
Mollusca	18	24
Arthropoda	17	17
Total	67	67

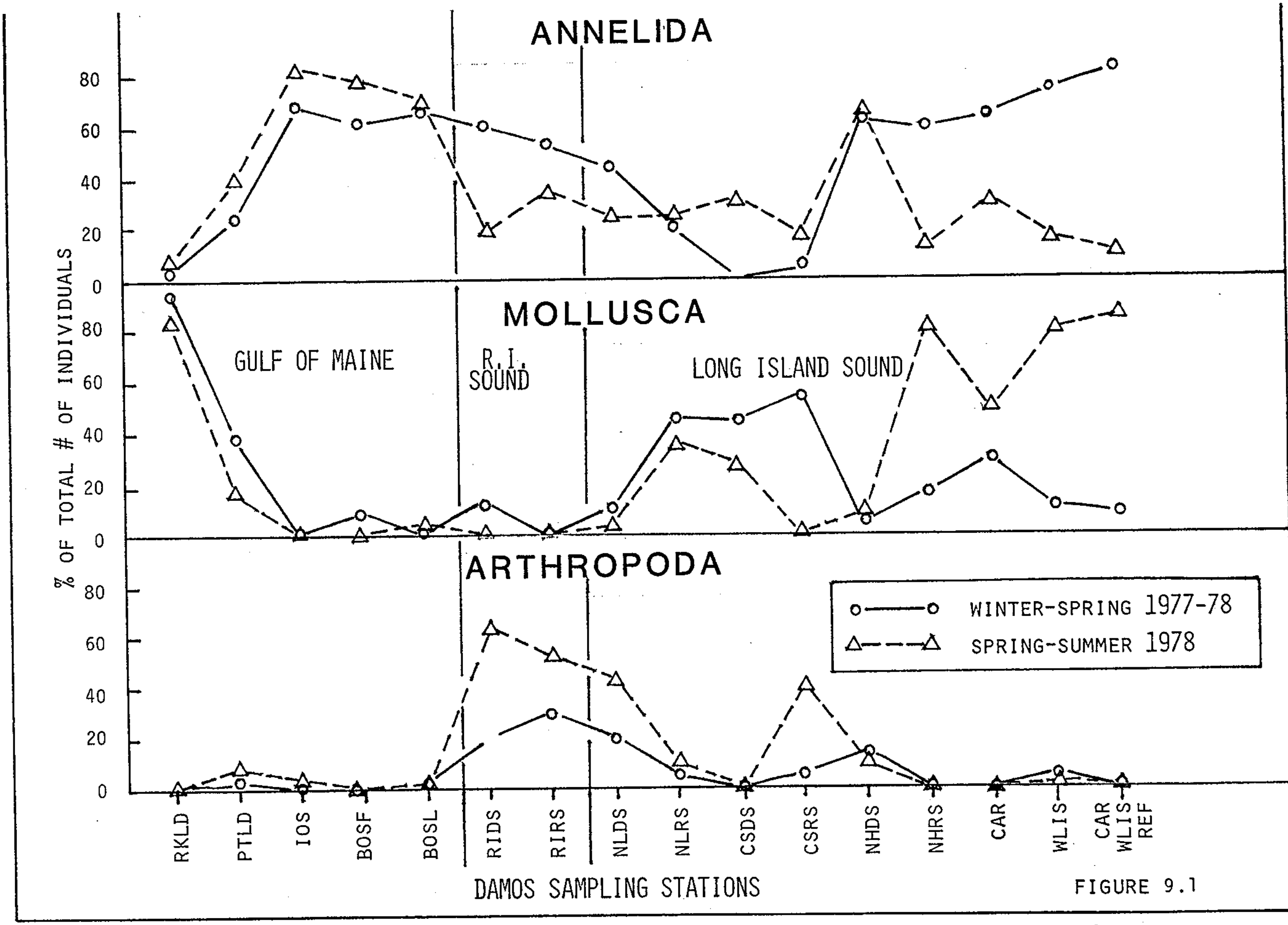

FIGURE 9.1

DISTRIBUTION OF INDIVIDUALS BY PHYLA

1977 and for spring 1978. There appears to be minor seasonal differences in the abundance of individuals of a given phylum of each station, with the exception of annelids and molluscs in western Long Island Sound. When the percent of annelids in samples was high in western Long Island Sound, that of molluscs was low and vice versa. Arthropods were relatively sparse except at the Brenton Reef dump, reference sites, and the New London dump sites.

9.3.5 Benthos-sediment relationships

The importance of sedimentary parameters in delimiting macrobenthic species assemblages or communities is well known. Though sediment samples have been collected from all sites during the course of the DAMOS studies, information on sedimentary characteristics such as grain size and organic carbon content are not yet available. Interpretation of the DAMOS benthos data has suffered from the lack of these vital sediment statistics. It is anticipated that these data will be forthcoming in the near future.

9.4 CONCLUSIONS

In general, conclusions reached as a result of the study of samples collected during the spring-summer 1978 are identical to the conclusions reached from results of the analyses of the winter-spring collections of 1977-78.

- Sample-to-sample variability in number of individuals and species is high with standard deviations often exceeding their means.
- With rare exceptions the coefficients of dispersion indicate a highly clumped spatial distribution pattern at all stations.
- A small percentage of the total number of species predominate, commonly accounting for 80 percent or more of the total number of individuals collected at a given station.
- No seasonal differences could be demonstrated for $\bar{N}$ or $\bar{S}$ for any of the sampling sites except at the Brenton Reef dump site where $\bar{N}$ and $\bar{S}$ were both significantly greater in the summer of 1978.
- No significant seasonal differences could be demonstrated for $\bar{H}'$ at any of the sample stations.

- In the 1977-78 winter, the mean number of individuals was highest at the Brenton Reef reference site and lowest at the Cornfield Shoals dump site.

- In the summer of 1978, the highest mean number of species was collected at the New London dump site; lowest $\bar{S}$ was found in Winter 1977-78 samples taken at the Cornfield Shoals dump site.

- Mean diversity was higher in the Gulf of Maine stations ($\bar{H}' = 2\text{-}3$) and lower at the stations in Rhode Island Sound and Long Island Sound ($\bar{H}' = 1\text{-}2$).

- During both summer and winter seasons molluscs and annelids predominate in the Gulf of Maine; arthropods and annelids comprise the largest percentage of benthos at the Rhode Island Sound stations, and the Long Island Sound fauna is dominated by arthropods, molluscs, and annelids.

In summary, data on macrobenthos at each DAMOS site are now available, and can be used in evaluating the populations at these sites. To date, no significant effects resulting from disposal have been identified, however, the high variability of the benthos data have made specific interpretation of effects difficult. Future work will be aimed at reducing this variability through correspondence analysis and discriminate function techniques, relating population parameters to substrate conditions.

9.5 REFERENCES

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APPENDIX 9.1

Abundance and diversity of benthos at five dumpsites in the Gulf of Maine, summer 1978.

ROCKLAND

Date: 11 May 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Nucula Proxima	49	249	76	374	124.7	108.5	94.5	0 -394.3	1	82.9	82.9
Terebellides stroemi	2	7	4	13	4.3	2.5	1.5	0 - 10.5	2	2.9	85.8
Ampharete (arctica)	5	5	2	12	4.0	1.7	0.7	0 - 8.2	3	2.7	88.5

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	1.36	0.70	0.89	0.98	0.34
Equitability (J'):	0.53	0.24	0.37	0.38	0.15

APPENDIX 9.1 (cont.)

PORTLAND

Date: 18 May 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Amphareta (arctica)	12	14	14	40	13.3	1.2	0.1	10.3- 16.3	1	10.7	10.7
Cyclocardia borealis	0	28	8	36	12.0	14.4	17.3	0 - 47.8	2	9.7	20.4
Haploops tubicola	5	17	6	28	9.3	6.7	4.8	0 - 25.9	3	7.5	27.9
Astarte (undata)	6	12	9	27	9.0	3.0	1.0	1.5- 16.5	4	7.2	35.1
Melinna cristata	2	12	6	20	6.7	5.0	3.7	0 - 19.1	5	5.4	40.5
Lumbrineris fragilis	3	7	9	19	6.3	3.1	1.5	0 - 14.0	6	5.1	45.6
Goniada maculata	5	10	1	1	5.3	4.5	3.8	0 - 16.5	7	4.3	49.9
Nephytys incisa	1	5	6	12	4.0	2.7	1.8	0 - 10.7	8	3.2	53.1
Ninoe nigripes	4	3	5	12	4.0	1.0	0.3	1.5- 6.5	8	3.2	56.3
Sternaspis scutata	2	4	6	12	4.0	2.0	1.0	0 - 9.0	8	3.2	59.5
Polycirrus sp.	1	0	7	8	2.7	3.8	5.3	0 - 12.1	9	2.1	61.6
Streblosoma spiralis	0	6	2	8	2.7	3.1	3.6	0 - 10.4	9	2.1	63.7

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	3.21	3.22	3.46	3.30	0.14
Equitability (J'):	0.90	0.83	0.89	0.87	0.04

APPENDIX 9.1 (cont.)

ISLE OF SHOALS

Date: 20 May 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Maldane sarsi	4	3	591	598	199.3	339.2	577.3	0 - 1042.0	1	45.1	45.1
Ampharete (arctica)	57	21	152	230	76.7	67.7	59.8	0 - 244.9	2	17.3	62.4
Myriochele heeri	0	2	168	170	56.7	96.4	163.9	0 - 296.2	3	12.8	75.2
Sternaspis scutata	5	13	37	55	18.3	16.7	15.2	0 - 59.8	4	4.1	79.3
Haploops tubicola	5	9	22	36	12.0	8.9	6.6	0 - 34.1	5	2.7	82.0
Spio filicornis	6	4	24	34	11.3	11.0	10.8	0 - 38.6	6	2.6	84.6

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	2.63	2.70	1.59	2.31	0.62
Equitability (J'):	0.76	0.81	0.45	0.67	0.20

APPENDIX 9.1 (cont.)

BOSTON FOUL GROUND

Date: 23 May 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Sternaspis scutata	6	22	0	28	9.3	11.4	14.0	0 - 37.6	1	13.8	13.8
Spio filicornis	5	18	2	25	8.3	8.5	8.7	0 - 29.4	2	12.3	26.1
Scoloplos acutus	1	21	1	23	7.7	11.6	17.5	0 - 36.5	3	11.3	37.4
Amphareta (arctica)	2	2	11	15	5.0	5.2	5.4	0 - 17.9	4	7.4	44.8
Micrura sp.	4	5	3	12	4.0	1.0	0.3	1.5- 6.5	5	5.9	50.7
Lumbrineris fragilis	1	3	7	11	3.7	3.1	2.6	0 - 11.4	6	5.4	56.1
Praxillella gracilis	5	4	1	10	3.3	2.1	1.3	0 - 8.5	7	4.9	61.0
Ninoe nigripes	3	0	6	9	3.0	3.0	3.0	0 - 10.5	8	4.4	65.4
Cirratulid sp.	0	4	3	7	2.3	2.1	1.9	0 - 7.5	9	3.4	68.8
Heteromastus filiformis	0	7	0	7	2.3	4.0	7.0	0 - 12.2	9	3.4	72.2
Maldane sarsi	0	5	1	6	2.0	2.7	3.6	0 - 8.7	10	3.0	75.2
Notomastus latericeus	6	0	0	6	2.0	3.5	6.1	0 - 10.7	10	3.0	78.2
Prionospio sp.	0	5	1	6	2.0	2.7	3.6	0 - 8.7	10	3.0	81.2
Melinna cristata	0	1	3	4	1.3	1.5	1.7	0 - 5.0	11	2.0	83.2

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	2.83	2.30	2.75	2.63	0.29
Equitability (J'):	0.90	0.81	0.88	0.86	0.05

APPENDIX 9.1 (cont.)

BOSTON LIGHTSHIP

Date: 23 May 1978

Predominant Species	Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Maldane sarsi	2	13	25	40	16.7	16.8	16.9	0 - 58.4	1	15.2	15.2
Sternaspis scutata	3	8	16	27	9.0	6.6	4.8	0 - 25.4	2	10.3	25.5
Lumbrineris fragilis	7	7	6	20	6.7	0.6	0.1	5.2- 8.2	3	7.6	33.1
Spio filicornis	8	6	5	19	6.3	1.5	0.4	2.6- 10.0	4	7.2	40.3
Amphareta (arctica)	9	7	2	18	6.0	3.6	2.2	0 - 14.9	5	6.8	47.1
Goniada maculata	9	4	2	15	5.0	3.6	2.6	0 - 13.9	6	5.7	52.8
Ninoe nigripes	3	2	8	13	4.3	3.2	2.4	0 - 12.3	7	4.9	57.7
Scoloplos acutus	0	3	8	11	3.7	4.0	4.3	0 - 13.6	8	4.2	61.9
Terebellides stroemi	6	5	0	11	3.7	3.2	2.8	0 - 11.7	8	4.2	66.1
Cerastoderma pinnulatum	6	0	3	9	3.0	3.0	3.0	0 - 10.5	9	3.4	69.5
Nephtys incisa	1	5	2	8	2.7	2.1	1.6	0 - 7.9	10	3.0	72.5
Ctenodiscus crispatus	1	2	3	6	2.0	1.0	0.5	0 - 4.5	11	2.3	74.8
Cerebratulus sp.	1	2	2	5	1.7	0.6	0.2	0.2- 3.2	12	1.9	76.7
Micrura sp.	0	1	4	5	1.7	2.1	2.6	0 - 6.9	12	1.9	78.6

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	3.05	2.90	2.84	2.93	0.11
Equitability (J'):	0.89	0.89	0.83	0.87	0.03

APPENDIX 9.2

Abundance and diversity of benthos at two locations in Rhode Island Sound, summer 1978.

BRENTON REEF

Date: 3 August 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Unciola irrorata	7	158	118	283	94.3	78.2	64.9	0 -288.6	1	54.2	54.2
Ninoe nigripes	45	1	4	50	16.7	24.6	36.2	0 - 77.8	2	9.6	63.8
Ampelisca agassizi	21	0	7	28	9.3	10.7	12.3	0 - 35.9	3	5.4	69.2
Nephytys incisa	23	0	2	25	8.3	12.7	19.4	0 - 39.9	4	4.8	74.0
Leptocheirus pinguis	1	5	7	13	4.3	3.1	2.2	0 - 12.0	5	2.5	76.5
Scalibregma inflatum	1	6	6	13	4.3	2.9	2.0	0 - 11.5	5	2.5	79.0
Byblis serrata	2	8	1	11	3.7	3.8	3.9	0 - 13.1	6	2.1	81.1

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	2.53	1.21	1.66	1.80	0.67
Equitability (J'):	0.75	0.37	0.48	0.53	0.20

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APPENDIX 9.2 (cont.)

BRENTON REEF REFERENCE

Date: 3 August 1978

Predominant* Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Ampharete (arctica)	61	101	80	242	80.7	20.0	5.0	31.0-130.4	1	15.7	15.7
Harpinia propinqua	70	93	65	228	76.0	14.9	2.9	39.0-113.0	2	14.8	30.5
Unciola irrorata	56	75	68	199	66.3	9.6	1.4	42.5- 90.2	3	12.9	43.4
Leptocheirus pinguis	56	67	64	187	62.3	5.7	0.5	32.7- 91.9	4	12.1	55.5
Eudorella truncatula	48	69	49	166	55.3	11.9	2.6	25.7- 84.9	5	10.8	66.3
Ampharete arctica	36	31	32	99	33.0	2.7	0.2	26.3- 39.7	6	6.4	72.7
Chone infundibuliformis	34	12	17	63	21.0	11.5	6.3	0 - 49.6	7	4.1	76.8
Ophelina accuminata	14	13	15	42	14.0	1.0	0.1	11.5- 16.5	8	2.7	79.5
Ninoe nigripes	10	9	22	41	13.7	7.2	3.8	0 - 31.6	9	2.7	82.2
Nephtys incisa	20	7	12	39	13.0	6.6	3.4	0 - 29.4	10	2.5	84.7

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	1.25	1.19	1.19	1.21	0.03
Equitability (J'):	0.32	0.31	0.31	0.31	0.01

*The amphipod, Ampelisca agassize, accounted for 78.8 percent (4869/6175) of all individuals collected at this station. To gain a better insight into the species composition here, it was excluded from this list.

APPENDIX 9.3

Abundance and dity of benthos at 9 sites in Long Island Sound, summer 1978.

NEW LONDON

Date: 2 August 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Ampelisca vadorum	41	28	41	110	36.7	7.5	1.5	18.1- 55.3	1	29.6	29.6
Ninoe nigripes	22	13	11	46	15.3	5.9	2.3	0.6- 30.0	2	12.4	42.0
Unciola irrorata	8	7	10	25	8.3	1.5	0.3	4.6- 12.0	3	6.7	48.7
Pagurus longicarpus	6	1	8	15	5.0	3.6	2.6	0 - 13.9	4	4.0	52.7
Leptocheirus pinguis	6	1	7	14	4.7	3.2	2.2	0 - 12.7	5	3.8	56.5
Scalibregma inflatum	2	1	8	11	3.7	3.8	3.9	0 - 13.1	6	3.0	59.5
Ampharete arctica	6	2	2	10	3.3	2.3	1.6	0 - 9.0	7	2.7	62.2
Astarte undata	4	4	1	9	3.0	1.7	1.0	0 - 7.2	8	2.4	64.5
Potamilla reniformis	0	4	5	9	3.0	2.7	2.4	0 - 9.7	8	2.4	67.0
Nephytys incisa	4	3	1	8	2.7	1.5	0.8	0 - 6.4	9	2.2	69.2

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	1.91	3.44	3.06	2.80	0.80
Equitability (J'):	0.50	0.86	0.79	0.72	0.19

APPENDIX 9.3 (cont.)

NEW LONDON REFERENCE (F-8)

Date: 2 August 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Mytilus edulis	184	0	3	187	62.3	105.4	178.3	0 -324.1	1	35.5	35.5
Ampelisca vadorum	1	18	19	38	12.7	10.1	8.0	0 - 37.8	2	7.2	42.7
Ninoe nigripes	2	20	12	34	11.3	9.0	7.2	0 - 33.7	3	6.5	49.2
Euclymene collaris	9	7	8	24	8.0	1.0	0.1	55 - 10.5	4	4.6	53.8
Capitella capitata	23	0	0	23	7.7	13.3	23.0	0 - 40.7	5	4.4	58.2
Cirratulid sp.	14	0	3	17	5.7	7.4	9.6	0 - 24.1	6	3.2	61.4
Lumbrineris tenuis	13	4	0	17	5.7	6.7	7.9	0 - 22.3	6	3.2	64.6
Clymenella torquata	11	4	0	15	5.0	5.6	6.3	0 - 18.9	7	2.8	67.4

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	2.20	3.14	3.13	2.82	0.54
Equitability (J'):	0.57	0.86	0.80	0.74	0.15

APPENDIX 9.3 (cont.)

CORNFIELD SHOAL

Date: 31 July 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Ammodytes americanus	1	6	0	7	2.3	3.2	4.5	0- 10.3	1	31.8	31.8
Buccinum undatum	3	0	0	3	1.0	1.7	2.9	0- 5.2	2	13.6	45.4
Proceraea cornutus	2	0	0	2	0.7	1.2	2.1	0- 3.7	3	9.1	54.5
Sabellaria vulgaris	2	0	0	2	0.7	1.2	2.1	0- 3.7	3	9.1	63.6
Stylactis sp.	2	0	0	2	0.7	1.2	2.1	0- 3.7	3	9.1	72.7
Ampharete arctica	1	0	0	1	0.3	0.6	1.2	0- 1.8	4	4.5	77.2
Cerastoderma pinnulatum	1	0	0	1	0.3	0.6	1.2	0- 1.8	4	4.5	81.7
Dacrydium vitreum	1	0	0	1	0.3	0.6	1.2	0- 1.8	4	4.5	86.2
Lumbrineris tenuis	0	1	0	1	0.3	0.6	1.2	0- 1.8	4	4.5	90.7
Nassarius trivittatus	0	1	0	1	0.3	0.6	1.2	0- 1.8	4	4.5	95.2
Phloe minuta	0	1	0	1	0.3	0.6	1.2	0- 1.8	4	4.5	99.7

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	2.92	1.57	0	1.50	1.46
Equitability (J'):	0.97	0.81	0	0.59	0.52

APPENDIX 9.3 (cont.)

CORNFIELD SHOAL REFERENCE

Date: 31 July 1978

Predominant Species	Number of Individuals								Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
	Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean			
Ammodytes americanus	9	1	0	10	3.3	4.9	7.3	0- 15.5	1	40.0	40.0
Parahaustorius (longimerus)	6	0	0	6	2.0	3.5	6.1	0- 10.7	2	24.0	64.0
Parahaustorius (holmesi)	4	0	0	4	1.3	2.3	4.1	0- 7.0	3	16.0	80.0
Nephytys bucera	3	0	0	3	1.0	1.7	2.9	0- 5.2	4	12.0	92.0
Cerebratulus sp.	1	0	0	1	0.3	0.6	1.2	0- 1.8	5	4.0	96.0
Cirratulid sp.	0	1	0	1	0.3	0.6	1.2	0- 1.8	5	4.0	100.0

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	1.30	1.10	0	0.80	0.70
Equitability (J'):	0.94	1.00	0	0.65	0.56

APPENDIX 9.3 (cont.)

NEW HAVEN

Date: 29 July 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Nephtys incisa	39	18	17	74	24.7	12.4	6.2	0- 55.5	1	55.2	55.2
Melinna cristata	8	0	0	8	2.7	4.6	7.8	0- 14.1	2	6.0	61.2
Unciola irrorata	0	6	1	7	2.3	3.2	4.5	0- 10.3	3	5.2	66.4
Yolida Limatula	4	0	3	7	2.3	2.1	1.9	0- 7.5	3	5.2	71.6
Leptocheirus pinguis	2	2	2	6	2	0	0	2.0	4	4.5	76.1
Micrura sp.	1	4	0	5	1.7	2.1	2.6	0- 6.9	5	3.7	79.8
Cerianthus (borealis)	0	3	1	4	1.3	1.5	1.7	0- 5.0	6	3.0	82.8
Pherusa affinia	0	4	0	4	1.3	2.3	4.1	0- 7.0	6	3.0	85.8
Pitar morrhuana	0	3	0	3	1.0	1.7	2.9	0- 5.2	7	2.2	88.0

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	1.93	1.96	1.29	1.73	0.38
Equitability (J'):	0.68	0.82	0.66	0.72	0.09

APPENDIX 9.3 (cont.)

NEW HAVEN REFERENCE

Date: 29 July 1978

Predominant Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Nucula proxima	134	231	267	632	210.7	68.8	22.5	39.8-381.6	1	75.9	75.9
Nephtys incisa	17	22	27	66	22.0	5.0	1.1	9.6- 34.4	2	7.9	83.8
Yoldia limatula	9	10	22	41	13.7	7.2	3.8	0- 31.6	3	4.9	88.7
Pherusa affinis	16	5	9	30	10.0	5.6	3.1	0- 23.9	4	3.6	92.3

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	1.13	0.82	1.22	1.06	0.21
Equitability (J'):	0.47	0.32	0.41	0.40	0.08

APPENDIX 9.3 (cont.)

CABLE AND ANCHOR REEF (CAR)

Date: 27 July 1978

Predominant* Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Mulinia lateralis	3	39	10	52	17.3	19.1	21.1	0- 64.8	1	32.7	32.7
Nephtys incisa	8	31	5	44	14.7	14.2	13.7	0- 50.0	2	27.7	60.4
Yoldia limatula	11	15	0	26	8.7	7.8	7.0	0- 28.1	3	16.4	76.8
Pherusa affinis	0	0	5	5	1.7	2.9	4.7	0- 8.9	4	3.1	79.9
Cerebratulus sp.	0	2	2	4	1.3	1.2	1.1	0- 4.3	5	2.5	82.4

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	1.76	1.51	2.11	1.79	0.30
Equitability (J'):	0.80	0.66	0.82	0.76	0.09

APPENDIX 9.3 (cont.)

WESTERN LONG ISLAND SOUND (WLIS)

Date: 27 July 1978

Predominant* Species	Number of Individuals: Sample No. 1	Sample No. 2	Sample No. 3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Yoldia limatula	53	7	17	77	25.7	24.2	22.8	0- 85.8	1	73.3	73.3
Nephtys incisa	9	3	4	16	5.3	3.2	1.9	0- 13.3	2	15.2	88.5
Mulinia lateralis	4	2	0	6	2.0	2.0	20.0	0- 7.0	3	5.7	94.2
Cerianthus (*borealis*)	0	1	2	3	1.0	1.0	1.0	0- 3.5	4	2.9	97.1
Evadne sp.	0	0	2	2	0.7	1.2	2.1	0- 3.7	5	1.9	99.0

	Sample 1	Sample 2	Sample 3	Mean	Std. Dev.
Species Diversity (H'):	0.75	1.16	0.99	0.97	0.21
Equitability (J'):	0.47	0.83	0.55	0.62	0.19

APPENDIX 9.3 (cont.)

CAR AND WLIS REFERENCE

Date: 27 July 1978

Predominant* Species	Number of Individuals: Sample No. 1	2	3	Total	Mean	Std. Dev.	Coeff. of Dispersion	95% Conf. Limits of Mean	Species Abundance Rank	Percent of Total Individuals	Cumulative Percent of Individuals
Mulinia lateralis	69	45	292	406	135.3	136.2	137.1	0- 473.7	1	72.6	72.6
Yoldia limatula	25	22	13	60	20.0	6.2	1.9	4.6- 35.4	2	10.7	83.3
Nephtys incisa	10	22	19	51	17.0	6.2	2.3	1.6- 32.4	3	9.1	92.4
Mitrella lunata	0	4	11	15	5.0	5.6	6.3	0- 18.9	4	2.7	95.1

	Sample 1	2	3	Mean	Std. Dev.
Species Diversity (H'):	1.15	1.50	0.61	1.09	0.45
Equitability (J'):	0.50	0.72	0.29	0.50	0.22

10.0

DAMOS FISHERIES PROGRAM

SHELDON D. PRATT

10.0 DAMOS FISHERIES PROGRAM

10.1 INTRODUCTION

This project, like the DAMOS program as a whole, evolved over the last year as problems were defined and constraints uncovered. Herein I discuss the present scope and direction of the program, some of the fisheries of each area, and some special problems common to spoil-disposal sites in the Gulf of Maine.

The area of concern was limited to a 2-5 km radius at each site. This is the "near field" where spoil-derived materials may be detected without sophisticated techniques. Disposal effects on the burial of lobster pots and benthic animals, changes in the abundance of benthos eaten by fish, and changes in fish abundance due to gross turbidity are being studied. These are direct, short-term effects and are easier to interpret than those of long-term pollution. Analyses of distant areas are not justified unless near-field effects are shown.

10.2 PROGRAM DESCRIPTION

Three tasks were proposed for the first year's work. The first consisted of identification of fisheries and potential fisheries in the vicinity of each site and their seasonal and long-term patterns while information was collected mainly from interviews with fishermen; published and unpublished information from research and regulatory agencies was also examined. Short descriptions of each area were given to the fisherman for their review. Common names and measurements were used where possible.

Preparation of this descriptive material took most of the year. This time appears well spent since the fisheries data at sites other than Rhode Island had not been mapped although extensive environmental studies had been conducted. It is clear that these descriptions need to be constantly updated due to changes in catch quotas, stock availability, and gear development.

The second task was monitoring the catch. Agreements were made with fishermen to fish selected areas using standardized methods. Site-specific data generated by state or federal programs were also examined.

Lobster catches are presently monitored by cooperating fishermen at the Rhode Island and New Haven sites. They record catches of "keepers, shorts, eggers, softshells, and crabs" for each three-day set. At the Rhode Island Brenton Reef site there are two lines of three, 10-pot trawls on spoil material and a similar line on natural bottom. Data are recorded each set-day on catches from each 10-pot trawl. Thus there are nine sets of observations obtained every set-day. At New Haven, three lines of three-pot trawls were placed around the site used for disposal of Stamford, Connecticut, spoil in the spring of 1979. The pot locations have been changed several times to protect them from towboat and scow traffic. It is desirable to monitor lobster catches at the Portland, Maine, site; however, to date no lobsterman has agreed to work with the DAMOS program and fish at the site.

It now seems doubtful that finfish catches in the disposal areas can be monitored using commercial gear. The substrate on or around the sites is too irregular to effectively use trawl gear. At the Portland site, however, tows are made reasonably near the spoil pile, and interviews with fishermen can be conducted. The National Marine Fisheries Service regional catch data can be reviewed to detect gross changes in fish populations.

The third task was determining catch quality. Fin rot disease of winter flounder (<u>Pseudopleuronectes</u> <u>americanus</u>) and shell disease of crustaceans have been found in the New York Bight (Young and Pearce, 1965, Mahoney et al., 1974), and moribund ocean quahogs were caught off Rhode Island in 1967. No recent problems of this sort have been reported, however. In the future, selected commercial species may be collected for analysis of metals or hydrocarbons by cooperating DAMOS programs.

10.3 AREA FISHERIES

The following descriptions of fisheries at each study site should serve as an introduction to the areas and species "at risk" and summarize the information collected during interviews. The descriptions are more complete for Maine and Rhode Island sites than for those in Massachusetts and Connecticut. A map accompanies each description.

10.3.1 Rockland, Maine

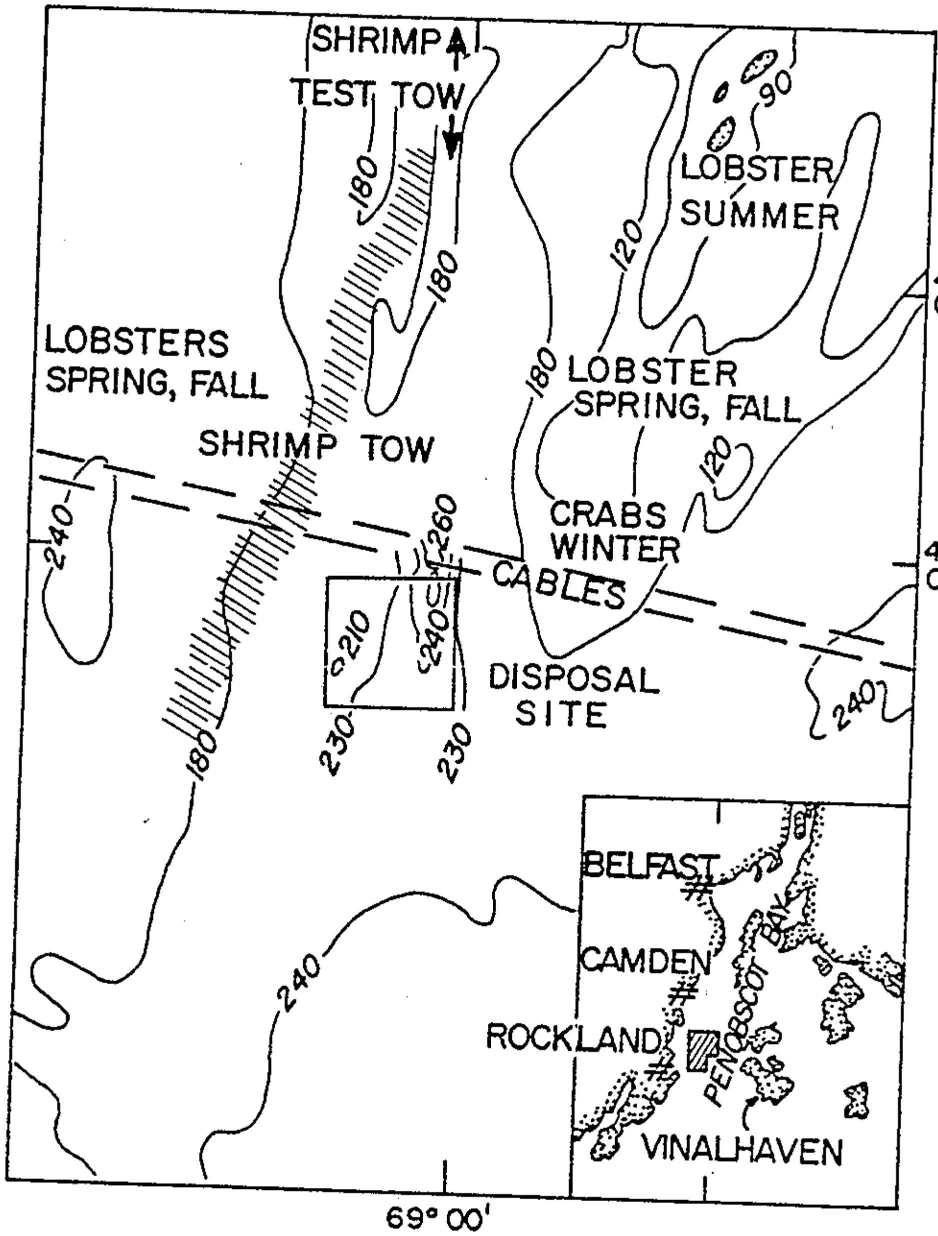
This site (Fig. 10.1) is in a relatively deep part of Penobscot Bay with muddy bottom and cold winter temperatures. There is virtually no commercial finfishing in this area; the nearest productive fishing grounds are found outside of the bay. Sea scallops (Placopecten magellanicus) were dredged in the bay until the mid-1950's, when they became rare throughout Maine. Patches of scallops are not limited to a particular substrate and could occur in the disposal area if populations increased in the future. Heavy scallop dredges would easily scour soft spoil.

Most lobster (Homarus americanus) fishing in this area occurs in summer in shallow depths (20 m). The fishery moves into deeper water in fall, but there deep water, strong currents, wind exposure, and vessel traffic at the disposal site make the area unattractive for fishing. Fishermen report that lobster pots were buried by an accidental short dump in the fall of 1973 outside Rockland Harbor; otherwise, spoil disposal has had no effect on lobstering.

Before the recent decline in catches and closure of the fishery, northern shrimp (Pandalus borealis) were caught by at least one vessel towing west of the disposal site. This shrimper fished throughout the period in which spoil from Rockland was dumped and reported no decrease in catch. The Maine Department of Marine Resources has made some test tows extending north of the area mapped. Data from these tows might increase our understanding of the natural history of the local shrimp population.

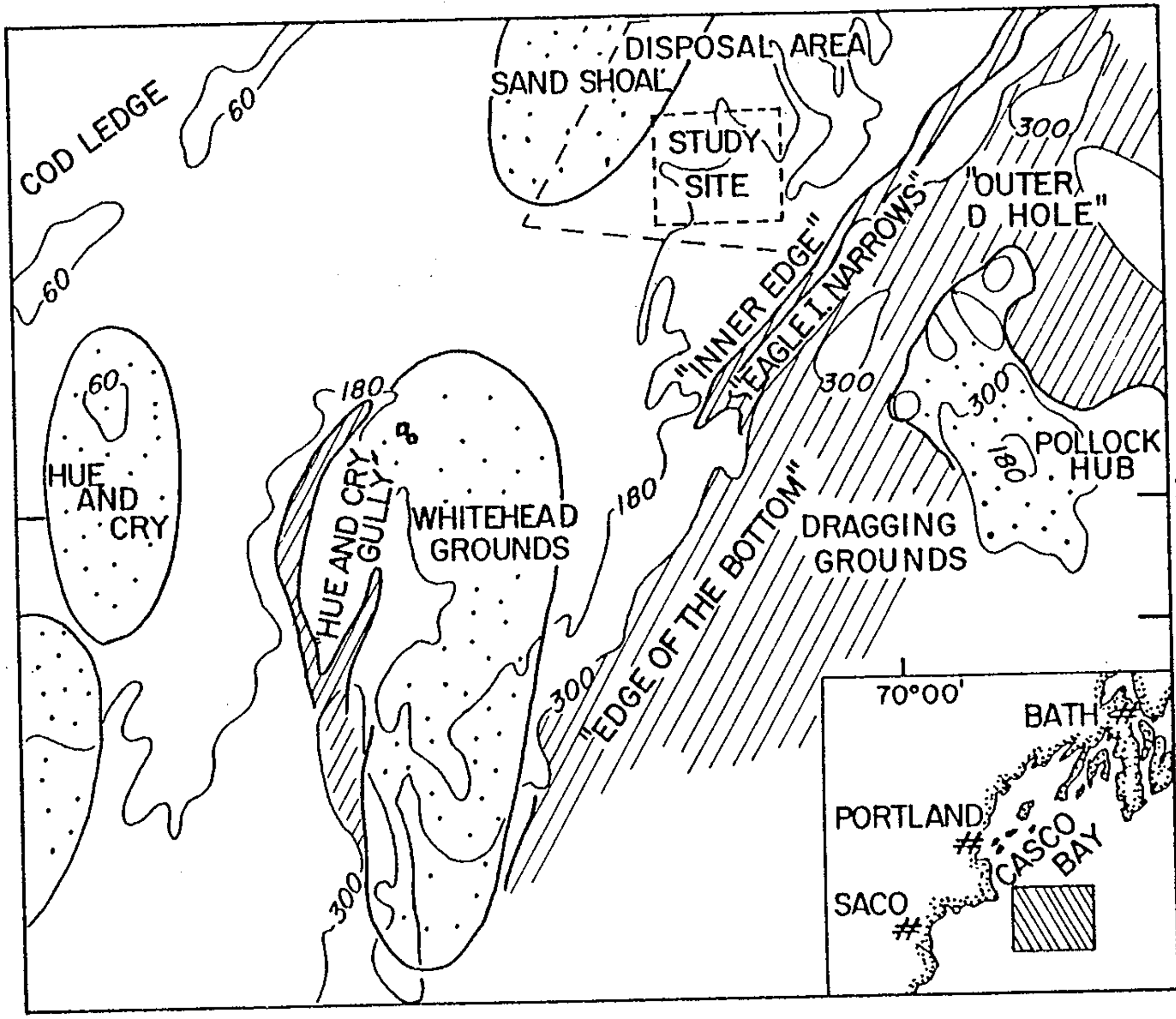
10.3.2 Portland, Maine

The proposed disposal site at Portland (Fig. 10.2) is in a "valley" surrounded by rocky bottom. It is about 2 km shoreward of an important area for finfish trawling, where a variety of fish are caught including dab (American plaice Hippoglossoides platessoides) and gray sole (witch



ROCKLAND DISPOSAL SITE COMMERCIAL SHRIMP TOW SHADED, FORMER MAINE DMR TEST SHRIMP TOW EXTENDS NORTH OF THE MAPPED AREA

FIGURE 10.1



PORTLAND DISPOSAL SITE HISTORICAL DISPOSAL AREA AND PRESENT STUDY SITE OUTLINED, DOTTED AREAS ARE FORMER HOOK AND LINE FISHING GROUNDS (RICH, 1930), DRAGGING GROUNDS ARE SHADED

FIGURE 10.2

flounder, Glyptocephalus cynoglossus) in the summer, and cod (Gadus morrhua), haddock (Melanogrammus aeglefinis), and other groundfish in the winter and spring. A few vessels enter the "inner edge" behind a line of rock outcrops.

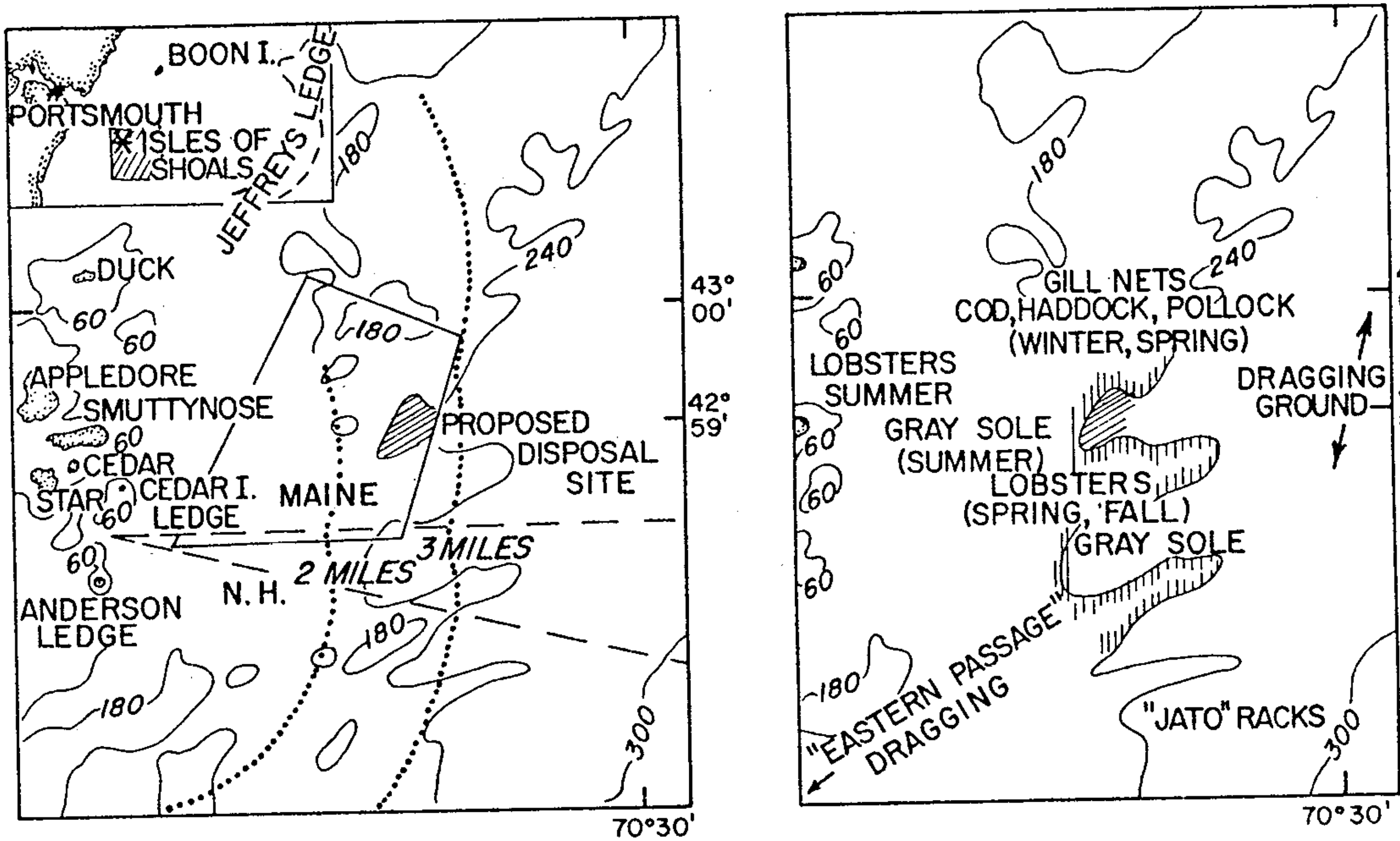
In winter and spring gill nets are set for cod along the edge and on rough bottom throughout the area. The traditional hook-and-line fishing areas shown in the map (dotted areas) are fish sheltering and feeding grounds, while dragging grounds (shaded areas) are smooth-bottomed areas where migrating fish concentrate. All of the commercially important fish in the area have buoyant eggs or spawn in estuaries (winter flounder) with the exception of Atlantic herring (Clupea harensus).

The disposal site is offshore of most lobstering, which is concentrated in shallow water around the Cod Ledges and shoreward during the summer. Lobsters are caught at the disposal site between November and April after they move out of the colder shallow water. A fisherman who left pots at the dump site in summer found that some lobsters remained in deep water all year. In 1977-78 three vessels fished at the disposal site, but in 1978-79 only one vessel had gear at the site. Pots are set in a northeast-southwest line. Trawls consist of 10 pots each, and 6-7 trawls are set per km. It is possible that several hundred of a fisherman's 2,000-3,000 pots could be placed in the disposal site "valley."

Northern shrimp were abundant at the "edge of the bottom" and the "inner edge" during the past. Disposal-shrimp interactions are discussed in a following section.

10.3.3 Isle of Shoals

This proposed site (Fig. 10.3), like the Portland site, is in a valley surrounded by rocky ledges and shoreward of most dragging grounds. However, knowledgeable fishermen drag for gray sole on small patches of smooth bottom between the ledges. Fishing was reported close to the Isle of Shoals west of the site and in the valley south of the site, but not at the site itself. Gill nets are set on the edges of the rocky areas to catch pollock (Pollachius virens) during November and December and cod and haddock from March to May.



ISLE OF SHOALS DISPOSAL SITE HISTORICAL DISPOSAL AREA AND PRESENT STUDY SITE OUTLINED, POSSIBLE MAINE-NEW HAMPSHIRE BORDERS SHOWN BY DASHED LINES, DISTANCE FROM LAND SHOWN BY DOTTED LINES, APPROXIMATE LOCATION OF GILL NETS SHOWN BY VERTICAL SHADING

FIGURE 10.3

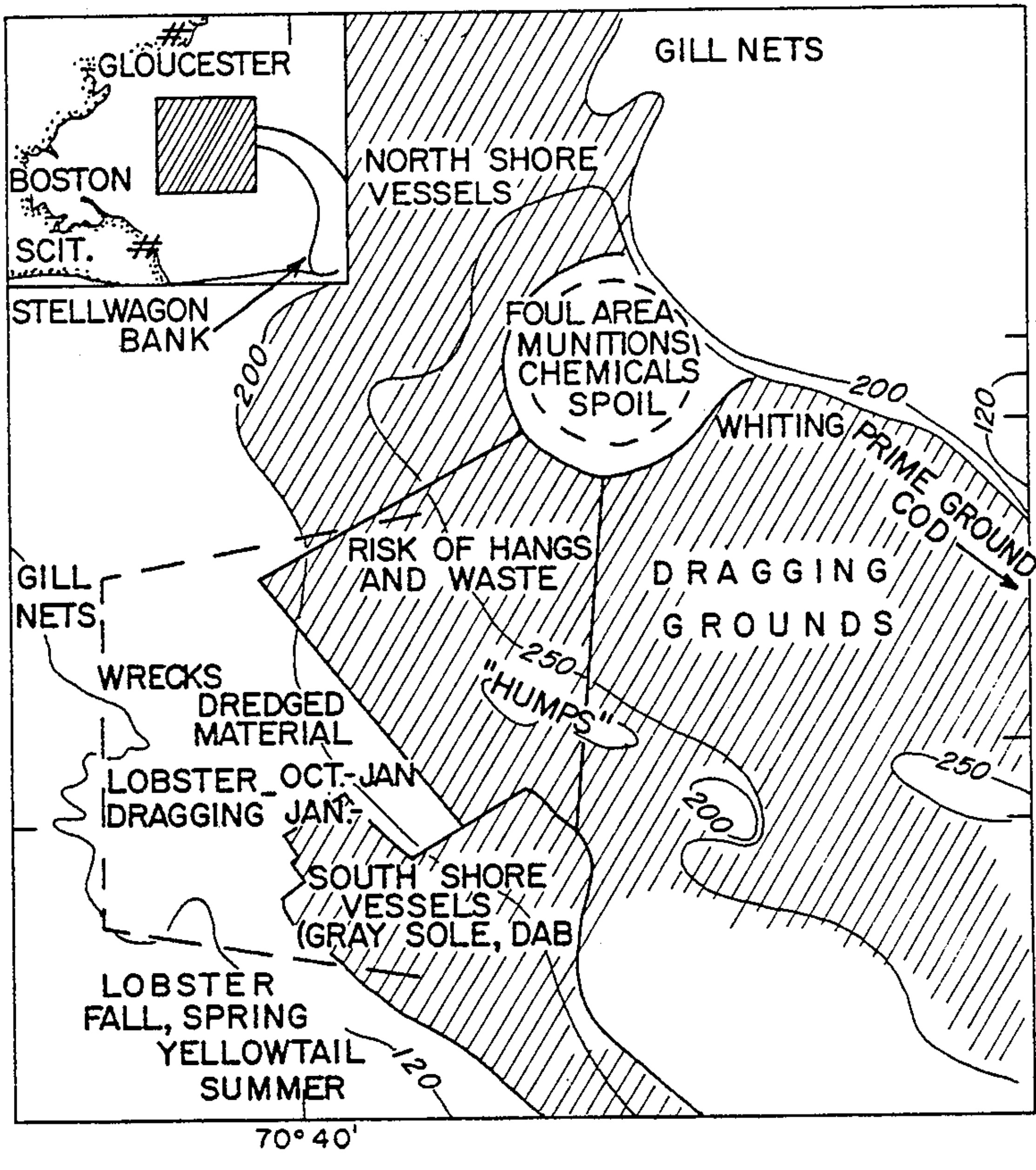
The area between the Isle of Shoals and Cape Ann is an important spawning ground for pollock and cod. Both species have floating eggs.

Lobsters are caught close to the Isle of Shoals during the summer. Catch per effort within Maine waters is high because entry into the fishery is restricted. In the winter and spring, lobstering extends out to the vicinity of the proposed site. Lobstering at the site yielded variable catches, relatively large lobsters (0.7 - 1.4 kg), and clawless lobsters injured by finfish dragging gear. In the winter of 1977-78, lobstermen from New Hampshire fished the deeper waters east of the site. Earlier spoil disposal within the former large disposal ground has had no effects on lobstering.

10.3.4 Massachusetts Bay

The Boston Foul Ground disposal area (Fig. 10.4) is in a deep (100 m) basin that has irregular features caused by disposal of military equipment and munitions. The site is closed to all types of fishing within 1.6 km of its center because chemical and radioactive wastes were previously dumped there. The Boston Lightship disposal ground (Fig. 10.4) is shallower (60 m) and has been used for rocky spoil and vessel and dock debris.

Vessels from the entire Massachusetts Bay region fish these areas. Those from the north shore of Boston fish north of the Foul Ground and along the edges of Stellwagon Bank, while those from Scituate fish east and southeast of the Lightship disposal site. Fishing occurs throughout the year in the areas shaded on the map. Cod are caught from January to February or until dogfish sharks (Squalidae) appear in the summer. Dab and gray sole are caught in the spring and summer. Sometimes these flatfish are caught immediately east of the Lightship site dumping buoy. Yellowtail flounder (Limanda ferruginea) are caught inshore of the Lightship site but details of this fishery have not been determined. Whiting (ilver hake, Merluccius bilinearis) are caught west of Stellwagon Bank from June to October and herring are caught on the bank during their October spawning period. Gill nets are used in winter and spring to fish for cod on the northern extension of Stellwagon Bank on hard bottom 3.7 km north-northwest of the Lightship site, and south of the ground in depths less than 33 m.



MASSACHUSETTS BAY DISPOSAL SITES BOSTON LIGHTSHIP SITE ENCLOSED BY DASHED LINES

FIGURE 10.4

Concrete containers of radioactive waste and containers of chemicals have been netted south of the Foul Ground. Around the Lightship site parts of the bottom have been systemically swept clear of timbers by draggers. Large masses of dredged and dumped saltmarsh peat have interfered with trawling in the past, but these appear to break up after several years.

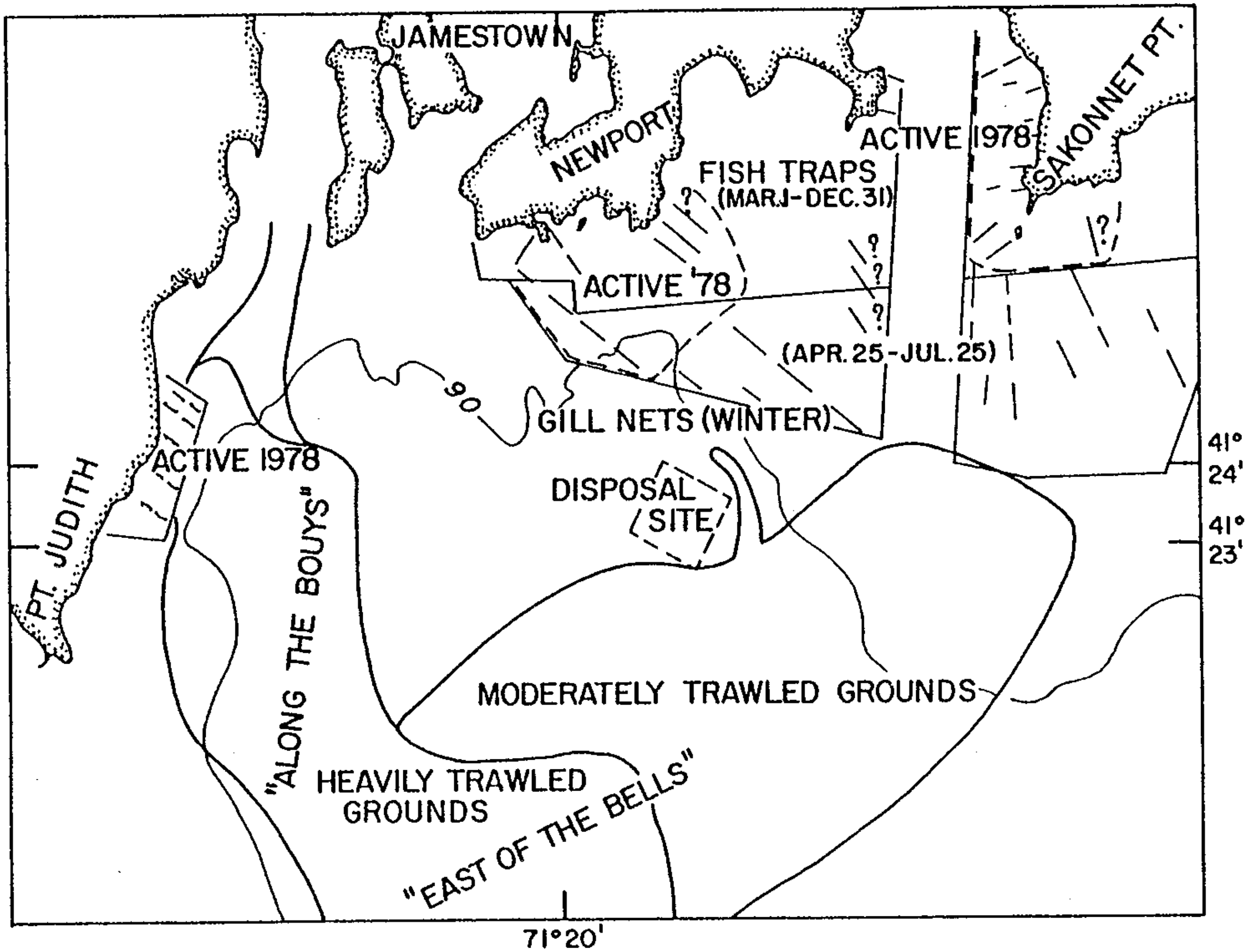
Relatively large lobster boats from both the North and South Shores fish the Lightship site. Lobsters, migrating into deeper water reach this area in October or November. Lobstering continues near the disposal site until January, when it is interrupted by draggers seeking cod. It was reported that many lobsters with broken claws have been caught in the disposal area. A test set in the summer of 1978 yielded no lobsters.

Before stocks declined, northern shrimp were caught in deep muddy areas near the disposal sites in winter. Ocean quahogs (Arctica islandica) were collected from the southern part of the Lightship disposal site by Riser and Jankowski (1974). It is unlikely that a quahog fishery will develop here because stocks are found closer to shore, the scattered rocks and wreakage near the site are a deterrent, and contamination from old spoil is a possibility.

10.3.5 Brenton Reef

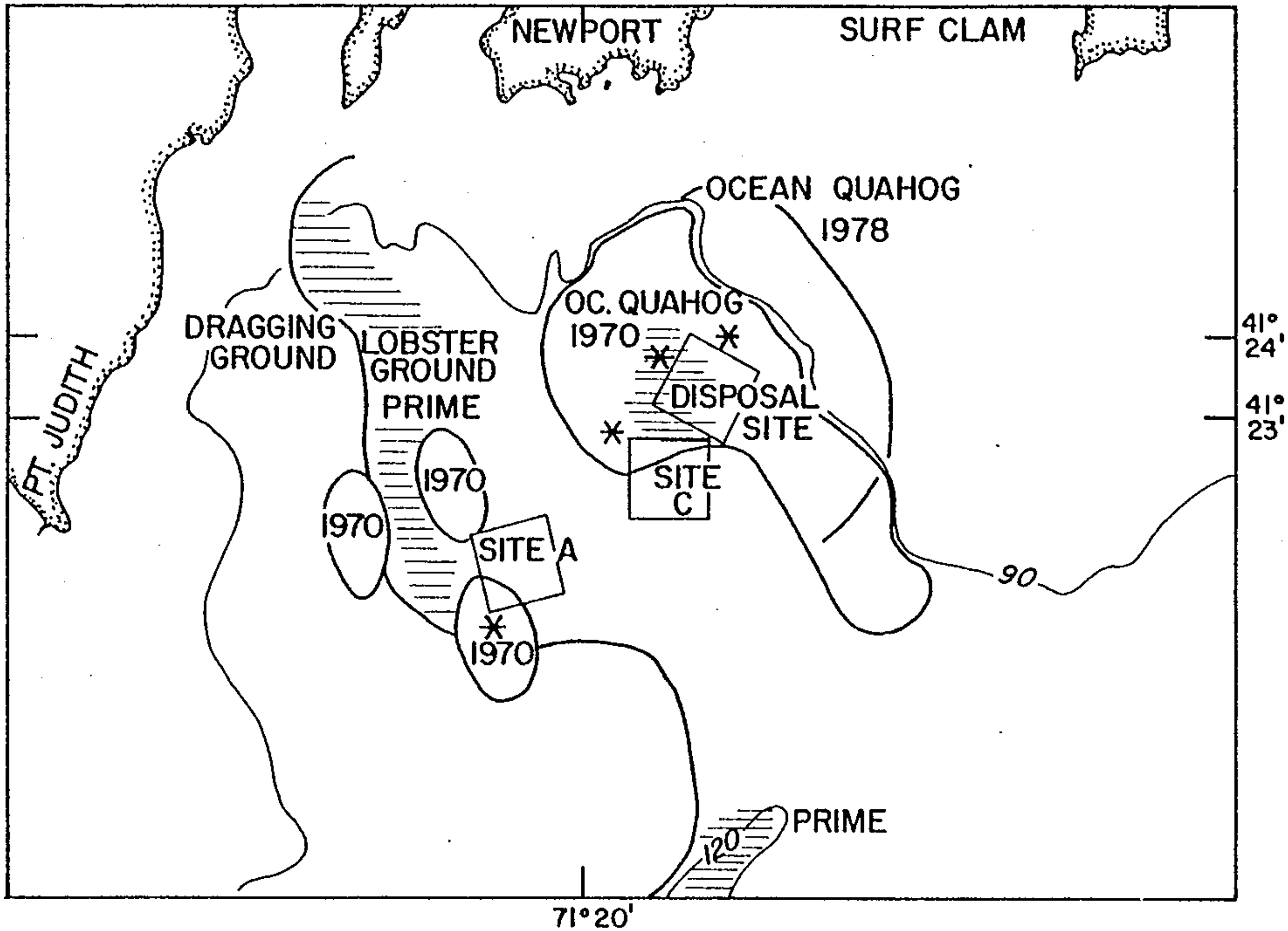
The site off Newport, Rhode Island (Fig. 10.5), is located in relatively shallower water (30 m) than the Massachusetts Bay sites. Most of the spoil at the site was dumped between 1967 and 1971 when the Providence channel was dredged. The spoil lies in a single mound in the west corner of the site and in two areas (sites A and C) southwest of the prime site that were used for short periods in 1967 (Fig. 10.6). The site was located to avoid interference with the most important finfish and lobster grounds; however, it has affected the fisheries near it. The Rhode Island site has been under almost continuous study since 1970, and details of fisheries-disposal site interactions have been reported by Saila, Pratt, and Polgar (1972) and Seavey and Pratt (1979).

The local fishery for ocean quahogs was severely affected by burial and contamination of clam beds during the 1967-71 disposal period. In 1978, ocean quahogs were again harvested northeast and south of the site on sandy bottoms.



RHODE ISLAND SOUND DISPOSAL SITE TRAWLING GROUNDS FROM OLSEN AND STEVENSON (1975), EXTENSION OF TRAWLING GROUND NEAR DUMPSITE FROM INTERVIEWS, GILL NETS ARE PLACED ALONG 90′ CONTOUR, FLOATING FISH TRAPS ENCLOSED BY DASHED LINES

FIGURE 10.5



RHODE ISLAND SOUND DISPOSAL SITE AREAS FISHED FOR OCEAN QUAHOGS INDICATED, AREAS FROM WHICH DEAD OR MORIBUND QUAHOGS WERE DREDGED ARE MARKED BY ASTERISKS, LOBSTERS ARE CAUGHT THROUGHOUT THE AREA WEST OF THE FINFISH DRAGGING GROUND

FIGURE 10.6

A limited butterfish (*Peprilus triacanthus*) and scup (*Stenotomus chrysops*) trawl fishery in the disposal area ended because of both dumping and the extension of the lobster fishery into the area. No effect on finfish outside the sites has been recorded. Gill nets have been set for cod on the spoil site and along the 27-m contour during the last two winters, in an area formerly fished by hook and line.

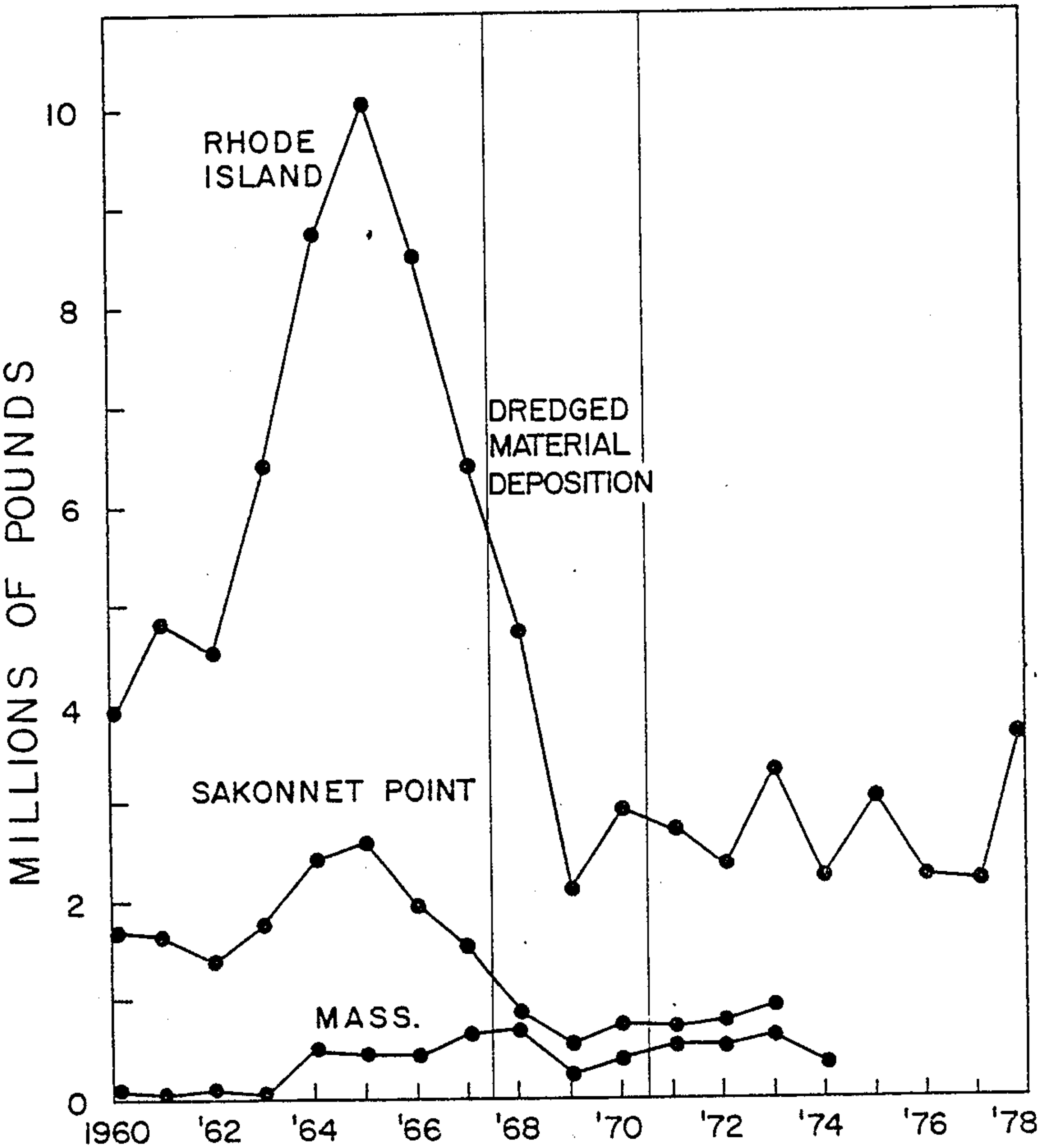
Floating fish traps are found within 3.7 km of the site. Large catches of shoreward-migrating scup are taken in April and May. Catches decreased from 1965 to 1969 (Fig. 10.7); some trap operators believe that this was due to turbidity from spoil disposal. Sissenwine and Saila (1974) concluded that the decrease in catches was part of a regional decline in populations and not a consequence of disposal. There are records of the absence of scup from this coast for as long as 150 years (Baird, 1873). Neville and Talbot (1964) concluded that the success of early life history stages determined the size of the summer fishery.

Little is known about the relationship of fish movements to areas of rapid change (fronts) of temperature, salinity, or turbidity. There are both horizontal and vertical discontinuities in natural turbidity in Rhode Island Sound (Pratt and Heavers, 1975). Interviews and fieldwork are underway in an attempt to determine whether the approach of scup to the coast can be correlated with the presence of turbidity.

Lobstering is carried out on and adjacent to the disposal site from June to August. Catches are less than those from prime grounds but are larger than those on surrounding natural areas. A limited number of "groundskeepers" are taken from the spoil mound but most of the lobsters appear to be migrating through the area offshore following molting.

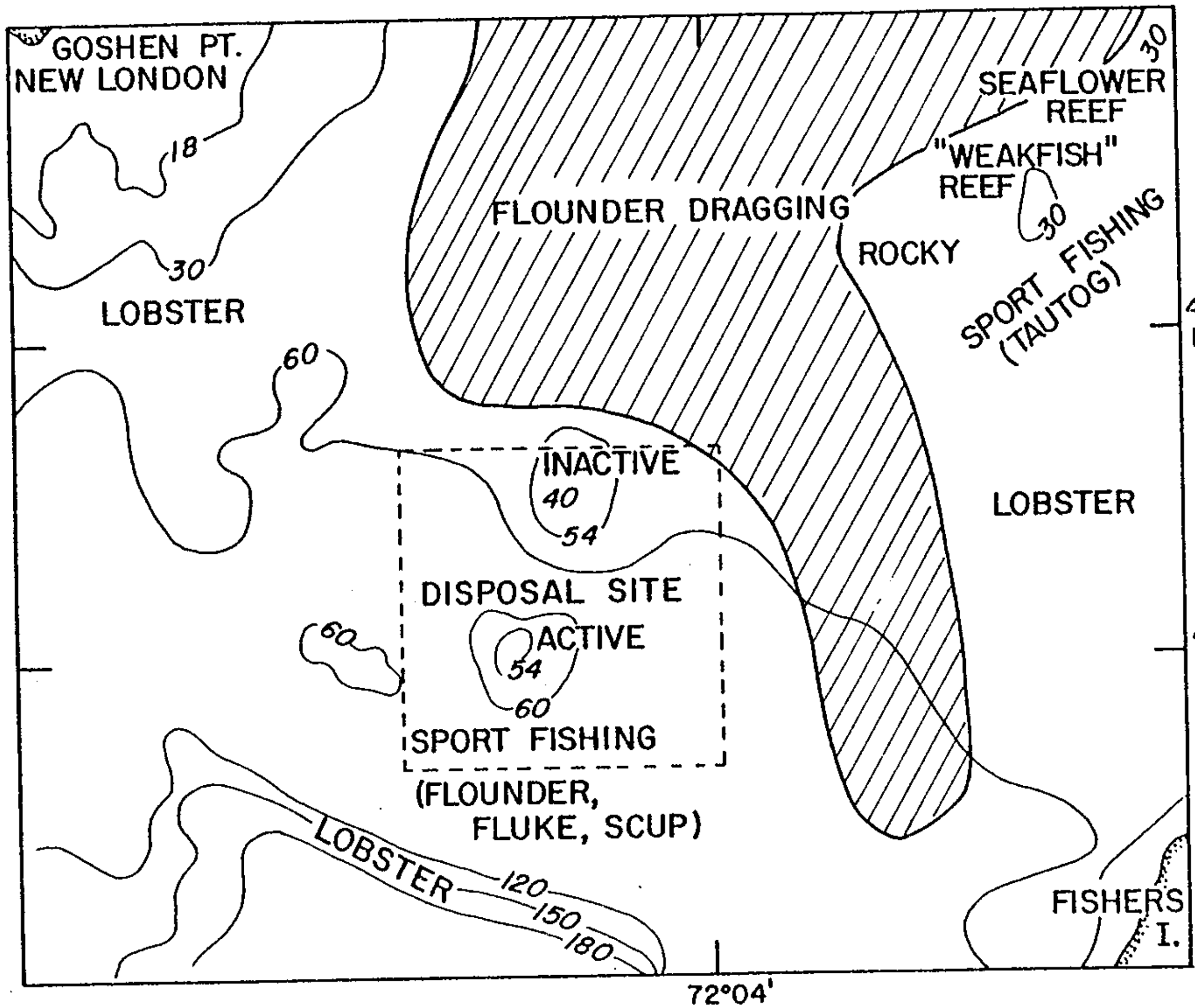
10.3.6 New London

Large volumes of relatively clean spoil have been deposited at the New London site over the last several years (Fig. 10.8). Collapse of blocks of cohesive sediment and winnowing of the surface are still taking place. These changes, along with epifaunal colonization and abundance of demersal fish and crustaceans, are being studied by L. Stewart of the University of Connecticut.



SCUP CATCH STATISTICS 1960-1978 CATCHES IN FLOATING FISH TRAPS AND POUND NETS, RHODE ISLAND AND MASSACHUSETTS CATCHES FROM U.S.FISHERY STATISTICS, SAKONNET POINT RECORDS ARE FROM THE POINT TRAP COMPANY WHICH IS THE ONLY GROUP THAT OPERATES TRAPS IN THAT AREA

FIGURE 10.7



NEW LONDON DISPOSAL SITE

FIGURE 10.8

Winter flounder and fluke (summer flounder Paralichthys dentatus are caught by a few small draggers during spring and summer north and east of the disposal site. Sport fish: tautog (Tautaga onitus), scup, striped bass (Morone saxatilis), and squeteague (weakfish, Cynoscion regalis) are caught close to shore, and bluefish (Pomatomus saltatrix) are taken in the Race, to the southeast. The southwest slope of the spoil mound has become an important location for sportfishing during the summer because of concentrations of winter flounder there. The presence of an "edge" may be the chief attraction of the disposal site to the fish, or it may be an abundance of benthic invertebrate prey. Stomach analyses are needed to confirm the latter speculation.

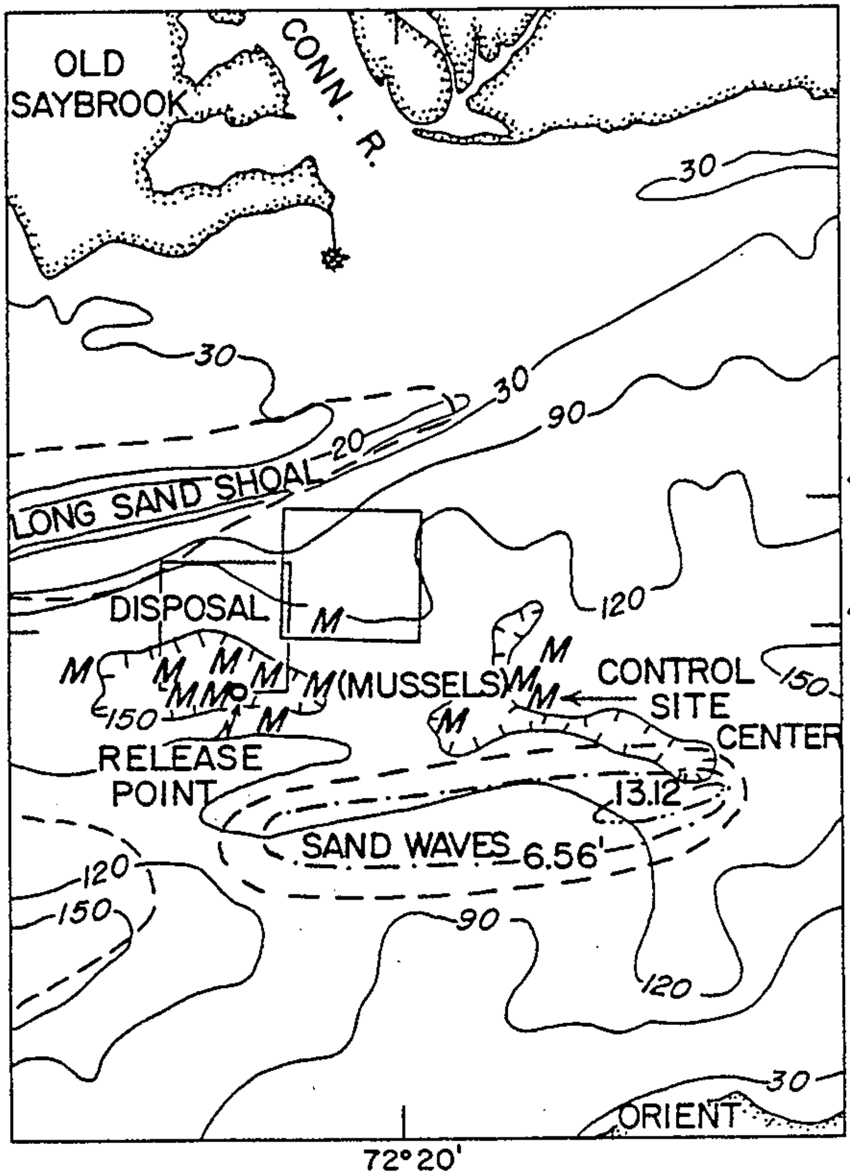
There has been little effect on lobstering by disposal activity since the area has not been a productive lobster ground in the past and is in a busy shipping lane. Lobstering is carried out in shallow rocky areas in the spring but in deeper water in the Race and Block Island Sound in midsummer.

10.3.7 Cornfield Point

Fisheries in the Cornfield Point area (Fig. 10.9) are restrcted by deep water, strong tidal currents, and areas of active sand transport. Flounder trawling is carried out only in shallow water at the mouth of the Connecticut River. The conch (winkel, Busycon canaliculatum) is caught in pots shoreward of Long Sand Shoal.

The release point shown on the map was established in 1976. The old disposal area to the northeast is fished by a small number of lobstermen. Egg-carrying females and "shedding" lobsters have been reported here in early summer. Some lobsters are caught in the central depressions and in the sandwave area south of the release point. Since there is no shelter and little food on the sand, it can be assumed that the lobsters are moving through these areas and are not resident.

Blue mussels (Mytilus edulis) and associated epifauna were recovered in benthic grab samples taken at the release point and a control site (Pratt, 1977). These disposal sites have more productive potential than the surrounding sandy areas and could provide food for lobsters and bottom-feeding fish.



CORNFIELD SHOALS DISPOSAL SITE FORMER AND PRESENT DISPOSAL AREAS OUTLINED, AREAS OF SAND WAVES FROM BOKUNIEWICZ ET AL (1977), "M" DENOTES STATIONS FROM WHICH M. EDULIS WERE RECOVERED BY PRATT (1977)

FIGURE 10.9

10.3.8 Central Long Island Sound

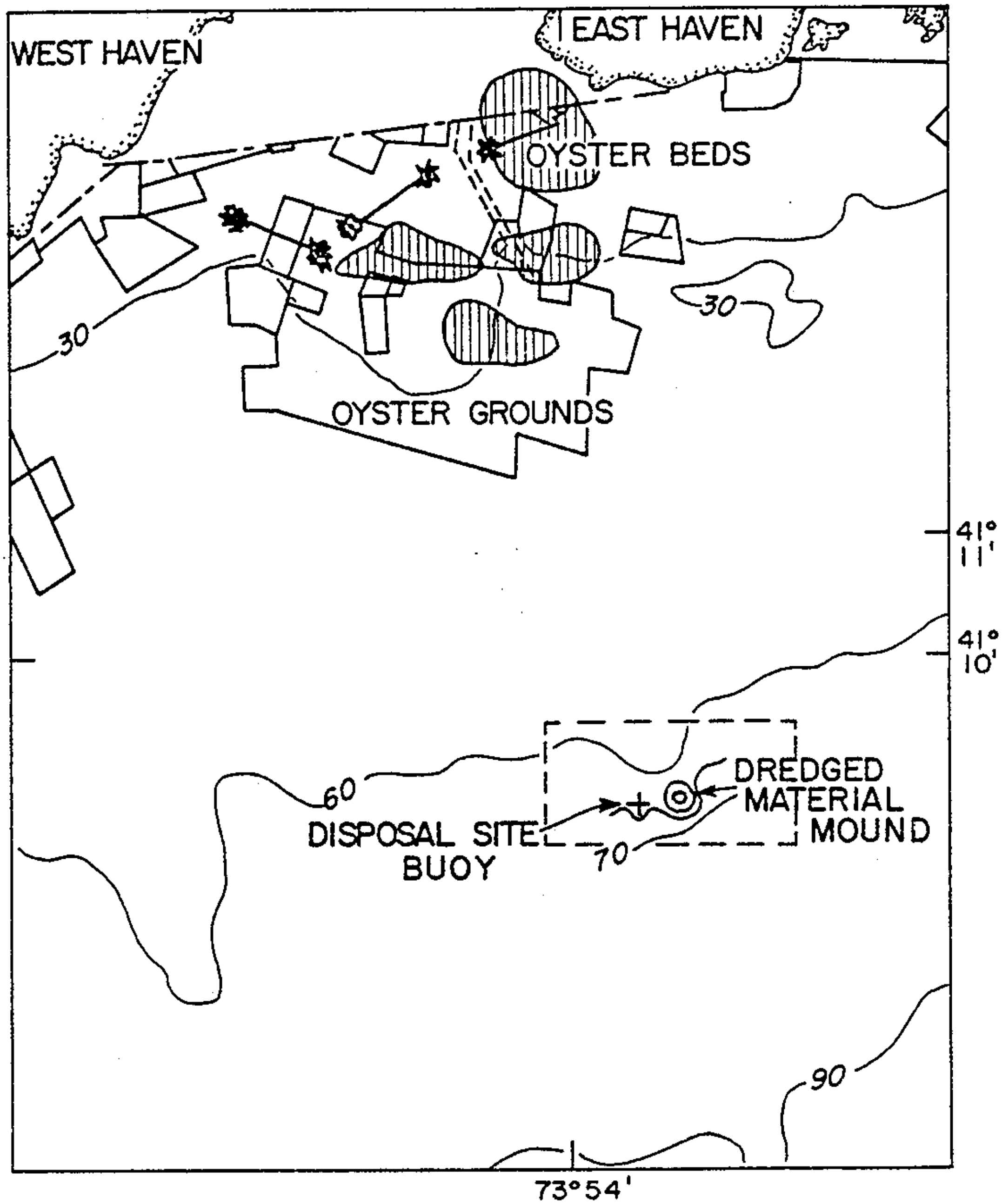
This site (Fig. 10.10) is one of the more active disposal sites in New England. Spoil from a large improvement project in New Haven harbor (1973-77) makes up the central mound shown on the map. Spoil from maintenance dredging is being deposited at a buoy to the west of the mound.

Lobstering is the most important fishery within the disposal site boundaries. Three fishermen set gear within the site in 1978, and several others used the immediately surrounding areas. There appeared to be a concentration of lobster pots in the disposal area in July 1978. However, fishermen stated that similar concentrations of pots could be found at equivalent depths east and west of the site. Lobstering is carried out on the site from spring to late fall or winter, sometimes with a layoff in early fall because of abundant wood-boring mollusks in Long Island Sound.

During dumping operations, fishing gear has been lost because of interference by boats and tow lines and reports of "mudding up" during periods of strong tides. Low lobster catches were reported following dumping, with recovery periods of about a year following small jobs but longer following the large New Haven project. In May 1979 a cooperating fisherman recorded catch data for pots set close to the point at which silty Stamford spoil was being dumped. This area has since been capped with sand, and data will be collected there in July.

There is little fishing for finfish at the New Haven disposal site. Lobstermen make occasional tows for bait there, and larger vessels drag occasionally for scup in the summer and fall. The disposal site is a very small part of the scup fishing grounds, and closure of this area would have no effect on the fishery as a whole.

Whelk have been reported at the disposal site by lobstermen and divers. A commercial pot fisherman intends to fish for whelk in this area during the summer of 1979.



NEW HAVEN DISPOSAL SITE DISPOSAL SITE SHOWN BY DASHED LINE, LEASED OYSTER GROUND LOCATIONS FROM CONN. DEPT. OF AGRICULTURE-AQUACULTURE, NATURAL OYSTER BED LOCATIONS FROM US DEPT. OF INTERIOR (1970)

FIGURE 10.10

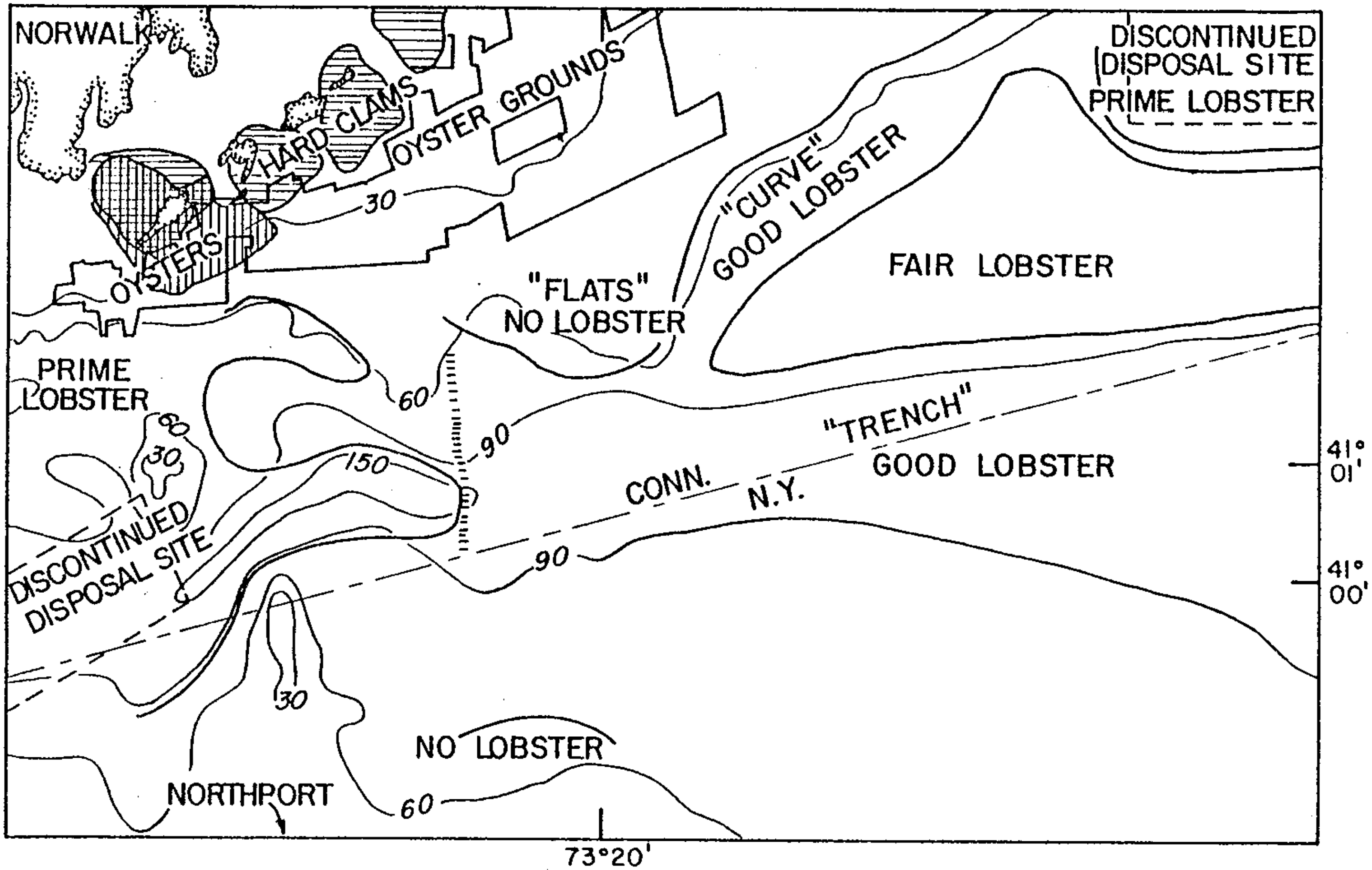
The nearest leased grounds where oysters are held for market are approximately 5.5 km shoreward of the disposal site. Areas supporting natural oyster beds are even closer to shore (Fig. 10.10). The Connecticut Aquaculture Division has been concerned about the potential effects of channel dredging on oyster eggs and larvae but not about the effects of ocean dumping on these life stages. This seems justified since little sediment appears to be released during disposal, water transport at the dump site is largely east and west, and vertical mixing is limited by stratification.

10.3.9 Western Long Island Sound

Dumping has been discontinued at the disposal sites south and east of Norwalk (Fig. 10.11) to protect prime lobster grounds and to satisfy the concerns of environmental groups. A large area east of the discontinued southern site is being surveyed for possible use in the future.

Lobstering is the most important fishery in western Long Island Sound. In 1977, 41.8 percent of the reported catch from Long Island Sound (Connecticut logbook data) came from the western Connecticut area. Smith (1977) showed that most western Long Island Sound lobsters are caught soon after reaching legal size. Both Smith (1977) and Briggs (1976) found that a high percentage of egg-bearing lobsters in the western Sound are below legal size. High yields of lobsters in the western Sound are supported by this pattern of early maturity, as well as by water circulation patterns which retain larvae in the region, and good lobster habitat. Smith (1977) recorded the presence of smaller-than-average egg masses in some western Long Island Sound lobsters, but Briggs (pers. comm.) did not find them consistently in recent samples taken in New York waters in December.

The only parts of the study area where lobster densities are low are shallow areas with sandy bottoms. Lobsters are concentrated along topographic features such as an "edge" at 20 m and a central trough. The flat bottom identified as "fair" lobster ground is fished with a large number of uniformly distributed pots to compensate for reduced catch per pot.



WESTERN LONG ISLAND SOUND DISPOSAL SITES LEASED OYSTER GROUND LOCATIONS FROM CONN. DEPT. OF AGRICULTURE-AQUACULTURE, NATURAL OYSTER BEDS (VERTICAL LINES) AND HARD CLAM BEDS (HORIZONTAL LINES FROM US DEPT. OF INTERIOR (1970), VERTICAL LINE AT 73°22' IS THE DIVISION OF LOBSTER GROUNDS BETWEEN VESSELS FROM NORWALK AND WESTPORT-SOUTHPORT

FIGURE 10.11

Cobb et al. (1978) found that three fishes predominated in samples taken from November to June. Windowpane flounder (Scophthalmus aquosus) were abundant in April, winter flounder in January, and red hake (Urophycis chuss) in June, especially east of the disposal site. Commercial dragging is limited by the presence of lobster pots in the western part of the area mapped (Fig. 10.11). A fall and summer scup fishery is carried out in the area marked "fair lobster."

Leased oyster grounds lie shoreward of potential disposal study areas. The deepest leased areas (15 m) are used more for holding than for grow-out operations. The 1978 set was very successful in Long Island Sound and most oyster grounds are fully utilized.

10.4 SPECIAL PROBLEMS

10.4.1 Northern Shrimp

Management of the northern shrimp fishery in the Gulf of Maine has been difficult and controversial because of the species, unusual life history, seasonal movements, and large natural fluctuations in abundance. It is hoped that the following review will identify possibilities for cooperative interaction between shrimp management and disposal activities.

The biology of the northern shrimp was reviewed by Haynes and Wigley (1969); they showed that a discrete Gulf of Maine stock exists. In 1963-65 surveys this stock was concentrated along the southern coast of Maine. Non-egg-bearing shrimp occurred in 80-120 m of water, and their distribution seemed controlled by the presence of fine sediments with moderate to high organic carbon (0.5-1.5 percent). Haynes and Wigley (1969) found that all Gulf of Maine northern shrimp were protandrous, maturing as males, then transforming to females after 2-3 years.

Mature females move shoreward and spawn from late August through November. Females retain eggs for about 5.5 months; then hatching occurs, usually in March and April, in water as shallow as 23 m. Thus the winter fishery is specifically directed toward egg-bearing females. This is not as detrimental to stocks as it might seem, since the females are much larger than males and most do not survive to spawn a second time. The winter inshore fishery is also convenient for lobstermen during their slack season. Dow (1979) has suggested that because late-hatching larvae have abundant food which would lead to high survival, shrimp fishing should end before March.

Males offshore are known to migrate into the water column at night (Haynes and Wigley, 1969). Recent sampling confirms that egg-bearing females do not leave the bottom (D. Schuck, Maine DMR) and thus would be more susceptible to effects of spoil disposal. Shrimp larvae are planktonic and should not be affected by disposal.

There are no specific "spawning grounds" for northern shrimp other than the areas where deep, soft bottom contacts shoaling bottom. All three Maine sites may be occupied by egg-bearing shrimp. Successful fisheries adjacent to the Rockland and Portland sites support this contention.

Shrimp would be killed if buried with cohesive sediments. However, they probably could evade the turbidity flow along the bottom associated with disposal: shrimp react to trawling gear with a rapid upward escape response. Shrimp might avoid spoil-covered bottom; however, large numbers of shrimp (not P. borealis) were seen on silty sediments surrounding the dump site at Brenton Reef several years after dumping ended. Because of the absence of marked concentrations of shrimp and the prolonged period of hatching, disposal activities will not affect regional shrimp populations.

The natural fluctuations in abundance of northern shrimp are greater than those of any other commercially important species in the Gulf of Maine (Dow, 1979). These fluctuations mean that at times there will be only a "potential" fishery around the disposal sites. It will be extremely difficult to differentiate between natural, fisheries-caused, and disposal-caused changes in the shrimp population.

Following development of the fishery in the late 1930's, annual catches rose to 0.26 million kg in 1945, then declined to zero by 1954. From 1961 to 1969 catches rose gradually to a record high of 12.8 million kg, remained over

9 million kg per year until 1973, then dropped to less than 0.4 million kg in 1977. The fishery was partially closed in 1976 and 1977, completely closed in 1978, and limited to a two-month season in 1979. The 1979 catch of about 0.3 million kg (National Fisherman, 1979) was small compared with the record high catches, but similar to catches in the 1940's and early 1960's.

The reason for periodic low stocks is disputed. While some say that overfishing has been important, Maine fisheries officials stress environmental factors, particularly temperature during hatching and larval development (National Fisherman, 1979; Dow, 1979). The decline in catches in the early 1950's, when average water temperatures were high but fishing effort low, substantiates this hypothesis.

Both general and site-specific information is necessary to predict possible effects of spoil disposal on shrimp fisheries. It is hoped that the Maine DMR's current program of stock assessment will provide such information. Available stocks are assessed annually by sampling offshore areas during the summer. Four stations in deep water southwest of the proposed Portland disposal site are of particular interest. This area was sampled monthly in 1976 and quarterly in 1977 and 1978. To study larval release sampling may continue in February and March in subsequent years. Recent samples have indicated that a resident population may have become established in the area (D. Schick, Maine, DMR).

Most plans to minimize the effect of spoil disposal emphasize the need to avoid spawning populations of valuable species. In northern shrimp, however, larval success is more important than brood stock abundance for the persistence of the population, and thus the fishery. Furthermore, the spawning area is large, and the shrimp may be able to survive the effects of turbidity flows associated with disposal. Disposal at the Portland site would provide the opportunity to determine (by photography, television, trapping, or trawling) whether spoil was attractive or repellant to northern shrimp. By combining shrimp observations with other studies, costs would be minimized.

Scheduling disposal at the present Gulf of Maine sites from May to September would significantly reduce the exposure of shrimp to spoil and avoid interference with commercial fishing. Despite the scheduling, there may be some residual effects on shrimp from the spoil deposits.

10.4.2 Atlantic Herring Spawning

The sites off Portland, Isle of Shoals, and Boston are within the broad areas mapped as spawning grounds of coastal Gulf of Maine herring stocks (TRIGOM, 1974). Since the spawning activity is often concentrated within small areas and egg masses adhere to the bottom, there is potential for damage by burial or siltation. Most studies of Gulf of Maine herring have been directed toward stock assessment rather than location of spawning grounds. The following is a review of the available information on spawning location and substrate.

Atlantic herring spawn on sediments ranging from coarse sand or gravel to rock and in both vegetated and nonvegetated areas (Boyer et al., 1973a). Depth of spawning probably depends on the presence of hard bottom and suitable temperatures. Bigelow and Schroeder (1953) report that most spawning takes place between 20 and 30 m; however, Boyer et al. (1973b) found herring spawning off Jeffreys Ledge at 60 m. The depths of the disposal sites (Rockland, 80 m; Portland, 65 m; Isle of Shoals, 70 m; and Boston 90 m and 60 m) are greater than this. The sediments at the sites, ranging from fine sand at Portland to clay or "mud" elsewhere (DAMOS, 1979), as well as their location in holes and canyon floors make tham all unlikely spawning grounds for herring.

It would be of concern, however, if any of the disposal sites were in the immediate vicinity or offshore from a discrete spawning area because of the possibility of an accidental release of spoil on the spawning grounds. Suspended sediments dispersed during descent (or originating from scow leakage) or erosion of spoil on the bottom would be of much less concern. There is little chance of sediment deposition in the turbulent environments used for spawning.

Two studies by Graham et al. (1972, 1973) on the distribution of larval herring give valuable information on spawning concentrations. In 1971 concentrations of larvae were found east of Penobscot Bay and between Casco Bay and Jeffreys Ledge. More detailed sampling in 1972 showed that the easternmost area was a major spawning ground and that hatching took place in early September. In mid-September concentrations were detectable south of Boothbay Harbor and Cape Elizabeth 18-27 km northeast and southwest of the Portland site, respectively. Recently hatched larvae were caught in mid-October near Jeffreys Ledge, 25 km offshore of the Isle of Shoals, and on Stellwagon Bank 7.2 km offshore from the Boston Foul Ground site. At each spawning area hatching extended over a period of about a month.

Boyer et al. (1973a) summarized observations on larval herring made during 1962-70. They identified a large "coastal Gulf of Maine" spawning area and discussed the role of a counterclockwise current in retaining larvae in the area. Boyer et al. (1973b) described concentrated spawning at a location on the southern edge of Jeffreys Ledge during 1972 and another spawning site between Cape Ann and Jeffreys Ledge. An attempt was made to study egg beds in detail the following year but no spawning concentrations were found.

Herring landings from both the coastal and Georges Bank areas have remained relatively stable: 1965-75 catches ranged from 23 to 42 million kg a year and 1976-78 catches were all about 50 million kg. Thus, although the location and success of spawning may vary unpredictably, the overall stocks are reproducing with enough success to sustain themselves against strong fishing pressure.

There ae no current studies to locate spawning concentrations along the Maine Coast (J. Graham, Maine DMR). Some additional site-specific information can probably be obtained from fishermen, including lobstermen who see egg masses attached to their gear.

In summary: there is only a small risk of burial or siltation of herring eggs because of the location of disposal sites on deep, muddy bottoms. Herring do spawn shoreward of the Portland site, but concentrations appear to be several km away from the site; interference with herring spawning would only take place during the September-October spawning period.

10.5 CONCLUSIONS

The information presented here is extremely useful in management of dredged material disposal sites. In the coming year, continued site descriptions will be integrated with the physical oceanographic and geologic data collected by DAMOS. Some small studies, such as the effect of turbidity on fish movement, will also be initiated. The following generalizations can be made from the information collected during the first year of fisheries monitoring:

- Lobstering is little affected and may be improved by disposal activities. Benefits result from exclusion of finfishermen using trawl gear and addition of shelter for lobsters in disposed rock and cohesive sediment. The time for recolonization of DAMOS sites and other disposal areas by lobsters appears to be about one year after dumping has ceased. Where regional disposal sites are in frequent use, lobster yield will be reduced. The greatest losses to lobstermen have been from surface disposal activity that results in loss of gear.

- Effects on fisheries will be minimized by scheduling disposal in the summer in the Gulf of Maine and in the winter in southern New England. In the Gulf of Maine, summer lobstering is carried out inshore of the disposal sites and the finfishing fleet is dispersed. In winter, lobstering taking place in deeper water while the dragging fleet concentrates near shore. Shrimp dragging and cod gillnetting are also winter fisheries. In southern New England, lobster fishing is carried out on or near disposal sites in the summer. The Long Island Sound whelk fishery and the Rhode Island floating-trap fishery are also active in the summer. In Rhode Island gillnetting and small vessel ocean quahoging would be affected by winter disposal.

- In most areas movement of sites short distances farther offshore would interfere with important finfisheries (all Gulf of Maine sites, the Rhode Island site, and the Long Island Sound sites if moved to Block Island Sound).

- The extreme variability of catches of many important fisheries make it impossible to infer a relationship between spoil disposal and catch (northern shrimp, sea scallops, scup, and oyster are examples). For these species, effects must be projected from observation of their behavior and physiology in response to spoil-related variables. Relatively stable populations such as lobster, ocean quahogs, and flounders are more amenable to catch monitoring.

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11.0

VISUAL OBSERVATIONS

LANCE L. STEWART

11.0 VISUAL OBSERVATIONS

11.1 CHRONOLOGICAL RECORD OF BIOLOGICAL AND PHYSICAL CONDITIONS ON THE NEW LONDON DISPOSAL SITE, 1978

11.1.1 Introduction

After disposal, benthic conditions were assessed at specific sites around the spoil perimeter rather than at random transects over the spoil surface. Since the termination of dredge disposal (June 1978), the spoil topography and borders have become more stable, permitting the establishment of stations to be used in long-term monitoring. Macrobenthic species observed on Phase II spoil material have been identified and their behavior and effect on spoil stability described. A more complete photographic record of benthic conditions has been compiled. Greater use of sonic beacons, diver propulsion vehicles (DPV), and coordinated surveys utilizing NUSC navigational instrumentation have permitted more extensive coverage than in the past and enabled detailed observation of critical zones on the Phase II spoil pile.

11.1.2 Underwater Photography

Observations of the Phase II spoil from dives made during March-December 1978 are given in Table 11.1. A record of underwater photography for this period is given in Table 11.2. A series of representative underwater photographs taken from June 1974 to November 1978 is shown in Figs. 11.1-11.23. These photographs illustrate in-situ biological and physical processes noted during the deposition of Phase II spoil. Organism-spoil sediment interactions (bioturbation, recolonization, opportunistic occurrence), and surface characteristics of the spoil sediment (homogeneity, erosion zones, topography, apron formation) were documented.

11.1.3 In-situ Observations

The composition of the benthic fauna during March-December 1978 appeared normal on natural bottom, within 10 m of the Phase II spoil. No evidence of

Table 11.1 Survey dives conducted on the New London disposal site and vicinity, January-November 1978

Date	Station location	Time (h)	Transect bearing and distance	Physical conditions Depth, T°C, tide stage, visibility, bottom type	Biological observations
29 March 78	200 m WNW of NL buoy	1135-1200	W, 200 m	21 m, 3°C, 3/4 flood, 3.7 m. Shell fragments on soft, fine-grain sediments.	New mussel patches 1-2 cm shell length. Abundant *Tubularia*, *Pagurus*, *Libinia*.
	0.9 km S of NL buoy	1230-1240	WSW, 50m	21 m, 3°C, 3/4 flood, 3.7 m. Phase I spoil with shell fragment patches and extensive mussel coverage.	*Mytilus* coverage 40-50% of bottom with associated epifauna: *Asterias*, *Cancer* spp., *Homarus*.
	0.9 km ENE of NL buoy	1300-1318	WSW, 200 m	17 m, 3°C, end flood, 3.0 m. At border spoil slope flat, 10m patch spoil.	Crustacea abundant; *Homarus*, *Pagurus*, *Cancer* spp., *Busycon*, *Polinices* numerous. *Henricia* 50+.
25 April 178	100 m E of NL buoy	1100-1120	ENE, 100 m	17 m, 6°C, ½ ebb, 1.8 m. New soft, fine-grain spoil. Clay lumps with dark striations, clay ball movement. Peat fragments evident.	All macrobenthic fauna sparse. *Asterias* predation on *Pitar*. *Polinices* (4), Small shrimp (6+), juvenile hake, embedded *Mercenaria* (2).
	100 m N of Sta. 1	1140-1200	N, 100 m	24 m, 6°C, ½ ebb, 1.8 m. Hard subsurface, cobble patches with thin (0.5 cm) silt overlay.	*Tubularia* tufts common. Stars *Asterias* and *Henricia* common (12+).
1 June 78	300 m NNW of NL buoy	1030-1050	N, 70 m	23 m, 10°C, ½ ebb, 3.7 m. 0.5 m spoil overlay to distinct spoil-natural bottom border.	Abundant *Corymorpha* on spoil. Mussel patches scattered at periphery, (10-cm clusters). Flounder *Pseudopleuronectes* (6+). *Busycon*, *Polinices*, *Pagurus*, approximately 6 each.

Table 11.1 (cont.)

Date	Station location	Time (h)	Transect bearing and distance	Physical conditions Depth, T°C, tide stage, visibility, bottom type	Biological observations
1 June 78	0.9 kmE of NL buoy	1110-1130	E, 300 m	20 m, 10°C, ½ ebb, 3.7 m. New, soft, fine grain spoil; unstable surface, winnowing and clay ball movement noted.	Embedded *Pitar* and *Mercenaria* (6) evident. Large *Urophysis* and *Tautogolabrus* (3).
21 June 78	0.9 km SSW of NL buoy	1040-1055	S, 100 m	23 m, 12°C, start ebb, 3.0 m. Mussel bed elevated patches on phase I spoil.	Mussel coverage (2-3 cm shells) 50%. Massive *Asterias* predation (100+). *Urosalpinx* (100+) Flounder abundant (10+) large.
	0.9 km E of NL buoy	1130-1150	E, 100 m	21 m, 12°C, ¼ ebb, 3.0 m. Barren, phase II spoil tailed out to border in very gradual slope, irregular edge.	Several hake in clay mound areas, also cunners and tautogs attracted to elevated clump sites.
28 June 78	0.9 km SE of NL buoy	1500-1520	W, 100 m	21 m, 11°C, flood, 3.0 m. Natural hard bottom to phase II border.	Flounder abundant at border. *Busycon* (3) *Asterias* and mussel bed association.
15 November 78	SW border	1100-1120	N, 50 m	21 m, 11°C, ¼ ebb, 3.0 m. Phase I, elevated (.5m) mussel bank perpendicular to current in NE-SW dir.	Mussel beds prolific 40-50% bottom coverage. Transplante quahogs exposed on sediment surface. *Libinia* and *Pagurus* common.
15 November 78	NW border	1145-1205		21 m, 11°C, 2/3 ebb, 1.8 m. Particular suspended material and reduced visibility. Winnowed surface sediments, exposed cobbles, ripple marks.	Epibenthic fauna scarce on unstable sediment. Large flounder (2).

Table 11.2 Underwater photographs taken at selected stations on the New London (NL) disposal site, March-November 1978.

Date	Station	No. Frames
29 March 78	50-100 m W of NL Buoy	15
	0.9 km S of NL	25
	0.9 km ENE of NL	10
25 April	100 m E of NL	10
	100 m N of Station 1	10
	0.9 km ENE of NL	10
1 June	NW border (at periphery)	7
21 June	0.9 km SSW of NL	10
	0.9 km E of NL	5
28 June	1.1 km SSE of NL	15
13 July	0.9 km SSW of NL	5
21 July	NE border	10
26 July	100 m NE of NL	10
28 September	Station 3	10
3 November	Station 1	10
15 November	SW border	20
	NW border	15

Macrobenthos and Bioturbation:

Figure

11.1 16 September 74, NL Buoy, Horizontal field of view of photo (HFVP) - 23 cm.
Winter flounder, Pseudopleuronectes americanus, the predominant fish observed throughout the survey. It utilized soft spoil as protective cover or in food seeking activities.

11.2 16 September 74, NL Buoy, HFVP - 38 cm.
Prionotus spp. was frequently observed manipulating substrate surface layer with modified pectoral and caudal fins during feeding.

11.3 25 April 78, 100 m E of NL, HFVP - 25 cm.
The moon snail Polinices heros, a predator on molluscan infauna, burrows and grazes in soft spoil sediment.

11.4 28 June 78, .6 mi. SSE of NL, HFVP - 25 cm.
The channeled whelk, Busycon canniculatum, demonstrates reworking of upper 10 cm of spoil substrate.

11.5 7 March 1975, NL Buoy, HFVP - 25 cm.
Jonah crab, Cancer borealis, abundant in clay mound areas, excavates numerous tunnels and pockets in the cohesive clay areas.

11.6 28 March 78, 100 m W of NL Buoy, HFVP - 15 cm.
The hermit crab Pagurus longicarpus excavates small depression in clay mound surfaces.

11.7 13 July 78, SW corner, HFVP - 122 cm.
Extensive excavation of clay mounds produce biologically sculpted structures. Surface sediment fragments, resulting in formation of small clay balls, which accelerates spoil topography leveling and increases sediment transport.

11.8 26 July 78, 100 m NE of NL Buoy, HFVP - 91 cm.
Space in clay mound crevice accommodates hake, Urophysis sp.

Spoil surface features:

11.9 21 July 78, NE border, HFVP - 38 cm.
Evidence of movement of spherical clay balls over spoil surface. Observation of biogenic origin of these fragmented particles have been cited.

11.10 7 March 75, NE sector, HFVP - 61 cm.
Fissure in clay mound altering adjacent bottom characteristics and providing an invasion point for epibenthic colonizers.

11.11 21 June 78, .5 nmi E of NL, HFVP - 15 cm.
Transplanted quahogs, Mercenaria mercenaria, were commonly observed embedded in spoil surface.

11.12 9 August 77, 5 m E of NL, HFVP - 51 cm.
Shells in heavy patches, 10-20 m in diameter occur on spoil surface shortly after disposal.

Epibenthic recolonizing species:

11.13 28 March 78, 100 m W of NL, HFVP - 10 cm.
Gravel spoil material provides attachment base for new growth of the hydroid Tubularia.

11.14 25 August 78, 100 m N of Sta. 1, HFVP - 15 cm.
Agglutinated tubes of annelid polychaetes at southeast spoil border. Vacant tubes sampled contained amphipods, Ampelisca.

11.15 29 March 78, 0.9 km E of NL, HFVP - 25 cm.
Growth of the bryozoan Bugula turrita recorded on exposed shell and cobble of Phase II spoil.

11.16 1 June 78, NNW of NL, HFVP - 10 cm.
The solitary hydroid Corymorpha pendula occurred on virgin Phase II spoil in dense concentrations of up to 10-15 m^2 in both spring 77 and 78.

11.17 21 June 78, SSW of NL at border, HFVP - 20 cm.
Mytilus edulis bed on Phase I spoil. Individuals matured from an average 0.5 cm in shell length (Sept. 77) to 4 cm in length (Nov. 78). Epifaunal growth is evident. Mytilus byssus threads attach to shell fragments and solidify spoil surface material. The space between mussels traps sediment.

11.18 15 November 78, SW border station, HFVP - 41 cm.
Projections of mussel bed illustrate the net growth pattern.

11.19 15 November 78, SW border station, HFVP - 51 cm.
Intensive predation by Asterias was noted on Phase I mussel bed.

11.20 21 June 78 - SSW of NL, HFVP - 51 cm.
Aggregations of up to 30 Asterias were observed in vicinity of mussel bed .

11.21 15 November 78, SW border sta., HFVP - 38 cm.
Busycon, the whelk, preys on blue mussel and burrows beneath sections of mussels, dislodging mussel and sediment clusters.

11.22 26 July 78, 5 m SE of Sta., 3, HFVP - 91 cm.
Impact penetration test of lead weight on natural bottom resulted in 10 cm penetration.

11.23 28 July 178, 100 m NE of N.L. Buoy, HFVP - 91 cm.
Impact test on Phase II spoil, approximately 50 days after last disposal, resulted in 45 cm penetration.

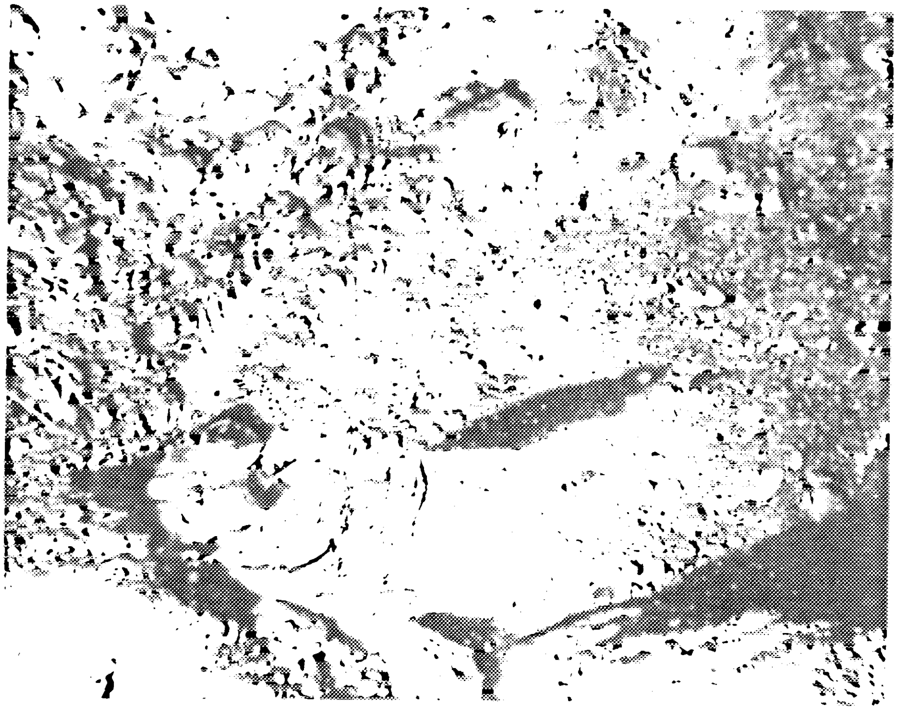


FIGURE 11.1
PSEUDOPLEURONECTES AMERICANUS

FIGURE 11.2
PRIONOTUS SP.

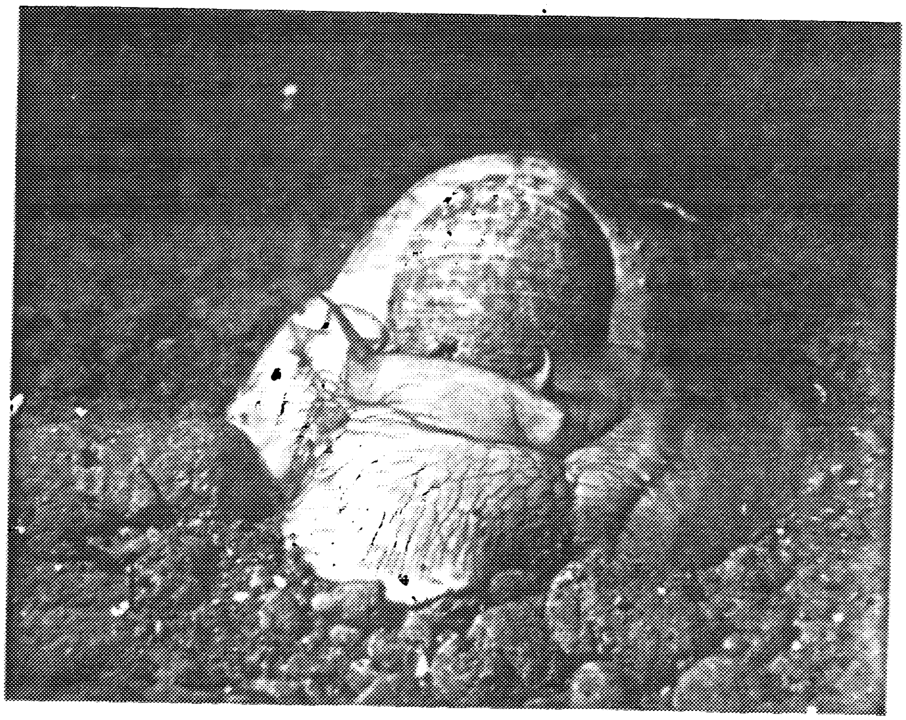


FIGURE 11.3
Polinices heros

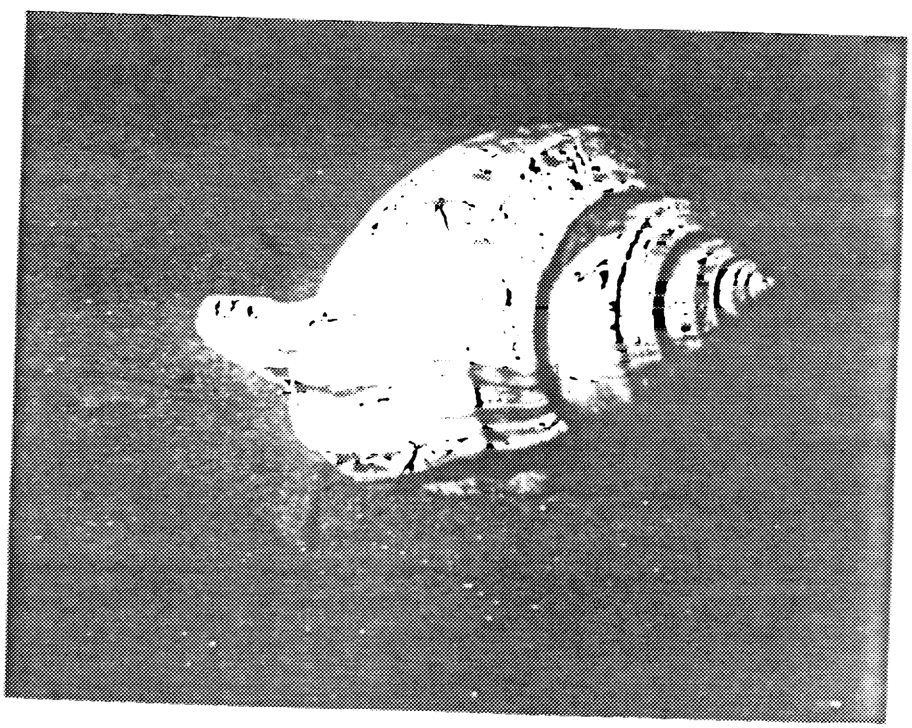


FIGURE 11.4
Busycon canniculatum

FIGURE 11.5
CANCER BOREALIS

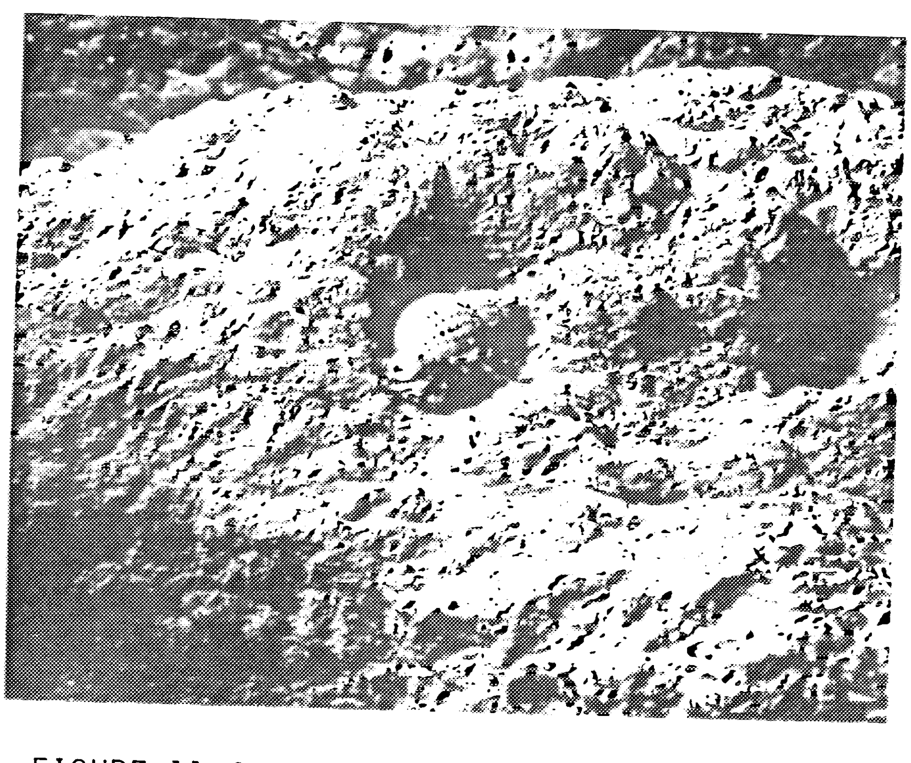


FIGURE 11.6
PAGURUS LONGICARPUS

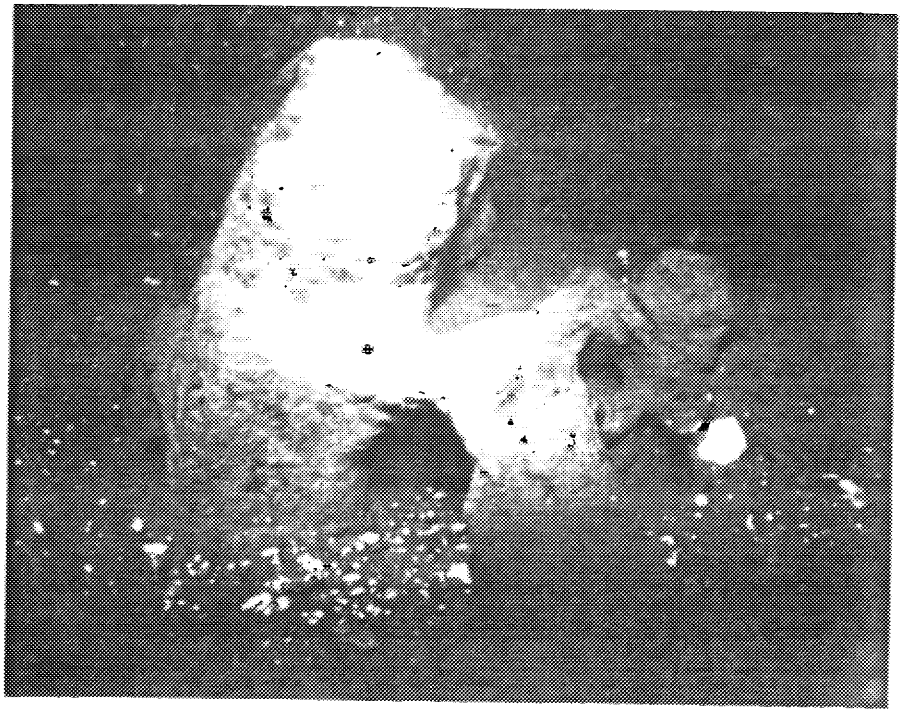


FIGURE 11.7
BIOLOGICALLY SCULPTURED CLAY MOUND

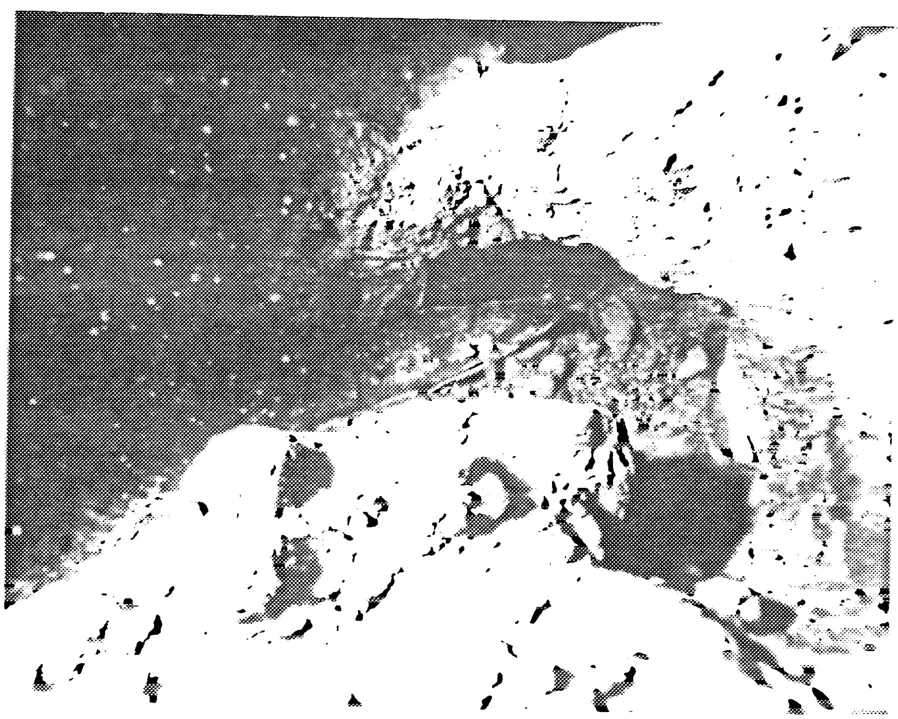


FIGURE 11.8
Urophysis sp.

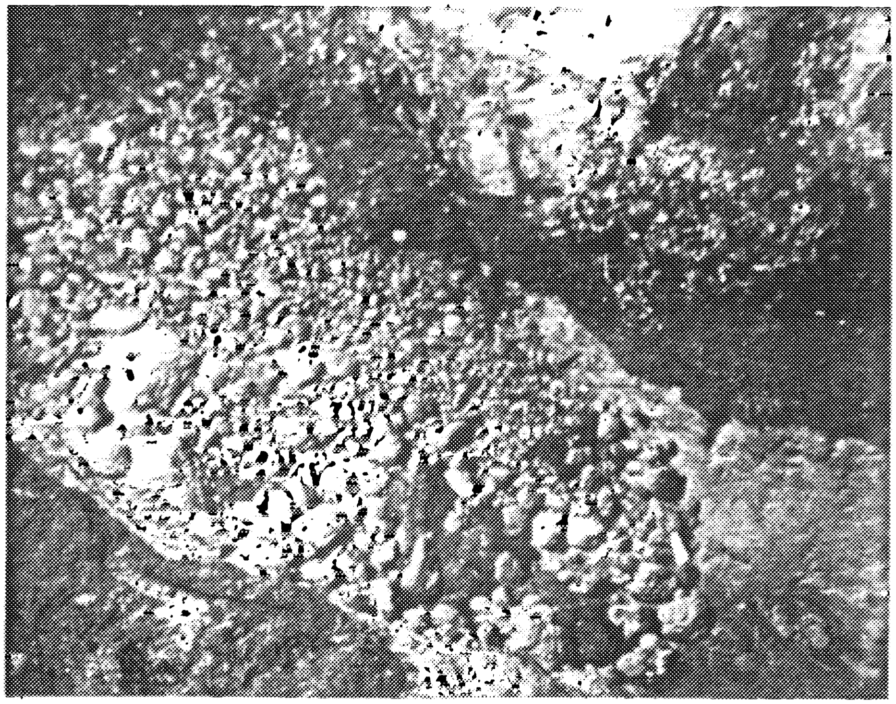


FIGURE 11.9
SPHERICAL CLAY BALLS

FIGURE 11.10
FISSURE IN CLAY MOUND

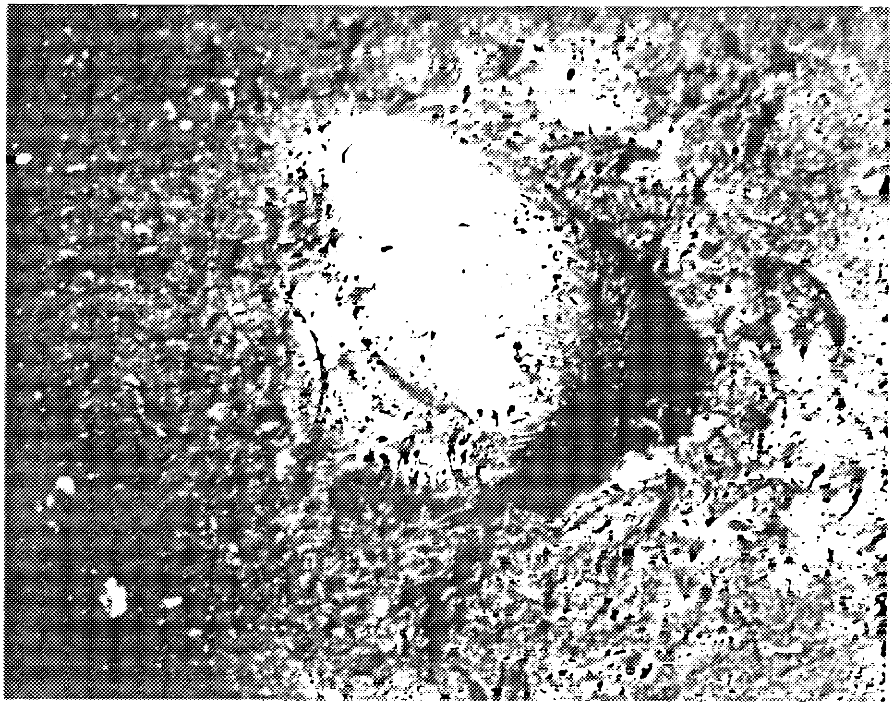


FIGURE 11.11
<u>MERCENARIA MERCENARIA</u>

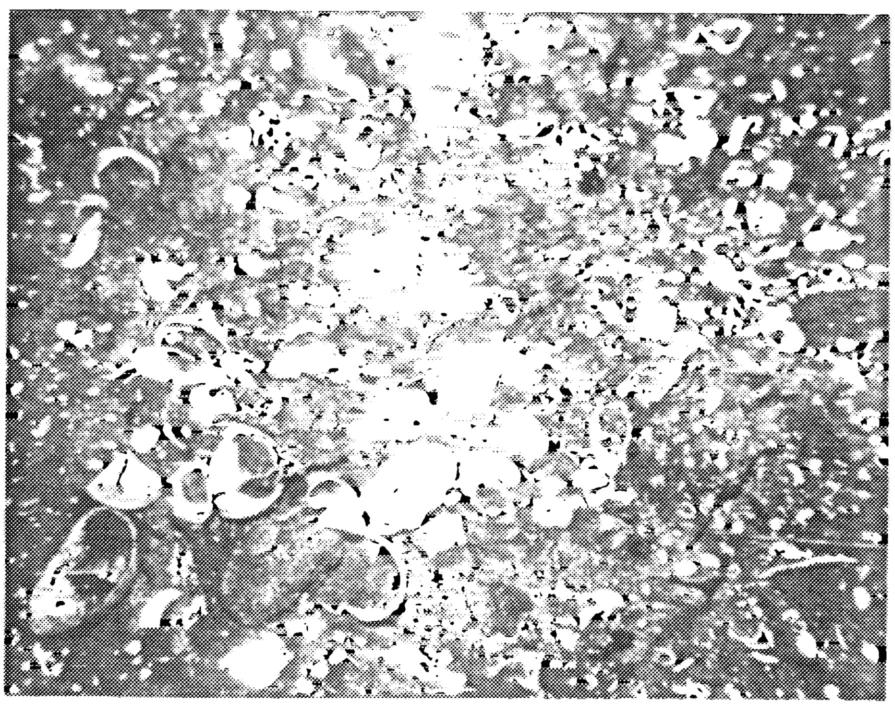


FIGURE 11.12
SHELL DEBRIS

FIGURE 11.13
Tubularia sp.

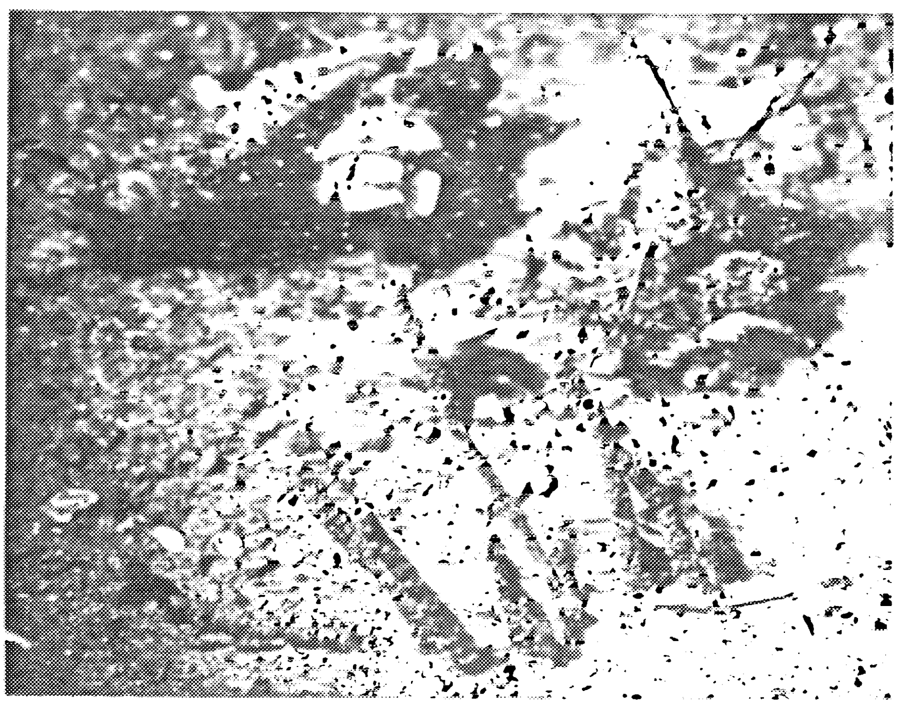


FIGURE 11.14
Ampelisca sp.

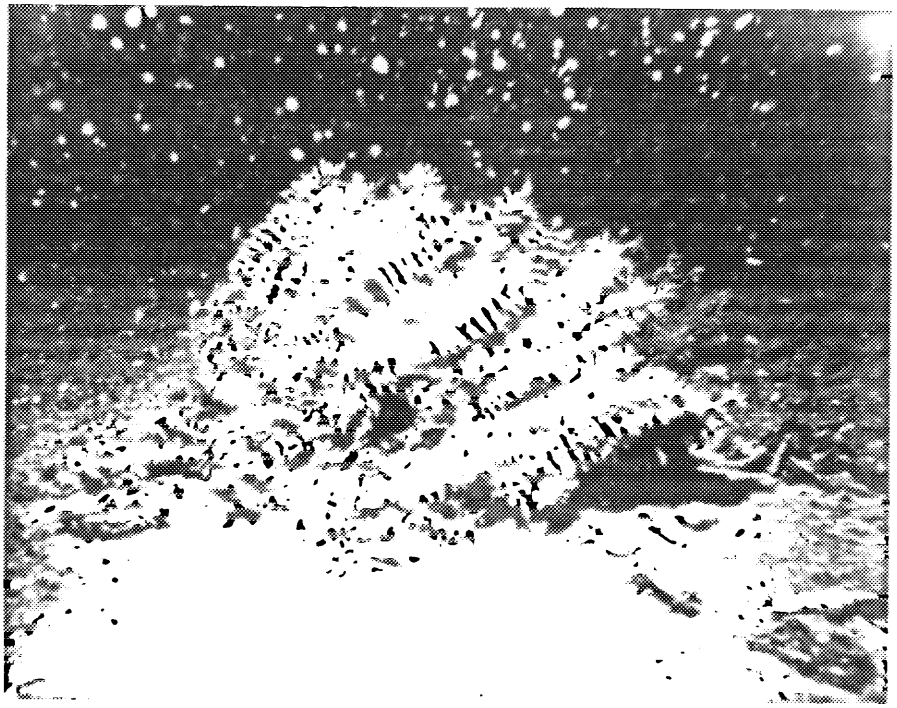


FIGURE 11.15
Bugula turrita

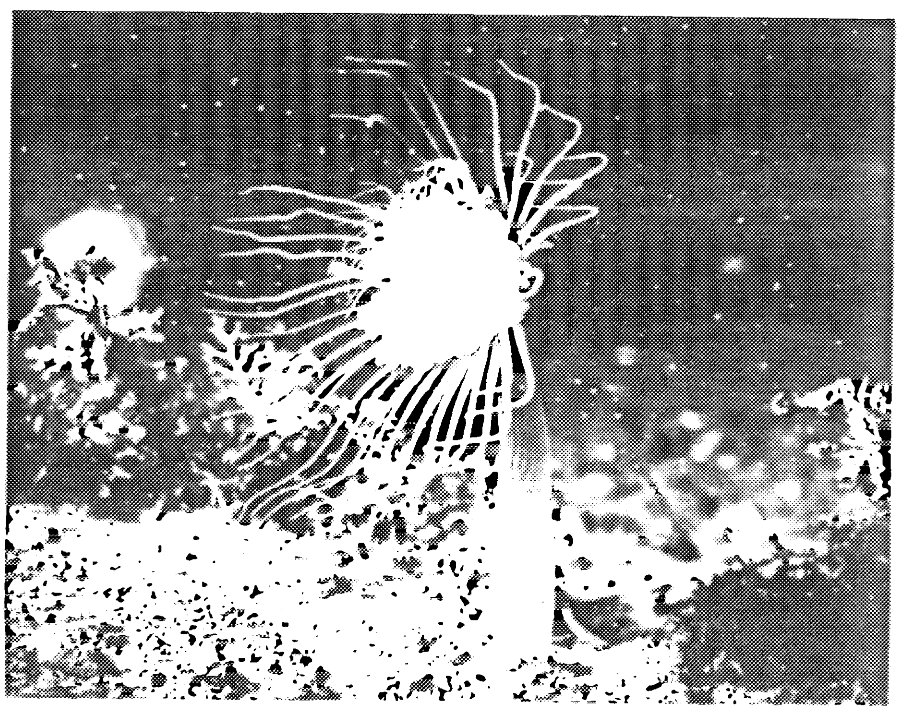


FIGURE 11.16
Corymorpha pendula

FIGURE 11.17
MYTILUS EDULIS PHASE I

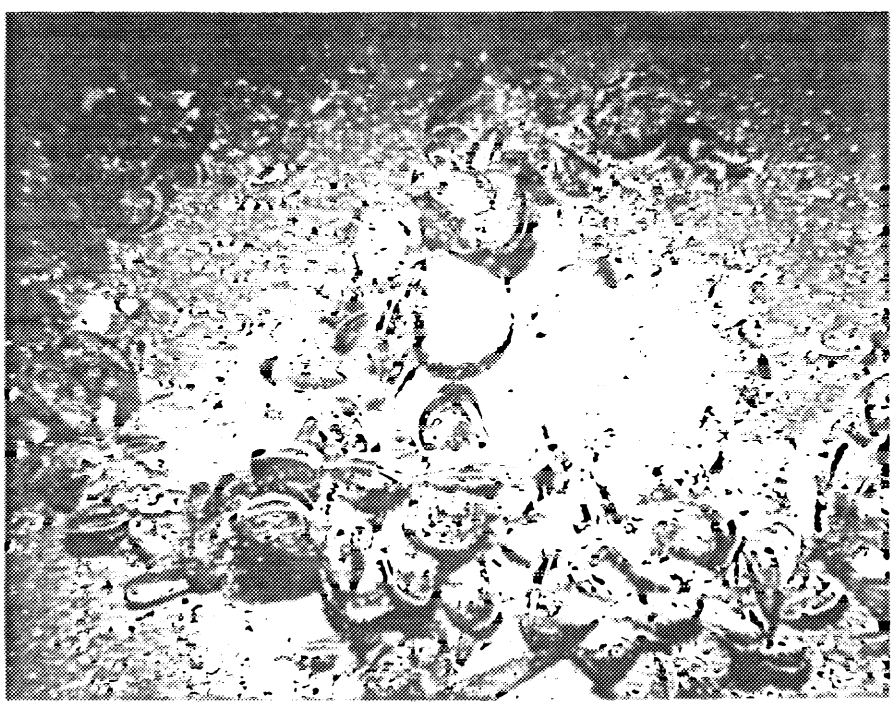


FIGURE 11.18
MYTILUS EDULIS SW BORDER

FIGURE 11.19
Asterias PREDATION

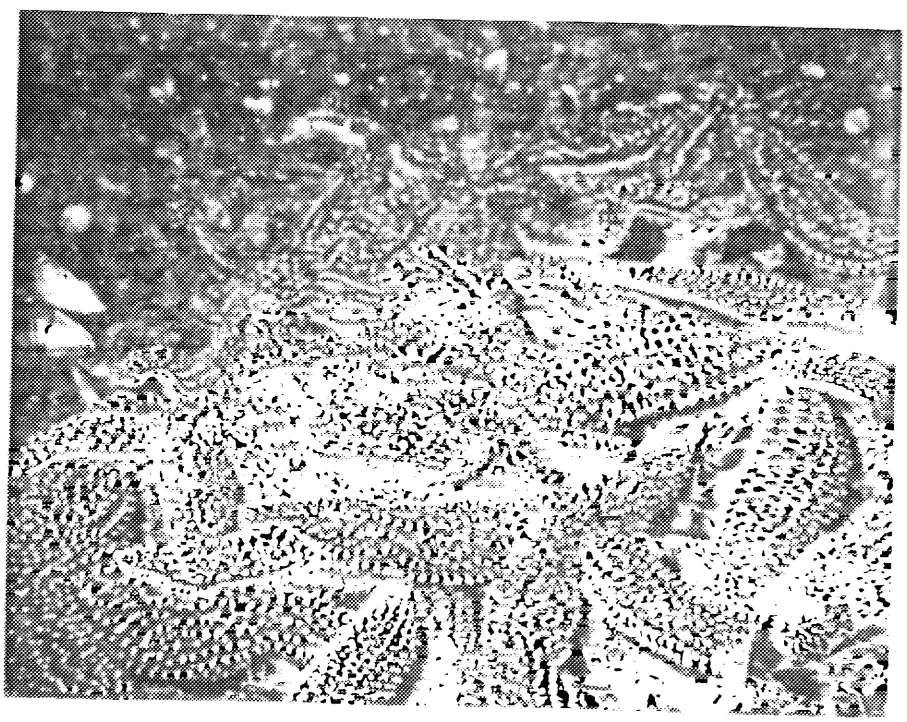


FIGURE 11.20
Asterias sp.

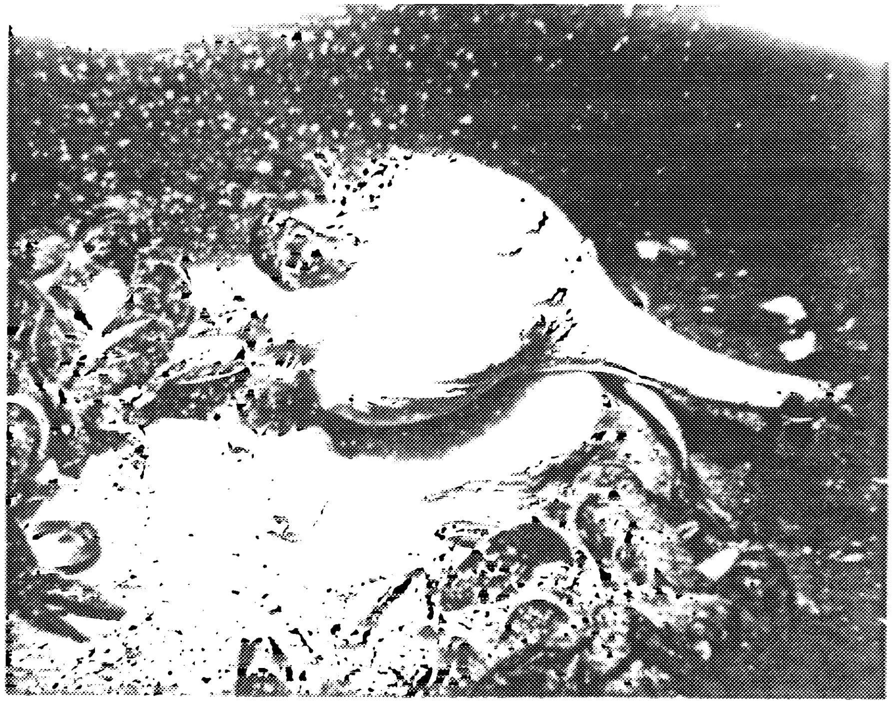


FIGURE 11.21
Busycon PREDATION

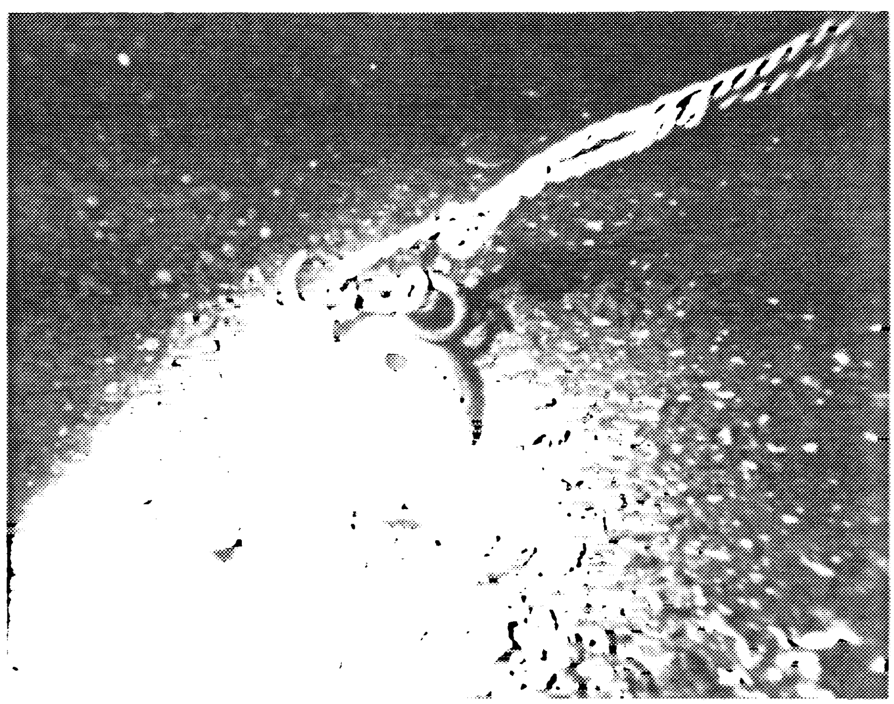


FIGURE 11.22
NATURAL BOTTOM PENETRATION

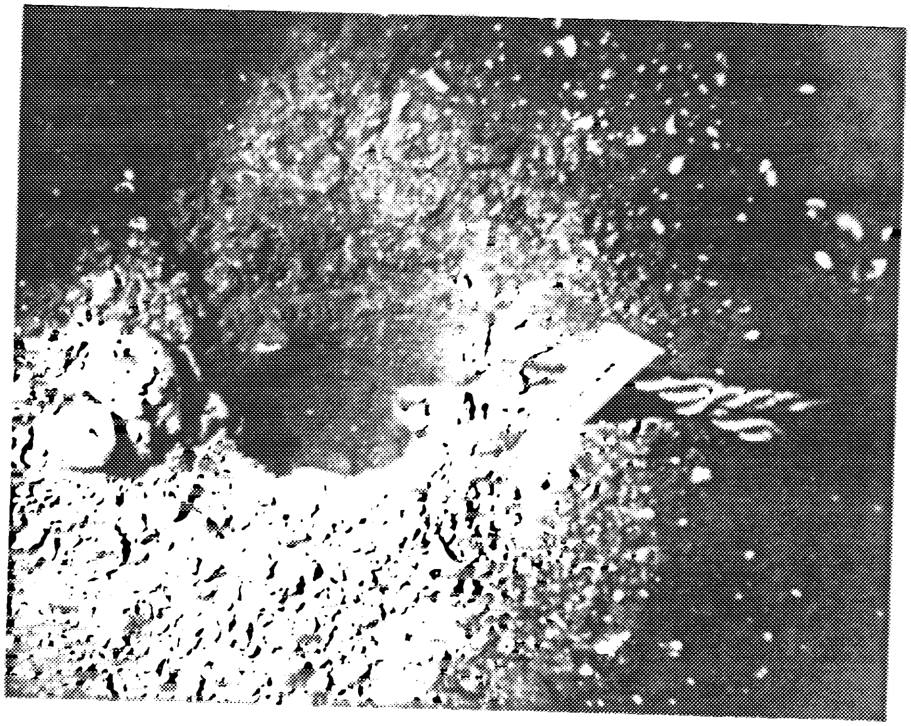


FIGURE 11.23
PHASE II MATERIAL PENETRATION

epibenthic smothering was observed beyond the border stations. The natural sediment veneer, in flux with each tidal cycle, did not show a wide gradient band (overburden with spoil material) at border locations in most sectors. The transition zone between spoil material and natural bottom sediments averaged 3-5 m around the south, west, and north sectors. A 20 to 30 m indistinct transition zone with patches of natural bottom enclosed by thin spoil overlay occurred in the eastern and southeastern sector. Adjacent undisturbed bottom communities appeared diverse, with a full range of fouling organisms.

The recolonization rate is slower in deeper, less frequently disturbed environments than in shallow inshore waters prone to storm disturbances. In deeper waters the smaller, infaunal community requires considerable time to repopulate an area. Thus, the progressive reworking of sediment (bioturbation) associated with these events is slow. Eventually the sediment turnover depth reaches a maximum of about 10 cm. In contrast, the bioturbation rate in shallower waters, where mobile macrobenthic organisms are frequently present, is more rapid. Macrobenthic organisms burrow, forage, excrete organic material into the sediments, thereby "conditioning" them. Infaunal succession rates appear to be more rapid in these marine environments. This type of community organization is found on dredge spoil deposits in shallow water.

The extent of sediment fragmentation and excavation at the New London disposal site has been reported previously. Much of the bioturbation was attributed to activities of macrobenthic organisms. Fishes, large crustaceans, predaceous mollusks, and echinoderms invaded the disposal area immediately in large numbers, and actively manipulated the sediments to depths exceeding one meter while feeding or seeking shelter. The dominant fauna from adjacent areas readily moved into the disturbed site. Many of the organisms used the disturbed area for a limited time only; numerous empty excavations were present, especially in a 20 m band surrounding the spoil pile.

The distribution of surface sediment is patchy at the New London disposal site, with 10 to 30 m irregular areas of soft clay-mud interspersed among areas of coarse gravel sediment. In theory, the infaunal associations should be extremely variable in such an irregular habitat. Species' diversity could be highly variable and successional series difficult to predict.

Disturbance of the dredge spoil pile by trawl fishing far exceeds that by the infaunal community. Sediments are disturbed when otter doors and weighted sweeplines are dragged across the spoil pile. Commercial trawl equipment was used near the New London disposal site during 1978. Furrows in the spoil surface 1 m deep have been observed at other sites. The consequences of re-exposure of contaminated, buried spoils during trawling should be considered in future management of disposal sites.

11.1.4 Epibenthic sampling by divers

Divers took epibenthic net samples in the vicinity of the New London disposal site between September 1977 and November 1978. Results are recorded in Table 11.3. Collections have been preserved and most sorting completed. A summary of findings using this method to sample the upper 1 cm of spoil is being compiled.

Divers periodically collected *Mytilus edulis*, a natural mussel set on Phase I spoil in the southwest sector; the population was found to grow progressively throughout the sampling period. Collections taken on 22 September 1977 revealed that individuals 0.5-1 cm in shell length were distributed over approximately 25 percent of Phase I surface in a network. Settling presumably occurred in July 1977. Mussels taken on 16 December 1977 had a mean shell length of 2 cm. The hundred individuals collected on 29 March 1978 had a mean shell length of 3.3 cm. On 15 November a final sample of 100 *Mytilus* averaged 4.1 cm in length. The bed appeared healthy throughout the 1978 sample period. Intensive predation by macrobenthic organisms was noted. About 50 percent of the Phase I spoil pile is covered by the mussel bed; banks of mature mussels are forming over an extensive area in the southwest sector (see Figs. 11. 17-11. 21).

11.2 DELINEATION OF SPOIL BOUNDARY AND EXTENT OF COVERAGE (PHASE II DREDGE MATERIAL) AT THE NEW LONDON SITE 1978

Table 11.3 Epibenthic samples taken by divers at stations on or directly adjacent to the New London Spoil Pile, September 77 - November 78. Method: 0.5-m net, 30-second traverse, hand-held approximately 1 cm below sediment surface.

Date	Location	Depth (m)
30 Sept. 77	Station 1	23
28 Oct. 77	Station 3	18
16 Dec. 77	NL buoy chain	
29 Mar. 78	200 m W of NL buoy	21
	0.9 km NNE of NL buoy	17
30 Mar. 78	Station 3	18
18 Apr. 78	0.9 km S of NL buoy	23
25 Apr. 78	90 m N of Station 1	24
	450 m NNE of NL buoy	18
	90 m of NL buoy	19
1 June 78	0.9 km E of NL buoy	20
	0.9 km NW of NL buoy	23
21 June 78	0.9 km SSW of NL buoy	23
23 Aug. 78	NW corner spoil pile at marker buoy	21
	SW corner spoil pile at marker buoy	23
15 Nov. 78	NW border	21
	SW border	21

11.2.1 Methods of station location

Immediately following termination of Phase II disposal (June 1978) intensive dive surveys were conducted around the perimeter of the spoil pile. Divers followed transects perpendicular to the spoil periphery to locate the limit of spoil dispersion that could be seen on the adjacent ocean bottom. Surface buoys were towed on short tether lines, and a pipe anchor was placed at the point where natural bottom first appeared from under the spoil apron. Pipe anchor surface buoys were used to assure that, if surface buoys were vandalized or accidently fouled, the marker would be carried away by tidal action and not replaced in an erroneous position.

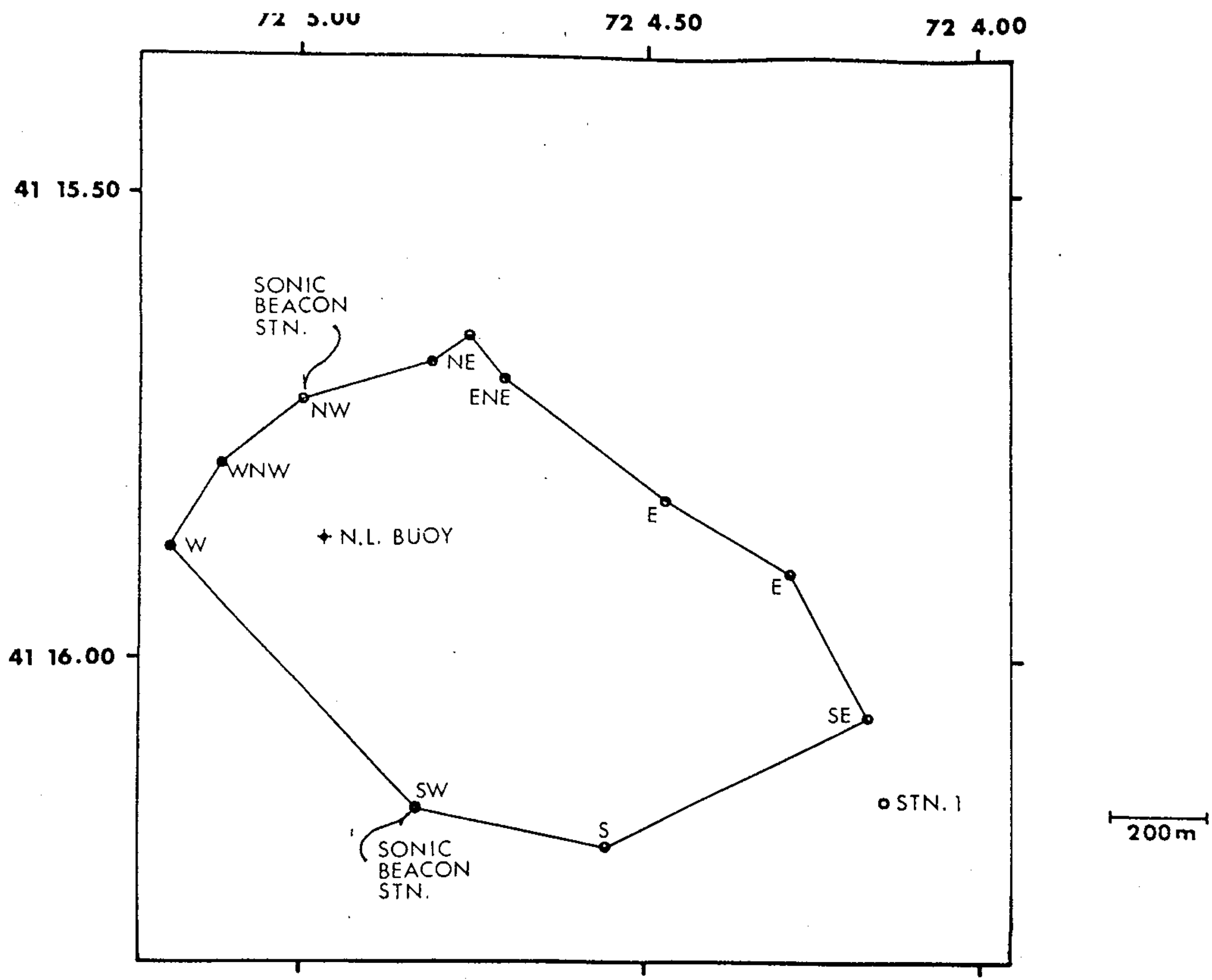
Compass bearings, sextant fixes, and Loran C coordinates were obtained for all nine marker buoys. Using the New London buoy as a reference, the marker buoys were placed at the perimeter of the spoil pile at bearings of W, NNW, NW, ENE, E, SE, S, and SW. Positions of the marker buoys are shown in Fig. 11.24.

Two permanent border stations in the northwest and southwest sectors were marked with sonic beacons. Underwater sonic receivers permit the diver to return to border stations for repeated observations of biological recolonization and spoil border stability. At each station, a 50 m polypropylene line was staked to the bottom perpendicular to the spoil periphery. Along the line, stakes marked in centimeters were driven into the spoil material at approximately 3 m intervals. These will be used to gauge spoil compaction or erosion.

11.2.2 Delineation of Phase II Spoil Periphery

Table 11.4 summarizes procedures for location of the Phase II spoil periphery. Over 26 dives were made to the border stations. Several buoys were lost, presumably due to heavy marine traffic and fishing activity in the area, and were replaced on subsequent survey dives.

Conversion of Loran C coordinates to direct Decca fix on existing marker buoys enabled us to plot the boundaries, as of 2 August, of the New London



NEW LONDON DISPOSAL SITE DREDGED MATERIAL BORDER LOCATIONS, DETERMINED BY DIVER INSPECTION AT LOCATIONS IN W,NW,NE,E,SE,S AND SW SECTORS. PLOT INDICATES DISPERSION LIMITS AS OF AUGUST, 1978. MARKERS ARE TRUE BORDER POSITIONS, CONNECTING LINES ARE NOT ACTUAL BORDER BUT WERE CONSTRUCTED TO INDICATE THE EXTENT OF PHASE II COVERAGE. SONIC BEACONS WERE INSTALLED AT THE NW AND SW LOCATIONS.

FIGURE 11.24

Table 11.4 Procedures to locate Phase II spoil boundary on the New London disposal site, define sector limits and establish permanent border stations.

Date	Station location	Objectives	Observations
28 June 78	NW, NE, E, W, SE sectors	Locate spoil border and place surface marker buoys. Locate the spoil-natural bottom border by divers.	Photographs taken along NW and SE sector transects.
7 July 78	Sta. 1, 2, 3 NL buoy, W, NW, NE (I), NE (O), E, SE, SW, S	Obtain Loran C coordinates, sextant fixes, and magnetic bearings for spoil border markers and adjacnt shellfish stations. Locate and place remaining spoil border markers.	Observations on intense sportfishing activity in vicinity. Vessels identified and counted.
13 July 78	Sta. 3, NL buoy, W, NE (I), NE (O) ENE, SW, S, SE	Take repetitive Loran C coordinates, sextant fixes and magnetic bearings for respective border markers.	
21 July 78	NW, ESE, SE, S SW	Take sextant and magnetic bearings for sector markers. Divers at ESE border.	Fishing activities concentrated at periphery of spoil pile in W, SE, and NE sectors.
26 July 78	50 m SE of Sta. 3, 100 m NE of NL	Spot dive to record natural bottom conditions in Sta. 3 vicinity. Make spoil compaction and impact test and take underwater photos.	No spoil invasion evident; hard, heavily fouled "normal" bottom.
2 August 78	W, NW, SW, S, SE, E, ENE, NE (I), NE (O)	Locate border buoys. Reposition lost markers. Chart Decca plot and Loran C conversions for all sector border markers.	
23 August 78	0.9 km S of NL SW border	Place border surface buoys. DPV track of spoil periphery - trial for surface track. Take epibenthic samples and underwater photos.	Distinct border readily detectable along entire course of boundary track 300 m.
6 September 78	NW border	Place sonic beacon, elevation stakes and transect line at periphery.	Surface marker buoys on location adjacent to benthic monitoring station.

Table 11.4 (cont.)

Date	Station location	Objectives	Observations
	SW border	Place sonic beacon, elevation stakes and transect line at periphery.	Surface marker buoys on location adjacent to benthic monitoring station.
22 September 78	SW border	Inspect border station, follow spoil periphery to W 50 m.	Observations on uniformity and definition of phase II spoil boundary. Correlation with limits of bathymetry determination.
15 November 78	0.9 km S of NL SW border	Transect 50 m N. Search for station markers.	Sonic receiver malfunctioning. Unsuccessful search location.
	0.6 km N of NL NW border	Transect 100 m NE follow phase II perimeter.	
10 January 79	SW border	Replace sonic beacon (1 PPS, 44 kHz), take photographs, read calibrated stakes.	Transect line in place, border still distinct at location.
	NW border	Transect survey for photography, replace sonic pinger.	Current strong, visibility poor, station not relocated.

spoil disposal pile (Fig. 11.24). The boundary corresponds well with a bathymetric survey made on this date (Table 11.5).

The slope and features of the apron at different positions around the spoil pile were noted during marker placement. Along the west, northwest, and northeast borders a sharp boundary of spoil/natural bottom was evident. The slope of the spoil material was steep (20-30°) at many points, and 1-2 banks of spoil, indicative of individual barge loads, were found on the natural bottom. At the northeast station, the Phase II border overlies about 2 m of Phase I spoil. In this area, Phase I material extends to the northeast 100 m beyond the Phase II boundary and forms the spoil/natural sea-floor break.

The east and southeast sectors were an extremely flat spoil apron with an irregular scalloped border. The spoil apron sloped uniformly from 1 meter to 1 cm in height over a distance of 100 m. Determination of a distinct spoil border from bathymetric data would be difficult in this sector.

Visual and bathymetric methods yielded similar sediment limits (± 30 m) in the western and northern sectors of the Phase II spoil site. In the eastern and southern sectors, the spoil edge tailed gradually from 1 m to the 1 cm minimum detectable spoil height over a distance of 100-150 m.

The southern border had a relatively straight edge, and the spoil pile sloped gradually to the natural bottom. A distinct border was observed over 300 m in this sector. This survey was conducted from a diver propulsion vehicle. Corrections of about 5 m were necessary to maintain course while following the visible spoil border.

Phase I material underlies Phase II spoil at the border in the southwest sector and extends to the south and southwest for an undetermined distance. Where Phase I and Phase II material meet and to what extent Phase I spoil lies outside the Phase II periphery have not been determined in the northeast or southwest sectors. Attempts to determine the extent of Phase I material lying outside Phase II limits will be conducted in the spring of 1979 in the southwest and northeast sectors.

Table 11.5 Coordinates of New London spoil pile (Phase II) periphery, 2 August 1978

Sector Location	Long./Lat.	Loran C	Depth (m)
NL buoy	-72.0459 41.1687	49956.2 69771.4	17
NW	-72.0508 41.1612	49956.9 69770.7	22
NE	-72.0449 41.1619	49954.1 69770.8	20
ENE	-72.0443 41.1618	49953.4 69771.1	19
E	-72.0428 41.1611	49952.3 69772.2	21
SE	-72.0411 41.1556	49951.3 69774.0	24
S	-72.0434 41.1548	49954.8 69773.9	25
SW	-72.0452 41.1548	49957.0 69773.2	23
W	-72.0513 41.1607	49957.9 69771.0	23

The lines drawn between stations (Fig. 11.24) do not represent true border locations, but are constructed to illustrate the shape and approximate coverage of Phase II spoil. The station positions are, however, all at the boundary of the Phase II spoil pile. Circumnavigation of the spoil pile by diver and DPV will be attempted this year. A ship will track a surface buoy attached to the DPV, thereby recording with greater precision the perimeter of the Phase II spoil.

The Phase II spoil has been deposited in a northwest-southeast elliptical pattern, well within the confines of the designated disposal area which is 1.6 km square. The spoil pile extends 1,000 m along the north-south axis and 1,400 m along the northwest-southeast axis. The exact distance between the limit of Phase II spoil dispersion and the shellfish monitoring stations 1-3 can be calculated. Changes in frontal location over time may be monitored. The volume of the spoil pile may be calculated by integration of bathymetric data and known dispersion limits of the pile.

Permanent benthic stations were established at the northwest and southwest border locations (Fig. 11.24), as described in Section 11.2.1. Successive epibenthic net samples of 30 sec duration were obtained by divers at each station. The northwest border station was chosen because it is the closest point between the Phase II spoil and shellfish station 3. Also, the steep border slope and edge characteristics differ in this sector from those of other locations and will be compared. The southwest border station marks the intrusion of Phase II spoil over a 1-m base of Phase I spoil. A natural population of blue mussels, *M. edulis*, has settled on the Phase I spoil, and this mussel bed will be observed to see if it colonizes Phase II material. This natural mussel bed, attached to Phase I material and in immediate contact with dredged sediment, provides an extremely important source of animals for the bioassays conducted in conjunction with the shellfish and heavy metal monitoring programs. Extensive excavation activities of decapod crustaceans (*Homarus americanus*, *Cancer borealis*, *C. irroratus*) also were observed in the southwest sector. Species occurrence and bioturbation effects in this sector will be recorded.

Considerable sport and commercial fishing was noted in immediate proximity to the New London spoil pile while the spoil boundaries were delimited in June-September 1978. The head boats, Blackhawk and Mijoy out of Niantic were consistently seen with parties of approximately 25 individuals on board. Fishing activity usually included a 500 m drift along the southern and western border of the Phase II disposal site. These commercial vessels were often accompanied by 5-10 small private sportfishing boats following a similar course.

The large populations of winter flounder, *Pseudopleuronectes americanus*, that occur around the entire perimeter of the spoil pile were the main target of fishermen. In August and September the target species was scup, *Stenotomus chrysops*. Other benthic fishes commonly caught were summer flounder, *Paralichthes dentatus*, tautog, *Tautoga onitis*, and sea robin, *Prionotus carolinus*.

11.3 STAMFORD/NEW HAVEN OCEAN DISPOSAL SITE MONITORING--MARCH-APRIL 1979

Diving investigations at the central Long Island Sound disposal site (both south and north target areas) commenced in March 1979. Initially, divers made baseline observations. Transect cables with station markers were installed. Objectives of the research were to:

- determine visually characteristics of spoil disposal;
- delineate visible spoil boundaries;
- evaluate capping procedures;
- investigate biological sediment reworking, faunal behavior, and recolonization; and
- conduct systematic sampling.

Baseline orientation cables were laid from east to west at the north and south sites on 22-23 March 1979. Station markers consisted of coded polypropylene line fastened to a wire cable at intervals from the center of the pile (Fig. 11.25). Underwater photographs were taken along both transect cables to document pre-disposal sediment features, occurrence of benthic organisms, core sample procedures, and calibrated stake placements.

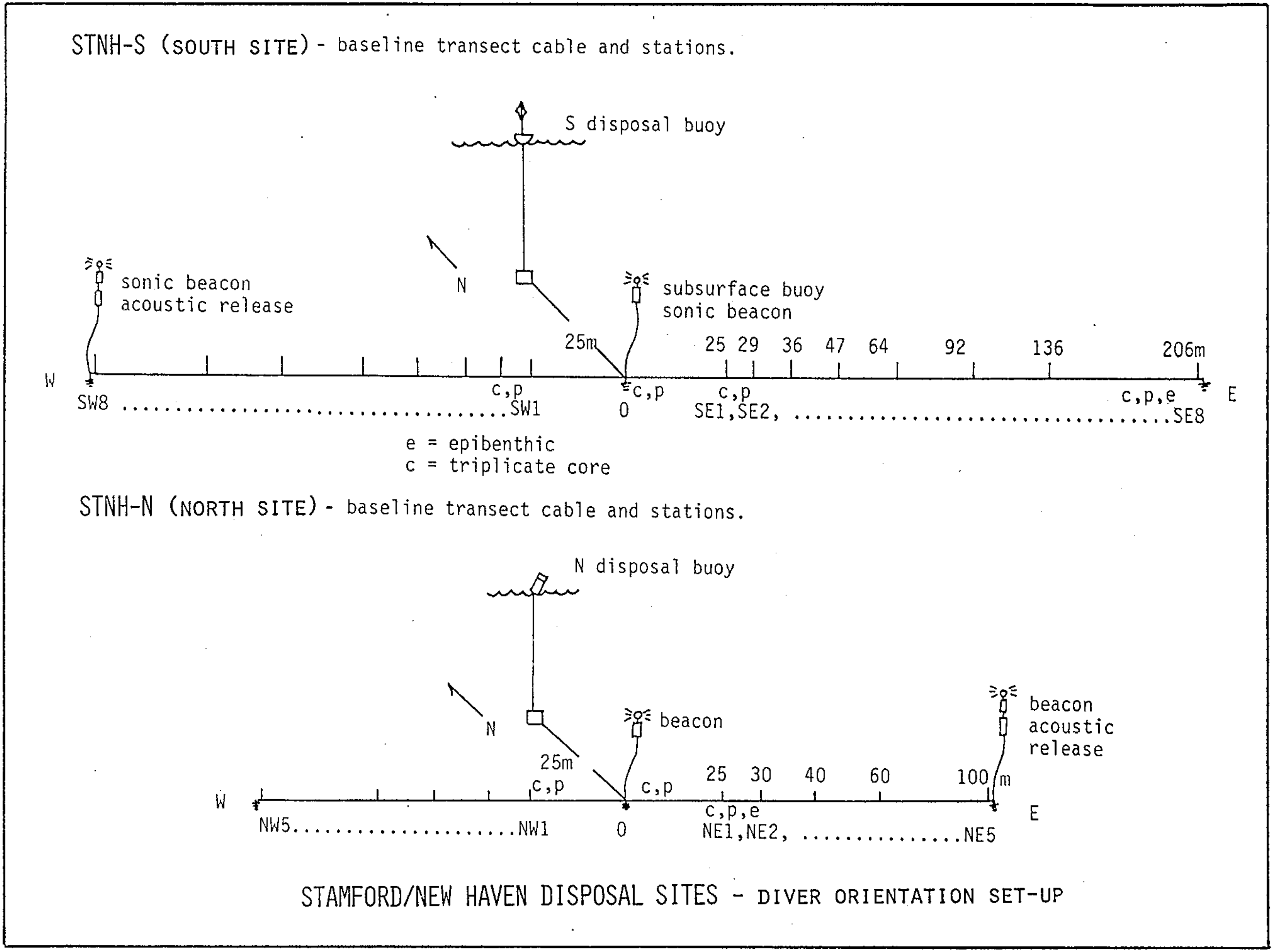

STNH-S (SOUTH SITE) - baseline transect cable and stations.
S disposal buoy
sonic beacon
acoustic release
N
subsurface buoy
sonic beacon
25m
25 29 36 47 64 92 136 206m
W
E
c,p
c,p
c,p
c,p,e
SW8 ....SW1
0
SE1,SE2, ...SE8
e = epibenthic
c = triplicate core
STNH-N (NORTH SITE) - baseline transect cable and stations.
N disposal buoy
N
beacon
beacon
acoustic
release
25m
c,p
c,p
25 30 40 60 100 m
W
E
c,p,e
NW5...................NW1
0
NE1,NE2, ...NE5
STAMFORD/NEW HAVEN DISPOSAL SITES - DIVER ORIENTATION SET-UP

FIGURE 11.25

Core samples were obtained along the south and north transects at stations SC, SW2, SE1, SE8 and NC, NW1, NW3, NE1. The corer consisted of three 7-cm diameter plastic cylinders 20 cm in length secured in line approximately 2 cm apart. The three cores were capped at each end immediately after the samples were taken. The advantage of divers coring the sediments is that they can do it with precision and knowledge of the exact location of the sample with respect to each station and local physiography. The diver samples were to augment surface sediment samples taken by a shipboard Smith-McIntyre grab at multiple stations radiating from the center of the spoil pile.

One meter calibrated elevation stakes were placed along the transect cable at SC, SW1, SW2 and NC, NW1, NW3, NE1 (see Fig. 11.25). About 40 cm of the calibrated stake were visible above the sediment surface at all stations. Stakes were designed to detect the depth of the spoil material after initial disposal.

Epibenthic net samples were taken at stations SE 8 and NE 1. The 50 and 20 cm (1 mm mesh) nets were drawn through the water by divers for 30 seconds over a known course. The net attitude was adjusted approximately to sample over extremely soft sediment and over variable contours. Bar depth was kept at about 2 cm below the sediment surface while sampling. Diver-recorded descriptions of surface sediment features and biogenic sedimentary structures, estimates of densities of epibenthic species, and occurrence of macrobenthic species were made during each dive.

On 10 April 1979, divers at the south disposal site (1) surveyed the extent of the dredged material dispersion along north-south axis; (2) inspected spoil surface characteristics, homogeneity, compaction, and topography; and (3) noted biological activity on newly deposited spoil.

Divers detected the boundary of the spoil pile by the presence or absence of the hydroid Corymorpha pendula. On undisturbed sediments in this area, this hydroid is ubiquitous and dense. Two other indicators of spoil boundary limits were the presence of cohesive clay mounds and slight textural and color differences of the sediment.

Distribution of spoil material in the target area appeared to be the result of sequential dumping and not the result of dispersion due to current transport. The spoil material observed on the bottom consisted of cohesive clay masses interspersed with less consolidated areas. This Phase I material appeared stable and not prone to migration. A distinct north and south perimeter could be detected. In general, most of the spoil material appeared more compact and denser than the surrounding natural bottom sediment.

The center of the spoil material was mounded and it tailed out to the east and west for more than 50 m and 100 m, respectively. Limits of east-west spoil coverage were not determined by diver survey. Visibility was exceptionally good (in excess of 3 m) on one susbsequent dive, and no spoil sediment surface turbidity was noted in the course of dive inspection.

Irregular clay mounds, 1 m in elevation, typified the central 50 m diameter region of the disposal pile (25 m south of the disposal buoy). Toward the perimeter, 2 m high mounds were more common, each representing a single barge load.

A silt veneer overlies approximately 3 m of spoil in the apron regions. Characteristic features of this spoil were:

- invertebrate tracks on the spoil surface;
- cohesive clay clump fragmentation and excavation at the base of the spoil pile; and
- considerable debris (e.g., steel bulkheads, pipe, rope, sheet metal, plastics, bottles, cans, etc.) incorporated in spoil material.

In general, macrobenthic organisms were more abundant and diverse later in the survey period than during the baseline survey on 22 March 1979.

From 24-26 April 1979, in-situ observations were made on the post-Stamford disposal phase material at the south site and interim-Stamford disposal phase material at the north site.

At the south site buoy, a post-Stamford disposal pile elevation line was staked from the disposal chain. The line extended 30 m to the northern border and 170m to within 30m of the southern border. Stakes position the line at the final Stamford sediment surface along the course to indicate baseline of post-Stamford disposal and provide a reference for New Haven capping effectiveness (Fig. 11.26).

Table 11.6 summarizes research conducted on the Stamford/New Haven site from March to April 1979. Reduced visibility in the western portion of Long Island Sound did not limit diver's photography and observations of benthic conditions at north and south sites. Figs. 11.27-11.35, taken during the survey, show:

- features of the natural bottom sediment;
- initial dredge disposal topography; and
- epifauna and motile megabenthos on north and south disposal sites.

Figure captions follow:

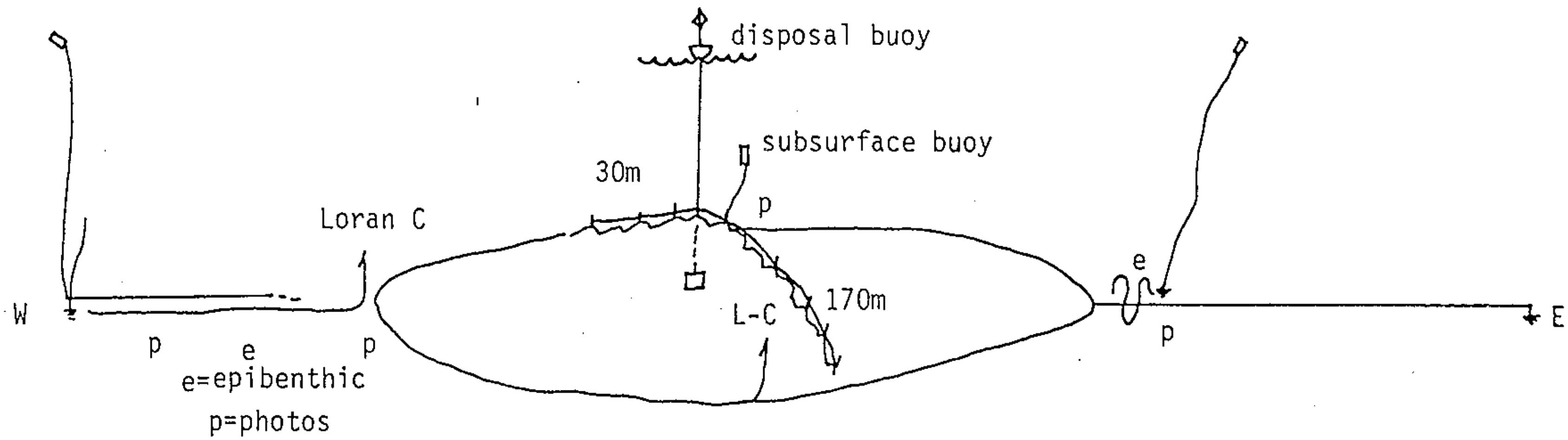
Figs. 11.27 and 11.28 — Abundant juvenile flounder, P. americanus and sand dab, and Scophthalmus aquosus were observed on natural bottom at north and south sites during predisposal inspection.

Fig. 11.29 — The ubiquitous solitary hydroid C. pendula occurred in sufficient densities on natural bottom to be used to monitor spoil limits during initial disposal phases.

Figs. 11.30 and 11.31 — Elevation stakes were placed at selected station markers, along the north and south diver orientation cables. The weight of the cable caused burial of line in soft natural sediments.

Fig. 11.32 — Disposal surface consisted of large (1-2 cm) clay blocks with soft interstitial sediment. Stamford material was black, coarse, granular sediment with a high quantity of detritus.

Fig. 11.33 — The most abundant immigrant to newly deposited spoil was the crab C. irroratus.



STNH-S DIVER ORIENTATION SET-UP FOR POST STAMFORD DISPOSAL SURVEY

FIGURE 11.26

Figs. 11.34 Partial burial of Corymorpha basal stalks indicated spoil dispersion limits in most all sectors surrounding the north and south piles. Limits could be followed by divers for 10-100 m.

University of Connecticut Marine Sciences Institute graduate students and research technicians assisted greatly with dive operations, benthic collections, and underwater photography. The efforts of the following individuals are greatly appreciated: Robert DeGoursey, Peter Auster, John Watson, Richard Grillo, Fred Dobbs, Ron McMahon, and Richard Arimoto.

Table 11.6 Stamford/New Haven dive survey, March-April 1979

Date	Site	Dive Observation
22 March 79	South	Pre-disposal on transect line. Bottom at SC cohesive but very soft. SC anchor buried to approximately 0.5 cm. At SE 1 to SE 3, bottom cohesive and firm. Boulder north of SE 1. Species - H. americanus in mud burrows (2); C. pendula (100+); Urophysis sp. (1); P. americanus (10); C. irroratus (25+) on surface; ctenophore; Pleurobrachia pileus; bryozoan, Bugula turrita (2).
23 March 79	North	On transect line NE 1-NW 3. Bottom soft and cohesive. Species: C. irroratus; Asterias forbesi, 5-10 cm; C. pendula. P. americanus.
23 March 79	South	At east end of transect line, SE 8. Surface ripple marks. Cylindrical vertical burrows - no lobster. Species: Hippoglossoides platessoides (1); P. americanus (2); C. pendula (15 ind. .25 m^2).
10 April 79	South	Disposal in progress. Compass transect to SW of dump buoy and north-south. No distinct color difference between spoil and natural sediment. Possible slit veneer overlay on each tidal cycle. Cohesive clay clumps. 1-m mounds at center. Height above original level 1.5-m maximum. Clump splitting occurring (some due to benthic fauna). Debris on surface and partially buried (e.g., leaves, Phragmites, timber, aluminum foil, plastic). Species: P. americanus (16); Urophysis sp. (4), 1 burrowed in side of clay clump, 1 adjacent to plastic debris on clump excavating sediment; Myoxocephalus octodecemspinosus (8); T. onitis (1) on base of dump buoy; Pagurus longicarpus (20) Libinia emarginata (9); C. irroratus (50) excavating clay clumps and surface sediment, some burrowed over entire bottom; Crangon septemspinosa; Mysis sp. over entire bottom; pandalid shrimp, 2 cm vertical burrowed Geletheoides; A. forbesi; B. turrita on fouled clumps or eddy zone; gastropod on Laminaria blade; C. pendula: none on spoil buried at periphery (15/25 m^2) gastropods (10). Immediate colonization after dumping.

Table 11.6 (cont.)

Date	Site	Dive observation
25 April 79	South	Dive on dump buoy to west periphery. Cable broken between SW 7 and SW 8. Divers did not find far end of cable. Concentration of _A. forbesi_ in 20-m band at border of spoil; 20-30 individuals. Divers surfaced after locating spoil periphery and Loran C fix obtained.
25 April 79		Species: _P. americanus_ (10); _M. octodecemspinosus_ (5-6); _Syngnathus_ sp. (7); _Urophysis_ sp. (5-7); _Tautogolabrus adspersus_ (2); _C. pendula_; 15-20/m^2 Uniform distribution 3-10 cm height. _L. emarginata_ (8); _C. irroratus_ (25). North-south transect line deployed and followed to south periphery. Loran C position taken at surfaced diver positions. _R/V UConn_ placed marker buoys at apparent east periphery (determined by Smith-McIntyre grab samples). _Corymorpha_ evenly distributed over the area (apparently no spoil). The sediment had a 3-layered profile. The top layer was very loosely cohesive and aerobic, possibly organics that have absorbed and settled on bottom). Beneath this appeared to be an anaerobic layer (but it may have been buried spoil) and a clay (?) layer under all. Species: _P. americanus_ 8-12 cm (7); _Crangon_ (?) (8); _C. irroratus_ (12).
26 April 79	North	At periphery was an approximately 3-meter intermediate zone (patches of spoil and natural sediment) with sparse _Corymorpha_ and clay clumps. Species: _Cancer irroratus_ (6); _Crangon_ (2); _B. turrita_ (3); _P. longicarpus_ (1); _P. americanus_ (6); _Nassarius trivittatus_ (1), 6-cm burrow in spoil sediment and worm tubes near periphery.
26 April 79	North	Approximately 60 m east of dump buoy at edge of spoil was some debris probably from dumping, on natural sediment surface past pile edge (i.e., _Laminaria_ orange peel, clay clump). There is probably current transport of light debris farther than heavier sediment. Some _Corymorpha_ partially buried by surface sediments (by current transport).

Table 11.6 (cont.)

Date	Site	Dive observation
		Species: Urophysis sp. (3); A. forbesi (15); P. americanus (8); T. adspersus (5+); H. americanus (3); Crangon (?) (6+); C. irroratus (8); B. turrita (?) (5); P. longicarpus (4); P. pollicaris (2); C. pendula at borders.

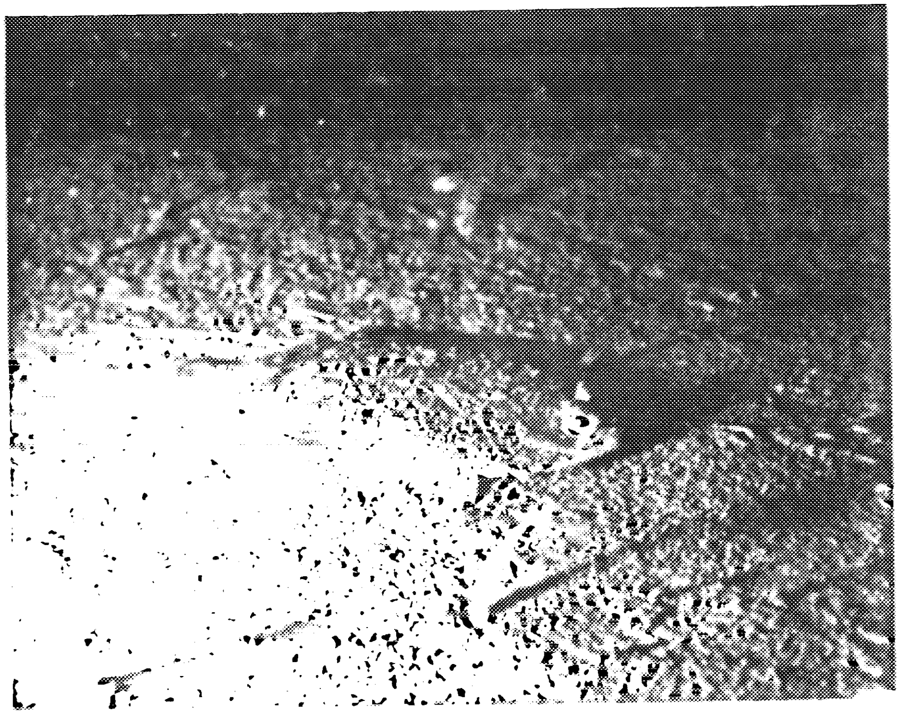


FIGURE 11.27
JUVENILE <u>P. AMERICANUS</u>

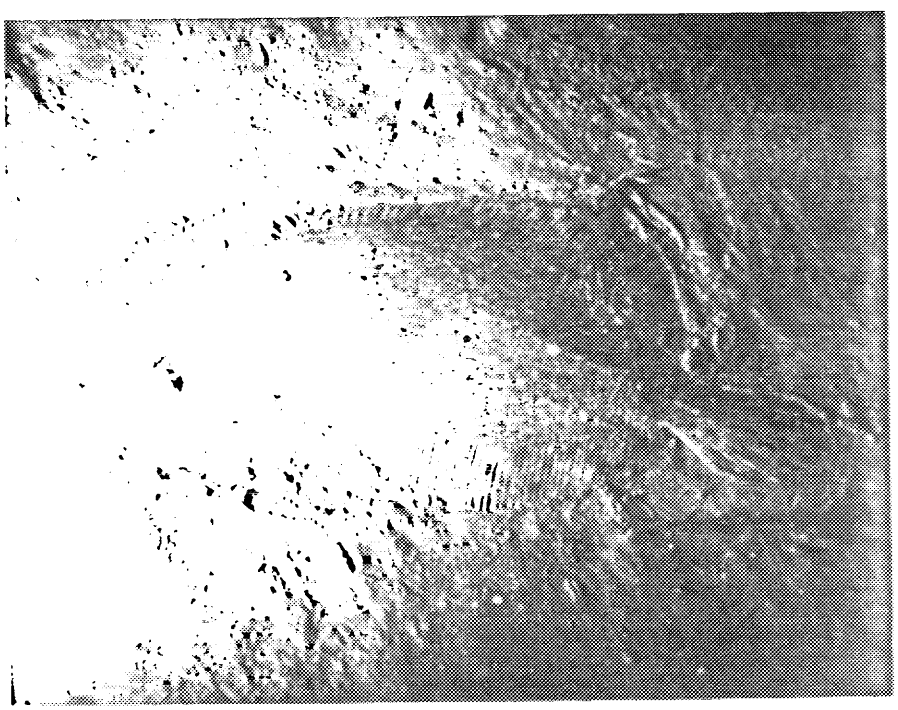


FIGURE 11.28
<u>SCOPHTHALMUS AQUOSUS</u>

FIGURE 11.29
CORYMORPHA PENDULA

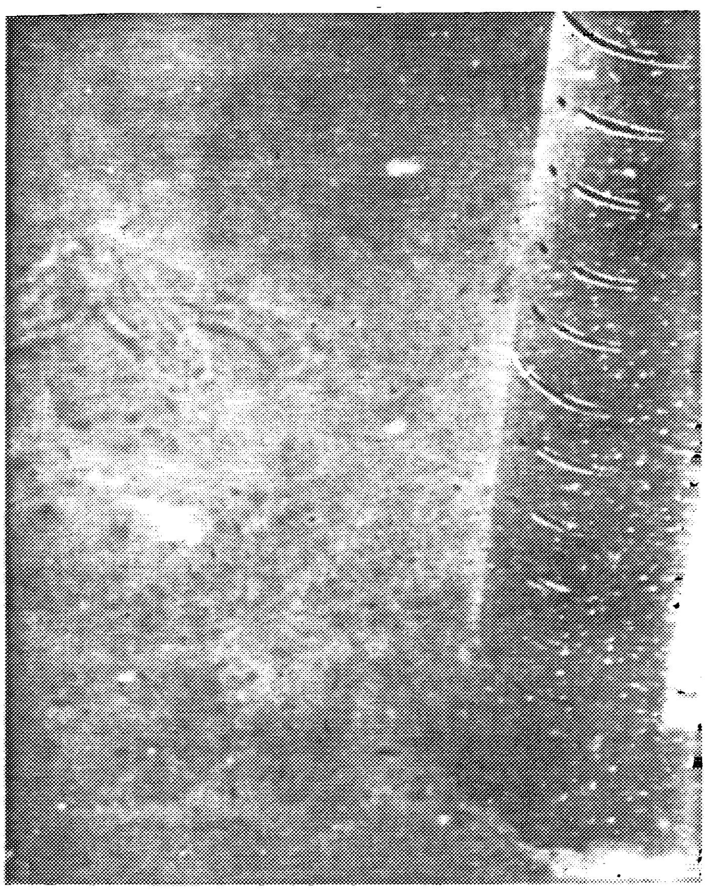


FIGURE 11.30
ELEVATION STAKE

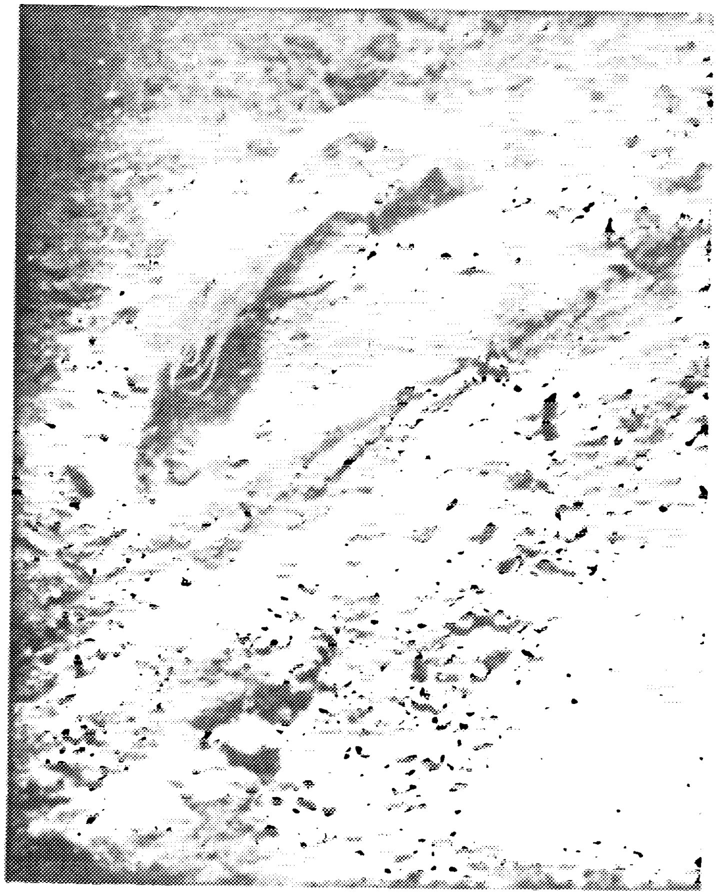


FIGURE 11.31
BURIED ORIENTATION CABLE

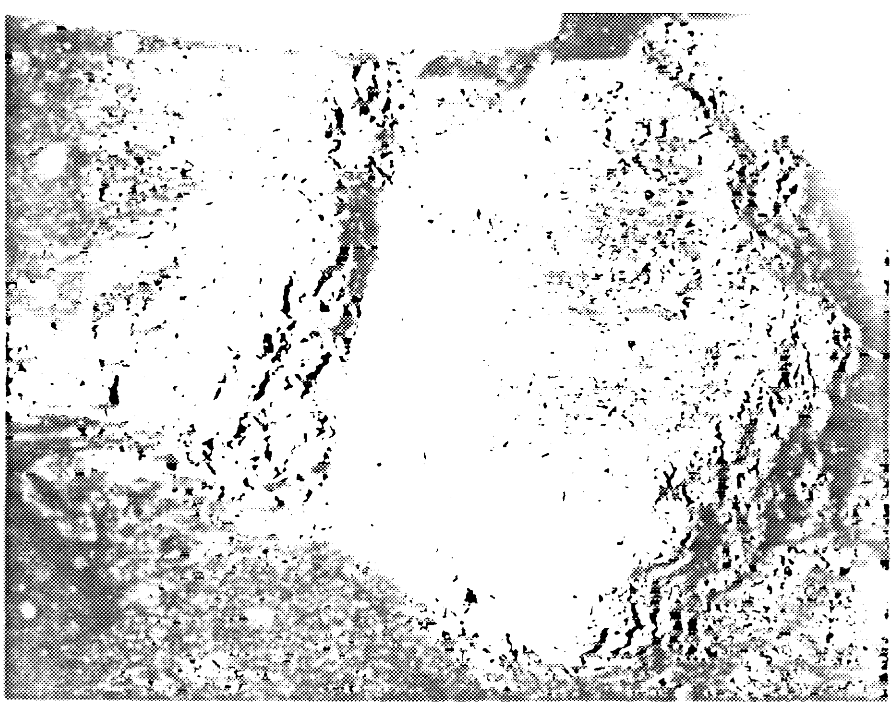


FIGURE 11.32
DREDGED MATERIAL CLUMPS

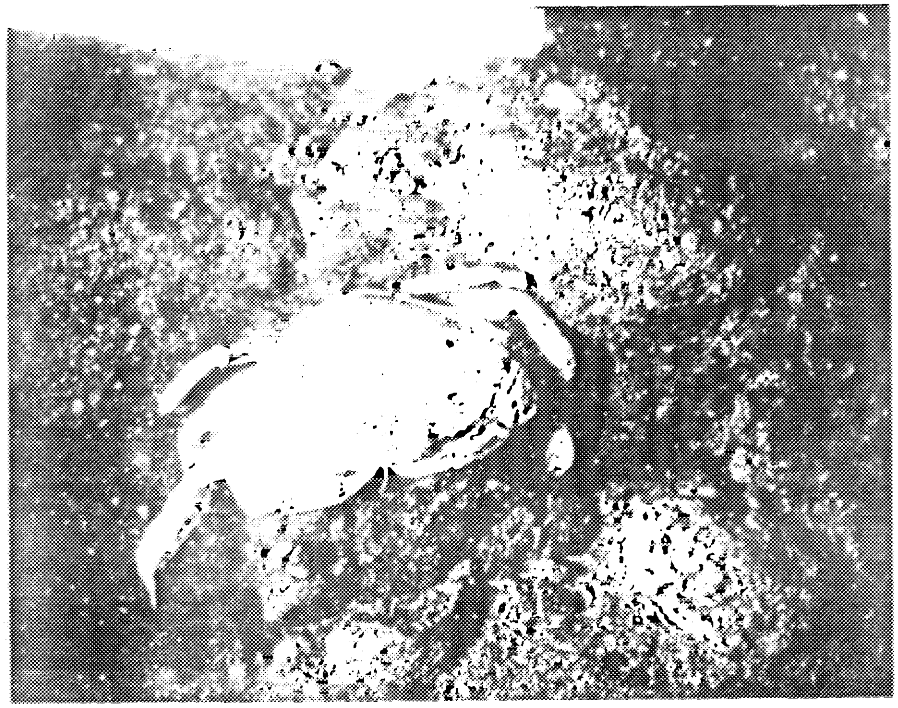


FIGURE 11.33
CANCER IRRORATUS

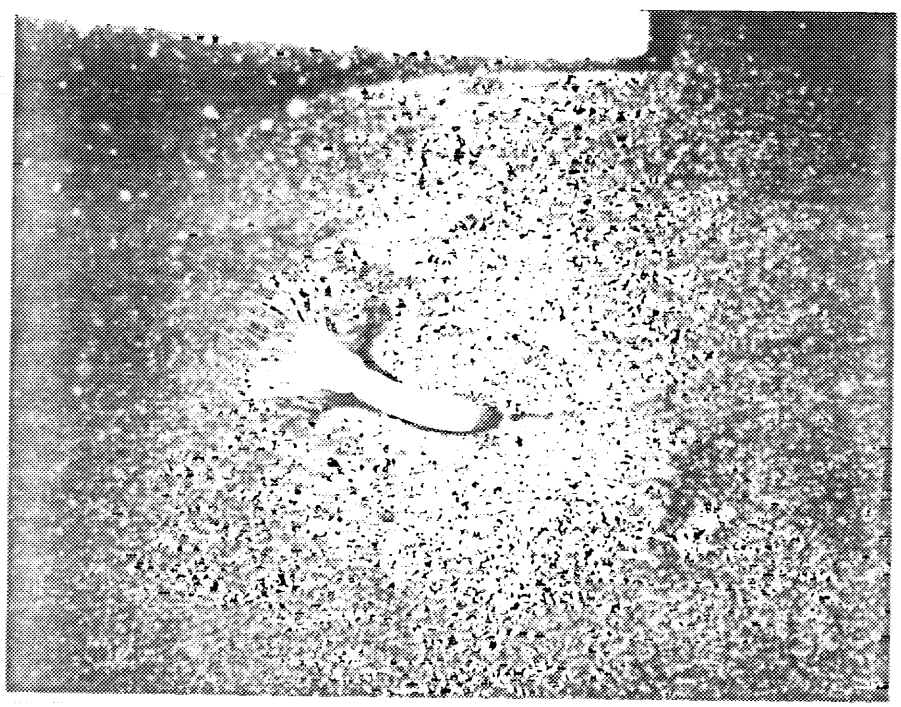


FIGURE 11.34
PARTIALLY BURIED CORYMORPHA