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ENVIRONMENTAL SURVEY OF TWO INTERIM DUMPSITES

MIDDLE ATLANTIC BIGHT

JANUARY 1974

U.S. ENVIRONMENTAL PROTECTION AGENCY
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PHILADELPHIA, PENNSYLVANIA 19106

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION III

6TH AND WALNUT STREETS

PHILADELPHIA, PENNSYLVANIA 19106

January 23, 1974

To The Reader:

As is noted in the text, not all of the analyses were performed in sufficient time to be included in the report and evaluations. This information will be tabulated and discussed in a supplement to be issued at a later date.

The reader in examining this publication should be cognizant of the fact that the assessments and conclusions were drawn in part after comparing the many applicable factors in this report and associated data collected on a previous cruise and published in a report entitled, "Environmental Survey of An Interim Ocean Dumpsite, Middle Atlantic Bight", EPA 903/9-73-001A, September 1973.

ENVIRONMENTAL SURVEY OF TWO INTERIM DUMPSITES

MIDDLE ATLANTIC BIGHT

OPERATION "FETCH"

Cruise Report 5-10 November 1973

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ABSTRACT

A second oceanographic survey cruise was made to an interim municipal sludge dumpsite and initially to an interim dumpsite for the disposal of industrial acid waste in the fall of 1973. Both sites are located on the continental shelf in the Middle Atlantic Bight. Observations were made of hydrographic and bathymetric conditions, major circulation patterns, water quality, sediment composition, heavy metals in sediments and biota, bacteriology, phytoplankton and zooplankton communities, vertebrates and benthic invertebrates.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

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Introduction - D. W. Lear, EPA, Annapolis

I. Water Quality Investigations

   A. *Hydrography*

      1. Local Hydrographic Structures - D. W. Lear and R. J. Callaway, EPA, Corvallis

      2. Major Circulation Patterns - R. J. Callaway

   B. Water Quality Parameters - D. W. Lear

C. Biology

1. Phytoplankton - S. K. Smith, EPA, Annapolis

2. Metals in Zooplankton - P. Johnson and D. W. Lear, EPA, Annapolis

II. Benthic Investigations

A. Bathymetry - D. W. Lear

B. Sediments

1. Size Distribution - H. D. Palmer, Westinghouse Ocean Research Laboratory, and D. W. Lear

2. Metals - P. Johnson and D. W. Lear

3. Chlorinated Hydrocarbons - R. Kaiser and D. W. Lear, EPA, Annapolis

C. Biota

1. Infauna - D. Maurer, University of Delaware

2. Macrobiota - M. O'Malley, EPA, Annapolis

3. Heavy Metals in Macrobiota - Bruce Reynolds, EPA, Narragansett, D. W. Lear, and P. Johnson

4. Bacteriology - M. O'Malley

CONCLUSIONS

Temperature and salinity profiles of the area indicated the presence of a pycnocline but with relatively small differences between surface and bottom waters.

Net bottom water movements, as indicated by neutral buoyancy seabed drifters released on the spring "Quicksilver" cruise, indicated a net movement towards the west and southwest to the Delaware, Maryland and Virginia beaches.

Nutrient concentrations in waters near the bottom showed seasonal variation in concentrations. Nitrate plus nitrite concentrations were elevated in bottom waters at the municipal sludge site.

Phytoplankton populations of these waters were characteristic of mid-temperate coastal communities during the fall and winter regime. Diatoms were dominant organisms generally, and the marine filamentous blue-green alga *Trichodesmium* was found throughout the area.

Mercury, nickel and manganese concentrations were greater in zooplankton samples taken during this cruise as compared with the spring cruise in May 1973. This suggests that certain metals may be accumulating in the zooplankton.

There are indications that Fe, Mn, Cr, Hg, Zn, Cu, and Pb are being deposited in sediments as a result of acid waste disposal practices, and Fe, Mn, Cr, Pb, Zn, and Ni are depositing as a result of municipal sludge disposal operations. These inferences were drawn on geographical distribution patterns. An increase in mercury and lead concentrations was detected in the sediments at the municipal sludge disposal site when compared between spring and fall conditions.

A significant relationship was found between iron concentrations in sediments and those of zinc, manganese and chromium. These relationships may be useful as management indicators for dumping practices.

There was no evidence of accumulations of organohalogens, including PCB and DDE.

Intensive investigations of bottom dwelling faunal communities showed no major shifts of key species (Goniadella gracilis, Lumbrinereis acuta, Trichophoxus epistomus) between the spring and fall cruises. Faunal diversity increased sigrificantly between spring and fall sampling and was attributable primarily to seasonal recruitment and secondarily to artifacts of taxonomy. No measurable effects of pollution on benthic organism communities was detected.

Macroinvertebrates and vertebrates taken by bottom trawl and dredge showed no visible signs of ecological stress.

In a systematic survey of sand dollars (Echinarachnius parma) iron concentrations were found to be less during this fall cruise than found in the spring cruise. A mechanism is postulated in which iron is not as available to the bottom community because of accumulation at the pycnocline.

The moon snail (Polinices), a predator, showed copper concentrations a decimal order of magnitude greater than prey species, illustrative of the fact that metals can concentrate in higher trophic levels.

Sponges, fish, crabs, and a clam were analyzed for metals and showed greater concentrations of manganese, nickel, leas, and cadmium at the municipal waste site in fall compared with spring observations, although there were too few data for firm conclusions.

Bacteriological analyses indicated no accumulations of coliform or fecal coliform bacteria as a result of dumping activities.

Some evidence (bacteria, metals, organohalogens) suggested the inshore "control" Stations 9 and 17 may be influenced by additions other than the specified ocean dumping activities.

INTRODUCTION

The vastness of the seas is diminishing as man's technology, population density and the cumulative effects of time progress. An awareness of man's role in the total environment in the past decade led to serious efforts to lessen the burdens on rivers and harbors, and a consequence of this activity has increased use of the seas for waste disposal. These practices are, however, required to be supervised by a vigilant program specified by Public Law 92-532, the "Marine Protection Research and Sanctuaries Act of 1972."

Results of several ocean survey cruises to the vicinity of the acid waste dumpsite (du Pont, 1972; Meyers, 1973) and to the municipal sludge dumpsite (Palmer and Lear, 1973) indicated measurable environmental changes may have occurred as a result of ocean disposal practices.

Some observations included:

1. Unexplained mortalities of sand dollars in the proximity of the acid waste dumpsite.

2. Apparent accumulation of some metals in the sand dollar population at the sludge dumpsite.

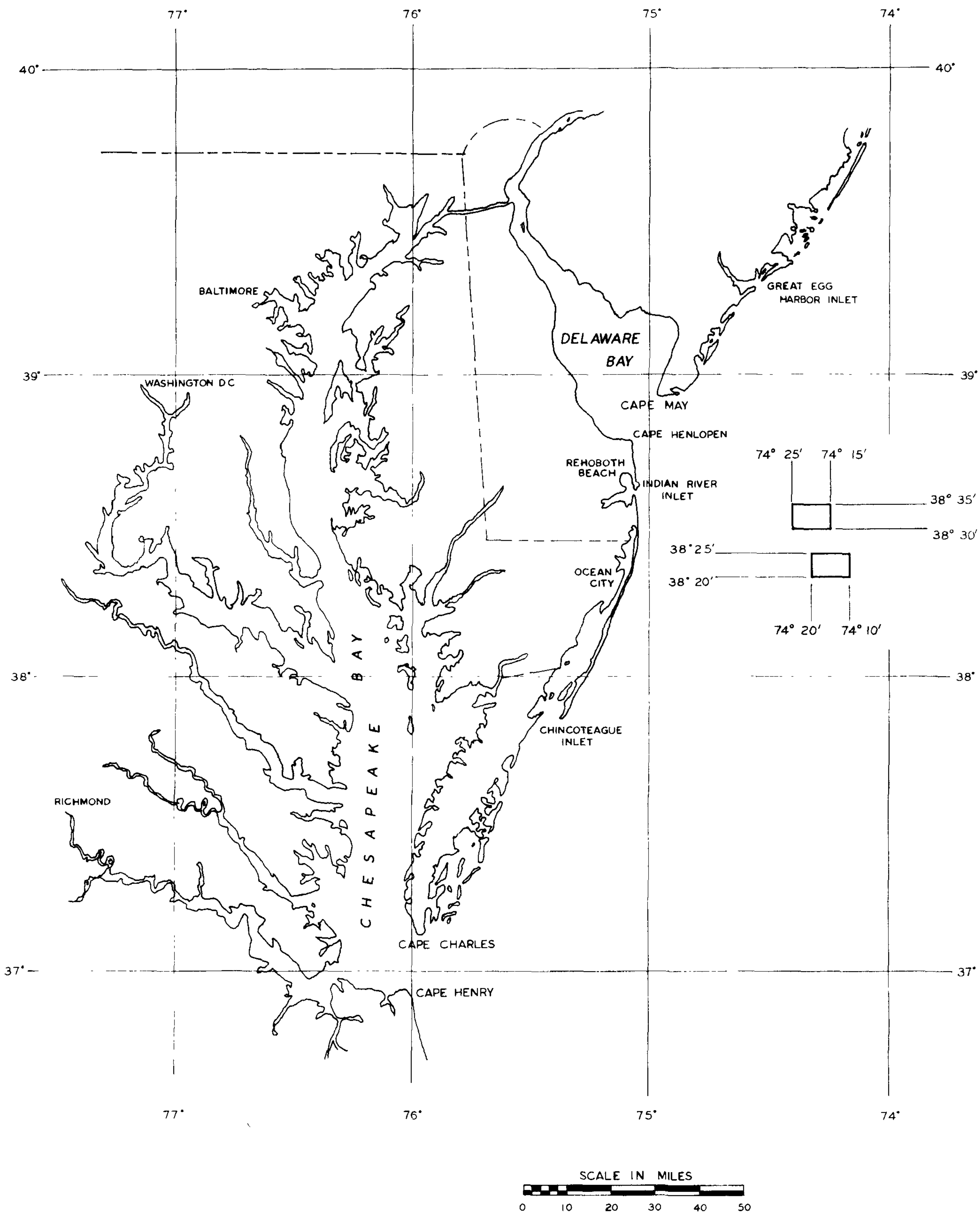
3. Possible deposition of materials from the acid waste dumpsite on the sludge dumpsite.

An oceanographic cruise was designed to resolve some of these uncertainities and to further develop practical field and laboratory methods for continuing programs to evaluate environmental conditions under the impact of man's additions.

Station locations (figures 1 and 2, and Table 1) were selected to replicate the stations from the previous spring cruise (Palmer and Lear, 1972) and to assay conditions on the acid waste dumpsite as well as the sludge waste dumpsite. A major portion of daylight cruise time was allocated to search for cylindrical sediment traps buoyed out on the spring cruise.

Oceanographic operations were conducted on eight hour round-the-clock watches, and one working day was lost due to such wind and wave conditions as to make deck work impractical. Details of routine are given in the ship's log and scientific log, included as appendices.

AREA OF STUDY



STATION LOCATIONS

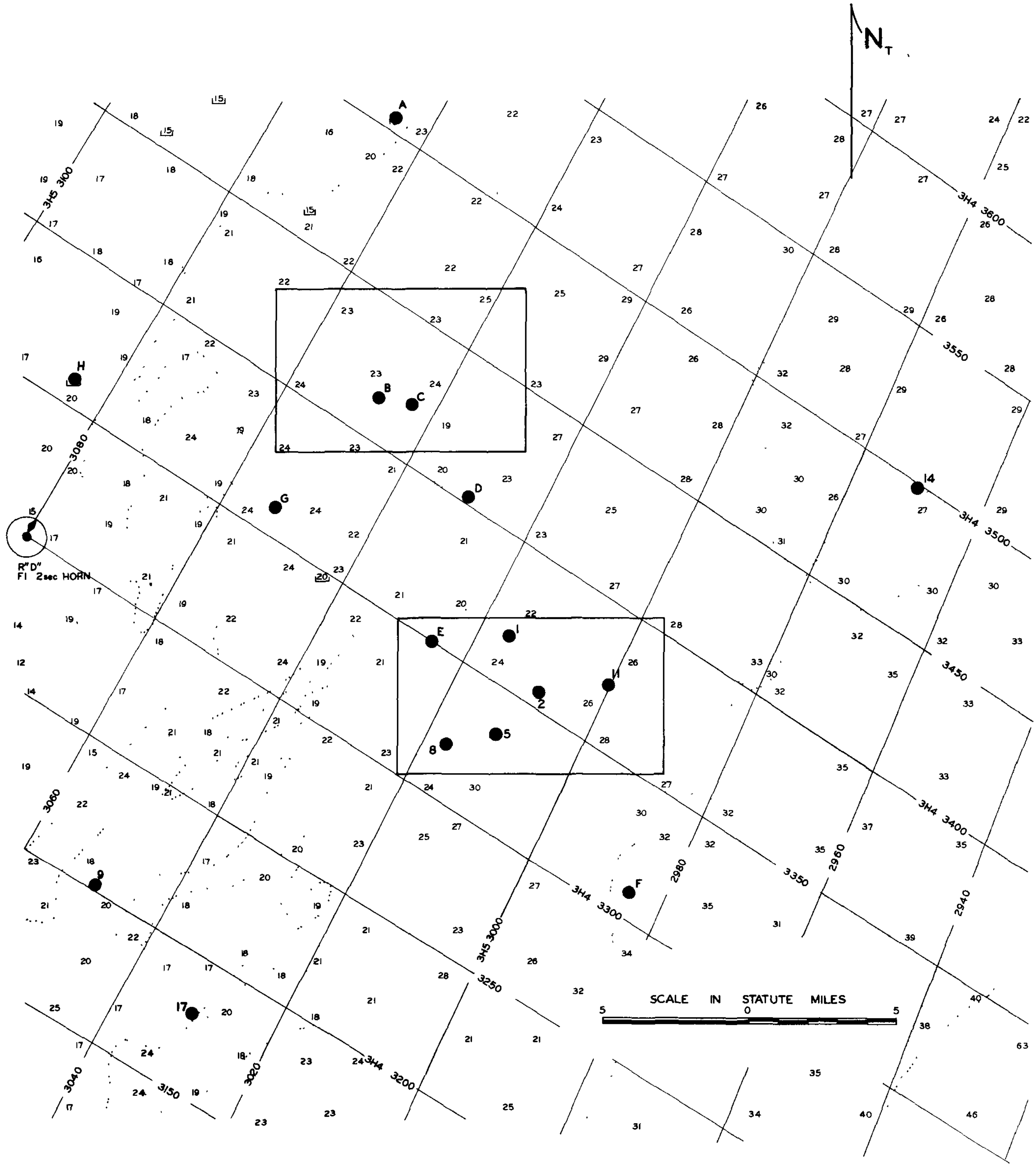


Figure 3

R/V ANNANDALE

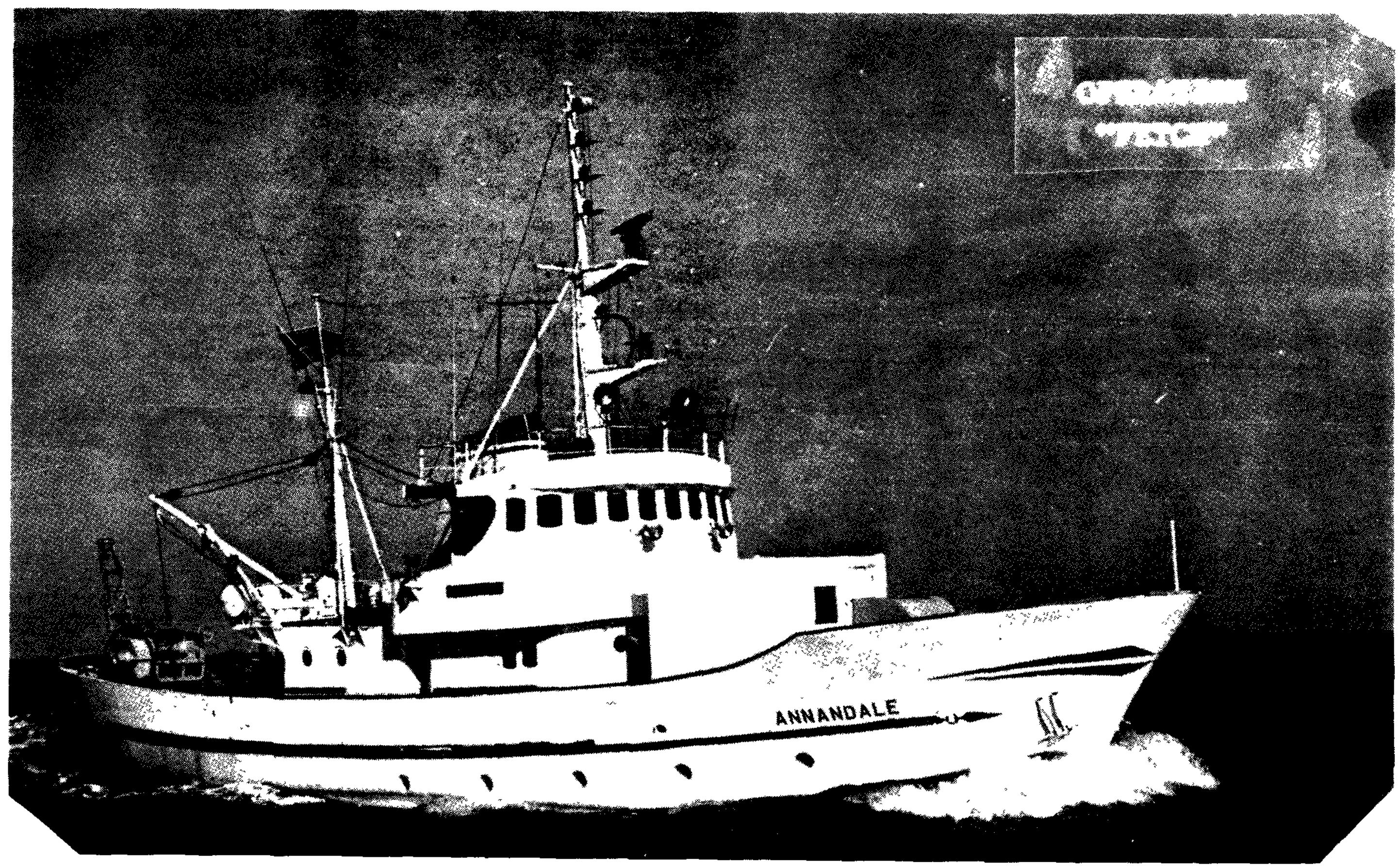


Table 1

Station Locations
Operation "Fetch"

11/5-10/73

STATION	DATE	TIME	LORAN LOCATION	DEPTH (meters)
9	11-7-73	1536	3222 - 3051	36.6
17	11-7-73	2000	3183 - 3034	37.2
1	11-8-73	2330	3371 - 3000	45.7
8	11-8-73	0115	3313 - 3020	39.6
2	11-8-73	0705	3356 - 3019	47.9
14	11-8-73	1605	3513 - 2963	51.8
11	11-8-73	2030	3371 - 3000	48.2
D	11-9-73	1355	3401 - 3030	39.6
F	11-5-73	2230	3310 - 2985	63.7
E	11-5-73	1645	3350 - 3025	45.7
5	11-8-73	0350	3334 - 3013	48.2
C	11-9-73	0239	3420 - 3043	48.8
B	11-9-73	0930	3416 - 3048	45.7
A	11-9-73	0620	3505 - 3065	40.2
G	11-9-73	1635	3360 - 3053	39.6
H	11-9-73	1900	3360 - 3085	36.6

I. WATER QUALITY INVESTIGATIONS

A. HYDROGRAPHY

1. Local Hydrographic Structure

Hydrographic conditions can materially affect the distribution of dumped materials. For the design purposes of this cruise, the presence or absence of a pycnocline, due to thermal and/or salinity discontinuities, was measured. Previous studies (du Pont, 1972) indicated released industrial acid wastes may be delayed in reaching bottom in the presence of a well established density discontinuity, and possibly may be transported from the loci of dumping by advective forces before eventually depositing.

Bathythermographs (BT's) were taken at Stations 9, 14 and 17, and temperature and salinity readings made with a Beckman RS-5 induction salinometer at Station 9.

Bathythermograph data were reduced at sea by aligning the surface temperature in the viewing grid to match the surface bucket temperature. Bathythermographs are shown in Figures 4, 5, and 6.

Temperature and salinity profiles are shown in Table 2 and Figure 7. The temperature data showed a relatively cool isothermal surface layer increasing to 15°C at about 30 meters. At Station 14 a maximum of 17.5° was reached at 38 meters decreasing to less than the surface temperature below 45 meters. The salinity-temperature profile shows that the stability of this inversion layer is maintained by an increase in salinity of approximately 2‰ between 20 and 30 meters.

The difference between surface and bottom layer temperatures was approximately one-degree C , indicating the fall overturn was nearly reached, for these waters can become isothermal in winter (Bumpus, et al, 1972; Meyers, 1973).

The halocline was coincident with the thermocline, augmenting the stability of the upper layer.

During the course of this cruise, winds of up to 52 knots were recorded, with seas greater than 3 meters, indicating that storm conditions do not, in short periods of time, disrupt even relatively small density discontinuities. The deposition of wastes into this environment would not, therefore, be materially accelerated by short term turbulence factors.

The discrepancies in temperature, approximately 1.5 °C, between the BT and the induction salinometer, are probably due to the more recent calibration of the BT. The relative differences by both instruments, however, are valid.

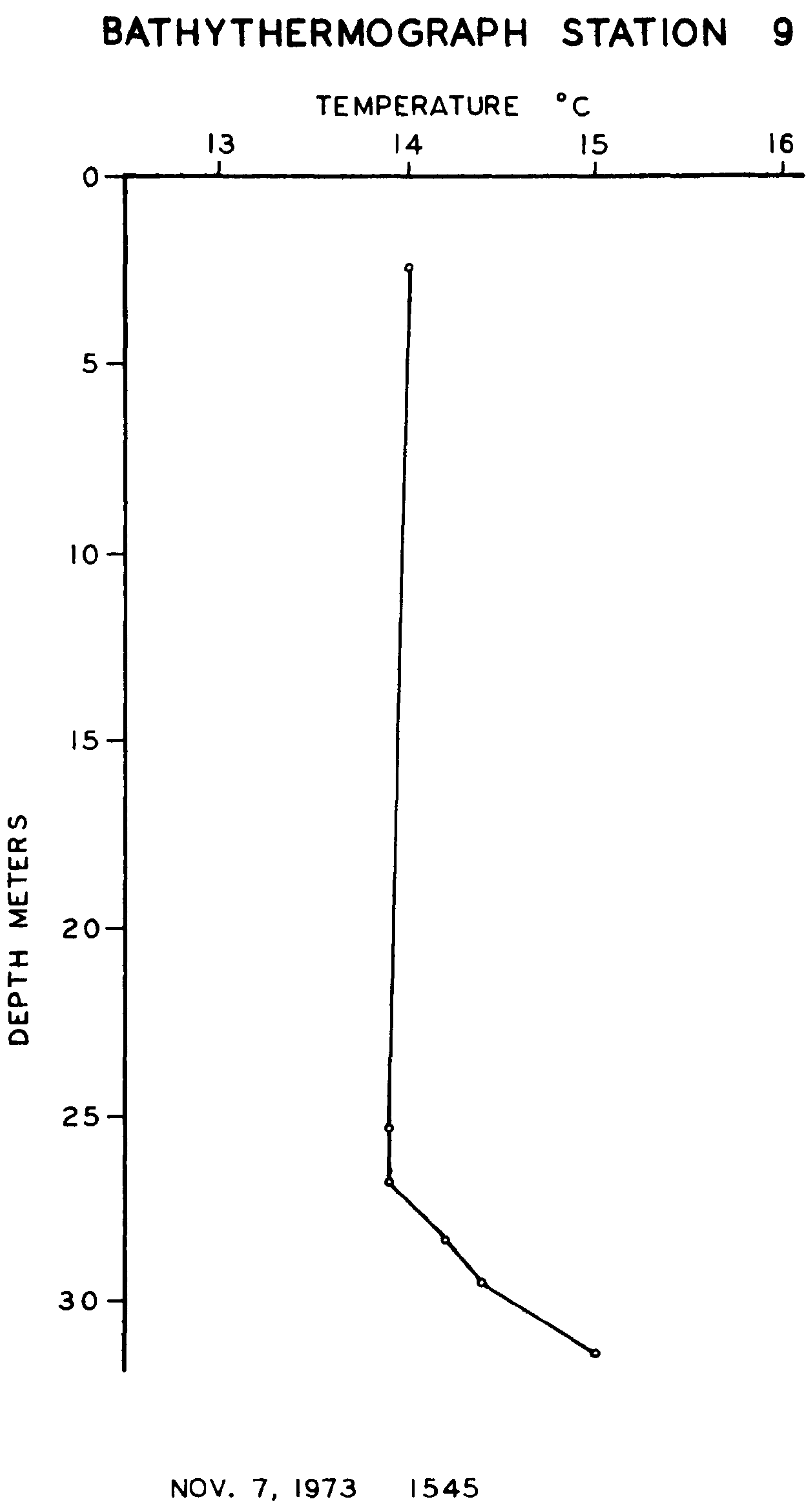

BATHYTHERMOGRAPH STATION 9
TEMPERATURE °C
13
14
15
16
0
5
10
15
20
25
30
DEPTH METERS
NOV. 7, 1973 1545

FIGURE-4

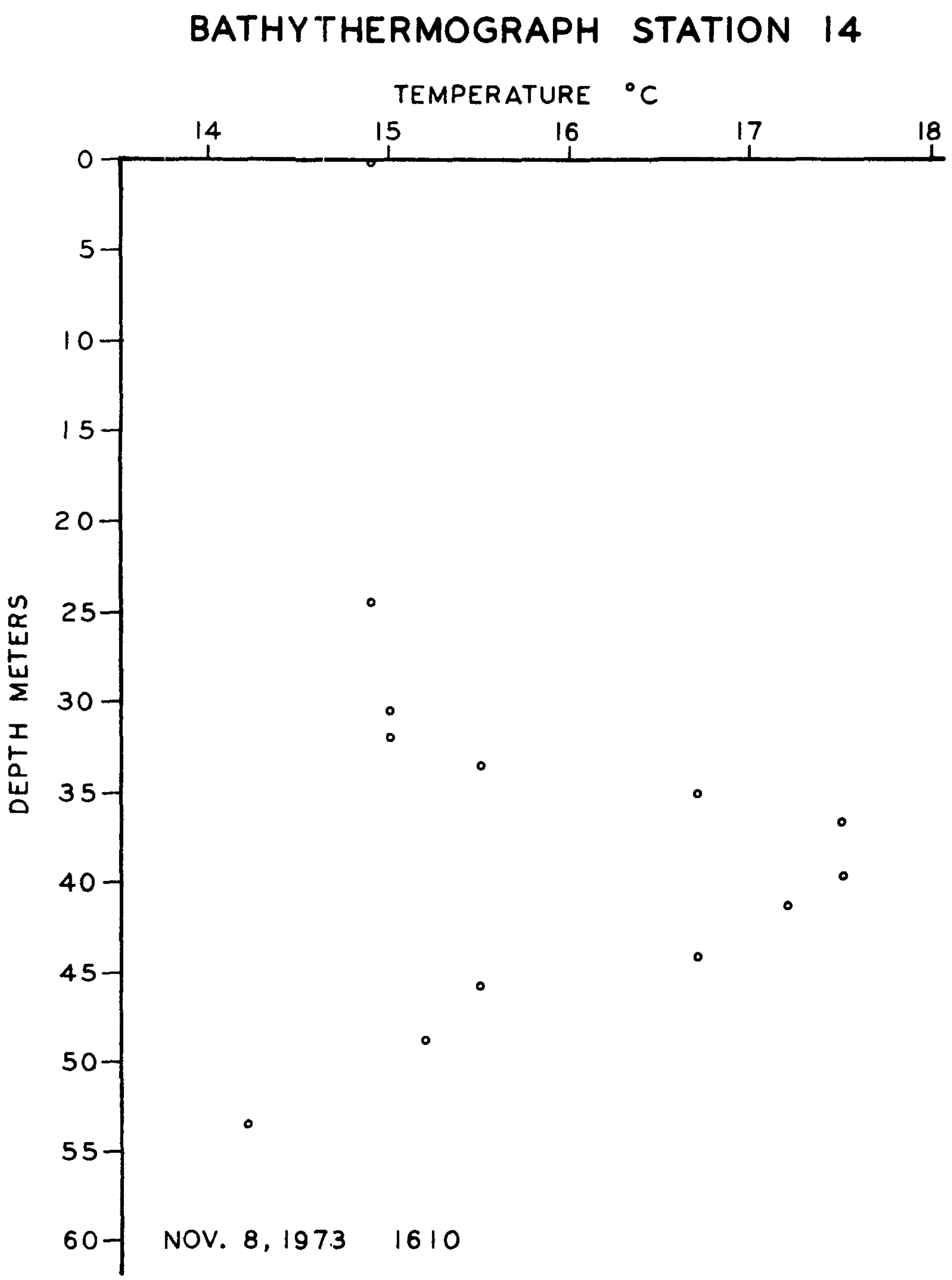

BATHYTHERMOGRAPH STATION 14
TEMPERATURE °C
14
15
16
17
18
DEPTH METERS
0
5
10
15
20
25
30
35
40
45
50
55
60
NOV. 8, 1973 1610

FIGURE - 5

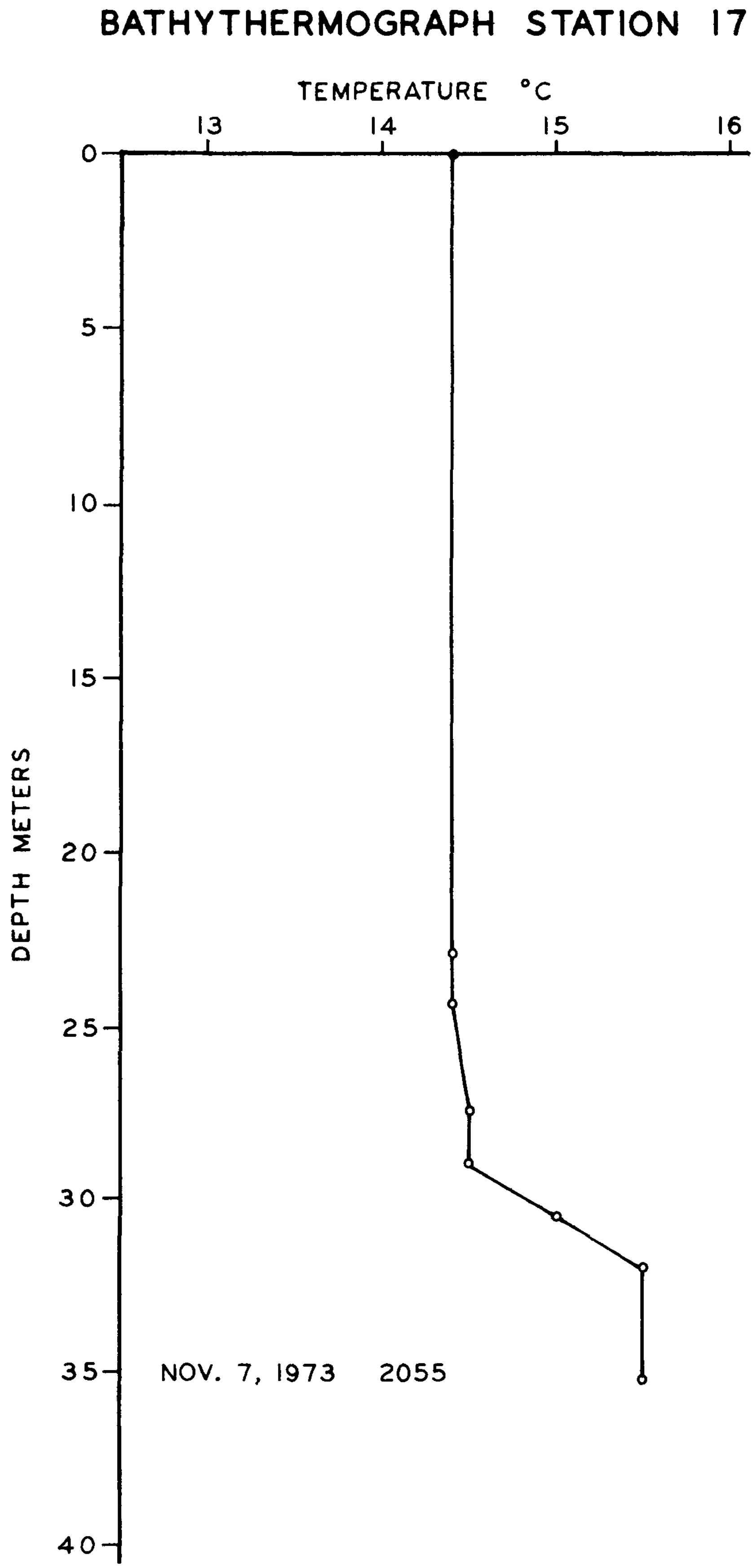

BATHYTHERMOGRAPH STATION 17
TEMPERATURE °C
13
14
15
16
0
5
10
15
20
25
30
35
40
DEPTH METERS
NOV. 7, 1973 2055

FIGURE-6

SALINITY – TEMPERATURE PROFILE AT STATION 9

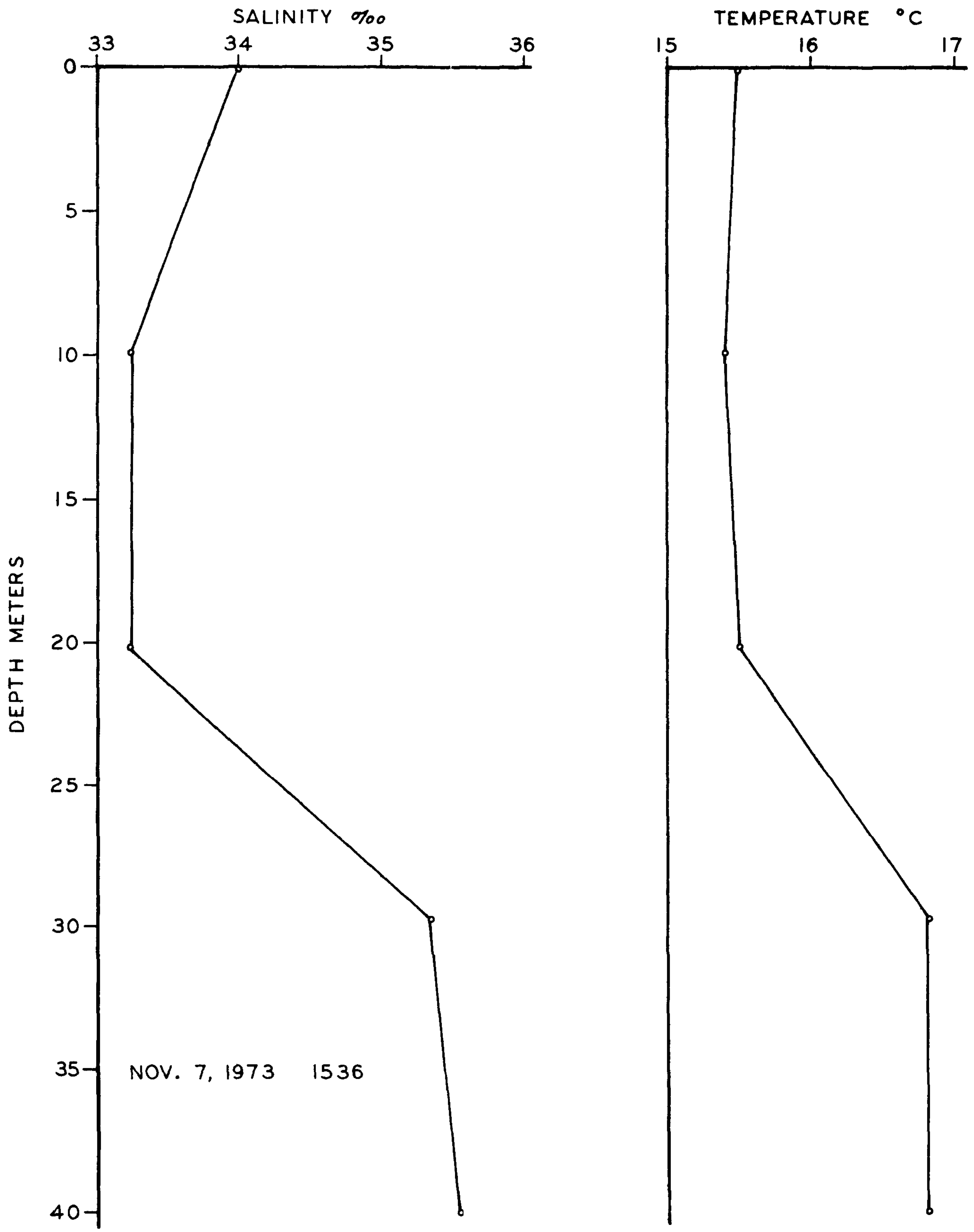


FIGURE – 7

Table 2

Bathythermograph (BT) and Salinometer Readings

Operation "Fetch"

Station 9, BT
Date - 7 Nov. 1973
Time - 1545 EST

Depth (meters)	Temperature* °C	°F
0	14.0	57.3
22.8	13.9	57.2
24.4	13.9	57.2
25.9	14.2	57.5
27.4	14.4	57.9
28.9	15.0	59.0

Station 9, Salinometer
Date - 7 Nov. 1973
Time - 1536 EST

Depth (meters)	Temperature °C	°F	Salinity °/₀₀
0	15.5	60.0	34.00
10.0	15.4	59.8	33.24
20.1	15.5	60.0	33.22
29.9	16.8	62.2	35.33
40.0	16.8	62.3	35.54

Station 17, BT
Date - 7 Nov. 1973
Time - 2055 EST

Depth (meters)	Temperature °C	°F
0	14.4	58.0
22.8	14.4	58.0
24.4	14.5	58.1
27.4	14.5	58.2
28.9	14.5	58.2
30.5	15.0	59.0
32.0	15.5	60.0
35.1	15.5	60.0

Station 14, BT
Date - 8 Nov. 1973
Time - 1610 EST

Depth (meters)	Temperature °C	°F
0	14.9	58.9
24.4	14.9	58.9
30.5	15.0	59.0
32.0	15.0	59.0
33.5	15.5	60.0
35.1	16.7	62.0
36.6	17.5	63.5
39.6	17.5	63.5
41.2	17.2	63.0
44.2	16.7	62.0
45.7	15.5	60.0
48.8	14.7	58.5
53.4	14.2	57.5

* Conversion was from F to C, the centrigrade figures are approximations of the farenheit, which was the temperature scale used during the sampling cruise.

2. Major Circulation Patterns

Seasonal circulatory patterns were estimated by release of surface drifter cards and by bottom drifers (Woodhead and Lee, 1960). Previous releases have also been made from this area (du Pont, 1972); Palmer and Lear, 1973; Ketchum, 1953). These techniques demonstrate semi-quantitatively the larger scale transport of surface and bottom materials of neutral density.

a. Surface drifter releases.

During a previous cruise (Palmer and Lear, 1973) 269 surface drifters were released. During this cruise one hundred and forty surface drift cards were released as shown in Table 3a. To date no returns have been made from either cruise.

b. Seabed drifter releases.

A total of 199 yellow seabed drifters (Woodhead and Lee, 1960) were released in the survey area, as shown in Table 3b. The distance from the release point nearest to shore was 26 nautical miles. Assuming an average onshore drift rate of 0.015 knots, the first recoveries should not be made before January 1974.

c. Seabed drifter returns from the spring cruise.

Two hundred yellow bottom drifters were released by EPA and 480 red drifters by Westinghouse Ocean Research Laboratory during the spring cruise, Operation "Quicksilver". Four EPA (yellow) drifters have been recovered from the spring cruise. Statistics of recovery data are shown in Table 4. The drifters traveled for approximately 202 days towards the southwest at an average rate of 0.014 knots.

Of the 480 red drifters released by Westinghouse Ocean Research Laboratory, only 12 drifters were returned in this period of time. Most of the recoveries were made on the Delaware, Maryland and Virginia beaches. The low recovery may reflect a seaward transport of the majority of drifters, and firmer conclusions will be made with more return data.

d. Buoy search operations.

Sediment traps were buoyed and anchored at eight stations during the spring cruise, Operation "Quicksilver". One of the objectives of the fall cruise, Operation "Fetch", was retrieval of this apparatus.

Watches were maintained during daylight hours while on stations, and on two days an "expanding square" search plan with all available hands on watch was instituted. No buoys were sighted, possibly due to the wave heights encountered during most of this cruise, and possibly due to trawler activity known in this area.

Table 3(a)

Surface Drifter Releases, Operation "Fetch"

1973

EST	- Date	Station	Numbers	Total	Latitude, N.	Longitude, W.
1545	7 Nov.	9	3631-3640 3671-3680	20	38°18.7'	74°31.6'
2017	7 Nov.	2	3621-3630 3661-3670	20	38°12.6'	74°29.1'
1605	8 Nov.	14	3601-3620 3641-3660 3681-3690	50	38°29.5'	73°58.0'
2030	8 Nov.	11	3691-3700 3751-3760	20	38°45.5'	73°58.0'
1355	9 Nov.	D	3701-3710 3741-3750 3761-3770	30	38°28.4'	74°17.4'

Table 3(b)

Seabed Drifter Releases, Operation "Fetch"

1973

EST	- Date	Station	Numbers	Total	Latitude, N.	Longitude, W.
1545	7 Nov.	9	1400-1424	25	38°18.7'	74°31.6'
2017	7 Nov.	17	1375-1399	25	38°12.6'	74°29.1'
0115	8 Nov.	8	1525-1549	25	38°20.4'	74°19.2'
0705	8 Nov.	2	1374 1450-1473 1500-1524	50	38°21.8'	74°13.1'
1605	8 Nov.	14	1425-1449 1550-1573	49	38°29.5'	73°58.0'
2030	8 Nov.	11	1474-1499	25	38°45.5'	73°58.0'

Table 4

EPA Seabed Drifter Returns as of 12/13/73

"Quicksilver" Releases

	Release			Recovery							
Number	Date	N. Lat.	W. Long.	Date	N. Lat.	W. Long.	Locality	Days	Dir. °T	Dist. N.M.	Speed Knots
318	5-2-73	38°23.8'	74°15.3'	11-17-73	37°51.5'	75°20.2'	Assateague I.	199	240	61	.013
355	5-2-73	38°23.8'	74°15.3'	11-26-73	37°29.5'	75°38.5'	Panamore I.	208	230	85	.012
378	5-3-73	38°20.7'	74°19.0'	11-22-73	37°53.0'	75°21.0'	Assateague I.	203	240	56	.012
379	5-3-73	38°20.7'	74°19.0'	11-17-73	37°39.0'	75°35.5'	Cedar I.	198	235	79	.017

B. WATER QUALITY PARAMETERS

Bottom water samples for analysis for nutrients were collected with a 10-liter PVC Van Dorn bottle, placed in polyethylene containers, frozen in dry ice and maintained in the frozen state until analysis at the Annapolis Field Office, EPA.

Nitrate plus nitrite nitrogen was determined by using the Technicon "Autoanalyzer". This procedure utilizes cadmium reduction of nitrate to nitrite and subsequent diazotization with sulfanilamide and N-(1-naphthyl)-ethylenediamine dihydrochloride with the optical density measured at 540 mμ. The results were reported as nitrogen (Strickland and Parsons, 1968).

Distribution patterns indicate elevated concentrations of nitrate plus nitrite in bottom waters at Stations 1, 2, 5, 11, and F, indicating deposition of materials from the municipal sludge activities southeastward of the release zones. This sustains the observations that metals were similarly transported and deposited. Concentrations were greater at these stations, compared with other stations observed on the fall cruise, and the concentrations at the specified stations were greater than observed on the spring "Quicksilver" cruise at the same sites.

Total Kjeldahl nitrogen includes ammonia and organic nitrogen and was determined by the standard micro-Kjeldahl procedure. The sample was digested in the presence of strong acid to convert the organic nitrogen to ammonia. The ammonia was then distilled, collected in boric acid solution, nesslerized, and determined colorimetrically. The values found generally agree with those reported in other coastal waters

(Duursma, 1965), and with the previous cruise (Palmer and Lear, 1973), but may be greater at Station 1, 8, B, and E.

Total phosphorus was determined after persulfate oxidation of the sample in an autoclave at 15 psi for 30 minutes. The resultant orthophosphate was then determined colorimetrically as the molydenum-blue complex with optical density measured at 882 mμ. Orthophosphate was determined on a Technicon "Autoanalyzer" (Menzel and Corwin, 1965; Murphy and Riley, 1962).

The concentrations found are in agreement with other observations reported by Kester and Courant and in the spring cruise (Palmer and Lear, 1973), with the expected seasonal variation.

Table 5

Water Quality Parameters

Station	Date	Time	Sample Depth (meters)	Total P PO_4 mg/l	Inorganic PO_4 mg/l	TKN mg/l	NO_2+NO_3 mg/l NO_3-N
F	11-5-73	2230	63.7	.085	.077	.011	.205
E		1645	22.1	.028	.023	.265	.060
E			44.2	.035	.016	.197	.025
9	11-7-73	1536	36.6	.050	.040	.079	.110
1	11-8-73	2230	47.2	.083	.076	.248	.230
8		0115	38.1	.025	.008	.299	.025
5		0350	44.2	.087	.075	.192	.240
2		0705	44.2	.081	.081	<.01	.230
14		1605	50.3	.072	.057	.118	.190
11		2030	46.6	.086	<.001	.152	.230
D	11-9-73	1355	39.6	.045	.035	.163	.075
C		0239	48.8	.056	.047	.011	.120
C			48.8	.067	.049	.085	.120
B		0930	44.2	.022	.007	.462	.035
A		0620	38.1	.059	.039	.011	.095

C. BIOLOGY

1. Phytoplankton

There are two major phytoplankton regimes found in this typical mid-temperate shelf area. The spring-summer regime is primarily a dinoflagellate community, developing during the presence of a well defined thermocline and exhibiting lower diversity and larger standing crop of phytoplankton. This regime was typified by the May, 1973, "Quicksilver" cruise.

The phytoplankton samples taken on the "Fetch" cruise, November, 1973, was indicative of the fall-winter regime. These samples were composed primarily of diatoms. There was a larger diversity of species and appeared to be a reduced phytoplankton volume at many stations. Several dinoflagellate species were found in each sample, but at greatly reduced standing crops. At all stations the thermocline was relatively poorly defined.

The phytoplankton was dominated by several diatoms and one genus of filamentous blue-green alga. Diatoms, Rhizosolenia alata, Chaetoceros spp., Skeletonema spp., Nitzschia spp., and Stephanopyxis sp. were found at all stations in abundance. The filamentous marine blue-green alga, Trichodesmium sp. was found at all stations and was the dominant phyto-plankter at Stations E and 11.

In summary, the phytoplankton in this area, at this time of year, seemed to be as expected from previously published work by Mulford (1971) and University of Delaware, College of Marine Studies (1972). It was a healthy,diverse,diatom dominated community.

Table 6

Phytoplankton Observations, Operation "Fetch"

	Stations							
	1	E*	2	11	9*	17	F	14
Diatoms:								
Asterionella kariana	x	-	x	x	x	x	x	-
Bacteriastrum delicatulum	x	-	x	-	x	x	6	-
Biddulphia alternans	x	-	-	-	-	-	-	-
Chaetoceros spp.	4	x	2	x	6	4	2	2
Clemacodium sp.	-	-	-	x	-	-	-	x
Coscinodiscus sp.	x	x	x	-	x	-	-	x
Ditylum brightwellii	x	-	x	-	-	-	x	-
Navicula spp.	x	-	x	x	x	x	-	-
Nitzschia closterium	5	4	5	2	1	x	x	x
Nitzschia longissima	x	x	x	x	x	x	x	-
Nitzschia seriata	x	x	3	-	-	7	4	8
Nitzschia spp.	x	x	-	6	3	x	x	x
Pleurosigma sp.	-	-	-	-	-	-	x	-
Rhizosolenia alata	1	5	1	7	2	1	3	1
Rhizosolenia sp.	-	-	x	-	-	-	x	-
Skeletonema spp.	5	x	7	3	5	3	1	3
Stephanopyxis spp.	7	-	x	x	x	5	8	7
Thalassionema nitzschioides	6	-	6	x	x	x	x	x
Thalassiosira spp.	8	-	4	-	-	8	5	x

x occurrence

1-8 indicates most abundant species

* light sample

Table 6 (continued)

	Stations							
	1	E*	2	11	9*	17	F	14
Dinoflagellates:								
Ceratium belone	-	-	-	-	-	-	x	-
Ceratium fusus	-	x	-	-	-	-	-	-
Ceratium lineatum	-	x	x	-	-	-	x	x
Ceratium longipes	2	x	x	8	-	6	x	5
Ceratium macroceros	-	2	x	5	4	-	x	6
Peridinium spp.	x	3	x	4	-	-	x	x
Filamentous Blue-Green:								
Trichodesmium sp.	3	1	8	1	x	2	7	4

x occurrence

1-8 indicates most abundant species

* light sample

2. Metals in Zooplankton

Zooplankton tows were made for 15 minutes with 0.5 x 0.5 meter nets with 202μ mesh aperature. Collections from the net were placed in "whirl-Pak" polyethylene bags, quick frozen on dry ice and maintained frozen until laboratory analysis. Analytical procedures were the same as for sediments. Results are shown in Table 7.

A comparison can be made between the spring and fall cruises to this area. The variability of results seemed to be the most striking feature; however there is a suggestion that mercury, nickel and manganese concentrations may be greater in the fall cruise. No consistent ratios of either elements or of geographical differences could be found.

Vaccaro et al, (1972) found higher concentrations of metals in zooplankton at the acid waste dumpgrounds on the New York Bight, but such differences were not evident with the amount of data available from this cruise.

Table 7

Metals in Zooplankton

Operation "Fetch"
November 1973

mg/kg wet weight

Station	Cd	Cr	Cu	Pb	Zn	Mn	Ni	Fe	Hg
1	1.0	4.1	6.5	14.6	60.4	14.6	9.4	105.6	0.40
2	0.7	1.4	4.2	4.3	27.0	7.7	4.4	66.3	0.30
14	1.2	5.9	17.8	41.6	111.8	13.9	4.5	256.2	0.16
17	2.1	5.2	12.0	11.6	84.9	11.0	10.8	178.6	0.18
Operation "Quicksilver" May 1973									
2	0.4	3.4	<1.0	<1.0	39.2	<1.0	<1.0	<1.0	<0.10
14	2.8	5.8	<1.0	<1.0	61.0	<1.0	<1.0	26.4	<0.10
9	0.3	35.0	8.1	182.4	117.4	5.5	<1.0	807.9	0.10

II. BENTHIC INVESTIGATIONS

A. BATHYMETRY

Bathymetric configurations of the municipal sewage sludge dumpsite were described by a previous cruise (Palmer and Lear, 1973), with an account of previous surveys in the area. The typical bottom terrain is dominated by relatively small basin-like depressions. In the time allocated for the present cruise, bathymetric survey time was impracticable. In addition, the sea state was generally rough, making resolution difficult, consequently no systematic observations were made.

B. SEDIMENTS

1. Size Distribution of Sediments

Sediments in the areas of investigation were primarily sands, with very little finer materials. The properties have been described previously from the spring cruise, Operation "Quicksilver" (Palmer and Lear, 1973).

Sediment size analyses, done by Dr. H. D. Palmer, Westinghouse Ocean Research Laboratory, are shown in Table 8. Very similar properties were shown on both cruises, indicating the sandy composition of the substrate, and the variation in sorting reflecting the minor ridges and basins characteristic of the bottom configuration. No major changes in substrate quality were noted, by visual observation or collection, nor by size categories, between spring and fall.

Table 8

Sediment Size Data

Station	$M\phi$	$\sigma\phi$	$<-1\phi$(gr.)	$0-(-1)\phi$(gr.)	$<0\phi$(gr.)	Deviation	% Coarser than (0ϕ) 1 mm
E	1.32	0.57	6.318	10.339	38.979	moderately well sorted	29.93
9	1.34	0.57	4.258	7.480	33.362	moderately well sorted	18.31
17	1.42	0.52	0.500	1.379	34.083	moderately well sorted	3.88
2	1.63	0.91	1.270	3.573	83.039	moderately sorted	5.51
5	2.49	0.55	4.365	0.535	49.067	moderately well sorted	9.07
8	1.27	0.57	2.406	3.683	37.429	moderately well sorted	13.99
11	0.94	0.87	3.683	10.896	32.047	moderately sorted	31.26
14	2.21	0.21	0.232	0.033	27.751	very well sorted	0.94
1	2.37	0.54	0.000	0.044	24.141	moderately well sorted	0.18
A	1.45	0.45	0.272	0.874	34.538	well sorted	3.21
B	2.26	0.51	0.174	0.314	29.421	moderately well sorted	1.63

1. $M\phi$, or mean diameter, of a sediment sample is one-half the sum of the 16th percentile and 84th percentile. It approximates the central tendency, or "average" size of a sample (after Inman, 1952). Phi (ϕ) units are used to indicate size according to the relationship (ϕ) = $-\log_2$(diameter in millimeters). This convention avoids awkward fractional notation and permits simplified plotting of size data on arithmetic scales (see Figure 11).

Table 8 (continued)

2. $\sigma\phi$, or "sorting", measures the degree of scatter, or "spread", of a cumulative frequency curve with regard to its central tendency (mean). It reflects the standard deviation based upon half the difference between the 84th and 16th percentiles (Inman, 1952). Sorting provides a measure of the range of conditions present at a site such as the range in velocity, degree of turbulence, etc. The greater the $\sigma\phi$ value, the broader the range of conditions which affect the overall sediment character at a site. Low values indicate fairly uniform conditions.

3. Verbal modifiers of sorting have been established (Friedman, 1962) to facilitate discussion of sediment statistics. The following ranges apply to the sand fractions from this study, all of which display a relatively high degree of sorting for the marine environment:

$\sigma\phi 0.00 - 0.35$ = very well sorted

$\sigma\phi 0.35 - 0.48$ = well sorted

$\sigma\sigma 0.48 - 0.75$ = moderately well sorted

2. Metals in Sediments

The non-biodegradable metal contents of wastes offer a convenient, and possibly sensitive, tag for the fate of ocean disposed materials.

Typical analyses of materials transported to the ocean dumpsites are shown in Table 9.

Sediment samples were taken using a Shipek sampler. The sediment samples were well-mixed in their containers and a portion removed and spread to air-dry at room temperature for 48 hours. The samples were again mixed and pulverized to separate the sand grains and expose surface areas. At this time any large rocks and pebbles were removed. The samples were allowed to further air-dry for another 48 hours.

A known weight (5.0000 gm) of dry sediment was put in a 125 ml glass-stoppered flask. Small amounts of de-ionized distilled water were used to aid in the transfer. The addition of 25 ml conc. HNO_3 provided a digestion solution of 50-75 ml. This solution was heated at 48-50°C (Carpenter, 1970) for 4-6 hours in a shaking hot water bath. After digestion the samples were cooled and filtered through a .45 micron millipore filter and the volume adjusted to 100 ml. Blank solutions were run throughout the same disgestion procedure (APHA, 1971, Fuller, 1969).

The filtered acid extracts were analyzed for Pb, Zn, Mn, Ni, Cu, and Fe using a Varian Techtron AA-6 atomic absorption spectrophotometer equipped with a standard pre-mix burner. Air-acetylene was used for all flame techniques. Cd and Cr were analysed using a Perkin and Elmer 303 atomic absorption spectrophotometer equipped with a graphite

Table 9

Analyses of Barged Waste Materials

	du Pont Industrial Acid Wastes mg/l	City of Philadelphia Sludge mg/l
pH	<0.01	
Acidity	206,017	
Cl	10,034	
NO_3	1.41	0.16
Total P	2.15	3,600
Total solids	255,679	139,000
Total volatile solids	113,931	510,000
Total suspended solids	1,663	
Total dissolved solids	254,016	
Total settleable solids	0.5 ml/l	
F	<1.0	
CN	7.8	
Sulfide	5.6	
Sulfate	65,549	
Oil & Grease	45.5	193,400
Spec. Cond.	225,000 μmhos/cm	
Turbidity	32	
As	0.15	26
BOD - 5 day	115	
COD	7,585	209,600
TOC	615	
NH_3	11.0	
Kjeldahl N	14.6	5,600
Organic N	3.6	
Phenols	0.12	
Ag	0.30	
Al	860	
B	90	
Ba	<0.5	

Table 9 (Continued)

Analyses of Barged Waste Materials

	du Pont Industrial Acid Wastes mg/l	City of Philadelphia Sludge mg/l
Be	< 0.2	24
Ca	39	
Cd	0.5	30
Co	8.7	
Cr	51	1,730
Cu	12	1,630
Fe	42,083	22,400
Hg	< 0.002	87
K	32	
Mg	198	
Mn	1,060	1,730
Mo	3	
Na	170	
Ni	9.13	106
Pb	12	2,330
Sb	17	
Se	< 0.013	170
Sn	47	
Ti	2,222	
V	137	37
Zn	26	5,810
Total hardness	912	
Endrin		13.7 μgm/l
Heptachlor		3.6 "
Heptachlor epoxide		32.50 "
DDT, mixed isomers		44.80 "
Lindane		1.14 "

atomizer attachment which provided greater stability and sensitivity for these elements. Standard operating parameters are shown in Tables 10 and 11.

Mercury was analyzed using an automated flameless atomic absorption technique (Goulden and Afghan, 1970; Finger, 1970; Southeast Water Laboratory, 1972). All sediment results were expressed as mg/kg dry weight.

Table 10

Atomic Absorption Spectrophotometer

Flame Operating Parameters

Metal	Wavelength	Lamp Current	Spectral Band Pass
Cu	324.7	5	.2
Pb	217.0	4	1.0
Zn	213.9	5	.2
Mn	279.5	10	.2
Ni	232.0	12.5	.2
Fe	248.3	15	.2

Table 11

Furnace Operating Parameters

Metal	Wavelength	Lamp Current	Spectral Band Pass
Cd	228.8	8	7A
Cr	357.9	25	2A

The high loadings of iron in the acid and municipal sludge wastes offer a potential tool in determining loci of deposition in bottom sediments. While localized concentrations of iron flocs may occur in the small depressions on the sites (Palmer and Lear, 1973; Meyers, 1973) possible larger scale distribution was the objective of the study design of Operation "Fetch". Table 12 shows the qualitative texture of the sediments and concentrations of selected metals in the sediments. The trend for all of the detectable metals to be concurrently high or low is suggested in this table. Figure 8 shows distribution of iron in the sediments. These distributions would suggest iron deposition is occurring at all locations in the boundaries and north of the acid waste site, with greatest concentrations southeast of the release areas. Similarly, on the municipal sludge site, irons are found in the greatest concentrations southeast of the indicated release zones, which are in the northeast quadrant of the site.

Station C, as indicated by the data in Table 12, was highest in Fe, Mn, Cr, Hg, Zn, Cu, and second highest in Pb. Similarly, Station 5 was high in Fe, Mn, Cr, Pb, Zn, and Ni. These elevated concentrations at these sites would augment the suspicion that materials are settling a few kilometers to the southeast of the indicated release zones. More data, and replicate sampling and analyses are needed to confirm this supposition.

Comparison of metals concentrations found from this cruise with those of the spring cruise (Palmer and Lear, 1973) indicate cadmium, manganese, nickel, zinc, copper, and chromium levels are approximately the same, while levels of mercury and lead may be slightly elevated.

DISTRIBUTION OF Fe (Mg/Kg) IN SEDIMENTS

OPERATION FETCH

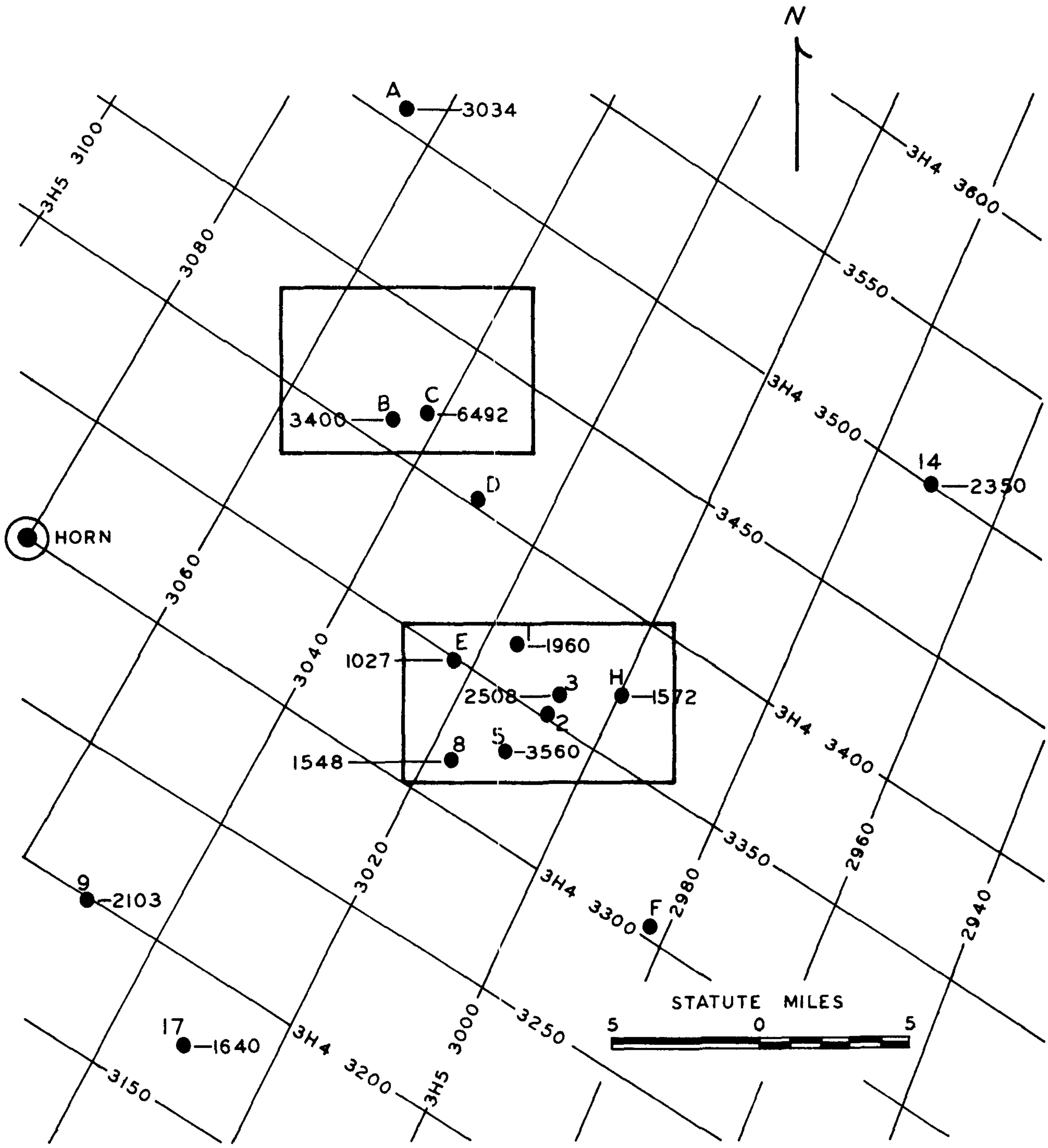


FIGURE – 8

The relationships of metals in sediments are shown in Figures 9, 10, 11, and 12. Zinc, manganese, chromium,and lead concentrations are shown plotted against iron concentrations. These relationships were tested with regression analysis, and relationships statistically significant at P 0.01 were found for iron and manganese, iron and zinc, iron and chromium, while the iron and lead relationship fell just short of significance.

Since these relationships were derived from both "control" areas and presumably affected areas, it can be postulated that occurrence of these metals represents (1) natural fluctuations of these elements, with little or no burden by dumping detectable; (2) proportional additions of these metals; (3) possible coprecipitation of these materials with iron as the scavenger; (4) or possibly combinations of these forces. Concentrations of metals as a function of sediment particle size were not examined, due to the paucity of the size analysis data.

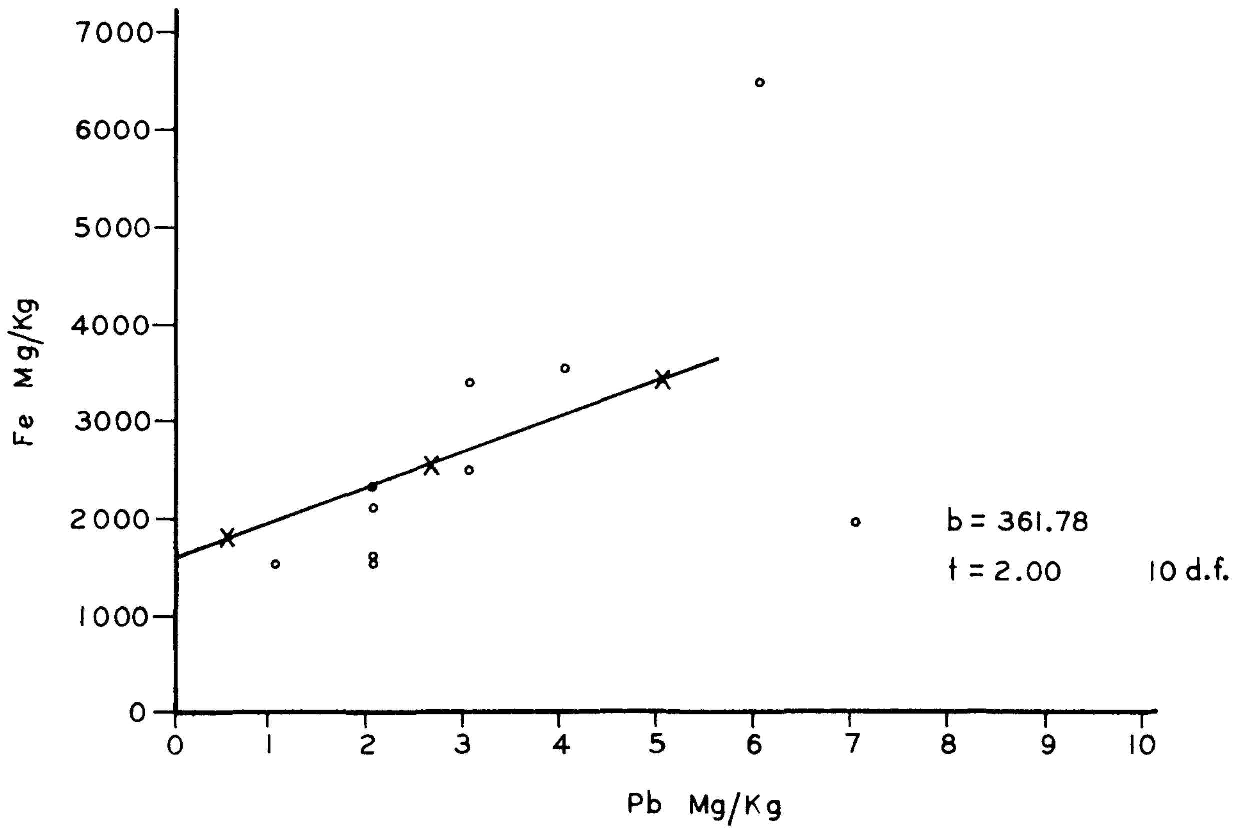
The higher concentrations near active dumping areas indicate dumping activities are detectable, and the other postulated factors are also active. If such relationships can be verified by further examination of continental shelf environments, deviations from such regressions may be a useful tool in evaluating accumulations of specific metals.

Table 12

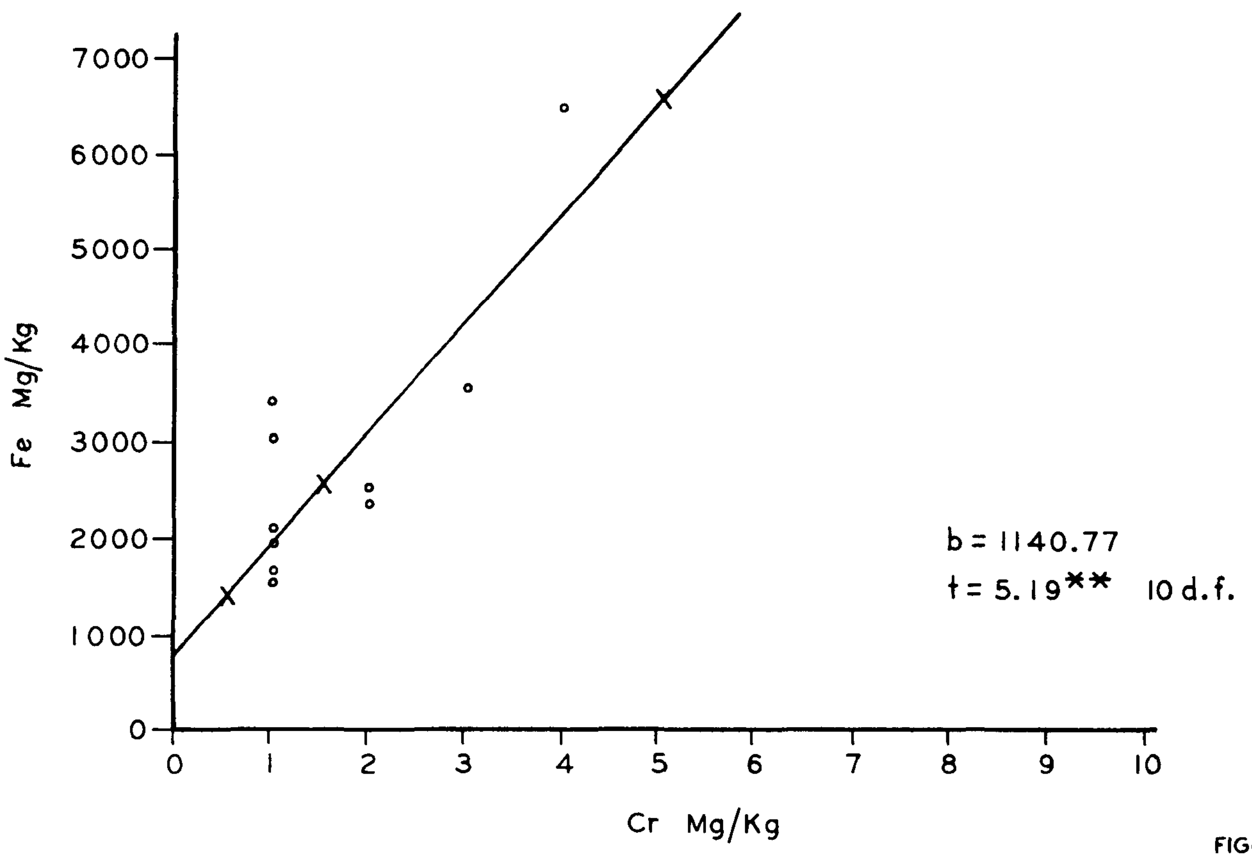
Qualitative Texture and Metals Contents of Sediments

Station	Water Depth Feet	Water Depth Meters	Description	mg/kg Cd	Cr	Cu	Pb	Zn	Mn	Ni	Fe	Hg
E	150	45.7	Large grain sand & pebbles (1/16"-1/4")	<1	1	<1	<1	3	6	<1	1027	<.01
9	120	36.6	Large grain size, some pebbles	<1	2	<1	3	4	30	<1	2103	<.01
17	122	37.2	Medium grain size, small pebbles (1/16"-1/8")	<1	2	<1	3	4	22	1	1640	<.01
2	157	47.9	Very fine sand, no pebbles	<1	3	<1	4	5	37	1	2508	.03
5	158	48.2	Dark, fine sand, no pebbles, some shells	<1	4	<1	5	10	42	2	3560	<.01
8	130	39.6	Large grain sand, small pebbles & shells	<1	2	<1	2	2	34	<1	1548	<.01
11	158	48.2	Very large grain sand & pebbles (1/16"-1/2")	<1	2	<1	3	3	34	<1	1572	.03
14	170	51.8	Fine grain sand, no pebbles	<1	3	<1	3	6	27	1	2350	<.01
1	150	45.7	Fine grain sand, no pebbles	<1	2	<1	8	6	27	1	1960	<.01
A	132	40.2	Fine grain sand, some pebbles, mostly shells	<1	2	<1	1	4	35	<1	3034	.04
B	150	45.7	Fine grain sand, no pebbles	<1	2	<1	4	6	34	1	3400	<.01
C	160	48.8	Fine grain sand, no pebbles	<1	5	1	7	11	72	2	6492	.04

REGRESSION OF Pb & Fe IN SEDIMENTS

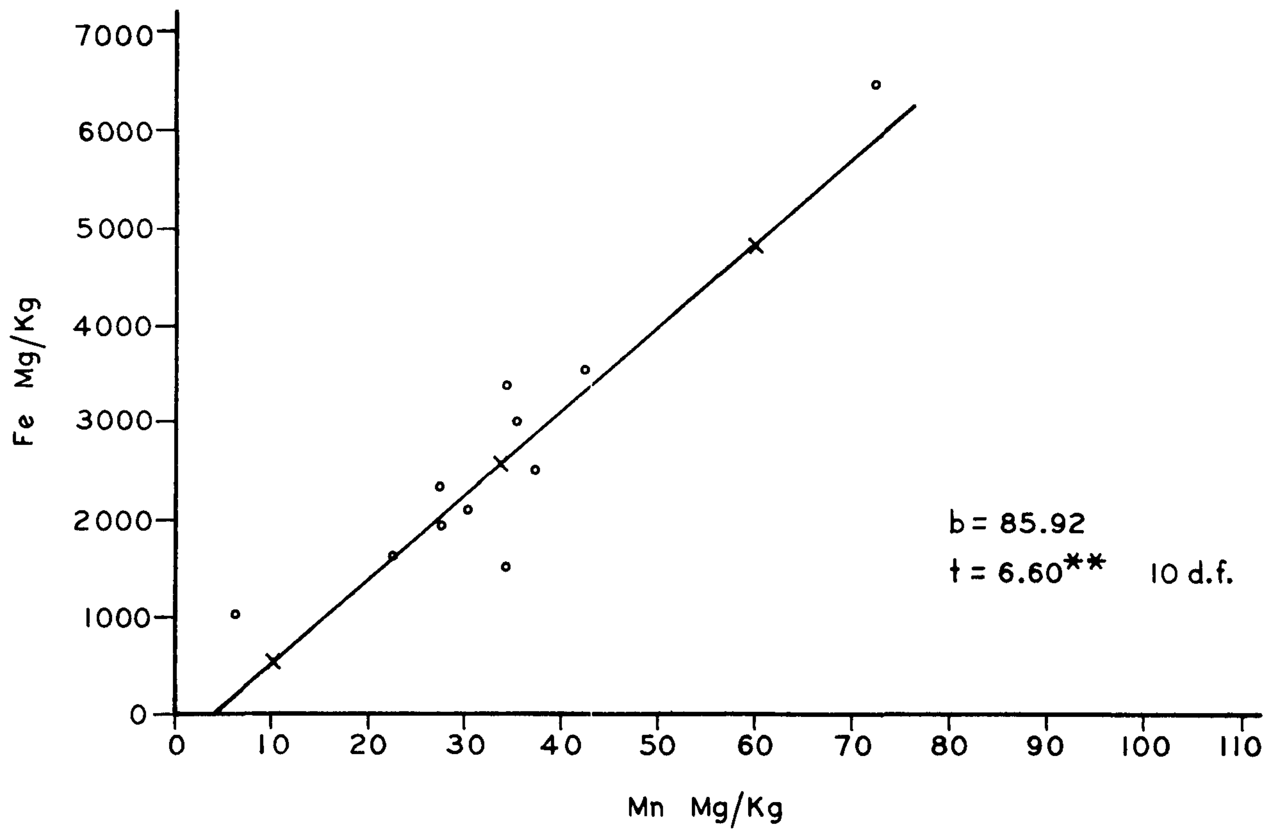


REGRESSION OF Cr & Fe IN SEDIMENTS

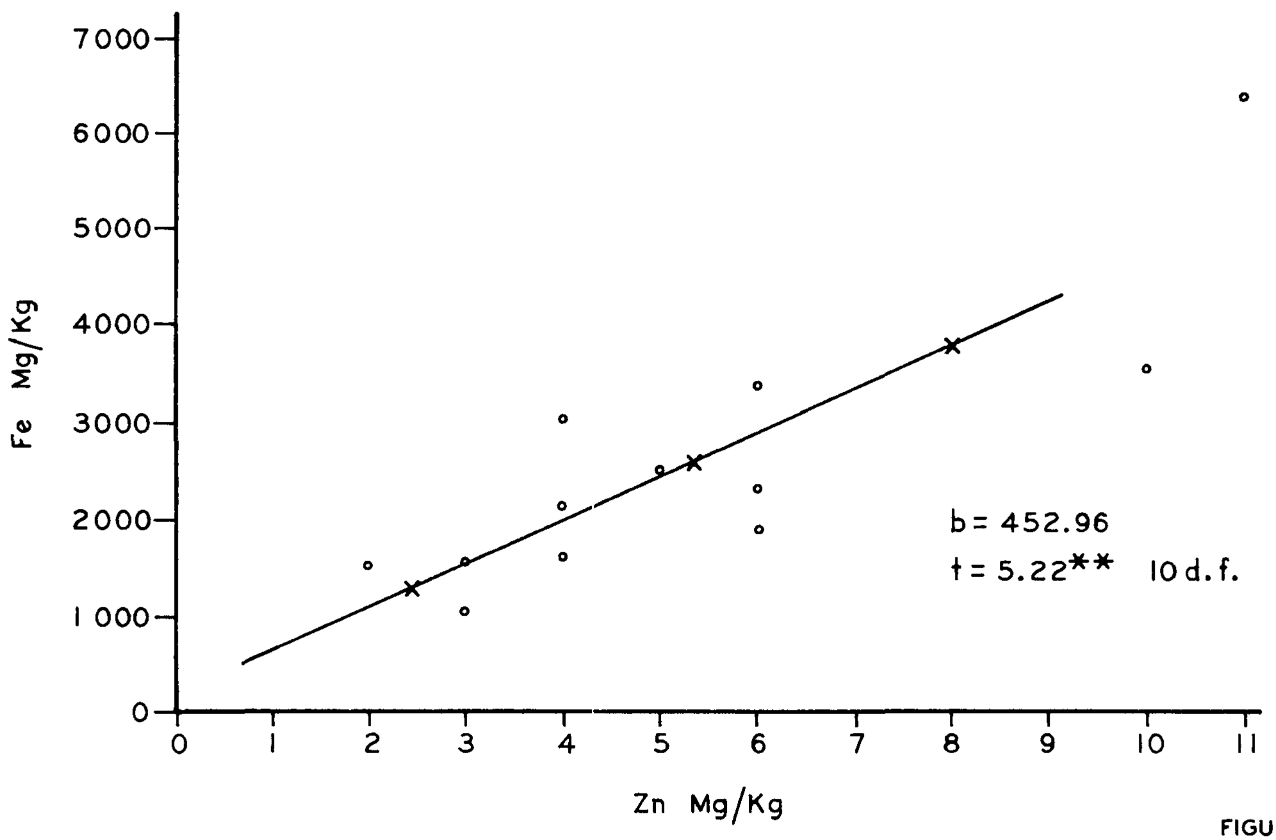


FIGURES - 9, 10

REGRESSION OF Mn & Fe IN SEDIMENTS



REGRESSION OF Zn & Fe IN SEDIMENTS



FIGURES—11, 12

3. Chlorinated Hydrocarbons in Sediments

Sediment samples taken with a Shipek bottom sampler were placed in specially washed bottles for delivery to the EPA laboratory at Annapolis for analysis. Samples were processed by:

1. Air drying, ground in mortar and passed through 1 mm seiving;

2. Approximately 80 gm dried sample were extracted for 7 hours in Soxlet apparatus with 2:1 hexane acetone;

3. The extract was concentrated to approximately 2 ml in a Kuderna-Danish evaporator;

4. Condensed sample was passed through a Florisil column (6%, 15%, 50% ethyl ether in hexane) followed by concentration to less than 1 ml; and

5. Quality and quantity were determined by electron capture gas chromatography.

Results are shown in Table 13.

No geographical patterns were evident in the distribution of organohalogens. The levels are generally low, and approximately similar at dumpsite stations as at control stations removed from loci of dumping activity. Comparison with levels of the spring cruise (Palmer and Lear, 1973) indicate no appreciable accumulations over the time interval.

Table 13

Chlorinated Hydrocarbons in Sediments

Sample Number	Station	Concentration (ppb) Aroclor 1254	Aroclor 1242	P.P'DDE	High S Content
730811-2404	11	3.1	1.9		
7305 E-2404	E	1.7	0.8		
7309 A-2404	A	3.5	0.3	0.6	+
730609-2404	9	1.7	5.6		+
730702-2404	2	ND	ND		
730708-2404	8	0.4	0.5		
730814-2404	14	ND	2.5		
730705-2404	5	2.1	1.4		
730801-2404	1	9.1	5.8	0.5	+
730617-2404	17	0.9	5.2		
7309 C-2404	C	5.0	6.1		

C. BIOTA

1. Infauna

Purpose

The purpose of this report is several fold: 1) to describe the benthic invertebrates of an interim ocean dump site, 2) to compare data on the benthic invertebrates collected prior to dumping and after dumping, 3) to offer a preliminary assessment of the effect of dumping on benthic invertebrates.

Previous Work

Previous research in benthic ecology encompassing the area from southern New Jersey to the northern part of the Delmarva Peninsula was summarized in a report on the probable effects of a deep water oil terminal (Maurer and Wang, 1973). This report included research conducted three miles east of Great Bay, New Jersey (Raney, et al., 1972), Cape Henlopen near the mouth of Delaware Bay (Maurer, et al., 1974), the former Philadelphia dump site 14 miles southeast of the mouth of Delaware Bay (Maurer, unpublished data), and an acid dump site approximately 38 nautical miles southeast of Cape Henlopen (DuPont, et al., 1972).

Research at the New Jersey site is still in progress, but a preliminary checklist of invertebrates was presented in Raney, et al. (1972). In general, the fauna consisted mainly of suspension feeders (surf clam, bay scallop) and epifaunal (rock barnacle, hydroids), and vagile (lady crab, blue crab) species commonly associated with a clean sand bottom and/or a hard substrate.

Near the mouth of Delaware Bay, 115 species were collected (Leathem, et al., 1973; Maurer, et al., 1974 a). The bivalves, *Nucula proxima* and *Tellina agilis*, were the dominant species throughout the area and represented mud (< 0.063 mm) and sand ($> 0.063 - 0.50$ mm) bottom communities, respectively. These communities contained a greater number of deposit feeders than the New Jersey situation (Raney, et al., 1972), but this varied with the amount of fine sediment present.

Research was conducted by Davey (1972) and Watling, et al. (1974 a) at the former Philadelphia dump site, approximately 14 miles southeast of Delaware Bay. The latter study revealed a diverse and interesting mixture of epifaunal and infaunal species. Depending on sediment type, and to some extent water depth, the fauna was dominated by infaunal deposit feeders, *Nucula proxima*, *Yoldia limatula*, *Tellina agilis*; infaunal suspension feeders, *Ensis directus*, *Arctica islandica*; and a variety of epifaunal species, *Obelia longissima*, *Sertularia argentea*, *Electra hastingsae*, etc. Huge numbers (35,750 - 122,380/m^2) of *Nucula proxima* were found in organic muds. Even though *N. proxima* is normally a deposit feeder associated with silty sand and organic muds, the large numbers of bivalves are suggestive of an enriched environment.

At an acid waste dump site, approximately 10 miles north of the interim dump site, research is still in progress, but a preliminary description of benthos is contained in DuPont, et al. (1972). The general character of the stations was considered similar. Stations were dominated by number by the sand dollar, Echinarachnius parma, the sand shrimp, Crangon septemspinosa, and by a small ascidean, Bostrichobranchus pilularis. Other common invertebrates were the sea stars, Asterias forbesi and A. vulgaris; bivalves, Cardita borealis and Arctica islandica; rock crab, Cancer irroratus; and the hermit crab, Pagurus annulipes.

A preliminary report of benthic invertebrates at the interim dump site prior (Operation Quicksilver-QK) to dumping was prepared by Maurer, et al. (1973) in Palmer and Lear (1973). The most significant conclusion was that based on the benthos, the site appeared unpolluted.

Methods

Forty-one samples distributed among 17 stations were collected from the dump site (N 74° 20' - 74° 10' and W 38° 25' - 38° 20') and the surrounding area during Operation Fetch (FE). The vessel track for the cruise was outlined in the cruise plan prepared by the EPA Annapolis office. Collections were made with a shipek grab (0.04 m^2) from November 5-10, 1973, aboard the R.V. Annandale. Samples were preserved in 10% buffered formalin.

In the laboratory the entire sample was picked and sorted into four groups: annelids, arthropods, molluscs, and miscellaneous phyla. Specimens were then identified under microscope to species whenever possible and counted. Identifications were based on local reference collections confirmed by taxonomic specialists (amphipods, isopods, hydroids) or on reference collections (polychaetes) from the U.S. National Museum. Sources for taxonomic literature can be found in Watling and Maurer (1972 a, b), Maurer and Watling (1973 a, b), Watling and Maurer (1973 a, b), Maurer, et al. (1974 b), Watling, et al. (1974 b).

Data from the two collections have been presented in species lists with comparisons of species composition, occurrence, abundance, and diversity indices (Fager, 1963) being included for both the pre and post dumping samples. Analyses did not include meiofaunal species. Moreover, only data from those stations sampled during both collecting periods were compared. These were stations 1, 2, 5, 8, 9, 11, 14, and 17. New stations (A-H) and stations (13), not sampled after dumping, precluded comparison. However, these data will be included in a paper at a later date. Hereafter, the pre-dumping phase will be termed Quicksilver-QK (Palmer and Lear, 1973), and the post-dumping phase Fetch-FE (EPA Cruise Plan).

Results

Species List

A list of species collected during Quicksilver and Fetch is included in Table 14. Approximately 118 species were identified during Quicksilver. Molluscs represented 33% (39) of the species. Among the molluscs, gastropods comprised 14 species (36%) and pelecypods 25 species (64%). Molluscs were followed closely by annelids with 32.1% (38) of the fauna. Arthropods comprised 22.1% (26), ectoprocts 5.1% (6), and the remaining phyla (Cnidaria, Rhynchocoela, Echinodermata, Urochordata) contained 7.7% (9) of the species.

Approximately 133 species were identified during Fetch. Annelids, including species of oligochaetes, archiannelids, and polychaetes, contained 53.5% of the fauna. In terms of number of species, the polychaetes were highest with 68 of 71 species of annelids. Molluscan species represented 22.5% of the fauna with 11 (36.6%) species of gastropods and 19 (63.4%) species of pelecypods. The majority of molluscan species from Quicksilver and Fetch were identified from valves (Table 14). Arthropods comprised 12.7% (17) of all species, ectoprocts 3% (4), and miscellaneous (Protozoa, Cnidaria, Rhynchocoela, Entoprocta, Echinodermata) contained 8.5% (10).

Table 14

Species List of Benthic Invertebrates
from Operation Quicksilver (QK) and Operation Fetch (FE)

Phylum Protozoa
  Class Sarcodina
    Order Foraminifera
      Family Astrorhizidae
(FE) *Astrorhiza* sp.
      Family Miliolidae
(FE) Miliolidae sp.
  Class Ciliophora
    Order Heterotricha
      Family Folliculinidae
(FE) *Folliculina simplex* Dons

Phylum Cnidaria
  Class Hydrozoa
    Order Hydroida
      Family Bougainvilliidae
(FE) *Bougainvillia superciliaris* Agassiz
      Family Campanulariidae
(FE) *Campanularia hincksi* (Alder)
(QK) *Campanularia neglecta* (Alder)
      Family Sertulariidae
(QK, FE) *Sertularia argentea* (Linne)

Phylum Rhynchocoela
(QK, FE) Nemertean sp. 1
(QK) Nemertean sp. 2

Phylum Annelida
  Class Oligochaeta
(QK, FE) Oligochaete sp.
  Class Archiannelida
      Family Polygordiidae
(FE) *Polygordius* sp.
  Class Polychaeta
      Family Ampharetidae
(FE) *Asabellides* sp.
      Family Arabellidae
(FE) *Drilonereis* sp. cf. *D. magna* Webster and Benedict
      Family Cirratulidae
(FE) *Caulleriella* sp.
(FE) *Caulleriella killariensis* (Southern)
(QK) *Chaetozone* sp.
(FE) *Chaetozone setosa* Malmgren
(QK, FE) Cirratulidae sp.
(FE) *Tharyx* sp. cf. *T. acutus* Webster and Benedict
(QK, FE) *Tharyx marioni* (Saint-Joseph)
(FE) *Tharyx* sp. cf. *T. marioni* (Saint-Joseph)
(FE) *Tharyx setigera* Hartman

Table 14 (continued)

(FE)	Tharyx sp. cf. T. setigera Hartman
(FE)	Tharyx sp.
	Family Dorvilleidae
(QK, FE)	Stauronereis rudolphi (Delle Chiaje)
(QK)	Stauronereis sp.
	Family Eunicidae
(QK)	Marphysa bellii (Audouin and Milne-Edwards)
(QK)	Eunice sp.
	Family Flabelligeridae
(FE)	Pherusa affinis (Leidy)
	Family Glyceridae
(FE)	Glycera capitata Oersted
(QK, FE)	Glycera dibranchiata Ehlers
(FE)	Glyceridae ?
	Family Goniadidae
(QK, FE)	Goniadella gracilis (Verrill)
	Family Lumbrinereidae
(FE)	Lumbrinereis latereilli (Audouin and Milne-Edwards)
(QK, FE)	Lumbrinereis acuta (Verrill)
(FE)	Lumbrinereis coccinea (Renier)
(FE)	Lumbrinereis fragilis (O.F. Muller)
(QK)	Lumbrinereis sp.
	Family Magelonidae
(FE)	Magelona sp. cf. M. phyllisae Jones
	Family Maldanidae
(QK, FE)	Clymenella sp.
(QK, FE)	Clymenella torquata (Leidy)
(FE)	Clymenella sp. cf. C. torquata (Leidy)
(FE)	Clymenella zonalis (Verrill)
(FE)	Maldanidae sp.
	Family Nephtyidae
(QK)	Nephtyidae sp.
(QK, FE)	Nephtys (Aglaophamus) circinata Verrill
(FE)	Nephtys sp. cf. N. incisa Malmgren
(QK, FE)	Nephtys picta Ehlers
(FE)	Nephtys sp. cf. N. picta Ehlers
	Family Nereidae
(QK)	Ceratocephale loveni (Malmgren)
(FE)	Nereis sp.
(FE)	Nereis grayi Pettibone
	Family Opheliidae
(FE)	Ophelia denticulata Verrill
(FE)	Travisia carnea Verrill
	Family Orbiniidae
(FE)	Orbinia ornata (Verrill)
(FE)	Scoloplos fragilis (Verrill)
	Family Paraonidae
(QK, FE)	Aricidea sp.
(QK, FE)	Aricidea jeffreysii Laubier
(FE)	Aricidea suecica Eliason

Table 14 (continued)

(QK, FE)	*Aricidea wassi* Pettibone
(FE)	*Paraonis lyra* Southern
(QK, FE)	*Paraonis* sp.
	Family Phyllodocidae
(FE)	*Eteone* ?
(QK)	*Eteone* sp.
(QK)	*Eteone lactea* (Claparede)
(QK)	*Eteone heteropoda* (Hartman)
(QK)	*Eteone* sp. cf. *E. heteropoda* (Hartman)
(FE)	Phyllodocidae sp.
(FE)	*Phyllodoce mucosa* Oersted
(QK)	*Phyllodoce (Anaitides) maculatus* (Linne)
	Family Polynoidae
(FE)	*Harmothoe imbricata* (Linnaeus)
	Family Sabellidae
(QK)	*Euchone* sp.
(FE)	*Potamilla neglecta* (Say)
(QK)	*Sabella microphthalma* (Verrill)
(QK)	Sabellidae sp.
	Family Scalibregmidae
(FE)	*Scalibregma inflatum* Rathke
	Family Sigaliondae
(FE)	*Neoleanira* sp. cf. *N. tetragona* (Oersted)
(FE)	*Neoleanira tetragona* (Oersted)
(QK, FE)	*Sigalion arenicola* Verrill
(QK)	*Sthenelais limicola* (Ehlers)
	Family Spionidae
(QK)	*Spiophanes bombyx* (Claparede)
(QK)	*Scolecolepides viridis* (Verrill)
	Family Syllidae
(QK)	*Autolytus cornutus* (Agassiz)
(FE)	*Brania* ?
(QK, FE)	*Exogone verugera* (Claparede)
(QK, FE)	*Parapionosyllis longicirrata* (Webster and Benedict)
(FE)	*Sphaerosyllis erinaceus* Claparede
(FE)	*Sphaerosyllis hystrix* Claparede
(FE)	*Streptosyllis arenae* Webster and Benedict
(FE)	*Syllides longocirrata* Oersted
(FE)	*Syllis* sp.
(QK)	*Syllis* sp. cf. *S. cornuta* (Rathke)
(FE)	*Syllis cornuta* Rathke
(FE)	*Syllis gracilis* (Grube)
	Family Terebellidae
(QK)	Terebellidae sp.

Phylum Mollusca
Class Scaphopoda
Scaphopoda sp.
Class Gastropoda
Subclass Prosobranchia

Table 14 (continued)

	Order Archaeogastropoda
	Family Trochidae
(QK, FE)	*Margarites groenlandicus* Gmelin
	Family Vitrinellidae
(FE)	*Vitrinella* sp. cf. *V. helicoidea* C.B. Adams
	Order Mesogastropoda
	Family Caecidae
(QK)	*Caecum cooperi* S. Smith
	Family Calyptraeidae
(QK, FE)	*Crepidula fornicata* (Linne)
(QK, FE)	*Crepidula plana* (Say)
	Family Capulidae
(FE)	*Capulus* ?
	Family Naticidae
(FE)	*Lunatia heros* Say
(QK)	*Natica* sp.
(QK)	*Natica canrena* Linne
(QK, FE)	*Polinices duplicatus* (Say)
(QK)	*Polinices immaculatus* Totten
	Order Neogastropoda
	Family Buccinidae
(QK, FE)	*Colus pygmaea* (Gould)
	Family Melongenidae
(QK)	*Busycon canaliculatum* (Linne)
	Family Nassariidae
(QK)	*Nassarius trivittatus* (Say)
	Family Turridae
(QK)	*Mangelia cerina* (Kurtz and Stimpson)
	Subclass Opisthobranchia
	Order Tectibranchia
	Family Acteonidae
(QK)	*Acteon* sp.
	Family Pyramidellidae
(QK, FE)	*Turbonilla interrupta* (Totten)
	Family Retusidae
(FE)	*Retusa canaliculata* (Say)
(FE)	*Retusa obtusa* Montagu
	Class Pelecypoda
	Order Protobranchia
	Family Nuculidae
(QK, FE)	*Nucula proxima* (Say)
	Order Filibranchia
	Family Anomiidae
(QK, FE)	*Anomia simplex* Orbigny
	Family Arcidae
(QK)	*Anadara transversa* (Say)
	Family Mytilidae
(QK, FE)	*Crenella glandula* Totten
(QK, FE)	*Mytilus edulis* (Linne)
	Family Ostreidae
(QK)	*Crassostrea virginica* (Gmelin)

Table 14 (continued)

	Family Pectinidae
(QK, FE)	*Placopecten magellanicus* Gmelin
	Order Eulamellibranchia
	Family Arcticidae
(QK, FE)	*Arctica islandica* Linne
	Family Astartidae
(FE)	*Astarte borealis* Schumacher
(QK)	*Astarte castanea* Say
(QK, FE)	*Astarte subequilatera* Sowerby
(QK)	*Astarte undata* (Gould)
	Family Cardiidae
(QK, FE)	*Cerastoderma pinnulatum* Conrad
(QK, FE)	*Trachycardium muricatum* Linne
	Family Carditidae
(QK, FE)	*Venericardia borealis* (Conrad)
	Family Corbulidae
(QK, FE)	*Corbula contracta* (Say)
	Family Lucinidae
(QK)	*Phacoides filosus* Stimpson
	Family Lyonsiidae
(FE)	*Lyonsia hyalina* (Conrad)
	Family Mactridae
(QK, FE)	*Spisula solidissima* (Dillwyn)
	Family Pandoridae
(QK)	*Pandora gouldiana* (Dall)
(QK, FE)	*Pandora trilineata* Say
	Family Semelidae
(QK)	*Abra lioica* Dall
(FE)	*Cumingia* ?
	Family Solenidae
(QK, FE)	*Ensis directus* (Conrad)
	Family Tellinidae
(QK, FE)	*Tellina agilis* (Stimpson)
	Family Veneridae
(QK)	*Dosinia discus* Reeve
(QK)	*Pitar morrhuana* (Linsley)
(QK)	*Transenella stimpsoni* Dall
	Phylum Arthropoda
	Class Crustacea
	Subclass Malacostraca
	Order Cumacea
	Family Diastylidae
(QK)	*Diastylis* sp.
	Family Leuconidae
(QK)	*Eudorella* sp.
(FE)	*Eudorellopsis deformis* (Kroyer)
	Order Tanaidacea
	Family Paratanaidae
(QK)	*Leptochelia* sp.

Table 14 (continued)

	Family Tanaidae
(FE)	Tanaissus lilljeborgi (Stebbing)
	Order Isopoda
	Suborder Anthuridea
	Family Anthuridae
(FE)	Ptilanthura tricarina Menzies and Frankenberg
	Suborder Flabellifera
	Family Cirolanidae
(QK)	Cirolana concharum (Stimpson)
(QK, FE)	Cirolana impressa (Harger)
(QK, FE)	Cirolana polita (Stimpson)
	Suborder Valvifera
	Family Idoteidae
(QK)	Chiridotea arenicola (Wigley)
(QK)	Chiridotea stenops (Menzies and Frankenberg)
(QK)	Edotea triloba (Say)
	Order Amphipoda
	Suborder Gammaridea
	Family Ampeliscidae
(QK)	Ampelisca vadorum (Mills)
(QK, FE)	Ampelisca aequicornis Bruzelius
(QK, FE)	Byblis serrata (Smith)
	Family Calliophiidae
(QK)	Apherusa gracilis (Holmes)
	Family Corophiidae
(FE)	Leptocheirus pinguis (Stimpson)
(FE)	Pseudounciola obliquua (Shoemaker)
(QK)	Siphonoecetes smithianus (Rathbun)
(QK)	Unciola dissimilis (Shoemaker)
(QK)	Unciola inermis (Shoemaker)
(QK)	Unciola irrorata (Say)
	Family Haustoriidae
(FE)	Acanthohaustorius millsi Bousfield
(QK)	Protohaustorius deichmannae (Bousfield)
(QK, FE)	Protohaustorius wigleyi (Bousfield)
	Family Lyssianassidae
(QK, FE)	Hippomedon serratus (Holmes)
	Family Phoxocephalidae
(QK)	Paraphoxus spinosus (Holmes)
(QK, FE)	Phoxocephalus holbolli (Kroyer)
(QK)	Trichophoxus epistomus (Shoemaker)
	Family Stenothoidae
(QK)	Proboloides holmesi (Bousfield)
	Suborder Caprellidea
	Family Caprellidae
(QK)	Aeginina longicornis (Kroyer)
	Order Decapoda
	Family Cancridae
(FE)	Cancer irroratus Say
(FE)	Cancer borealis Stimpson

Table 14 (continued)

	Phylum Ectoprocta
	Class Gymnolaemata
	Order Ctenostomata
	Family Alcyonidiidae
(QK)	*Alcyonidium polyoum* (Hassall)
	Family Flustrellidae
(QK)	*Flustrellidra hispida* (Fabricius)
	Family Vesiculariidae
(FE)	*Bowerbankia* sp. cf. *B. gracilis* Leidy
	Order Cheilostomata
	Suborder Anasca
	Family Alderinidae
(QK. FE)	*Callopora* sp.
	Family Scrupariidae
(QK)	*Scruparia chelata* (Linne)
	Suborder Ascophora
	Family Microporellidae
(QK, FE)	*Microporella ciliata* (Pallas)
	Family Schizoporellidae
(FE)	*Schizoporella errata* (Watess)
	Family Smittinidae
	Parasmittina sp.
	Phylum Entoprocta
	Family Pedicellinidae
(FE)	*Barentsia* sp.
	Phylum Echinodermata
	Class Echinoidea
	Family Arbaciidae
(QK, FE)	*Arbacia punctulata* (Lamarck)
	Family Echinarachnidae
(QK, FE)	*Echinarachnius parma* (Lamarck)
	Class Ophiuroidea
(QK, FE)	Ophiuroid sp.
	Phylum Chordata
	Subphylum Urochordata
	Class Ascidiacea
(QK)	Ascidian sp.

Comparison of Species Rank, Number, and Cumulative Percent of Benthic Invertebrates from Quicksilver and Fetch

Species from both sampling periods were ranked according to number of individuals (Tables 15 and 16). In addition, the percent of fauna by number, the cumulative percent of fauna, the number of occurrences per species, and the percent of occurrences were included in the same tables. Comparison of these tables revealed the following trends.

The top ten species of Quicksilver comprised approximately 81% of the fauna whereas the top 17 species of Fetch represented about 81% of the fauna (Tables 15 and 16). The top two species of Quicksilver contained about 47% of the fauna while a similar percent was represented by the top five species of Fetch. Dominance was more widely distributed in species from Fetch than Quicksilver. The total number of individuals collected in Quicksilver and Fetch was 1,121 and 1,664, respectively. The addition of meiofauna, to be described later, would double the abundance for Fetch (Table

In Quicksilver, two polychaetes, *Goniadella gracilis* and *Lumbrinereis acuta*, and the amphipod, *Trichophoxus epistomus*, were the dominant (number) species (Table 15). These polychaetes were identified as *Progoniada regularis* and *Lumbrinereis paradoxa* in an earlier report in Maurer, et al. (1973) (Palmer and Lear, 1973). Since then, these species were reexamined at our request by a polychaete specialist and identified as *Goniadella gracilis* and *Lumbrinereis acuta* (K. Fauchald, personal communication).

Table 15

Rank, Number, and Cumulative Percent of
Benthic Invertebrates from Operation Quicksilver

Species	Rank	No. of Individuals	Percent of Fauna	Cumulative Percent of Fauna	No. of Occurrences	Percent Occurrence
Goniadella gracilis	1	363	32.27	32.27	31	63.27
Lumbrineris acuta	2	165	14.70	46.97	30	61.22
Trichophoxus epistomus	3	92	08.18	55.15	31	63.27
Clymenella sp.	4	65	05.78	60.93	16	32.65
Echinarachnius parma	5	59	05.24	66.17	22	44.90
Nemertea sp. 1	6	46	04.04	70.22	6	12.24
Protohaustorius wigleyi	7	27	02.40	72.62	13	26.53
Unciola irrorata	7	27	02.40	75.02	15	30.61
Aricidea jeffreysii	8	21	01.87	76.89	11	22.45
Aeginina longicornis	9	18	01.60	78.49	1	2.04
Byblis serrata	10	15	01.33	79.82	7	14.29
Cirolana polita	10	15	01.33	81.15	13	26.53
Ampelisca aequicornis	11	11	00.98	82.13	6	12.24
Cirolana concharum	12	10	00.89	83.02	5	10.20
Unciola inermis	12	10	00.89	83.91	9	18.37
Eteone heteropoda	13	9	00.80	84.71	3	6.12
Axiothella sp.	14	8	00.71	85.42	2	4.08
Autolytus cornutus	15	7	00.62	86.04	1	2.04
Solus pygmaea	15	7	00.62	86.66	6	12.24
Chaetozone sp.	16	6	00.53	87.19	4	8.16
Eteone lactea	16	6	00.53	87.72	2	4.08
Glycera dibranchiata	17	5	00.44	88.16	5	10.20
Nephtyidae sp.	17	5	00.44	88.60	4	8.16
Phoxocephalus holbolli	17	5	00.44	89.04	4	8.16
Ampeliscidae sp.	18	4	00.36	89.40	3	6.12
Asabellides sp.	18	4	00.36	89.76	2	4.08
Cirratulidae sp.	18	4	00.36	90.12	4	8.16
Goniadidae sp.	18	4	00.36	90.48	1	2.04

Table 15 (continued)

Species	Rank	No. of Individuals	Percent of Fauna	Cumulative Percent of Fauna	No. of Occurrences	Percent Occurrence
Nephtys picta	18	4	00.36	90.84	3	6.12
Stauronereis rudolphi	18	4	00.36	91.20	3	6.12
Syllis cornuta	18	4	00.36	91.56	2	4.08
Aricidea wassi	19	3	00.27	91.83	2	4.08
Nephtys (Aglaophamus) circinata	19	3	00.27	92.10	2	4.08
Sigalion arenicola	19	3	00.27	92.37	3	6.12
Arctica islandica	19	3	00.27	92.64	2	4.08
Cerastoderma pinnulatum	19	3	00.27	92.91	3	6.12
Polinices immaculatus	19	3	00.27	93.18	3	6.12
Chiridotea stenops	19	3	00.27	93.45	3	6.12
Luciola dissimilis	19	3	00.27	93.72	1	2.04
Clymenella torquata	20	2	00.18	93.90	2	4.08
Euchone sp.	20	2	00.18	94.08	1	2.04
Paraonidae sp.	20	2	00.18	94.26	2	4.08
Scolecolepides viridis	20	2	00.18	94.44	1	2.04
Syllis cf. cornuta	20	2	00.18	94.62	1	2.04
Astarte castanea	20	2	00.18	94.80	2	4.08
Ensis directus	20	2	00.18	94.98	2	4.08
Margarites groenlandicus	20	2	00.18	95.16	2	4.08
Nassarius trivittatus	20	2	00.18	95.34	2	4.08
Natica sp.	20	2	00.18	95.52	2	4.08
Spisula solidissima	20	2	00.18	95.70	2	4.08
Ampelisca vadorum	20	2	00.18	95.88	2	4.08
Leptochelia sp.	20	2	00.18	96.06	2	4.08
Protohaustorius deichmannae	20	2	00.18	96.24	1	2.04
Siphonoecetes smithianus	20	2	00.18	96.42	2	4.08
Aricidea sp.	21	1	00.09	96.60	1	2.04
Parapionosyllis longicirrata	21	1	00.09	96.69	1	2.04
Ceratocephale loveni	21	1	00.09	96.78	1	2.04
Eteone cf. heteropoda	21	1	00.09	96.87	1	2.04

Table 15 (continued)

Species	Rank	No. of Individuals	Percent of Fauna	Cumulative Percent of Fauna	No. of Occurrences	Percent Occurrence
Eunice sp.	21	1	00.09	97.05	1	2.04
Exogone verugera	21	1	00.09	97.14	1	2.04
Lumbrinereis sp.	21	1	00.09	97.23	1	2.04
Marphysa belli	21	1	00.09	97.32	1	2.04
Nephtys buccera	21	1	00.09	97.41	1	2.04
Phyllodoce maculata	21	1	00.09	97.50	1	2.04
Sabella microphthalma	21	1	00.09	97.59	1	2.04
Sabellidae sp.	21	1	00.09	97.68	1	2.04
Spiophanes bombyx	21	1	00.09	97.77	1	2.04
Stauronereis sp.	21	1	00.09	97.86	1	2.04
Sthenelais limicola	21	1	00.09	97.95	1	2.04
Terebellidae sp.	21	1	00.09	98.04	1	2.04
Tharyx sp.	21	1	00.09	98.13	1	2.04
Tharyx marioni	21	1	00.09	98.22	1	2.04
Natica canrena	21	1	00.09	98.31	1	2.04
Nucula proxima	21	1	00.09	98.40	1	2.04
Pandora trilineata	21	1	00.09	98.49	1	2.04
Tellina agilis	21	1	00.09	98.58	1	2.04
Stenopleustes gracilis	21	1	00.09	98.67	1	2.04
Chiridotea arenicola	21	1	00.09	98.76	1	2.04
Cirolana impressa	21	1	00.09	98.85	1	2.04
Cumacea sp.	21	1	00.09	98.94	1	2.04
Diastylus sp.	21	1	00.09	99.03	1	2.04
Edotea triloba	21	1	00.09	99.12	1	2.04
Eudorella sp.	21	1	00.09	99.21	1	2.04
Hippomedon serratus	21	1	00.09	99.30	1	2.04
Paraphoxus spinosus	21	1	00.09	99.39	1	2.04
Proboloides holmesi	21	1	00.09	99.48	1	2.04
Arbacia punctulata	21	1	00.09	99.57	1	2.04
Asterias vulgaris	21	1	00.09	99.66	1	2.04
Nemertea sp. 2	21	1	00.09	99.75	1	2.04
Oligochaeta sp.	21	1	00.09	99.84	1	2.04
Ophiuroridea sp.	21	1	00.09	99.93	1	2.04
Total		121				

Table 16

Rank, Number, and Cumulative Percent of Benthic Invertebrates from Operation Fetch

Species	Rank	No. of Individuals	Percent of Fauna by No.	Cumulative Percent of Fauna by No.	No. of Occurrences	Percent Occurrence	Percent of Fauna with Polygordius'
[illegible]della gracilis	1	19[illegible]	11.51	11.54	15	62.50	3.45
[illegible] Verrilli	2	177	10.64	22.18	17	70.33	3.18
[illegible]losyllis longicirrata	3	156	9.38	31.56	9	37.50	2.80
[illegible] sp.	4	120	7.21	38.77	13	54.17	2.16
[illegible]	5	116	6.97	45.74	16	66.67	2.08
[illegible]ophoxus epist[illegible]us	6	96	5.77	51.51	16	66.67	1.73
[illegible]cia punctulata	7	72	4.33	55.84	14	58.33	1.29
[illegible]inereis acuta	8	71	4.27	60.11	14	58.33	1.28
[illegible] serrata	9	63	3.79	63.90	11	45.83	1.13
[illegible]ciola serrata	10	61	3.67	67.57	11	45.83	1.10
[illegible]idea jeffreysii	11	46	2.76	70.33	12	50.00	
[illegible]htys picta	12	37	2.22	72.55	11	45.83	
[illegible]otohaustorius wigleyi	13	36	2.16	74.71	10	41.67	
[illegible]hinarachnius parma	14	32	1.92	76.63	14	58.33	
[illegible]ymenella zonalis	15	30	1.80	78.43	6	25.00	
[illegible]ymenella torquata	16	28	1.68	80.11	8	33.33	
[illegible]phtys cf. picta	17	22	1.32	81.43	6	25.00	
[illegible]aissus lilljeborgi	18	19	1.14	82.57	7	29.17	
[illegible]tosyllis arenae	19	16	0.96	83.53	5	20.83	
[illegible]lleriella [illegible]llariensis	20	15	0.90	84.43	8	33.33	
[illegible]rhiza sp.	21	14	0.84	85.27	8	33.33	
[illegible]idea [illegible]assi	22	12	0.72	85.99	5	20.83	
[illegible]olana polita	22	12	0.72	86.71	5	20.83	
[illegible]gochaete A.	23	11	0.66	87.37	5	20.83	
[illegible]ra capitata	24	8	0.48	87.85	7	29.17	
[illegible]ra dibranchiata	24	8	0.48	88.33	5	20.83	
[illegible]ymenella sp.	24	8	0.48	88.81	2	8.33	
[illegible]rastoderma pinnulatum	25	7	0.42	89.29	6	25.00	

Table 16 (continued)

Species	Rank	No. of Individuals	Percent of Fauna by No.	Cumulative Percent of Fauna by No.	No. of Occurrences	Percent Occurrence
Stauronereis rudolphi	25	7	0.42	89.71	5	20.83
Streptosyllis hystrix	25	7	0.42	90.13	3	12.50
Sigalion arenicola	25	7	0.42	90.55	3	12.50
Oligochaete B.	25	7	0.42	90.97	1	4.17
Pseudunciola obliquua	26	6	0.36	91.33	4	16.67
Lumbrineris fragilis	26	6	0.36	91.69	3	12.50
Travisia carnea	27	5	0.30	91.99	3	12.50
Tharyx cf. acutus	27	5	0.30	92.29	3	12.50
Phyllodocidae sp.	27	5	0.30	92.59	3	12.50
Syllides longocirrata	27	5	0.30	92.89	2	8.33
Spiophanes wigleyi	28	4	0.24	93.13	4	16.67
Potamilla neglecta	28	4			3	12.50
Nephtys (Aglaophamus) circinata	28	4	0.24	93.37	2	8.33
Nephtys incisa	28	4	0.24	93.61	2	8.33
Tharyx setigera	28	4	0.24	93.85	2	8.33
Chaetozone setosa	28	4	0.24	94.57	2	8.33
Aricidea sp.	28	4	0.24	94.33	2	8.33
Leptocheirus pinguis	28	4	0.24	94.57	1	4.17
Asabellides sp.	29	3	0.18	94.75	3	12.50
Syllis cornuta	29	3			3	12.50
Tharyx sp.	29	3	0.18	94.93	3	12.50
Cirratulidae sp.	29	3	0.18	95.11	3	12.50
Venericardia borealis	29	3	0.18	95.29	3	12.50
Lyonsia hyalina	29	3	0.18	95.47	3	12.50
Arctica islandica	29	3	0.18	95.65	2	8.33
Paraonis lyra	29	3	0.18	95.83	2	8.33
Polydora caulleryi	29	3	0.18	96.01	2	8.33
Caulleriella sp.	29	3	0.18	96.19	2	8.33
Phoxocephalus holbolli	29	3	0.18	96.37	2	8.33
Harmothoe imbricata	30	2	0.12	96.49	2	8.33

Table 16 (continued)

Species	Rank	No. of Individuals	Percent of Fauna by No.	Cumulative Percent of Fauna by No.	No. of Occurrences	Percent Occurrence
Phyllodoce mucosa	30	2	0.12	96.61	2	8.33
Tharyx marioni	30	2	0.12	96.73	2	8.33
Nereis grayi	30	2	0.12	96.85	2	8.33
Lumbrinereis latreilli	30	2	0.12	96.97	2	8.33
Ophiuroid sp.	30	2	0.12	97.09	2	8.33
Lindorellopis deformis	30	2	0.12	97.21	2	8.33
Cancer irroratus	30	2	0.12	97.33	2	8.33
Cumingia ?	30	2	0.12	97.45	1	4.17
Brania ?	30	2	0.12	97.57	1	4.17
Scalibregma inflatum	30	2	0.12	97.69	1	4.17
Scaphopoda sp.	30	2	0.12	97.81	1	4.17
Ensis directus	31	1	0.06	97.87	1	4.17
Margarites groenlandicus	31	1	0.06	97.93	1	4.17
Nucula proxima	31	1	0.06	97.99	1	4.17
Tellina agilis	31	1	0.06	98.05	1	4.17
Polinices duplicatus	31	1	0.06	98.11	1	4.17
Pandora trilineata	31	1	0.06	98.17	1	4.17
Aricidea suecica	31	1	0.06	98.23	1	4.17
Eteone ?	31	1	0.06	98.29	1	4.17
Glyceridae ?	31	1	0.06	98.35	1	4.17
Nereis sp.	31	1	0.06	98.41	1	4.17
Spionidae ?	31	1	0.06	98.47	1	4.17
Tharyx cf. marioni	31	1	0.06	98.53	1	4.17
Tharyx cf. setigera	31	1	0.06	98.59	1	4.17
Paraonis sp.	31	1	0.06	98.65	1	4.17
Maldanidae sp.	31	1	0.06	98.71	1	4.17
Ophelia denticulata	31	1	0.06	98.77	1	4.17
Syllis sp.	31	1	0.06	98.83	1	4.17
Drilonereis magna	31	1	0.06	98.89	1	4.17
Lumbrinereis coccinea	31	1	0.06	98.95	1	4.17
Neoleanira cf. tetragona	31	1	0.06	99.01	1	4.17

Table 16 (continued)

Species	Rank	No. of Individuals	Percent of Fauna by No.	Cumulative Percent of Fauna by No.	No. of Occurrences	Percent Occurrence
Aeoleanira tetragona	31	1	0.06	99.07	1	4.17
Magelona cf. phyllisae	31	1	0.06	99.13	1	4.17
Pherusa affinis	31	1	0.06	99.19	1	4.17
Scoloplos fragilis	31	1	0.06	99.25	1	4.17
Orbinia ornata	31	1	0.06	99.31	1	4.17
Ptilanthura tricarina	31	1	0.06	99.37	1	4.17
Acanthohaustorius millsi	31	1	0.06	99.43	1	4.17
Cirolana impressa	31	1	0.06	99.49	1	4.17
Cancer borealis	31	1	0.06	99.55	1	4.17
Edotea triloba	31	1	0.06	99.61	1	4.17
Total		1664				
* *Polygordius* sp.		3901	70.10		22	53.66

(meiofaunal species included in calculations of the percent of the fauna for the first 10 species for comparison)

In Fetch, G. gracilis and L. acuta were ranked 1 and 8, respectively (Table 16). Three species of polychaetes, the syllids, Exogone verugera, Parapionsyllis longicirrata, and the spionid, Spiophanes bombyx were also important as they ranked 2, 3, and 5, respectively. The amphipods, Trichophoxus epistomus and Byblis serrata, remained in the top ten. The polychaete, Aricidea jeffreysii, shifted from 8 to 11. In terms of species composition, the presence of the syllids and the spionid represent the biggest changes in the top ten or eleven species between Quicksilver and Fetch.

Life Stage

During the examination of species collected for Quicksilver (March 1973), there was some evidence of reproductive activity. Specimens of the syllid, Autolytus cornutus contained chains of female sexual buds. However, specimens from Fetch showed additional indications of reproductive activity or young of the year. Among specimens of the echinoderm Arbacia punctulata, about 98% were less than 5 mm in diameter. This size would indicate setting within two to six weeks of sampling (November 5-10, 1973). Specimens of syllids were collected in various stages of reproduction. Parapionosyllis longicirrata and Exogone verugera commonly contained sexual epitokes with long swimming setae. Another syllid identified as Streptosyllis arenae showed the swollen eyes and long setae characteristic of sexual epitokes. According to Pettibone (1963) sexual epitokes are unknown for this species. The nephtyid, Nephtys picta and the goniadid, Goniadella gracilis, were collected as adults during Quicksilver, but commonly as juveniles in Fetch. Finally, approximately 75% of the ampeliscid amphipod, Byblis serrata, contained developing young in brood pouches.

Meiofauna

Although this emphasized macroscopic benthic organisms, specimens of the meiofauna (normally less than 0.5 mm) were also collected. Because sampling techniques were not designed to collect the meiofauna and their systematics are locally poorly known, only a few of easily recognizable species were identified. However, for general information purposes, some comments can be made.

Specimens of calcareous and arenaceous Foraminifera were recognized in Fetch samples. In the former group, the Family Miliolidae was represented by species of Quinqueloculina, Triloculina, and Miliola. The genus, Eponides in the Family Rotaliidae was also collected. Astrorhiza was the principle representative of arenaceous Foraminifera. None of the above genera of Foraminifera were included in the species list except Astrorhiza (Table 14).

Specimens of ostracods, nematodes, oligochaetes, and fragments of nemerteans were also collected. The oligochaetes did not occur in high numbers and were not widely distributed.

In contrast, nemerteans and fragments of nemerteans were abundant and occurred in a variety of samples (Tables 15 and 16).

The archiannelid tentatively identified as Polygordius sp. deserves special mention. This species, a member of the meiofauna, was the most abundant benthic invertebrate collected for either sampling period. The total number was 3,901 individuals. When this meiofaunal organism was compared with the macroscopic forms, it was ranked number one and accounted for 70% of the fauna and occurred in 54% of the samples (Table 16). These figures were presented to illustrate the dramatically different results which can be obtained using meiofaunal organisms compared to macrofauna.

Faunal Diversity

The diversity of each sample (Tables 17 and 18 was determined according to Fager (1962). These values were pooled and averaged for a single diversity value per station per sampling period. The station diversity values per sampling period were compared with the nonparametric sign test (Table 19). Assumptions for the sign test and its computation can be found in Conover (1971). The null hypothesis was that for a one-tailed test diversity values of Fetch were smaller than or equal to diversity values of Quicksilver. Results of the sign test indicate that the null hypothesis must be rejected at a probability level of .05 (Table 19). Thus, the diversity values for Fetch stations were significantly greater than diversity values for Quicksilver. The occurrence of benthic invertebrates for all samples examined during Quicksilver and Fetch were included in Tables 20 through 28 and 29 through 36.

Table 17

Numbers of Species (S), Individuals (I), and Scaled Diversity (SD) Indices for Operation Quicksilver

Station 1	01	02	03	04	05	06
S	7	8	7	7	8	6
I	17	30	20	26	47	31
SD	.506	.305	.458	.256	.432	.194
Station 1 (cont.)	**07**	**08**	**09**			**Total**
S	10	10	6			26
I	27	37	13			248
SD	.602	.472	.859			.540
Station 2	***11**	***12**	**13**	**14**	**15**	**Total**
S	2	4	7	10	9	20
I	6	8	14	14	12	54
SD	.502	.625	.310	.756	1.00	.604
Station 5	***38**	***39**	**40**	**41**	**42**	**Total**
S	3	2	8	9	3	16
I	4	3	22	38	11	78
SD	1.00	1.00	.421	.608	.765	.558
Station 8	**43**	**44**	**45**	**46**	**47**	**Total**
S	7	12	10	10	9	27
I	12	32	22	22	47	135
SD	.670	.627	.569	.535	.458	.571

Table 17 (continued)

Station 9	18	*49	50	*51	52	Total
S	9	4	3	7	10	21
I	16	7	11	8	19	59
SD	.656	.543	.206	1.00	.393	.689
Station 11	**16**	**17**	**18**	**19**	**20**	**Total**
S	8	7	11	6	7	19
I	33	64	162	30	38	327
SD	.386	.429	.320	.398	.320	.368
Station 13	**22**	**23**	**24**	**25**	**26**	**Total**
S	11	10	6	9	7	27
I	15	15	17	16	17	80
SD	.758	.475	.492	.598	.815	.702
Station 14	**28**	**29**	***30**	**31**	**32**	**Total**
S	8	7	5	11	8	26
I	17	19	7	23	12	78
SD	.459	.592	1.00	.544	.748	.594
Station 17	**33**	**34**	**35**	**36**	**37**	**Total**
S	6	6	10	9	7	21
I	12	14	14	18	11	69
SD	.368	.511	.756	.399	.742	.635

* Index invalid for less than ten individuals.

Table 18

Numbers of Species (S), Individuals (I), and Scaled Diversity (SD) Indices for Operation Fetch

Station 1	01	02	03	Total
S	9	16	10	20
I	20	38	21	77
SD	.483	.357	.200	.563
Station 5	**01**	**02**	**03**	**Total**
S	9	9	11	21
I	24	22	27	73
SD	.523	.628	.578	.561
Station 9	**01**	**02**	**03**	**Total**
S	16	17	19	36
I	37	47	49	131
SD	.778	.655	.569	.668
Station 14	**01**	**02**	**03**	**Total**
S	10	14	17	28
I	16	40	61	111
SD	.396	.536	.704	.699

Station 2	01	02	03	Total
S	21	18	21	34
I	70	58	94	213
SD	.765	.737	.698	.763
Station 8	**01**	**02**	**03**	**Total**
S	19	14	14	31
I	79	73	87	238
SD	.548	.641	.568	.632
Station 11	**01**	**02**	**03**	**Total**
S	14	25	20	34
I	55	192	85	333
SD	.524	.587	.564	.592
Station 17	**01**	**02**	**03**	**Total**
S	19	29	25	43
I	99	224	179	493
SD	.757	.621	.632	.648

Table 19

Sign Test for Comparison of
Faunal Diversity for Comparable Stations of
Operation Quicksilver and Operation Fetch

Station	Quicksilver Diversity *	Fetch Diversity *	Sign
1	.540	.563	+
2	.604	.763	+
5	.558	.561	+
8	.571	.632	+
9	.689	.668	–
11	.368	.592	+
14	.594	.699	+
17	.635	.648	+

Null hypothesis rejected at $\alpha = .05$.

* Diversity values were computed from pooled replicate samples.

Discussion

Species List and Comparison of Abundance

One parameter commonly used as an indicator of marine pollution is a shift in species composition (Sindermann, 1972). This may involve deletion or introduction of a key species or a decrease or increase in abundance. In the present case, there has been very little shift in key species composition or change in abundance that cannot be explained by natural processes. Moreover, the difference in total species and total numbers between Quicksilver (118, 1121) and Fetch (133, 1664), exclusive of meiofauna, (Tables 15 and 16) can be explained in several ways. One is an artifact of taxonomic methodology, the second is based on seasonality.

Examination of Tables 15 and 16 shows that the number of polychaete species has almost doubled in Fetch. In part, this is due to the common practice of using the taxonomic notation sp. and cf. (compares favorably) to indicate some doubt as to the reliability of the identification. Sometimes an organism may have been damaged in collection, lost key morphological features in preservation, or is in a juvenile stage with only general diagnostic features. Under such circumstances identifications can be difficult and so qualifications such as cf. or sp. are placed on the identification. As a result, the apparent number of species can be increased very rapidly, when in fact some of the organisms are really poorly preserved specimens of species already identified.

The second reason for an increased number of species and greater number of individuals in Fetch is biological and is considerably more important than taxonomic reasons. Since there were only two collecting dates (March and early November), seasonality cannot be invoked unequivocally to explain the differences. However, the juvenile sizes, sexual stages, and egg-bearing mode among adult-size invertebrates from Fetch strongly indicated recent and ongoing recruitment. This contrasted with the adult size and general lack of reproductive stages among Quicksilver adults. Samples from Quicksilver primarily represented adult populations with a shift to smaller size classes corresponding to recruitment prior to and during Operation Fetch.

Other data which supported this seasonal explanation was the presence of large numbers of the archiannelid, *Polygordius*. The seasonal nature of members of the meiofauna has been discussed (McIntyre, 1969). The settlement of *Polygordius* between sampling periods was consistent with annual recruitment by some members of the macrofauna.

Faunal Diversity

Diversity is a complex biological concept which can be useful in pollution studies when applied with other data. Shifts in diversity have commonly been used to indicate the response of communities to changing environments. Increased diversity has been interpreted as an improved environment, decreased diversity as a reduction in environmental quality. However, diversity applied without supporting data to pollution studies can be misleading. A discussion of diversity is beyond the scope of this report; however, we urge caution in blindly following the direction of diversity indices.

For example, in this study there was a statistically significant increase in diversity between sampling periods (Table 19). Based on diversity alone one might conclude that dumping in the study area significantly improved the environment. We do not subscribe to this point of view. Rather we submit that the increase in diversity was primarily caused by natural seasonal recruitment and, to a considerably lesser extent, taxonomic artifacts. We would discourage the use of the increased diversity values computed here as an indication of an improved environment.

General Statement

The benthic invertebrate fauna recorded for Quicksilver and Fetch was characteristic of many areas in the shallow continental shelf area north of the Delmarva Peninsula through Nantucket (Pratt, 1973). In general, these faunas were considered indicative of unpolluted oceanic waters. The main exception would be the New York Bight (Pararas-Carayannis, 1973).

In the area under study, it would be highly unlikely that the interim dumping to date would cause immediate lethal effects to the benthos. The particulate nature of the disposal waste, the short duration of dumping time, the dispersion of the waste, and relatively small volume of waste compared to annual rates in the New York Bight would support this opinion. What may be more insidious are long range chronic effects related to other activities. Palmer and Lear (1973) presented data which indicated accumulation of copper and iron in invertebrates from the study area. They tentatively suggested there may be some leaching from the acid waste dump site 10 miles north of the interim dump site. Palmer and Lear were reluctant to make stronger statements pending further study. In view of the fact that the general direction of the surface current moves south from the acid dump site, the interim dump site would be down current. Whether this is part of a trace metal sink remains unknown for now.

Regardless of the source of the trace metals, many invertebrates are known to accumulate high concentrations without obvious adverse effects to themselves (Kopfler and Mayer, 1973). However, this response primarily holds for adults because embryonic and larval development may be very sensitive and adversely affected by trace metals (Calabrese, et al., 1973). Indeed chronic effects on long term biological processes (reproduction, growth, incidence of disease) are poorly known even among adults. It would seem that small scale, detailed studies of chronic effects on larvae of benthic invertebrates, holoplanktors, and long-term biological processes on adults would be productive in resolving this problem. Waste from both dump sites should be used.

Summary

1. The number of macrobenthic species and individuals from "Quicksilver" were 118 and 1,121, respectively.

2. The same categories for "Fetch" were 133 species and 1,664 individuals.

3. Inclusion of the meiobenthic archiannelid, Polygordius to the "Fetch" total yielded another 3,901 individuals.

4. There were no major shifts of key species (Goniadella gracilis, Lumbrinereis acuta, Trichophoxus epistomus) between collecting periods.

5. The presence of many juvenile stages, sexual stages, adults with eggs and brood pouches with developing young in "Fetch" invertebrates strongly indicated seasonal recruitment here.

6. Faunal diversity increased significantly between "Quicksilver" and "Fetch", but was attributable primarily to seasonal recruitment and secondarily to artifacts of taxonomy.

7. Based on the benthic organisms alone no measurable effect of pollution was determined.

8. Long term studies of chronic effects of sewage waste disposal and acid waste disposal on larvae of benthic invertebrates, holoplankters and on biological processes (reproduction, growth, incidence of disease) of adults were urged.

Table 20

Occurrence of Benthic Invertebrates at Station 1 (Quicksilver)

Species	Sample 01	02	03	04	05	06	07	08	09
Polychaeta									
Lumbrinereis acuta	1	5	3	2	6	3	1	13	3
Goniadella gracilis	-	17	1	16	25	22	-	12	3
Tharyx sp.	-	1	-	-	-	-	-	-	-
Ceratocephale loveni	-	1	-	-	-	-	-	-	-
Clymenella sp.	-	-	-	1	6	1	-	1	1
Paraonidae sp.	-	-	-	1	-	-	-	-	-
Chaetozone sp.	-	-	-	2	2	-	-	-	-
Aricidea jeffreysii	-	-	-	-	1	3	-	-	-
Cirratulidae sp.	-	-	-	-	-	-	1	1	-
Asabellides sp.	-	-	-	-	-	-	-	2	-
Nephtys (Aglaophamus) circinata	-	-	-	-	-	-	-	1	-
Nephtyidae sp.	-	-	-	-	-	-	-	-	2
Mollusca*									
Spisula solidissima	V	V	V	-	V	V	-	-	V
Venericardia borealis	V	V	V	V	V	V	V	V	V
Placopecten magellanicus	V	V	V	V	V	V	V	V	-
Cerastoderma pinnulatum	V	V	V	D	D	V	V	D	-
Astarte undata	V	V	-	-	-	-	-	-	-
Crepidula plana	D	D	-	-	D	-	D	-	D
Margarites groenlandicus	1	-	V	-	-	V	-	-	-
Acteon sp.	D	-	-	-	-	-	-	-	-
Ensis directus	-	V	D	-	V	V	-	V	V
Nucula proxima	-	V	V	-	V	V	-	V	-
Anomia simplex	-	V	V	-	V	V	-	V	-
Crepidula fornicata	-	V	-	-	D	-	-	-	-
Transenella stimpsoni	-	-	V	V	-	V	-	-	V
Astarte castanea	-	-	-	D	V	D	V	V	V
Tellina sp.	-	-	-	V	-	-	-	-	-
Nassarius trivittatus	-	-	-	-	D	D	-	-	-
Busycon canaliculatum	-	-	-	-	D	-	-	-	-
Anadara transversa	-	-	-	-	V	-	-	-	-
Crassostrea virginica	-	-	-	-	-	-	V	-	-
Mytilus edulis	-	-	-	-	-	-	-	V	-
Trachycardium muricatum	-	-	-	-	-	-	-	V	-
Polinices duplicatus	-	-	-	-	-	-	-	-	D
Crustacea									
Protohaustorius deichmannae	6	-	2	3	-	1	3	-	-
Trichophoxus epistomus	5	3	9	1	4	1	8	4	2
Cirolana concharum	2	1	-	-	-	-	-	-	-
Byblis serrata	1	-	1	-	-	-	3	-	-

Table 20 (continued)

Species	Sample 01	02	03	04	05	06	07	08	09
Crustacea (continued)									
Siphonoecetes smithianus	1	-	-	-	-	-	-	-	-
Chiridotea stenops	-	1	-	-	-	-	-	-	-
Cirolana polita	-	-	1	-	2	-	1	1	-
Hippomedon serratus	-	-	-	-	1	-	-	-	-
Unciola inermis	-	-	-	-	-	-	1	-	-
Phoxocephalus holbolli	-	-	-	-	-	-	-	1	-
Ampelisca aequicornis	-	-	-	-	-	-	1	-	-
Unciola irrorata	-	-	-	-	-	-	2	-	-
Others*									
Echinarachnius parma	-	1	3	-	-	-	6	-	2
Obelia sp.	-	-	P	-	-	-	-	-	-
Microporella ciliata	-	-	P	-	-	-	-	-	-
Eudendrium dispar	-	-	-	P	-	-	-	-	-
Sertularia argentea	-	-	-	-	-	-	-	P	-
Ophiuroid sp.	-	-	-	-	-	-	-	1	-

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 21

Occurrence of Benthic Invertebrates at Station 2
(Quicksilver)

Species	Sample 11	12	13	14	15
Polychaeta					
Nephtys (Aglaophamus) circinata	2	-	-	-	-
Clymenella sp.	-	2	2	-	1
Goniadella gracilis	-	-	1	1	-
Nephtyidae sp.	-	-	-	1	1
Lumbrinereis acuta	-	-	-	2	-
Mollusca*					
Cerastoderma pinnulatum	V	-	V	-	-
Mytilus edulis	-	V	-	-	-
Venericardia borealis	-	V	V	V	V
Phacoides filosus	-	V	-	-	-
Transenella stimpsoni	-	V	-	-	V
Astarte undata	-	V	V	V	V
Colus pygmaea	-	1	-	2	-
Arctica islandica	-	-	V	-	V
Polinices immaculatus	-	-	1	-	-
Margarites groenlandicus	-	-	V	-	-
Ensis directus	-	-	-	1	-
Nucula proxima	-	-	-	1	-
Mangelia cerina	-	-	-	V	-
Astarte subequilatera	-	-	-	-	V
Natica canrena	-	-	-	-	1
Crustacea					
Cirolana concharum	4	-	-	-	-
Trichophoxus epistomus	-	2	2	1	2
Paraphoxus spinosus	-	-	1	-	-
Ampeliscidae sp.	-	-	1	1	-
Cumacea sp.	-	-	-	1	-
Cirolana impressa	-	-	-	-	1
Protohaustorius deichmannae	-	-	-	-	2
Cirolana polita	-	-	-	-	1
Others*					
Echinarachnius parma	-	[illegible]	6	3	2
Cellepora sp.	-	-	-	P	-
Ascidian sp.	-	-	-	P	-
Nemertean sp.	-	-	-	-	1

* 1 - Live gastropod or dead valves joined together
V - Separate valve
[illegible]

Table 22

Occurrence of Benthic Invertebrates at Station 5
(Quicksilver)

Species	Sample 38	39	40	41	42
Polychaeta					
Goniadella gracilis	1	2	10	9	5
Paraonidae sp.	1	-	-	-	-
Lumbrinereis acuta	-	1	2	6	-
Aricidea jeffreysii	-	-	-	-	2
Chaetozone sp.	-	-	-	1	-
Clymenella sp.	-	-	-	7	-
Mollusca*					
Ensis directus	V	-	-	-	-
Spisula solidissima	V	V	V	V	V
Venericardia borealis	V	V	-	V	V
Placopecten magellanicus	V	V	V	V	V
Cerastoderma pinnulatum	D	-	-	V	D
Arctica islandica	2	-	-	-	-
Tellina agilis	-	V	-	-	-
Crepidula plana	-	D	-	-	-
Anomia simplex	-	-	V	V	-
Astarte undata	-	-	V	-	-
Astarte castanea	-	-	1	1	V
Crenella glandula	-	-	-	-	V
Trachycardium muricatum	-	-	-	D	-
Colus pygmaea	-	-	-	D	-
Crustacea					
Cirolana polita	-	-	3	-	-
Edotea triloba	-	-	1	-	-
Unciola inermis	-	-	1	1	-
Unciola irrorata	-	-	3	-	-
Phoxocephalus holbolli	-	-	-	1	-
Leptochelia sp.	-	-	-	1	-
Others					
Echinarachnius parma	-	-	1	-	-
Microporella ciliata	-	-	-	-	P
Nemertean sp. #1	-	-	-	11	4

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 23

Occurrence of Benthic Invertebrates at Station 8
(Quicksilver)

Species	Sample 43	44	45	46	47
Polychaeta					
Goniadella gracilis	3	7	7	4	22
Clymenella sp.	1	2	3	-	11
Lumbrinereis acuta	1	8	3	3	4
Nephtys (Aglaophamus) circinata	-	1	-	-	-
Stauronereis rudolphi	-	-	1	1	2
Parapionosyllis longicirrata	-	-	-	1	-
Glycera dibranchiata	-	-	-	-	1
Aricidea jeffreysii	-	-	-	-	4
Tharyx marioni	-	-	-	-	1
Stauronereis sp.	-	-	1	-	-
Nephtys picta	-	-	2	-	-
Mollusca*					
Anomia simplex	-	-	V	-	V
Spisula solidissima	-	V	V	-	V
Venericardia borealis	V	V	V	-	V
Astarte castanea	-	V	D	V	-
Placopecten magellanicus	V	V	V	V	V
Cerastoderma pinnulatum	1	V	D	D	D
Nassarius trivittatus	D	D	-	-	-
Crenella glandula	V	V	V	-	V
Crepidula plana	-	D	-	-	-
Tellina agilis	-	V	1	1	-
Arctica islandica	-	V	-	-	-
Natica sp.	-	1	-	-	-
Transenella stimpsoni	-	V	-	-	V
Dosinia discus	-	V	-	-	-
Ensis directus	-	-	V	D	V
Nucula proxima	-	-	V	-	-
Margarites groenlandicus	-	-	-	D	-
Crustacea					
Unciola inermis	-	-	1	1	-
Phoxocephalus holbolli	2	-	-	-	-
Leptochelia sp.	-	1	-	-	-
Diastylis sp.	1	-	-	-	-
Unciola dissimilis	3	-	-	-	-
Cirolana polita	-	1	2	-	-
Unciola irrorata	-	2	1	2	-
Trichophoxus epistomus	-	1	-	1	1
Ampelisca vadorum	-	-	-	-	1

Table 23 (continued)

Species	Sample 43	44	45	46	47
<u>Others</u>*					
Nemertean sp. #1	-	4	-	7	-
Echinarachnius parma	-	3	-	-	-
Sertularia argentea	P	-	-	-	-
Flustrellidra hispida	P	-	-	-	-
Oligochaete sp. #1	-	1	-	-	-

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 24

Occurrence of Benthic Invertebrates at Station 9 (Quicksilver)

Species	Sample 48	49	50	51	52
Polychaeta					
Sigalion arenicola	1	1	-	-	-
Goniadella gracilis	4	-	-	-	-
Lumbrinereis acuta	1	-	8	-	2
Clymenella sp.	1	-	-	2	1
Aricidea jeffreysii	-	1	-	-	-
Nephtys picta	-	-	-	1	-
Sthenelais limicola	-	-	-	1	-
Autolytus cornutus	-	-	-	-	7
Mollusca*					
Ensis directus	V	V	-	-	-
Anomia simplex	V	-	V	-	-
Pandora trilineata	V	-	-	-	-
Venericardia borealis	V	V	V	-	V
Cerastoderma pinnulatum	V	V	D	-	D
Transenella stimpsoni	V	-	-	-	-
Astarte castanea	V	V	V	-	V
Tellina agilis	V	-	-	-	V
Turbonilla interrupta	D	-	-	-	-
Phacoides filosus	-	V	-	-	-
Pitar morrhuana	-	V	-	-	-
Crenella glandula	-	V	-	-	-
Placopecten magellanicus	-	V	-	-	V
Margarites groenlandicus	-	-	D	-	-
Polinices immaculatus	-	-	1	-	-
Spisula solidissima	-	-	V	V	-
Crepidula plana	-	-	D	-	-
Arctica islandica	-	-	-	V	-
Nassarius trivittatus	-	-	-	1	D
Crustacea					
Chiridotea stenops	1	-	-	1	-
Protonaustorius wigleyi	1	3	-	-	-
Trichophoxus epistomus	3	2	2	-	2
Cirolana concharum	2	-	-	-	-
Cirolana polita	-	-	-	1	-
Cancer irroratus	-	-	-	-	2
Chiridotea arenicola	-	-	-	-	1
Aeginina longicornis	-	-	-	-	1
Ampelisca aequicornis	-	-	-	-	1
Stenopleustes gracilis	-	-	-	-	1
Proboloides holmesi	-	-	-	-	1

Table 24 (continued)

Species	Sample 48	49	50	51	52
<u>Others</u>*					
<u>Echinarachnius parma</u>	2	-	-	-	-
<u>Sertularia argentea</u>	-	-	-	-	P
<u>Scruparia chelata</u>	-	-	-	-	P
<u>Campanularia neglecta</u>	-	-	-	-	P
<u>Eudendrium dispar</u>	-	-	-	-	P

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 25

Occurrence of Benthic Invertebrates at Station 11
(Quicksilver)

Species	Sample 16	17	18	19	20
Polychaeta					
Goniadella gracilis	17	33	103	14	23
Lumbrinereis acuta	7	8	37	11	8
Syllis cf. cornuta	2	-	-	-	-
Terebellidae sp.	1	-	-	-	-
Cirratulidae sp.	-	1	-	-	-
Glycera dibranchiata	-	-	1	1	1
Clymenella sp.	-	-	6	2	-
Aricidea jeffreysii	-	-	4	-	-
Syllis cornuta	-	-	2	-	2
Mollusca*					
Astarte castanea	V	V	V	V	V
Venericardia borealis	V	-	V	V	-
Ensis directus	V	-	-	-	-
Placopecten magellanicus	V	-	V	V	V
Crenella glandula	V	-	-	-	V
Colus pygmaea	1	-	1	1	-
Spisula solidissima	-	V	-	-	V
Polinices immaculatus	-	D	-	-	-
Tellina agilis	-	-	V	V	V
Nucula proxima	-	-	V	-	-
Corbula contracta	-	-	V	-	-
Transenella stimpsoni	-	-	V	-	-
Cerastoderma pinnulatum	-	-	1	-	D
Nassarius trivittatus	-	-	V	-	-
Crustacea					
Unciola inermis	1	-	2	-	-
Unciola irrorata	2	-	4	1	2
Siphonoecetes smithianus	-	1	-	-	-
Leptochelia sp.	-	1	-	-	-
Cirolana concharum	-	1	-	-	-
Cirolana polita	-	-	1	-	1
Ampelisca vadorum	-	-	-	-	1
Others*					
Nemertean sp. #1	-	19	-	-	-
Eudendrium dispar	-	-	-	-	P

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 26

Occurrence of Benthic Invertebrates at Station 13 (Quicksilver)

Species	Sample 22	23	24	25	26
Polychaeta					
Clymenella sp.	1	3	-	-	-
Lumbrinereis sp.	1	-	-	-	-
Exogone verugera	1	-	-	-	-
Marphysa belli	1	-	-	-	-
Goniadella gracilis	1	1	6	3	-
Sabella microphthalma	1	-	-	-	-
Glycera dibranchiata	-	1	-	-	-
Aricidea jeffreysii	-	1	2	-	-
Lumbrinereis paradoxa	-	-	6	3	3
Aricidea wassi	-	-	-	1	-
Phyllodoce maculatus	-	-	-	1	-
Eunice sp.	-	-	-	1	-
Mollusca*					
Astarte castanea	V	-	V	V	-
Venericardia borealis	V	V	V	V	V
Ensis directus	V	-	V	-	-
Crenella glandula	V	-	-	-	-
Placopecten magellanicus	V	-	V	V	-
Cerastoderma pinnulatum	V	-	D	V	V
Natica sp.	1	-	-	-	-
Busycon canaliculatum	D	-	-	-	-
Colus pygmaea	-	1	-	-	D
Arctica islandica	-	V	1	-	-
Margarites groenlandicus	-	1	-	-	D
Trachycardium muricatum	-	-	V	-	-
Crustacea					
Unciola irrorata	3	1	1	-	1
Ampelisca sp.	2	-	-	-	-
Byblis serrata	-	4	-	1	3
Unciola inermis	-	1	-	-	1
Eudorella sp.	-	1	-	-	-
Ampelisca aequicornis	-	-	-	4	3
Trichophoxus epistomus	-	-	-	-	4
Others*					
Ophiuroidea sp.	1	-	1	-	-
Echinarachnius parma	2	-	-	-	2
Microporella ciliata	P	-	P	-	-

Table 26

Species	Sample 22	23	24	25	26
Others (continued)					
Sertularia argentea	P	P	-	-	-
Eudendrium dispar	P	P	-	-	-
Callopora sp.	-	P	P	-	-
Asterias vulgaris	-	-	-	1	-
Arbacia punctulata	-	-	-	1	-
Alcyonidium polyoum	-	-	-	P	-
Parasmittina sp.	-	-	-	P	-

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 27

Occurrence of Benthic Invertebrates at Station 14 (Quicksilver)

Species	Sample 28	29	30	31	32
Polychaeta					
Clymenella sp.	2	–	–	3	–
Goniadidae sp.	4	–	–	–	–
Goniadella gracilis	1	–	1	1	–
Eteone heteropoda	2	5	–	5	3
Sabellidae sp.	1	–	–	–	–
Aricidea suecica	–	1	–	–	–
Aricidea jeffreysii	–	1	–	–	–
Eteone sp.	–	–	1	–	–
Euchone sp.	–	–	2	–	–
Nephtyidae sp.	–	–	–	1	–
Clymenella torquata	–	–	–	1	1
Eteone cf. *heteropoda*	–	–	–	–	1
Asabellides sp.	–	–	–	–	2
Mollusca*					
Ensis directus	V	D	1	D	–
Cerastoderma pinnulatum	1	V	–	–	–
Astarte castanea	V	–	–	–	–
Placopecten magellanicus	–	V	–	–	V
Astarte undata	–	–	V	V	–
Venericardia borealis	–	–	V	–	–
Arctica islandica	–	–	V	V	V
Trachycardium muricatum	–	–	V	–	–
Polinices immaculatus	–	–	–	2	–
Spisula solidissima	–	–	–	–	V
Crustacea					
Trichophoxus epistomus	6	5	2	6	1
Siphonoecetes smithianus	–	1	–	–	–
Ampelisca aequicornis	–	1	–	–	–
Unciola irrorata	–	–	–	1	–
Byblis serrata	–	–	–	1	–
Phoxocephalus holbolli	–	–	–	1	–
Protohaustorius wigleyi	–	–	–	–	1
Others*					
Callopora sp.	P	–	–	–	–
Echinarachnius parma	–	5	–	1	2
Ophiuroidea sp.	–	–	–	–	1

* D – Dead gastropod or dead valves joined together
V – Separate valve
P – Present

Table 28

Occurrence of Benthic Invertebrates at Station 17 (Quicksilver)

Species	Sample 33	34	35	36	37
Polychaeta					
Clymenella sp.	4	2	1	6	-
Lumbrinereis acuta	4	-	-	-	-
Chaetozone sp.	1	-	-	-	-
Aricidea jeffreysii	-	1	1	-	-
Cirratulidae sp.	-	1	-	-	-
Nephtys picta	-	-	1	-	-
Aricidea wassi	-	-	2	-	-
Nephtys bucera	-	-	1	-	-
Sigalion arenicola	-	-	-	1	-
Spiophanes bombyx	-	-	-	1	-
Scolecolepides viridis	-	-	-	-	2
Mollusca*					
Spisula solidissima	V	V	V	1	V
Tellina agilis	V	V	V	V	V
Venericardia borealis	V	-	-	V	-
Crenella glandula	V	V	V	D	V
Astarte castanea	V	V	-	V	-
Cerastoderma pinnulatum	D	-	V	V	V
Busycon canaliculatum	D	-	-	-	-
Crepidula plana	D	D	D	-	D
Nassarius trivittatus	D	D	-	-	-
Anomia simplex	V	V	-	V	V
Pandora trilineata	V	-	1	-	-
Astarte undata	-	-	V	-	-
Caecum cooperi	-	-	D	-	-
Anadara transversa	-	-	V	-	-
Abra lioica	-	-	V	-	-
Corbula contracta	-	-	-	V	-
Ensis directus	-	-	-	D	-
Natica pusilla	-	-	-	D	-
Pandora gouldiana	-	-	-	V	-
Marginellidae sp.	-	-	-	V	-
Placopecten magellanicus	-	-	-	-	V
Margarites groenlandicus	-	-	-	-	V
Crustacea					
Trichophoxus epistomus	1	6	2	2	1
Cirolana polita	1	-	-	-	1
Protohaustorius wigleyi	-	2	1	1	2
Cirolana impressa	-	-	1	1	-
Ampelisca aequicornis	-	-	-	-	1
Byblis serrata	-	-	-	-	1

Table 28 (continued)

Species	Sample 33	34	35	36	37
Others					
Echinarachnius parma	1	2	3	4	3
Nemertean sp. #2	-	-	-	1	-

* D - Dead gastropod or dead valves joined together
V - Separate valve

Table 29

Occurrence of Benthic Invertebrates at Station 1
(Fetch)

Species	Sample 01	Sample 02	Sample 03
Polychaeta			
Spiophanes bombyx	7	16	1
Harmothoe imbricata	-	1	1
Nephtys picta	-	1	1
Glycera capitata	-	1	1
Exogone verugera	1	2	-
Spiophanes wigleyi	1	1	1
Nephtys cf. picta	3	2	-
Goniadella gracilis	-	1	1
Phyllodoce mucosa	-	1	-
Aricidea wassi	-	-	3
Caulleriella killariensis	1	-	-
Magelona cf. phyllisae	-	-	1
Mollusca*			
Ensis directus	V	-	V
Cerastoderma pinnulatum	V	-	V
Spisula solidissima	V	-	-
Venericardia borealis	1	-	-
Margarites groenlandicus	-	D	D
Arthropoda			
Eudorellopsis deformis	1	1	-
Trichophoxus epistomus	4	2	10
Ptilanthura tricarina	-	1	-
Byblis serrata	-	4	-
Protohaustorius wigleyi	-	1	1
Others*			
Echinarachnius parma	1	-	-
Polygordius sp.	50	153	36
Nemertean sp.	-	1	-
Oligochaete sp. A.	-	-	1

* D - Dead gastropod or dead valves joined together
V - Separate valve

Table 30

Occurrence of Benthic Invertebrates at Station 2 (Fetch)

Species	Sample 01	Sample 02	Sample 03
Polychaeta			
Nephtys picta	–	4	–
Spiophanes bombyx	1	4	7
Glycera capitata	2	–	–
Exogone verugera	4	2	10
Nephtys cf. *picta*	5	–	7
Travisia carnea	–	1	–
Aricidea wassi	2	1	–
Aricidea jeffreysii	1	1	–
Tharyx sp.	–	1	1
Lumbrinereis acuta	1	–	4
Aricidea suecica	–	–	1
Tharyx cf. *acutus*	–	–	2
Cirratulidae sp.	–	–	1
Streptosyllis arenae	2	–	3
Parapionosyllis longocirrata	–	–	1
Caulleriella killariensis	2	–	2
Aglaophamus circinata	3	–	–
Mollusca*			
Ensis directus	–	–	1
Cerastoderma pinnulatum	–	1	V
Spisula solidissima	–	V	–
Venericardia borealis	1	V	V
Margarites groenlandicus	D	–	–
Retusa canaliculata	D	–	–
Trachycardium muricatum	1	–	-
Capulus ?	D	–	-
Placopecten magellanicus	V	V	V
Anomia simplex	–	V	–
Astarte subequilatera	–	–	V
Crenella glandula	–	–	V
Arthropoda			
Trichophoxus epistomus	11	8	4
Byblis serrata	6	5	5
Protohaustorius wigleyi	8	2	5
Cirolana polita	2	2	6
Ampelisca aequicornis	1	–	1
Acanthohaustorius millsi	1	–	–

Table 30 (continued)

Species	Sample 01	02	03
Arthropoda (continued)			
Unciola irrorata	2	-	-
Cirolana impressa	-	1	-
Tanaissus lilljeborgi	-	2	2
Pseudounciola obliquua	-	1	-
Others			
Echinarachnius parma	3	2	1
Polygordius sp.	141	83	149
Nemertean sp.	3	4	24
Arbacia punctulata	9	6	6

* D - Dead gastropod or dead valves joined together
V - Separate valve

Table 31

Occurrence of Benthic Invertebrates at Station 5 (Fetch)

Species	Sample 01	02	03
Polychaeta			
Nephtys picta	1	-	-
Spiophanes bombyx	9	6	5
Exogone verugera	-	1	-
Goniadella gracilis	1	-	-
Phyllodoce mucosa	-	-	1
Glycera dibranchiata	1	3	2
Nephtys incisa	-	1	-
Clymenella torquata	1	1	-
Eteone ?	-	1	-
Glyceridae	-	-	1
Nereis sp.	-	-	1
Clymenella sp.	-	-	1
Spionidae ?	-	-	1
Aricidea sp.	3	-	-
Phyllodocidae	3	-	-
Mollusca*			
Ensis directus	-	V	-
Spisula solidissima	-	V	-
Venericardia borealis	V	V	V
Margarites groenlandicus	D	-	-
Placopecten magellanicus	-	V	V
Anomia simplex	-	-	V
Astarte subequilatera	-	V	-
Corbula contracta	V	-	-
Lyonsia hyalina	1	-	-
Colus pygmaea	D	-	D
Nucula proxima	-	1	-
Mytilus edulis	-	-	V
Arctica islandica	-	-	V
Arthropoda			
Trichophoxus epistomus	4	3	7
Byblis serrata	-	-	1
Ampelisca aequicornis	-	1	-
Others*			
Echinarachnius parma	1	5	6

Table 31 (continued)

Species	Sample 01	02	03
Others (continued)*			
Polygordius sp.	11	-	30
Microporella ciliata	-	-	P
Callopora sp.	-	-	P

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 32

Occurrence of Benthic Invertebrates at Station 8
(Fetch)

Species	Sample 01	02	03
Polychaeta			
Nephtys picta	–	2	–
Glycera capitata	–	1	–
Exogone verugera	1	–	1
Goniadella gracilis	8	18	32
Travisia carnea	1	–	3
Aricidea jeffreysii	8	6	14
Lumbrinereis acuta	–	6	12
Tharyx cf. acutus	–	–	2
Parapionosyllis longocirrata	29	18	5
Caulleriella killariensis	1	–	1
Nephtys incisa	3	–	–
Clymenella torquata	4	4	–
Tharyx marioni	1	–	–
Tharyx setigera	1	–	–
Lumbrinereis fragilis	–	1	–
Sigalion arenicola	–	2	–
Chaetozone setosa	–	3	–
Clymenella zonalis	–	–	10
Sphaerosyllis hystrix	5	–	–
Mollusca*			
Ensis directus	V	–	–
Cerastoderma pinnulatum	–	V	–
Spisula solidissima	V	V	V
Venericardia borealis	V	V	–
Placopecten magellanicus	–	V	V
Anomia simplex	V	V	–
Crenella glandula	V	–	V
Lyonsia hyalina	1	–	–
Arctica islandica	V	V	V
Tellina agilis	V	–	–
Crepidula fornicata	D	–	–
Crepidula plana	–	D	–
Polinices duplicatus	–	D	–
Arthropoda			
Byblis serrata	1	–	–
Cirolana polita	–	1	–
Ampelisca aequicornis	–	1	–

Table 8 (continued)

Species	Sample 01	02	03
<u>Arthropoda</u> (continued)			
<u>Unciola irrorata</u>	4	9	1
<u>Tanaissus lilljeborgi</u>	1	-	-
<u>Cancer irroratus</u>	-	-	1
<u>Others</u>			
<u>Polygordius</u> sp.	139	351	3
<u>Arbacia punctulata</u>	2	1	-
<u>Astrorhiza</u> sp.	4	-	3
Scaphopoda	2	-	-
Oligochaete A.	2	-	-

* D - Dead gastropod or dead valves joined together
V - Separate valve

Table 33

Occurrence of Benthic Invertebrates at Station 9
(Fetch)

Species	Sample 01	Sample 02	Sample 03
Polychaeta			
Spiophanes bombyx	--	--	1
Glycera capitata	-	-	1
Exogone verugera	2	3	7
Goniadella gracilis	-	5	1
Lumbrinereis acuta	4	2	1
Tharyx cf. marioni	-	1	-
Glycera dibranchiata	1	-	1
Clymenella torquata	1	8	-
Paraonis sp.	1	-	-
Aricidea sp.	1	-	-
Paraonis lyra	-	2	-
Polydora caulleryi	-	1	-
Brania ?	-	2	-
Phyllodocidae	-	1	1
Caulleriella sp.	-	2	-
Asabellides sp.	-	-	1
Clymenella zonalis	-	-	2
Syllis cornuta	-	1	-
Lumbrinereis latereilli	-	-	1
Mollusca*			
Cerastoderma pinnulatum	2	-	V
Spisula solidissima	V	V	-
Margarites groenlandicus	-	D	-
Placopecten magellanicus	V	-	-
Tellina agilis	1	-	-
Cumingia ?	2	-	-
Arthropoda			
Trichophoxus epistomus	3	-	2
Byblis serrata	7	11	14
Protohaustorius wigleyi	2	-	-
Ampelisca aequicornis	-	-	1
Unciola irrorata	3	-	6
Tanaissus lilljeborgi	-	1	-
Pseudunciola obliqua	2	2	1
Cancer irroratus	-	1	-
Cancer borealis	-	1	-
Phoxocephalus holbolli	-	-	1

Table 33 (continued)

Species	Sample 01	02	03
<u>Others</u>*			
Echinarachnius parma	-	3	3
Polygordius sp.	462	322	109
Nemertean sp.	2	-	-
Arbacia punctulata	3	-	-
Microporella ciliata	P	-	-
Astrorhiza sp.	-	-	2

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 34

Occurrence of Benthic Invertebrates at Station 11 (Fetch)

Species	Sample 01	Sample 02	Sample 03
Polychaeta			
Nephtys picta	1	8	4
Exogone verugera	-	7	7
Goniadella gracilis	17	70	31
Aricidea jeffreysii	1	2	1
Lumbrinereis acuta	12	16	7
Tharyx cf. acutus	-	1	-
Cirratulidae sp.	1	-	-
Parapionosyllis longocirrata	-	4	2
Caulleriella killariensis	-	2	-
Clymenella torquata	5	-	-
Tharyx setigera	-	3	-
Paraonis lyra	-	1	-
Asabellides sp.	1	-	-
Stauronereis rudolphi	1	1	1
Clymenella zonalis	-	7	3
Syllis cornuta	-	2	-
Orbinia ornata	-	-	1
Lumbrinereis latereilli	-	-	1
Mollusca*			
Ensis directus	V	-	V
Cerastoderma pinnulatum	1	1	V
Venericardia borealis	-	1	-
Placopecten magellanicus	V	-	V
Lyonsia hyalina	-	1	-
Arctica islandica			
Crepidula fornicata	-	-	D
Crepidula plana	D	-	-
Polinices duplicatus	1	-	-
Lunatia heros	D	-	D
Arthropoda			
Pyblis serrata	-	-	1
Cirolana polita	-	-	1
Ampelisca aequicornis	1	2	3
Unciola irrorata	11	18	5
Tanaissus lilljeborgi	1	10	2
Phoxocephalus holbolli	-	2	-

Table 34 (continued)

Species	Sample 01	02	03
Others*			
Ecninarachnius parma	–	1	–
Polygordius sp.	60	177	214
Nemertean sp.	–	19	5
Arbacia punctulata	–	4	2
Microporella ciliata	–	V	–
Callopora sp.	–	V	–
Astrorhiza sp.	–	–	2
Schizoporella errata	–	V	–
Sertularia argentea	V	–	–
Oligochaete A.	–	2	4
Oligochaete B.	–	7	–

* D - Dead gastropod or dead valves joined together
V - Separate valve

Table 35

Occurrence of Benthic Invertebrates at Station 14
(Fetch)

Species	Sample 01	02	03
Polychaeta			
Nephtys picta	-	1	-
Spiophanes bombyx	3	13	2
Glycera capitata	1	1	-
Exogone verugera	-	-	9
Nephtys cf. picta	1	-	-
Goniadella gracilis	1	-	2
Aricidea wassi	-	4	-
Aricidea jeffreysii	-	-	7
Lumbrinereis acuta	-	-	1
Streptosyllis arenae	1	-	-
Aglaophamus circinata	-	1	-
Clymenella torquata	-	-	1
Stauronereis rudolphi	-	-	2
Potamilla neglecta	1	2	1
Maldanidae sp.	-	-	1
Nereis grayi	-	1	-
Scalibregma inflatum	-	-	2
Neoleanira tetragona	1	-	-
Pherusa affinis	-	1	-
Scoloplos fragilis	-	1	-
Mollusca*			
Ensis directus	-	V	V
Cerastoderma pinnulatum	V	V	V
Venericardia borealis	-	V	-
Margarites groenlandicus	D	-	1
Trachycardium muricatum	V	-	-
Capulus ?	-	D	-
Placopecten magellanicus	-	V	-
Crenella glandula	-	-	D
Colus pygmaea	-	V	V
Arctica islandica	V	V	V
Lunatia heros	D	D	-
Retusa obtusa	-	D	-
Turbonilla interrupta	-	D	-
Astarte borealis	-	V	V
Arthropoda			
Trichophoxus epistomus	7	12	7

Table 35 (continued)

Species	Sample 01	02	03
Arthropoda (continued)			
Byblis serrata	–	8	–
Protohaustorius wigleyi	–	2	8
Leptocheirus pinguis	–	4	–
Others*			
Echinarachnius parma	–	1	2
Polygordius sp.	–	50	104
Nemertean sp.	5	–	–
Arbacia punctulata	1	2	7
Microporella ciliata	–	–	V
Callopora sp.	–	V	–
Ophiuroidea	1	1	–

* D – Dead gastropod or dead valves joined together
V – Separate valve

Table 36

Occurrence of Benthic Invertebrates at Station 17 (Fetch)

Species	Sample 01	02	03
Polychaeta			
Nephtys picta	10	-	4
Spiophanes bombyx	7	21	13
Exogone verugera	21	57	42
Spiophanes wigleyi	-	1	-
Nephtys cf. picta	-	4	-
Goniadella gracilis	-	1	3
Aricidea wassi	-	2	-
Aricidea jeffreysii	3	1	1
Tharyx sp.	1	-	-
Lumbrinereis acuta	1	1	3
Cirratulidae sp.	-	1	-
Streptosyllis arenae	3	7	-
Parapionosyllis longocirrata	9	45	43
Caulleriella killariensis	3	4	-
Clymenella torquata	-	4	-
Clymenella sp.	7	-	-
Tharyx marioni	-	-	1
Lumbrinereis fragilis	2	3	-
Tharyx cf. setigera	-	-	1
Sigalion arenicola	-	3	2
Chaetozone setosa	-	1	-
Polydora caulleryi	2	-	-
Caulleriella sp.	-	-	1
Asabellides sp.	-	1	-
Stauronereis rudolphi	2	-	-
Ophelia denticulata	-	1	-
Syllides longocirrata	-	4	-
Syllis sp.	-	1	-
Clymenella zonalis	-	1	7
Sphaerosyllis hystrix	-	1	1
Drilonereis magna	-	-	1
Nereis grayi	-	-	1
Lumbrinereis coccinea	-	-	1
Mollusca*			
Cerastoderma pinnulatum	D	1	V
Spisula solidissima	V	-	V
Venericardia borealis	-	V	D
Retusa canaliculata	D	-	-
Placopecten magellanicus	-	-	V

Table 36 (continued)

Species	Sample 01	02	03
Mollusca (continued)*			
Anomia simplex	V	-	V
Crenella glandula	V	-	V
Arctica islandica	-	-	V
Tellina agilis	-	V	V
Crepidula fornicata	D	-	-
Crepidula plana	-	-	D
Pandora trilineata	D	1	-
Vitrinella cf. helicoidea	-	D	D
Arthropoda			
Trichophoxus epistomus	7	3	9
Protohaustorius wigleyi	8	3	4
Unciola irrorata	-	1	1
Edotea triloba	-	-	1
Others*			
Echinarachnius parma	2	-	1
Polygordius sp.	97	745	415
Nemertean sp.	6	32	18
Arbacia punctulata	3	18	8
Astrorhiza sp.	2	-	1

2. Macrobiota

Macrobiota collected during Operation Fetch are listed in Table 37. Collection was either by using a Fall River "rocking chair" dredge or a 16-foot otter trawl. That the otter trawl fished bottom was shown by the occurrence of benthic invertebrates. A total of 19 species were collected. Of this number 7 were molluscans and 6 fishes. The remaining species were distributed among the Porifera, Arthropoda, Cnidaria, and Echinodermata. Collection of macrobiota was primarily for metals analyses but physical condition of organisms was noted. Organisms showed no outward signs of stress (e.g. fin rot) Previous work in the dump site (Palmer and Lear, 1973) included deploying a trawl at Station 2. Recovery of Echinodermata and 4 species of fishes was recorded. Organisms were also regarded as healthy.

√ Rocking chair dredge
x Otter trawl

Table 37
MACROBIOTA

		Stations														
		A	5	17	14	2	1	E	G	H	C	11	8	9	D	B
Porifera																
Suberites sp.	Sponge	√		√							x					
Cnidaria																
Aurelia sp.	Jellyfish				√	x										
Mollusca																
Astarte sp.				√		√										
Arctica islandica		√	√	√	√	√	√	√	√	√	√	√	√	√	√	
Placopecten magellanicus	Scallop		√	√	√	√	√				√	√	√	√		
Polinices immaculatus	Drill		√	√	√	x√	√				√		√			√
Modiolus modiolus	Horse mussel									√						√
Spisula solidissima	Surf clam			√					√	√				√		
Loligo pealei	Squid	√	√					x√								
Arthropoda																
Cancer irroratus	Crab			√	√				√	√	x					
Pagurus sp.	Hermit crab			√		x√		x								
Echinopermata																
Echinarachnius parma	Sand dollar	√	√	√	√		√	x√	√		√	√		√		
Asterias sp.	Starfish			√	√				√		x					
Pisces																
Prionotus carolinus	Sea robin		√					x								
Raja sp.	Skate	√	x					x	√		x					
Peprilus cuvier	Butterfish		√	√		x										
Scombresox saurus	Saury			√												
Pseudopleuronectes americanus	Flounder					x	√									
Stenotomus crysops	Scup		√													

3. Metals in Macrobiota

The introduction of non-biodegradable materials, with a potential for toxicity, into the food web of the biota is of prime concern in the management of ocean disposal practices. Other field observations have consistently shown detectable increases of metals in the benthic biota (Buelow, 1968; Davey, 1972; Palmer and Lear, 1973; Vaccaro, et al, 1972).

Table 38 shows iron and copper concentrations in the tissue of five species of benthic invertebrates, *Echinarachnius parma*, the sand dollar, *Pecten (Placopecten) magellanicus*, the sea scallop, *Artica icelandica*, the mahogany clam, *Polinices heros*, the moon snail, and *Spisula solidissima*, the surf clam. In the case of *Pecten* and *Spisula*, large enough animals were occasionally collected to permit the separation of the adductor muscle (the part normally eaten in the scallop) from the viscera and foot so that each could be evaluated separately and the results combined for the total animal measurements.

Metal determinations were made through atomic absorption spectrophotometry after HNO_3 digestion of the tissue and ashing at 425°C for 24 hours. The results are reported as micrograms of metal per gram of tissue ash or in the case of the sand dollars per gram of dry tissue (parts per million).

The following observations and conclusions may be derived from the results:

1. In general, the iron concentration in sand dollars was found to be significantly less (7-10 times) than those reported for the same

station for the QUICKSILVER Cruise in May 1973 (Palmer and Lear, 1973). This is consistent with the University of Delaware-Hydroscience study of the acid waste site (duPont, 1972) in which the conclusion is reached that the summer thermocline prevents dumped material from reaching the bottom while the lack of a thermocline in winter permits such exposure. Thus, samples were taken after the summer protection period. This also suggests that the iron is subsequently lost seasonally rather than permanently accumulated indicating possibly surface adsorption rather than ingestion. In any case, these values would be expected to rise again by the time of the proposed sampling next May.

2. The copper concentration in sand dollars was found to have increased consistently since last May. This suggests that copper is not lost seasonally but is permanently and continuously incorporated in the tissues from residual sediment accumulations. Whether or not such accumulations are present has yet to be determined from the sediment samples collected. Both of the foregoing conclusions depend heavily on the dynamics of sand dollar populations in the area. Since the University of Delaware-Hydroscience study (du Pont, 1972) postulates a significant winter kill (November-March), observed accumulations result from the complex interaction of animal age (hence length of exposure), dumping times which correspond to the presence or absence of a thermocline, and the presence or absence of large viable populations to receive such material such that there is definitely not a uniform deposition and uptake pattern over the months.

3. The separated samples of Pecten and Spisula show higher concentration of both metals in the gut portion than in the adductor muscle portion as might be expected since the former contains transient amounts contained in the food and gut linings while the latter contains only that incorporated into muscle tissue. The whole-animal measurement approach the viscera measurements because of the much higher concentrations and proportionate weights of the latter. It is worth noting here that the copper levels in both shellfish are much lower than those found in coastal oysters. The iron concentration in the viscera of both shellfish are the highest measured, further substantiating the idea that iron, while in high concentration in the environment, is largely passively taken up by the animals and only slightly metabolized.

4. Other differences between samples are not markedly demonstrated by the iron concentrations (sand dollar measurements cannot be compared thus because of the different weight bases); however, with respect to copper, it is clearly obvious that the levels in Polinices are up to 10 times greater than those found in the other shellfish. This is of particular importance because Polinices feeds directly on other shellfish, hence the amounts observed are the result of the consumption and bioaccumulation of copper from that contained in the tissue of other shellfish and not the passage of the dumped waste itself. Further examples of this common phenomenon are expected when the analyses for other metals, now in progress, are completed.

5. The minimal differences in the results observed between the stations in the two dump sites and those more remote locations is again perhaps due to the seasonal variation in deposition as a result of the presence or absence of a thermocline. In the summer, it would be expected that the material being dumped in both sites would be mixed and well distributed in the surface water before it eventually reaches the bottom in a much more uniform depositional pattern than would be expected from the disposal of a more dense and compacted material. All of the foregoing, it must be emphasized, overlooks any consideration of short dumping which would have a profound effect on the results and their interpretation.

Table 38

Metal Concentrations in Echinoderm and Mollusc Tissue

IRON (μgm/gm)

	NE Control		SW Control			Sludge Dumpsite			
	14	9	17	1	2	5	8	11	E
Echinarachnius	29.0	44.9	24.7	54.0		53.8	291.0	273.0	21.6
Arctica	628.0	973.0	1320.0	1160.0	862.0	680.0	1250.0	976.0	1140.0
Pecten muscle only	636.0		553.0				270.0	1480.0	
Pecten viscera & foot	3120.0		3980.0				5010.0	8780.0	
Pecten total	2590.0	1670.0	2600.0	2880.0	1320.0	4060.0	4100.0	6680.0	
Polinices	1930.0		3480.0	2160.0	2070.0	2680.0	3170.0		
Spisula total		4150.0	1300.0						
Spisula muscle only		1600.0							
Spisula viscera & foot		4690.0							

Table 38 (continued)

Metal Concentrations in Echinoderm and Mollusc Tissue

COPPER (μgm/gm)

	NE Control		SW Control	Sludge Dumpsite					
	14	9	17	1	2	5	7	11	E
Echinarachnius	6.42	7.5	7.08	4.8		7.0	6.23	6.58	5.8
Arctica	20.2	22.1	20.7	27.9	24.1	20 0	19.9	16.0	19.1
Pecten muscle only	15.7		12.8				15.6	11.3	
Pecten viscera & foot	27.8		81.2				29.1	47.9	
Pecten total	25.4	45.0	53.7	32.9	23.8	46.8	26.5	37.0	
Polinices	142.0		197.0	302.0	236.0	160.0	209.0		
Spisula total		28.9	38.8						
Spisula muscle only		19.2							
Spisula viscera & foot		48.3							

Table 38 (continued)

Metal Concentrations in Echinoderm and Mollusc Tissue

IRON (μgm/gm)

	Acid Waste Dumpsite				Near Acid Waste Site	
	C	D	G	B	A	H
Echinarachnius	18.40		45.0		29.9	
Arctica	6090.0	792.0	1370.0		8160.0	915.0
Pecten muscle only	1870.0					
Pecten viscera & foot	5770.0					
Pecten total	4490.0		2790.0			
Polinices	3110.0			1810.0		
Spisula total			4490.0			6850.0
Spisula muscle only						2620.0
Spisula viscera & foot						7750.0

Table 38 (continued)

Metal Concentrations in Echinoderm and Mollusc Tissue
COPPER (μgm/gm)

	Acid Waste Dumpsite				Near Acid Waste Site	
	C	D	G	B	A	H
Echinarachnius	5.84		6.01		5.91	
Arctica	40.5	20.1	28.8		56.6	23.0
Pecten muscle only	32.0					
Pecten viscera & foot	56.7					
Pecten total	48.6		22.9			
Polinices	199.0			205.0		
Spisula total			28.8			25.1
Spisula muscle only						17.4
Spisula viscera & foot						26.8

Heavy metals in randomly selected benthic macrofauna samples are shown in Table 39 . These samples were selected to phylogenetically scan some of the available biota, in contrast to the systematic comparison of metal levels in sand dollars and mahogany clams from all stations (vide supra).

Samples of the viscera of fish show higher levels of Fe, Mn, Ni, Zn, Pb, and Cu than in flesh or gonads, probably reflecting the ingestion of materials. Chromium, cadmium and mercury do not seem to be similarly distributed.

While most of the samples shown in Table 39 are from organisms from the acid waste dumpsite, a comparison with organisms from the sewage sludge dumpsite, before dumping operations began, is instructive (Palmer and Lear, 1973).

There are apparently greater concentrations of Mn, Ni, Pb, and Cd in the organisms generally at this later time at the acid waste site, although the paucity of data precludes statistical comparison.

The available evidence suggests accumulations of metals at these sites, and accumulation of statistically significant bodies of data as a function of time, space and phylogeny is indicated.

Table 39

Operation "Fetch"

Heavy Metals in Benthic Macrofauna
(mg/kg wet weight)

	Station	Fe	Mn	Ni	Zn	Pb	Cu	Cr	Cd	Hg
Sponge (Suberites sp)	C	70.8	1.5	0.9	6.5	1.7	1.3	0.9	0.4	0.22
Starfish (Asterias sp)	C	52.1	4.6	5.9	51.3	7.3	3.2	1.7	0.1	0.23
Crab fat (Cancer pagurus)	C	153.6	4.3	2.2	19.0	2.2	32.8	1.6	3.3	0.14
Crab eggs	C	19.8	1.9	9.2	37.9	1.1	17.3	<0.2	2.7	0.19
Skate viscera (Raja sp)	C	65.7	3.1	2.6	22.3	2.1	10.7	0.8	1.4	0.24
Skate viscera	E	45.2	1.5	12.5	9.9	0.9	9.7	1.2	0.5	7.79
Sea robin viscera (Prionotus carolinus)	E	105.2	5.5	2.8	43.1	2.0	12.0	1.2	0.5	0.07
Sea robin muscle	E	4.5	<0.1	1.0	2.1	1.3	1.0	0.4	0.8	0.14
Skate muscle	A	4.9	<0.1	0.6	5.3	<0.3	0.2	0.2	1.4	0.37
Skate gonads	A	15.4	2.4	<0.3	16.4	0.4	1.7	1.0	1.7	0.05
Skate viscera	A	68.9	2.0	15.9	14.3	1.5	3.8	0.2	1.1	0.23
Flounder viscera	#1	101.4	1.7	2.6	18.5	1.7	4.2	<0.2	0.6	0.47
(Pseudopleuronectes americanus)	#1	6.9	0.2	0.3	4.0	1.8	1.0	1.0	1.2	0.43
Spisula solidissima	#17	47.8	1.9	2.7	9.6	<0.3	1.6	1.4	0.2	0.41

4. Bacteriology

Baseline conditions for the area are described in a report by EPA, Region III, previously cited (Palmer and Lear, 1973). Results from another study in relatively close proximity to this study area are reported by the U. S. Public Health Service (Buelow, 1968).

Twelve bacteriological stations were occupied in the vicinity of two interim ocean dumpsites. Stations 14, 17, 9, and A were control areas outside the sites while the remainder of the stations were located in the immediate sites. Stations B and C were occupied in the interim site for disposal of industrial acid wastes. Numerical stations and Station E were located in the interim area designated for the disposal of municipal sludge.

Water samples were taken from varying depths 1.5 m from the bottom with a Niskin sterile bag sampler (General Oceanics, Inc.). Sediments were subsampled, using a 2.7 ml flame-sterilized cylindrical spoon, from an undisturbed Shipek bottom grab. Samples were introduced into a French square bottle containing 100 ml sterile distilled water. These were treated as normal bacteriological samples.

Standard total coliform and fecal coliform MPN's (most probable number/100 ml sample) were estimated following analyses outlined in "Standard Methods for the Examination of Water and Wastewater," 13th Ed., APHA, 1971. A 3-tube, 4-dilution scheme was employed using sample aliquots of 10, 1.0, 0.1, and 0.01 ml. Water from a sterile dilution blank was used as a laboratory control.

MPN results are shown in Table 40. A negative result indicates an MPN index of <3 coliforms/100 mo sample at the 95% confidence limit. Positive coliform counts were recorded for Stations 9 and A. Station 9 had 3.0 coliforms in sediment sampled while Station A had a 23 MPN in the water column. Fecal coliforms were not found at any station. The laboratory controls were negative for both coliforms and fecal coliforms.

Discussion

Previous data (Palmer and Lear, 1973) indicated a 4 MPN coliform count for Station 9 in the water column. Data gathered from this cruise show a MPN coliform count of 3.0 in sediment sampled for the same station. Both counts could possibly be due to the proximity of the station to shore. This might also apply to the 23 MPN count detected at Station A in the water column. Wastes from ocean-going ships is another possible source of contamination. However, results indicate an aqueous environment relatively free from terrestrial bacteriological influences.

Table 40

Coliforms, Fecal Coliforms in Water Column and Sediments (MPN/100 ml) Operation "Fetch

Sample No.	Station	Date	Time	Depth(ft)	(m)	Sample	Coliform	Fecal Coliform
FE7309011101	1	11-9-73	0200	155'	47.2	Water	-	-
FE7309011201	1	11-9-73	0200	155'		Sediment	-	-
FE7309021101	2	11-9-73	0950	145'	44.2	Water	-	-
FE7309022101	2	11-9-73	0950	145'		Sediment	-	-
FE7307051101	5	11-7-73	0500	145'		Water	-	-
FE7307052101	5	11-7-73	0500	145'		Sediment	-	-
FE7309081101	8	11-9-73	0300	125'	38.1	Water	-	-
FE7309082101	8	11-9-73	0300	125'		Sediment	-	-
FE7307091101	9	11-7-73	1630	115'	35.1	Water	-	-
FE7307092101	9	11-7-73	1630	115'		Sediment	3.0	-
FE7308111101	11	11-8-73	0800	153'	46.6	Water	-	-
FE7308112101	11	11-8-73	0800	153'		Sediment	-	-
FE7308141101	14	11-8-73	1700	165'	50.3	Water	-	-
FE7308142101	14	11-8-73	1700	165'		Sediment	-	-
FE7307171101	17	11-7-73	2100	117'	35.7	Water	No sample	
FE7307172101	17	11-7-73	2100	117'		Sediment	-	-
FE7309A 1101	A	11-9-73	0700	125'	38.1	Water	23	-
FE7309A 2101	A	11-9-73	0700	125'		Sediment	-	-
FE7309B 1101	B	11-9-73	1300	145'	44.2	Water	-	-
FE7309B 2101	B	11-9-73	1300	145'		Sediment	-	-
FE7309C 1101	C	11-9-73	0300	155'	47.2	Water	-	-
FE7309C 2101	C	11-9-73	0300	155'		Sediment	-	-
FE7305E 1101	E	11-5-73	1730	145'	44.2	Water	-	-
FE7305E 2101	E	11-5-73	1730	145'		Sediment	LA*	LA

*Laboratory accident

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APPENDIX A

PARTICIPANTS IN OPERATION "FETCH" ABOARD R/V ANNANDALE

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John Miller, Captain
Bill Flohr, Mate
Sandy Hislop, Mate
Gary Tasselman, Engineer
Maggie Nugent, Cook

Operation "Fetch"

R/V Annandale

SHIP'S LOG

Date: 11/7/73

Time	Depth	Position 3 H4	3 H5	Comments
1340		3227	3054	
1343		3224	3051	
1430		3231	3051	
1535		3222	3051	On Station 9
1700		3226	3048	
1900		3222	3054	One mile north of 9
2000		3183	3034	Station 17
3115		3196	3037	2 miles NW of 17 (tow) - clam
2200	121'	3183	3029	Wind WNW - back on 17
2325		3178	3026	NW to 8 - 11.4 miles - ETA 0033
0015		3274	3016	
0045	130'	3312	3020	On station 8
0200		3330	3018	
0315		3292	3022	To station 5 - 4 miles - course 62°
0355		3334	3013	On station 5
0625		3346	3013	
0630	157'	3356	3009	Station 2
0730		3362	3018	140
0930		3329	3006	
1000		3343	3007	Start of box search

Date: 11/7/73 (cont.)

Time	Depth	Position 3 H4	Position 3 H5	Comments
1216		3330	3009	End search - cc to 58° for sta. 14 16.5 miles - 98 min. - ETA 1402
1307		3405	2987	cc to 51° - 9.2 miles
1408	170'	3513	2967	On station 14
1650		3511	2963	cc to 238° for sta. 11 - 13.2 miles
1800		3450	2981	
2000	166'	3348	3000	

Date: 11/8/73

Time	Depth	Position 3 H4	Position 3 H5	Comments
2130	156'	3379	3994	Trawl out
2215		3374	2993	Trawl in
2300		3345	3012	
2325	150'	3368	3019	Station 1

Date: 11/9/73

Time	Depth	Position 3 H4	Position 3 H5	Comments
0012		3366	3020	Wind 320/20 G 28
0145		3370	3021	cc to 340° to sta. C - 7.2 miles
0220		3401	3038	
0243	160'	3420	3043	On sta. C
0800	132'	3483	3051	A
0915	3	3459	3027	
0930	149'	3440	3045	B - 2 trawls - small catch
1035	142'	3416	3048	
1105		3415	3029	

Date: 11/9/73 (cont.)

1145		3411	3053	
1215		3422	3432	C
1312	110'	3410	3045	On C end cc 137° - 21 min.
1347	130'	3401	3030	On D
1515	150'	3385	3035	Finished dredge
1538		3389	3038	cc 267° - 4.1 miles
1615	130'	3364	3052	
1625		3360	3053	Station G
0024		3370	3153	
0142	Abeam	BW "DC"		

APPENDIX C

Scientific Log - Operation "Fetch"

11-05-73 - 0900 - Engines needed new injectors

1130 - Underway - cast off brow line - snowing

Delaware light - Loran fix - right on

1300 - Monster buoy - Loran fix - right on

1645 - Station E - anchored

Wind NE 18-20 - rough - 150' depth - thermocline BT 75'

1720 - Hydrocast 35' 70' 110' 150'

1735 - Hydrocast up

1700 - Shipek - 5 drops

1730 - Shipek up (1) 4 biologicals fixed - buffered formalin

(2) 5 pesticides samples

(3) 1 bacti - sed.

(4) 1 particle size

(5) 1 metals

(6) 3 TOC sediments

Probe readings Cona., Sal., Temp. DO

Hydrocast Fe samples - 4

C samples - 4

Bacti sample - 1

Metals in H_2O - 1 gal. 110'

Phyto. - 2 tows - 4 samples

1915 - Station E - up anchor

Rocking chair dredge- many sea clam, oyster, Arctica and Pecten shells, Arctica live and abundant

2030 - Trawl - 15 min.

1 adult, 2 juvenile skates

Sea robins, small fish (juveniles)

Many live sand dollars

Adult and juveni¯e squid, Pagurus

2100 - Departed for Sta. F. Sky cleared, wind NW, rough

2230 - Anchored Station F

Loran 3310, 2985

Depth - 35 fathoms

Shipek - 10 tries - none

Phyto - 2 tows - 4 samples

Rocking chair dredge - 1 try - no samples

Shells - 1 Pecten - 1 Arctica - 1 Spisula

2230 - Hydrocast

Depth 30', 70', 200'

Very rough

2235 - Secured station

2330 - Underway - Bow into sea toward beach & Lewes

Wind NW 40+

Seas up to 18'

11-06-73 - 1330 - Arrived Lewes

Secure MSC dock

11/7/73 - 0700 - Weather advisory indicates 10-20 NW

0853 - Cast off - laying off dock for pictures

0928 - Underway

1345 - Search for buoys on Station 9 - expanding square pattern 1/2 mi. legs - wind NW 10-15,chop

1420 - Radio call to Al Montague - RO

<u>1536 - Station #9</u>

Loran 3051, 3222 - 120'

Drifting

1545 - BT taken

Seabed drifters 01400-01424

Seabed drifters 3631-3640, 3671-3680

Probe readings RS-5

	Cond.	Sal.	Temp.
Surface	42.00	34.00	15.56
10'	41.08	33.24	15.44
20'	41.14	33.22	15.50
30'	44.64	35.33	16.80
40'	45.01	35.54	16.86

Copper cable caught in rocking chair dredge - also many artica

1845 - Trawling

Shipek - 4 drops

No zooplankton tow

1925 - Secured station

Final Loran fix 3224, 3054

1925 - Underway to Station #17

11/7/73 - 2000 - Station #17

Loran 3183, 3034 - 120'

Zooplankton & Phytoplankton tows

2017 - Seabed drifters - 01375-01399

Surface drifters - 3621-3630
3661-3670

2055 - BT

2100 - Clam dredge - very full- many Arctica & sand dollars

No trawl - Steamed back to station

2200 - Anchored - Hydrocast & Shipek

Wind NW 15 - small sea running

Niskin did not trip

2245 - Secured station

2325 - Underway to Station #8

11/8/73 - 0035 - Station #8

Loran 3313, 3020 - 130'

0035 - Shipek down

0055 - Shipek completed

0055 - Hydrocast 20', 60', 110' sterile bag 5' from bottom

0115 - Seabed drifters 01525-01549

0135 - Rocking chair dredge down

0155 - Rocking chair dredge up - no sand dollars -

many Arctica, skate & flounder

0210 - Rocking chair clam dredge back down

0240 Rocking chair clam dredge back up - no sand dollars, 1 Arctica

0245 - Otter trawl - no catch

0325 - Underway to Station #5

0350 - Arrived Station #5

Loran 3334, 3013 158'

0355 - Shipek

0410 - Finished Shipek

0400-0415 - Hydrocast 30' 60' 150'

0420-0450 - Clam dredge - no catch

0455-0515 - Clam dredge reset - no sand dollars, several Arctica

0530 - Trawl deployed

0600 - Trawl up - squid, scup, sea robin, sea nettles

3 sand dollars

0610 - Underway to sta. #2

0630 - Arrived Station #2

Loran 3356, 3014 157'

0640 - Shipek

Hydrocast 30' 60' 150'

0700 - Seabed drifters 01450-01473

01374

01500-01524

0720-0745 - Clam dredge - Astarte , Arctica , scallops,

Policines, hermit crabs, flounder

0830 - Zooplankton & phytoplankton tows - Calm, winds from S

0915 - Otter trawl - jelly fish, 2 small pelagic fish,

did not fish bottom

0945-1225 - Buoy watch

Wind freshened SW 25-30

1225 - Underway to Sta. #14

1415 - Arrived Station #14

Loran 3513, 2967   170'   wind SW 20-25

1420 - Trawl out - few jellyfish - trawled in following sea

one engine - apparently sailed

1445 - Rocking chair clam dredge - scallops

1530 - Phytoplankton & zooplankton tows

1605 - BT, Shipek, hydrocast

Shipek caught best in trough

1605 - Seabed drifters 01425-01449, 1550-1573

Surface drifters 3611-3620

3651-3660, 3641-3650

3601-3610

3681-3690

1650 - Secured Station #14, underway to Station #11

2030 - Arrived Station #11

Loran 3371, 3000   158'

2030 - Seabed drifters 01474-01499

Surface drifters 3751-3760

3691-3700

2030-2110 - Shipek

2040-4055 - Hydrocast 30' 60' 150'

2120 - Clam dredge - starfish, Arctica, Astarte, scallops,

drill Polinices, sand dollars

2125-2150 - Phytoplankton

2200 - trawl - nothing - sailed

2305 - Underway for Sta. #1

2330 - Arrived Station #1

Loran 2368, 3319 160'

2335 Rocking chair clam dredge - good catch

Shipek

Phytoplankton & zooplankton tows

Winds NW 25 knots

11-9-73 - 0239 - Arrived Station C

Loran 3420, 3043 160' raining

0312 - Shipek - Hydrocast

Phytoplankton tow

Rocking chair dredge - small catch of Arctica, starfish

0350 - Reset rocking chair - scallops, Polinices, Arctica, starfish, skate, sponge, Cancer

Tried Ponar drop on BT winch - empty

Underway to Sta. A

0620 - On Station A

Loran 3065, 3505 132'

0625 - Shipek - Hydrocast

Rocking chair dredge - skate, sponge, skatecases, sand dollars, no clams

0800 - Reset clam dredge - no clams, many shells

0855 - Underway to Sta. B

0930 - Station B

Loran 3416, 3048 150'

0935-1000 - Clam dredge - horse mussels, Polinices, skates

1000-1025 - Reset rocking chair clam dredge - no clams

skates & flounder

1 mi. west of B - returned to station

1035 - Shipek - looked very rich in worms, worm cases, small crabs present

1035 - Hydrocast 25' 70' 140'

1120 - Phytoplankton tow

Underway for Sta. C

1230 On Station C (returned to Sta. C)

1235 - Otter trawl - sand dollars, small squid, small flounder, hermit crabs, some dead sand dollars

1330 - Underway for Sta. D

1335 - Station D

Loran 3401, 3030 130'

1335 Surface drifters - 3701-3710

3741-3750

3761-3770

1335 - Hydrocast 30' 60' 125'

1335 - Shipek - 1 sample - broke Shipek

Peterson too light, wouldn't trip

1445-1510 - Rocking chair clam dredge - live Arctica

1520 - Phytoplankton tow

1540 - Underway to Sta. G

Wind NW 25-28 - getting rough

1625 - Station G

Loran 3360, 3053 130'

Anchor dredge - good catch

1645 - Rocking chair dredge

1900 - Station H

Loran 3085, 3360

Rocking chair dredge

1930 - Winds 45+ - Very rough - secured watch

Returning to Lewes

11-10-73 - 0345 - Anchored behind breakwater

0630 - Arrived Lewes