# THE *ARGO MERCHANT* OIL SPILL
# AND ITS EFFECTS ON THE
# BENTHIC ENVIRONMENT OF NANTUCKET SHOALS

Final Report to the MESA Program Office
Environmental Research Laboratory
National Oceanic and Atmospheric Administration
Boulder, Colorado

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NOAA Contract 03-7-022-35123
January, 1977 - April, 1978

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FRONTISPIECE: ARGO MERCHANT WRECK, DECEMBER 22, 1976 (URI photo by Robert Izzo)

## ABSTRACT

The investigations undertaken for NOAA Contract 03-7-022-35123 were concerned primarily with the effect of the ARGO MERCHANT oil spill at Fishing Rip in Nantucket Shoals on sediments of the Nantucket Shoals-Georges Bank area, with emphasis on sediments near the wreck. Sediment samples were collected in a 4000-$km^2$ area on five cruises to the wreck site and the Little Georges Bank area. Sediment hydrocarbon concentrations 40 times higher than background levels were found at three sites -- at the original wreck site, where the stern and midsection have remained; at the present bow location, 3 km SE of the wreck site; and 3 km south of the above two locations. Most of the oil in the sediment was in the form of tar particles or oil droplets (0.03 - 2 mm in diameter), not as coatings on the sediment grains. At most, 10-15 $km^2$ of sediments in the vicinity of the wreck were contaminated with ARGO MERCHANT oil in February, 1977. Results of on-board UV-fluorescence screening of sediments for hydrocarbon content were compared with results from gas chromatography analysis.

The tar particles were inhomogeneously mixed with the sand; heterogeneity was noticed for adjacent stations (a distance of 1-2 km), within replicate grab samples (<100 m) and within individual grab samples (<30 cm). No consistent trend was found for hydrocarbon penetration into the sediment although at the bow section in February hydrocarbons were found as deep as 8-13 cm (the deepest core section available). Extreme, continual erosion and redeposition of sediments by strong tidal currents of the shoals probably produced this inhomogeneous vertical and areal distribution.

Oil droplets were found in the water column above the contaminated

sand in February, 1977. It is postulated that they were dislodged from the sediments by the highly turbulent tidal currents.

Seabed drifters released at the wreck site in late February, 1977, began washing up on Nantucket in June, 1977, confirming that at least one component of the bottom current moved northwest toward shore. Less than 1% of the spilled oil was estimated to have reached the sediment, however; contamination of the coastline by sediment transport via bottom currents was thus not significant in this spill. Tar balls which washed ashore on Cape Cod, Martha's Vineyard, Nantucket and Rhode Island three to four months after the spill were shown not to be ARGO MERCHANT oil.

Seabird observations in January and February, 1977, found that 0-12% of the species observed were oiled, most lightly.

Stations with high sediment hydrocarbon concentrations in February, 1977, were reoccupied on a cruise in July, 1977. Only the sediments at the bow section of the wreck showed any traces of anthropogenic hydrocarbons, which did not match ARGO MERCHANT oil. Sediments between the original wreck site and the present location of the bow section (3 km SE) had only background levels.

In addition to the sediment work, some preliminary studies were done on the effects of this oil on benthic organisms. A slight increase was observed in the density and diversity of interstitial benthic animals at the wreck site from February to July, 1977; this increase may have been a natural seasonal variation. Oil was found in the guts of interstitial harpacticoids and a polychaete species and adhering to the appendages of a burrowing amphipod, all collected at the wreck site; however, any effect on the organisms was not clear.

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# INTRODUCTION

This report gives the results of seven URI investigations funded by NOAA contract 03-7-022-35123 and briefly describes ancillary projects conducted on NOAA-funded cruises.

On December 15, 1976, the tanker ARGO MERCHANT ran aground on Fishing Rip of Nantucket Shoals off the Massachusetts coast. Within one week she had broken into three parts. The stern and midsection remained aground near the original point of impact; the bow section floated off and eventually sank 2.8 km SE of the stern section. Approximately 7.7 million gallons of No. 6 fuel oil was spilled.

Several research groups from the University of Rhode Island, which were already actively engaged in oil spill studies, began to organize after the grounding in order to study the spill if it occurred. An oil spill response center was formed with Mason Wilson and James Quinn as coordinators. The center distributed questionnaires among scientists at URI, EPA, NMFS and other institutions to plan field studies. Over 30 groups responded, requesting ship time or portions of samples. The R/V ENDEAVOR was then committed to field work. Lines of communication were established with the other responding institutions and agencies (Woods Hole Oceanographic Institution, Coast Guard Research and Development Center, the NOAA-SOR team, NMFS and MIT). The observations, station locations, and slick maps of these groups were used in planning the URI field work, to avoid duplication of effort.

The initial studies were of short-term effects of the oil spill. The behavior of the surface oil was observed. Surface and subsurface trajectories were plotted to predict the movement of the oil (Spaulding, in press). A deterministic model for Narragansett Bay oil spills was adapted to predict ARGO MERCHANT oil movement. Overflights were begun to determine the extent of the spill and to observe marine mammals (Winn, Appendix A). The URI emphasis then shifted to studying potential longer-term effects as well.

On January 3-4, 1977, a meeting was held in Woods Hole at which a large group of scientists devised a NOAA cruise plan to determine longer term environmental consequences of the ARGO MERCHANT oil spill. This plan was estimated to cost $255,000. URI had a ship and a mobilized team and was awarded a contract for this work (03-7-022-35123) on January 15, at the reduced funding level of $60,000. A revised cruise plan emphasizing the benthic environment was designed at a meeting at URI on January 21, with elements of the original plan and with available funding and equipment in mind.

The objectives of the contract were: (1) to determine whether ARGO MERCHANT oil had contaminated the sediments at the wreck site area and in the area covered by the surface slick; (2) to inventory the benthic community in the oil spill area; (3) to determine the extent of entrainment of oil in the water column; and (4) to determine sea bird density and distribution in the oil spill area.

Two cruises, EN-003 and EN-004, were made in January and February, 1977. It was found that contamination of the sediments was confined to the immediate vicinity of the wreck.

URI then submitted a second proposal to NOAA to conduct another cruise to collect more benthic organisms at contaminated stations and to determine in finer detail the areal extent of contaminated sediments. An additional $25,051 was awarded on February 22, 1977, primarily for field work. Cruise EN-005 took place in February, 1977, with the following basic objectives: (1) to determine the areal extent of sediment contamination by ARGO MERCHANT oil through on-board UV-fluorescence scanning by Coast Guard personnel; (2) to collect benthic organisms for various investigators; and (3) to deploy bottom drifters at the wreck site and at the farthest extent of sediment contamination.

In July, 1977, a follow-up cruise on the rented vessel SIDE SHOW (SS-001) was made to the wreck site. The objectives of this last cruise were: (1) to determine the extent of weathering of petroleum hydrocarbons from sediments around the ARGO MERCHANT WRECK SITE; (2) to determine the extent of transportation of contaminated sediments from the wreck site; (3) to collect macrobenthos for histopathological studies and chemical analysis for comparison with similar samples collected in February; (4) to collect zooplankton in the area for comparison with similar samples collected in February; and (5) to collect sediment samples to preserve for future meiobenthic studies.

A total of 21 ship days were expended occupying 72 stations, 16 of which were occupied at least twice. The majority of the NOAA funds were used for ship and marine technician costs. Because these cruises were conducted simultaneously with the shakedown of the ship, NSF funded the remainder of the ship-time necessary to complete the field work portion of this program.

On the NOAA-funded cruises, samples and data were also collected for ancillary projects. Several have been completed; some of these samples are still in storage. These projects are listed below.

(1) Determining the depth of sediment contamination. This project has been completed with an EPA grant (Hoffman and Quinn, in press).

(2) Studying the relationship between the hydrocarbon content of sediments and that of benthic organisms. This project has

low priority at present but might be completed in the future in cooperation with EPA.

(3) Determining the density and relative abundance of benthic organisms and their interactions with the oil. Preliminary work on this has been started (Pratt, in press). NMFS funding for this project is pending.

(4) Collecting and preserving sediment samples for future meiobenthic work. The archiving process is complete; sample examination is planned with NMFS funding.

(5) Collecting and describing phytoplankton over contaminated and uncontaminated sediments. The samples are presently being examined as part of a project entitled "Flora of the Northeast Coast" (Hargraves, Appendix A; Hargraves, in preparation).

(6) Collecting contaminated sediment and appropriate controls for laboratory studies. Nutrient flux studies were completed (Rudnick, Appendix A). Additional sediments have been stored for possible later use in EPA winter flounder hatching experiments.

(7) Collecting epibenthos in dredge samples for histopathologic studies. This study is essentially complete with partial funding by API (Brown and Cooper, in press).

(8) Collecting ichthyoplankton for oil effects research at NMFS. These samples are being examined presently at NMFS (Sherman and Busch, in press; Sherman, ed., 1977).

(9) Collecting and describing zooplankton in the areas over contaminated and uncontaminated sediments. This project is essentially complete (Polak, Fillon, Fortier, Cooper and Laniel, in press).

A symposium on the ARGO MERCHANT Oil Spill was held on January 11-13, 1978, under the sponsorship of the Center for Ocean Management Studies at URI. Most of the results of these primary and ancillary projects were presented at this symposium. The conference proceedings were published in October, 1978.

## Sampling

### Sediment

The primary objective of the NOAA contract was to determine the areal extent of sediment contamination. It was decided to examine the most probable areas of contamination first; then, on the basis of these results, the area of sampling could be widened or narrowed.

Oil would most probably be found in the sediments in areas covered by the slick for the longest period of time. Two areas which had been covered by heavy pancake concentrations or consolidated slicks for at least six days were identified from NOAA-USCG slick maps. These areas, labelled "A" and "B," (Fig. 1) are 1200 n.mi$^2$. Area A is the area surrounding the wreck itself, bounded by 41°04'N and 40°54'N latitude and 69°35.2'W and 69°07'W longitude. Area B is an area where heavy concentrations of pancakes and slicks stalled for six days before continuing to head east. Area B, a commercially important fisheries resource area, is bounded by 40°58'N and 40°33'N latitude and 68°53'W and 68°04'W longitude. Stations were selected in each of these two areas.

A regular N-S sampling grid was suggested in the January 3-4 NOAA plan for this survey; such a grid in this area, however, would statistically bias the survey results. Regular N-S grids are appropriate only when there is no N-S function to the parameters being studied. Since depth was postulated to be a factor in the interaction of oil with the sediment, and since the shoals have a N-S alignment, the N-S grid was rejected. Instead, 26 prospective sampling locations were selected randomly within the two areas. These stations are indicated by the prefix A for area A (five stations) or B for area B (21 stations). (For details on the random selection of stations, see the cruise report for EN-003 in Appendix B.)

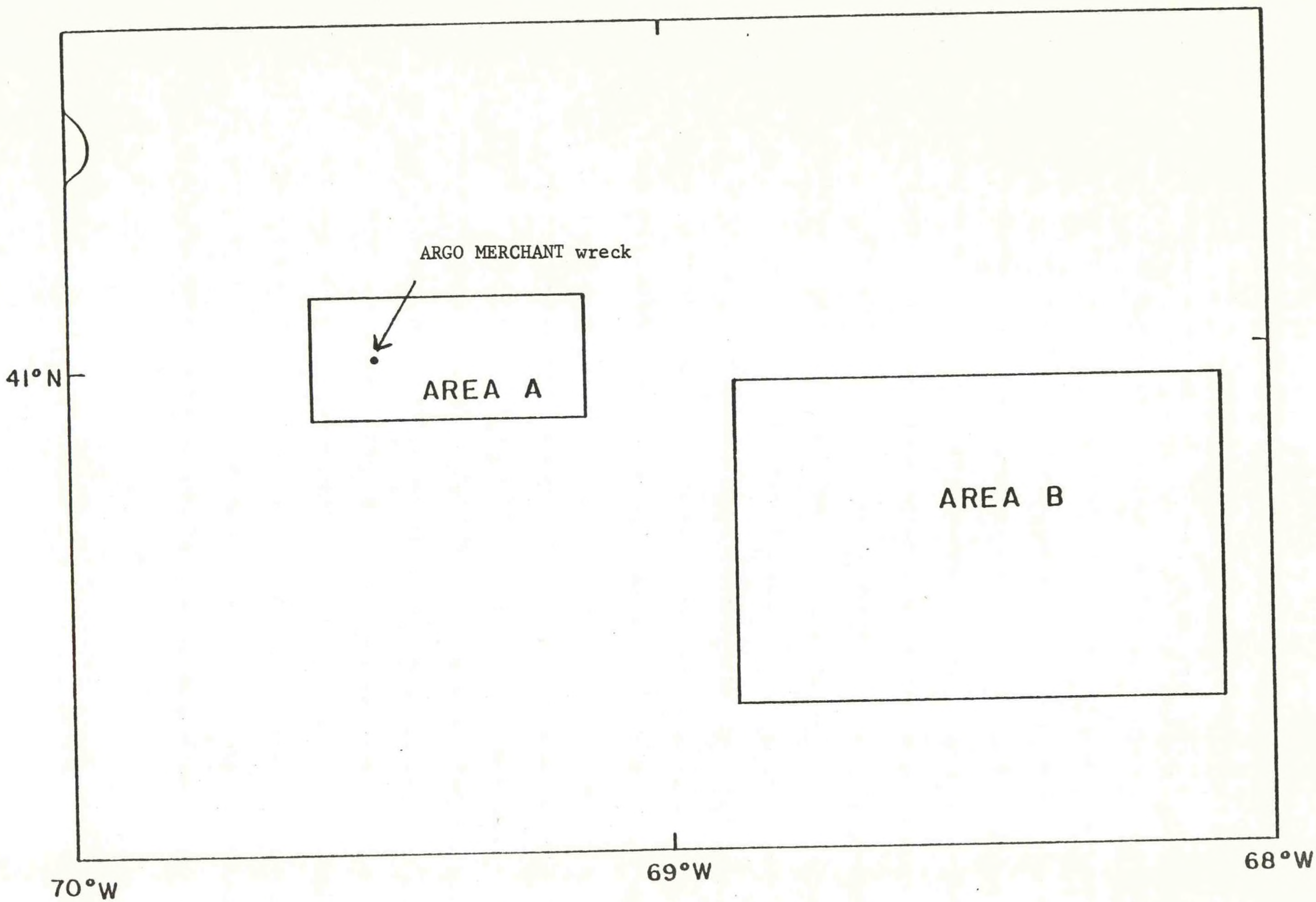


Fig. 1. Sampling areas for cruises EN-003 and EN-004.

The shallower areas within areas A and B were considered more likely to have contaminated sediments than deeper ones. Sediments suspended in the water column might interact with the surface oil; because the sediment-oil mixture would have a higher density than seawater, it would sink when the water was less turbulent. Three stations in shallow areas of A and B were selected to test this hypothesis (C-37, C-39 [ occupied twice ] , C-23).

In the W. Falmouth oil spill in September, 1969, large concentrations of No. 2 fuel oil were mixed into the sediments by turbulent seas in shallow waters. Therefore, three stations were chosen in shallower areas covered by the ARGO MERCHANT slick when the sea state was high (D-24, D-35, D-36).

Other areas where oil might have reached the sediments were considered and rejected as enlarging the search area impracticably.

Stations were also chosen between areas A and B and are indicated by the prefix F. Additional stations chosen at sea on the basis of screening results have the prefix G. Two stations occupied on cruise EN-002 have the letter E as a prefix.

The primary sediment sampling device used in these studies was the Smith-McIntyre grab sampler. The box corer could not be used on R/V ENDEAVOR during EN-003 and EN-004 because the ship's deep-sea winch was not yet operational. The box corer was used occasionally on EN-005 at stations with contaminated grab samples. Each core was trisected for use in different projects.

Surface sediment samples (0-15 cm) from EN-005 and SS-001, collected with a Smith-McIntyre grab sampler, were subdivided. One-half was preserved in formalin for biological studies. The other half, for chemical analysis, was divided into a vertical sequence of subsamples, each of which was placed into a one-quart Mason jar. On EN-005, about 5 cc of each subsample was removed for on-board screening by Coast Guard personnel; the remainder of each subsample was frozen for later analysis. SIDE SHOW sediment samples were stored in an ice locker while at sea and frozen upon return to the laboratory. Each sediment core (13-14 cm long) obtained on EN-005 with a box corer was divided into three subsamples. Two subsamples were used in benthic flux experiments. The third subsample was frozen immediately after collection, for hydrocarbon analysis.

### Benthic Organisms

The second objective of the NOAA contract was to conduct a preliminary survey of the benthic community in the oil spill area. Area B is important to the commercial fisheries and needed to be assessed from this point of view. The sampling scheme for sediment samples was also appropriate for this objective.

### Water

The third objective, to determine the entrainment of oil in the water column, was met by taking hydrocasts at each of the sediment stations. Water samples were collected with both Niskin bottles and butterfly sterile bag samplers. Water samples taken with Niskin bottles when the surface is contaminated can be contaminated because the bottles are open when they pass through the surface. The butterfly sterile bag samplers also had disadvantages. They use either black plastic or clear Teflon bags. The black plastic bags leach such high levels of organic contaminants that they interfere with both IR and UV analysis. It was not known how much hydrocarbon each kind of bag adsorbs.

Also, both kinds of bags often split in the cold water. Although neither Niskin bottles nor bag samplers were ideal, both were used, with the bag sampler as the primary collection device.

Sea bird studies

The fourth objective involved sea bird studies, which were conducted for ten minutes per hour during the daylight hours.

Tar balls

During February and March of 1977, between 60 and 90 days after the grounding, tar balls were found along the New England coast from Jamestown, Rhode Island to Provincetown, Massachusetts, including the islands of Martha's Vineyard and Nantucket. Twelve tar balls were collected in Jamestown, ranging in weight from a few ounces to 15 lbs. During the next two months, 30 tar balls were collected along the Massachusetts shore; seventeen of these were from Nantucket.

Twenty-two of the tar balls were analyzed. Data on these tar balls is given in Table A; the sites are located in Fig. 2. The Nantucket collection dates are approximate.

Cruise EN-002

The first ARGO MERCHANT oil spill cruise by R/V ENDEAVOR (EN-002) took place December 28-30, 1976. Three stations (Fig. 3, Table B) were occupied -- 1, a clean station in the predicted path of subsurface oil drift; 2, a relatively shallow area affected by the slick during high wave activity; and 3, an area that had a heavy oil slick at one time. The cruise was then

TABLE A

Locations and dates of tar ball collection

| Tar Ball No. | Site | ∿Date | Comment |
|---|---|---|---|
| 1 | Jamestown, Rhode Island | 2/9/77 | a,∿1 lb.,composite |
| 2 | Jamestown, Rhode Island | 2/9/77 | a,∿1 lb.,outside |
| 3 | Jamestown, Rhode Island | 2/9/77 | a,∿1 lb.,inside |
| 4 | Jamestown, Rhode Island | 2/9/77 | b,∿5 lb.,inside |
| 5 | Jamestown, Rhode Island | 2/9/77 | c,∿15 lb.,inside |
| 6 | Martha's Vineyard | 2/12/77 | |
| 7 | Nantucket | 2/15/77 to | |
| 8 | Nantucket | 3/1/77 | |
| 9 | Nantucket | 3/1/77 | |
| 10 | Nantucket | 3/1/77 | |
| 11 | Nauset Beach | 3/1/77 | |
| 12 | Nauset Beach | | No. 11 weath. at GSO |
| 13 | Marconi Beach | 3/1/77 | |
| 14 | Marconi/Lecount | 3/14/77 | |
| 15 | Race Pt. Beach | 2/10/77 | Sewage |
| 16 | Race Pt. Light | 3/1/77 | |
| 17 | 1000 yds. from Race Pt. Light | 3/1/77 | |
| 18 | Long Pt. | 3/12/77 | |
| 19 | Provincetown Wharf (a) | 3/15/77 | |
| 20 | Provincetown Wharf (b) | 3/15/77 | |
| 21 | Pilgrim Beach (a) | 3/12/77 | |
| 22 | Pilgrim Beach (b) | 3/12/77 | |

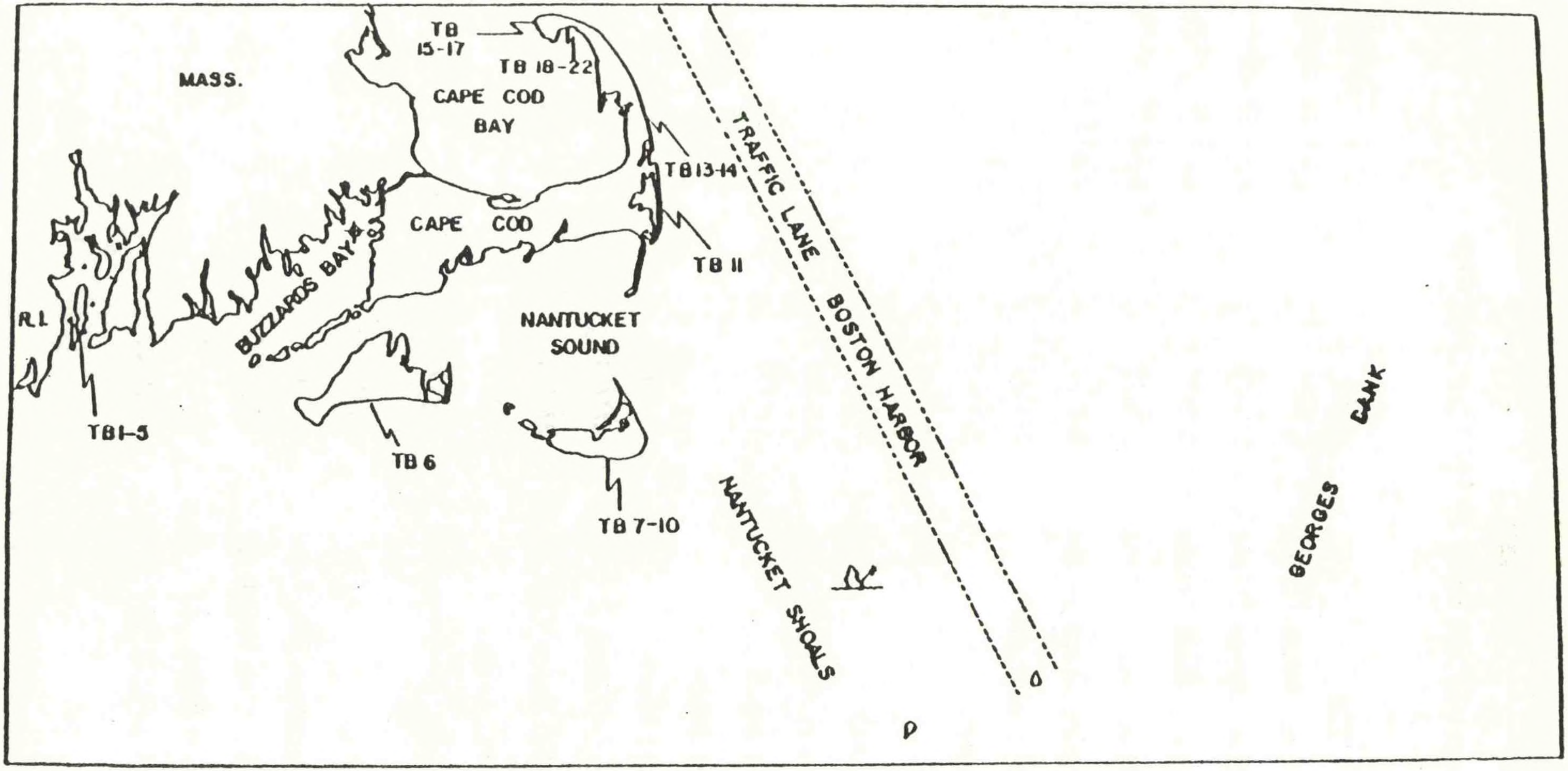


Fig. 2. Locations where tar balls were collected.

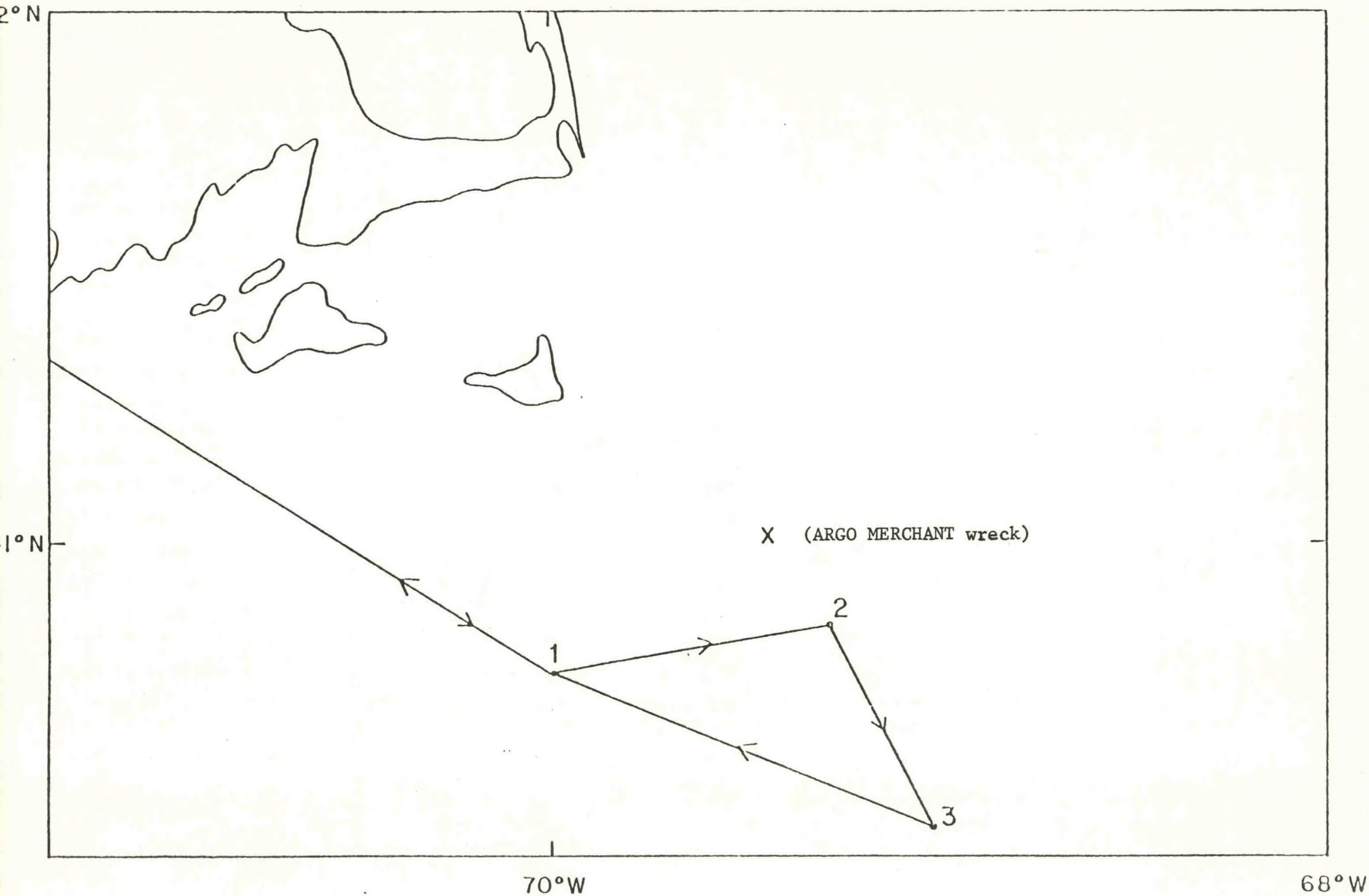


Fig. 3. Station locations for cruise EN-002.

Table B. Summary of URI cruises at the ARGO MERCHANT wreck site and types of samples taken. (The complete cruise reports are given in Appendix B.)

| URI Cruise designation | EN-002 | EN-003 | EN-004 | EN-005 | SS-001 | Totals |
|---|---|---|---|---|---|---|
| Dates | Dec. 28-30,1976 | Jan. 26-29,1977 | Feb. 9-13,1977 | Feb. 22-27,1977 | July 22-24,1977 | |
| Ship time funding | NSF | NOAA | NOAA - 3 days<br>NSF - 2 days | NOAA - 4 days<br>NSF - 2 days | NOAA - 2 days | |
| No. of Stations | 3 | 5 | 38 | 34 | 18 | |
| Side scan sonar tows | 1 | -- | -- | -- | -- | 1 |
| Plankton tows | 5 | -- | -- | 61 | 6 | 72 |
| Neuston tows | 2 | -- | -- | 20 | -- | 22 |
| Hydrocasts | 4 | 5 | 38 | 40 | -- | 87 |
| Sediment grab samples | 7 | 9 | 104 | 53 | 36 | 209 |
| Current meter array deployment | 1 | -- | -- | -- | -- | 1 |
| Bird observations | no | yes | yes | no | no | -- |
| Bottom drifters released | -- | -- | -- | 150 | -- | 150 |
| Macro benthos tows-scallop dredge | -- | -- | 2 | 9 | 4 | 15 |
| Magnetometer tows | -- | -- | 1 | -- | -- | 1 |
| Sediment box cores | -- | -- | -- | 8 | -- | 8 |

terminated because of gale force winds and high seas.

Plankton and neuston samples were collected from surface waters, to be analyzed for species abundance and diversity. Water samples were collected from depths of 1m, 6m and the bottom using Niskin bottles for analysis of total hydrocarbons, oil droplet size distribution, total organic carbon, nutrients, T, S, pH, $O_2$, particulate trace metals, and total suspended material.

Benthic samples were collected using a Smith-McIntyre grab sampler, for analysis of species abundance and diversity and sediment hydrocarbons (Brown, Appendix A). Side-scanning sonar measurements were made while approaching station 1. An array of current meters was released at the beginning of station 2.

### Cruise EN-003

ENDEAVOR cruise EN-003 (January 26-29, 1977) ended after five stations because of gale force winds, rough seas, and severe icing conditions. Some hydrocast and grab samples were obtained (Fig. 4, Table B).

### Cruise EN-004

Cruise EN-004 (February 9-13, 1977) completed work begun on EN-003. At 38 stations (Fig. 5, Table B), grab samples were taken (three at most of the stations, one or two at the rest) and hydrocasts were made with Niskin bottles. Macrobenthic samples were collected with a scallop dredge at two stations. Magnetometer readings were made during part of the cruise, as part of an unrelated project.

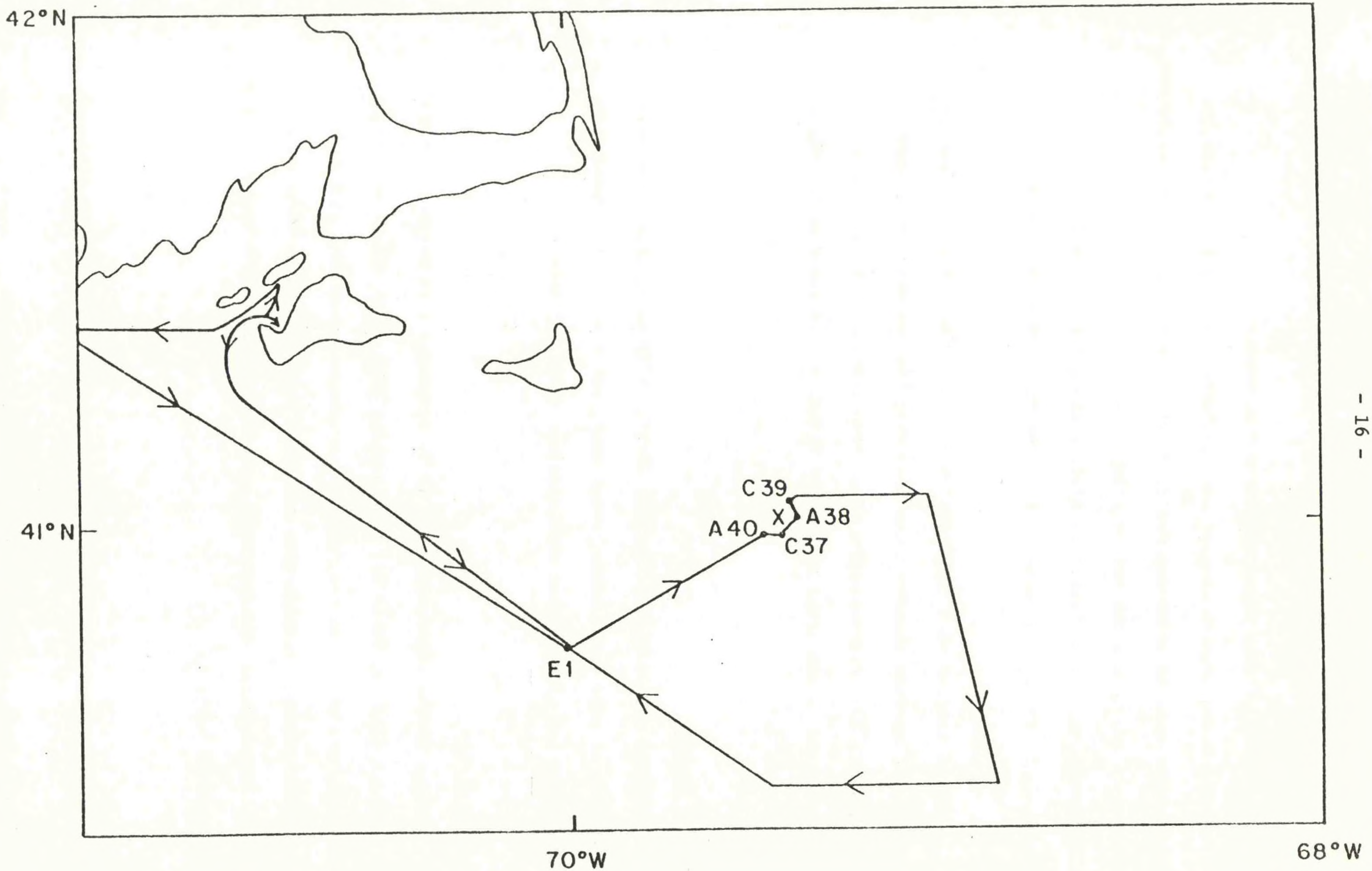


Fig. 4. Station locations for cruise EN-003.

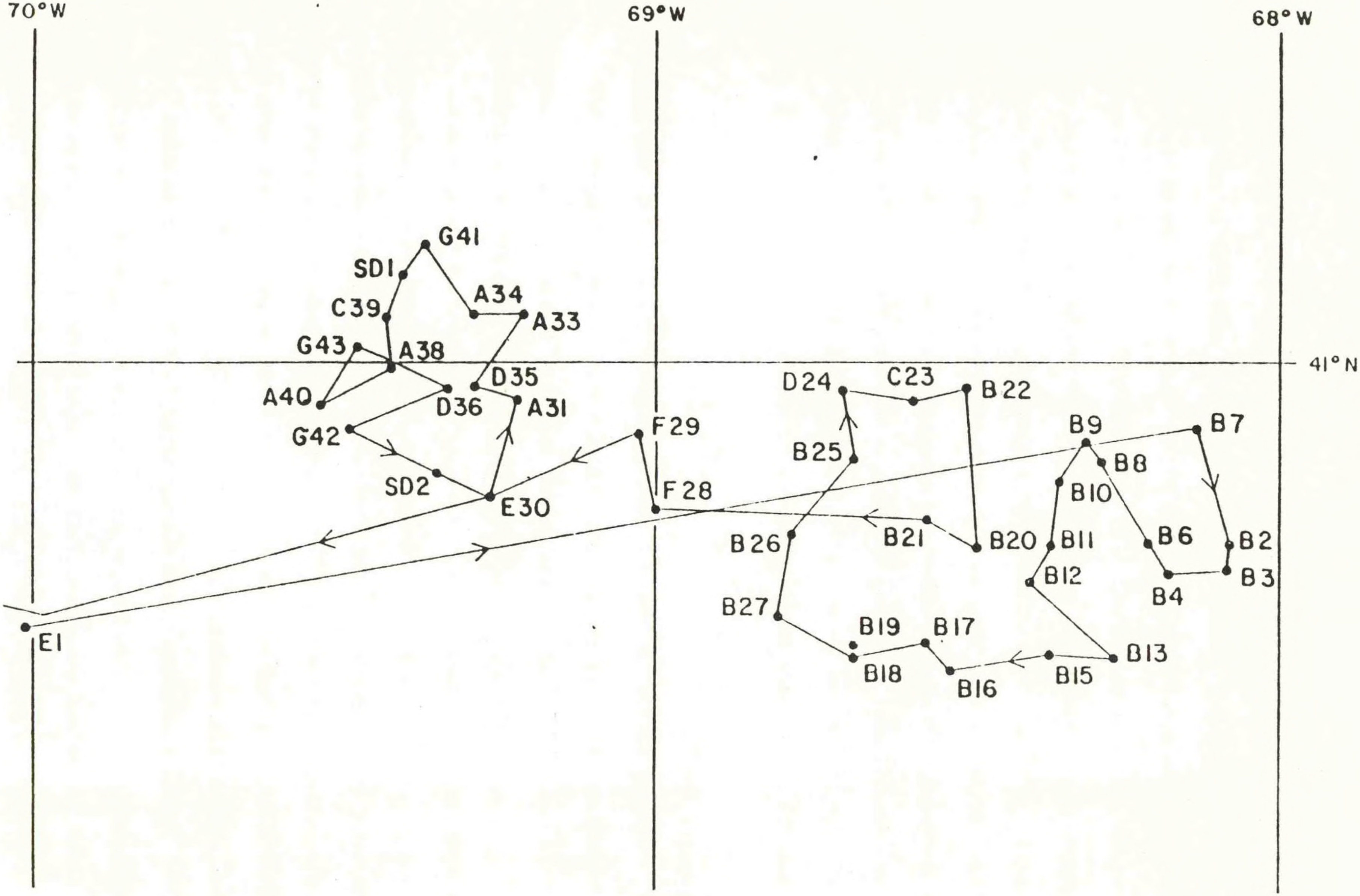


Fig. 5. Station locations for cruise EN-004.

Cruise EN-005

Cruise EN-005 (February 22-27, 1977) was conducted in the immediate vicinity of the wreck (Fig. 6, Table B), primarily to determine the areal extent of sediment contamination by ARGO MERCHANT oil, to collect benthic organisms and to deploy bottom drifters. Grab samples and box cores were collected; zooplankton (vertical), phytoplankton, and neuston tows were performed. Scallop dredge samples of macrobenthos were collected, seabed drifters were released, and surface water and hydrocast samples were taken. The area sampled was 200 $n.mi^2$. Twenty stations were planned around the wreck and up to 20 n.mi. SW of the wreck. Additional stations were selected based on preliminary Coast Guard on-board screening results.

Cruise SS-001

Cruise SS-001, on the F/V SIDE SHOW (July 22-24, 1977), was made to investigate the fate of the ARGO MERCHANT oil in the sediments. R/V ENDEAVOR was not available. The cruise had five objectives: 1) to determine the extent of weathering of petroleum hydrocarbons from sediments around the ARGO MERCHANT wreck site; 2) to determine the extent of transportation of contaminated sediments from the wreck site; 3) to collect macrobenthos for histopathological studies and chemical analysis for comparison with similar samples collected in February; 4) to collect zooplankton to compare with similar samples collected in February; and 5) to collect sediment samples for future meiobenthic studies.

The stations which were contaminated in February and adjacent stations were reoccupied. In addition, stations on Fishing Rip were selected since the fishing boat had a shallow draft and could work in these waters without

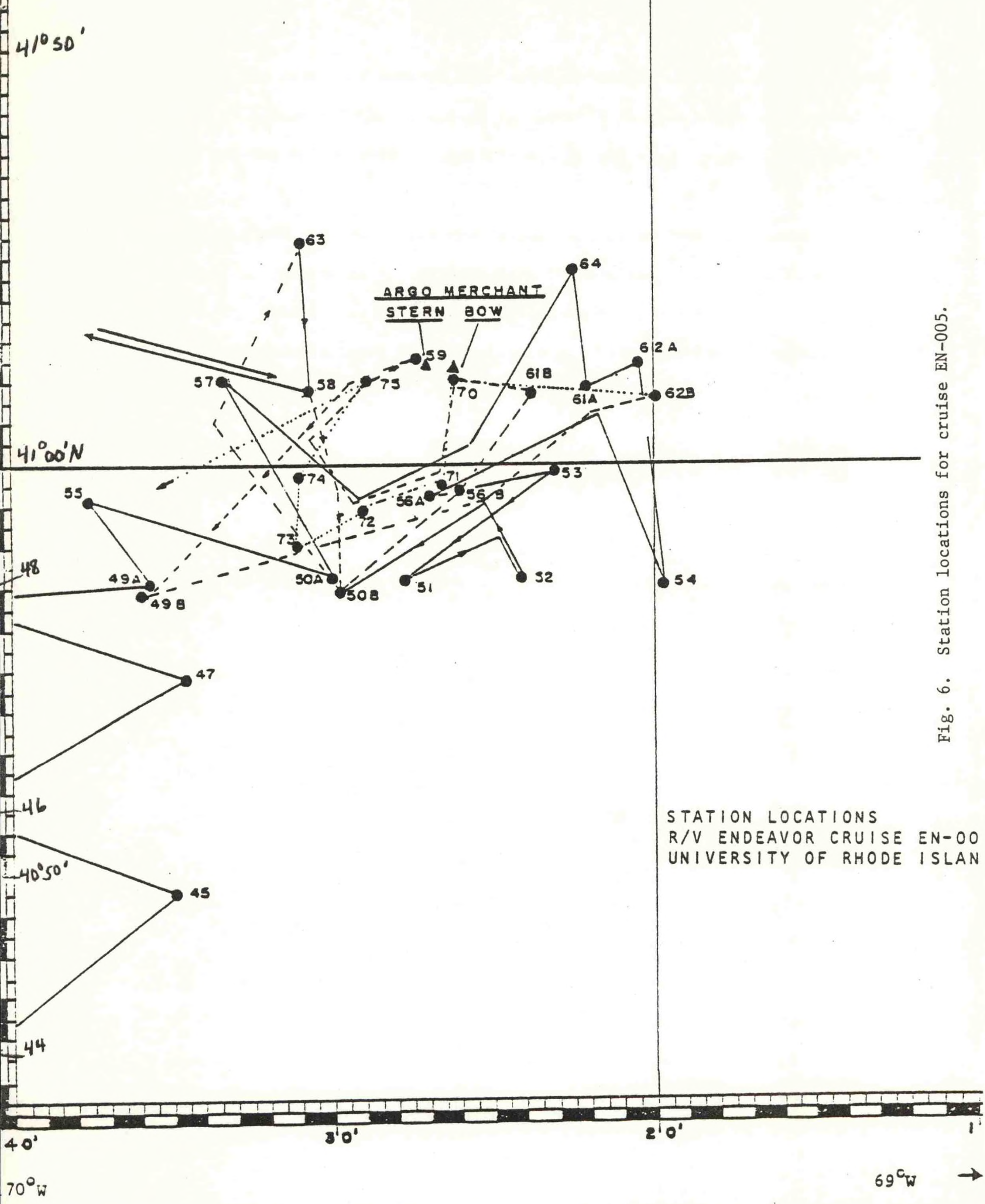


Fig. 6. Station locations for cruise EN-005.

risk of running aground. Transects were made between the stern and bow sites and from the southern edge of Fishing Rip Shoals across the shoals to the northern edge. Fig. 7 is a map of the stations of this cruise and the previous one.

Because no heavy hauling equipment was available, the Smith-McIntyre grab sampler was used to collect sediment samples. A commercial scallop dredge was used to collect macrobenthic organisms (at four sites). Zooplankton samples were collected for microscopic and chemical studies (Table B).

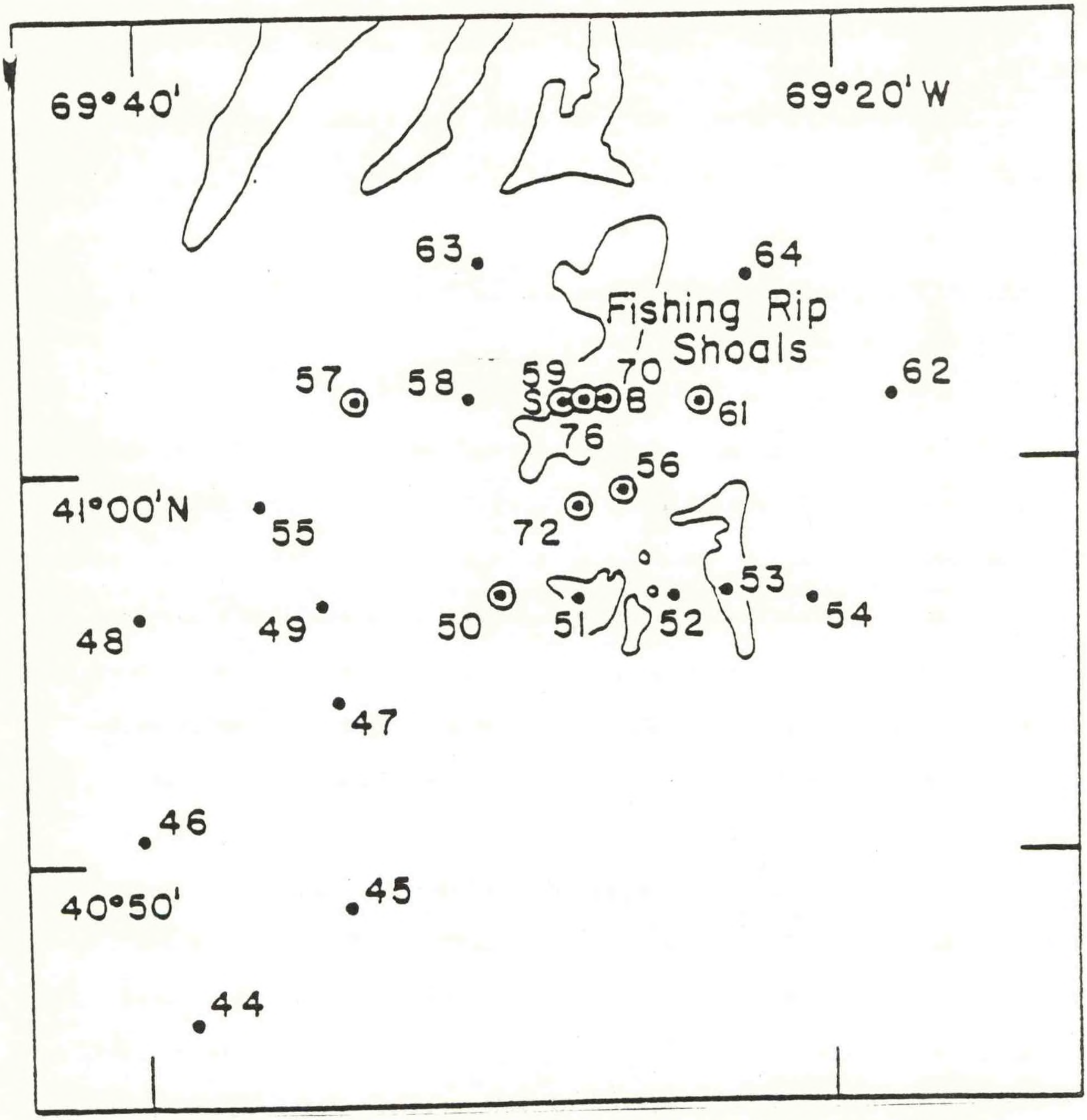


Fig. 7. Station locations for cruises EN-005 and SS-001. "S" (station 59) is the location of the ARGO MERCHANT stern and mid-section; "B" (station 70) is the location of the ARGO MERCHANT bow section. Sediments from the circled stations were analyzed by gas chromatography.

Studies

The following studies were completed, with total or partial NOAA funding.

Gas chromatography of hydrocarbons in sediments, cargo oil, and slick (Hoffman and Quinn, in press)

Analysis

Subsamples of selected surface sediment samples and sediment cores from EN-005 and SS-001 were analyzed. Forty-five samples from six EN-005 stations were chosen which contained petroleum, based on Coast Guard screening, and visible tar particles. Fifteen samples from six SS-001 stations were chosen from previously contaminated stations and adjacent stations. Occasionally minute tar particles (1 to 2 mm) were removed from the samples with tweezers before analysis; the tar particles and sediment were analyzed separately.

After the moisture content was determined using a small portion of each sediment sample, 70-240 gms of wet sediment (50-200 gms dry weight) was weighed into a two-l round-bottom flask. Internal standards were added. The samples were extracted with MeOH-KOH and partitioned into petroleum ether. The hydrocarbon fraction was isolated using a silica-gel column, evaporated to dryness, and analyzed by gas-liquid chromatography (GLC).

The hydrocarbons measured eluted from the column between n-$C_{14}$ and n-$C_{34}$, using temperature programming from 90°C to 260°C for a packed column and 60°C to 240°C at 4°/minute for a capillary column. The chromatograms were quantified by comparing the areas of the chromatograms with the areas of the internal standards, with blank corrections.

The average blank was 23 $\pm$ 10 μg/sample. Concentrations were reported for all sediment samples in which the blank correction represented <50% of the blank plus sample value. For a 200-gm sediment sample, this would yield a detection limit of approximately 0.1 ppm (23 μg/200 g). Whenever the blank correction was greater than 50% of the total, the values were reported as less than the detection limit for that specific sediment sample weight. All the values reported in the tables have been corrected for the blank.

Portions of one cargo sample and two surface slick samples, collected by Dr. Jerome Milgram, were also analyzed. The ARGO MERCHANT cargo oil sample was collected from a full tank. The first slick sample (Milgram #1), taken at a distance of 2 to 4 km from the tanker, is estimated to have been on the water for about one hour. The second sample (Milgram #2), collected from a large pancake, had probably been on the water for about four or five days. After weighing, these samples were dissolved and charged to the column described previously. The hydrocarbon elutant was evaporated to dryness, dissolved in methylene chloride, and analyzed by GLC as described above.

Results

The data (Table C) indicate that in February, 1977, the sediments were significantly contaminated (i.e., had concentrations greater than 20 μgHC/gm dry weight) at three stations. Two of these stations (59 and 70) were at the original wreck site (now the location of the midsection and stern) and at the present bow location, respectively; the sediment was coarse sand. The third station (56) was 3.2 km SE of the bow section in the channel adjacent to Fishing Rip Shoals, where the sediment is gravel mixed with crushed shells and mud.

Trace levels of petroleum were found at two stations -- 50 (4.8 km south of the original wreck site) and 61 (3.2 km east of the original wreck site). Both stations were located in the channel south and east of the wreck; the petroleum could have been from other sources. The Coast Guard found no evidence of ARGO MERCHANT oil at the other stations. Our findings indicate that significant sediment contamination in February extended at most 3-4 km from the wreck site in a southeast direction. Traces of contamination from an unknown source were found 3-5 km east and south from the bow. Thus, in February, 1977, at most an area of 10-15 $km^2$ was contaminated. It is likely that only a small percentage of this area was significantly contaminated -- primarily in the immediate vicinity of the tanker, especially around the bow section.

An attempt was made to determine the depth of sediment contamination using successive subsamples of grab samples and box cores. Neither sampling device collected sand deeper than 13-20 cm, and in the case of stations with a gravel bottom, a maximum of only 3-4 cm of sediment was collected. No clear trend as a function of depth was noted in the EN-005 sediment samples. For example, at stations 70(1)BC and 70(1)G the hydrocarbon concentrations were fairly constant with depth, while at Stations 59(1)BC, 70(4)G, and 70(2)BC, the higher concentrations generally appear in the subsurface sediments, and at Stations 59(1)G, and 59(3)G the highest concentrations appear in the surface sediments (Table C). This variation is probably due to inhomogeneous distribution of minute tar particles in the sand. In this present study, it can only be concluded that oil was present in the sediments at least as deep as 8-13 cm. Oil could have been present significantly deeper.

Table C. Total hydrocarbons in selected sediment samples from Cruise EN005.

| Station (replicate) | Latitude | Longitude | Depth of sediment (cm) | Total hydrocarbons µg/gm (dry wt sediment) |
|---|---|---|---|---|
| 50(1) G* | 40°57.1'N | 69°30.1'W | 0-1 | <0.1 |
| 50(2) G | 40°56.9'N | 69°29.9'W | 0-1 | 0.8 |
| 50(2) G | " | " | 1-3 | 0.4 |
| 50(2) G | " | " | 3-5 | <0.1 |
| 56(1) G | 40°59.2'N | 69°27.0'W | 0-1 | 1.2 |
| 56(3) G | 40°59.2'N | 69°27.3'W | 0-1 | <0.3 |
| 56(4) G | 40°59.0'N | 69°29.0'W | 0-1 | 21.5 |
| 57(1) G | 41°02.0'N | 69°33.5'W | 0-1 | <0.1 |
| 59(1) G | 41°02.5'N | 69°27.3'W | 0-1 | 2.4† |
| 59(1) G | " | " | 1-3 | 0.5 |
| 59(1) G | " | " | 3-5 | <0.1† |
| 59(3) G | 41°03.0'N | 69°27.5'W | 0-1 | 2.6† |
| 59(3) G | " | " | 1-3 | <0.1 |
| 59(3) G | " | " | 3-5 | <0.1 |
| 59(4) G | 41°02.9'N | 69°27.2'W | 0-1 | 0.3 |
| 59(4) G | " | " | 1-3 | 0.1 |
| 59(4) G | " | " | 3-5 | <0.1 |
| 59(1) BC** | 41°02.5'N | 69°27.0'W | 0-3 | 5.1 |
| 59(1) BC | " | " | 3-8 | 1.3 |
| 59(1) BC | " | " | 8-13 | 24.6 |
| 59(2) BC | 41°02.6'N | 69°27.0'W | 0-4 | 0.3 |
| 59(2) BC | " | " | 4-9 | 0.8 |
| 59(2) BC | " | " | 9-14 | 0.4 |
| 61(2) G | 41°02.6'N | 69°22.5'W | 0-1 | 1.1 |
| 61(3) G | 41°01.0'N | 69°23.0'W | 0-1 | 0.7 |
| 70(1) G | 41°01.8'N | 69°26.2'W | 0-1 | 12.8 |
| 70(1) G | " | " | 1-3 | 29.6 |
| 70(1) G | " | " | 3-5 | 11.5 |
| 70(1) G | " | " | >5 | 19.7 |
| 70(3) G | 41°02.0'N | 69°26.6'W | 0-1 | 10.2 |
| 70(3) G | " | " | 1-3 | 4.0 |
| 70(3) G | " | " | 3-5 | 5.6† |
| 70(4) G | 41°02.0'N | 69°26.5'W | 0-1 | 118, 69.7, 35.7†† |
| 70(4) G | " | " | 1-3 | 5.1 |
| 70(4) G | " | " | 3-5 | 122 |
| 70(1) BC | 41°02.0'N | 69°26.5'W | 0-3 | 1.9 |
| 70(1) BC | " | " | 3-8 | 2.7 |
| 70(1) BC | " | " | 8-13 | 2.2 |
| 70(2) BC | 41°01.9'N | 69°26.3'W | 0-3 | 2.7 |
| 70(2) BC | " | " | 3-8 | 28.2 |
| 70(2) BC | " | " | 8-13 | 37.5 |

*G = Smith-McIntyre grab samples;
† tarball removed prior to analysis;
**BC = Box core samples;
†† triplicate analysis.

At least some of the petroleum hydrocarbons in the sediments were minute tar particles. To find out the approximate percentage of the total hydrocarbons these tar particles represented, particles were physically isolated with spatula and tweezers from four of the samples. Sediments without their tar particles and the tar particles were analyzed separately. The result of this experiment is given in Table D. In all cases, the tar particle contribution was the major contribution rather than any coating on the sand. The number and size of the tar particles in any one sediment analysis will greatly affect the results. To minimize this problem, large amounts of sediment (usually 100 to 200 gms) were used for each analysis in this study. In spite of this precaution, replicate analyses (Table C - station 70(4)0-1) of the same grab sample indicate variabilities of a factor of three. Since the uncertainty for the analysis procedure is no greater than 10%, the sediment samples were inhomogeneous even when taken from the same storage container. This is undoubtedly one of the reasons, perhaps the major one, why the Coast Guard on-board screening results do not agree in all cases with the results presented here. Although our values are generally lower, there is some correlation between the Coast Guard screening method and our analysis ($r = 0.69$ for 20 samples) in spite of the inhomogeneous distribution. Still greater variations were seen from grab sample to grab sample, even within 50 meters of each other. At Station 70, for example, the upper sediments (0-3 cm depth) in replicate grab and core samples contained 12.8, 10.2, 118, 1.9 and 2.7 μgHC/gm, a variation of over two orders of magnitude.

The chromatographically resolved portion of the tar particles, sediments and slick samples were compared with the resolved components of the ARGO MERCHANT cargo oil, by comparing the areas of each resolved component.

Table D. Comparison of total sediment hydrocarbon concentrations with and without inclusion of tar particles (EN005 sediments).

| Stat/Rep/Depth* | Total hydrocarbons µg/gm (dry wt sediment) | | |
|---|---|---|---|
| | Sediment with tar particles physically removed | Tar contribution | Sediment with tar particle contributions included |
| 59(1)0-1 | 2.4 | 73.5 | 75.9 |
| 59(1)3-5 | <0.1 | 48.5 | 48.6 |
| 59(3)0-1 | 2.6 | 324 | 327 |
| 70(3)3-5 | 5.6 | 29.1 | 34.7 |

*all grab samples, depth in cm.

It should be pointed out that the ARGO MERCHANT carried two cargos, both #6 fuel oils, but only one of the cargos was sampled at the scene. It was this cargo sample that was used for matching purposes in this study. Although these oils were reported to be nearly identical (Grose and Mattson, 1977), some of the following matching experiments could have been affected by differences in the resolved component patterns of the two cargos.

Using an HP-5840 integrator, the area of each peak (or resolved component) was expressed in area percent as follows:

$$A\%_i = \frac{A_i}{\Sigma A_i} \times 100\% \qquad (1)$$

where $A\%_i$ is the area % of the individual resolved component, and $A_i$ is the area in arbitrary units of each individual peak. The individual area percents of each peak of the standard (in this case, the ARGO MERCHANT cargo oil sample collected by J. Milgram) are then plotted versus the corresponding area percents (using peaks having the same retention times) of the sample. An example of the result is given in Fig. 8. The area percents of each resolved peak in the chromatogram (Fig. 8a) were plotted versus the corresponding peaks in the cargo sample (Fig. 9a) to yield the resulting graph given in Fig. 8b. Visually the chromatograms look similar and linear least squares regression analysis of the individual area percents confirms a strong correlation (r = 0.90). An example of a poorer match is given in Fig. 10. Here the pattern of the sample does not look like the cargo sample. The peaks are less pronounced and in some places are absent altogether. Again the linear least squares regression analysis of the area percents of the resolved species indicates a poor correlation (r = 0.44). A summary of these

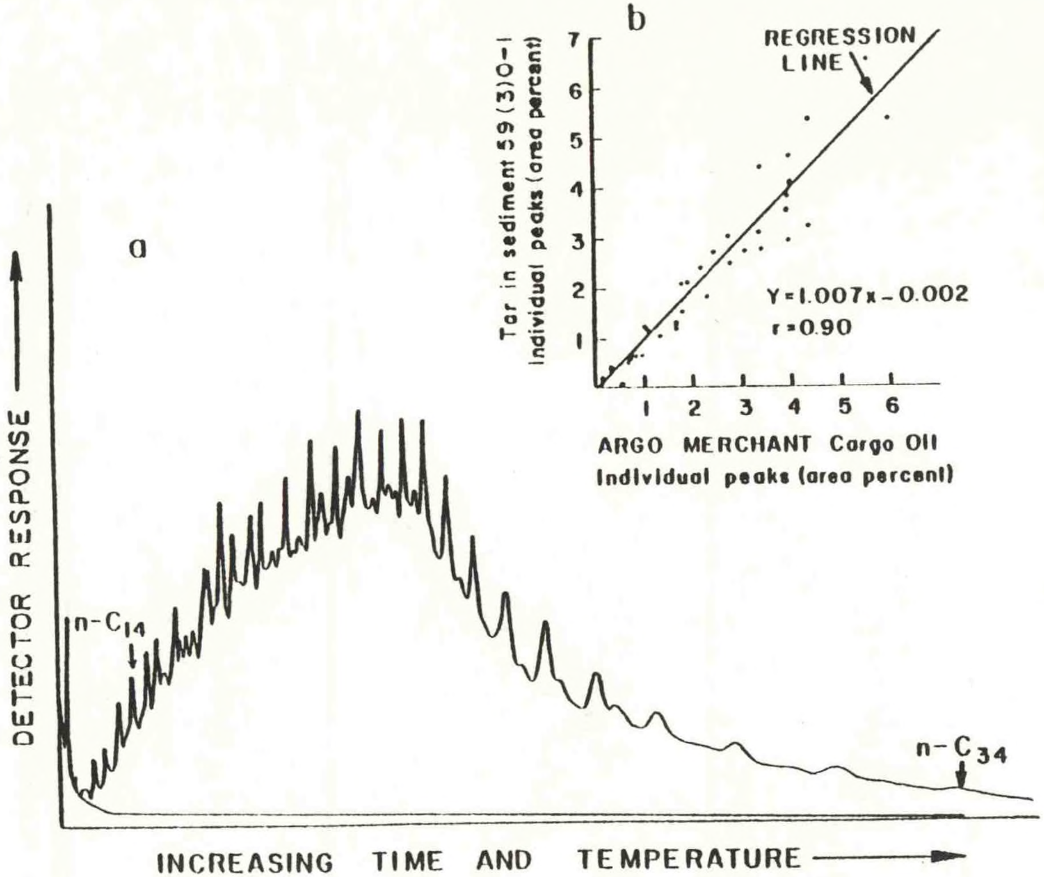


Fig. 8. a - Gas chromatogram (packed column) of tar particles separated from the sediment collected at Station 59, Grab 3, 0-1 cm depth, in February, 1977. b - Graph of the areas of each resolved hydrocarbon component of this tar particle sample versus the area of the corresponding peaks in the ARGO MERCHANT cargo oil.

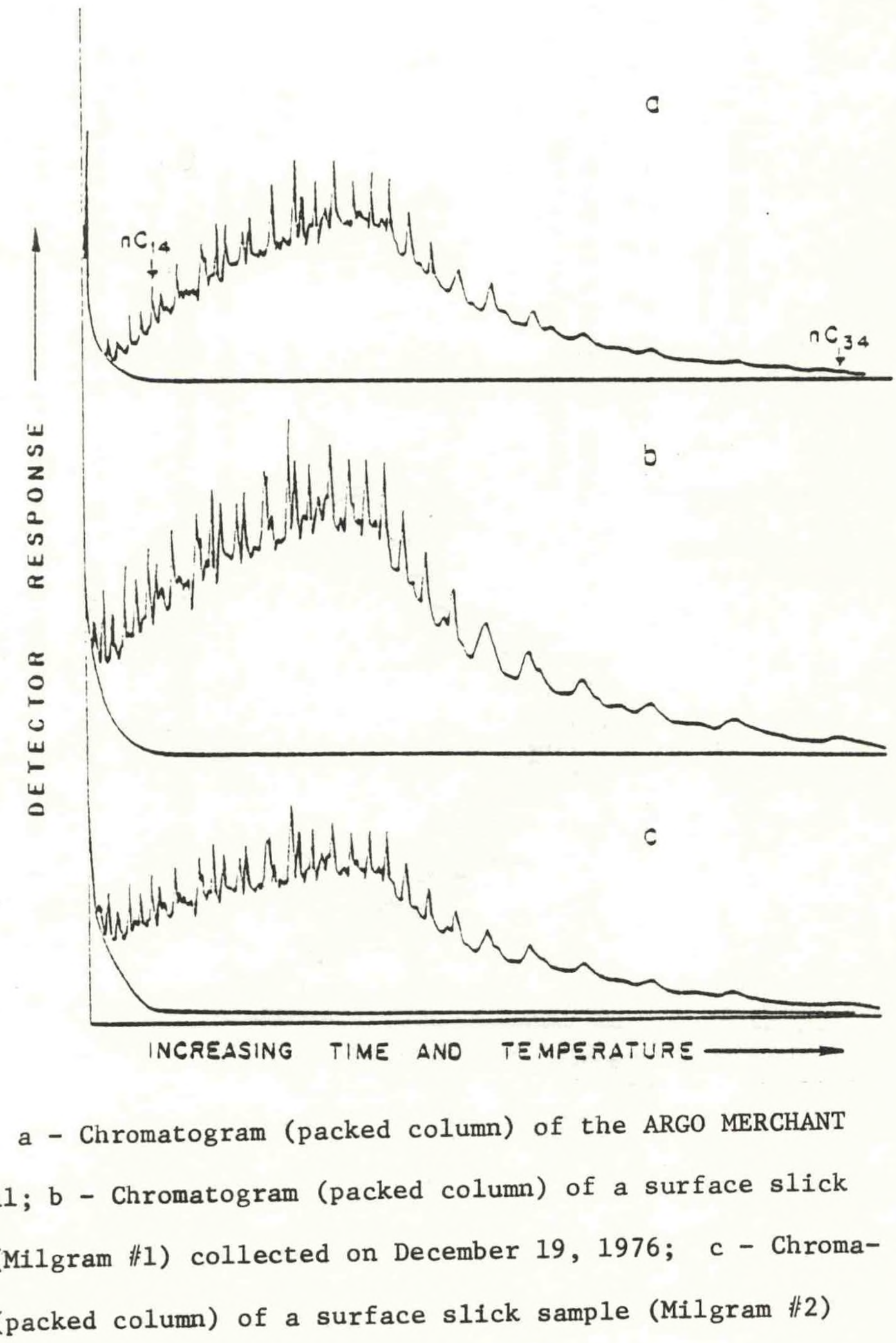


Fig. 9. a - Chromatogram (packed column) of the ARGO MERCHANT cargo oil; b - Chromatogram (packed column) of a surface slick sample (Milgram #1) collected on December 19, 1976; c - Chromatogram (packed column) of a surface slick sample (Milgram #2) collected on December 25, 1975.

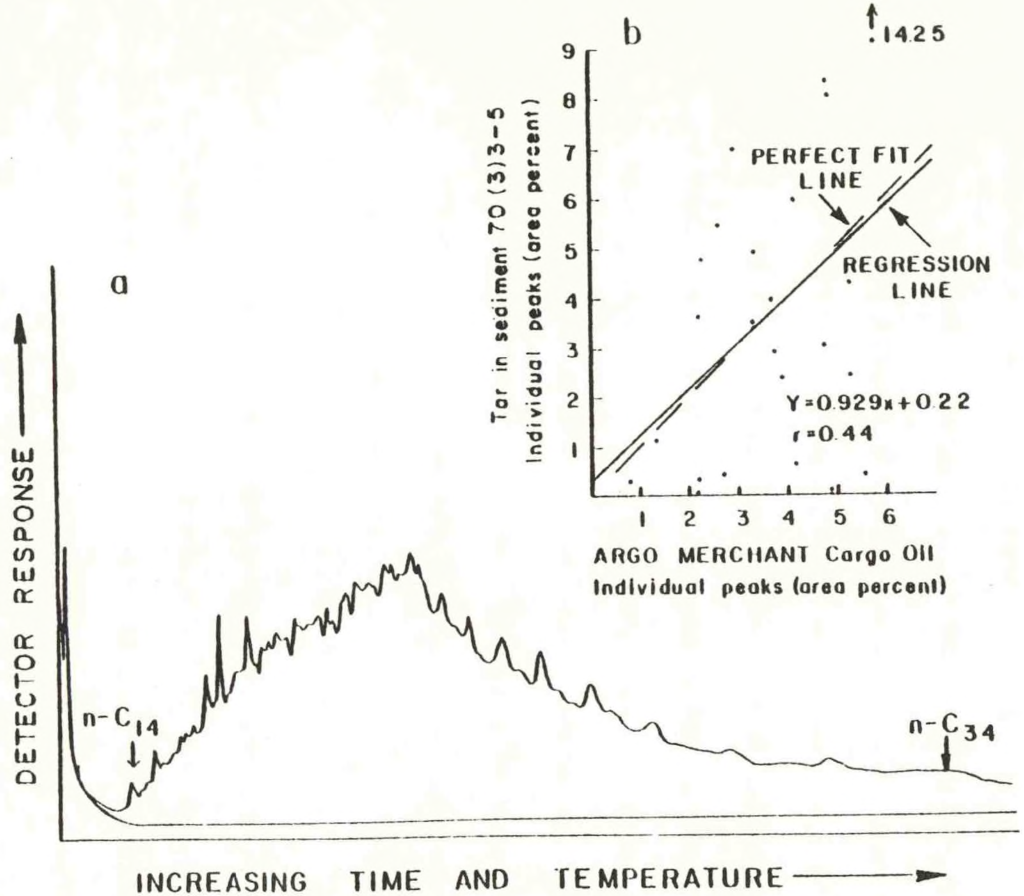


Fig. 10. a - Chromatogram (packed column) of tar particles separated from the sediment collected at Station 70, Grab 3, 3-5 cm depth, in February, 1977. b - Graph of the areas of each resolved hydrocarbon component of this tar particle sample versus the area of the corresponding peaks for the ARGO MERCHANT cargo oil.

examples and other samples compared to the ARGO MERCHANT cargo is given in Table E. An example of the ARGO MERCHANT oil chromatogram using glass capillary gas chromatography is given in Fig. 11a.

In order to demonstrate the correlations obtained using duplicate injections, ARGO MERCHANT cargo oil was analyzed using different injection conditions (as noted on Table E). All of these procedures yielded strong correlations ($r > 0.90$) for ARGO MERCHANT oil versus ARGO MERCHANT oil. The chromatograms of the cargo and surface slick oil samples are given in Fig. 9. Visually there is a strong resemblance; the correlations of the resolved area percents confirms this strong correlation (Table E). There is little evidence of weathering in slick samples up to five days. This is particularly interesting since the ARGO MERCHANT cargo contained about 20% of a cutter stock of light oil added to the #6 oil (Grose and Mattson, 1977). Apparently, there had not been substantial losses of these lighter components during the five days it was on the surface of the water. Undoubtedly the cold atmospheric temperature (-3$^{o}$C mean temperature) impeded losses by evaporation and dissolution.

Three of the four tar particle subsections also match well with the cargo oil ($r = 0.79$ to $0.90$, Table E). The other tar particle subsection (sample 70 (3) 3-5, also shown in Fig. 10) had undergone some weathering or was from a different source. The sediments collected around the wreck site matched well with the cargo although the sediment with the visible tar particles removed did not match as well. The hydrocarbons in the sediments collected 3 km from the wreck site in February (Station 56 (4)0-1, EN-005) did not match with the cargo oil; the chromatogram showed that either extensive weathering of ARGO MERCHANT oil had taken place or the hydrocarbons at this

Table E. Comparison of resolved components in slick, sediment and tar particle samples with ARGO MERCHANT cargo oil sample.

| y | y vs. ARGO MERCHANT correlation coefficient | No. of area %'s | sig. level |
|---|---|---|---|
| Argo Merchant duplicate analyses same day | 0.99 | 31 | >0.995 |
| Argo Merchant duplicate analyses 2 days apart | 0.97 | 38 | >0.995 |
| Argo Merchant duplicate analyses - same day | 0.93* | 17 | >0.995 |
| Oil sample on water one day (Milgram #1) | 0.91 | 38 | >0.995 |
| Oil sample on water five days (Milgram #2) | 0.96 | 39 | >0.995 |
| Tar - station 59 (1) 0-1 (EN-005) | 0.89 | 24 | >0.995 |
| Tar - station 59 (1) 3-5 (EN005) | 0.79* | 17 | >0.995 |
| Tar - station 59 (3) 0-1 (EN005) | 0.90 | 40 | >0.995 |
| Tar - station 70 (3) 3-5 (EN005) | 0.44 | 25 | 0.975 |
| Sediment and tar station 70 (4) 3-5 (EN005) | 0.98 | 39 | >0.995 |
| Sediment without tar station 70 (3) 3-5 (EN005) | 0.74 | 27 | >0.995 |
| Sediment - station 59 (1) BC 8-13 (EN005) | 0.86 | 19 | >0.995 |
| Sediment - station 56 (4) 0-1 (EN005) | 0.21* | 13 | <0.95 |
| Sediment - station 70 (1) 0-1 (SS001) | 0.18* | 14 | <0.95 |

*glass capillary major peaks.

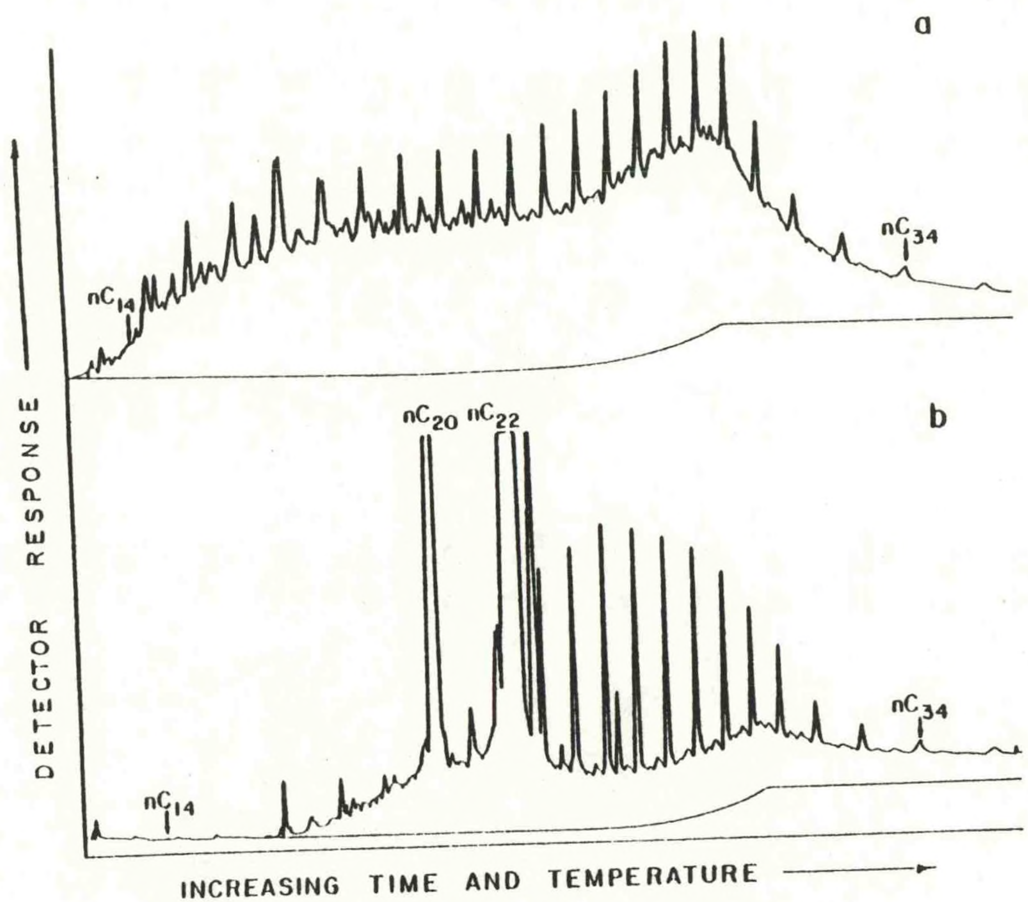


Fig. 11. a - Chromatogram (Glass capillary column) of the ARGO MERCHANT cargo oil. b - Chromatogram (Glass capillary column) of the sediment collected at Station 70(1), 0-1 cm depth in July , 1977.

station were a weathered product of some other petroleum input. The hydrocarbons found in the sediments in July (Station 70(1), SS-001) also did not match with ARGO MERCHANT oil; the glass capillary chromatogram of these hydrocarbons is given in Fig. 11b. Visually there is little similarity between the resolved hydrocarbon pattern of the ARGO MERCHANT cargo and this July sample. The July sediment pattern does, however, resemble patterns of tar lumps found on Bermuda beaches (Butler et al., 1973), patterns of tar particles > 1 cm in diameter in the N. Atlantic (Wade et al., 1976), and patterns of hydrocarbons in surface microlayers in coastal waters south of Martha's Vineyard in February, 1977 (Boehm, 1977). The source of the hydrocarbons in the vicinity of the ARGO MERCHANT wreck site in July is unknown.

On July 22-24, 1977, samples were collected for chemical analysis at all the previously contaminated stations found on EN-005, except for stations 56 and 57 (where the July samples contained only cobbles and shell fragments). The hydrocarbon analytical results are given in Table F. The samples all contained 0.6 μg HC/gm or less. At only one station (70(1)) were traces of petroleum hydrocarbons found. An example of the chromatograms for this station is given in Fig. 11b. Note that the chromatogram does not compare well with the ARGO MERCHANT oil cargo chromatogram (Fig. 8a), and there is no statistical correlation for the resolved components ($r = 0.18$, Table E). Since this sediment sample was collected at the ARGO MERCHANT bow section, it is tempting but highly unlikely to conclude that this is ARGO MERCHANT oil after seven months of physical, chemical, and/or biological weathering. It is unlikely since the n-alkanes which appear predominantly in the sample are usually the first to degrade with time relative to the complex mixture of

Table F. Total hydrocarbons in selected sediment samples from Cruise SS001.

| Station* (replicate) | Latitude | Longitude | Depth of sediment (cm) | Total hydrocarbons µg/gm (dry wt sediment) |
|---|---|---|---|---|
| 50(2) | 40°56.9'N | 69°30.1'W | 0-1 | 0.1 |
| 59(1) | 41°02.5'N | 69°27.8'W | 0-1 | 0.2 |
| 59(2) | " | " | 0-1 | <0.1 |
| 59(3) | " | " | 0-1 | <0.2 |
| 61(1) | 41°01.5'N | 69°24.3'W | 0-1 | 0.4 |
| 70(1) | 41°02.0'N | 69°26.8'W | 0-1 | 0.5 |
| 70(1) | " | " | 1-3 | 0.6 |
| 70(1) | " | " | 3-5 | 0.6 |
| 70(1) | " | " | 5-10 | 0.4 |
| 70(2) | 41°02.0'N | 69°26.8'W | 0-1 | 0.2 |
| 70(3) | 41°02.0'N | 69°26.8'W | 0-1 | <0.2 |
| 72(2) | 40°59.2'W | 69°27.7'W | 0-1 | 0.2 |
| 76(1) | 41°02.0'N | 69°26.5'W | 0-1 | 0.2 |
| 76(2) | 41°02.4'N | 69°26.8'W | 0-1 | <0.2 |
| 76(3) | 41°02.7'N | 69°27.7'W | 0-1 | 0.4 |

*all grab samples.

cycloparaffins, aromatics and naphtheno-aromatics. These hydrocarbons could have been from non-cargo oil from the ARGO MERCHANT (e.g., hydraulic fluids) or from non-ARGO MERCHANT sources. With the exception of this station (70(1)), the rest of the samples gave no evidence of petroleum hydrocarbons, weathered or otherwise, above normal background levels.

The fishing vessel used for the last cruise had a much smaller draft than the R/V ENDEAVOR had; thus it was possible to collect sediment samples on top of the shoals, between the bow and stern. Stations 76(1), 76(2), and 76(3) represent a transect across the shoals from the bow to the stern of the ARGO MERCHANT. It was felt that sediments at these stations might have been heavily contaminated with oil as the bow section drifted over them before it sank (Grose and Mattson, 1977). In July, no evidence of such contamination was found. Again because of the turbulence in the area, such contamination could have been degraded, buried or transported away from the shoals, especially in seven months time.

No evidence of transportation to adjacent stations (50, 61, 72) or burial at the wreck site was found. We obtained sediments only as deep as 13 cm, however, and much larger daily fluctuations are possible.

A rough estimate of the percentage of spilled oil which became incorporated into the sediments can be made if a series of assumptions are made. Generally these assumptions tend to maximize the amount of oil in the sediments: (1) Assume an average concentration of hydrocarbons in the vicinity of the wreck (Stations 59 and 70) at February, 1977, is 16 ppm (arithmetic mean $\pm$ the standard deviation was 16 $\pm$ 30 ppm); (2) Assume a linear rate of weathering or dispersal with time, such that 16 ppm in February decreased to an average of 0.3 ppm in July in a linear decrease; (3) Assume an affected area of 15 $km^2$; (4) Assume a depth of contamination of 15 cm, and a constant concentration of hydrocarbons with depth; and (5) Average sediment density is approximately 3 $gm/cm^3$. Using these assumptions, it was calculated that a maximum of $1.5 \times 10^2$ metric tons of oil was incorporated in the sediments, or 0.5% of the total oil spilled. This amount represents a maximum estimate. This calculation indicates that surface sediments in the vicinity of the wreck site were not a major sink for the ARGO MERCHANT oil.

Comparison of gas chromatography and UV-fluorescence analysis of hydrocarbons (Hoffman, Quinn, Jadamec, and Fortier, Appendix A)

A suite of sediment samples collected on EN-005 was analyzed jointly by the U.S. Coast Guard Research and Development Center, and the University of Rhode Island. Each group used a different technique for hydrocarbon analysis -- UV-fluorescence for the Coast Guard and gas chromatography for URI. The two sets of data were compared. Successful intercalibrations between investigators using gas chromatographic analysis techniques have been conducted previously (Farrington et al., 1976) but never using two different analytical methods.

Analysis

Detailed descriptions of the analytical techniques used by the URI and USCG groups are described elsewhere (Hoffman and Quinn, in press; Jadamec, Appendix A; Jadamec, in press).

These techniques vary in the extraction procedure and the analytical instrumentation used for quantification. The extraction techniques used by Hoffman and Quinn (in press) utilized methanolic KOH in the extraction procedure. Use of methanol probably enhances the extraction efficiency of hydrocarbons, especially in the case of weathered hydrocarbons. The solvent hexane, as used in the procedure of Jadamec (Appendix A), may be sufficient to extract recently spilled hydrocarbons (Gearing, personal communication).

The fluorescence technique detects compounds which fluoresce, such as 2 - 5 ring aromatic hydrocarbons. If other fluorescing organic compounds are present in the sample, they may interfere, causing the reported values to be too large. On the other hand, if the aromatic fraction is preferentially weathered or lost, errors can be introduced.

Gas chromatographic analysis is not affected by these problems. Isolation steps are routinely used before gas chromatographic analysis; only hydrocarbons are analyzed. Also, progressive weathering of the hydrocarbons would be apparent from the disappearance of some components and from lower quantitative results. Hydrocarbons with very low and high molecular weights (lower than n-$C_{14}$ or higher than n-$C_{34}$), were not quantified; thus, the technique gives a lower limit value for total hydrocarbons.

For each sediment sample, 5 $cm^3$ of sediment was removed, extracted with hexane, and analyzed within 30 minutes after collection by UV-fluorescence. The remaining contents of the sample (~200g) were frozen for later analysis in the laboratory, extracted and analyzed by gas chromatography as described earlier.

## Results

The results for samples analyzed by both URI and the Coast Guard are given in Table G.

A plot of the Coast Guard values versus the URI values is given in

Table G. Sediment hydrocarbons in the vicinity of the ARGO MERCHANT wreck analyzed by two methods.

| Station | Coast Guard UV-fluorescence value (ppm) | URI GC value (ppm dry wt) |
|---|---|---|
| 50(1) 0-1 | 0 | <0.1 |
| 50(2) 0-1 | 0 | 0.8 |
| 56(1) 0-1 | Trace[1] | 1.2 |
| 56(2) 0-1 | 0 | <0.3 |
| 57(1) 0-1 | Trace | <0.1 |
| 59(1) 0-1 | Trace | 2.4[2] |
| 59(1) 1-3 | 3.5 | 0.5 |
| 59(1) 3-5 | 0 | <0.1[2] |
| 59(3) 0-1 | 10 | 2.6[2] |
| 59(3) 1-3 | 0 | <0.1 |
| 59(3) 3-5 | 6 | <0.1 |
| 59(4) | 0 | 0.3 |
| 61(2) 0-1 | 0.9 | 1.1 |
| 61(3) 0-1 | 0 | 0.7 |
| 70(1) 0-1 | 70 | 12.8 |
| 70(1) 1-3 | 15 | 29.6 |
| 70(1) 3-5 | 90 | 11.5 |
| 70(1) 5-10 | 118 | 19.7 |
| 70(2) 0-1 | 8.2 | 10.2 |
| 70(2) 1-3 | 0 | 4.0 |
| 70(2) 3-5 | 10 | 5.6[2] |
| 70(4) 0-1 | 100 | 75 |
| 70(4) 1-3 | 50 | 5.1 |
| 70(4) 3-5 | >118 | 122 |

[1] trace as defined as < 0.24 ppm but above background;

[2] tar particles removed prior to analysis;

Fig. 12. Linear regression analysis with no zero values or trace values considered indicated a regression equation as follows:

$$\text{URI values} = 0.50 \times \text{USCG values} - 0.03 \qquad (1)$$

$$(n = 16)$$

When zero values and trace values are considered the regression equation becomes:

$$\text{URI values} = 0.498 \times \text{USCGRD values} + 0.26 \qquad (2)$$

$$n = 24)$$

and the correlation coefficient improves slightly to 0.72.

Therefore, there is some correlation between the two sets of analyses. The URI values are generally lower than the Coast Guard values; there is usually good agreement in the case of the lower values of background and trace quantities. The oil present in these samples was minute tar particles or oil droplets distributed inhomogeneously in the samples (Hoffman and Quinn, in press; and Pratt, in press). This distribution led to poor reproducibility even when samples were taken from the same jar, as they were for the URI and Coast Guard subsamples. No attempt was made to mix the sediments before the Coast Guard aliquot was removed, or when the URI portions were taken from the jar. Thus replicate analysis of sediment by URI from station 70(4), 0-1 cm in depth, yielded values of 118, 69.7 and 35.7 ppm (74.5 $\pm$ 41.3), a relative standard deviation of 55%. The usual error with the URI technique and more homogeneous sediment samples is on the order of less than 20%. Use of small samples could result in even worse replication problems, depending on the presence or absence of even one tar particle.

This comparison of UV-fluorescence and gas chromatography using ARGO MERCHANT sediment samples has demonstrated the need for homogeneous intercalibration samples. Considering the sample inhomogeneity and the different sample

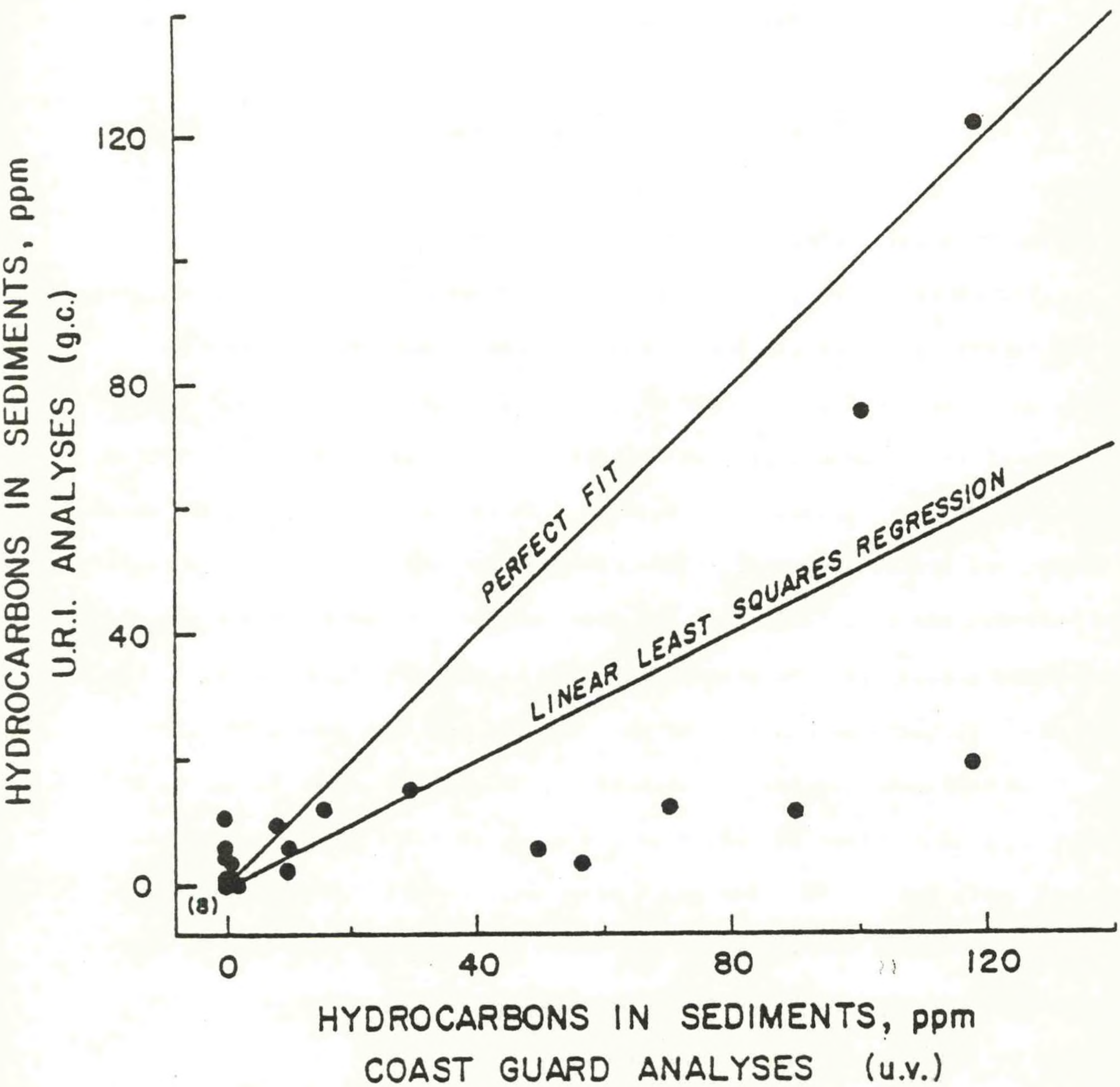


Fig. 12. Hydrocarbon analyses of sediments collected near the ARGO MERCHANT wreck site: UV-fluorescence concentrations plotted versus gas chromatography concentrations.

sizes, extraction procedures, analytical methods, and length of storage, it is amazing that the agreement is so good.

Visual and microscopic examination of sediment for benthic fauna and oil (Pratt, in press)

Grab samples ($0.1m^2$) collected on cruise EN-005 in February, 1977, and cruise SS-001 in July, 1977, were inspected for benthic organisms. In 14 of these samples, benthos were partially identified.

Analysis

The half of the grab samples allocated for biological analysis was further subdivided. A subsample ($35.2\ cm^2 \times 10\ cm$) was removed with a length of core tube and preserved in 10% buffered seawater-formalin (with rosebengal dye added for cruise EN-005 and SS-001).

A seive was not used to separate macrobenthos since many samples were coarse-grained. A floatation technique was developed. The sample was washed on an 0.074 mm seive to remove preservative and stain. The sample was slowly added to a 500-ml graduated cylinder containing a dense colloidal silica solution (Ludox; sp. wt. 1.39; deJonge and Bouwan, 1977). A film of tap water was floated on the Ludox. After one hour animals and particles were pipetted from the Ludox-water interface, washed and preserved. Particles still in suspension in the Ludox were removed on 0.039 mm netting. The sediment was washed and examined microscopically for heavy-bodied animals and animals or oil particles adhering to sand grains.

An aliquot of sediment was then removed, dried, and seived at $1/2\phi$ intervals; grain size fractions were weighed and retained.

Results

Three sediment types with characteristic benthic fauna were sampled.

(1) At reference station 1 (44 m) and at the deep eastern stations (80-90 m), fine compact sand is found with abundant macrobenthic species. Free burrowing amphipods and isopods are numerically dominant. Sand dollars are found in shallower areas and ocean quahogs in deeper areas. Oil was never found in sediments of this type.

(2) Gravelly sediments in Great South Channel and in the channels between sand ridges near the wreck site support diverse faunal assemblages. Biomass may be very high, particularly where the horse mussel (Modiolus modiolus) is present. A $0.1m^2$ sample in loose gravel from station 2-2 contained over 37 species and 598 individuals. A 1000-cc mass of sponge and colonial tunicate from dredge station 64 contained over 27 macrobenthic species and 224 individuals. Although sessile suspension feeders make up the greatest biomass in these areas, species of all purchase and feeding types are found. A large polychaete (Nereis pelagica) and a bivalve (Hiatella arctica) occupy burrows in sponge. Brittle stars, scale worms, nudibranchs, and turbellarians crawl on surfaces. Deposit feeding polychaetes are present. Crabs and starfish are present. This community could not be quantitatively described because of its spatial heterogeneity.

(3) The final sediment type was the motile, shelly sand making up Fishing Rip Ridge and areas to the southwest. Macrobenthos in this type of sediment seems to be the remnant of a community in a less physically active area. The populations of meiofauna were relatively dense and spatially homogeneous. Table H shows that harpacticoid copepods and turbellarians are numerically dominant while nematodes are relatively unimportant.

Table H. Number of organisms for selected taxa recovered from sediment at the bow of the ARGO MERCHANT. (Core sample 35 $cm^2$ x 10 cm, seive size 0.074 mm. See Hoffman and Quinn (in press) for details of hydrocarbon analysis.)

| | February 22-27, 1977 (EN-005) | | | | July 22-24, 1976 (SS-001) | | |
|---|---|---|---|---|---|---|---|
| | 70-1 | 70-2 | 70-3 | 70-4 | 70-1 | 70-2 | 70-3 |
| Crustaceans | | | | | | | |
| Harpacticoid copepods | 35 | 24 | 60 | 62 | 109 | 600 | 78 |
| Ostracods | 6 | 1 | 2 | - | 4 | 53 | 20 |
| Polychaetes | | | | | | | |
| *Ophryotrocha* sp. | - | 22 | 3 | 4 | 1 | 5 | 2 |
| Polychaete A | 1 | 11 | - | - | - | 2 | 2 |
| Nemetodes | 7 | 7 | 10 | 10 | 8 | 72 | 80 |
| Soft bodied forms (turbellarians and small nemerteans) | 30 | 45 | 25 | 19 | 28 | 51 | 50 |
| Minimum number of species | 9 | 8 | 6 | 4 | 11 | 12 | 13 |
| Total Individuals | 88 | 111 | 107 | 95 | 156 | 794 | 248 |
| Mean grain diameter (mm) | 1.55 | 0.80 | 0.93 | 1.3 | 0.74 | 0.60 | 0.66 |
| Hydrocarbons (μg/gm dry wt.) | 11.5-19.7 | - | 4.0-10.2, 34.7 | 5.1-122 | 0.4-0.6 | 0.2 | <0.2 |

Interstitial species could interact with oil within sediments by contact or ingestion of droplets or by exposure to toxic soluble fractions released in interstitial waters. Ingestion is possible because most of the individuals are deposit feeders.

Insufficient data is available to draw conclusions about population numbers or diversity, although it can be seen that in July there was a slight increase in density and diversity of interstitial benthos.

In the February samples, taken at the bow section, oil was observed in the guts of interstitial harpacticoids and polychaetes. In two heavily contaminated samples, half the polychaete *Ophryotrocha* sp. and a few percent of the larger harpacticoids had ingested oil. Oil was also found adhering to the uropod of a burrowing amphipod, with tissue apparently removed distal to the oil (Fig. 13). The grain size distributions in 14 subsamples (Fig. 14) were both unimodal and bimodal at individual stations, suggesting that sorting occurred continuously. This variation will complicate biological conclusions.

The form of the oil in the sediments at the spill site was observed during sorting of benthic animals. The oil was present as droplets ranging in size from 0.03 mm to 2 mm in diameter. Many did not adhere to sand grains, but floated free during handling. They had little tendency to coat mineral grains, shell fragments, or echinoderm skeletons. Rings of loosely adhering droplets (0.1 mm) were observed on several grains, when large droplets broke into smaller ones.

The loose droplets of oil would be available to larger selective deposit feeders but less available to very small forms and to those feeding on sand grain coatings.

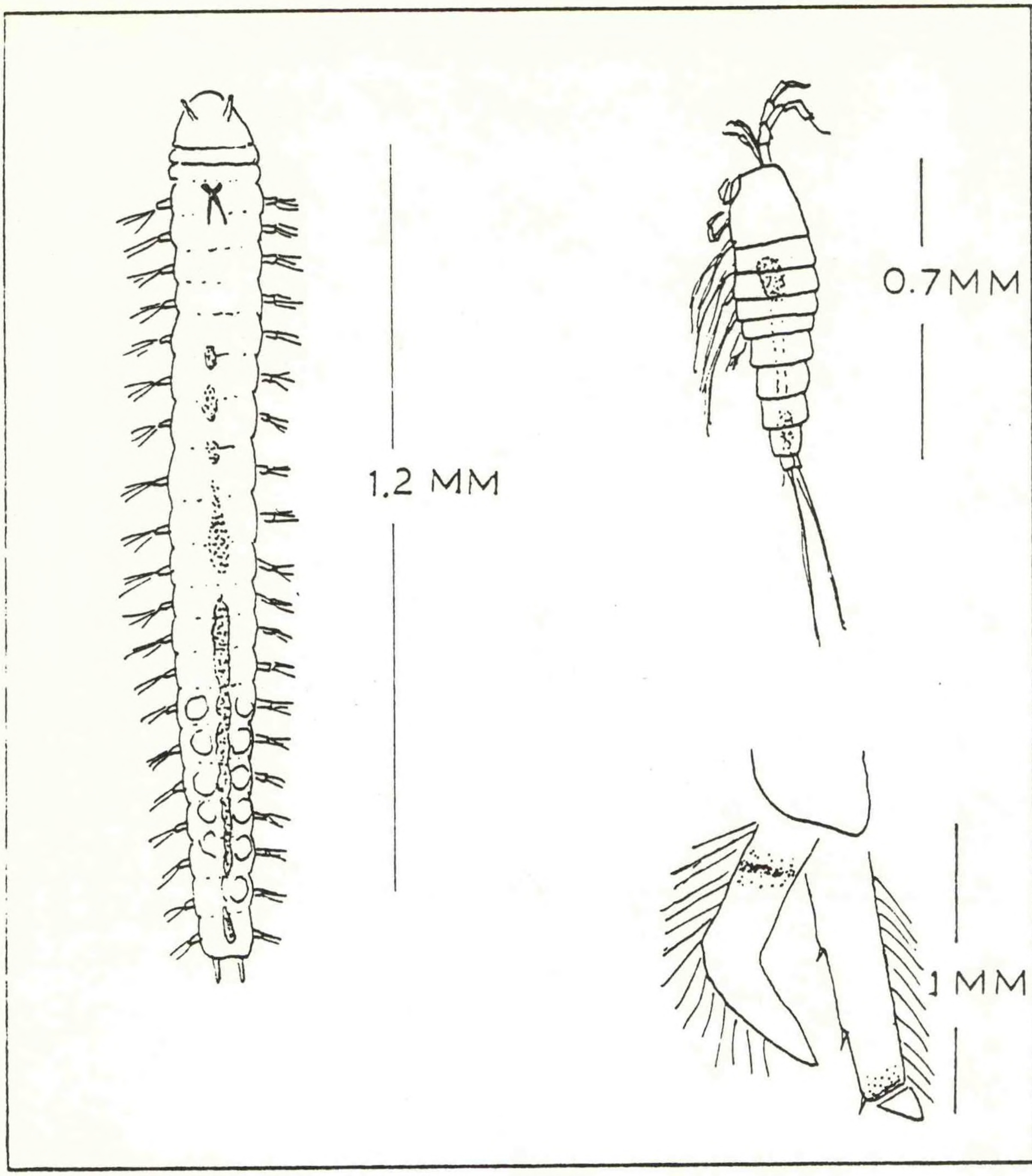


Fig. 13. Examples of interactions between benthic organisms and oil from EN-005 samples. A polychaete (Ophryotrocha sp.) and a harpacticoid copepod contain ingested oil (sta. 70-2). Oil adheres to an appendage of the amphipod Psammanyx nobilis (sta. 50-1); there is no tissue distal to the oil.

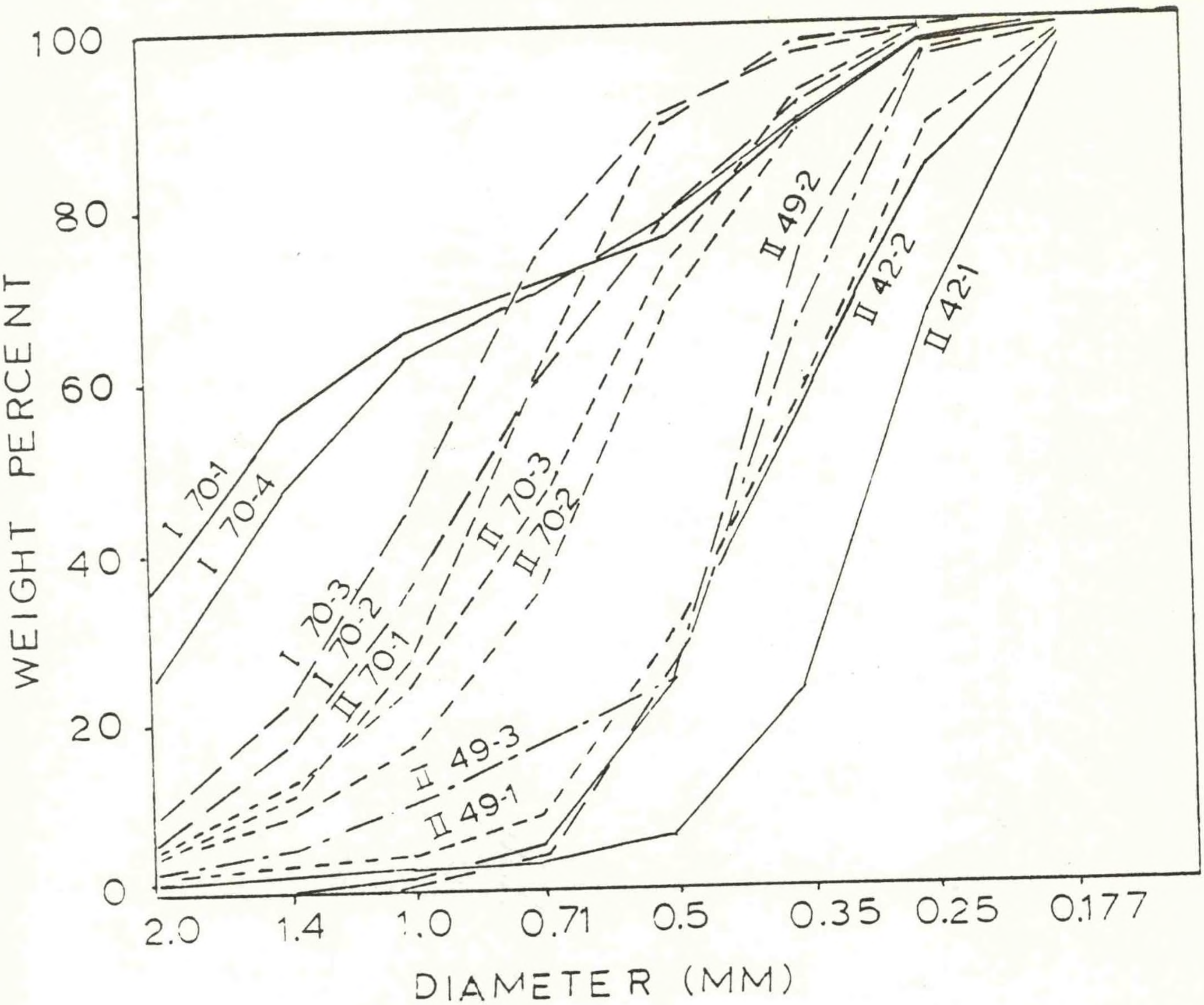


Fig. 14. Cumulative grain size distribution of sediment samples. (I and II indicate February and July samples respectively).

Near-bottom sediment transport study with seabed drifters

(Collins, Griscom, and Hoffman, in press)

Deployment of drifters

The University of Rhode Island and the National Marine Fisheries Service (NMFS) of Woods Hole deployed approximately 1700 Woodhead-type seabed drifters in Nantucket Shoals, Georges Bank, and the approaches to Rhode Island Sound to determine the possible transport direction of any oil from the ARGO MERCHANT that sank to the bottom (Fig. 15). A total of 1150 drifters were released by helicopter and ship at nine URI stations and 535 released during two NMFS cruises between January and March, 1977. Bundles of 75, 100, or 150 drifters were deployed at the URI stations and groups of five at each NMFS station.

Results

During the period from January 6, 1977, to December 1, 1977, approximately 10 percent of the drifters were recovered. Of the total of 176 returned, 84 are known to have lost their stems and weights. When this occurs the drifter loses its negative buoyancy and becomes a surface drifter. The plastic drifters may have become brittle in the cold waters and broken apart as they moved through the surf zone. Follow-up letters confirm that only 38 of the drifters were found intact; the condition of the remaining 54 is not known.

A seasonal analysis of the recovery data (Figs. 16 - 19) shows a five percent return in January and February (Fig. 16) increasing to 25 percent in March through May (Fig. 17). The return maximum of 44 percent in June through August (Fig. 18)

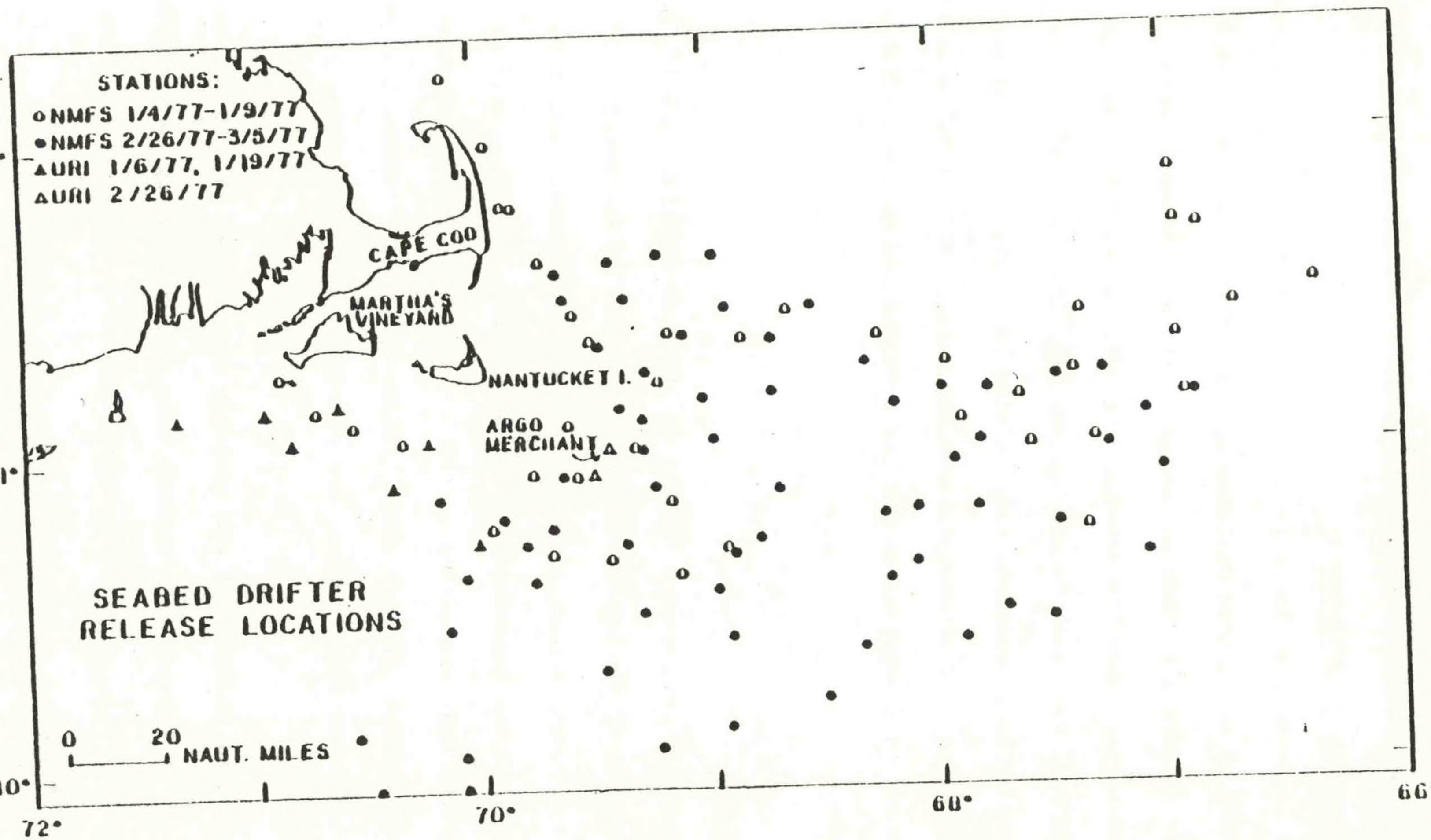


Fig. 15. Seabed drifter release locations in the vicinity of the ARGO MERCHANT

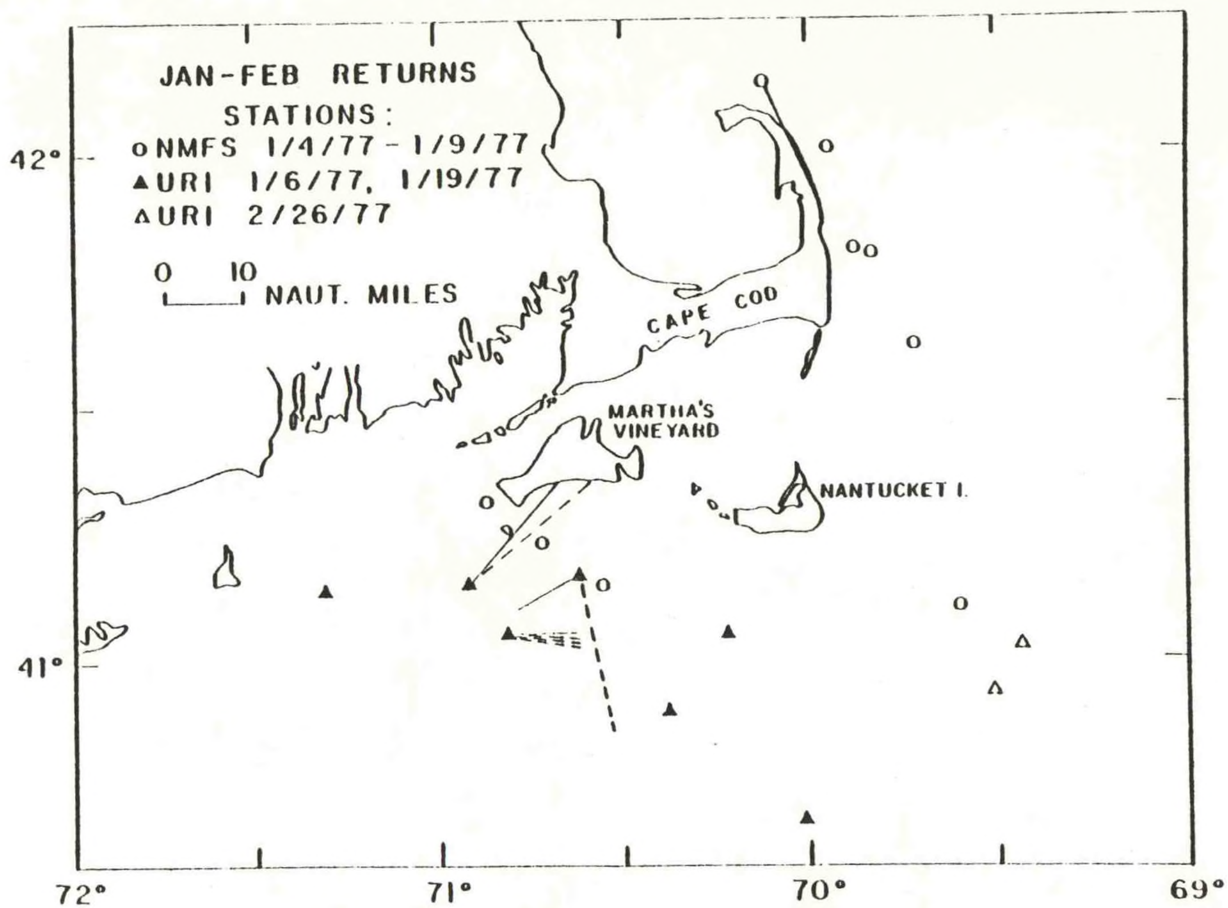


Fig. 16. January through February, 1977, seabed drifter returns in the vicinity of the ARGO MERCHANT. Solid lines show inferred travel paths of all drifters that were recovered broken or the state of the drifter is not known. Dashed lines show inferred travel paths of all drifters known to have been recovered intact.

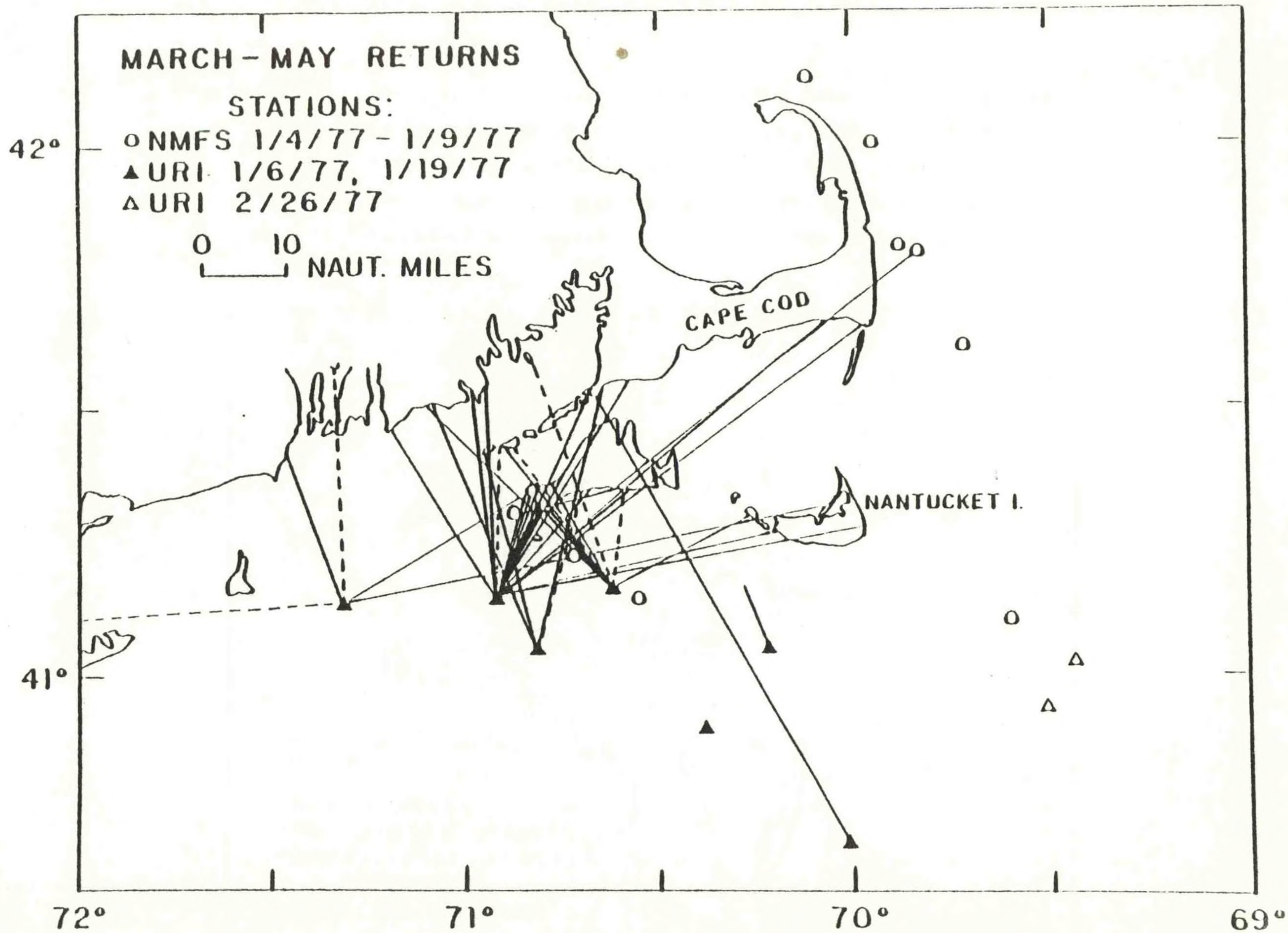


Fig. 17. March through May, 1977, seabed drifter returns.

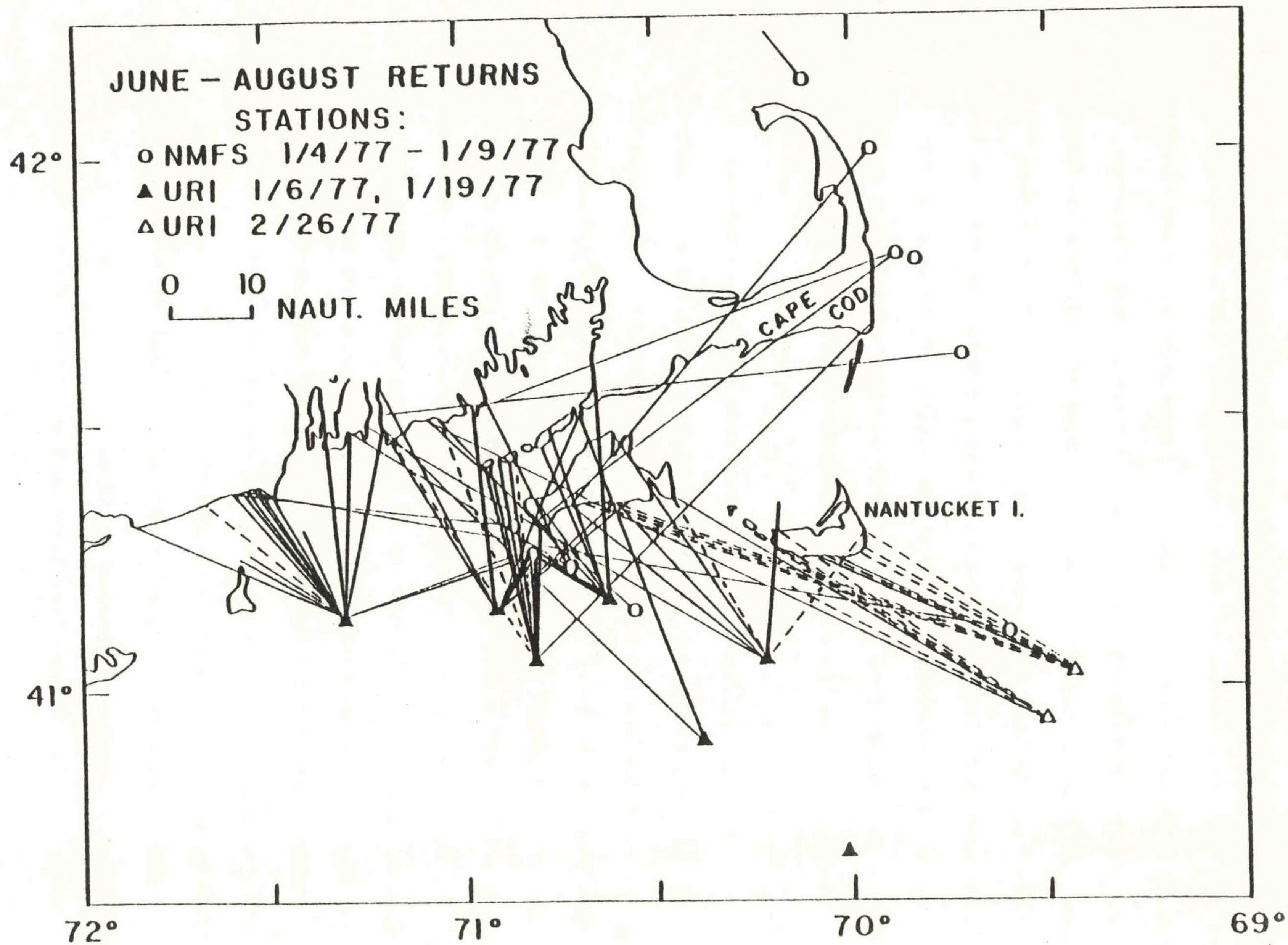


Fig. 18. June through August, 1977, seabed drifter returns.

falls off rapidly to only 14 percent in September, October, and November (Fig. 19). The three-month recovery plots show that although the majority of the drifters were recovered broken, the predominant direction of drifter movement was the same as the intact seabed drifters. During December, January, and February the wind direction is predominantly from the northwest (Gross and Mattson, 1977; Morgan and Anthony, 1977). Therefore, if the drifters had broken apart at some time before stranding, an offshore direction of travel would be expected. Although the quality of the data is poor, there appears to be a change from a predominantly northeastward drifter movement during March through May to a strong northwestward drift in June, July, and August.

Of the total released, 150 drifters were deployed on February 26, 1977, at URI stations 8 and 9, located eight nautical miles south southwest of the wreck at the leading edge of sediment contamination and at the ARGO MERCHANT site, respectively (Fig. 15). These were ship-launched and have the largest number of intact drifter returns; 13 of the 18 returned intact. Based on a 12 percent return from these stations there appears to be a component of near-bottom drift to the northwest. These results corroborate the findings of Bumpus (1973) in this area. The first drifter recoveries from the two stations did not occur until mid-June with the majority recovered in July. Drift rates of 0.3 - 0.6 nautical miles/day calculated for stations 8 and 9 are similar to the rate of $0.7 \pm 0.2$ nautical miles/day found by Bumpus (1973) from Great South Channel to south of Rhode Island.

Only three drifters released east of longitude $69^{\circ}$W were recovered suggesting a divergence of residual drift in this area. Bumpus (1976) notes an offshore drift on Georges Bank based on low drifter returns from this

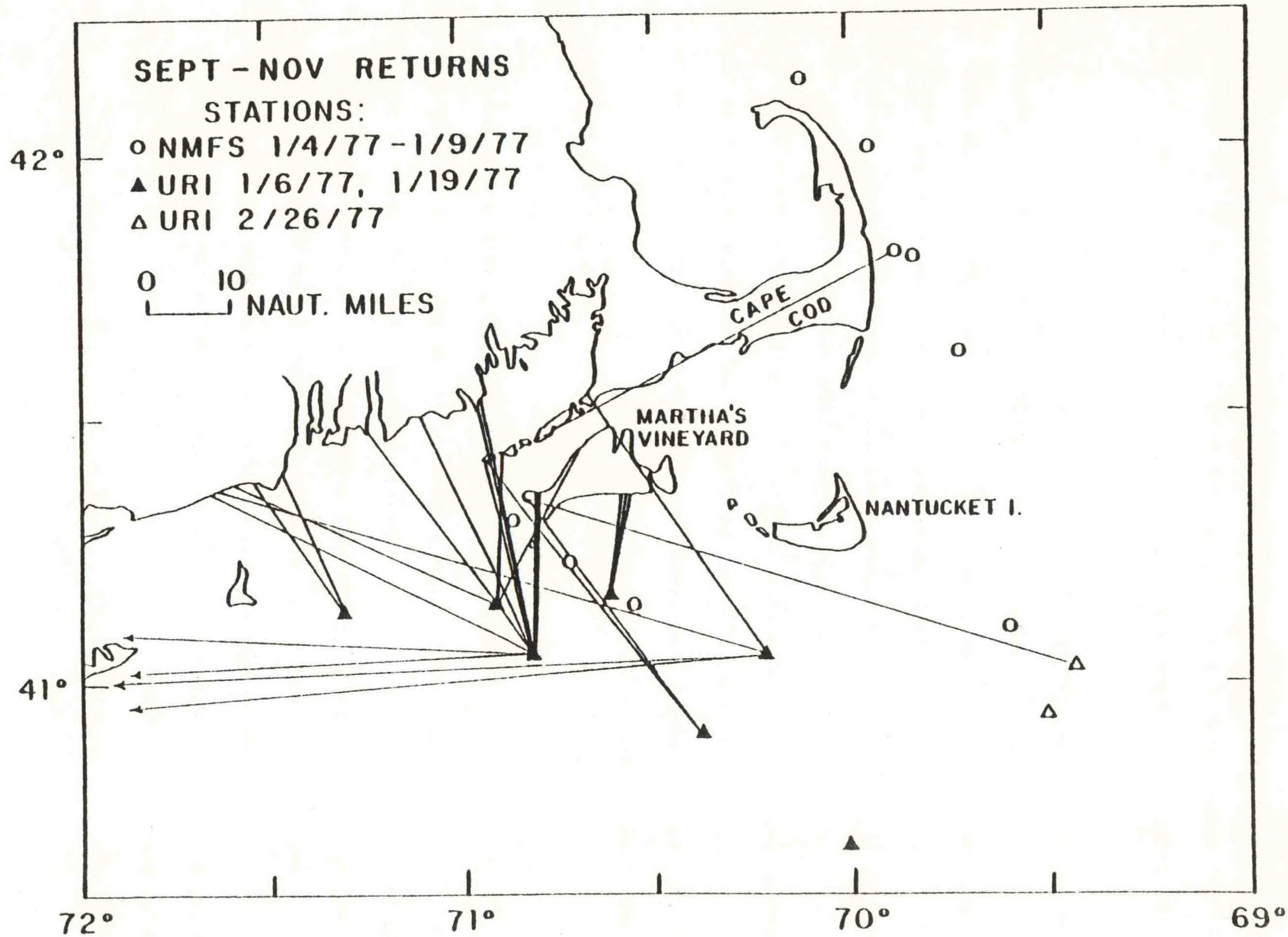


Fig. 19. September through November, 1977, seabed drifter returns.

region. Great South Channel, approximately delineated by the 69°W longitude line, may convey many of the drifters from both Nantucket Shoals and the western portion of Georges Bank offshore.

Oil Droplet Measurements (Cornillon, in press)

Water samples collected on cruises EN-002, EN-003, EN-004 and EN-005 were analyzed. The size distribution of 1- to 100-μm-diameter oil droplets dispersed in the water was to be determined, using a method developed by Forrester (1971). This distribution could not be measured, however, primarily because at most locations the large sediment load and the large number of microorganisms made it impossible to determine whether or not there were any oil droplets less than 100μ on the filter. Oil droplets larger than 100μ were detectable, however; the areal distribution of samples with such droplets is discussed below.

Analysis

500 - 1000 ml of seawater was filtered through a Millipore filter (pore size 018 - 8 μm; area <10 cm$^2$) under a microscope. The filtering apparatus is shown in Fig. 20. Although this figure shows only one in-line filter, there were actually three such assemblies each leading to the same vacuum trap. In this way it was possible to filter the three different samples of each station simultaneously. The first was taken approximately one meter below the surface, the second six meters below the surface and the third one meter above the bottom.

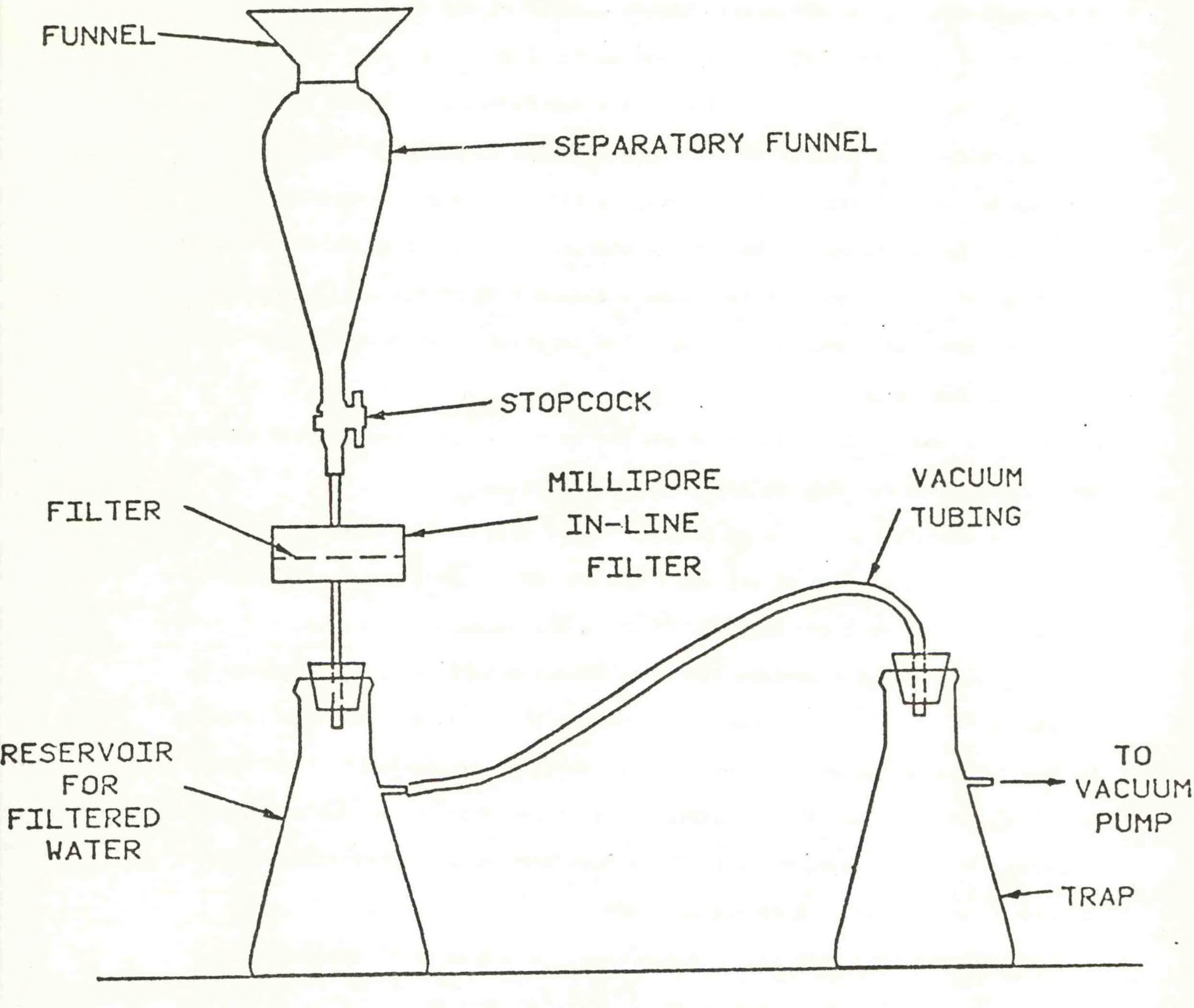


Fig. 20. Apparatus for filtering seawater for oil droplet measurements.

Results

On cruise EN-002, only one oil droplet was detected, this is a sample taken approximately 30 kilometers east-southeast of the ARGO MERCHANT wreck. This droplet was irregular in shape and measured approximately 100μ by 300μ. It was dissolved with carbon tetrachloride and showed no sediment inside it. A photograph of the droplet at 100X magnification is shown in Fig. 21. The results of the analysis of the filters for this cruise are summarized in Table I. The locations of the various stations as a function of depth are indicated in Fig. 22 where + indicates a sample with no oil and □ indicates a sample with at least one oil droplet. The location of the wrecked ARGO MERCHANT is indicated by a △.

The samples from cruise EN-003 showed no oil in a preliminary scan. The filters were too damaged for detailed analysis.

A significant number of samples from cruise EN-004 were analyzed in detail and no indication of oil was found on any of the filters. Table J summarizes those analyzed and Fig. 23 shows the sampling locations.

Oil droplets exceeding 100μ were detected at several locations on cruise EN-005 (Table K). These locations are shown in Fig. 24. The location of the bow and stern sections of the ARGO MERCHANT are marked in the figure with a △ and a "b" and an "s," respectively. The size of the □ 's designating locations where oil droplets were found have been made proportional to the square of the number of droplets observed.

Oil droplets were found at <u>all</u> three levels at which samples were taken. The oil droplets observed may be divided into three groups determined by their structure -- oil with no sediment in or adhering to the droplet, oil droplet with sediment particles inside, sediment coated with oil. Those

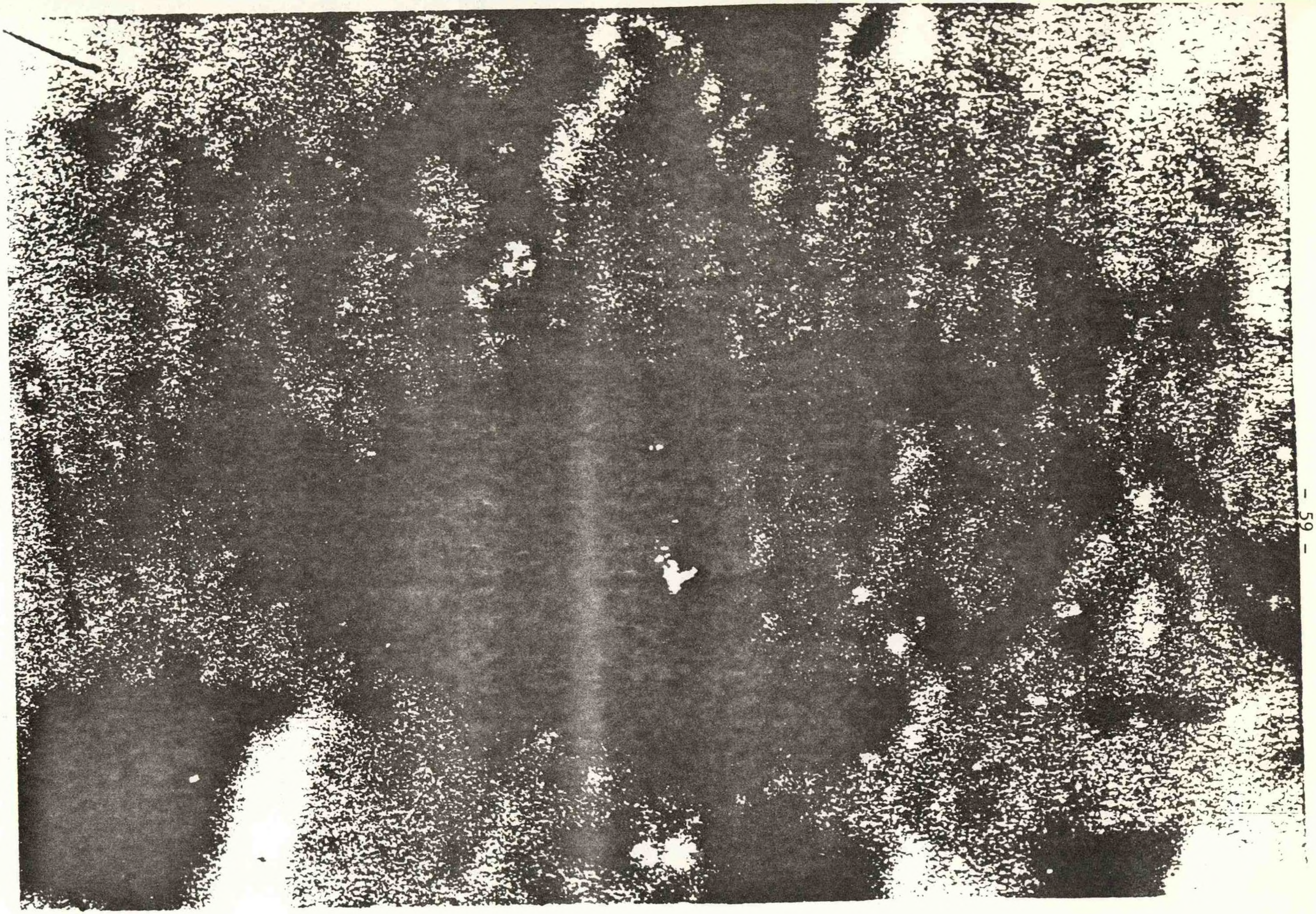

Fig. 21. Oil droplet on filter paper. Magnification 100x.

Table I. Millipore filter results from cruise EN-002

| Station # | Depth Meters | Sampling Technique | Latitude/Longitude | Volume Sampled ML | # of Drops | Concentration* PPB | Oil in Sediments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | Nisken | $40^{o}41.5'$ $69^{o}59.4'$ | 850 | 0 | 0 | --- |
| 1 | 6 | Nisken | $40^{o}41.5'$ $69^{o}59.4'$ | 1100 | 0 | 0 | --- |
| 1 | 39 | Nisken | $40^{o}41.5'$ $69^{o}59.4'$ | 800 | 0 | 0 | --- |
| 2 | 0 | Bucket | $40^{o}50.1'$ $69^{o}19.4'$ | 1000 | 0 | 0 | --- |
| 2 | 6 | Nisken | $40^{o}50.1'$ $69^{o}19.4'$ | 1100 | 0 | 0 | --- |
| 3 | 0 | Bucket | $40^{o}51.0'$ $68^{o}48.3'$ | 1500 | 1 | 3.1 | NO |

* The concentration is that resulting from the oil droplets only.

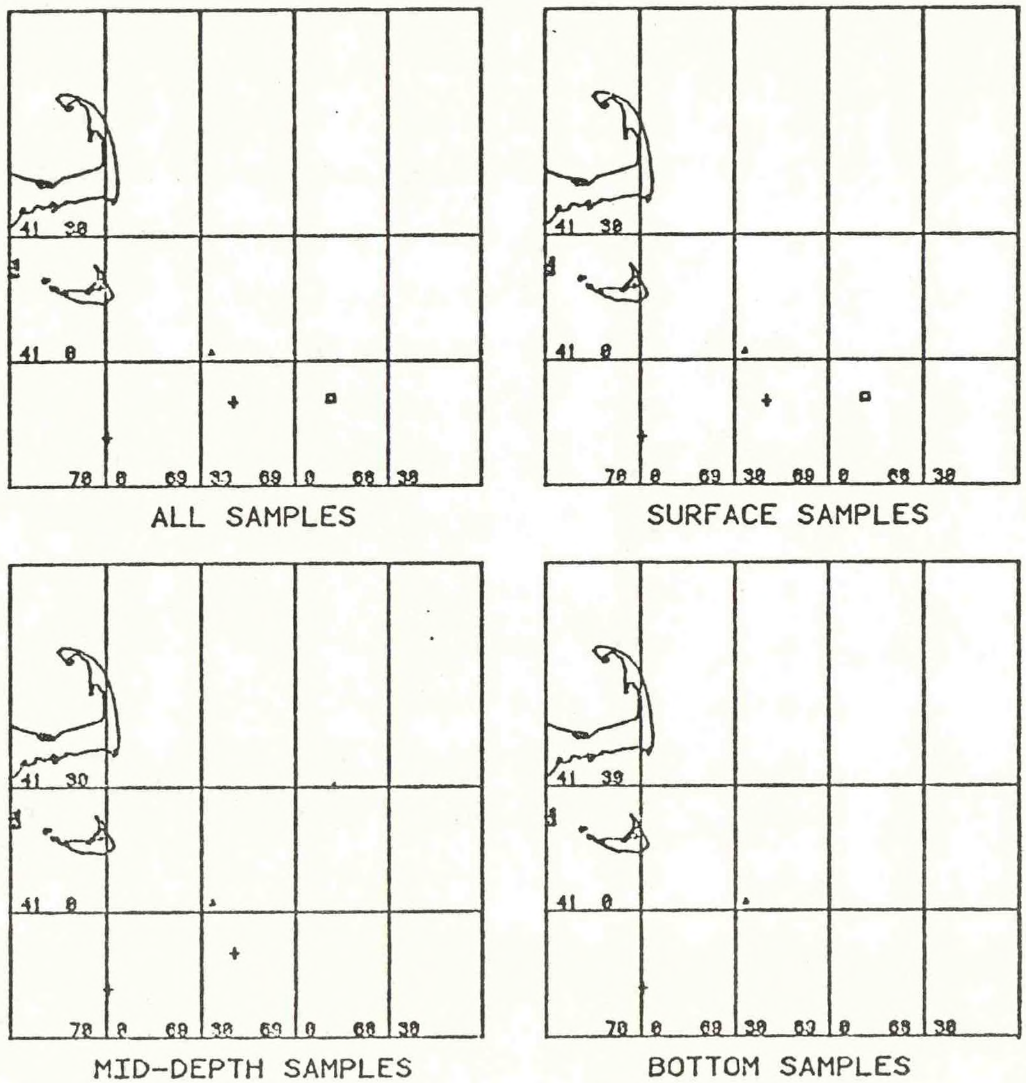


Fig. 22. Locations of EN-002 samples with (0) and without (+) oil droplets.

TABLE J. MILLIPORE FILTER RESULTS FROM CRUISE EN-004.

| STATION # | DEPTH METERS | SAMPLING TECHNIQUE | LATITUDE/LONGITUDE | VOLUME SAMPLED ML | # OF DROPS | CONCENTRATION* PPB | OIL IN SEDIMENTS |
|---|---|---|---|---|---|---|---|
| A34 | 1 | NISKEN | 41° 2.5′ 69° 17.5′ | 750 | Ø | | |
| A34 | 6 | NISKEN | 41° 2.5′ 69° 17.5′ | 750 | Ø | | |
| A34 | BOT | NISKEN | 41° 2.5′ 69° 17.5′ | 750 | Ø | | |
| G41 | 1 | NISKEN | 41° 6.5′ 69° 22.3′ | 750 | Ø | | |
| G41 | 6 | NISKEN | 41° 6.5′ 69° 22.3′ | 750 | Ø | | |
| G41 | BOT | NISKEN | 41° 6.5′ 69° 22.3′ | 750 | Ø | | |
| G42 | 1 | NISKEN | 40° 54.8′ 69° 36.1′ | 750 | Ø | | |
| G42 | 6 | NISKEN | 40° 54.8′ 69° 36.1′ | 750 | Ø | | |
| G42 | BOT | NISKEN | 40° 54.8′ 60° 36.1′ | 750 | Ø | | |
| D36 | 1 | NISKEN | 41° Ø.9′ 69° 31.9′ | 750 | Ø | | |
| D35 | BOT | NISKEN | 41° Ø.9′ 69° 31.9′ | 750 | Ø | | |
| C39 | 1 | NISKEN | 41° 3.3′ 69° 26.2′ | 750 | Ø | | |
| C39 | 6 | NISKEN | 41° 3.3′ 69° 26.2′ | 750 | Ø | | |
| C39 | BOT | NISKEN | 41° 3.3′ 69° 26.2′ | 750 | Ø | | |
| B15 | 1 | NISKEN | 40° 39.5′ 68° 22.Ø′ | 750 | Ø | | |
| B15 | 6 | NISKEN | 40° 39.5′ 68° 22.Ø′ | 750 | Ø | | |
| B11 | 1 | NISKEN | 40° 46.8′ 68° 22.Ø′ | 750 | Ø | | |
| B1Ø | 6 | NISKEN | 40° 51.6′ 68° 20.7′ | 750 | Ø | | |
| A4Ø | 6 | NISKEN | 40° 56.8′ 69° 31.5′ | 750 | Ø | | |
| A33 | BOT | NISKEN | 41° 2.4′ 69° 13.9′ | 750 | Ø | | |
| E3Ø | BOT | NISKEN | 40° 5Ø.2 69° 15.9′ | 750 | Ø | | |

* THE CONCENTRATION IS THAT RESULTING FROM THE OIL DROPLETS ONLY.

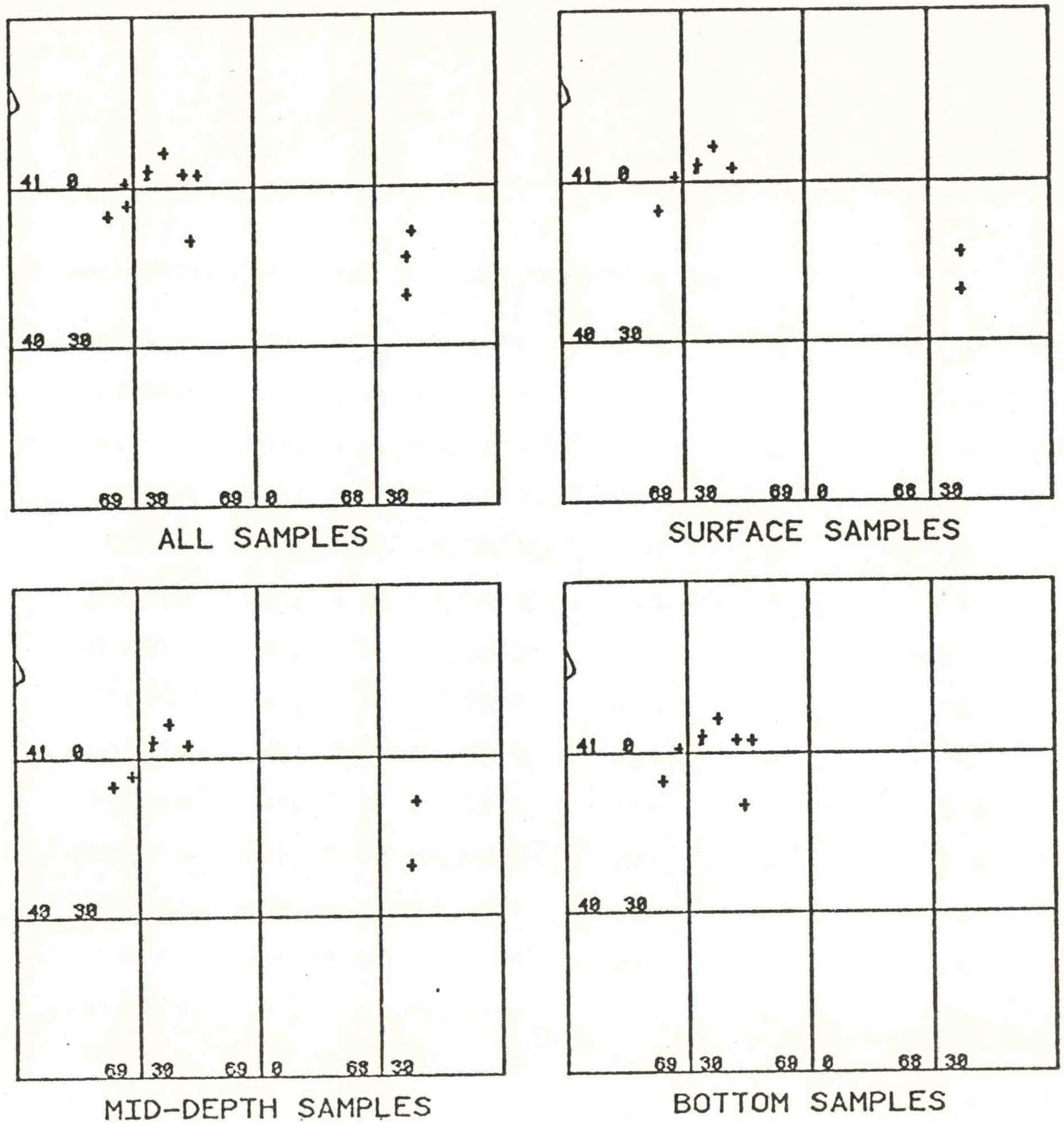


Fig. 23. Locations of EN-004 samples with (0) and without (+) oil droplets

TABLE K. Millipore filter results from cruise EN-005.

| STATION # | DEPTH METERS | SAMPLING TECHNIQUE | LATITUDE/LONGITUDE | VOLUME SAMPLED ML | # OF DROPS | CONCENTRATION * PPB | OIL IN SEDIMENTS |
|---|---|---|---|---|---|---|---|
| 48 | 0 | BUCKET | 40°56.6′ 69°41.9′ | 500 | 0 | 0 | --- |
| 57 | 0 | BUCKET | 41° 2.0′ 69°33.5′ | 500 | 0 | 0 | --- |
| 72 | 0 | BUCKET | 40°58.8′ 69°29.2′ | 500 | 0 | 0 | --- |
| 74 | 0 | BUCKET | 40°59.6′ 69°31.2′ | 1000 | 0 | 0 | --- |
| 59 | 1 | NISKEN | 41° 2.5′ 69°28.0′ | 500 | 1 | 1.6 | NO |
| 59 | 6 | NISKEN | 41° 2.5′ 69°28.0′ | 500 | 1 | 3.8 | YES |
| 59 | BOT | NISKEN | 41° 2.5′ 69°28.0′ | 500 | 0 | 0 | --- |
| 75 | 0 | BUCKET | 41° 2.0′ 69°29.0′ | 1000 | 0 | 0 | --- |
| 70 | 0 | BUCKET | 41° 1.6′ 69°26.3′ | 1000 | 4 | 100. | NO |
| 73 | 1 | NISKEN | 41° 1.6′ 69°26.3′ | 500 | 0 | 0 | --- |
| 70 | 6 | NISKEN | 41° 1.6′ 69°26.3′ | 500 | 0 | 0 | --- |
| 70 | 38 | NISKEN | 41° 1.6′ 69°26.3′ | 500 | 1 | ? | YES |
| 58 | 1 | NISKEN | 41° 0.6′ 69°33.8′ | 500 | 0 | 0 | --- |
| 58 | 6 | NISKEN | 41° 0.6′ 69°33.8′ | 500 | 1 | 4.5 | YES |
| 58 | BOT | NISKEN | 41° 0.6′ 69°33.8′ | 500 | 0 | 0 | --- |

* THE CONCENTRATION IS THAT RESULTING FROM THE OIL DROPLETS ONLY.

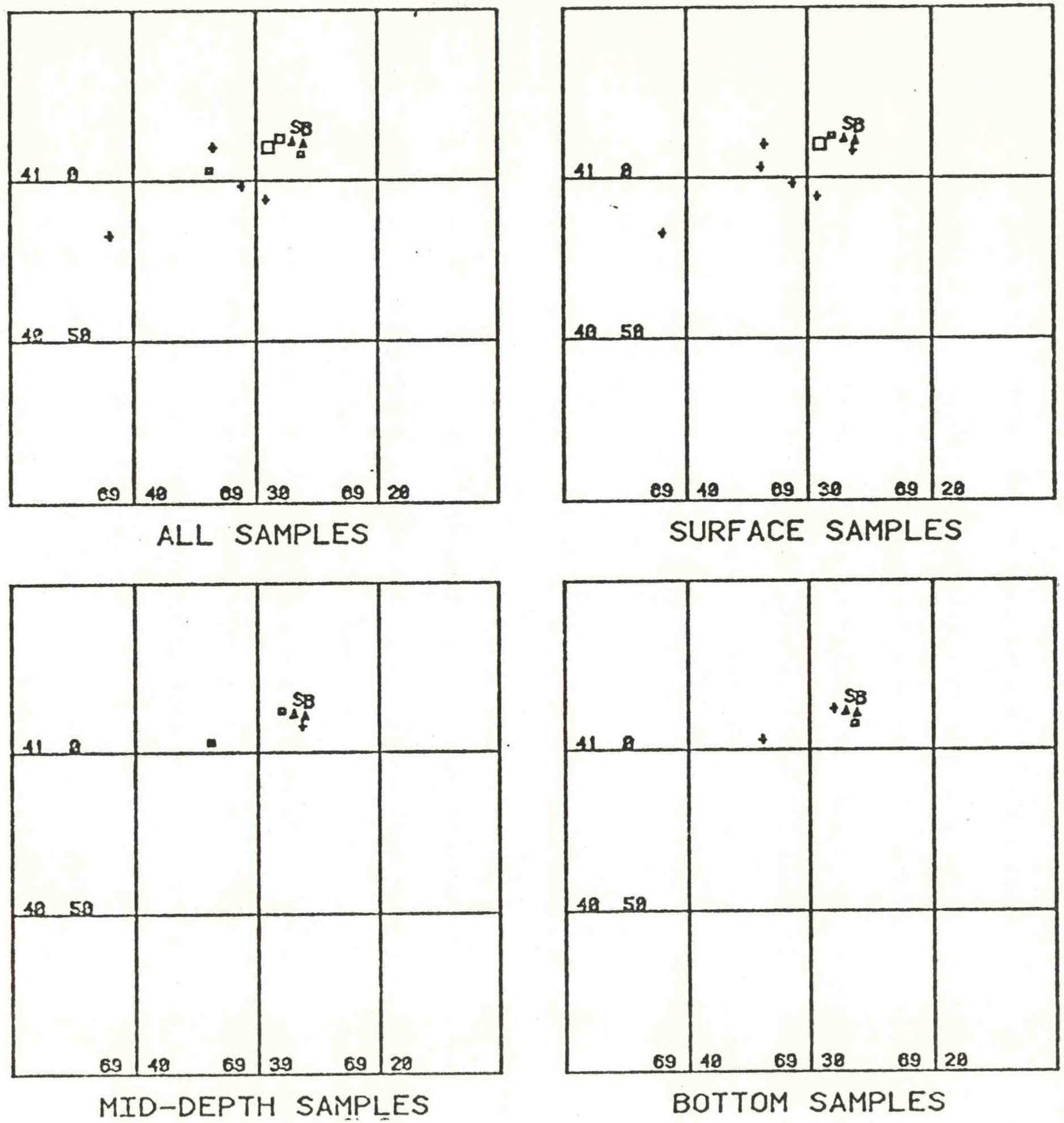


Fig. 24. Locations of EN-005 samples with (O) and without (+) oil droplets

samples with the first kind of droplets were taken from the surface (bucket samples) or one meter below the surface. Those samples with the second and third kinds of droplets were taken at six meters and a meter above the bottom. These three kinds of droplets are characteristically 100 - 500 μm.

The concentration of droplets is about one droplet per liter, similar to that observed by Forrester (1971).

From the following three observations it can be theorized that the oil droplets found in the water column in February were released from the sediments: (1) the areal distribution of oil droplets observed for this cruise, to the southwest of the wreck, is similar to that observed for oil in the bottom sediments; (2) small oil droplets were observed to leave the sediment samples when formalin solution was stirred into them; and (3) some droplets contained sediment.

<u>Seabird oiling, density and distribution</u> (Manomet Bird Observatory, Appendix A)

Seabird observations were made on cruises EN-003 and EN-004; ten-minute counts were made each hour. On cruise EN-003 observations were made for seven hours on January 28, 1977. About 192 seabirds were seen. For the four species checked, 0 - 7% of the seabirds were oiled, most lightly.

On cruise EN-004, observations were made during 22 hours. Six hundred and sixty-three seabirds were observed. About 12% of two species were oiled.

Infrared spectrometry analysis of tar balls (Brown, Lynch and Ahmadjian, in press)

Analysis

Twenty-two of the tar balls were analyzed. All were treated prior to analysis to remove water, sand, and marine debris. Approximately 5 ml of each sample was centrifuged for two minutes; the top oil layer was transferred to another test tube. Five ml of $CCl_4$ were added; the sample was shaken vigorously and centrifuged for five minutes. The top three-quarters of the sample was transferred to another test tube, anhydrous $MgSO_4$ was added, and it was centrifuged for another five minutes at $35^{o}C$. The latter step was repeated several times until all of the water was removed; the $CCl_4$ was then removed by evaporation.

The treated samples were analyzed with an infrared spectrometer. The spectra were digitized and compared with each other, with cargo from the ARGO MERCHANT, and with oil from the lost tanker, GRAND ZENITH.

If these tar balls came from either the ARGO MERCHANT or the GRAND ZENITH, they were in the ocean for over one month and the fingerprints could have changed due to "weathering." Thus, we artificially weathered the two neat oils under similar temperature conditions in flowing seawater at the URI aquarium. Weathered samples were collected periodically for one month and analyzed. Their spectra were compared to those of the tar balls.

A method for obtaining the probability of matching spilled oil to one or more suspects from infrared spectra of the samples can be obtained by a ratio method (Ahmadjian et al., 1976; Kileen and Chen, 1976).

In the ratio method, the ratios of absorbances at 18 frequencies in the spectrum of one sample to absorbances at the same frequencies in the spectrum of another sample are calculated. The log of each ratio, the average log-ratio, and the differences between each log-ratio and the average log-ratio are determined. Initially, we used the log-ratios of the absorbances in the spectrum of each suspect to those in the spectrum of the spill sample; the best match was assigned to the spectrum having the most ratios within 10% of the average. Later, the method was extended to give a single value, $S^2$ ("sum of squares"), for estimating the differences between spectra (Brown et al., 1976a). $S^2$ values have been calculated (Brown et al., 1976b) for all possible pairs of oils from spectra of 198 neat and 647 weathered oils; histograms of the frequency of occurrence for the $S^2$ values have been plotted for pairs of oils from the same and from different sources. The histograms give distributions which are used to obtain the probability of matching of the oil sample coming from a source.

## Results

Infrared spectra of the ARGO MERCHANT cargo and of the spilled oil collected two days after the tanker broke apart are shown in Fig. 25. When the digitized spectrum of the spilled oil was compared with that of the cargo, the following probabilities were obtained:

| | Probability |
|---|---|
| ARGO MERCHANT | 0.986 |
| Another Source | 0.014 |

The deviation from 1.0 is possibly due to weathering of the spilled oil.

Infrared spectra of the 22 tar balls listed in Table A were measured and the digitized fingerprints stored in a computer data file. Many of the spectra had similar contours and some were almost identical as is shown in

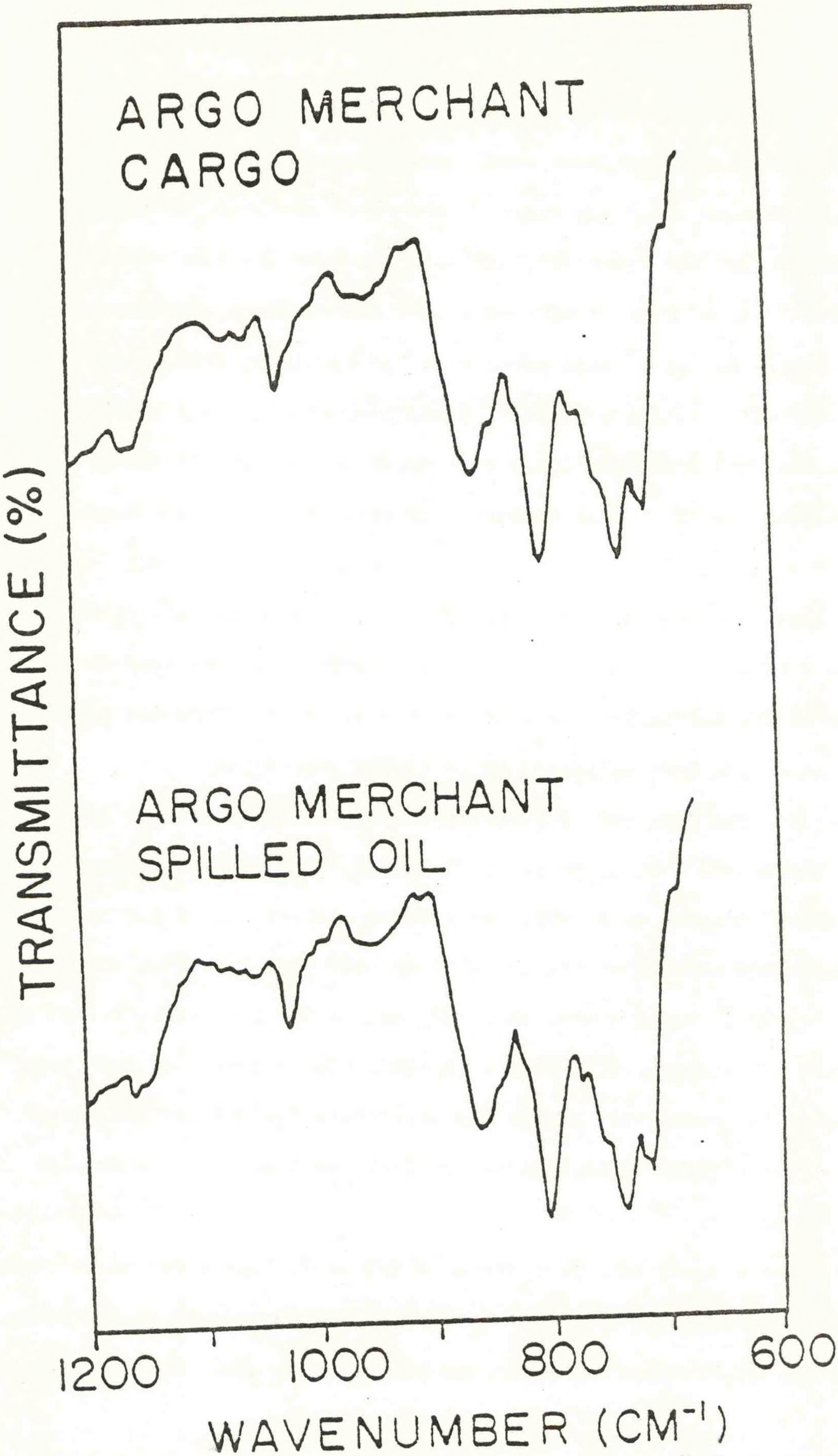


Fig. 25. Infrared spectra of the Argo Merchant cargo and of the spilled oil collected 2 days after the spill.

Fig. 26. The spectrum of each tar ball was compared with that of each of the others; the probability that they came from the same source is given in Table L. The results are categorized according to magnitude in Fig. 27.

All samples from Jamestown, Martha's Vineyard and Nantucket have probabilities >0.85 of being identical except for sample 2 from Jamestown. This was a sample of the outside layer of a tar ball; the differences reflect excessive weathering on the surface. In addition to samples 1-10 being from the same source, the probabilities that samples 11, 12, 16, 17 and 19 came from this source are >0.5. Furthermore, tar balls 11 and 13 are virtually identical (P = 0.99).

It should be mentioned that the differences between many of the tar balls could be due to weathering and that this effect is more pronounced on the surface of the tar balls. Many of the tar balls from Cape Cod were very small and could have been subjected to extensive weathering.

The infrared spectral fingerprint of the ARGO MERCHANT oil is compared to that of the Martha's Vineyard tar ball in Fig. 28. The general contours of the spectra are entirely different. We treated each of the 22 tar balls as a spill sample and determined the probability that each came from the cargo. The results given in Table M show that only sample No. 11 (Nauset Beach) had a probability of matching >0.3; most were <0.2. The spectrum of the cargo and the tar balls (except for sample 15) were characteristic of No. 6 fuel oils. Thus, these finite probabilities reflect the fact that the samples are the same type of oil.

If the tar balls came from the ARGO MERCHANT, they were "weathered" in the Atlantic for almost two months; thus, we weathered some of the cargo oil at the URI aquarium for one month and periodically analyzed samples. In

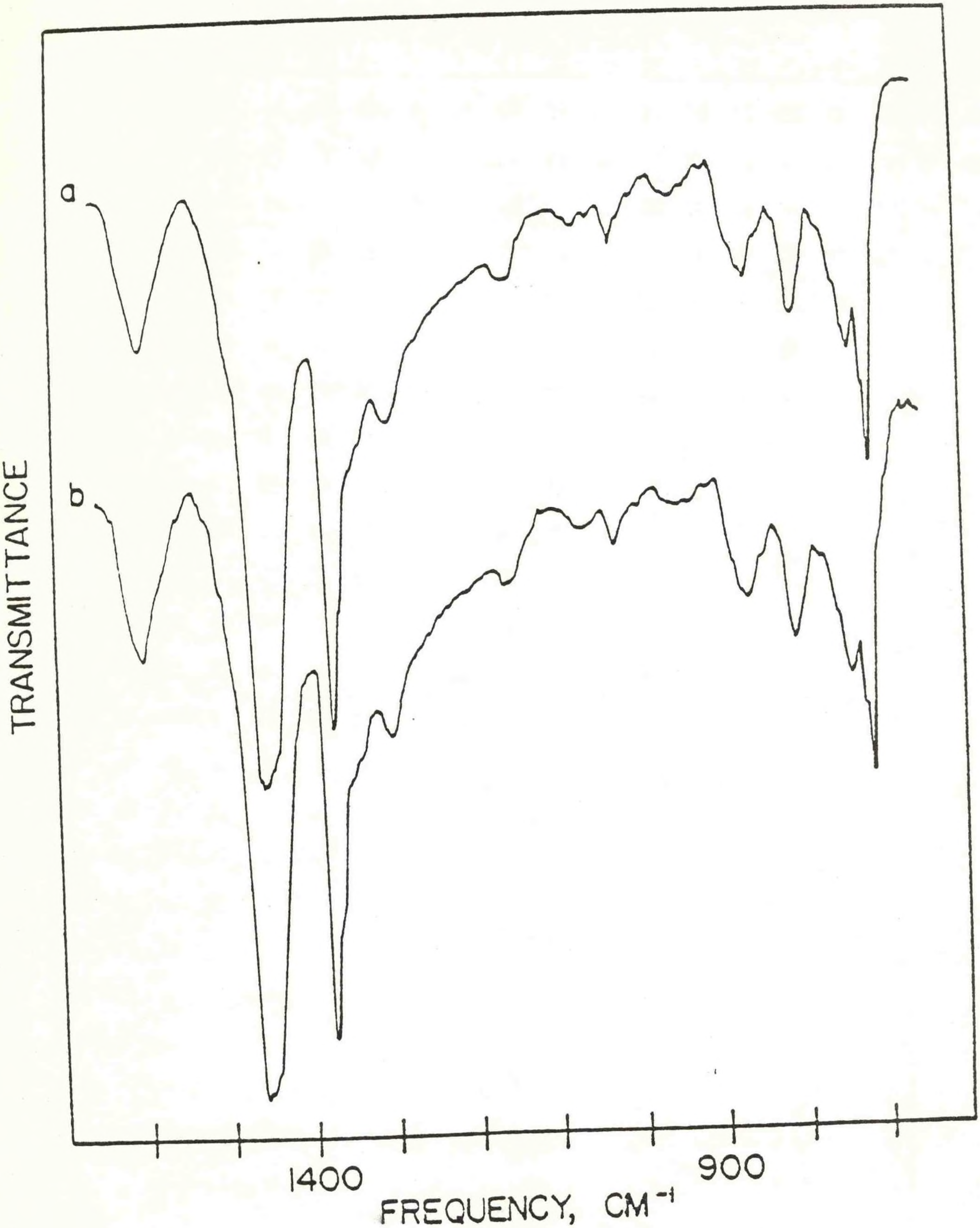


Fig. 26. Infrared spectra of tar balls - a, Jamestown; b, Martha's Vineyard.

TABLE L

Probabilities of Tar Balls Matching.
Probabilities are in % Units.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 66 | 96 | 96 | 97 | 99 | 95 | 97 | 97 | 99 | 46 | 55 | 43 | 20 | 0 | 86 | 66 | 16 | 89 | 16 | 22 | 18 |
| 2 | | - | 76 | 70 | 67 | 79 | 77 | 77 | 71 | 71 | 45 | 56 | 41 | 33 | 0 | 56 | 51 | 16 | 58 | 18 | 19 | 20 |
| 3 | | | - | 96 | 100 | 97 | 96 | 99 | 97 | 98 | 38 | 45 | 36 | 18 | 0 | 90 | 77 | 20 | 91 | 17 | 19 | 18 |
| 4 | | | | - | 100 | 98 | 93 | 100 | 97 | 99 | 33 | 41 | 31 | 18 | 0 | 87 | 83 | 17 | 90 | 16 | 18 | 17 |
| 5 | | | | | - | 97 | 93 | 99 | 98 | 100 | 35 | 42 | 34 | 18 | 0 | 90 | 80 | 20 | 91 | 14 | 18 | 18 |
| 6 | | | | | | - | 98 | 98 | 97 | 99 | 47 | 60 | 44 | 22 | 0 | 84 | 76 | 17 | 89 | 18 | 22 | 18 |
| 7 | | | | | | | - | 95 | 98 | 95 | 55 | 72 | 53 | 26 | 0 | 74 | 73 | 16 | 82 | 18 | 28 | 19 |
| 8 | | | | | | | | - | 96 | 99 | 38 | 48 | 35 | 19 | 0 | 84 | 84 | 19 | 84 | 16 | 17 | 18 |
| 9 | | | | | | | | | - | 97 | 45 | 50 | 42 | 21 | 0 | 91 | 63 | 16 | 73 | 17 | 23 | 18 |
| 10 | | | | | | | | | | - | 40 | 48 | 38 | 19 | 0 | 91 | 76 | 18 | 86 | 16 | 20 | 18 |
| 11 | | | | | | | | | | | - | 94 | 99 | 81 | 0 | 33 | 23 | 21 | 33 | 34 | 55 | 59 |
| 12 | | | | | | | | | | | | - | 94 | 57 | 0 | 31 | 37 | 18 | 44 | 32 | 39 | 36 |
| 13 | | | | | | | | | | | | | - | 80 | 0 | 31 | 23 | 19 | 33 | 32 | 54 | 48 |
| 14 | | | | | | | | | | | | | | - | 0 | 18 | 18 | 21 | 18 | 44 | 36 | 71 |
| 15 | | | | | | | | | | | | | | | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | | | | | | | | | | | | | | | | - | 25 | 16 | 58 | 15 | 20 | 19 |
| 17 | | | | | | | | | | | | | | | | | - | 0 | 70 | 16 | 17 | 17 |
| 18 | | | | | | | | | | | | | | | | | | - | 22 | 19 | 19 | 43 |
| 19 | | | | | | | | | | | | | | | | | | | - | 15 | 18 | 17 |
| 20 | | | | | | | | | | | | | | | | | | | | - | 23 | 55 |
| 21 | | | | | | | | | | | | | | | | | | | | | - | 44 |
| 22 | | | | | | | | | | | | | | | | | | | | | | - |

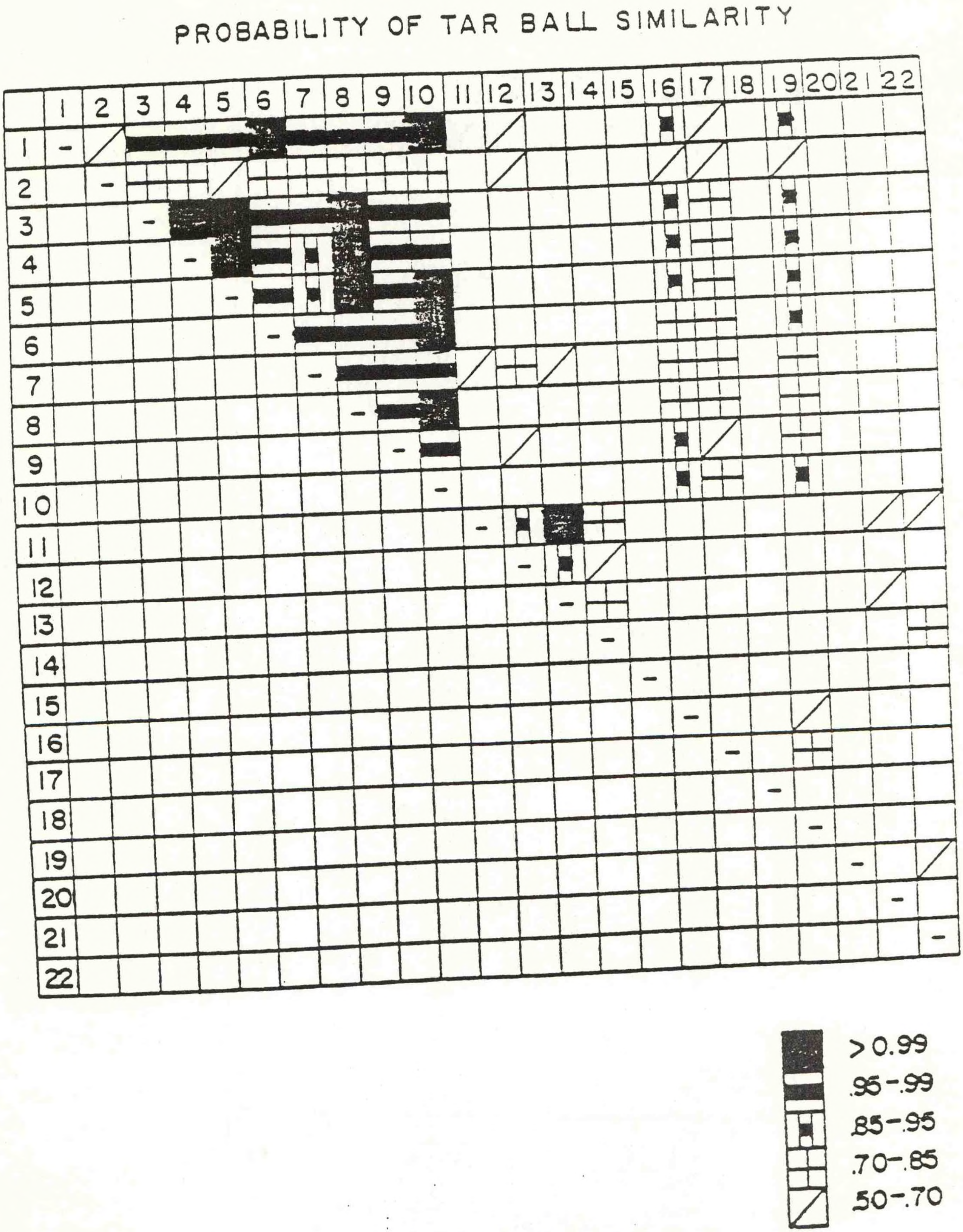


Fig. 27. Probabilities of tar balls matching.

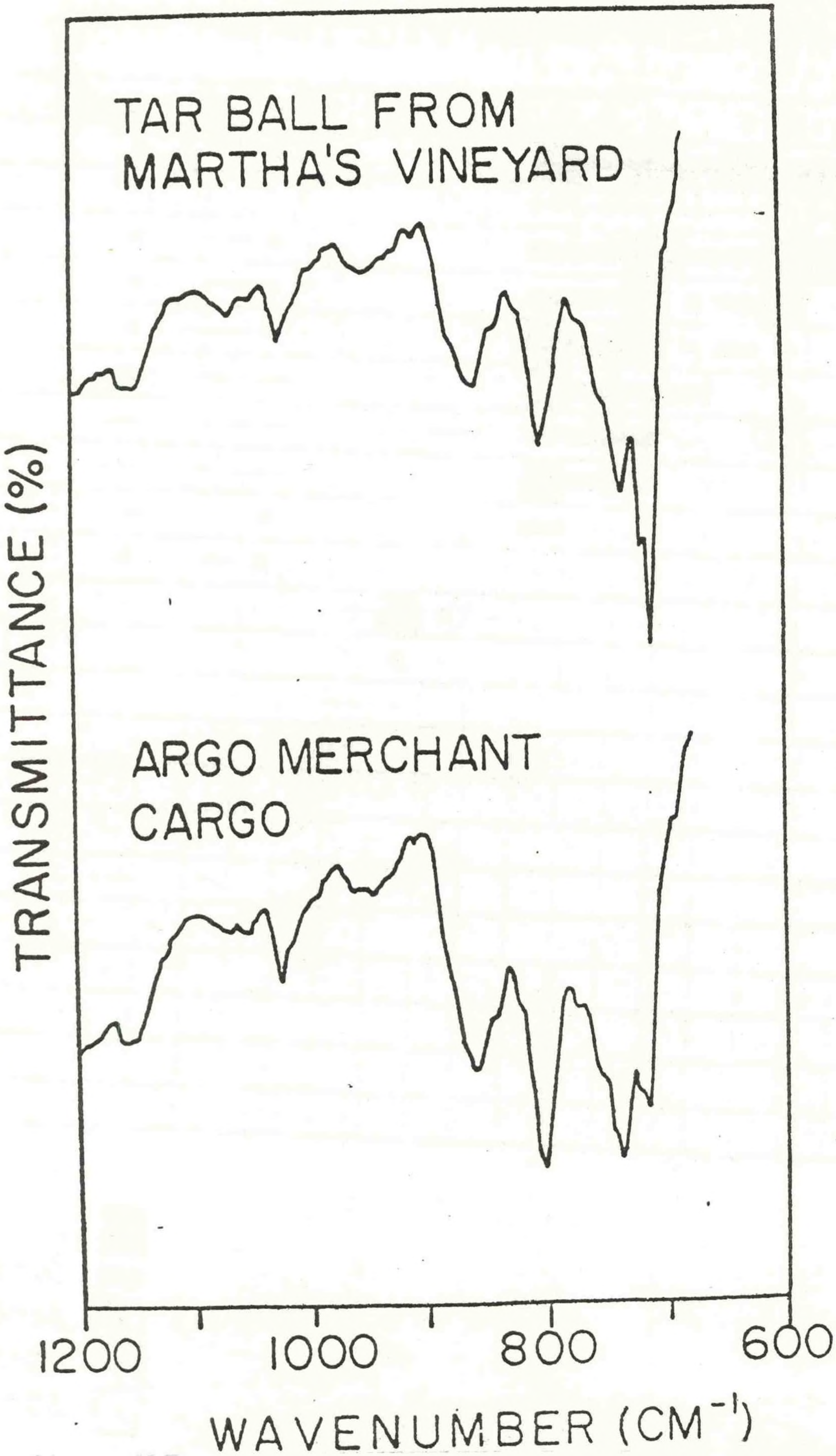


Fig. 28. Infrared spectra of tar ball from Martha's Vineyard and Argo Merchant cargo.

all cases, the spectra of the tar balls and the weathered ARGO MERCHANT became less similar. The probabilities of matching for the three and ten day samples are also given in Table M.

The tanker GRAND ZENITH disappeared somewhere off of the New England coast on the way from Teeside, England, to Fall River, Massachusetts, during January, 1977; thus, its cargo was also a possible source of the tar balls. The U.S. Coast Guard R & D Center supplied us with a sample of the oil loaded aboard the GRAND ZENITH. We measured infrared spectra of the neat oil and of samples collected periodically during one month of weathering at the URI aquarium. The infrared spectrum of the GRAND ZENITH oil is compared with the ARGO MERCHANT cargo and the Martha's Vineyard tar ball in Fig. 29.

The probabilities obtained when comparing the spectra of the neat and seven weathered samples to the tar balls are given in Table N. The probabilities run as high as 0.83 when the neat oil is compared to tar balls No. 3 and 4; however, the highest probability (90%) was obtained from matching the 14 day weathered sample with tar ball No. 11 from Nauset Beach (see Fig. 30 for spectra). Other tar balls found in this area (No. 13 and 14) have probabilities of ~0.85 of matching the weathered GRAND ZENITH oil.

According to the probabilities in Table N, the tar balls can generally be placed into three categories: i) those with high probabilities of matching the neat or short term weathered samples; ii) those with high probabilities of matching the long term weathered samples; and iii) those with low probability matches. Samples 1, 3-10, 16 and 19 fall in category i, samples 11-14, 21 and 22 in category ii, and the rest in iii.

The present study showed conclusively that the tar balls found along the New England coast after the ARGO MERCHANT incident were not from that

TABLE M

Probability of Tar Balls Originating From Argo Merchant Cargo. (In % Units)

| Tar Ball | Neat | Argo Merchant Cargo 3 Days Weathered | Argo Merchant Cargo 10 Days Weathered |
|---|---|---|---|
| 1 | 22 | 18 | 18 |
| 2 | 18 | 25 | 18 |
| 3 | 21 | 5 | 18 |
| 4 | 19 | 0 | 18 |
| 5 | 20 | 0 | 18 |
| 6 | 20 | 7 | 18 |
| 7 | 19 | 19 | 18 |
| 8 | 20 | 22 | 18 |
| 9 | 21 | 23 | 18 |
| 10 | 21 | 20 | 18 |
| 11 | 32 | 18 | 32 |
| 12 | 23 | 18 | 27 |
| 13 | 27 | 19 | 27 |
| 14 | 18 | 18 | 18 |
| 15 | 0 | 0 | 0 |
| 16 | 21 | 0 | 18 |
| 17 | 15 | 17 | 16 |
| 18 | 18 | 16 | 18 |
| 19 | 18 | 25 | 18 |
| 20 | 18 | 28 | 21 |
| 21 | 19 | 18 | 22 |
| 22 | 22 | 18 | 28 |

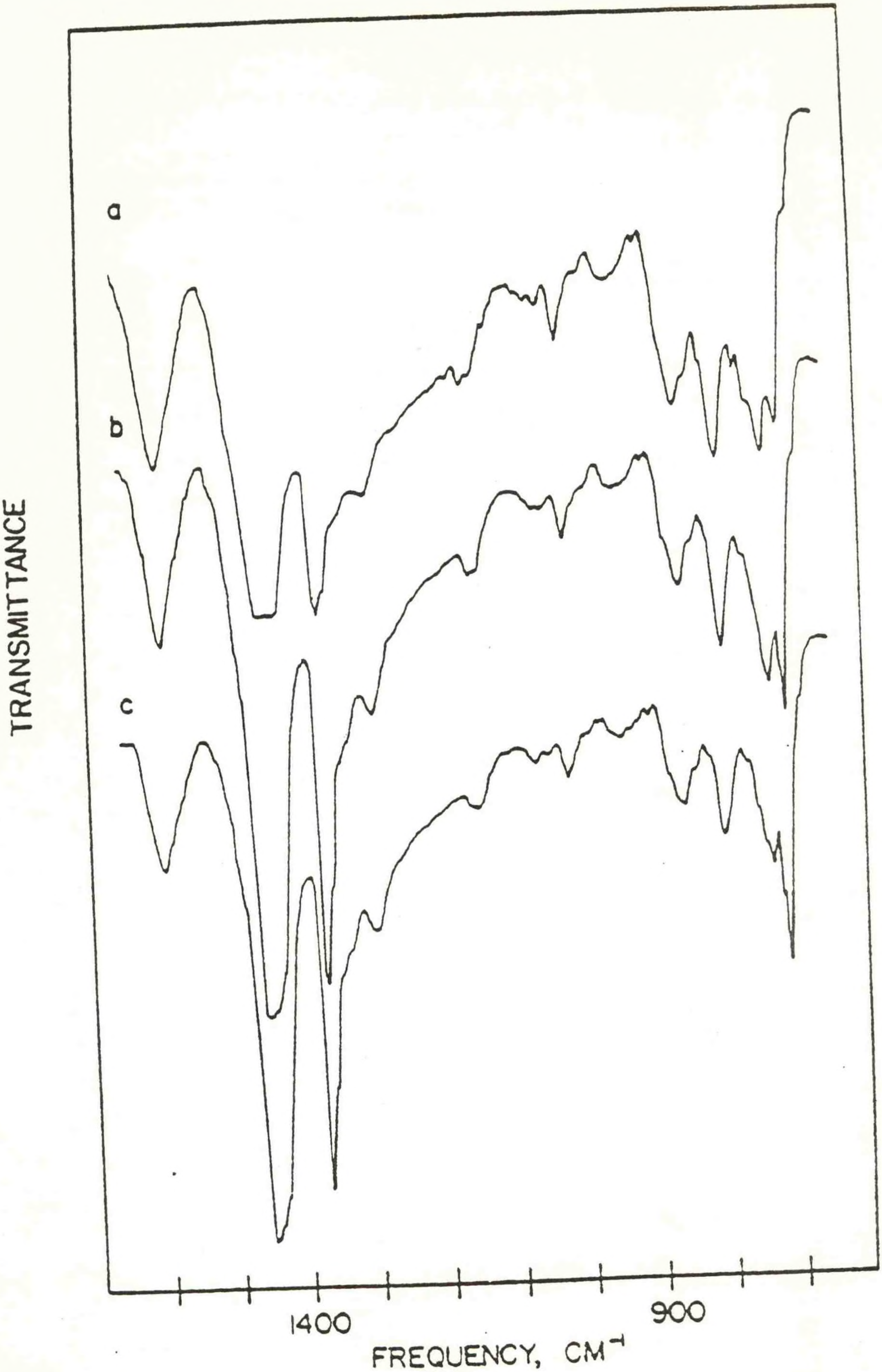


Fig. 29. Infrared spectra: a, Argo Merchant cargo; b, Grand Zenith oil; and c, Martha's Vineyard tar ball.

TABLE N

Probability of Tar Balls Originating from GRAND ZENITH Cargo
(In % Units)

| Tar ball number | Days of weathering GRAND ZENITH cargo oil 0 | 1 | 2 | 4 | 7 | 14 | 21 | 28 |
|---|---|---|---|---|---|---|---|---|
| 1 | 74 | 77 | 75 | 51 | 73 | 55 | 26 | 27 |
| 2 | 45 | 45 | 52 | 55 | 58 | 47 | 33 | 34 |
| 3 | 83 | 87 | 86 | 66 | 77 | 50 | 22 | 24 |
| 4 | 83 | 87 | 88 | 69 | 75 | 49 | 20 | 21 |
| 5 | 82 | 88 | 86 | 63 | 76 | 47 | 20 | 21 |
| 6 | 73 | 75 | 76 | 57 | 77 | 58 | 29 | 29 |
| 7 | 60 | 65 | 70 | 52 | 70 | 63 | 35 | 34 |
| 8 | 76 | 81 | 81 | 58 | 72 | 47 | 23 | 23 |
| 9 | 69 | 73 | 73 | 44 | 74 | 61 | 29 | 30 |
| 10 | 79 | 83 | 83 | 55 | 78 | 54 | 25 | 26 |
| 11 | 36 | 35 | 38 | 31 | 55 | 90 | 86 | 87 |
| 12 | 38 | 38 | 42 | 41 | 51 | 73 | 64 | 58 |
| 13 | 32 | 33 | 35 | 30 | 47 | 84 | 81 | 83 |
| 14 | 18 | 18 | 18 | 18 | 23 | 41 | 87 | 77 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 75 | 78 | 77 | 40 | 85 | 58 | 23 | 28 |
| 17 | 33 | 37 | 40 | 44 | 32 | 24 | 18 | 18 |
| 18 | 14 | 16 | 16 | 20 | 17 | 19 | 18 | 21 |
| 19 | 71 | 75 | 74 | 81 | 59 | 37 | 18 | 20 |
| 20 | 16 | 16 | 16 | 15 | 18 | 22 | 37 | 30 |
| 21 | 18 | 18 | 20 | 19 | 27 | 46 | 61 | 63 |
| 22 | 18 | 18 | 18 | 18 | 22 | 40 | 58 | 64 |

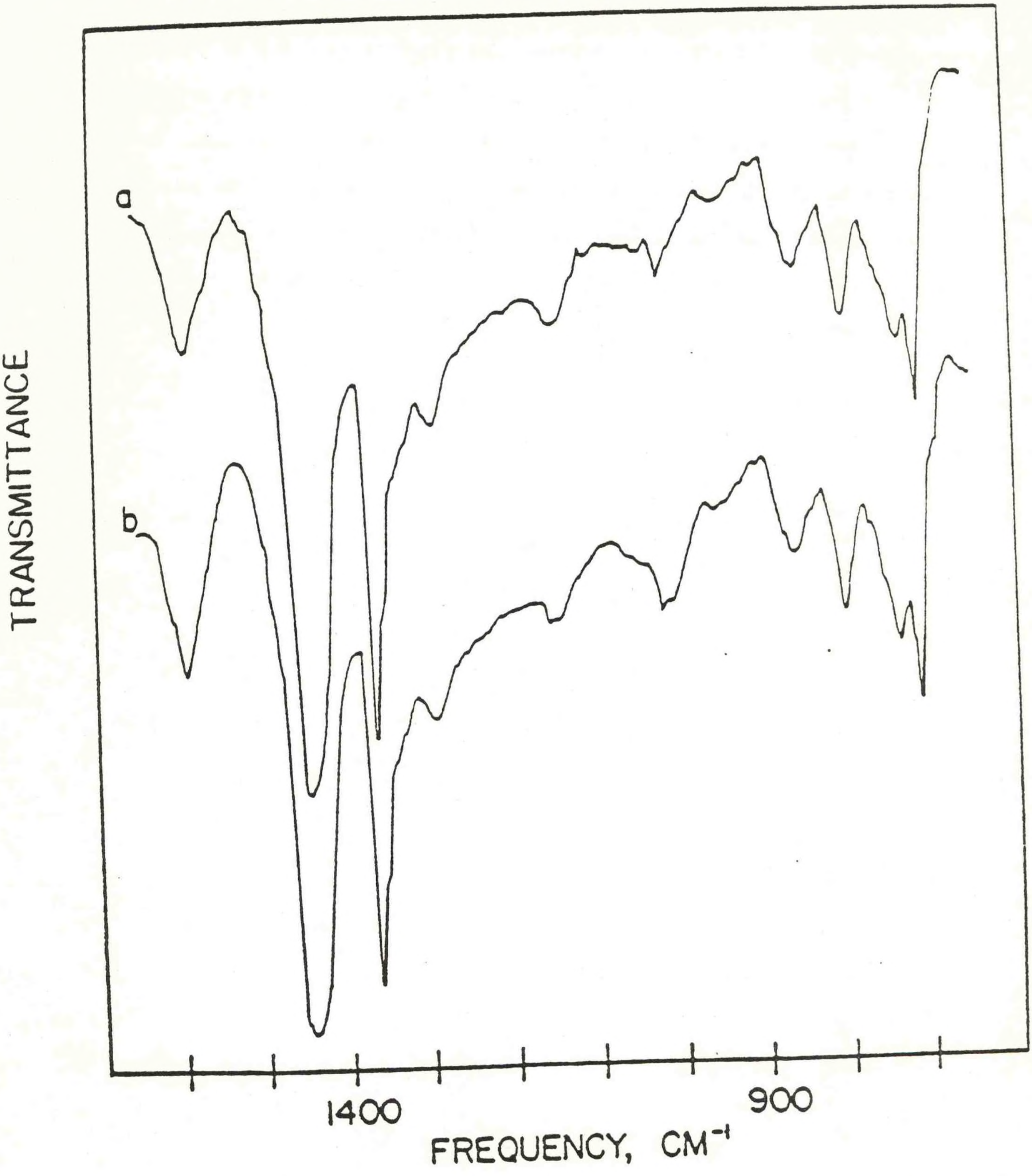


Fig.30. Infrared spectra: a, tarball from Nauset Beach, and b, *Grand Zenith* oil weathered 14 days.

tanker. Many of the tar balls had similar infrared spectra and there is a high probability that a number of these came from the same source. Finally, there is a reasonably high probability that some of the tar balls originated from the tanker, GRAND ZENITH. It should be noted that the tar balls were compared with the oil loaded onto the GRAND ZENITH, and not to the oil actually contained in the tanker. The composition of the oil in the tanker could have been slightly different due to residues in the tanker from previous shipments.

## Summary

The URI investigations for NOAA contract 03-7-022-35123 involved five cruises to the ARGO MERCHANT oil spill site, in a 4000-km$^2$ area. Seven studies have been completed; ancillary studies were conducted as well. The main conclusions are given below.

### Sediments

Significant sediment contamination in February, 1977, extended at most 3 - 4 km SE of the wreck, encompassing an area of no more than 10 - 15 km$^2$. Traces of contamination from an unknown source were found 3 - 5 km east and south of the bow. The oil was present mainly as droplets 0.03 - 2 mm in diameter, and not as a surface coat or as coatings on grains. The areal and vertical distributions were inhomogeneous. Surface sediments near the wreck site were not a major sink for the ARGO MERCHANT oil.

In July, 1977, the only oil found in the sediments, a trace amount near the bow, did not match ARGO MERCHANT oil.

The two methods used to measure the hydrocarbon content of sediments near the tanker wreck were compared -- UV-fluorescence, used by the Coast Guard, and gas chromatography, used by URI. While there is usually good agreement for background and trace values, the URI values are generally lower than the Coast Guard values. These inhomogeneous sediments were not adequate samples for a rigorous intercalibration exercise.

The seabed drifter studies showed a predominantly NE bottom transport between March and May changing to a strong NW drift during June to

August. Since surface sediments were not a major sink of ARGO MERCHANT oil, however, transportation of oil to the shoreline via bottom currents was not important in this case.

Benthic organisms

The sand ridge had few macrobenthos and a relatively homogeneous interstitital community. The gravel-bottomed channels adjacent to the ridge had a large amount of diverse benthic organisms. In February, oil was found in and on a few organisms. In July, there was a slight increase in the density and diversity of benthic organisms, possibly a natural seasonal variation.

Water

On cruises EN-002, EN-003, and EN-004, essentially no oil droplets were detected in the seawater samples taken. On cruise EN-005, oil droplets larger than 100 μm were detected at the surface, 6 m below the surface, and 1 m above the bottom, to the SW of the wreck, in parallel with the distribution in the bottom sediments. Droplets smaller than 100 μm could not be detected by this method.

Samples of slick up to five days old showed no evidence of weathering.

Seabird studies

Observations on cruises EN-003 and EN-004 showed that 0 - 7% and 12% of the observed seabird species were oiled, most lightly.

Tar balls

Digitized infrared spectra of cargo oil samples from the ARGO MERCHANT and a missing tanker, the GRAND ZENITH, were compared to the spectra of 22 tar balls found two to three months after the spill from Jamestown to Cape Cod. Probabilities that each tar ball came from one of the two cargos were calculated. None of the tar balls came from the ARGO MERCHANT oil spill. Some of them were probably from the other tanker.

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APPENDIX A

APPENDIX A

Unpublished Contributions

Brown, C. W. Chemical Analysis of Water and Sediment Samples Collected in the Vicinity of the ARGO MERCHANT Spill - EN-002.

Hargraves, P. Phytoplankton Studies in Area of ARGO MERCHANT Oil Spill.

Hoffman, E. J., J. G. Quinn, J. R. Jadamec, and S. Fortier. Comparison of UV Fluorescence and Gas Chromatographic Analyses of Hydrocarbons in the Sediments from the Vicinity of the ARGO MERCHANT Wreck Site on Nantucket Shoals: A Preliminary Assessment.

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Winn, H. Report of Overflights to Observe Marine Mammals in the Vicinity of ARGO MERCHANT Wreck Site.

Winn, H. Recommendations for Marine Mammal Research Relative to Oil Spill Impact.

CHEMICAL ANALYSIS OF WATER AND SEDIMENT SAMPLES COLLECTED

IN THE VICINITY OF THE ARGO MERCHANT SPILL - EN-002

Submitted by Chris W. Brown, Chemistry Department,
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Samples were collected by members of this group aboard ENDEAVOR on December 29, 1976, at three stations:

Station 1: Assumed to be clean. Water samples at surface, 6m and bottom (36m), and sediment sample.

Station 2: Oil had been found at this station approximately one week earlier. Water samples at surface and 6m, and sediment sample.

Station 3: East of Station 2 - towards the reported movement of the oil. Water sample at surface.

The two sediment samples were extracted with $CCl_4$ and the amounts of total extractable organics measured by infra-red spectroscopy. At Station 1, 15 μg/g wet wt. were found and at Station 2, 9 μg/g wet wt. These values were typical of "clean" sediments.

The six water samples were extracted with $CCl_4$ and the total amounts of extractable organics are listed in Table 1. The average values for total extractable organics of 23 and 33 ppb with a range of 9 to 67 ppb were found during two studies along the Atlantic Coast.[1] Thus, the values of 191, 455, 435 found in the present investigation are high. The first value for the sample collected near the bottom of Station 1 could be high

(1) R.A. Brown, J.J. Elliott and T.D. Searl, Esso Research and Engineering Co., Linden, N.J., Report AID.4BA.74, May 16, 1974.

if the sediment was disturbed while sampling. The other two high values at Station 2(6m) and Station 3 (surface) appear unusually high, and we subjected these samples to further analyses.

The hydrocarbons found in the two questionable samples by gas chromatography are also high, but they are not significantly different from the types and amounts found in the "clean" samples. We suspect that the high values of total extractable organics are due to soluble chemicals rather than dispersed oil. Further analysis by infra-red spectroscopy of the 6m sample from Station 2 indicated the presence of two types of chemicals; phthalic acid esters, and undentifiable chemical. We have tried to determine that these chemicals came from ARGO MERCHANT oil, but so far this has not been possible in a laboratory scaled experiment on the ARGO MERCHANT oil. Possibly, these chemicals are formed by biodegradation of the oil and we are not able to simulate this in the laboratory.

PHYTOPLANKTON STUDIES IN AREA

OF ARGO MERCHANT OIL SPILL

(Report of results of R/V ENDEAVOR Cruise EN-002)

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University of Rhode Island
Kingston, Rhode Island 02881

Two phytoplankton tows were conducted by Mr. Skip French aboard R/V ENDEAVOR Cruise EN-002. We have material from a "clean" area (Station 1) and from a "contaminated" area (Station 2). Since tows are not quantitative, we were only able to compare the species composition of large diatoms and dinoflagellates. There was no obvious difference between the two areas. Both were very abundant in Coscinodiscus species, Thalassionema species, Ceratium species, and the tintinnid Stenosemella. Station 2 had small oil droplets in low numbers. There was considerable similarity in species composition with a tow taken in the same area during the delivery cruise of ENDEAVOR in early November. In short, the phytoplankton showed no obvious response to the oil spill, on the basis of two samples (which is certainly far from conclusive).

Further phytoplankton samples were collected aboard R/V ENDEAVOR Cruise EN-005. These are now being examined and the results will be reported in "Flora of the Northeast Coast" edited by Melbourne Carrikar, NOAA Special Publication.

# COMPARISON OF UV FLUORESCENCE AND GAS CHROMATOGRAPHIC ANALYSES OF HYDROCARBONS IN THE SEDIMENTS FROM THE VICINITY OF THE ARGO MERCHANT WRECK SITE ON NANTUCKET SHOALS: A PRELIMINARY ASSESSMENT

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Avery Point, Groton, Conn.

(This is a preliminary draft and should not be cited without the author's permission.)

The sediments collected aboard R/V ENDEAVOR were subdivided and distributed among several different investigators for chemical analysis. One such suite of samples, collected on EN-005, was used jointly by the U.S. Coast Guard Research and Development Center, and the University of Rhode Island. Since these two groups analyzed samples from the same container, it was hoped that the two sets of data could provide an opportunity to compare, using real samples, two different analytical techniques for hydrocarbons. Successful intercalibrations between investigators using gas chromatographic analysis techniques have been conducted previously (Farrington, et al., 1976) but never using two different analytical methods. Detailed descriptions of the analytical techniques used by the URI and USCG groups are described elsewhere (Hoffman and Quinn, 1978; Jadamec, 1977, 1978).

These techniques vary in two aspects: extraction procedure and the analytical instrumentation used for quantification. The extraction techniques used by Hoffman and Quinn (1978) utilized methanolic KOH in the extraction procedure. Use of methanol probably enhances the extraction efficiency of hydrocarbons, especially in the case of weathered hydrocarbons. The solvent hexane, as used in the procedure of Jadamec (1977), may be sufficient to extract recently spilled hydrocarbons (Gearing, personal communication, 1978). The different extraction techniques used by the two groups may introduce variables whose effects are unknown at present.

The instrumentation used for quantification, gas chromatography and UV fluorescence, respond to different parameters. The fluorescence technique responds to compounds which fluoresce such as 2 - 5 ring aromatic hydrocarbons. But the presence of other organic compounds in the sample which also fluoresce may interfere with this technique, causing the reported values to be too large. On the other hand, if preferential weathering or losses of the aromatic fraction takes place, errors in quantification can be introduced.

Gas chromatographic analysis is not influenced by these problems. Since isolation steps are routinely used before gas chromatographic analysis, the instrumentation responds only to hydrocarbons. Weathering of the hydrocarbons would result in the disappearance of some of the individual components which can be detected from the gas chromatogram. Materials with very low and high molecular weights (lower than n-$C_{14}$ or higher than n-$C_{34}$), however, are not measured and thus the technique gives a lower limit value for total hydrocarbons.

The results of analyses where URI and the Coast Guard analyzed the same samples are given in Table 1. In this case, 5 $cm^3$ of sediment

Table 1. Sediment hydrocarbons in vicinity of ARGO MERCHANT wreck analyzed by two methods.

| Station | Coast Guard UV fluorescence value (ppm) | URI GC value (ppm dry wt) |
|---|---|---|
| 50(1) 0-1 | 0 | <0.1 |
| 50(2) 0-1 | 0 | 0.8 |
| 56(1) 0-1 | Trace[1] | 1.2 |
| 56(2) 0-1 | 0 | <0.3 |
| 57(1) 0-1 | Trace | <0.1 |
| 59(1) 0-1 | Trace | 2.4[2] |
| 59(1) 1-3 | 3.5 | 0.5[2] |
| 59(1) 3-5 | 0 | <0.1[2] |
| 59(3) 0-1 | 10 | 2.6[2] |
| 59(3) 1-3 | 0 | <0.1 |
| 59(3) 3-5 | 6 | <0.1 |
| 59(4) | 0 | 0.3 |
| 61(2) 0-1 | 0.9 | 1.1 |
| 61(3) 0-1 | 0 | 0.7 |
| 70(1) 0-1 | 70 | 12.8 |
| 70(1) 1-3 | 15 | 29.6 |
| 70(1) 3-5 | 90 | 11.5 |
| 70(1) 5-10 | 118 | 19.7 |
| 70(2) 0-1 | 8.2 | 10.2 |
| 70(2) 1-3 | 0 | 4.0[2] |
| 70(2) 3-5 | 10 | 5.6[2] |
| 70(4) 0-1 | 100 | 75 |
| 70(4) 1-3 | 50 | 5.1 |
| 70(4) 3-5 | >118 | 122 |

[1]trace as defined as < 0.24 ppm but above background;

[2]tar particles removed prior to analysis;

was removed from the glass container, extracted with hexane, and analyzed within 30 minutes after collection by the Coast Guard using their UV fluorescence technique. The remaining contents of the sample were frozen until extraction (200 g with 0.5N KOH in methanol/toluene). A plot of the Coast Guard values versus the URI values is given in Figure 1. Linear regression analysis with no zero values or trace values considered indicated a regression equation as follows:

$$\text{URI values} = 0.50 \times \text{USCG values} - 0.03 \qquad (1)$$
$$(n = 16)$$

When zero values and trace values are considered the regression equation becomes:

$$\text{URI values} = 0.498 \times \text{USCGRD values} + 0.26 \qquad (2)$$
$$(n = 24)$$

and the correlation coefficient improves slightly to 0.72.

Therefore, there is some correlation between the two sets of analyses. Generally, the URI values are lower than the Coast Guard's values and usually there is good agreement in the case of the lower values of background and trace quantities. There is not much to be gained in examination of the data in any further detail. As noted by Hoffman and Quinn (1978) and Pratt (1978) the oil present in these samples was in the form of minute tar particles or oil droplets mixed inhomogeneously into the samples. This led to poor reproducibility even when samples were taken from the same jar, as was the case with the URI and Coast Guard subsamples. No attempt was made to mix the sediments before the Coast Guart aliquot was removed, nor when the URI portions were taken

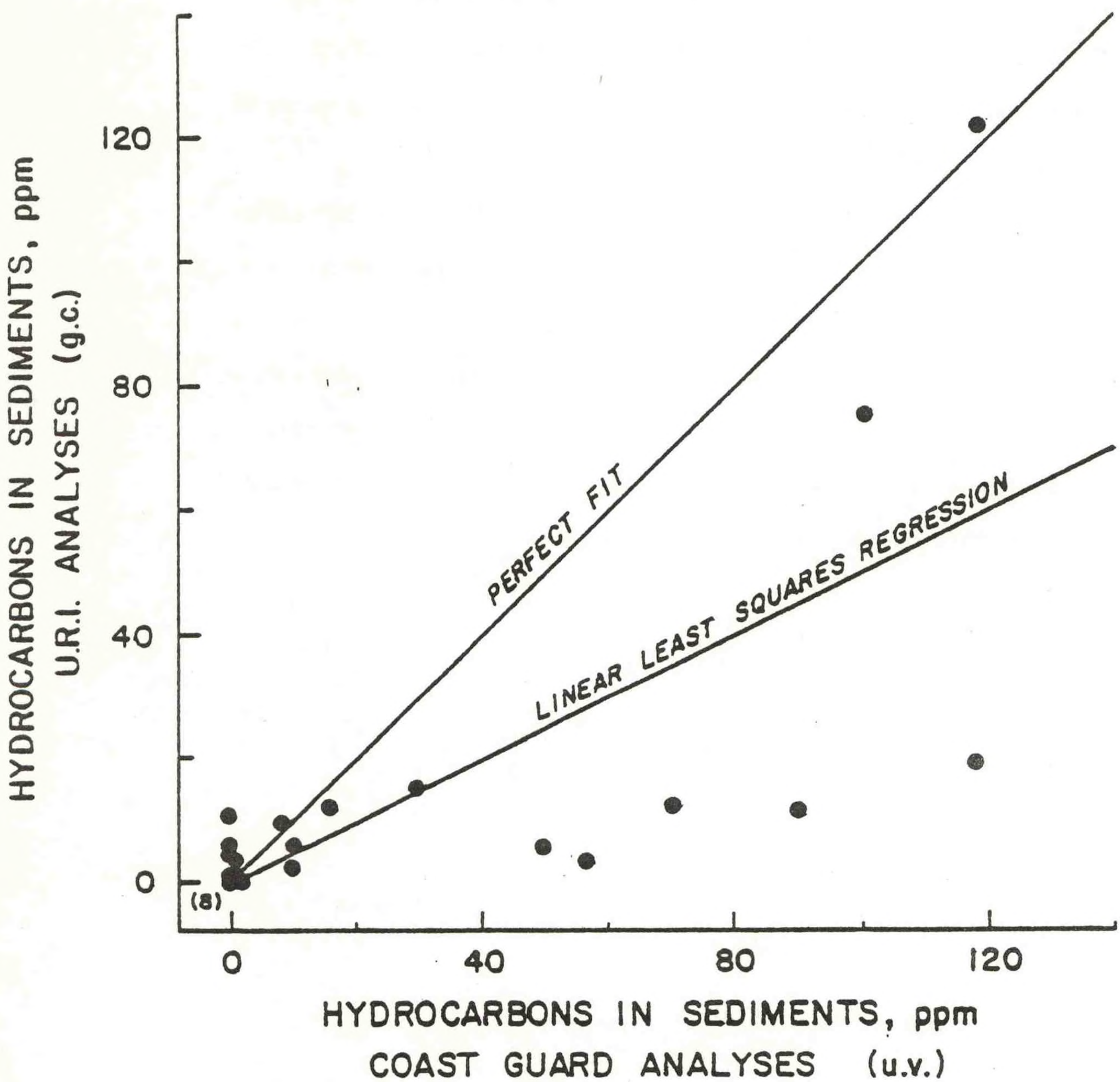


Figure 1: Hydrocarbon analyses of sediments collected near the ARGO MERCHANT wreck site: u.v. fluorescence technique versus gas chromatographic analysis

from the jar. Thus replicate analysis of sediment by URI from Station 70, grab 4, 0-1 cm depth, yielded values of 118, 69.7 and 35.7 ppm ($74.5 \pm 41.3$), a relative standard deviation of 55%. The usual reproducibility with the URI technique and more homogeneous sediment samples is on the order of less than 20%. Use of small samples could result in even worse replication problems, depending on the presence or absence of even one tar particle.

Thus, although there is great interest in the intercomparison of these two techniques (UV fluorescence and gas chromatography), the use of the ARGO MERCHANT samples to attempt this only demonstrated the need for homogeneous intercalibration samples. Considering the nature of the samples, the differing sample sizes, the differing extraction procedures, the differing analytical methods, and the length of storage, it is amazing that the agreement is so good.

RESULTS OF UV FLUORESCENCE SCANNING OF

ENDEAVOR SEDIMENT AND WATER SAMPLES

Submitted by J. R. Jadamec
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Groton, Connecticut

(Excerpts from "The ARGO MERCHANT Oil Spill: A Preliminary Scientific Report" edited by P. Grose and J. Mattson, NOAA Special Report, March, 1977.)

## Water Sampling and Analyses

### Samples

Water samples obtained after the ARGO MERCHANT grounding included the first taken during the WHOI R/V OCEANUS II cruise on December 20 and 21 and those obtained on the cruise of the URI R/V ENDEAVOR, February 8-12. Other vessels involved in water sampling were the USCGC's EVERGREEN, VIGILANT, BITTERSWEET, and NOAA's DELAWARE II.

By far the largest number of samples were taken with Sterile Bag Samplers (Model 1030, General Oceanics, Inc., Miami, Florida). This sampler is designed to be lowered through the sea-air interface while sealed, opened by messenger at depth, and automatically closing before being returned to the surface. The sample of approximately 1 liter thus obtained is uncontaminated by a surface oil slick, and is representative of the subsurface water. In areas thought to be uncontaminated, additional samples were taken with standard Niskin bottles of the type that passes through the air-sea interface in an "open" configuration and is closed at depth by a messenger.

All water samples were either immediately frozen, or were extracted with hexane aboard ship (on the later ENDEAVOR cruises) in order to stabilize any hydrocarbons contained within against bacterial degradation. Frozen samples were transported, using a completely documented chain of custody, by G. Heimerdinger, NOAA Liaison at Woods Hole Oceanographic Institution, to the USCG R&D Center at Groton, Connecticut. The water samples were then extracted and prescreened for petroleum hydrocarbons (PHC) by R. Jadamec of the Center.

A Chemical Analysis Committee, formed at a meeting at Woods Hole, January 3-4, 1977, is monitoring the continuing analyses of all water samples.

Ultra-violet fluorescence screening of water samples

By this procedure, one liter of sample is extracted twice, using 10-milliliter portions of spectroquality hexane. The two hexane extracts are combined and then analyzed by synchronous scanning ultraviolet fluorescence. The excitation and emission monochromators are initially set at 225 and 280 nanometers, respectively. The continuous excitation-emission spectrum is recorded until final settings of 475 and 500 nanometers on the excitation and emission monochromators, respectively, are obtained. The resulting fluorescence spectrum reveals the distribution of the polyaromatic rings present in the sample. Comparison of the sample spectrum with that of the reference oil spectrum, obtained at various concentration levels, will indicate the relative concentration of oil present in the sample. The sample taken from surface slick by Galt and Mattson on December 19 is being used as the reference oil.

The screening of water column samples is still in progress.

Analyses of samples collected by the USCGC's BITTERSWEET, EVERGREEN, and VIGILANT directly beneath the slick indicate very low levels of PHC concentration. All water samples analyzed indicate an absence of high-molecular-weight polyaromatic hydrocarbons at various depths beneath and around the slick from December 20 through December 31. The absence of 4- and 5-ring polyaromatic compounds in the water makes it difficult to use the whole oil as a concentration standard. As a temporary compromise, the 2- and 3-ring portion of the whole oil spectrum was employed as the concentration reference. The error this introduces is one of <u>slightly</u> <u>overestimating</u> the amount of oil present in the water column samples. Using this method of calibration, as well as calibrating against the API "pool" No. 2 fuel oil (available from the Biology Department, Texas A&M University), the highest petroleum hydrocarbon (PHC) concentrations measured were approximately 250 parts per billion. These were found in samples taken beneath the slick by the USCGC's VIGILANT and BITTERSWEET. Samples on these cruises were taken at two depths ranging from 1 to 10 feet below the surface. It is in the deeper of the two samples that the highest concentrations were found according to R. Jadamec. It is the consensus of the chemical analysis committee that the oil observed in the water samples is actually the "cutter stock," which represents about 20% of the cargo oil. An effort is being made by P. Fricke of WHOI to obtain an authentic sample of this "cutter stock." When a sample is obtained, the water column samples will be corrected to it as a new standard.

Samples taken during the January 26-29 and February 8-12 ENDEAVOR cruises included water samples taken at the surface, at a depth of 6 meters, and near the bottom, as well as bottom sediment samples at each station. The near-bottom and sediment samples will be carefully analyzed to see if there is any relationship between sediment PHC's and PHC's in the water column. The water samples taken on both ENDEAVOR cruises show a lower hydrocarbon content than that observed in samples obtained from the EVERGREEN, BITTERSWEET, and VIGILANT directly beneath the slick. In all cases, only the light aromatic fraction of the ARGO MERCHANT oil could be detected, if indeed it was ARGO MERCHANT oil at all. Representative samples of water column extracts are being selected for additional GC-MS analysis at the NOAA National Analytical Facility in Seattle, and several samples will be archived for eventual intercalibration with BLM's "bench-mark" survey contractors for the Georges Bank lease area.

Sediment Sampling and Analyses

A large number of sediment samples were taken from the EVERGREEN, OCEANUS, DELAWARE II, and ENDEAVOR during the last two weeks of December, but for a variety of purposes and by different sampling procedures. At the meeting at Woods Hole on January 3-4, 1977, all the cooperating investigators agreed that the sediment samples should be handled in the same way as the water samples, i.e., after extraction and prescreening by R. Jadamec at the Coast Guard R&D Center, selected samples were to be sent to the NOAA National Analytical Facility in Seattle for GC-MS analysis.

Screening Procedures

Sediment samples are being screened by two methods: thin-layer chromatography, and ultraviolet fluorescence. Selected samples are then forwarded to the NOAA National Analytical Facility in Seattle for GC-MS analysis.

The ultraviolet fluorescence procedure developed by Gordon and Krisa (1974) is being used on both the water column and sediment samples to determine if substantial quantities of oil are present. The thin-layer chromatographic method was developed by Mississippi State University under contract to the U.S. Coast Guard.

Thin-layer chromatographic screening of sediments. A measured volume of sediment (5 cubic centimeters) is extracted with 2 milliliters of spectroquality hexane by stirring the slurry for 1 minute. The hexane is then decanted into a 5-milliliter vial and reduced in volume to 0.5 milliliter by gentle warming over a hot plate. Twenty-five microliters of the concentrated hexane extract is spotted on the active side of type 5A chromatographic paper strip approximately 1.5 centimeters above the bottom edge. The spot is allowed to dry thoroughly and then developed in a mixture of 35% petroleum ether and 65% benzene for 45 to 60 seconds. The chromatographic strip is allowed to dry and viewed under ultraviolet lights. The presence of a blue fluorescent spot is indicative of the presence of oil. The greater the intensity of the fluorescence, the greater the quantity of oil. The minimum detectable level of fluorescences is equivalent to 2 micrograms of oil contained in 5 cubic centimeters of sediment.

Ultraviolet fluorescence screening of sediment samples. A measured volume of sediment (10 cubic centimeters) is extracted with 5 milliliters of spectroquality hexane by stirring the slurry for 1 minute. The extract is then removed and analyzed by the synchronously scanning fluorescence technique used for the water samples. Comparison of the sample spectrum with that of the reference oil spectrum at various concentrations indicates the relative concentration of oil present in the samples. The reference oil is the same as that being used for the water samples.

Preliminary Results

All sediment samples have been screened by the thin-layer chromatographic procedure. Samples collected on the EVERGREEN, DELAWARE II 76-13, and DELAWARE II 77-01 cruises indicate extremely low levels of petroleum concentrations, with a majority of these samples having no fluorescent blue spot. Sediment samples collected on OCEANUS cruises 19 and 20 indicate substantially higher levels of petroleum concentrations than those obtained on the EVERGREEN and DELAWARE II cruises. The samples collected on OCEANUS cruise 20 at stations 1 and 5 have the highest level of petroleum concentration. The PHC found at station 1 is a light distillate, while that found at station 5 is a heavy fuel oil that appears unrelated to the ARGO MERCHANT oil. Splits of significant samples from all cruises are being forwarded to the NOAA National Analytical Facility in Seattle, for complete GC-MS analysis under the direction of W. MacLeod. Petroleum concentration levels in these samples will also be determined by ultraviolet fluorescence and combined high pressure liquid chromatographic and fluorescence spectroscopic techniques by the USCG Research and Development Center and by Mississippi State University.

Analyses of sediment and water column samples collected on the ENDEAVOR 003 and 004 cruises are still in progress. Preliminary analyses of stations occupied in the vicinity of the bow section of the ARGO MERCHANT indicate high levels of ARGO MERCHANT oil in the sediment. Analyses of three sediment samples collected at station G-43 on the ENDEAVOR 004 cruise indicate concentrations higher than 50 parts per million based on wet sediment, with the highest level found in grab 2 at station G-43. Table 3-4 and Figure 3-6 summarize the preliminary sediment analysis data for samples collected in the vicinity of the bow section of the ARGO MERCHANT. All concentrations are approximate levels of concentrations based on the December 19 sample collected by J. Mattson and J. Galt of NOAA. Analysis of water column samples collected on the ENDEAVOR 004 cruise, incidentally, again indicate no presence of polyaromatic hydrocarbons.

## Summary

If the ARGO MERCHANT oil has entered the water column in any significant amounts, only the light aromatic fractions have done so. There is no evidence to date of any significant amounts of the heavy polyaromatics. Analyses are in progress to determine if there is a relationship between the light petroleum fraction found in the water column and the lighter components of the ARGO MERCHANT oil. However, since representative samples of the original cargo of the tanker are not yet available, the December 19 slick sample collected by Mattson and Galt will be used in the interim.

Analyses of sediment samples collected in the area around the bow section of the ARGO MERCHANT show considerable levels of oil from the tanker, and since these levels have been found only in this vicinity it

TABLE 3-4. Estimated oil concentrations per cubic centimeters of wet sediment samples collected on the ENDEAVOR 004 cruise

| Sample | Concentration (ppm) | Sample | Concentration (ppm) |
|---|---|---|---|
| G-43 Grab 1 | > 50 | D-35 Grab 1 | < 0.1 |
| G-43 Grab 2 | >100 | D-35 Grab 2 | < 0.1 |
| G-43 Grab 3 | > 10 | D-35 Grab 3 | < 0.1 |
| D-36 Grab 1 | > 0.1 | G-41 Grab 1 | < 0.1 |
| D-36 Grab 2 | < 0.1 | G-41 Grab 2 | < 0.1 |
| D-36 Grab 3 | < 3.0 | G-41 Grab 3 | < 0.1 |
| G-42 Grab 1 | > 1.0 | A-34 Grab 1 | < 0.1 |
| G-42 Grab 2 | < 1.0 | A-34 Grab 2 | < 0.1 |
| G-42 Grab 3 | > 1.0 | A-34 Grab 3 | < 0.1 |
| A-40 Grab 1 | < 0.1 | A-33 Grab 1 | < 0.1 |
| A-40 Grab 2 | < 0.1 | A-33 Grab 2 | < 0.1 |
| A-40 Grab 3 | > 1.0 | A-33 Grab 3 | < 0.1 |
| C-39 Grab 1 | < 0.1 | B-18 Grab 1 | < 0.1 |
| C-39 Grab 2 | < 0.1 | B-18 Grab 3 | < 0.1 |
| C-39 Grab 3 | < 0.1 | F-28 Grab 1 | < 0.1 |
| C-23 Grab 1 | < 0.1 | B- 7 Grab 1 | < 0.1 |
| C-23 Grab 2 | < 0.1 | B- 7 Grab 2 | < 0.1 |
| B-15 Grab 2 | > 1.0 | | |
| B-15 Grab 3 | < 1.0 | | |

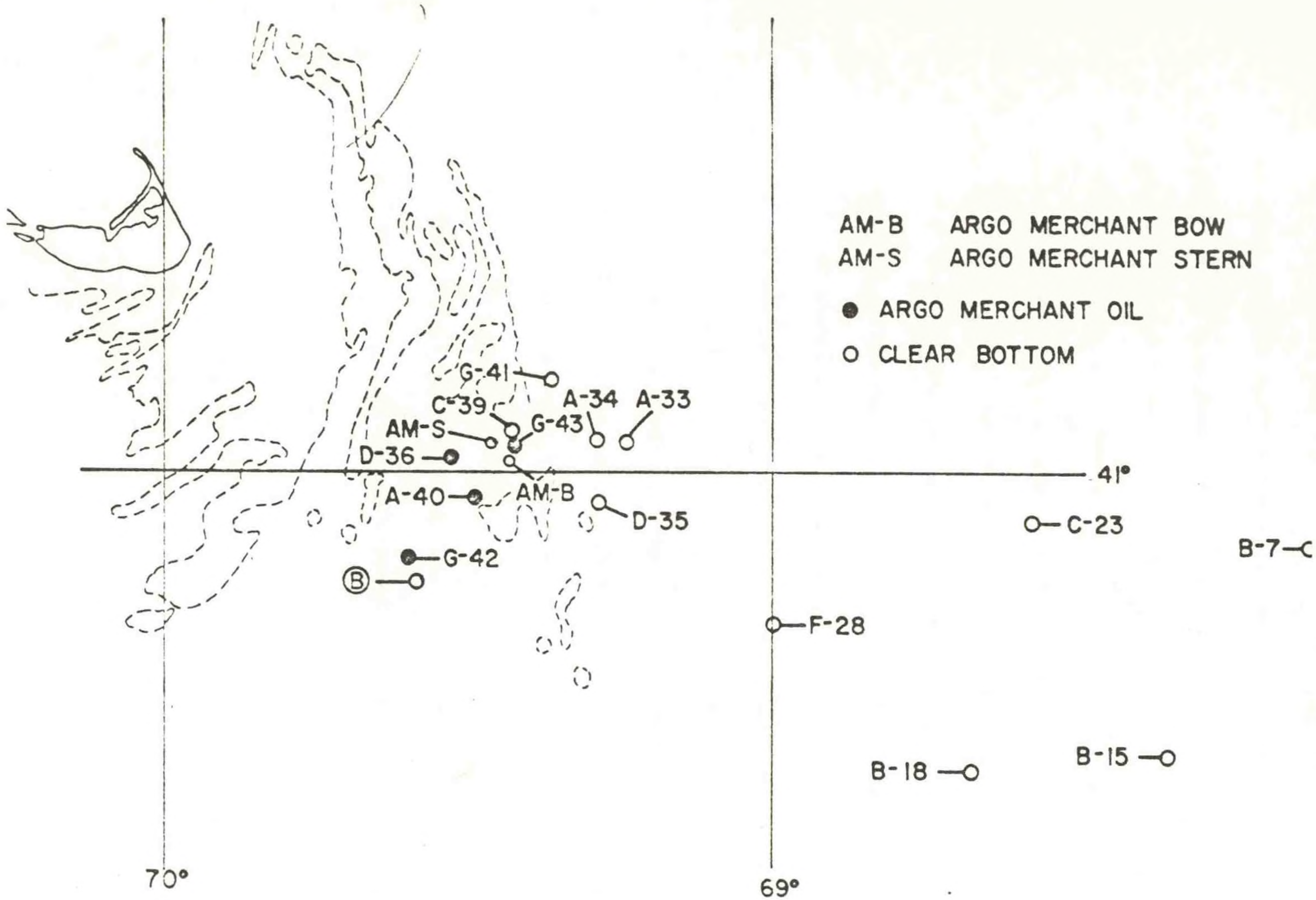


Figure 3-6. Preliminary results of sediment screening.

is reasonable to infer that residual oil remaining in the bow section was imparted to the sediment as the bow drifted along the bottom toward deeper water. All sediment screening results to date are summarized in Table 3-4, which indicate a moderate degree of PHC contamination throughout the area. An indication of ARGO MERCHANT oil found in B-15 grabs 2 and 3 from ENDEAVOR cruise 004 has been noted and is being investigated. The presence of ARGO MERCHANT oil shown in Figure 3-6, can best be explained at present by the bottom transport of suspended oil sediments. Bottom currents in December and January in the area are 10 centimeters per second (Bumpus, 1973), which is sufficient to keep sand (grain sizes from 0.125 to 0.75 mm), the primary sediment type in the area, in suspension and move the suspended load at approximately 3 kilometers per day. This explanation is further substantiated by comparing the sediment screening results for EVERGREEN station B and ENDEAVOR station G-42. The former based on samples taken in December, indicate a clean bottom; the latter, based on samples taken in February, indicate the presence of ARGO MERCHANT oil. The conclusion arrived at is that the movement of the tanker's bow section, after it was sunk on December 31, over the sand bottom mechanically worked oil into the sediment and these sediments are being transported by the southwesterly bottom currents in the area.

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MANOMET BIRD OBSERVATORY SEABIRD STUDIES

An Oil Bird Survey on Nantucket Shoals

26-29 January 1977

## INTRODUCTION

The following seabird observations were made on a non-interference basis by Natalie T. Houghton and Lisa L. Gould on the R/V ENDEAVOR, cruise EN-003. The purpose of the cruise was to look for oil in the water column and bottom sediments, and survey the benthic community, at various stations in the vicinity of the T/V ARGO MERCHANT wreck. Rough sea conditions greatly curtailed the number of stations sampled. Seabird observations were limited to seven hours during one day out over the Nantucket Shoals: approximately 192 individuals of seven or more species were seen.

We wish to thank Dr. Eva J. Hoffman of the Graduate School of Oceanography, University of Rhode Island, for logistical help, and Captain Bennett, the crew and scientists on the R/V ENDEAVOR for their cooperation and assistance.

## METHODS

Ten-minute counts beginning on the hour were made while the ship was traveling. Virtually all viewing was from the bridge.

## RESULTS

26 January Departed Quonset Point about noon, traveling within sight of land most of the afternoon. No gulls followed us out from the dock; in mid-afternoon, four or five Herring and Great Black-backed Gulls

followed the ship for half an hour to an hour. A few Black-legged Kittiwakes were seen, as was one adult Glaucous Gull and two Black Guillemots. Station E-1 ($40^{\circ}43'$N, $70^{\circ}0'$W) was reached in the evening.

27 January Anchored in Vineyard Sound to repair machinery and wait for seas to subside.

28 January Departed Vineyard Sound by 0700, heading southeast toward the Nantucket Shoals. Stations A40 ($40^{\circ}58'$N, $69^{\circ}29'$W), C37 ($40^{\circ}58'$N, $69^{\circ}26'$W) and A38 ($41^{\circ}00'$N, $69^{\circ}24'$W) were sampled during the afternoon, and C39 ($41^{\circ}02'$N, $69^{\circ}24'$W) after dark. Table 1 shows birds seen in 10-minute counts; Table 2 gives estimated totals for each species.

TABLE 1. Hourly Ten-minute Counts, 28 January 1977.

| SPECIES | 13 | 14 | 15 | 16 | 17 | 18 | 19* | 20 | 21* | TOTAL | MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. Fulmar | | 3 | 4 | 1 | | | | | | 8 | 1.1 |
| Glaucous Gull | | | | | 1 | | | | | 1 | 0.1 |
| Gt. Black-bkd. Gull | 4 | | | 2 | 1 | 3 | | 3 | | 13 | 1.9 |
| Herring Gull | | 1 | 1 | 3 | 1 | 1 | | 1 | | 8 | 1.1 |
| Gull, sp. | | | | | 2 | | | | | 2 | 0.3 |
| Black-lg. Kittiwake | | 1 | | 2 | | 2 | | 8 | | 13 | 1.9 |
| Black Guillemot | | | | | | 2 | | | | 2 | 0.3 |
| unidentified large alcid, sp. | | | | | 2 | 1 | | | | 3 | 0.5 |

*At station and maneuvering, no ten-minute transects taken

TABLE II. Estimated Totals and Ages of Seabirds Observed, 28 January 1977

| SPECIES | TOTAL | ADULT | SUBADULT | UNKNOWN |
|---|---|---|---|---|
| No. Fulmar | 24 | | | 24 |
| Glacous Gull | 1 | | 1 | |
| Gt. Black-bkd. Gull | 42 | 30 | 10 | 2 |
| Herring Gull | 23 | 20 | 2* | 1 |
| Black-lg. Kittiwake | 57 | 41 | 8 | 8 |
| Thick-billed Murre | 2 | | | 2 |
| Black Buillemot | 2 | | | 2 |
| unidentified large alcid, sp. | 36 | | | 36 |

*Both subadult Herring Gulls were in second-winter plumage.

29 January Returned to Vineyard Sound in the night and anchored: a cold front had come through causing rough seas and icing on the ship. Weather forecasts indicated no improvement in conditions for several days, therefore departed for Quonset midday.

SPECIES ACCOUNTS

Northern Fulmar. These often followed the ship or took a parallel course, but did not persist long. All were of the light phase except for two slightly brownish individuals (8.3%, intermediate phase).

Great Black-backed Gull. This and the following species tended to follow the ship, although not very persistently, perhaps because little or no garbage was dumped off. Great Black-backs appeared to be somewhat more independent of the ship than Herring Gulls. Of known-age Great Black-backs, 75% were adult, the rest subadult (first, second, or third winter).

Herring Gull. There were fewer of this species than of Great Black-backs. Of Herring Gulls that were aged, 91% were adults and the remainder second winter birds. No first or third winter immatures were seen at sea.

Black-legged Kittiwake. Usually both individuals and small flocks were attracted to the ship and followed it for a few minutes before departing. Eighty-four percent of those aged were in adult plumage.

Alcids. Single birds or small groups of two to four were seen sitting on the water or diving. Small flocks, up to 9 and 10 birds, were seen flying low over the water. All alcids seen were large, though mostly unidentified as to species: one of the larger flocks may have been Razorbills; a smaller group was probably Common Murres. Two birds on the water were Black Guillemots, and two individuals were Thick-billed Murres.

Landbirds, Mammals. None were seen.

OBSERVATIONS ON OILING

No oil was seen during the trip, nor was any T/V ARGO MERCHANT oil found at the few stations which could be sampled.

On the trip out from Quonset, no oiled birds were noted. At station E-1, the first evening, some of the scientists reported four oiled birds among those attracted to the ship's lights. Three oiled gulls were seen while the ship was anchored off Martha's Vineyard: an adult Great Black-backed Gull, a second winter Herring Gull, and an immature Bonaparte's Gull. Of these three, the Herring Gull was moderately oiled and the other two only lightly oiled.

On January 28, at least three quarters of the gulls and Fulmars seen at sea were checked for oil. No oiled Northern Fulmars were detected. Two adult Great Black-backed Gulls, one adult Herring Gull, and one immature and two adult Black-legged Kittiwakes showed oil on their feathers. With one exception these were lightly oiled, some with only one or two spots on the belly feathers; the Herring Gull, however, had a moderate amount of oil on the breast and belly feathers and some on the bend of one wing and the undertail coverts. Alcids were not checked because of their small size and situation on or very low to the water.

The only behavioral difference noted was that of the immature Black-legged Kittiwake. This bird followed the ship much more closely, swooping back and forth behind and over the ship, often within 30 feet of the stern, and for a longer time period (at least 20 minutes), than did any of the non-oiled Kittiwakes.

## DISCUSSION

Seabirds were not abundant on the Nantucket Shoals on 28 January 1977. Of species seen at sea, Black-legged Kittiwake was the most common, followed by Great Black-backed Gull, Northern Fulmar and Herring Gull. At least three dozen alcids were seen in the two hours preceding arrival at Station 40, indicating a more localized distribution than for the gulls and Fulmar. Percentages of oiled birds were low for the four species checked: 0 for Northern Fulmar, about 6% for the two common large gulls, and about 7% for the smaller Black-legged Kittiwake.

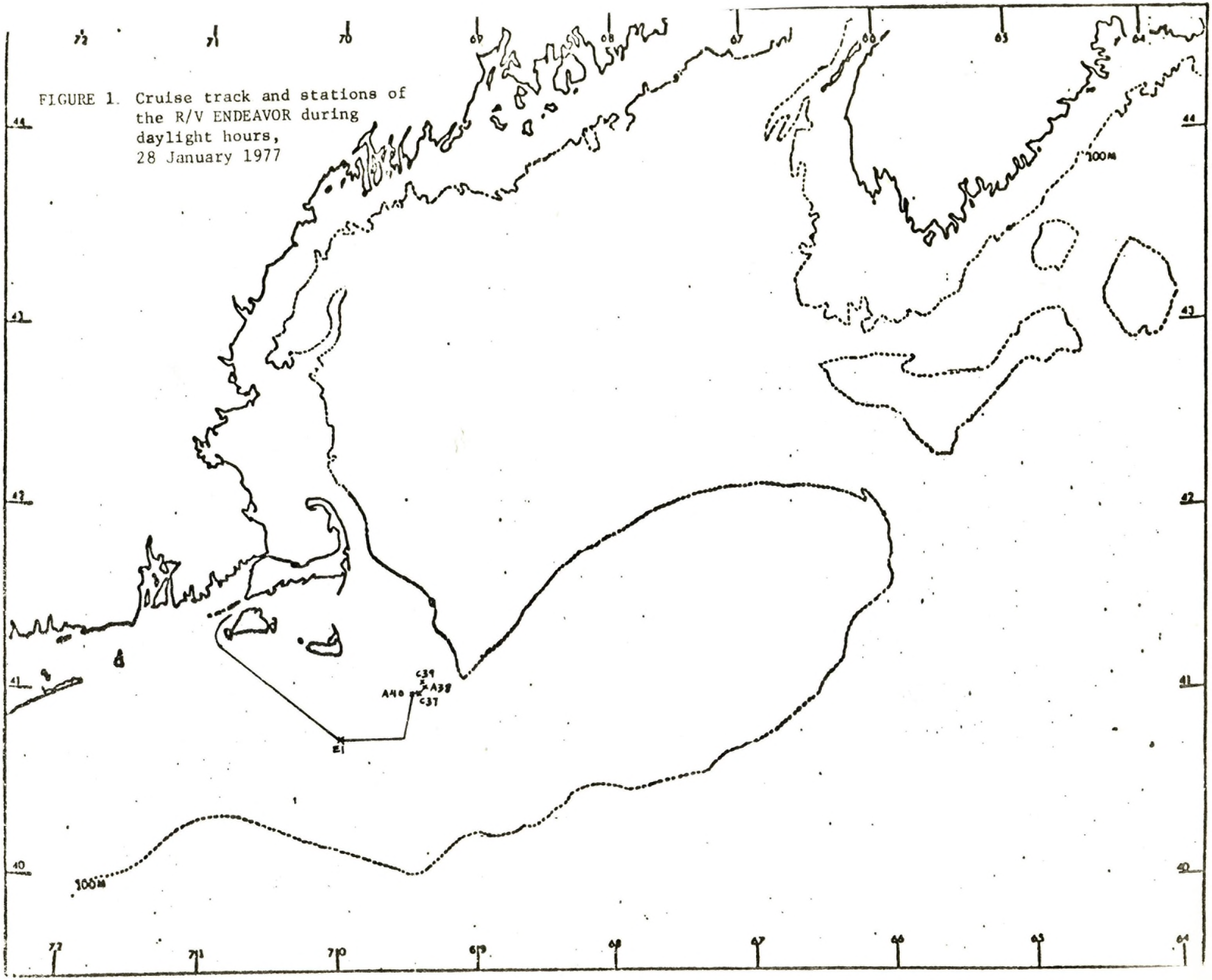



FIGURE 1. Cruise track and stations of the R/V ENDEAVOR during daylight hours, 28 January 1977

MANOMET BIRD OBSERVATORY SEABIRD STUDIES

# A CRUISE REPORT ON SEABIRD OBSERVATIONS FROM NANTUCKET SHOALS AND GEORGES BANK

9-13 February 1977

Submitted by Craig S. Scharf

The following report is a summary of seabird observations made by Craig S. Scharf aboard the R/V ENDEAVOR. Objectives of the cruise were to conduct studies on the effects of the oil spill from the T/V ARGO MERCHANT. I was aboard on a non-interference basis making observations on abundance, behavior, distribution, diversity, and degree of oiling of seabirds.

I gratefully acknowledge the cooperation of the University of Rhode Island in permitting my observations aboard the R/V ENDEAVOR. I also would like to thank the captain and crew for their assistance aboard ship.

## METHODS

Observations were made between 9 February and 13 February 1977, aboard the R/V ENDEAVOR. A good view was obtained from the pilot house and bridge deck of the ship. An attempt was made to count all birds within sight of the ship for the first ten minutes of each daylight hour. Variations in the actual distances from the ship that birds could be sighted due to winds, and sun glare preclude use of the data to estimate bird densities. The data was used to indicate relative abundance and distribution. Figure 1 indicates the study areas involved. Tables 1-4 summarize the hourly ten-minute counts per day and per species with a

Gannets

One adult Gannet was observed on 10 February when the ship was within study area two.

Gulls

Three Iceland Gulls were observed and all were in first year plumage. Great Black-backed Gulls were the most abundant gull and of the 188 examined 19% were oiled. Herring Gulls were widespread but were not as numerous as the former species. Of the 126 Herring Gulls examined 13% were oiled. Black-legged Kittiwakes were widespread but were not observed wth regularity.

Alcids

Three Common Murres were sighted when the ship was sailing within sight of the wreck. Within the same area, 14 unidentified large alcids were observed out of the total of 27 sighted for the cruise.

DISCUSSION

In relationto previous cruises the number of birds from hourly counts are low. This may simply reflect the normal number of birds typical for the area during this time of year. It is also known that seabirds follow fishing vessels. Therefore, the low number of birds may reflect the low number of fishing vessels within the area. Finally, many of the seabirds could have perished subsequent to the oil spill. No doubt, some or many, of the oiled birds observed on previous cruised died. In retrospect, all of the above may have contributed to the low number of birds within the study areas.

daily total (T) and mean number (X). The tables include brief notes on location, observer conditions, and important field notes. An asterisk (*) indicates that the ten-minute count was not the first ten minutes of the hour. All hours are GMT. Table 5 is a table of probably real numbers of seabirds for the cruise. When possible, birds were examined for the presence of oil and were notes as such.

TABLE 1

Hourly Ten-Minute Counts 9 February 1977

| SPECIES | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | (T) | (X) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gt. Blk-backed Gull | | | | | | | -- | 2 | -- | 1 | 3 | .75 |
| Herring Gull | ---NO | | OBSERVATIONS--- | | | | -- | 1 | 1 | -- | 2 | .50 |
| Blk-lg. Kittiwake | | | | | | | -- | -- | 1 | -- | 1 | .25 |

Weather: Seas calm 0-2 feet. Wind SSW 5-10 knots. Visibility good 4-6 miles with 20% cloud cover.

Ship proceeding to survey area number two. Several alcides were observed but were too far from the ship for species identification.

Table II

Hourly Ten-Minute Counts 10 February 1977

| SPECIES | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19* | 20 | 21* | (T) | (X) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N. Fulmar | -- | -- | -- | -- | -- | 2 | 1 | -- | -- | -- | 3 | .3 |
| Gt. Blk-backed Gull | 13 | 3 | 4 | 5 | 4 | 3 | 8 | 3 | 2 | 8 | 53 | 5.3 |
| Herring Gull | 3 | 13 | 9 | 2 | 1 | -- | 3 | 1 | 3 | 5 | 40 | 4.0 |
| Blk-lg. Kittiwake | 2 | 2 | 2 | 1 | -- | 2 | 2 | -- | -- | 5 | 16 | 1.6 |

Weather: Seas calm ranging from 2-4 feet. Winds SSE 5-15 knots. Visibility food 204 miles and the cloud cover increased to 100% by sunset.

The ship was on station in survey area two. A Ring-billed Gull, Gannet, and several large alcids were observed. Several gulls were sighted with oil on them and a few were observed attempting to preen the oil while in flight.

TABLE III

Hourly Ten-Minute Counts 11 February 1977

| SPECIES | 12 | 13 | 14 | 15* | 16* | 17* | 18* | 19* | 20 | 21 | (T) | (X) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N. Fulmar | 5 | 1 | 6 | -- | 1 | -- | 2 | -- | 2 | 7 | 24 | 2.4 |
| Iceland Gull | 1 | -- | 1 | -- | -- | -- | -- | -- | -- | 1 | 3 | .3 |
| Gt. Blk-backed Gull | 175 | 4 | 29 | 5 | 8 | 7 | 4 | -- | 3 | 20 | 225 | 25.5 |
| Herring Gull | 10 | 10 | 15 | 3 | 4 | 4 | 2 | -- | 1 | 40 | 89 | 8.9 |
| Blk-lg. Kittiwake | 1 | -- | -- | -- | 5 | 2 | -- | 3 | 3 | 10 | 24 | 2.4 |

Weather: Seas calm 0-2 feet. Winds SSW 5-10 knots. Visibility 2-4 miles with 10% cloud cover during the day.

Ship finished assigned stations in study area two. While the ship was steaming to study area one, it encountered two fishing vessels. Four hundred birds were observed following these vessels.

TABLE

Hourly Ten-Minute Counts 12 February 1977

| SPECIES | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | (T) | (X) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N. Fulmar | -- | 3 | 2 | -- | -- | -- | -- | -- | 2 | -- | 7 | .7 |
| Gt. Blk-backed Gull | 3 | 3 | 8 | 4 | 1 | 2 | 2 | -- | 1 | -- | 24 | 2.4 |
| Herring Gull | 5 | 2 | 3 | 5 | 2 | 1 | -- | -- | 1 | 2 | 21 | 2.1 |
| Blk-lg. Kittiwake | 1 | -- | -- | 3 | -- | -- | -- | -- | 2 | -- | 6 | .6 |

Weather: Seas calm 0-2 feet. Winds SSW 1-10 knots. Visibility 4-6 miles with 40% cloud cover.

Ship steaming to the wreck site of the T/V ARGO MERCHANT after completing stations in area one. Several new collecting stations were added close to the wreck site. The ship at this point was within 200 yards of the wreck. Fourteen unidentified alcids and three Common Murres were sighted in the vicinity.

TABLE V

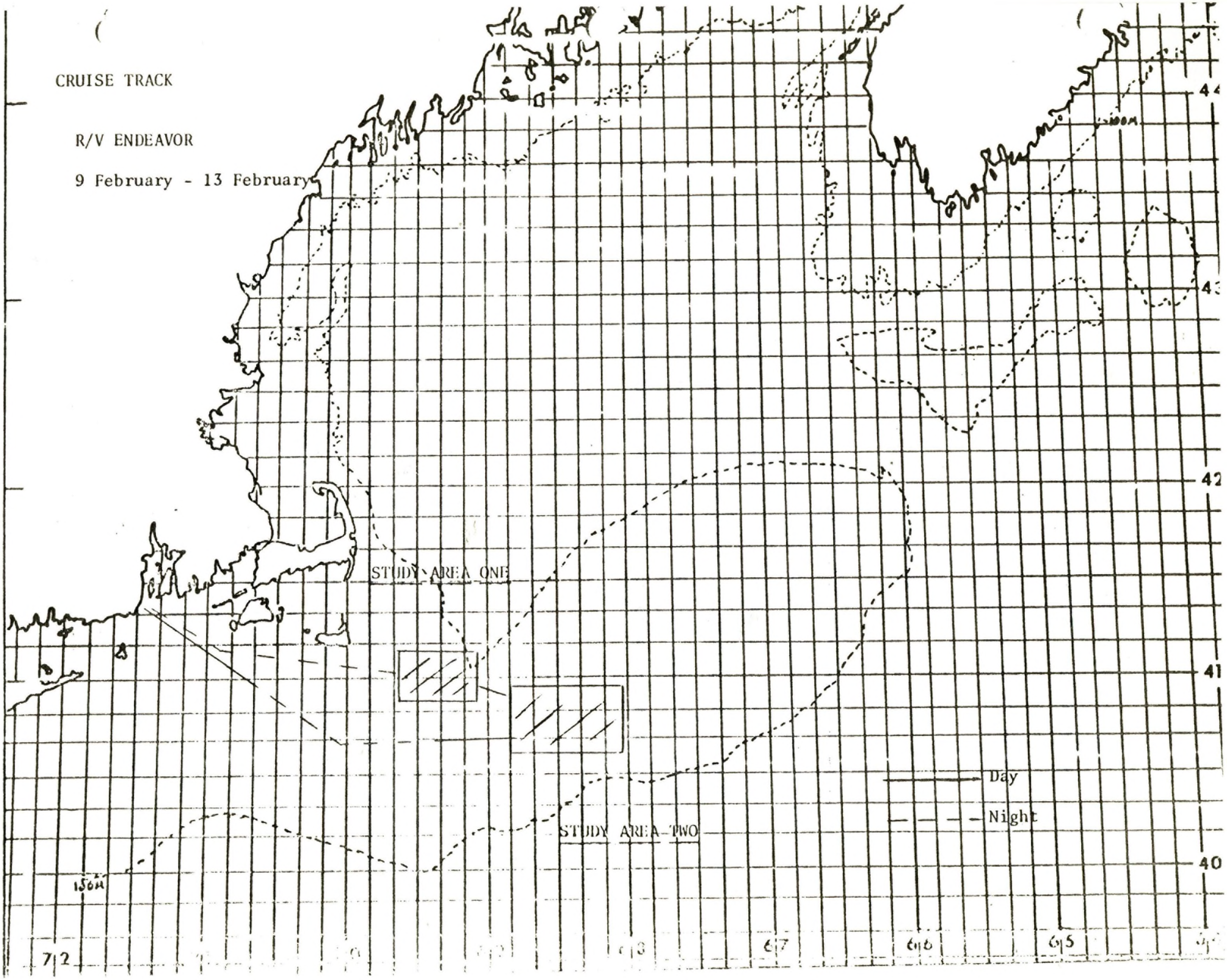
Probable Real Daily Total

| SPECIES | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|
| N. Fulmar | --- | 7 | 25 | 3 | 35 |
| Gannet | --- | 1 | --- | --- | 1 |
| Iceland Gull | --- | --- | 3 | --- | 3 |
| Gt. Blk-backed Gull | 5 | 95 | 275 | 35 | 410 |
| Herring Gull | 10 | 45 | 60 | 30 | 145 |
| Blk-lg. Kittiwake | 3 | 15 | 20 | 4 | 42 |
| Razorbill Auk | --- | 1 | --- | --- | 1 |
| Common Murre | --- | --- | --- | 3 | 3 |
| Unidentified alcid | 3 | --- | 1 | 19 | 23 |
| TOTAL | 21 | 164 | 384 | 94 | 663 |
| Hours of Observation | 3 | 5.5 | 7 | 6.5 | 22 |

SUMMARY

N. Fulmars

Fulmars were observed daily excluding 9 February. The light, dark, and intermediate color phas ratios were (28-8-5) respectively. Three oiled fulmars were sighted out of the 25 examined (12%).



CRUISE TRACK
R/V ENDEAVOR
9 February - 13 February
STUDY AREA ONE
STUDY AREA TWO
Day
Night
44
43
42
41
40
72
67
66
65
150M
100M

# THE EFFECTS OF THE <u>ARGO MERCHANT</u> OIL SPILL ON THE BENTHIC METABOLISM OF NANTUCKET SHOALS

Submitted by David T. Rudnick, Graduate School of Oceanography
University of Rhode Island, Kingston, Rhode Island 02881

## ABSTRACT

Sediment cores were taken from the site of the ARGO MERCHANT oil spill on Nantucket Shoals to determine any effects on the metabolic activity of the benthic community, as measured by oxygen uptake and ammonia fluxes. $O_2$ uptake was significantly greater in the cores of an oil contaminated station than the cores of two clean control stations. This increase is probably due to the bacterial degradation of hydrocarbons.

## INTRODUCTION

The effects of hydrocarbon stress on the benthic community of Nantucket Shoals was investigated by the measurement of the oxygen uptake and ammonia flux of sediment cores. These analyses are indicative of the metabolic activity of the entire benthic community. The subtidal sands off LaJolla, California (median grain size of about 0.1 mm) have been measured to release approximately 400 µg at $NH_3 m^{-2}$ $day^{-1}$ at 15°C (Hartwig, 1976a), while taking up about 800 mg $O_2 m^{-2}$ $day^{-1}$ (Hartwig, 1976b).

The finer sediments (67% silt-clay) of a Mercenaria community of Narragansett Bay, R.I., at about 5°C, utilized approximately 600 mg $O_2$

$m^{-2}$ $day^{-1}$ and released approximately 250 μg at $NH_3$ $m^{-2}$ $day^{-1}$ (Nixon, et al., 1976).

These measurements do not distinguish the importance of the major biotic groupings within the benthos, such as bacteria, ciliates, meiofauna and macrofauna. Within the coarse sands of Nantucket Shoals (the median grain size at station 70 was 1.14 mm), few macrofauna (>750μ) are found and meiofauna greater than 74 μ are dominated by harpactacoid copepods and turbellarians (Pratt, 1978). The biota passing through the latter sieve size are likely to be predominantly bacteria, since ciliate populations are generally small within such coarse sands (Fenchal, 1969). The response of the benthos to hydrocarbon contamination will thus largely be due to bacteria and a few meiofaunal groups. The degradation of hydrocarbons by some groups of bacteria is well documented (Atlas, 1977). The availability of oxygen or nutrients is generally the limiting factor of such processes. Effects of oil on the meiofauna are far more nebulous. In the fine sediments of the Marine Ecosystem Research Laboratory tanks, the abundance of meiofauna, including harpactacoid copepods and nematodes was greatly decreased with the addition of oil (R. Elmgren, personal communication).

Sediment cores from the vicinity of the bow and stern of the ARGO MERCHANT (stations 70 and 59, respectively), were found to contain high concentrations of hydrocarbons (Table 1), although their distribution was quite patchy (Hoffman and Quinn, 1978). Clean sediments of stations 62 and 49 were cored to serve as controls (Figure 1). They were chosen because of the qualitative similarity of their appearance, and their proximity to the oiled stations. Stations 49 and 59 were slightly finer and contained more shell fragments than the sands of stations 70 and 62.

Table 1. Hydrocarbon content of 35 $cm^2$ subcores, taken from the box cores of stations 59 and 70. All values are from Hoffman and Quinn (1978).

| Station No. | Box Core No. | Depth (cm) | ug HC/g |
|---|---|---|---|
| 59 | 1 | 0-3 | 5.1 |
| | 1 | 3-8 | 1.3 |
| | 1 | 8-13 | 24.6 |
| | 2 | 0-4 | 0.3 |
| | 2 | 4-9 | 0.8 |
| | 2 | 9-14 | 0-4 |
| 70 | 1 | 0-3 | 1.9 |
| | 1 | 3-8 | 2.7 |
| | 1 | 8-13 | 2.2 |
| | 2 | 0-3 | 2.7 |
| | 2 | 3-8 | 28.2 |
| | 2 | 8-13 | 37.5 |

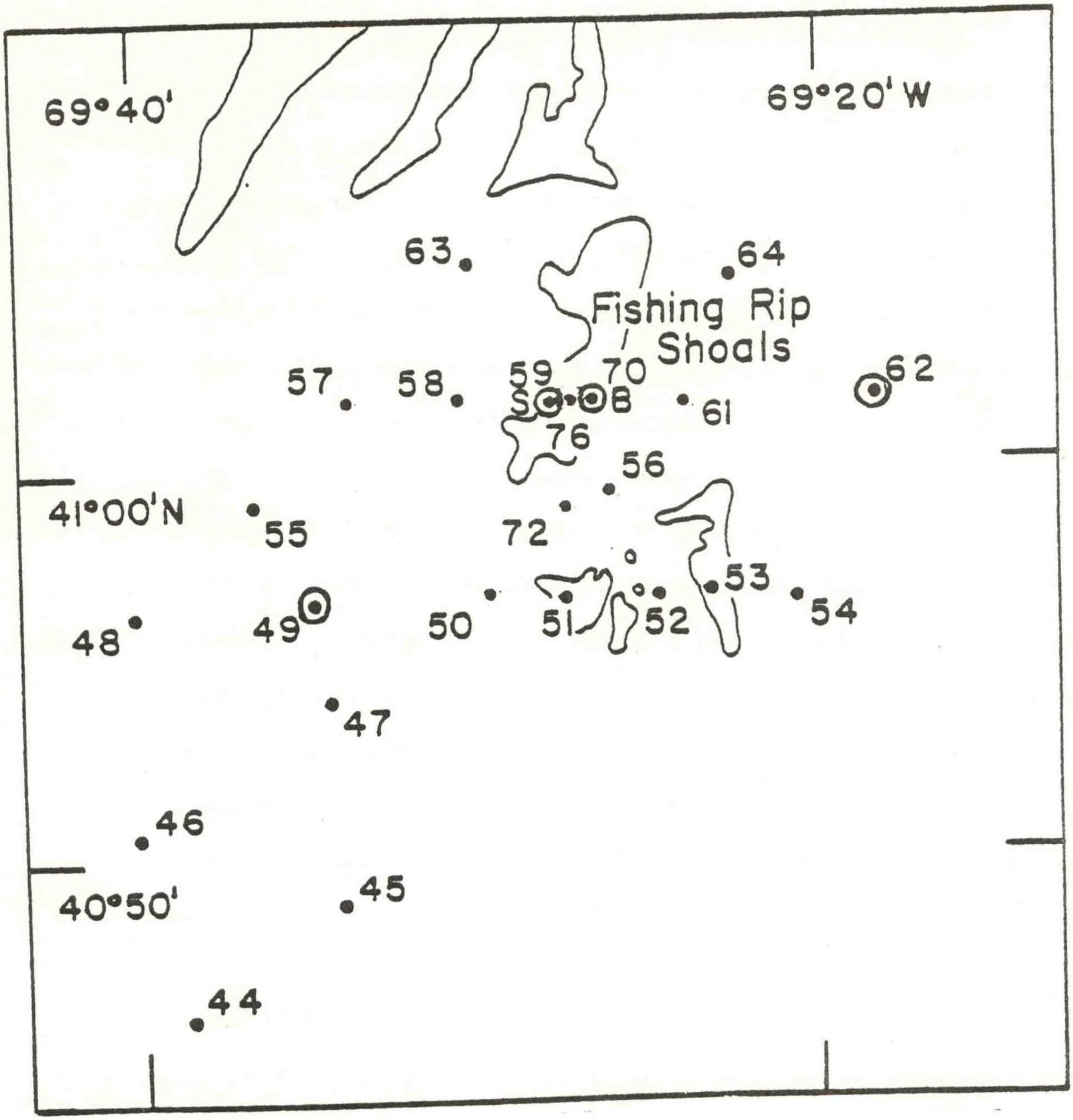



Figure 1. Station locations of EN-005 (February 22-27, 1977), and SS-001 (July 22-24, 1977). The "S" (Station 59) is the location of the ARGO MERCHANT stern and mid section wrecks and the "B" (Station 70) is the location of the ARGO MERCHANT bow section. The circled dots are the stations from which the sediments used in this study were collected.

## METHODS

Duplicate box cores, using a cover with a design similar to an USNEL spade corer (Bouma, 1969) were taken from stations 49, 59, 62 and 70 of EN-005 (Figure 1) on February 26, 1977, 67 days after the rupture of the ARGO MERCHANT. Each box core was subsampled, in triplicate to a depth of approximately 15 cm, with transparent butyrate core tubes ($35\ cm^2$), by hand. The middle core was used for hydrocarbon analysis by Hoffman and Quinn (1978); the outer cores were used in this investigation. All cores, with overlying seawater of 33 ‰ were refrigerated at $4^{o}C$ until transported to the aquarium facility of the Graduate School of Oceanography of the University of Rhode Island, where they were kept in the dark in a water bath of glass fiber filtered (0.45μ) bay water (32 ‰) at approximately $4^{o}C$ for the duration of the experiment. The water of each core was mixed by vigorous bubbling. Fluxes were measured on March 3 and 7. Cores were flushed with fresh, filtered bay water, initial samples taken and analyzed for dissolved oxygen by titration (Strickland and Parsons, 1968) and ammonia (Solorzano, 1969). The analytical precision of these measurements, when calculated as a flux were, for a 36 hour incubation: $O_2 \pm 11.5$ mg $m^{-2}\ day^{-1}$; $NH_3 \pm 15.3$ μg at $m^{-2}\ day^{-1}$. Each core was then stoppered and allowed to sit for between 24 and 48 hours. Two additional core tubes, with filtered bay water, alone, were simultaneously incubated for this period. They were used to correct for any part of the flux not attributable to the sediment itself. Final samples were taken and analyzed after the water above the sediment was gently mixed.

Changes of the $O_2$ concentration of the two bay water controls indicated that the core tubes are permeable to $0_2$. Measurements of $0_2$ uptake must therefore be considered as minimum estimates for the first incubation, when dissolved $0_2$ was approximately 90 to 95% saturated, and as maximum estimates during the second incubation when dissolved $0_2$ was 105 to 100% saturated. The calculated fluxes, because of their extremely low magnitude, were greatly influenced by the correction for this leakage. The changes within the two bay water control cores, when calculated as a flux (mg $0_2$ $m^{-2}$ $day^{-1}$ $\pm$ 1 standard deviation) for a core with 0.500 $\ell$ of overlying water, was +29 $\pm$ 5 for the first incubation and -46 $\pm$ 8 for the second incubation. Comparison of the cores' $0_2$ uptake within each of the 2 incubations is likely to involve little error, since the standard deviations of the correction factors (in mg $0_2$ $\ell^{-1}$ $day^{-1}$) are so low. Comparison of fluxes between the 2 incubations, however, may involve a considerably greater error, since the 2 factors are so different.

At the conclusion of the experiment, the cores were sieved through a 1 mm sieve to determine the presence of any large macrofauna.

## RESULTS

The presence of oil droplets was observed for all four cores of station 70 and a single core of station 59 (from box core 1). No macrofauna greater than 1 mm were found in any core.

The cores of station 70 had the largest $0_2$ uptake of any station during both incubations (Figure 2). During the March 2 incubation, the $0_2$ uptake of the station 70 cores was significantly greater than its

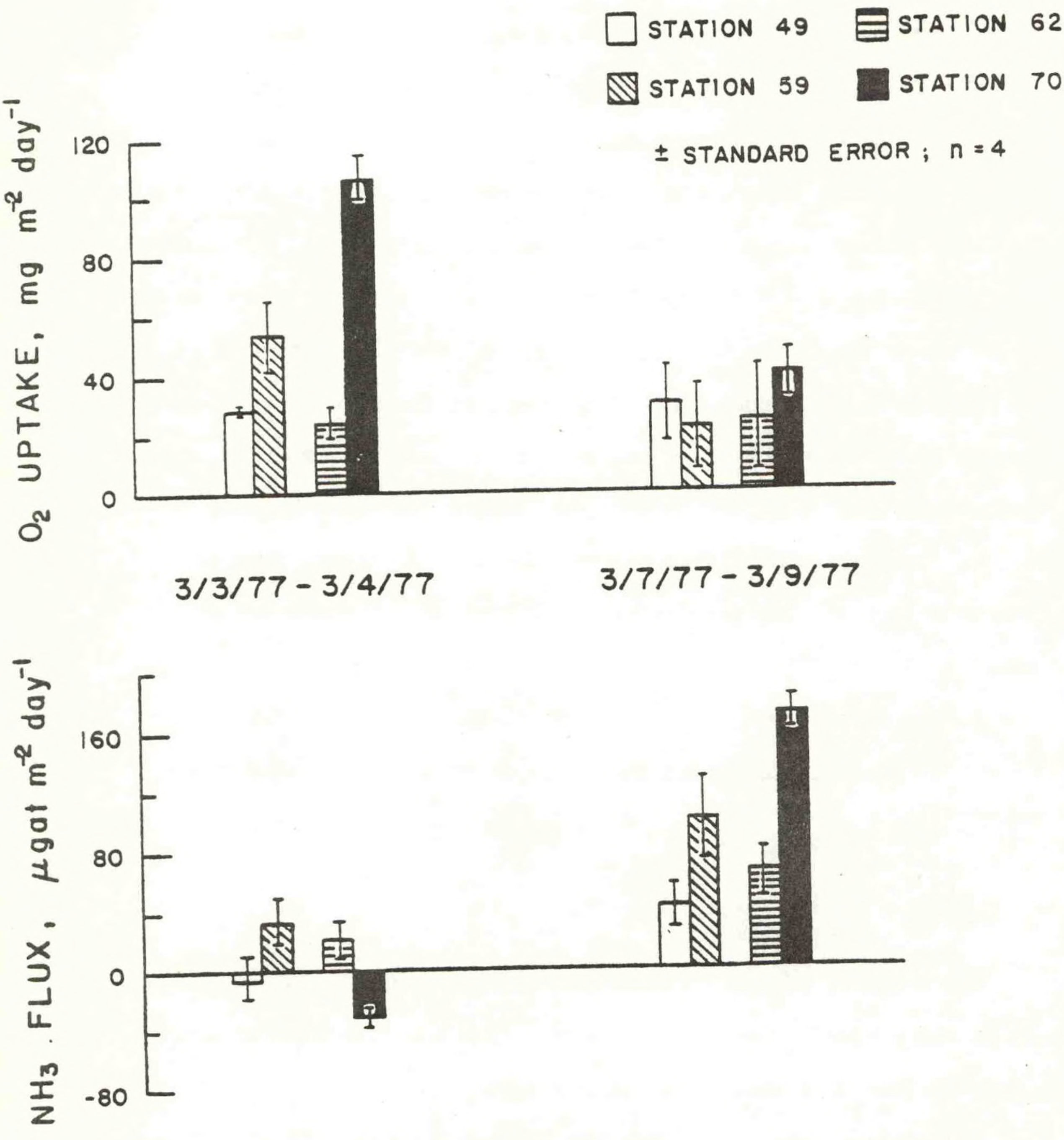



FIGURE 2. Mean oxygen uptake and ammonia flux of 4 replicate cores from 4 sampling stations at Nantucket Shoals. Station 70 cores are known to have contained oil, station 59 cores may have contained oil and stations 62 and 49 respectively served as clean controls.

control cores (station 62), as well as the other stations' cores. (Significance is here defined with $\alpha = 0.05$, using a 2 tailed t-test for the difference of 2 means with unequal variance). Station 59, the other oil contaminated station, had the second largest uptake at this time. During the second incubation (March 7), only the uptake of station 70 was significantly different from 0.

The $NH_3$ fluxes of the cores of station 70 were significantly different from its control station's (62) cores for both incubations. During the first set of measurements, all stations with the exception of station 70 were not significantly different from 0. $NH_3$ was taken up by the sediments of the station 70 cores, at this time. During the second measurement, however, $NH_3$ release from the sediments of all stations, except station 49, increased to a level significantly different from 0, with station 70 again being the most extreme.

## DISCUSSION

Despite the problem of the permeability of the core tube to $O_2$, it is clear from the results that the benthos of station 70 was considerably more active than the other stations. It is thus implied that the addition of hydrocarbons to these sediments results in a greater uptake of $O_2$. Such a result, however, may be the consequence of the innate properties of station 70 cores, in the absence of oil contamination, since the station 59 cores failed to respond in a manner similar to the station 70 cores. It is, however, uncertain how many of the station 59 cores actually contained hydrocarbons. No discernable trend is evident between the duplicate cores from box core 1 and the cores of box core 2. Hydrocarbons, in the third subcore of the box cores, were found only in box core 1 (Table 1).

If the response of the station 70 cores is closely linked to the addition of hydrocarbons, which seems most likely, the results of this study indicate that bacterial degradation of ARGO MERCHANT oil occurred _in situ_ within ten weeks of the spill. These hydrocarbons would thus be utilized as a source of organic matter within an organically sparse environment. This situation is consistant with the finding of $NH_3$ uptake by the station 70 cores; bacteria which utilize hydrocarbons require independent sources of nitrogen and phosphorus. The relatively high release of $NH_3$, during the second measurement may be indicative of a deteriorating condition within all of the cores, caused by the stagnation of the interstitial waters. The first measurements, five days after the cores were taken, may thus be a better, though innaccurate, estimate of _in situ_ activity than the measurements nine days after coring. A rapid change between fifth and ninth day is also quite possible, considering the shore generation time of bacteria.

Estimates of the partitioning of metabolic activity within the cores of station 70 indicates the vastly greater functional importance of the bacteria, as opposed to the meiofauna. Unsing the estimates of Gerlach (1971), meifauna respiration at 15 to 20$^{\circ}$C is likely to be between 6.72 and 67.2 mg $O_2$ day$^{-1}$ g wet weight$^{-1}$. A rough estimate of biomass for the 4.5 x $10^4$ individuals m$^{-2}$ for 15 cm deep cores at station 70 (Pratt, 1978), might be about 0.15 g wet weight (R. Elmgren, personal communication). Using the lower respiration rate, because of the lower temperature ($4^{o}C$), an order of magnitude estimate of meiofauna $0_2$ uptake would be 1 mg $0_2 m^{-2}$ $day^{-1}$ or 1% of the first incubation and 3% of the second. Thus with a model containing only meiofaunal and bacterial compartments, the greater metabolic activity of station 70, compared to stations 62, 49 and 59 is largely indicative of the dynamics of bacteria.

## ACKNOWLEDGEMENTS

I would like to thank Dr. Scott Nixon and Dr. Candace Oviatt for the use of their laboratory equipment. Dr. Eva Hoffman provided welcome support in succeeding to obtain the cores. Finally, I am grateful to Dr. Ragnar Elmgren, of the Marine Ecosystems Research Laboratory, for his interest and opinions. Support for this study was provided by NOAA contract 03-7-022-35123.

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REPORT OF OVERFLIGHTS TO OBSERVE MARINE MAMMALS IN THE

VICINITY OF ARGO MERCHANG WRECK SITE

Submitted by Howard Winn, Graduate School of Oceanography, University of Rhode Island, Kingston, Rhode Island 02881

The oil freighter ARGO MERCHANT grounded on an area 27 miles SE of Nantucket (69°21'W, 41°05'N) on December 15, 1976. Spillage of No. 6 oil started soon thereafter. Considerable concern was expressed about the possible impact on marine mammals, particularly on the grey seal, which occupies small islands near Nantucket. Aerial flights over the area affected were immediately instituted, one on December 20 and one the day after the tanker split in two, on December 22. Photographs were taken.

Following are observations recorded on the two flights.

December 20, 1976

1320 hr Left Quonset Airport. Twin engine Apache, Aero Marine Survey, Tim Flynn, pilot. Howard Winn and Gerald Scott on board as observers.

Weather fair but hazy. Storm coming on horizon. Tide near low. Flying at 1000 ft.

1341 hr Surveying Martha's Vineyard shores at 500 ft. Many ducks and seagulls.

1348 hr Heading for Nantucket. Surveying Muskeget at 500 ft. One object seen that could be a seal.

Over Tuckernuck Is. No sightings.

1406 hr Going to wreck. Haze much thicker. Nantucket hidden by fog bank. Five fishing vessels 5-8 mi. from wreck. Thousands of sea birds.

1428 hr Over wreck. Sunny and Clear. Two Coast Guard vessels in area, one helicopter. No work in progress. Oil coming out SW from ship with slight slick, diameter slightly larger than length of ship; current going SW, wind from NW. Does not appear to be much oil coming out. Photos taken.

1440 hr Heading back to Nantucket. 1600 ft. alt. Fog has lifted from Nantucket. Survey southwestern shore of Nantucket, Tuckernuck, Muskeget and Martha's Vineyard at 400 to 500 ft. Many birds. Four dead gulls on Nantucket Beach. Had to go up over fog on part of Nantucket run.

1518 hr Down to 400 ft. along Martha's Vineyard.

1527 hr Heading back to Quonset. Had to circle airport to attempt to get under low thick clouds over area.

1555 hr Landed.

No seals seen. One or two objects seen that were unidentified and might have been seals, but doubtful.

December 21, 1976. Ship broke in half and started leaking more oil immediately.

December 22, 1976

1250 hr Left Westerly, R.I. airport in two engine Islander. Edward Bergman, Jr., pilot. On board: Howard Winn, Gerald Scott, William Steiner, Thomas Thompson, Mark Ahmadjian (Representative

URI Oil Response Team, had aerial experience with Santa Barbara spill), Robert Izzo (URI photographer).

2,200 altitude; many white caps.

1315 hr Leaving Nantucket. No fishing vessels sighted; high seas.

1325 hr Over wreck. One Coast Guard vessel, one helicopter, one airplane. Wreck obviously broken in half. Circled wreck three times at 300 ft. Tide taking huge oil patches to SW from ship. Large pancakes, huge globs and a general surface sheen. Many birds in area. Circled out from wreck. Oil patches seen in various directions from ship: 3 mi. SW; 4 mi. SE; 4 mi. E, an apparent sheen; 6 mi. SE; 10 mi. SE; 10 mi. SSE; 10 mi. S; 10 mi. SSW; 10 mi. SW, perhaps surface sheen; and no oil seen as we went up to 10 mi. W and finally N of ship. Winds are WNW.

1420 hr Returning to Nantucket.

1434 hr Surveying southern Nantucket beaches at 200-300 ft., then southern side and ends of Tuckernuck, then circled Muskeget. Went along southern coast of Martha's Vineyard at 200-300 ft. around to Menemaha Bight, then surveyed part of Cuttyhunk and small island SW of it; then southern beaches of Martha's Vineyard. No seals sighted. Photos taken along some of the beaches. (Track enclosed)

1505 hr Returning to Westerly.

1520 hr Landed.

ACKNOWLEDGMENT

This work was funded by the Marine Mammal Commission. Order MM-7AD-032.

# RECOMMENDATIONS FOR MARINE MAMMAL RESEARCH RELATIVE TO OIL SPILL IMPACT

Submitted by Howard Winn, Graduate School of Oceanography
University of Rhode Island, Kingston, Rhode Island 02881

A meeting of marine mammalogists was held in Boston at the New England Aquarium on December 18, 1976, at the request of the Marine Mammal Commission. A general set of recommendations will be forthcoming from that meeting.

One observation I would like to make is that there has been a real lack of grant support for marine mammal studies on the east coast, particularly for field studies. Thus, we lacked even the very basic information about distributional patterns necessary for deciding what the potential impact of the December oil spill might have been. In December pilot whales, large unidentified whales, harbor seals and grey seals were seen in the general area of the spill. A general recommendation of the meeting in Boston was to support public sighting systems in the area from Long Island to Nova Scotia. It should be strongly emphasized that this approach will supply only generalized baseline data and is no substitute for organized, controlled sampling of the area by ship and airplane. Sighting systems can be started quickly and are relatively inexpensive. It was thought that small amounts of money could be made available immediately.

It appears that we know very little about the grey seal in the Nantucket area, although it is believed that they are year round residents of the area. An unsubstantiated December sighting of eight grey seals on Plum Island, Mass., was reported at the Boston meeting. If indeed these were grey seals, one wonders if they were migrating to the Nantucket area.

Valerie Schurman, professional biologist, saw two grey seals near Muskeget on December 24, 1976. I strongly recommend that Valerie Schurman and/or Drs. Gilbert and Richardson receive increased funds to carry out a proper survey of the Nantucket grey seal population. The present contract is totally inadequate to do this at its present funding level, and the survey is only a very insignificant part of the contract. This situation is most unfortunate, with or without an oil spill. It is essential that the survey start immediately, while there is still a small chance of immediate oil impact. There should be 12 additional flights and support for someone to visit Muskeget 4-6 times (now; during puping season in February; during molting season in April; and at other times of the year).

| | | |
|---|---|---|
| Budget: | 12 flights @ $120 | $1440 |
| | 20 days expenses @ $20 | 400 |
| | Consultant (Schurman) 20 days @ $60 | 1200 |
| | Travel to Nantucket | 300 |
| | TOTAL: | $3340 |

This budget represents a bare minimum necessary to produce appropriate information. Money should be made available for immediate flights over the area and a stay on Muskeget.

My general conclusion is that we were extremely lucky with regard to impact of the oil spill on local pinnipeds. We will probably never know what impact there might be on cetaceans out further on the shelf and along the 100 fathom line. Number 6 oil is apparently less toxic than other forms of oil. It is still possible, though not likely, that if the wind were to come from the south and east for 3-4 days or more, the inshore area would be affected; but winds in the winter from that direction usually last no more than a day or two. If the spill had occurred in the summer, prevailing winds would have pushed the oil toward shore.

APPENDIX B

# APPENDIX B

# CRUISE REPORTS

GRADUATE SCHOOL OF OCEANOGRAPHY

University of Rhode Island
Kingston, R.I. 02881

CRUISE REPORT

R/V ENDEAVOR Cruise EN-002

I. Itinerary:

The R/V ENDEAVOR departed Quonset, Rhode Island at 1800 on 28 December 1976, and returned to Quonset, Rhode Island at 1900 on 30 December 1976.

II. Ship Funding:

National Science Foundation Grant No. OCE 76-80104

III. Scientific Party:

| | |
|---|---|
| Dr. James G. Quinn | Chief Scientist, GSO/URI |
| Dr. Mason Wilson | Co-Investigator, Mech. Eng./URI |
| Dr. Peter Cornillon, | Co-Investigator, Ocean Eng./URI |
| Dr. Malcolm Spaulding | Co-Investigator, Ocean Eng./URI |
| Dr. Chris Brown | Co-Investigator, Chem/URI |
| Mr. Mark Ahmadjian | Research Assistant, Chem/URI |
| Ms. Pat Lynch | Research Assistant, Chem/URI |
| Dr. David Shonting | Co-Investigator, Naval Underwater Systems Center/Newport |
| Dr. Robert Morton | Co-Investigator, Naval Underwater Systems Center/Newport |
| Mr. Charles Finkelstein | Co-Investigator, Kline Associates, New Hampshire |
| Mr. Sheldon Pratt | Co-Investigator, GSO/URI |
| Dr. Dana Kester | Co-Investigator, GSO/URI |
| Mr. Doug Huizenga | Graduate Student, GSO/URI |
| Mr. Skip French | Graduate Student, GSO/URI |
| Dr. Eva Hoffman | Co-Investigator, GSO/URI |
| Mr. Joseph Kane | Technician, NMFS, Narragansett |
| Mr. William Hahn | Marine Technician, GSO/URI |
| Mr. Ted Benttinen | Marine Technician, GSO/URI |

IV. Objectives:

To investigate the effects of the ARGO MERCHANT oil spill on Nantucket Shoals and surrounding waters.

V. Summary of Research Program:

The following scientific programs were carried out during this cruise:

1) Plankton and neuston samples were collected from surface waters using plankton and bongo nets. These samples will be analyzed for species abundance an diversity.

2) Water samples were collected from depths of 1m, 6m and bottom usin 5L Niskin bottles. These samples will be analyzed for total hydrocarbons, oil droplet size distribution, total organic carbon, nutrients, T $^{o}C$, S o/oo, pH, $O_2$, particulate trace metals and total suspended material.

3) Benthic samples were collected using a Smith-McIntyre grab sampler. These samples will be analyzed for species abundance and diversity and sedimentary hydrocarbons.

4) Side scanning sonar measurements were taken as the ship approached station 1.

5) One array of three current meters was released at the beginning of station 2.

The cruise tract followed is given in Fig. 1. The locations of the stations occupied are given in Table 1, along with information on the samples collected at these stations.

The total cruise occupied 49 hours of which approximately 9 hours (18%) were devoted to station time. Total distance ~300 miles.

Table 1

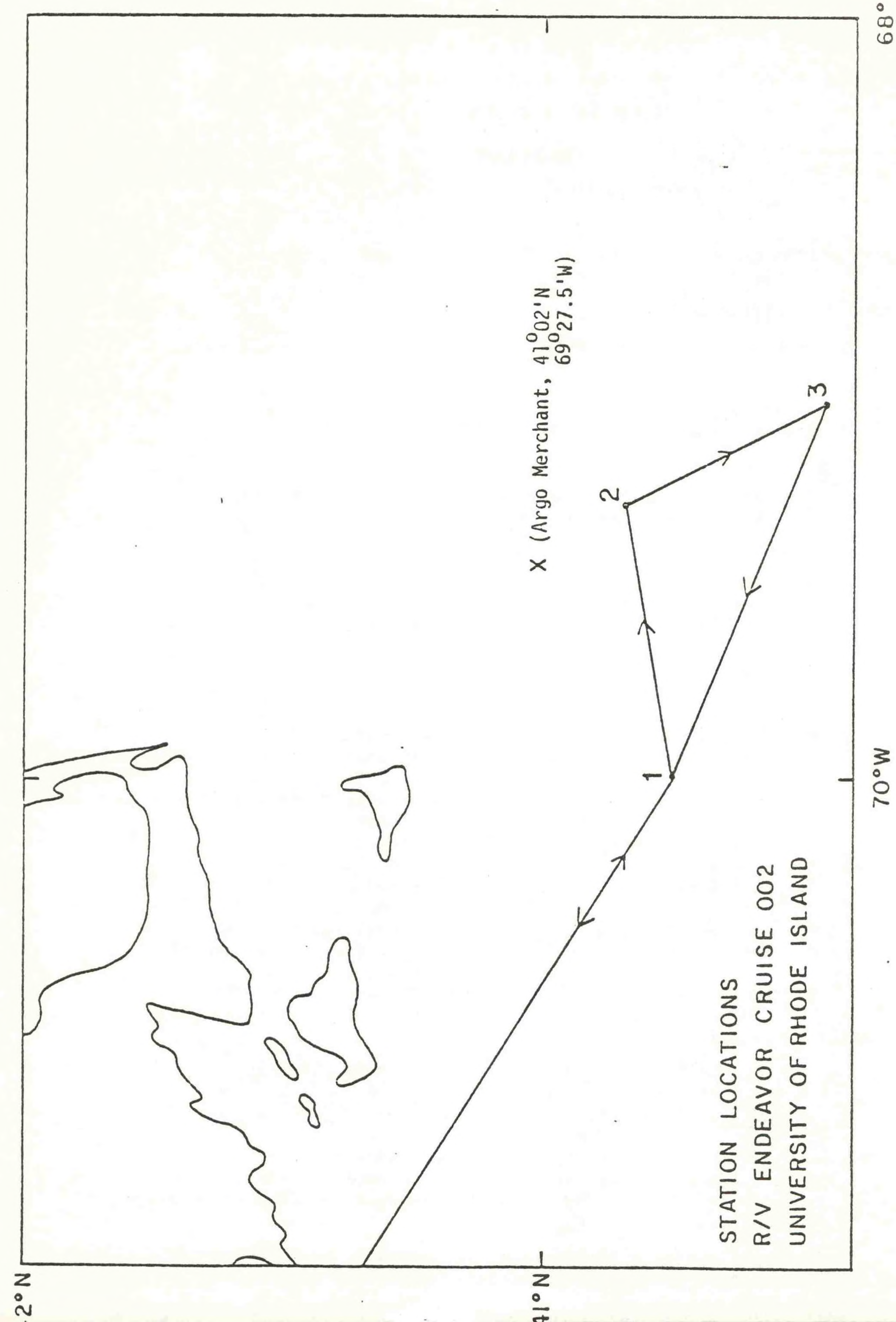
R/V ENDEAVOR Cruise EN-002

| Sta. No. | Samples or operation | Date | Time | Loran C | Lat/Long |
|---|---|---|---|---|---|
| 1 | side scan sonar in | 12/29/76 | 0130 | 38035.9<br>49350.1 | 40°-41'N<br>69°-58'W |
| 1 | plankton tow 1 | " | 0254 | 38033.8<br>49340.6 | 40°-40'N<br>69°-57.7'W |
| 1 | plankton tow 2 | " | 0301 | 38035.4<br>49341.4 | 40°-40.5'N<br>69°-57.8'W |
| 1 | side scan sonar out | " | 0313 | 38039.9<br>49342.2 | 40°-40.25'N<br>69°-56.25'W |
| 1 | grab 1 | " | 0413 | 38032.2<br>49344.2 | 40°-41.25'N<br>69°-59.08'W |
| 1 | grab 2 | " | 0433 | 38032.2<br>49344.6 | 40°-41.25'N<br>69°-59.08'W |
| 1 | grab 3 | " | 0455 | 38033.1<br>49347.6 | 40°-41'N<br>69°-58.6'W |
| 1 | hydrocast 1<br>5 l Niskin bottles<br>(1 m, 6m, bottom) | " | 0455 | 38033.1<br>49347.6 | 40°41'N<br>69°-58.6'W |
| 1 | hydrocast 2<br>5 l Niskin bottles<br>(1 m, 6 m, bottom) | " | 0547 | 38031.4<br>49346.0 | 40°-41.5'N<br>69°-59.4'W |
| 1 | neuston tow | " | 0707 | 38031.2<br>49346.1 | 40°-41.5'N<br>69°-59.4'W |
| 1 | Bongo net tow | " | 0750 | 38049.9<br>49363.9 | 40°-45.8'N<br>70°-4.9'W |
| 2 | current meter array deployed | 12/29/76 | 1420 | 37663.5<br>49219.2 | 40°-51.01'N<br>69°-21.9'W |
| 2 | hydrocast<br>5 l Niskins<br>(1 m, 6 m, bottom) | " | 1514 | 37666.9<br>49218.8 | 40°-50.1'N<br>69°-19.4'W |

Table 1 (continued)

| Sta. No. | Samples or operation | Date | Time | Loran C | Lat/Long |
|---|---|---|---|---|---|
| 2 | grab 1 | 12/29/76 | 1600 | 37650.6<br>49213.2 | $40^{o}$-51.75'N<br>$69^{o}$-20.5'W |
| 2 | grab 2 | " | 1610 | 37650.6<br>49213.2 | $40^{o}$-51.75'N<br>$69^{o}$-20.5'W |
| 2 | grab 3 | " | 1620 | 37650.6<br>49213.2 | $40^{o}$-51.75'N<br>$69^{o}$-20.5'W |
| 2 | grab 4 | " | 1630 | 37650.6<br>49213.2 | $40^{o}$-51.75'N<br>$69^{o}$-20.5'W |
| 2 | plankton tow | " | 1650 | 37648.0<br>49211.6 | $40^{o}$-51.50'N<br>$69^{o}$-20'W |
| 2 | neuston tow | " | 1700 | 37648.0<br>49211.6 | $40^{o}$-51.50'N<br>$69^{o}$-20'W |
| 2 | bongo net tow | " | 1710 | 37648.0<br>49211.6 | $40^{o}$-51.50'N<br>$69^{o}$-20'W |
| 3 | bucket sample (surface water) | 12/29/76 | 2005 | 37416.8<br>49234.3 | $40^{o}$-51'N<br>$68^{o}$-48.25'W |

Fig. 1



68°W
70°W
42°N
41°N
X (Argo Merchant, $41^{0}02'N$
$69^{0}27.5'W$)
1
2
3
STATION LOCATIONS
R/V ENDEAVOR CRUISE 002
UNIVERSITY OF RHODE ISLAND

GRADUATE SCHOOL OF OCEANOGRAPHY

University of Rhode Island

Kingston, R.I. 02881

CRUISE REPORT

R/V ENDEAVOR Cruise EN-003

PROJECT: ARGO MERCHANT Oil Spill: Fate and Effects
Cruise 2

REGION OF INVESTIGATION:

Nantucket Shoals and surrounding waters.

SCHEDULE:

| | |
|---|---|
| Depart Quonset, R.I. | 1100, 26 January 1977 |
| Arrive Quonset, R.I. | 1900, 29 January 1977 |

FUNDING:

National Oceanic & Atmospheric Administration (Proposed)
Energy Research & Development Agency

SCIENTIFIC PARTY:

| | |
|---|---|
| Dr. Eva J. Hoffman | Chief Scientist, GSO/URI |
| Dr. Peter Cornillon | Co-Investigator, OE/URI |
| Dr. Dick Jadamec | Co-Investigator, Research Chemist, U.S. Coast Guard |
| Dr. Edward Myers | Co-Investigator, National Oceanic & Atmospheric Administration |
| Ms. Andrea Hurtt | Graduate Student, GSO/URI |
| Mr. Sheldon Pratt | Co-Investigator, GSO/URI |
| Mr. Jeff Hyland | Co-Investigator, EPA and GSO/URI |
| Mr. Charles Young | Technician, MechEng/URI |
| Mr. Steven Buchanan | Marine Science Technician 2nd class, U.S. Coast Guard |
| Mr. F. Gene Franklin | Technician, Chem/URI |
| Mr. Robert Bowen | Technician, Chem/URI |
| Ms. Lisa Gould | Co-Investigator (Birds), Zool/URI |
| Mr. Jim Hannon | Marine Technician, GSO/URI |
| Mr. Ted Benttinen | Marine Technician, GSO/URI |
| Ms. Natalie Houghton | Co-Investigator (Birds), Manoment Bird Observatory |
| Mr. Art Buddington | Marine Technician, GSO/URI |

OBJECTIVES OF CRUISE:

A. To determine whether and where oil from the ARGO MERCHANT has reached the bottom in the vicinity of the wreck and the resulting surface oil slick. This objective will be implemented by:

1. Collection of sediments, benthic organisms and near bottom waters from a variety of locations, at various depths, with various sediment types, and with varying times of surface oil contamination.

2. Sediment and near bottom water samples will be screened for hydrocarbon content with shipboard instrumentation.

3. More extensive sampling of sediments, benthic organisms and near bottom waters in areas shown by rapid screening to be possibly contaminated with oil to determine the extent of such contamination.

4. Later detailed analysis of sediment samples to determine hydrocarbon levels in the sediment and to determine if high concentrations of hydrocarbons found by shipboard screening are specifically from the ARGO MERCHANT.

B. To conduct a preliminary survey of the benthic community in the oil spill area. The data will be used in conjunction with possible long term effect studies. This objective will be implemented by:

1. Collection and preservation of benthic organisms for use in later long-term studies; more extensive sampling in areas where the sediment has been shown by shipboard screening to contain significant concentrations of hydrocarbons.

2. Collection of benthic organisms for later hydrocarbon analyses.

3. Collection of benthic organisms for histopathologic study.

4. Collection of oil contaminated sediments and clean sediments to be used in laboratory bioassay experiments evaluating possible impact of oil on winter flounder hatchability and larval survival.

C. To determine to what extent oil has become entrained in the water column which may be moving with subsurface currents. This objective will be implemented by:

1. Collection of seawater samples at a variety of locations in the wreck vicinity at depths of 1m, 6m, and at bottom to be analyzed at URI for hydrocarbon content.

2. Collection of seawater samples to determine the oil droplet size distribution.

D. To determine sea bird density and distribution in the oil spill area, with possible future application to long-term studies. This objective will be facilitated by:

1. Observations of sea bird density and distribution at each station during daylight hours.

2. Observation of numbers and species of oiled birds and any abnormal behavior patterns of these birds.

3. Collection of dead birds for later autopsy.

ANCILLARY OBJECTIVES:

A. To determine how eathering changes the organic and inorganic chemistry of ARGO MERCHANT Oil.

B. To check and perhaps retrieve a current meter array at EN-002.

It is assumed that the following areas would be more likely to have significant quantities of ARGO MERCHANT oil in the sediments than other locations (in approximate order of importance):

1. Areas whose sediments have been shown by chemical analysis to contain significant quantities of ARGO MERCHANT oil.

2. Areas covered by the slick for the longest periods of time

3. Shallower areas.

4. Areas covered by the slick when the sea state was high.

5. Any area covered by the slick at any time.

6. Any area possibly affected by subsurface currents which could carry oil from slick areas to sediments a distance away from areas actually covered by the slick.

NOTE: Difference in sediment type was not considered because the area in question is quite uniform with regard to sediment type.

To date, none of the samples previously analyzed showed significant quantities of oil in the sediments. By examination of NOAA-CG slick maps, two areas (referred to hereafter as Area A and Area B) were found to have been covered with heavy oil pancake concentrations or consolidated slicks for at least 6 days. Area A is the area surrounding the wreck itself bounded by 41°04'N and 40°54'N latitude and 69°35.2'W and 69°07'W longitude. Area B is an area where heavy concentrations of oil pancakes and slick stalled for 6 days before continuing to head east. Area B is bounded by 40°58'N and 40°33'N latitude and 68°53'W and 68°04'W longitude.

With plans to collect sediments and water samples at a maximum of 50 stations, 30 of these stations were randomly distributed within Areas A & B. Since Area A covers 210 square nautical miles and Area B covers 880 square nautical miles, Area A was assigned 6 stations and Area B 24 stations. From M. G. Natrella's Experimental Statistics Table of Random Numbers (NBS Handbook #91, U.S. Department of Commerce, 1963), a series of random numbers was selected. Within Area A each nautical square mile was numbered with square mile number 1 in the NW corner, number 10 in the SW corner, number 201 in the NE corner and number 210 in the SE corner. Within Area B, number 1 was in the NW corner, 24 in the SW corner, 865 in the NE corner, and 888 in the SE corner. The following square mile areas, arrayed as described aboce, were designated as sampling stations in Area A: 076, 184, 133, 169, 173, and 029 (alternates 190 & 004). In area B, the sampling stations, the square mile numbers were: 732,783,571,564,405,756,544,235,409,355,820, 878,876,222, 346, 107, 583, 629, 444, 654, 236, 571, 692 and 089.

In addition to the 30 stations in areas A and B, another 3 stations were selected to examine sediments in shallower areas; 3 stations were selected in areas covered by heavy slick when the sea state was high; 2 stations were the previous ENDEAVOR #002 stations 1 and 2; and 2 stations were selected between Areas A & B.

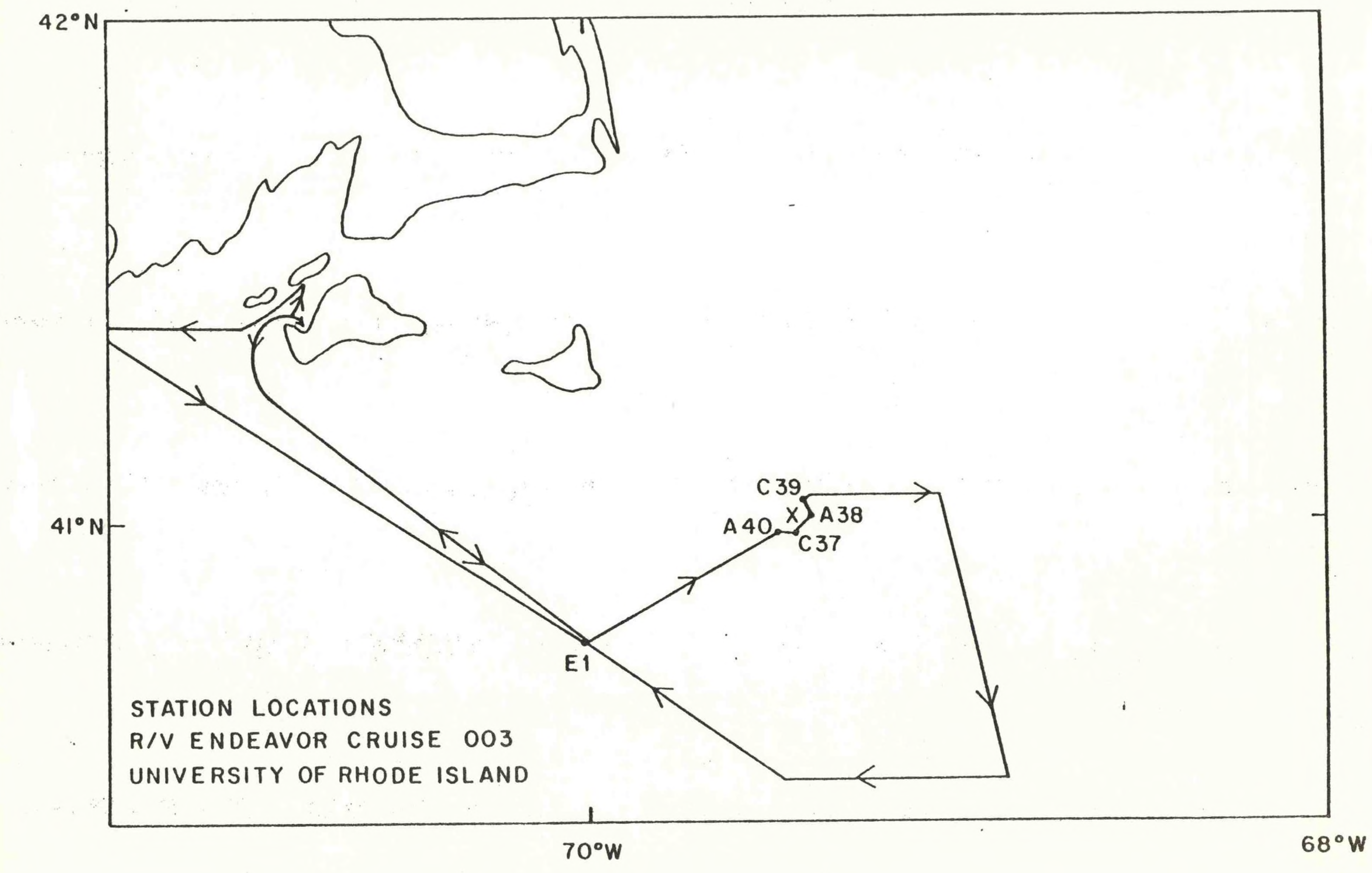
Station numbering system stations chosen at random in Area A have the letter "A" as a prefix. Stations chosen at random in Area B have the letter "B" as a prefix. Stations chosen in shallower areas have the letter "C" as a prefix. Stations in areas covered by a heavy slick when the sea state was high have the letter "D" as a prefix. ENDEAVOR 002 stations 1 and 2 have the letter "E" as a prefix. Stations between areas A and B have the letter "F" as a prefix. Additional stations chosen while at sea based on the results of onboard screening results will have a letter "G" as a prefix.

## R/V ENDEAVOR CRUISE #003

### Station Information

| TATION | SAMPLES | DATE | TIME(local time) | LORAN C | LAT./LO |
|---|---|---|---|---|---|
| E-1 | Hydrocast(5L Niskins & 4L sterile bag samples at depths 1, 6 & 37 m) | 1/26/77 | 2100 | 38029.1<br>70135.5 | 40°43.0<br>70°00.7 |
| A-40 | Hydrocast(5L Niskins & 4L sterile bag samples at depths 1, 6 & 47 m) | 1/28/77 | 1407 | 37715.7<br>70114.0 | 40°56.3<br>69°30.7 |
| A-40 | Grab 1 (depth 42m) | 1/28/77 | 1418 | 37693.1<br>70107.6 | 40°58.1<br>69°29.7 |
| A-40 | Grab 2 (depth 34-42 m) | 1/28/77 | 1429 | 37692.6<br>70107.0 | 40°58.3<br>69°29.5 |
| A-40 | Grab 3 (depth 42m) | 1/28/77 | 1446 | 37687.7<br>70105.1 | 40°58.8<br>69°29.2 |
| C-37 | Grab 1 (depth 30m) | 1/28/77 | 1507 | 37670.5<br>70112.6 | 40°57.9<br>69°26.3 |
| C-37 | Grab 2 (depth 36m) | 1/28/77 | 1517 | 37667.6<br>70111.8 | 40°58.2<br>69°26.0 |
| C-37 | Grab 3 (depth 36m) | 1/28/77 | 1524 | 37665.6<br>70111.1 | 40°58.4<br>69°25.9 |
| C-37 | Hydrocast(5L Niskins & 4L sterile bag samples at depths 1, 8 & 30m) | 1/28/77 | 1545 | 37665.55*<br>70114.20 | 40°57.8<br>69°25.4 |
| A-38 | Hydrocast(5L Niskins & 4L sterile bag samples at depths 1, 6 & 36m) | 1/28/77 | 1613 | 37643.35*<br>70108.55 | 40°59.5<br>69°24.4 |
| A-38 | Grab 1 (depth 41m) | 1/28/77 | 1642 | 37638.8<br>70106.8 | 40°59.7<br>69°24.2 |
| A-38 | Grab 2 (depth 44m) | 1/28/77 | 1653 | 37634.3<br>70105.9 | 41°00.2<br>69°23.6 |
| A-38 | Grab 3 (depth 44m) | 1/28/77 | 1703 | 37630.5<br>70104.7 | 41°00.5<br>69°23.5 |
| C-39 | Hydrocast(5L Niskins & 4L sterile bag samples at depths 1, 6 & 44m) | 1/28/77 | 1738 | 37620.25*<br>70094.95 | 41°02.5<br>69°24.1 |

*Mid-point of hydrocast


42°N
41°N
70°W
68°W
C39
X
A38
A40
C37
E1
STATION LOCATIONS
R/V ENDEAVOR CRUISE 003
UNIVERSITY OF RHODE ISLAND

GRADUATE SCHOOL OF OCEANOGRAPHY
University of Rhode Island
Kingston, R.I. 02881

CRUISE REPORT

R/V ENDEAVOR Cruise EN-004

**PROJECT:** ARGO MERCHANT Oil Spill: Fate and Effects
Cruise 3.

**REGION OF INVESTIGATION:**

Nantucket Shoals and Little George's Bank.

**ITINERARY:**

| | |
|---|---|
| Depart Quonset, R.I. | 1000, 9 February 1977 |
| Arrive Quonset, R.I. | 0830, 13 February 1977 |

**SHIP FUNDING:**

National Oceanic & Atmospheric Administration
Agency No. 03-7-022-35123

**SCIENTIFIC PARTY:**

| | |
|---|---|
| Mr, Sheldon Pratt | Chief Scientist, GSO/URI |
| Mr. Robert Bowen | Technician, Chem/URI |
| Ms. Jane Silver | Technician, Chem/URI |
| Mr. Steve Buchanan | Marine Science Technician 2nd Class, U.S. Coast Guard |
| Mr. Craig Schaarf | Bird Specialist, Manomet Bird Observatory |
| Mr. Dave Konigsberg | Student, Ocean Engineering/URI |
| Mr. William Hahn | Marine Technician, GSO/URI |
| Mr. Ted Benttinen | Marine Technician, GSO/URI |
| Mr. Barclay Collins | Graduate Student, GSO/URI |
| Mr. Doug Vaughn | Graduate Student, GSO/URI |
| Mr. Elwyn "Bud" Rolofson | NOAA-MESA, Boulder, Colorado |

OBJECTIVES OF CRUISE:

A. To determine whether and where oil from the ARGO MERCHANT has reached the bottom in the vicinity of the wreck and in the area at one time covered by the resulting surface oil slick.

B. To conduct a preliminary survey of the benthic community in the oil spill area. The data will be used in conjunction with possible long-term effect studies.

C. To determine to what extent oil has become entrained in the water column which may be moving with subsurface currents.

D. To determine sea bird density and distribution in the oil spill area, with possible future application to long-term studies.

SUMMARY OF RESEARCH PROGRAM:

A. Random stations were selected in the Nantucket-Little George's Bank areas, areas potentially affected by the ARGO MERCHANT oil spill (38 stations).

B. Three replicate sediment samples at each station were collected with a Smith-McIntyre sampler (104 grab samples).

C. A hydrocast with Niskins at 1m, 6m and bottom depths was completed at each station (38 hydrocasts).

D. Benthic samples were collected at two stations with a scallop dredge.

E. A magnetometer was towed between Brenton Reef light and Davis South Shoals Buoy.

## R/V ENDEAVOR CRUISE EN-004

## Station Location and Information

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH(m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| E-1 | Hydrocast | 2-9-77 | 1806 | 44 | 38033.3<br>70135.1 | 40°42.5'N<br>69°59.0'W |
| E-1 | Grab 1 | 2-9-77 | 1823 | 44 | 38035.2<br>70135.6 | 40°42.5'N<br>69°59.3'W |
| E-1 | Grab 2 | 2-9-77 | 1832 | 44 | 38035.2<br>70135.3 | 40°42.5'N<br>69°59.3'W |
| E-1 | Grab 3 | 2-9-77 | 1840 | 44 | 38035.6<br>70135.4 | 40°42.4'N<br>69°59.4'W |
| B-7 | Grab 1 | 2-10-77 | 0124 | 66 | 37098.2<br>70218.4 | 40°53.9'N<br>68°06.2'W |
| B-7 | Grab 2 | 2-10-77 | 0145 | 66 | 37093.6<br>70216.6 | 40°54.5'N<br>68°06.2'W |
| B-7 | Grab 3 | 2-10-77 | 0206 | 66 | 37099.3<br>70218.6 | 40°54.0'N<br>68°06.4'W |
| B-7 | Hydrocast | 2-10-77 | 0226 | 66 | 37092.1<br>70217.5 | 40°54.4'N<br>68°06.0'W |
| B-2 | Hydrocast | 2-10-77 | 0340 | 77 | 37136.1<br>70254.0 | 40°45.9'N<br>68°03.9'W |
| B-2 | Grab 1 | 2-10-77 | 0405 | 77 | 37139.5<br>70254.0 | 40°45.8'N<br>68°04.2'W |
| B-2 | Grab 2 | 2-10-77 | 0413 | 77 | 37138.2<br>70254.3 | 40°45.9'N<br>68°04.0'W |
| B-2 | Grab 3 | 2-10-77 | 0421 | 75 | 37136.9<br>70254.7 | 40°46.0'N<br>68°03.7'W |
| B-3 | Grab 1 | 2-10-77 | 0457 | 79 | 37154.7<br>70258.1 | 40°44.7'N<br>68°04.9'W |
| B-3 | Grab 2 | 2-10-77 | 0512 | 79 | 37153.3<br>70259.4 | 40°44.5'N<br>68°04.5'W |
| B-3 | Grab 3 | 2-10-77 | 0526 | 81 | 37152.1<br>70260.7 | 40°44.2'N<br>68°04.0'W |
| B-3 | Hydrocast | 2-10-77 | 0549 | 81 | 37155.2<br>70259.4 | 40°44.5'N<br>68°04.8'W |

Station Location and Information EN-004 (cont.)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH(m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| B-4 | Hydrocast | 2-10-77 | 0629 | 75 | 37196.2<br>70255.2 | 40°44.3'N<br>68°10.0'W |
| B-4 | Grab 1 | 2-10-77 | 0648 | 77 | 37198.3<br>70256.1 | 40°44.0'N<br>68°10.0'W |
| B-4 | Grab 2 | 2-10-77 | 0656 | 77 | 37198.5<br>70256.6 | 40°44.0'N<br>68°10.0'W |
| B-4 | Grab 3 | 2-10-77 | 0725 | 75 | 37200.4<br>70255.3 | 40°44.0'N<br>68°10.4'W |
| B-6 | Grab 1 | 2-10-77 | 0807 | 62 | 37200.9<br>70243.1 | 40°46.5'N<br>68°12.5'W |
| B-6 | Grab 2 | 2-10-77 | 0818 | 62 | 37202.0<br>70243.7 | 40°46.5'N<br>68°12.5'W |
| B-6 | Grab 3 | 2-10-77 | 0832 | 62 | 37203.5<br>70244.0 | 40°46.5'N<br>68°12.5'W |
| B-6 | Hydrocast | 2-10-77 | 0842 | 57 | 37204.4<br>70244.4 | 40°46.5'N<br>68°12.5'W |
| B-8 | Hydrocast | 2-10-77 | 0931 | 51 | 37187.4<br>70215.9 | 40°52.2'N<br>68°16.2'W |
| B-8 | Grab 1 | 2-10-77 | 0941 | 51 | 37187.8<br>70216.0 | 40°52.1'N<br>68°16.4'W |
| B-8 | Grab 2 | 2-10-77 | 0949 | 51 | 37188.0<br>60216.1 | 40°52.0'N<br>68°16.5'W |
| B-8 | Grab 3 | 2-10-77 | 1007 | 51 | 37188.2<br>70215.9 | 40°52.2'N<br>68°16.6'W |
| B-9 | Grab 1 | 2-10-77 | 1030 | 42 | 37192.5<br>70208.5 | 40°53.4'N<br>68°18.4'W |
| B-9 | Grab 2 | 2-10-77 | 1038 | 46 | 37192.1<br>70208.2 | 40°53.4'N<br>68°18.3'W |
| B-9 | Grab 3 | 2-10-77 | 1046 | 49 | 37191.7<br>70208.1 | 40°53.5'N<br>68°18.3'W |
| B-9 | Hydrocast | 2-10-77 | 1056 | 49 | 37190.9<br>70207.6 | 40°53.6'N<br>68°18.2'W |
| B-10 | Hydrocast | 2-10-77 | 1134 | 46 | 37226.8<br>70213.6 | 40°51.6'N<br>68°20.7'W |

## Station Location and Information EN-004 (cont.)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| B-10 | Grab 1 | 2-10-77 | 1143 | 42 | 37225.4<br>70212.0 | 40°51.7'N<br>68°20.7'W |
| B-10 | Grab 2 | 2-10-77 | 1152 | 44 | 37223.6<br>70211.9 | 40°51.8'N<br>68°20.7'W |
| B-10 | Grab 3 | 2-10-77 | 1203 | 44 | 37221.5<br>70211.3 | 40°51.8'N<br>68°20.6'W |
| B-11 | Grab 1 | 2-10-77 | 1243 | 46 | 37270.3<br>70232.7 | 40°46.6'N<br>68°21.9'W |
| B-11 | Grab 2 | 2-10-77 | 1253 | 49 | 37267.8<br>70231.6 | 40°46.8'N<br>68°21.9'W |
| B-11 | Grab 3 | 2-10-77 | 1302 | 48 | 37265.7<br>70231.1 | 40°47.2'N<br>68°21.8'W |
| B-11 | Hydrocast | 2-10-77 | 1312 | 49 | 37270.7<br>70232.0 | 40°46.8'N<br>68°22.0'W |
| B-12 | Hydrocast | 2-10-77 | 1409 | 55 | 37303.0<br>70242.0 | 40°43.9'N<br>68°23.5'W |
| B-12 | Grab 1 | 2-10-77 | 1420 | 60 | 37307.0<br>70243.6 | 40°43.7'N<br>68°23.8'W |
| B-12 | Grab 2 | 2-10-77 | 1436 | 62 | 37304.2<br>70243.3 | 40°44.0'N<br>68°23.8'W |
| B-12 | Grab 3 | 2-10-77 | 1446 | 59 | 37307.6<br>70242.8 | 40°43.8'N<br>68°24.2'W |
| B-13 | Grab 1 | 2-10-77 | 1533 | 88 | 37279.4<br>70272.3 | 40°38.6'N<br>68°15.8'W |
| B-13 | Grab 2 | 2-10-77 | 1550 | 88 | 37275.7<br>70272.7 | 40°38.6'N<br>68°15.0'W |
| B-13 | Grab 3 | 2-10-77 | 1558 | 90 | 37273.9<br>70273.3 | 40°38.7'N<br>68°14.8'W |
| B-13 | Hydrocast | 2-10-77 | 1613 | 90 | 37270.9<br>70273.6 | 40°38.5'N<br>68°14.2'W |
| B-15 | Hydrocast | 2-10-77 | 1658 | 77 | 37323.5<br>70262.9 | 40°39.5'N<br>68°22.0'W |
| B-15 | Grab 1 | 2-10-77 | 1710 | 79 | 37322.0<br>70263.8 | 40°39.5'N<br>68°21.7'W |

Station Location and Information EN-004 (cont.)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| B-15 | Grab 2 | 2-10-77 | 1717 | 79 | 37321.4<br>70264.3 | 40°40.2'N<br>68°22.4'W |
| B-15 | Grab 3 | 2-10-77 | 1730 | 79 | 37320.3<br>70265.2 | 40°39.3'N<br>68°21.5'W |
| B-16 | Grab 1 | 2-10-77 | 1820 | 70 | 37405.7<br>70261.4 | 40°37.6'N<br>68°31.0'W |
| B-16 | Grab 2 | 2-10-77 | 1829 | 70 | 37405.5<br>70262.3 | 40°37.4'N<br>68°30.7'W |
| B-16 | Grab 3 | 2-10-77 | 1836 | 71 | 37405.4<br>70263.1 | 40°37.3'N<br>68°30.8'W |
| B-16 | Hydrocast | 2-10-77 | 1846 | 71 | 37405.8<br>70264.5 | 40°37.0'N<br>68°30.6'W |
| B-17 | Hydrocast | 2-10-77 | 1922 | 62 | 37412.3<br>70250.6 | 40°39.4'N<br>68°33.9'W |
| B-17 | Grab 1 | 2-10-77 | 1930 | 62 | 37412.7<br>70251.5 | 40°39.3'N<br>68°33.8'W |
| B-17 | Grab 2 | 2-10-77 | 1936 | 64 | 37413.5<br>70252.2 | 40°39.2'N<br>68°33.9'W |
| B-17 | Grab 3 | 2-10-77 | 1945 | 66 | 37414.3<br>70253.2 | 40°39.0'N<br>68°33.3'W |
| B-18 | Grab 1 | 2-10-77 | 2018 | 68 | 37472.4<br>70248.9 | 40°38.3'N<br>68°40.7'W |
| B-18 | Grab 2 | 2-10-77 | 2031 | 66 | 37474.7<br>70250.8 | 40°38.0'N<br>68°40.5'W |
| B-18 | Grab 3 | 2-10-77 | 2039 | 66 | 37475.6<br>70251.3 | 40°37.8'N<br>68°40.5'W |
| B-18 | Hydrocast | 2-10-77 | 2050 | 64 | 37477.2<br>70252.5 | 40°37.7'N<br>68°40.5'W |
| B-27 | Hydrocast | 2-10-77 | 2137 | 71 | 37501.4<br>70224.8 | 40°42.3'N<br>68°48.3'W |
| B-27 | Grab 1 | 2-10-77 | 2149 | 71 | 37502.9<br>70224.9 | 40°42.2'N<br>68°48.3'W |
| B-27 | Grab 2 | 2-10-77 | 2153 | 71 | 37503.7<br>70225.6 | 40°42.0'N<br>68°47.4'W |

Station Location and Information EN-004 (cont.)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| B-27 | Grab 3 | 2-10-77 | 2206 | 71 | 37504.8<br>70226.1 | 40°41.8'N<br>68°48.3'W |
| B-26 | Grab 1 | 2-10-77 | 2259 | 70 | 37443.8<br>70198.1 | 40°48.8'N<br>68°46.8'W |
| B-26 | Grab 2 | 2-10-77 | 2307 | 70 | 37443.9<br>70197.4 | 40°48.8'N<br>68°46.8'W |
| B-26 | Grab 3 | 2-10-77 | 2313 | 64 | 37443.9<br>70197.2 | 40°48.8'N<br>68°46.8'W |
| B-26 | Hydrocast | 2-10-77 | 2323 | 68 | 37443.8<br>70197.0 | 40°48.8'N<br>68°46.8'W |
| B-25 | Hydrocast | 2-11-77 | 0012 | 70 | 37371.9<br>70188.1 | 40°53.6'N<br>68°41.2'W |
| B-25 | Grab 1 | 2-11-77 | 0032 | 66 | 37370.0<br>70185.4 | 40°52.5'N<br>68°40.6'W |
| B-25 | Grab 2 | 2-11-77 | 0040 | 66 | 37368.9<br>70184.7 | 40°51.4'N<br>68°41.3'W |
| B-25 | Grab 3 | 2-11-77 | 0050 | 70 | 37367.8<br>70183.6 | 40°53.6'N<br>68°41.5'W |
| D-24 | Grab 1 | 2-11-77 | 0122 | 62 | 37341.0<br>70168.0 | 40°57.5'N<br>68°41.8'N |
| D-24 | Grab 2 | 2-11-77 | 0125 | 42 | 37339.4<br>70167.1 | 40°57.7'N<br>68°41.3'W |
| D-24 | Grab 3 | 2-11-77 | 0133 | 48 | 37337.3<br>70166.3 | 40°57.8'N<br>68°41.3'W |
| D-24 | Hydrocast | 2-11-77 | 0146 | 64 | 37334.8<br>70165.2 | 40°58.0'N<br>68°41.4'W |
| C-23 | Hydrocast | 2-11-77 | 0259 | 37 | 37283.4<br>70173.1 | 40°58.0'N<br>68°34.3'W |
| C-23 | Grab 1 | 2-11-77 | 0305 | 48 | 37282.4<br>70173.1 | 40°58.2'N<br>68°33.9'W |
| C-23 | Grab 2 | 2-11-77 | 0316 | 46 | 37279.5<br>70172.0 | 40°58.4'N<br>68°34.1'W |
| C-23 | Grab 3 | 2-11-77 | 0324 | 51 | 37277.8<br>70172.0 | 40°58.5'N<br>68°34.1'W |

Station Location and Information EN-004 (cont.)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| B-22 | Grab 1 | 2-11-77 | 0356 | 51 | 37250.0<br>70180.7 | 40°57.5'N<br>68°29.7'W |
| B-22 | Grab 2 | 2-11-77 | 0403 | 51 | 37248.6<br>70180.9 | 40°59.5'N<br>68°29.3'W |
| B-22 | Grab 3 | 2-11-77 | 0413 | 48 | 37247.0<br>70181.3 | 40°57.5'N<br>68°28.9'W |
| B-22 | Hydrocast | 2-11-77 | 0424 | 35 | 37244.7<br>70181.7 | 40°57.5'N<br>68°29.2'W |
| B-20 | Hydrocast | 2-11-77 | 0530 | 59 | 37323.6<br>70226.2 | 40°46.6'N<br>68°28.9'W |
| B-20 | Grab 1 | 2-11-77 | 0545 | 49 | 37322.7<br>70227.5 | 40°46.4'N<br>68°28.8'W |
| B-20 | Grab 2 | 2-11-77 | 0553 | 55 | 37322.0<br>70228.0 | 40°46.3'N<br>68°28.1'W |
| B-20 | Grab 3 | 2-11-77 | 0605 | 59 | 37321.8<br>70229.5 | 40°46.0'N<br>68°28.0'W |
| B-21 | Grab 1 | 2-11-77 | 0638 | 59 | 37356.8<br>70216.3 | 40°47.5'N<br>68°34.1'W |
| B-21 | Grab 2 | 2-11-77 | 0650 | 53 | 37357.1<br>70217.5 | 40°47.2'N<br>68°33.9'W |
| B-21 | Grab 3 | 2-11-77 | 0658 | 53 | 37357.5<br>70218.7 | 40°47.2'N<br>68°34.0'W |
| B-21 | Hydrocast | 2-11-77 | 0714 | 57 | 37358.7<br>70221.1 | 40°46.7'N<br>68°33.6'W |
| F-28 | Hydrocast | 2-11-77 | 0903 | 79 | 37544.2<br>70184.0 | 40°48.7'N<br>69°00.2'W |
| F-28 | Grab 1 | 2-11-77 | 0912 | 82 | 37545.4<br>70184.5 | 40°48.5'N<br>69°00.0'W |
| F-28 | Grab 2 | 2-11-77 | 0929 | 81 | 37547.6<br>70185.5 | 40°48.3'N<br>69°00.1'W |
| F-28 | Grab 3 | 2-11-77 | 0945 | 81 | 37549.6<br>70186.1 | 40°48.0'N<br>69°00.2'W |
| F-29 | Grab 1 | 2-11-77 | 1041 | 77 | 37512.7<br>70159.7 | 40°54.2'N<br>69°01.7'W |

Station Location and Information EN-004 (cont.)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| F-29 | Hydrocast | 2-11-77 | 1112 | 88 | 37514.1<br>70159.0 | 40°54.2'N<br>69°01.7'W |
| E-30 | Hydrocast | 2-11-77 | 1218 | 59 | 37649.6<br>70158.7 | 40°50.2'N<br>69°15.9'W |
| E-30 | Grab 1 | 2-11-77 | 1236 | 57 | 37647.3<br>70157.4 | 40°50.6'N<br>69°15.3'W |
| E-30 | Grab 2* | 2-11-77 | 1249 | 57 | 37644.9<br>70156.3 | 40°51.0'N<br>69°15.8'W |
| A-31 | Grab 1 | 2-11-77 | 1525 | 75 | 37591.5<br>70143.8 | 40°54.7'N<br>69°13.7'W |
| A-31 | Grab 2 | 2-11-77 | 1533 | 73 | 37588.4<br>70142.8 | 40°55.0'N<br>69°12.5'W |
| A-31 | Grab 3 | 2-11-77 | 1541 | 71 | 37585.1<br>70141.8 | 40°55.1'N<br>69°12.4'W |
| A-31 | Hydrocast | 2-11-77 | 1551 | 81 | 37580.9<br>70141.3 | 40°55.5'N<br>69°11.8'W |
| D-35 | Hydrocast | 2-11-77 | 1626 | 37 | 37603.0<br>70123.5 | 40°58.2'N<br>69°17.3'W |
| D-35 | Grab 1 | 2-11-77 | 1633 | 27 | 37601.5<br>70123.2 | 40°58.2'N<br>69°17.2'W |
| D-35 | Grab 2 | 2-11-77 | 1640 | 29 | 37599.8<br>70122.9 | 40°58.2'N<br>69°17.0'W |
| D-35 | Grab 3 | 2-11-77 | 1648 | 35 | 37598.0<br>70122.8 | 40°58.2'N<br>69°16.9'W |
| A-33 | Grab 1 | 2-11-77 | 1720 | 62 | 37550.9<br>70109.8 | 41°02.0'N<br>69°14.5'W |
| A-33 | Grab 2 | 2-11-77 | 1728 | 62 | 37549.5<br>70109.7 | 41°02.2'N<br>69°14.1'W |
| A-33 | Hydrocast | 2-11-77 | 1752 | 60 | 37544.8<br>70108.7 | 41°02.4'N<br>69°13.9'W |
| A-34 | Hydrocast | 2-11-77 | 1836 | 59 | 37571.3<br>70103.8 | 41°02.5'N<br>69°17.5'W |
| A-34 | Grab 1 | 2-11-77 | 1851 | 59 | 37572.6<br>70104.4 | 41°02.5'N<br>69°17.6'W |

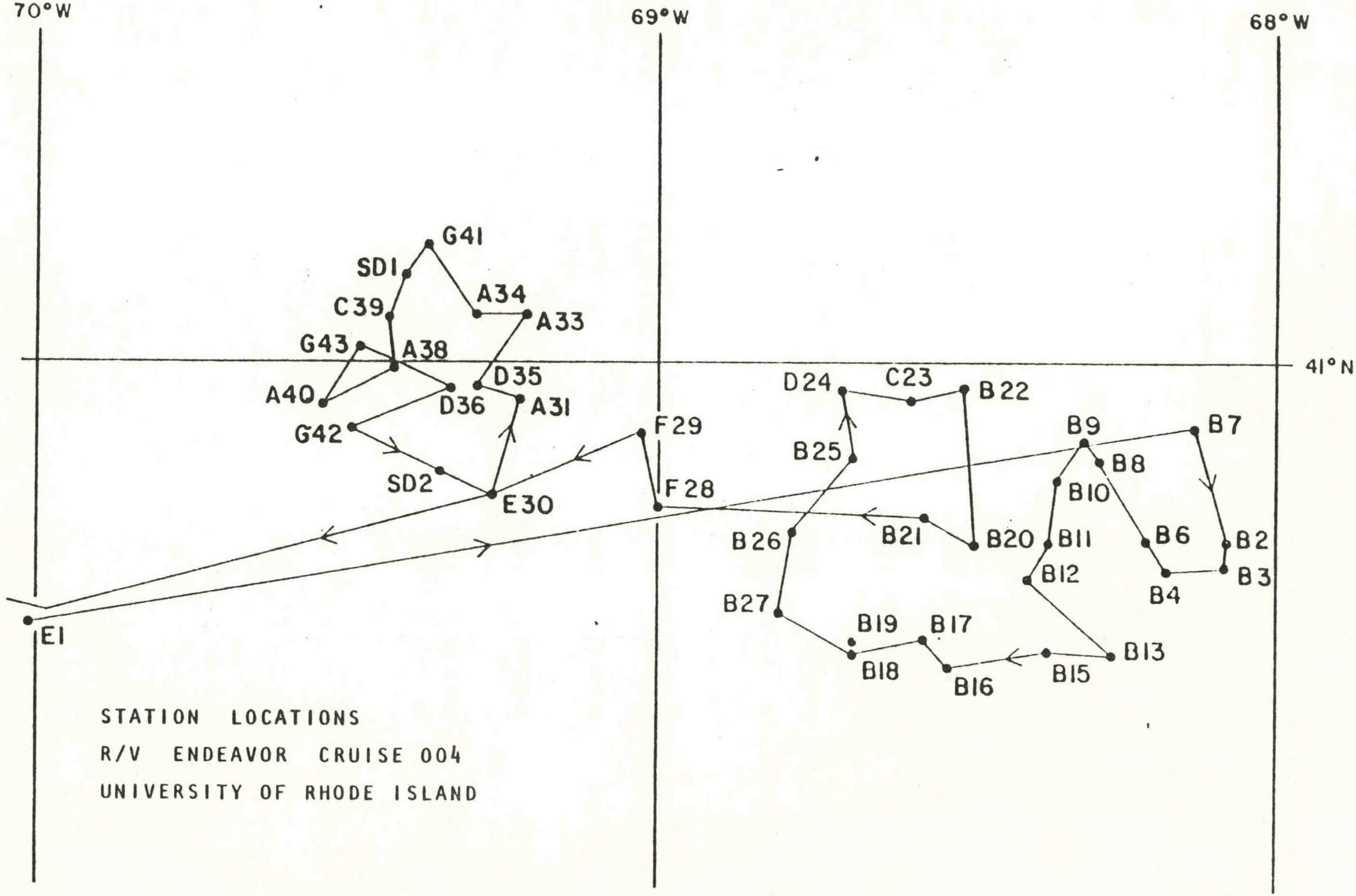
* Biology only.

Station Location and Information EN-004 (cont.)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| A-34 | Grab 2 | 2-11-77 | 1900 | 60 | 37573.1<br>70104.7 | 41°02.2'N<br>69°17.6'W |
| A-34 | Grab 3 | 2-11-77 | 1913 | 60 | 37573.3<br>70105.2 | 41°02.7'N<br>69°17.9'W |
| G-41 | Grab 1 | 2-11-77 | 2001 | 48 | 37573.6<br>70079.4 | 41°06.7'N<br>69°22.1'W |
| G-41 | Grab 2 | 2-11-77 | 2008 | 49 | 37575.1<br>70080.0 | 41°06.8'N<br>69°22.3'W |
| G-41 | Grab 3 | 2-11-77 | 2022 | 46 | 37577.6<br>70080.7 | 41°06.6'N<br>69°22.3'W |
| G-41 | Hydrocast | 2-11-77 | 2029 | 46 | 37579.3<br>70081.4 | 41°06.5'N<br>69°22.3'W |
| SD-1 | Scallop dredge start | 2-11-77 | 2210 | 49 | | 41°11.0'N<br>69°22.5'W |
| SD-1 | Scallop dredge end | 2-11-77 | 2301 | 49 | | 41°12.3'N<br>69°22.4'W |
| C-39 | Hydrocast | 2-12-77 | 0650 | 11 | 37628.6<br>70089.8 | 41°03.3'N<br>69°26.2'W |
| C-39 | Grab 1 | 2-12-77 | 0655 | 11 | 37629.4<br>70090.1 | 41°03.2'N<br>69°26.2'W |
| C-39 | Grab 2 | 2-12-77 | 0700 | 11 | 37630.2<br>70090.5 | 41°03.2'N<br>69°26.2'W |
| C-39 | Grab 3 | 2-12-77 | 0706 | 7 | 37631.6<br>70090.7 | 41°03.2'W<br>69°26.1'W |
| A-38 | Hydrocast | 2-12-77 | 0721 | 42 | 37653.6<br>70105.5 | 40°59.7'N<br>69°26.0'W |
| A-40 | Hydrocast | 2-12-77 | 0850 | 38 | 37718.5<br>70111.6 | 40°56.8'N<br>69°31.5'W |
| G-43 | Hydrocast | 2-12-77 | 1013 | 20 | 37647.7<br>70097.4 | 41°01.4'N<br>69°26.8'W |
| G-43 | Grab 1 | 2-12-77 | 1025 | 17 | 37652.1<br>70098.5 | 41°01.2'N<br>69°26.8'W |
| G-43 | Grab 2 | 2-12-77 | 1043 | 22 | 37644.2<br>70096.3 | 41°01.5'N<br>69°26.8'W |

Station Location and Information EN-004 (cont.)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| G-43 | Grab 3 | 2-12-77 | 1051 | 14 | 37646.6<br>70096.6 | 41°01.1'N<br>69°26.1'W |
| D-36 | Grab 1 | 2-12-77 | 1157 | 38 | 37689.9<br>70093.8 | 41°00.8'N<br>69°32.2'W |
| D-36 | Grab 2 | 2-12-77 | 1217 | 35 | 37687.3<br>70092.4 | 41°01.0'N<br>69°31.9'W |
| D-36 | Grab 3 | 2-12-77 | 1224 | 38 | 37686.2<br>70092.0 | 41°01.1'N<br>69°31.9'W |
| D-36 | Hydrocast | 2-12-77 | 1206 | 37 | 37688.6<br>70092.9 | 41°00.9'N<br>69°31.9'W |
| G-42 | Grab 1 | 2-12-77 | 1307 | 40 | 37770.7<br>70117.0 | 40°54.2'N<br>69°36.0'W |
| G-42 | Grab 2 | 2-12-77 | 1316 | 40 | 37769.6<br>70116.3 | 40°54.3'N<br>69°36.0'W |
| G-42 | Grab 3 | 2-12-77 | 1324 | 38 | 37768.0<br>70115.6 | 40°54.5'N<br>69°36.0'W |
| G-42 | Hydrocast | 2-12-77 | 1340 | 40 | 37764.7<br>70114.0 | 40°54.8'N<br>69°36.1'W |
| SD-2 | Scallop dredge start | 2-12-77 | 1700 | 55 | | 40°50.5'N<br>69°16.0'W |
| SD-2 | Scallop dredge end | 2-12-77 | 1715 | 55 | | 40°50.5'N<br>69°15.5'W |




STATION LOCATIONS
R/V ENDEAVOR CRUISE 004
UNIVERSITY OF RHODE ISLAND

GRADUATE SCHOOL OF OCEANOGRAPHY

University of Rhode Island
Kingston, R.I. 02881

CRUISE REPORT
R/V ENDEAVOR Cruise EN-005

PROJECT: ARGO MERCHANT Oil Spill: Fate and Effects
Cruise 4

REGION OF INVESTIGATION:

Nantucket Shoals

SCHEDULE:

| | |
|---|---|
| Depart Quonset, R.I. | 0830, 22 February 1977 |
| Arrive Quonset, R.I. | 1600, 27 February 1977 |

FUNDING:

National Oceanic and Atmospheric Administration (4 days)
Agency No. 03-7-022-35123

SCIENTIFIC PARTY:

| | |
|---|---|
| Dr. Eva Hoffman | Chief Scientist, GSO/URI |
| Mr. Sheldon Pratt | Co-Investigator, GSO/URI |
| Dr. Robert S. Brown | Co-Investigator, Animal Pathology/URI |
| Ms. Patricia Boyd | Student, URI |
| Mr. Jack Greene | Plankton Physiologist, NMFS, Narragansett |
| Mr. Scott Fortier | Staff Chemist, U.S. Coast Guard R & D Center, Groton, Connecticut |
| Mr. Bill Osberg | MST III, U.S. Coast Guard, R & D Center Groton, Connecticut |
| Mr. David Rudnick | Graduate Student, GSO/URI |
| Mr. Keith Cooper | Graduate Student |
| Ms. Vicki Murray | Research Assistant, Animal Pathology Department/URI |
| Tatsusaburo Isaji | Student, Ocean Engineering/URI |
| Mr. Jim Hannon | Marine Technician, GSO/URI |
| Ms. Audrey Fillion | Graduate Student, McGill University |
| Ms. Renate Pollack | Graduate Student, McGill University |

OBJECTIVES OF CRUISE:

Primary Objective: Determination of the areal extent of sediment contamination by ARGO MERCHANT oil, the collection of benthic organisms, and deployment of bottom drifters. (Hoffman, Fortier, Osberg, Pratt, Brown)

Ancillary Objectives:

1) Determination of depth of sediment contamination by ARGO MERCHANT oil. (Hoffman)

2) Determination of relationship between contamination of sediments and hydrocarbon content of benthic organisms in the area. (Hoffman)

3) Determination of the density and relative abundance of benthic organisms retained by a 1 mm sieve. (Pratt)

4) Archive and preserve sediment samples for future meiobenthic work. (Pratt)

5) Collection and description of phytoplankton in the area over contaminated and uncontaminated sediments. (Boyd)

6) Collection of contaminated sediment and appropriate controls for laboratory studies (bioassays, benthic nutrient flux, $O_2$ uptake, etc.). (Rudnick, Pratt, Hoffman)

7) Qualitative dredge samples for collection of epibenthos for histopathologic studies. (Brown, Cooper, Murray)

8) Collection of ichthyoplankton for oil effects research at NMFS. (Greene)

9) Collection & description of zooplankton in the area over contaminated & uncontaminated sediments. (Brown, Cooper, Murray, Pollack, Fillion)

SUMMARY OF RESEARCH:

1) Collection of 53 Smith-McIntyre grab sediment samples for:

   a) archives for possible future biological analyses (Pratt)
   b) hydrocarbon analyses (Hoffman)
   c) bioassay studies of winter flounder egg hatchability (Everich)
   d) rapid screening for oil contamination (Fortier & Osberg)

2) Collection of 8 Box Cores of bottom sediment:

   a) benthic flux of nutrients (Rudnick)
   b) hydrocarbon analyses (Hoffman)

3) Zooplankton vertical tows - 55:

   a) species population & diversity (Fillion & Pollack)
   b) hydrocarbon content (Brown, Fillion, Pollack & Fortier)

4) Phytoplankton tows - 6 (Boyd)

5) Neuston tows for fish egg and larval effects studies. (NMFS, Greene)

6) 9 Scallop Dredge samples of epibenthos:

   a) histopathology (Brown, Cooper & Murray)
   b) hydrocarbon analyses (Hoffman)

7) Release of 150 bottom drifters in vicinity of ARGO MERCHANT wreck. (Hoffman & Griscom)

8) Surface water samples (40) and hydrocasts (1m, 6m & bottom):

   a) oil droplet size distribution (Isaji)
   b) phytoplankton distribution (Boyd)
   c) rapid screening for ARGO MERCHANT oil content (Fortier & Osberg)

R/V ENDEAVOR CRUISE EN-005

Station Location and Information

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 44 | Grab 1 | 2-22-77 | 1856 | 40 | 37867.3<br>70148.1 | $40^\circ 45.8'N$<br>$69^\circ 40.9'W$ |
| 44 | Bongo tow | 2-22-77 | 1915 | 40 | 37867.5<br>70147.0 | $40^\circ 45.9'N$<br>$69^\circ 40.9'W$ |
| 44 | McGill tow<br>Start | 2-22-77 | 1934 | 40 | 37865.4<br>70146.2 | $40^\circ 46.4'N$<br>$69^\circ 41.0'W$ |
| 44 | McGill tow<br>End | 2-22-77 | 1945 | 40 | 37862.7<br>70145.2 | $40^\circ 46.5'N$<br>$69^\circ 40.7'W$ |
| 44 | Neuston tow<br>Start | 2-22-77 | 1950 | 40 | 37861.6<br>70144.6 | $40^\circ 46.8'N$<br>$69^\circ 40.6'W$ |
| 44 | Neuston tow<br>End | 2-22-77 | 2000 | 40 | 37858.7<br>70144.0 | $40^\circ 46.8'N$<br>$69^\circ 40.5'W$ |
| 45 | Grab 1 | 2-22-77 | 2048 | 29 | 37798.4<br>70139.2 | $40^\circ 49.4'N$<br>$69^\circ 35.0'W$ |
| 45 | Bongo tow | 2-22-77 | 2054-<br>2057 | 37 | 37795.6<br>70138.8 | $40^\circ 49.5'N$<br>$69^\circ 34.8'W$ |
| 45 | McGill tow | 2-22-77 | 2100-<br>2102 | 33 | 37795.1<br>70138.6 | $40^\circ 49.6'N$<br>$69^\circ 34.7'W$ |
| 45 | Neuston tow<br>Start | 2-22-77 | 2108- | 33 | 37793.5<br>70139.4 | $40^\circ 49.5'N$<br>$69^\circ 34.3'W$ |
| 45 | Neuston tow<br>End | 2-22-77 | 2120 | 44 | 37791.6<br>70139.5 | $40^\circ 49.5'N$<br>$69^\circ 34.2'W$ |
| 46 | Grab 1 | 2-22-77 | 2209 | 35 | 37830.9<br>70121.7 | $40^\circ 51.5'N$<br>$69^\circ 41.7'W$ |
| 46 | Bongo tow<br>Start | 2-22-77 | 2216 | 38 | 37828.5<br>70121.8 | $40^\circ 51.5'N$<br>$69^\circ 41.4'W$ |
| 46 | Bongo tow<br>End | 2-22-77 | 2219 | 35 | 37828.2<br>70122.0 | $40^\circ 51.6'N$<br>$69^\circ 41.3'W$ |
| 46 | McGill tow | 2-22-77 | 2224 | 40 | 37827.1<br>70122.7 | $40^\circ 51.4'N$<br>$69^\circ 41.0'W$ |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 46 | Neuston tow Start | 2-22-77 | 2228 | 40 | 37826.4<br>70123.1 | 40°51.4'N<br>69°40.8'W |
| 46 | Neuston tow End | 2-22-77 | 2239 | 40 | 37823.7<br>70123.7 | 40°51.4'N<br>69°40.5'W |
| 47 | Grab 1 | 2-22-77 | 2310 | 38 | 37758.7<br>70117.2 | 40°54.6'N<br>69°34.7'W |
| 47 | Bongo tow | 2-22-77 | 2315 | 42 | 37755.6<br>70116.3 | 40°54.8'N<br>69°34.6'W |
| 47 | McGill tow Start | 2-22-77 | 2321 | 38 | 37753.1<br>70115.6 | 40°54.8'N<br>69°34.4'W |
| 47 | McGill tow End | 2-22-77 | 2326 | 42 | 37752.3<br>70113.9 | 40°55.2'N<br>69°34.7'W |
| 47 | Neuston tow Start | 2-22-77 | 2328 | 44 | 37751.5<br>70113.4 | 40°55.4'N<br>69°34.8'W |
| 47 | Neuston tow End | 2-22-77 | 2339 | 44 | 37748.2<br>70112.1 | 40°55.6'N<br>69°34.5'W |
| 48 | Grab 1 | 2-23-77 | 0027 | 31 | 37795.0<br>70098.5 | 40°56.6'N<br>69°41.9'W |
| 48 | Bongo tow | 2-23-77 | 0032 | 29 | 37792.9<br>70098.0 | 40°56.7'N<br>69°41.7'W |
| 48 | McGill tow Start | 2-23-77 | 0039 | 31 | 37792.0<br>70096.9 | 40°57.1'N<br>69°41.8'W |
| 48 | McGill tow End | 2-23-77 | 0050 | 31 | 37787.3<br>70095.4 | 40°57.5'N<br>69°41.6'W |
| 48 | Neuston tow Start | 2-23-77 | 0053 | 33 | 37785.8<br>70095.0 | 40°57.5'N<br>69°41.5'W |
| 49 | Neuston tow End | 2-23-77 | 0104 | 35 | 37784.5<br>70093.8 | 40°58.0'N<br>69°41.6'W |
| 49 | Grab 1 | 2-23-77 | 0145 | 40 | 37748.2<br>70105.0 | 40°57.0'N<br>69°35.9'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 49 | Bongo tow | 2-23-77 | 0146 | 40 | 37747.7<br>70104.2 | 40°57.1'N<br>69°35.9'W |
| 49 | McGill tow Start | 2-23-77 | 0155 | 37 | 37745.2<br>70106.6 | 40°56.8'N<br>69°35.9'W |
| 49 | McGill tow End | 2-23-77 | 0205 | 38 | 37741.9<br>70107.5 | 40°56.8'N<br>69°34.5'W |
| 49 | Neuston tow Start | 2-23-77 | 0209 | 38 | 37739.4<br>70109.0 | 40°56.6'N<br>69°34.1'W |
| 49 | Neuston tow End | 2-23-77 | 0219 | 38 | 37733.2<br>70109.4 | 40°56.7'N<br>69°33.5'W |
| 55 | Grab 1 | 2-23-77 | 0250 | 44 | 37746.6<br>70093.1 | 40°59.1'N<br>69°37.8'W |
| 55 | Bongo tow | 2-23-77 | 0255 | 44 | 37746.8<br>70093.2 | 40°59.0'N<br>69°37.8'W |
| 55 | Neuston tow Start | 2-23-77 | 0300 | 44 | 37747.7<br>70093.1 | 40°59.0'N<br>69°37.9'W |
| 55 | Neuston tow End | 2-23-77 | 0310 | 44 | 37751.4<br>70093.1 | 40°58.9'N<br>69°38.1'W |
| 50 | Grab 1 | 2-23-77 | 0834 | 40 | 37705.0<br>70111.4 | 40°57.1'N<br>69°30.1'W |
| 50 | Bongo tow Start | 2-23-77 | 0840 | 40 | 37705.5<br>70111.1 | 40°57.1'N<br>69°30.1'W |
| 50 | Bongo tow End | 2-23-77 | 0843 | 40 | 37706.2<br>70110.8 | 40°57.2'N<br>69°30.4'W |
| 50 | McGill tow #1 Start | 2-23-77 | 0846 | 38 | 37707.2<br>70110.4 | 40°57.2'N<br>69°30.5'W |
| 50 | McGill tow #1 End | 2-23-77 | 0855 | 42 | 37709.3<br>70110.3 | 40°57.2'N<br>69°30.6'W |
| 50 | Neuston tow Start | 2-23-77 | 0900 | 42 | 37710.0<br>70110.0 | 40°57.3'N<br>69°30.7'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 50 | Neuston tow End | 2-23-77 | 0912 | 42 | 37715.0<br>70109.5 | 40°57.2'N<br>69°31.4'W |
| 50 | McGill tow #2 Start | 2-23-77 | 0915 | 40 | 37716.4<br>70109.4 | 40°57.2'N<br>69°31.6'W |
| 50 | McGill tow #2 End | 2-23-77 | 0933 | 24 | 37723.4<br>70108.5 | 40°57.1'N<br>69°32.4'W |
| 50 | Hargraves tow start | 2-23-77 | 0937 | 38 | 37725.3<br>70108.2 | 40°57.0'N<br>69°32.9'W |
| 50 | Hargraves tow end | 2-23-77 | 0952 | 44 | 37730.4<br>70107.0 | 40°57.3'N<br>69°33.5'W |
| 57 | Grab 1 | 2-23-77 | 1021 | 35 | 37698.8<br>70086.3 | 41°02.0'N<br>69°33.5'W |
| 57 | Bongo tow Start | 2-23-77 | 1026 | 33 | 37697.5<br>70085.9 | 41°01.9'N<br>69°34.0'W |
| 57 | Bongo tow End | 2-23-77 | 1029 | 37 | 37697.6<br>70086.2 | 41°01.7'N<br>69°34.0'W |
| 57 | McGill tow Start | 2-23-77 | 1033 | 35 | 37697.9<br>70085.6 | 41°01.9'N<br>69°34.0'W |
| 57 | McGill tow End | 2-23-77 | 1047 | 33 | 37698.3<br>70083.7 | 41°02.6'N<br>69°34.9'W |
| 57 | Neuston tow Start | 2-23-77 | 1050 | 35 | 37698.3<br>70083.6 | 41°02.6'N<br>69°34.9'W |
| 57 | Neuston tow End | 2-23-77 | 1100 | 33 | 37698.3<br>70082.0 | 41°02.7'N<br>69°35.0'W |
| 64 | Grab 1 | 2-23-77 | 1852 | 44 | 37593.8<br>70089.2 | 41°04.6'N<br>69°22.5'W |
| 64 | Grab 2 (empty) | 2-23-77 | 1857 | 42 | 37596.0<br>70088.8 | 41°04.5'N<br>69°23.0'W |
| 64 | Grab 3 | 2-23-77 | 1901 | 42 | 37598.1<br>70088.8 | 41°04.4'N<br>69°23.1'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 64 | Bongo tow Start | 2-23-77 | 1921 | 46 | 37586.4<br>70087.0 | 41°05.1'N<br>69°22.3'W |
| 64 | Bongo tow End | 2-23-77 | 1924 | 46 | 37587.1<br>70086.5 | 41°05.1'N<br>69°22.4'W |
| 64 | McGill tow Start | 2-23-77 | 1933 | 46 | 37587.2<br>70085.3 | 41°05.4'N<br>69°22.6'W |
| 64 | McGill tow End | 2-23-77 | 1941 | 46 | 37586.6<br>70084.7 | 41°05.5'N<br>69°22.9'W |
| 64 | Neuston tow Start | 2-23-77 | 1945 | 46 | 37586.4<br>70084.9 | 41°05.5'N<br>69°23.0'W |
| 64 | Neuston tow End | 2-23-77 | 1956 | 46 | 37585.5<br>70083.1 | 41°06.0'N<br>69°23.0'W |
| 61 | Grab 1 (failure) | 2-23-77 | 2045 | 44 | 37614.2<br>70100.5 | 41°01.9'N<br>69°22.1'W |
| 61 | Grab 2 | 2-23-77 | 2050 | 44 | 37615.0<br>70101.0 | 41°02.6'N<br>69°22.5'W |
| 61 | Grab 3 | 2-23-77 | 2056 | 46 | 37616.2<br>70100.1 | 41°01.9'N<br>69°23.0'W |
| 61 | Bongo tow Start | 2-23-77 | 2102 | 46 | 37617.7<br>70099.0 | 41°02.0'N<br>69°23.3'W |
| 61 | Bongo tow End | 2-23-77 | 2104 | 44 | 37618.8<br>70099.1 | 41°01.9'N<br>69°23.9'W |
| 61 | McGill tow Start | 2-23-77 | 2108 | 46 | 37619.5<br>70098.6 | 41°01.9'N<br>69°23.5'W |
| 61 | McGill tow End | 2-23-77 | 2120 | 48 | 37616.7<br>70090.7 | 41°02.0'N<br>69°23.0'W |
| 61 | Neuston tow Start | 2-23-77 | 2124 | 46 | 37615.2<br>70096.3 | 41°02.6'N<br>69°23.5'W |
| 61 | Neuston tow End | 2-23-77 | 2134 | 46 | 37612.0<br>70095.4 | 41°02.8'N<br>69°23.3'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 61 | hydrocast (3 depths 1m, 6m, bottom) | 2-23-77 | 2141 | 42 | 37611.3<br>70093.6 | 41°03.2'N<br>69°23.6'W |
| 61 | scallop dredge start | 2-23-77 | 2200 | 40 | 37609.9<br>70091.3 | 41°03.7'N<br>69°23.8'W |
| 61 | scallop dredge end | 2-23-77 | 2238 | 42 | 37596.4<br>70087.2 | 41°04.9'N<br>69°23.0'W |
| 62 | Grab 1 (rocks) | 2-23-77 | 2326 | 49 | 37594.8<br>70102.0 | 41°02.4'N<br>69°20.5'W |
| 62 | Grab 2 | 2-23-77 | 2331 | 49 | 37594.3<br>70102.2 | 41°02.5'N<br>69°20.3'W |
| 62 | Grab 3 | 2-23-77 | 2336 | 49 | 37593.9<br>70101.4 | 41°02.2'N<br>69°20.1'W |
| 62 | Grab 4 | 2-23-77 | 2343 | 49 | 37593.9<br>70101.2 | 41°02.2'N<br>69°20.0'W |
| 62 | Bongo tow Start | 2-23-77 | 2348 | 49 | 37592.3<br>70100.0 | 41°02.5'N<br>69°20.2'W |
| 62 | Bongo tow End | 2-23-77 | 2351 | 49 | 37591.3<br>70099.2 | 41°02.8'N<br>69°20.7'W |
| 62 | McGill tow Start | 2-23-77 | 2353 | 31 | 37598.6<br>70097.7 | 41°02.8'N<br>69°21.5'W |
| 62 | McGill tow End | 2-24-77 | 0009 | 31 | 37583.5<br>70096.2 | 41°03.5'N<br>69°20.0'W |
| 62 | Neuston tow Start | 2-24-77 | 0013 | 31 | 37582.4<br>70095.6 | 41°03.5'N<br>69°20.1'W |
| 62 | Neuston tow End | 2-24-77 | 0023 | 31 | 37577.4<br>70092.2 | 41°04.5'N<br>69°21.0'W |
| 54 | Grab 1 | 2-24-77 | 0114 | 53 | 37628.5<br>70125.4 | 40°57.0'N<br>69°19.9'W |
| 54 | Bongo tow Start | 2-24-77 | 0127 | 51 | 37623.2<br>70122.2 | 40°57.8'N<br>69°14.8'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 54 | Bongo tow<br>End | 2-24-77 | 0128 | 51 | 37622.4<br>70122.7 | 40°57.5'N<br>69°19.3'W |
| 54 | McGill tow<br>Start | 2-24-77 | 0134 | 53 | 37619.7<br>70121.6 | 40°58.0'N<br>69°19.3'W |
| 54 | McGill tow<br>End | 2-24-77 | 0144 | 53 | 37613.3<br>70129.0 | 40°56.9'N<br>69°17.2'W |
| 54 | Neuston tow<br>Start | 2-24-77 | 0146 | 49 | 37612.4<br>70119.1 | 40°58.6'N<br>69°18.9'W |
| 54 | Neuston tow<br>End | 2-24-77 | 0156 | 49 | 37605.6<br>70117.8 | 40°59.0'N<br>69°18.5'W |
| 56 | Grab 1 | 2-24-77 | 0855 | 48 | 37666.6<br>70106.3 | 40°59.2'N<br>69°27.0'W |
| 56 | Grab 2<br>nothing | 2-24-77 | 0904 | 46 | 37669.7<br>70105.9 | 40°59.2'N<br>69°27.3'W |
| 56 | Grab 3<br>biology only | 2-24-77 | 0907 | 46 | 37671.1<br>70105.0 | 40°59.2'N<br>69°27.3'W |
| 56 | Bongo tow<br>Start | 2-24-77 | 0918 | 44 | 37675.4<br>70105.8 | 40°59.0'N<br>69°28.0'W |
| 56 | Bongo tow<br>End | 2-24-77 | 0920 | 44 | 37676.3<br>70106.0 | 40°59.0'N<br>69°28.2'W |
| 56 | McGill tow<br>Start | 2-24-77 | 0925 | 44 | 37679.1<br>70106.6 | 40°58.9'N<br>69°28.5'W |
| 56 | McGill tow<br>End | 2-24-77 | 0936 | 44 | 37685.0<br>70107.2 | 40°58.4'N<br>69°29.0'W |
| 56 | Neuston tow<br>Start | 2-24-77 | 0939 | 44 | 37685.2<br>70106.6 | 40°58.6'N<br>69°29.3'W |
| 56 | Neuston tow<br>End | 2-24-77 | 0949 | 44 | 37683.2<br>70105.0 | 40°59.0'N<br>69°28.8'W |
| 56 | Grab 4 | 2-24-77 | 0953 | 44 | 37684.0<br>70104.4 | 40°59.0'N<br>69°29.0'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 56 | Scallop dredge start | 2-24-77 | 1035 | 46 | 37661.3<br>70104.7 | 40°59.5'N<br>69°27.0'W |
| 56 | Scallop dredge end | 2-24-77 | 1103 | 46 | 37655.8<br>70102.4 | 41°00.2'N<br>69°26.8'W |
| 53 | Grab 1 | 2-24-77 | 1142 | 26 | 37632.5<br>70107.9 | 40°59.9'N<br>69°23.1'W |
| 53 | Bongo tow Start | 2-24-77 | 1145 | 26 | 37632.0<br>70107.6 | 41°00.1'N<br>69°23.1'W |
| 53 | Bongo tow End | 2-24-77 | 1147 | 26 | 37631.8<br>70107.3 | 41°00.3'N<br>69°23.2'W |
| 53 | McGill tow Start | 2-24-77 | 1150 | 31 | 37631.5<br>70106.8 | 41°00.4'N<br>69°23.2'W |
| 53 | McGill tow End | 2-24-77 | 1157 | 31 | 37632.6<br>70106.9 | 41°00.2'N<br>69°23.5'W |
| 53 | Neuston tow Start | 2-24-77 | 1151 | 31 | 37631.5<br>70106.8 | 41°00.2'N<br>69°23.1'W |
| 53 | Neuston tow End | 2-24-77 | 1200 | 31 | 37632.8<br>70106.8 | 41°00.1'N<br>69°23.6'W |
| 51 | Grab 1 | 2-24-77 | 1252 | 35 | 37687.3<br>70114.4 | 40°57.1'N<br>69°27.8'W |
| 51 | Neuston tow Start | 2-24-77 | 1257 | 35 | 37687.1<br>70113.9 | 40°57.2'N<br>69°27.8'W |
| 51 | Neuston tow End | 2-24-77 | 1309 | 35 | 37681.8<br>70111.5 | 40°57.8'N<br>69°27.5'W |
| 51 | Bongo tow Start | 2-24-77 | 1259 | 31 | 37687.2<br>70113.8 | 40°57.3'N<br>69°27.8'W |
| 51 | Bongo tow End | 2-24-77 | 1300 | 31 | 37687.0<br>70113.6 | 40°57.4'N<br>69°27.9'W |
| 51 | McGill tow Start | 2-24-77 | 1308 | 46 | 37682.4<br>70111.4 | 40°57.7'N<br>69°26.6'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 51 | McGill tow End | 2-24-77 | 1319 | 46 | 37676.5 70109.3 | 40°58.5'N 69°27.5'W |
| 52 | Grab 1 | 2-24-77 | 1414 | 22 | 37661.8 70119.6 | 40°57.1'N 69°24.1'W |
| 52 | Neuston tow Start | 2-24-77 | 1418 | 20 | 37661.8 70119.9 | 40°57.0'N 69°24.0'W |
| 52 | Neuston tow End | 2-24-77 | 1429 | 20 | 37662.0 70120.9 | 40°56.8'N 69°23.9'W |
| 52 | Bongo tow Start | 2-24-77 | 1419 | 27 | 37661.9 70120.2 | 40°57.0'N 69°24.0'W |
| 52 | Bongo tow End | 2-24-77 | 1421 | 27 | 37662.0 70120.1 | 40°56.9'N 69°24.0'W |
| 52 | McGill tow Start | 2-24-77 | 1425 | 27 | 37662.1 70120.7 | 40°56.8'N 69°24.0'W |
| 52 | McGill tow End | 2-24-77 | 1435 | 27 | 37663.2 70121.9 | 40°56.6'N 69°24.0'W |
| 50-57 | Scallop dredge #2 start | 2-24-77 | 1532 | 23 | 37699.9 70101.3 | 40°59.2'N 69°31.5'W |
| 50-57 | Scallop dredge #2 end | 2-24-77 | 1556 | 42 | 37699.2 70097.7 | 40°59.8'N 69°32.0'W |
| 50-57 | Scallop dredge #3 start | 2-24-77 | 1608 | 42 | 37699.3 70095.6 | 41°00.1'N 69°32.2'W |
| 50-57 | Scallop dredge #3 end | 2-24-77 | 1630 | 38 | 37701.3 70093.5 | 41°00.5'N 69°33.0'W |
| 63 | Grab 1 | 2-24-77 | 1715 | 31 | 37651.4 70076.1 | 41°05.4'N 69°31.1'W |
| 63 | Grab 2 | 2-24-77 | 1717 | 31 | 37653.6 70076.0 | 41°05.2'N 69°31.5'W |
| 63 | Grab 3 | 2-24-77 | 1725 | 35 | 37655.3 70076.5 | 41°05.2'N 69°31.8'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 63 | Bongo tow Start | 2-24-77 | 1731 | 33 | 37658.7<br>70077.9 | 41°04.5'N<br>69°31.3'W |
| 63 | Bongo tow End | 2-24-77 | 1733 | 33 | 37659.7<br>70077.7 | 41°04.5'N<br>69°31.6'W |
| 63 | McGill tow Start | 2-24-77 | 1739 | 33 | 37663.1<br>70079.3 | 41°04.1'N<br>69°31.5'W |
| 63 | McGill tow End | 2-24-77 | 1750 | 33 | 37669.5<br>70081.1 | 41°03.6'W<br>69°32.0'W |
| 63 | Neuston tow Start | 2-24-77 | 1743 | 33 | 37665.9<br>70080.3 | 41°03.7'N<br>69°31.6'W |
| 63 | Neuston tow End | 2-24-77 | 1754 | 33 | 37672.4<br>70082.2 | 41°03.2'N<br>69°31.9'W |
| 58 | Grab 1 | 2-24-77 | 1813 | 35 | 37675.8<br>70090.1 | 41°01.7'N<br>69°30.9'W |
| 58 | Grab 2 | 2-24-77 | 1819 | 37 | 37678.4<br>70090.0 | 41°01.6'N<br>69°31.0'W |
| 58 | Grab 3 | 2-24-77 | 1829 | 38 | 37681.8<br>70090.3 | 41°01.5'N<br>69°31.2'W |
| 58 | Bongo tow Start | 2-24-77 | 1834 | 37 | 37683.3<br>70090.3 | 41°01.5'N<br>69°31.5'W |
| 58 | Bongo tow End | 2-24-77 | 1836 | 37 | 37683.5<br>70090.4 | 41°01.5'N<br>69°31.5'W |
| 58 | McGill tow Start | 2-24-77 | 1840 | 40 | 37685.2<br>70091.1 | 41°01.3'N<br>69°31.5'W |
| 58 | McGill tow End | 2-24-77 | 1851 | 40 | 37693.9<br>70091.7 | 41°00.9'N<br>69°32.5'W |
| 58 | Neuston tow Start | 2-24-77 | 1842 | 40 | 37687.3<br>70091.3 | 41°01.2'N<br>69°31.9'W |
| 58 | Neuston tow End | 2-24-77 | 1853 | 40 | 37695.5<br>70092.0 | 41°00.9'N<br>69°32.8'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 58 | hydrocast (1m,6m, bottom) | 2-24-77 | 1900 | 40 | 37698.2<br>70092.2 | $41^{o}00.6'N$<br>$69^{o}33.8'W$ |
| TC (Tarpaulin Cove)* | plankton tows | 2-25-77 | various | 18 | --- | --- |
| 50 | Grab 1 | 2-26-77 | 0812 | 44 | 37705.2<br>70112.7 | $40^{o}56.9'N$<br>$69^{o}29.9'W$ |
| 50 | Bongo tow Start | 2-26-77 | 0827 | 44 | 37707.9<br>70012.7 | $40^{o}56.9'N$<br>$69^{o}30.1'W$ |
| 50 | Bongo tow End | 2-26-77 | 0830 | 44 | 37707.8<br>70112.8 | $40^{o}56.9'W$<br>$69^{o}30.1'W$ |
| 50 | Hargraves plankton tow Start | 2-26-77 | 0834 | 44 | 37706.7<br>70113.0 | $40^{o}56.9'N$<br>$69^{o}30.0'W$ |
| 50 | Hargraves plankton tow End | 2-26-77 | 0843 | 44 | 37708.7<br>70114.1 | $40^{o}56.5'N$<br>$69^{o}30.0'W$ |
| 50 | Hydrocast (1m,6m,bottom) | 2-26-77 | 0849 | 48 | 37709.6<br>70114.4 | $40^{o}56.5'N$<br>$69^{o}30.0'W$ |
| 50 | Bottom drifters released 3551-3625 | 2-26-77 | 0853 | 48 | 37710.2<br>70114.3 | $40^{o}56.5'N$<br>$69^{o}30.1'W$ |
| 56 | Grab 1 | 2-26-77 | 0926 | 44 | 37660.4<br>70106.8 | $40^{o}59.4'N$<br>$69^{o}26.2'W$ |
| 56 | Grab 2 | 2-26-77 | 0932 | 44 | 37661.8<br>70106.8 | $40^{o}59.2'N$<br>$69^{o}26.5'W$ |
| 56 | McGill tow Start | 2-26-77 | 0940 | 44 | 37663.9<br>70106.7 | $40^{o}59.1'N$<br>$69^{o}26.9'W$ |
| 56 | McGill tow End | 2-26-77 | 0943 | 46 | 37664.6<br>70106.5 | $40^{o}59.2'N$<br>$69^{o}26.9'W$ |

*While at anchor, Tarpaulin Cove off Naushon Island, Vineyard Sound.

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 56 | Bongo tow Start | 2-26-77 | 0946 | 44 | 37665.0<br>70107.0 | 40°59.1'N<br>69°26.9'W |
| 56 | Bongo tow End | 2-26-77 | 0948 | 46 | 37665.0<br>70106.5 | 40°59.1'N<br>69°26.9'W |
| 56 | Hargraves plankton tow Start | 2-27-88 | 0951 | 44 | 37665.0<br>70106.4 | 40°59.1'N<br>69°26.9'W |
| 56 | Hargraves plankton tow End | 2-26-77 | 0959 | 44 | 37664.2<br>70106.0 | 40°59.1'N<br>69°26.9'W |
| 56 | Scallop dredge start | 2-26-77 | 1008 | 44 | 37663.3<br>70105.9 | 40°59.5'N<br>69°26.9'W |
| 56 | Scallop dredge end | 2-26-77 | 1034 | 44 | 37657.1<br>70105.0 | 40°59.6'N<br>69°26.4'W |
| 61 | Grab 1 | 2-26-77 | 1116 | 40 | 37624.7<br>70099.9 | 41°01.6'N<br>69°23.9'W |
| 61 | Grab 2 | 2-26-77 | 1120 | 40 | 37624.3<br>70099.3 | 41°01.8'N<br>69°24.0'W |
| 61 | Grab 3 | 2-26-77 | 1125 | 40 | 37624.1<br>70098.9 | 41°01.8'N<br>69°24.0'W |
| 61 | hydrocast (1m,6m,bottom) | 2-26-77 | 1134 | 42 | 37623.3<br>70098.7 | 41°02.0'N<br>69°24.0'W |
| 61 | Hargraves plankton tow Start | 2-26-77 | 1140 | 46 | 37621.6<br>70098.3 | 41°02.0'N<br>69°24.0'W |
| 61 | Hargraves plankton tow End | 2-26-77 | 1142 | 46 | 37620.7<br>70097.6 | 41°02.0'N<br>69°23.8'W |
| 61 | McGill tow Start | 2-26-77 | 1148 | 51 | 37619.0<br>70096.8 | 41°02.5'N<br>69°24.0'W |
| 61 | McGill tow End | 2-26-77 | 1201 | 51 | 37615.8<br>70095.1 | 41°02.8'N<br>69°24.0'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 70 | Bow section buoy location | 2-26-77 | 1330 | 33 | 37641.3<br>70095.5 | 41°02.0'N<br>69°26.3'W |
| 70 | Box core 1 | 2-26-77 | 1342 | 16 | 37641.4<br>70094.8 | 41°02.0'N<br>69°26.5'W |
| 60 | Bongo tow #1 for McGill Start | 2-26-77 | 1406 | 24 | 37643.5<br>70095.4 | 41°02.0'N<br>69°26.4'W |
| 70 | Bongo tow #1 for McGill end | 2-26-77 | 1414 | 38 | 37641.7<br>70095.8 | 41°02.0'N<br>69°26.3'W |
| 70 | Box core 2 | 2-26-77 | 1406 | 18 | 37642.7<br>70095.7 | 41°01.9'N<br>69°26.3'W |
| 70 | Bongo tow #2 Start | 2-26-77 | 1418 | 37 | 37642.0<br>70096.3 | 41°01.8'N<br>69°26.1'W |
| 70 | Bongo tow #2 End | 2-26-77 | 1422 | 37 | 37642.0<br>70096.8 | 41°01.6'N<br>69°26.1'W |
| 70 | hydrocast (1m,6m,bottom) | 2-26-77 | 1435 | 37 | 37643.0<br>70096.3 | 41°01.6'N<br>69°26.3'W |
| 70 | Bottom drifters released (Serial # 3626-3699) | 2-26-77 | 1429 | 37 | 37639.6<br>70096.4 | 41°01.8'N<br>69°26.0'W |
| 70 | Grab 1 | 2-26-77 | 1446 | 20 | 37642.8<br>70095.5 | 41°01.8'N<br>69°26.2'W |
| 70 | Grab 2 (EPA grab) | 2-26-77 | 1512 | 24 | 37642.9<br>70095.5 | 41°01.9'N<br>69°26.3'W |
| 70 | Grab 3 | 2-26-77 | 1526 | 16 | 37643.4<br>70095.0 | 41°02.0'N<br>69°26.6'W |
| 70 | Grab 4 | 2-26-77 | 1532 | 26 | 37642.0<br>70095.8 | 41°02.0'N<br>69°26.5'W |
| 70 | Neuston tow Start | 2-26-77 | 1537 | 29 | 37641.6<br>70096.0 | 41°01.6'N<br>69°26.2'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 70 | Neuston tow End | 2-26-77 | 1547 | 40 | 37641.7<br>70098.1 | 41°01.5'N<br>69°26.0'W |
| 59* | Grab 1 | 2-26-77 | 1658 | 16 | 37645.7<br>70091.1 | 41°02.5'N<br>69°27.3'W |
| 59 | Box core 1 | 2-26-77 | 1707 | 11 | 37643.2<br>70091.5 | 41°02.5'N<br>69°27.0'W |
| 59 | Grab 2 (EPA Grab) | 2-26-77 | 1718 | 13 | 37642.1<br>70091.1 | 41°02.5'N<br>69°27.0'W |
| 59 | Box core 2 | 2-26-77 | 1724 | 14 | 37640.1<br>70091.7 | 41°02.6'N<br>69°27.0'W |
| 59 | Grab 3 | 2-26-77 | 1734 | 20 | 37642.0<br>70089.6 | 41°03.0'N<br>69°27.5'W |
| 59 | Grab 4 | 2-26-77 | 1741 | 22 | 37641.6<br>70090.1 | 41°02.9'N<br>69°27.2'W |
| 59 | Plankton tow Start | 2-26-77 | 1747 | 16 | 37641.3<br>70090.1 | 41°02.8'N<br>69°27.1'W |
| 59 | Plankton tow End | 2-26-77 | 1748 | 14 | 37641.9<br>70090.3 | 41°02.8'N<br>69°27.2'W |
| 59 | Bongo tow Start | 2-26-77 | 1753 | 22 | 37643.0<br>70090.3 | 41°02.7'N<br>69°27.3'W |
| 59 | Bongo tow End | 2-26-77 | 1755 | 18 | 37643.7<br>70090.1 | 41°02.7'N<br>69°27.5'W |
| 59 | Neuston tow Start | 2-26-77 | 1759 | 20 | 37644.7<br>70090.3 | 41°02.6'N<br>69°27.6'W |
| 59 | Neuston tow End | 2-26-77 | 1809 | 26 | 37647.6<br>70090.1 | 41°02.5'N<br>69°28.0'W |
| 59 | hydrocast (1m,6m,bottom) | 2-26-77 | 1815 | 24 | 37647.6<br>70090.1 | 41°02.5'N<br>69°28.0'W |

* At stern section of ARGO MERCHANT

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 49 | Grab 1 (EPA grab) | 2-26-77 | 1923 | 37 | 37751.8<br>70105.8 | 40°56.8'N<br>69°36.0'W |
| 49 | Box core 1 | 2-26-77 | 1934 | 31 | 37752.3<br>70106.6 | 40°56.5'N<br>69°36.0'W |
| 49 | Box core 2 | 2-26-77 | 1948 | 38 | 37753.9<br>70108.2 | 40°56.2'N<br>69°35.9'W |
| 62 | Grab 1 (EPA grab) | 2-26-77 | 2112 | 24 | 37598.5<br>70104.5 | 41°01.5'N<br>69°20.0'W |
| 62 | Grab 2 (EPA grab) | 2-26-77 | 2126 | 24 | 37601.9<br>70101.9 | 41°02.0'N<br>69°21.0'W |
| 62 | Box core 1 | 2-26-77 | 2132 | 24 | 37602.8<br>70101.8 | 41°02.0'N<br>69°21.0'W |
| 62 | Box core 2 | 2-26-77 | 2145 | 24 | 37604.7<br>70101.9 | 41°01.9'N<br>69°21.3'W |
| 62 | hydrocast (1m,6m,bottom) | 2-26-77 | 2208 | 22 | 37607.6<br>70102.5 | 41°01.6'N<br>69°21.5'W |
| 62 | Hargraves plankton tow Start | 2-26-77 | 2210 | 24 | 37609.0<br>70102.6 | 41°01.5'N<br>69°21.8'W |
| 62 | Hargraves plantion tow End | 2-26-77 | 2225 | 24 | 37605.8<br>70100.6 | 41°02.0'N<br>69°21.9'W |
| 70-71 | Scallop dredge start | 2-26-77 | 2306 | 40 | 37637.1<br>70094.9 | 41°02.1'N<br>69°26.0'W |
| 70-71 | Scallop dredge mid-pt | 2-26-77 | 2318 | 31 | 37634.4<br>70092.9 | 41°02.5'N<br>69°26.0'W |
| 70-71 | Scallop dredge end | 2-26-77 | 2330 | 24 | 37632.0<br>70091.5 | 41°02.9'N<br>69°26.0'W |
| 71 | Grab 1 | 2-27-77 | 0009 | 42 | 37660.9<br>70105.7 | 40°59.5'N<br>69°26.6'W |

R/V ENDEAVOR CRUISE EN-005

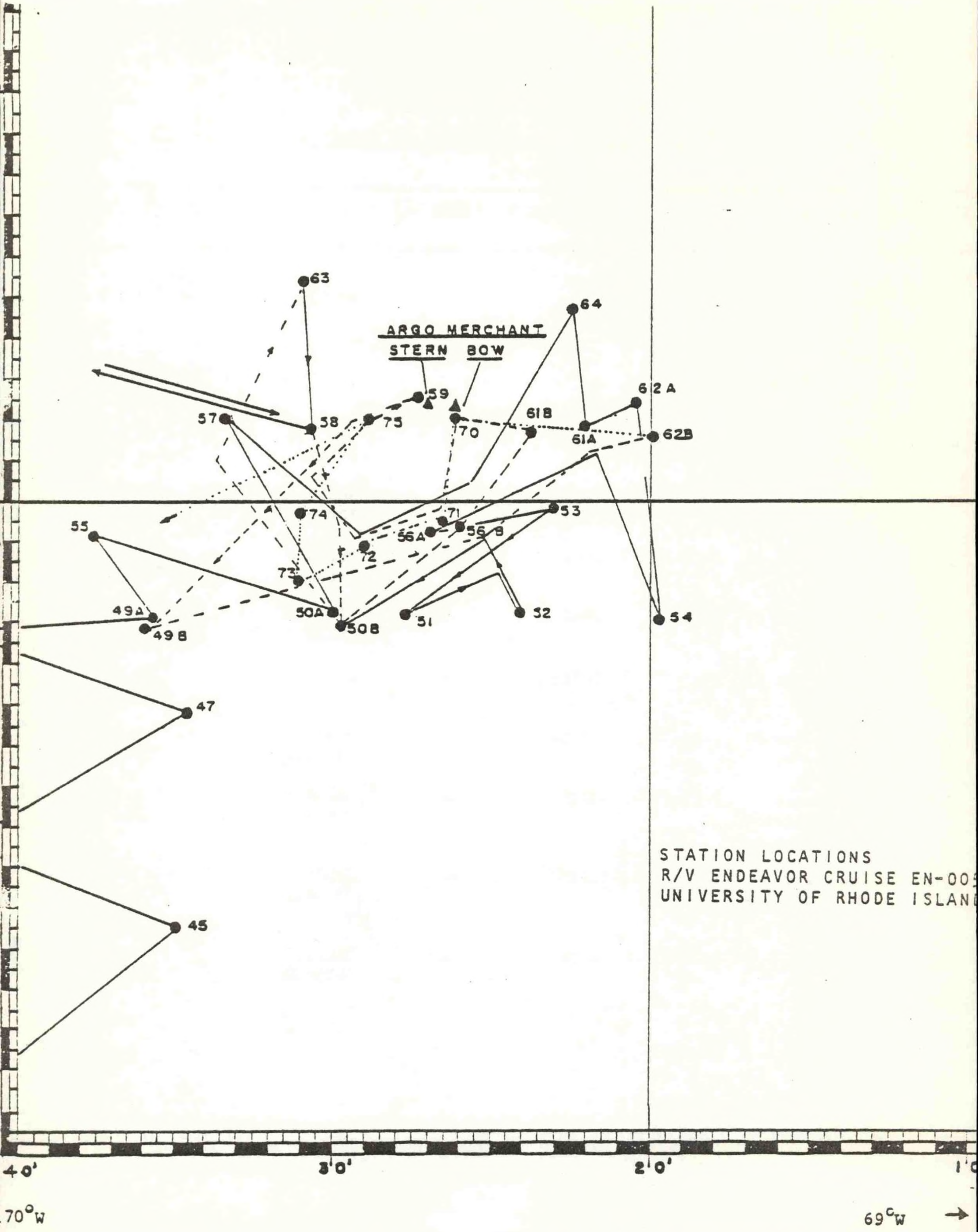
Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 71 | Bongo tow for McGill Start | 2-27-77 | 0017 | 44 | 37661.9<br>70105.1 | 40°59.5'N<br>69°26.7'W |
| 71 | Bongo tow for McGill End | 2-27-77 | 0019 | 44 | 37663.4<br>70105.6 | 40°59.5'N<br>69°26.8'W |
| 72 | Grab 1 | 2-27-77 | 0042 | 42 | 37686.0<br>70105.3 | 40°58.8'N<br>69°29.2'W |
| 72 | Scallop dredge start | 2-27-77 | 0059 | 42 | 37682.7<br>70104.7 | 40°59.0'N<br>69°29.0'W |
| 72 | Scallope dredge end (no sample) | 2-27-77 | 0117 | 42 | 37677.9<br>70104.3 | 40°59.1'N<br>69°28.7'W |
| 72 | Scallop dredge start | 2-27-77 | 0140 | 42 | 37680.4<br>70104.5 | 40°59.0'N<br>69°28.9'W |
| 72 | Scallop dredge end | 2-27-77 | 0200 | 42 | 37681.6<br>70104.7 | 40°59.0'N<br>69°29.0'W |
| 73 | Grab 1 | 2-27-77 | 0229 | 35 | 37707.7<br>70105.8 | 40°58.0'N<br>69°31.3'W |
| 73 | Bongo tow for McGill Start | 2-27-77 | 0233 | 33 | 37707.6<br>70105.5 | 40°58.0'N<br>69°31.3'W |
| 73 | Bongo tow for McGill End | 2-27-77 | 0236 | 33 | 37708.3<br>70105.3 | 40°58.0'N<br>69°31.6'W |
| 74 | Grab 1 | 2-27-77 | 0258 | 37 | 37695.3<br>70098.5 | 40°59.6'N<br>69°31.2'W |
| 74 | Scallop dredge start | 2-27-77 | 0320 | 37 | 37682.6<br>70095.0 | 41°00.6'N<br>69°30.6'W |
| 74 | Scallop dredge end | 2-27-77 | 0334 | 22 | 37677.1<br>70093.7 | 41°01.0'N<br>69°30.5'W |
| 75 | Grab 1 | 2-27-77 | 0359 | 31 | 37665.1<br>70091.5 | 41°02.0'N<br>69°29.0'W |

R/V ENDEAVOR CRUISE EN-005

Station Location and Information (Cont'd)

| STATION | SAMPLES | DATE (m-d-y) | TIME (local) | DEPTH (m) | LORAN C | LATITUDE/LONGITUDE |
|---|---|---|---|---|---|---|
| 75 | Bongo tow for McGill Start | 2-27-77 | 0407 | 31 | 37664.4<br>70090.5 | 41°02.2'N<br>69°29.0'W |
| 75 | Bongo tow for McGill End | 2-27-77 | 0410 | 31 | 37664.6<br>70090.9 | 41°02.1'N<br>69°29.0'W |
| E-1 | Bongo tow #1 Start | 2-27-77 | 0628 | 44 | 38033.0<br>70135.0 | 40°43.3'N<br>70°00.5'W |
| E-1 | Bongo tow #1 End | 2-27-77 | 0639 | 44 | 38030.0<br>70135.5 | 40°43.3'N<br>70°00.0'W |
| E-1 | Bongo tow #2 Start | 2-27-77 | 0644 | 42 | 38033.4<br>70135.8 | 40°43.0'N<br>70°00.0'W |
| E-1 | Bongo tow #2 End | 2-27-77 | 0648 | 42 | 38034.9<br>70135.6 | 40°43.0'N<br>70°00.3'W |
| E-1 | Bongo tow #3 Start | 2-27-77 | 0656 | 44 | 38038.4<br>70136.3 | 40°42.9'N<br>70°00.4'W |
| E-1 | Bongo tow #3 End | 2-27-77 | 0701 | 44 | 38040.8<br>70136.4 | 40°42.8'N<br>70°00.7'W |
| E-1 | Hargraves plankton tow Start | 2-27-77 | 0715 | 44 | 38038.9<br>70135.7 | 40°43.0'N<br>70°00.6'W |
| E-1 | Hargraves plankton tow End | 2-27-77 | 0730 | 44 | 38034.1<br>70136.1 | 40°43.0'N<br>70°00.2'W |
| E-1 | Grab 1 | 2-27-77 | 0734 | 44 | 38033.9<br>70136.0 | 40°43.0'N<br>70°00.2'W |




STATION LOCATIONS
R/V ENDEAVOR CRUISE EN-00
UNIVERSITY OF RHODE ISLAN

Graduate School of Oceanography
University of Rhode Island
Kingston, Rhode Island 02881

# CRUISE REPORT

## F/V SIDESHOW Cruise SS-001

Project: ARGO MERCHANT Oil Spill: Fate and Effects, Cruise 5.

Region of Investigation: Nantucket Shoals

Schedule: Depart Westport, MA 1930, 22 July 1977
Arrive Menemsha, MA 2230, 22 July 1977
Depart Menemsha, MA 1200, 23 July 1977
Arrive Westport, MA 2300, 24 July 1977

Funding: National Oceanic and Atmospheric Administration Agency
No. 03-7-022-35123

Scientific Party:

| | |
|---|---|
| Dr. Eva Hoffman | Chief Scientist, GSO/URI |
| Dr. Mr. Sheldon Pratt | Co-Investigator, GSO/URI |
| Dr. Robert Brown | Co-Investigator, Animal Pathology, URI |
| Mr. Keith Cooper | Graduate Student, Animal Pathology, URI |

Objectives of cruise:

1. Determination of extent of weathering of petroleum hydrocarbons from sediments around the ARGO MERCHANT wreck site (Hoffman).

2. Determination of the extent of transportation of contaminated sediments from the wreck site (Hoffman).

3. Collection of macrobenthos for histopathological studies and chemical analysis for comparison with similar samples collected in February (Brown and Cooper).

4. Collection of zooplankton in area for comparison with similar samples collected in February (Brown and Cooper).

5. Collection of sediment samples for archival and preservation for use in future meiobenthic studies. (Pratt)

Summary of research:

1. Collection of 36 Smith-McIntyre grab sediment samples for:

   a. archives for future biological studies (Pratt)
   b. hydrocarbon analyses (Hoffman)

2. Collection of six zooplankton samples for microscopic and chemical studies (Brown and Cooper).

3. Collection of macrobenthos at four locations for histopathological studies (Brown and Cooper).

F/V SIDESHOW Cruise SS-001

| Sta. | Sample | Date | Time (local) | Depth | Loran A | Latitude/ longitude |
|---|---|---|---|---|---|---|
| E-1 | Grab 1<br>Grab 2<br>Grab 3<br>Zooplankton tow | 7/23/77 | 1930 | 38 | 3H4-6150<br>1H3-3904 | 40°43.0'N<br>70°00.2'W |
| 47 | Grab 1<br>Grab 2<br>Grab 3<br>Grab 4<br>Zooplankton tow | 7/23/77 | 2345 | 38 | 3H4-1084<br>1H3-3794 | 40°53.8'N<br>69°35.8'W |
| 49 | Grab 1<br>Grab 2<br>Grab 3<br>Zooplankton tow | 7/24/77 | 0045 | 36 | 3H5-1068<br>1H7-2960 | 40°56.7'N<br>69°36.0'W |
| 50 | Grab 1<br>Grab 2<br>Grab 3<br>Zooplankton tow | 7/24/77 | 0215 | 38 | 1H7-2937<br>3H5-1060<br>1H3-3760 | 40°56.9'N<br>69°30.1'W |
| 72 | Grab 0<br>Grab 1<br>Grab 2<br>Zooplankton tow | 7/24/77 | 0310 | 40 | 3H5-1048<br>1H3-3742 | 40°59.2'N<br>69°27.7'W |
| 71 | Grab 1<br>Grab 2<br>Grab 3 | 7/24/77 | 0355 | 24 | 3H5-1046<br>1H3-3730 | 40°59.4'N<br>69°26.2'W |
| 61 | Grab 1<br>Grab 2<br>Grab 3<br>Zooplankton tow | 7/24/77 | 0450 | 37 | 1H7-2902<br>3H5-1037 | 41°01.5'N<br>69°24.3'W |

| Sta. | Sample | Date | Time (local) | Depth | Loran A | Latitude/ longitude |
|---|---|---|---|---|---|---|
| 70 | Grab 1<br>Grab 2<br>Grab 3 | 7/24/77 | 0545 | 18 | 1H3-3733<br>3H4-6370 | 41°02.0'N<br>69°26.8'W |
| 76 | Grab 1 | 7/24/77 | 0630 | 10 | 3H5-1037<br>1H3-3730 | 41°02.0'N<br>69°26.5'W |
| 76 | Grab 2 | 7/24/77 | 0700 | 9 | 3H5-1035<br>1H3-3733<br>3H4-6372 | 41°02.4'N<br>69°26.8'W |
| 76 | Grab 3 | 7/24/77 | 0730 | 11 | 3H5-1036<br>1H3-3739<br>3H4-6371 | 41°02.7'N<br>69°27.7'W |
| 59 | Grab 1<br>Grab 2<br>Grab 3<br>Slick sample | 7/24/77 | 0800 | 14 | 3H5-1035<br>1H3-3740<br>3H4-6371 | 41°02.5'N<br>69°27.8'W |
| 77 | Grab 1 | 7/24/77 | 0915 | 11 | 1H3-3737<br>3H4-6368 | 41°01.7'N<br>69°26.9'W |
| 77 | Grab 2 | 7/24/77 | 0925 | 13 | 1H3-3740<br>3H4-6340 | 41°01.2'N<br>69°27.7'W |
| 77 | Grab 3 | 7/24/77 | 0940 | 18 | 1H3-3745<br>3H4-6360 | 41°00.5'N<br>69°27.7'W |
| 78 | Grab 1 | 7/24/77 | 1015 | 13 | 1H7-2903<br>3H4-6380 | 41°03.5'N<br>69°26.3'W |
| 64 | Grab 1<br>Scallop dredge 1 | 7/24/77 | 1100 | 40 | 3H5-1026<br>1H3-3695<br>3H4-6383 | 41°04.6'N<br>69°22.4'W |
| D-2 | Scallop dredge 2 | 7/24/77 | 1130 | 38 | 3H5-1035<br>1H3-3720<br>3H4-6370 | 41°02.2'N<br>69°25.2'W |
| D-3 | Scallop dredge 3 | 7/24/77 | 1200 | 38 | 1H3-3730<br>3H4-6360 | 41°00.7'N<br>69°26.1'W |
| D-4 | Scallop dredge 4 | 7/24/77 | 1230 | 40 | 1H3-3743<br>3H5-1049<br>3H4-6347 | 40°59.0'N<br>69°27.8'W |