WATER POLLUTION PREVENTION AND CONTROL

OIL AND HAZARDOUS MATERIALS PROGRAM SERIES OHM 73-06-001

OIL SPILL, LONG ISLAND SOUND
MARCH 21, 1972
ENVIRONMENTAL EFFECTS

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PROGRAM OPERATIONS

OIL SPILL, LONG ISLAND SOUND
MARCH 21, 1972
ENVIRONMENTAL EFFECTS

FINAL REPORT

Division of Oil and Hazardous Materials
Office of Water Program Operations
Environmental Protection Agency
Washington, D.C. 20460

and

Region I
Environmental Protection Agency
Boston, Massachusetts 02203

Order No. 001
Contract No. 68-01-0044

January 1973

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $2.10

EPA Review Notice

This report has been reviewed by the Office of Water Programs, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

All spills of oil and hazardous materials have one thing in common -- their uniqueness. Each spill is different. The start of the chain of events leading to the cause of the spill can vary from a momentary lapse in human judgement to deliberate long term neglect of proper maintenance or prevention measures. The stress on the environment from a spill is also highly variable. The type of oil or hazardous material spilled, the weather and water movement patterns at the time of the spill, the shoreline geography and geology, the abundance and quality of biological activity, the effectiveness and timeliness of spill containment and cleanup, and quantity of pollutant spilled all play a key role in determining the resultant environmental impact.

This report is one of a continuing series of emergency response investigations by the Environmental Protection Agency into selected major spills. One of the principal objectives of this series by the EPA Division of Oil and Hazardous Materials is to develop a better understanding of the investigative tools and techniques available for assessing environmental damage and, from this understanding, be in an improved position for establishing environmental priorities in spill response and cleanup. These studies are not intended to be research and should not be compared to long term research projects. The investigations are specific in scope with emphasis on determining physical and biological effects and assessing the effectiveness of cleanup measures used in responding to the spill. This report of a major oil spill has been prepared by Vast, Inc., an EPA contractor, and includes the results of the contractor's surveys and analyses as well as information obtained by EPA, the State of Connecticut, and the U.S. Coast Guard.

Carl Eidam
Environmental Protection Agency
Region I
Boston, Massachusetts

Harold J. Snyder, Jr.
Environmental Protection Agency
Div. of Oil and Hazardous Materials
Office of Water Program Operations
Washington, D. C.

ABSTRACT

This study was principally undertaken to determine the effects of a No. 2 fuel oil spill on the benthic communities of Niantic Bay, on the Northern shore of Long Island Sound. Three benthic stations were chosen within the bay, and a control station was selected to the west of Black Point. Stations were analyzed for density and diversity of species as an indicator of stress. Sediments and selected biota were analyzed for fuel oil by gas chromatography. Results show that only the mid-bay station was definitely contaminated, which may have caused the loss of the amphipods. The hermit crab, *Pagurus*, may also be sensitive to the oil. Concentration of the pollutant in its tissues appears to make it a good indicator for low levels of residual oil. The bay was spared severe contamination by a storm which dissipated and weathered the oil. Ultimate disposition of residual oil was determined by the currents of the area rather than movement of the surface slick immediately following the spill.

CONTENTS

FIGURES

No.		Page

TABLES

SECTION I

CONCLUSIONS

(1) The effect of the Bartlett Reef oil spill on the Niantic Bay area was not one of immediate or total kill of the subtidal biota as occurred in the West Falmouth Spill (Blumer, 1972). Intertidal kill was confined to discrete areas of heavy contamination.

(2) The oil was apparently dispersed by the strong currents and short flushing times characteristic of the bay area. The current system scours the inshore areas of coarse sand and cobbles and forms a gyre, resulting in a depositional area of fine silt in mid-bay. Accumulation of oil at this mid-bay station was apparently by sediment transport.

(3) Heavy winds and seas which developed within three (3) days of the spill enhanced the weathering and dissolution of the oil.

(4) There was definitive chromatographic evidence of fuel oil in the sediments on only one station, Station B. This did not coincide with the visual reports of heavy contamination at Station A directly following the spill. However, at Station B, which was dominated by an infaunal soft-bottom community of worms and small bivalves intimately associated with the sediments, the expected amphipod component was missing. Amphipods are highly sensitive to petroleum pollutants and their absence supported the conclusion that this station was contaminated.

(5) There was no evidence of contamination of quahogs, lobsters, whelk or flounder from the Niantic Bay area, but hermit crabs apparently concentrated the fuel oil in their tissues and may be a good indicator of low levels of the pollutant.

(6) There was evidence for a hydrocarbon background in the sediments which was reflected in the animal tissues for each area. These background profiles differed between stations and were not wholly accounted for by biosynthetic processes. They could reflect earlier contamination or highly weathered remnants of this spill.

(7) There was no evidence of fuel oil at the beach stations sixteen (16) days after the spill. The beaches sampled were comprised of coarse sands and exposed to wave action.

(8) There were no indications for gross long-term effects from these results except for the loss of the amphipod community at Station B. The importance of the amphipod community would be difficult to quantify, as it includes their role in the breakdown of detritus and stabilization of sediments in addition to their being a food source for other invertebrates and fishes. A short-term study of this type does not assess possible reproductive damage to adults, loss of recruitment of new individuals through contamination of the substrate, or accumulation of hydrocarbons in the food chain. Any oil spilled in the area will contribute to a background of chronic hydrocarbon pollution. The gradual accumulation of small amounts of petroleum pollutants is potentially more hazardous than occasional large and spectacular spills because it can go unnoticed and eventually reach levels where it affects community structure and contaminates the food supply.

SECTION II

RECOMMENDATIONS

(1) Our best information for the assessment of the long-term effects of hydrocarbon pollution was derived from the chromatographic analyses and the study of density and diversity of sessile organisms. We therefore suggest that future field work be focussed on the benthic infaunal and epifaunal communities and that the pelagic components of water, plankton, and finfish be omitted.

(2) Based on the results of this study, further monitoring of the effects of this spill do not appear to be justified; however, since a hydrocarbon background of non-biogenetic origin appeared at all stations sampled, it is suggested that a library of background data be established for the Long Island Sound area. These data would provide a baseline for the study of future spills and would also indicate the level of contamination from other sources. Key stations for such a general survey should be coordinated to include the major current systems and major biotic communities.

SECTION III

INTRODUCTION

The Accident:

On 21 March 1972 the tanker F. L. Hayes, en route from Bayonne, New Jersey to Norwich, Connecticut, with a cargo of 596,757 gal. No. 2 fuel oil, grounded on Bartlett Reef in Long Island Sound at a position between Twotree Island Channel Buoy C1 and Bartlett Reef (Figs. 1 & 2). The grounding caused the rupture of her No. 1 port and starboard tanks and her No. 2 port tank causing an estimated 80,000 gal. of oil to be spilled.

The accident occurred at 0310 hrs. At 0345 the Coast Guard Station at New Haven was notified and by 0415 the Coast Guard commenced arrangements for a barge and tug to offload the vessel. By 0615 the tug Groton and the barge Seaboard Connecticut were dispatched to offload the tanker but could not get alongside due to the draft of the tug. They left a containment boom which was deployed by the Coast Guard at 0815 hrs but was ineffective due to the currents in the area. At 1220 hrs the tug Phoenix and the barge Poling Bros. No. 23 arrived on the scene and began offloading.

At 1418 the tanker was refloated on the high tide and anchored west of Bartlett Reef 3/4 - 1 mi north of the Bartlett Reef Light to complete offloading (Fig. 2).

By 2000 hrs with offloading completed, the tanker departed for Bayonne, New Jersey, and containment devices were removed from the area.

Purpose of the Study:

This short-term (3 1/2 months) field study was undertaken for the purpose of providing the EPA with information and assessment in the following categories:

1. Effectiveness of prevention and cleanup measures taken immediately after the accident to keep the damage to the environment at a minimum.
2. Evidence of immediate and acute damage to the biota of the affected area and indications for long-range effects.
3. Data on the fate and effects of an oil spill in a specific location under specific conditions for use

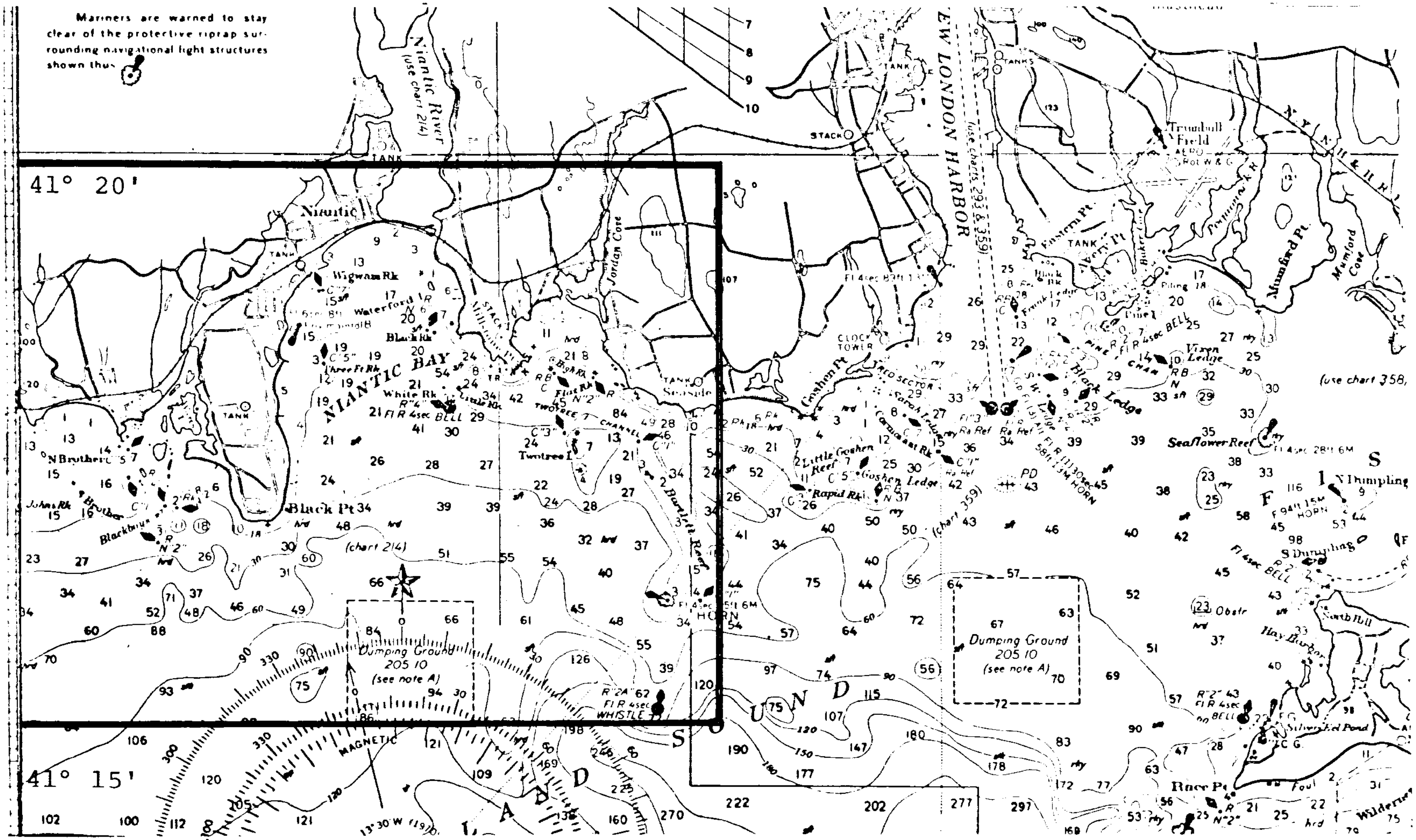


FIGURE 1
Area of the F. L. Hayes Oil Spill, Long Island Sound, 21 March 1972.

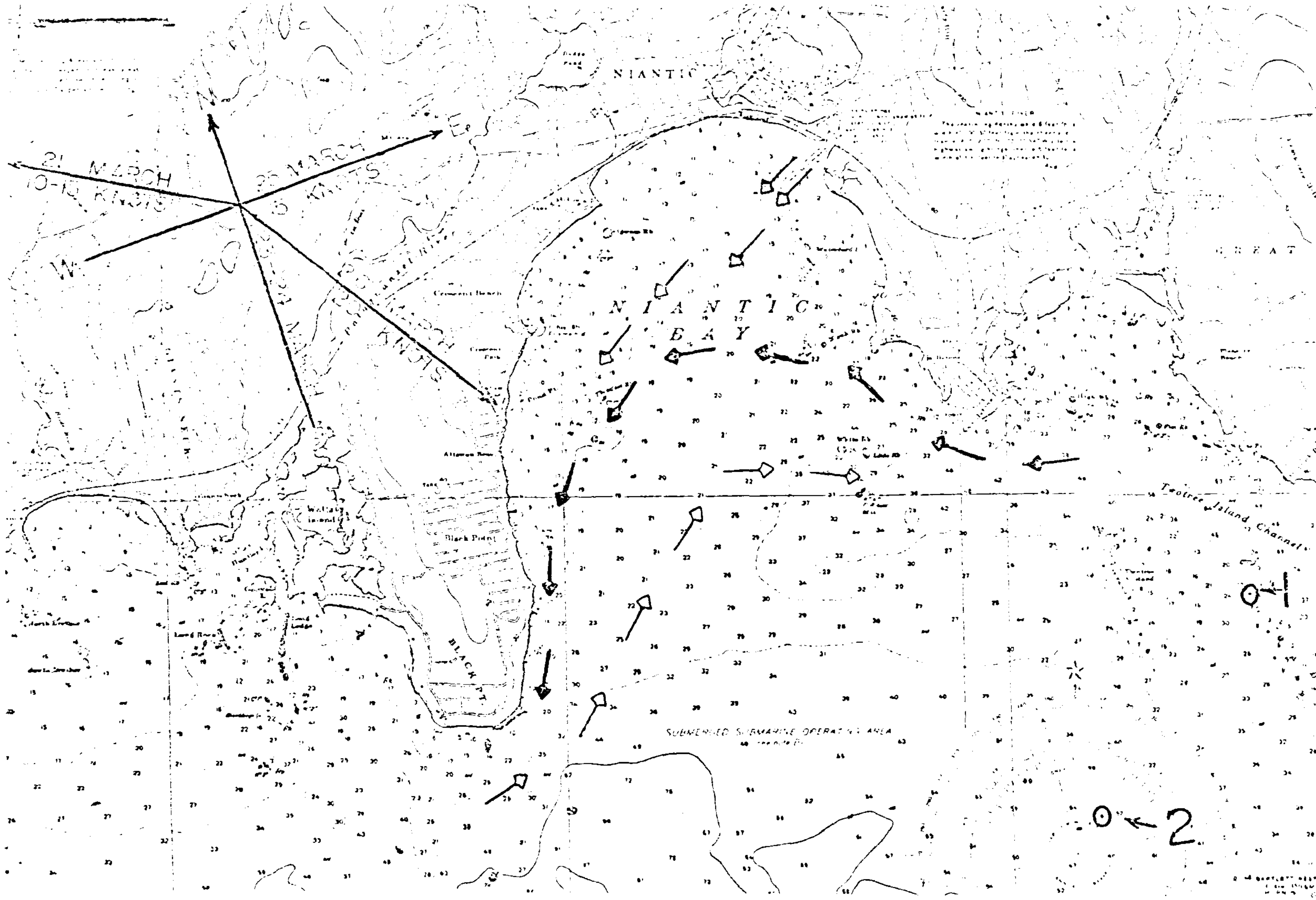


FIGURE 2

Positions of the F. L. Hayes (1) when grounded, (2) when anchored. Normal maximum intrusions on flood (solid arrows) and ebb (dashed arrows).

in the EPA's long-term program to develop a generalized predictive capacity for oil spills and their potential dangers under various conditions of weather, tidal currents and emergency response.

This survey was not intended as a comprehensive research effort on sublethal or long-term effects such as the loss of reproductive capacity in survivors of the spill or rendering of the substrate unsuitable for the recruitment of young stages.

Physical Oceanography of Niantic Bay and Adjacent Regions:

Niantic Bay is a coastal embayment on the northern shore of Long Island Sound. Fresh water enters Niantic Bay from the watershed of the Niantic River. The average fresh water runoff from this watershed is small and is on the order of 10 ft^3/sec, however, this runoff does affect the salinity distribution of Niantic Bay, especially during periods of high runoff in the spring and fall (Kollmeyer, 1971).

Salinity data collected during the surveys (Appendix, Table A-1) shows that the river water runs out along the western shore in a well-mixed layer extending to the bottom. At mid-bay the fresher water tends to be restricted to the surface layer with a more stable salt wedge below. On the eastern shore salinities are generally highest showing the least contribution from river flow with some stratification occurring.

Normal tidal currents off Millstone Point reach speeds in the east-west direction of 1.5 to 1.8 knots. Slack periods are of very short duration, on the order of 15-25 min at most. The flood tide enters Niantic Bay from the east through Two-tree Island Channel which separates Bartlett Reef from the Connecticut shore. Dye studies conducted in the region by VAST, Inc. for the Millstone Point Nuclear Power Station indicate that on a flood tide the currents dip into the bay and continue west past Black Point. When the currents reverse, the ebb also flows into the bay but to a lesser extent, bringing some of the same water which passed on the previous flood. Renewal rate estimates, based on dye and salinity studies and on tidal prism calculations, indicate that the renewal time for the water of Niantic Bay is on the order of 5-6 days. However, the magnitude of both the renewal rate and the tidal intrusions depend upon the strength of the wind such that severe weather conditions can be a more significant factor than the usual tidal processes.

The sediments in the nearshore areas in the outer portion of the bay (Fig. 3, A and C) are coarse sands, while a depositional bottom of fine silt occurs at mid-bay (B).

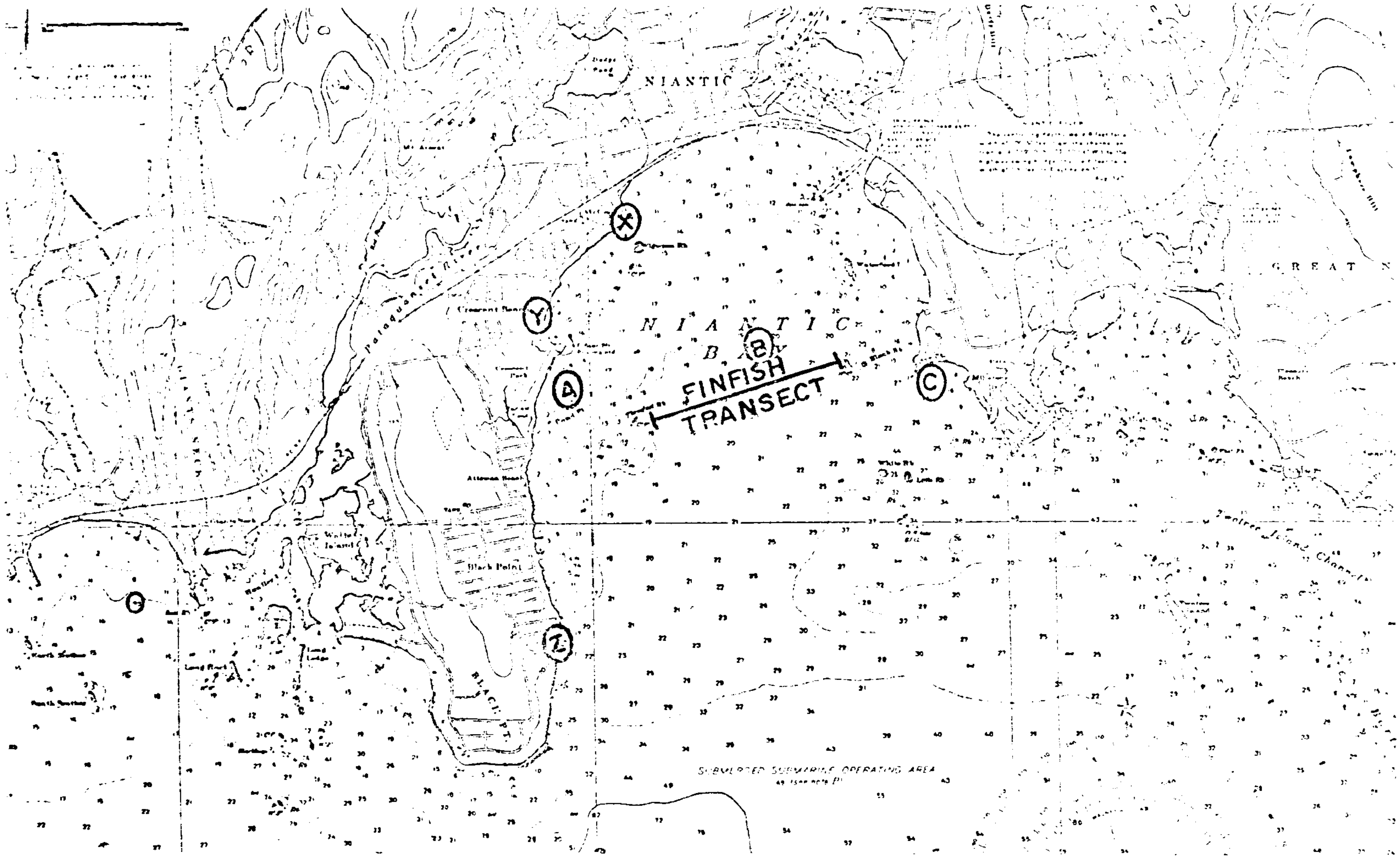


FIGURE 3
Location of Sampling Stations

Our divers reported that bottom sediments at A bore prominent east-west ripple marks 5-7 cm in amplitude and 20-30 cm in wave length, evidence that currents there were oriented north and south. Bottom currents at C also ran north and south, while those in the mid-bay area ran east and west.

Thus, the semicircular embayment at Niantic might be characterized somewhat as a gyre (Fig. 2). Currents were stronger close to shore and net transport greater there also, occurred in a counter-clockwise direction. While the flood waters tended to scour the bottom near shore well into the bay (solid arrows), the ebb did not intrude as deeply (dashed arrows).

Movement of Oil:

The tanker grounded on 21 March at 0258 hrs, approximately 1/2 hr after high slack water. Therefore, the oil was initially moved eastward, away from the Niantic Bay area for 5 1/2 hrs by the ebbing tide. Thus the first overflight revealed oil spreading eastward from the site of grounding to the northwest tip of Fishers Island and the Dumplings (Fig. 1). By afternoon, flood waters (high tide at 1420 hrs) brought the oil ashore in Connecticut with reports of oil 150 yds off the beach at Millstone Point. At 1450 hrs the Coast Guard reported that the slick covered an area of about 10 mi^2 (16 km^2). Residents of the Black Point and Attawan Beach areas and Connecticut State DEP observers reported heavy concentrations of oil along the western shore of Niantic Bay from Wigwam Rock to the southern tip of Black Point. Oil still remained to the east in the area of North Hill, Fishers Island, Black Ledge, and the Dumplings.

At 1522, during the second ebb, a flight over the Bartlett Reef region was made by VAST personnel, covering an area from Millstone Point to Trumbull Airport in Groton, Connecticut. The oil slick extended past the ship's containment device north through Twotree Island Channel into Niantic Bay. To the east of Bartlett Reef the slick widened, reaching the shore east of Goshen Point, and crossing the mouth of the Thames River where one band extended easterly to Trumbull Airport. A second band spread southeast to North Hill Point on Fishers Island. The wind at this time was from the east southeast.

On the third day (23 March 1972), visual surveys from the Connecticut River to the Pawcatuck River indicated that the western shore of Niantic Bay was the most severely affected area. The Niantic River was apparently free of oil as were public beaches other than the western bay beaches. On this day the wind picked up to 30-40 knots, gusting higher, from the south. Seas were 4-5 ft and there was intermittent rain. Adverse weather conditions severely limited containment operations but accelerated dispersal.

By Day 4 (24 March 1972) aerial, water, and land surveys indicated no new areas contaminated by spilled oil. Most visible oil on the waters of Long Island Sound had dispersed. Some fingers of oil remained in Fishers Island Sound. A film could still be seen on the western side of Niantic Bay and in the marshlands at Bakers Cove and Jupiter Point (Fig. 1). Water samples collected by the Coast Guard in Fishers Island Sound and in the area between the Thames River and Pataguanset River showed no visible evidence of oil.

Inspection of the Jupiter Point Marsh by VAST personnel on the same day indicated oil upwelling from the grass mat as it was flooded by waves. There was accumulation of oil on the lee side with several highly iridescent patches along the eastern shore. To the east of Niantic Bay observations in Watts Island marsh revealed an oily scum on the surface of marsh creeks and pools behind the protective beach. Oil had collected to a greater extent in the sheltered rock pools at the western end of this beach. Black Point was clear except for a slick along the eastern shore extending out off the point.

On Day 5 (25 March 1972), VAST personnel inspected the Watts Island and Jupiter Point marshes. Although some oil was collected in the tide pools of the breakwater south of Watts Island, there was no visible oil along the beach edge or in the marsh area. At Jupiter Point, however, oil was concentrated along the edges of the point and in the seaweeds and grasses.

By Day 6 (26 March 1972), there was no evidence of oil in the open waters of Long Island Sound or Fishers Island Sound except a slick in western Niantic Bay off Crescent Beach. The wind on this day was NW at 20 knots with seas NW of about 1 ft. VAST personnel observed no visible oil on the water surface at Trumbull Airport, but the marsh smelled of oil.

On Day 7 (27 March) and Day 12 (3 April), aerial reconnaissance revealed no evidence of oil in open waters of the area with the exception of the small slick in western Niantic Bay, a light sheen in the marsh areas behind Crescent Beach and another light sheen leaching from the kelp at Jupiter Point.

The evidence over the twelve (12) days following the spill thus indicated that heavy visual concentrations of oil occurred during the first three (3) days on the western shore of Niantic Bay, on North Point in Fishers Island, and in the marshes at Jupiter Point. Heavy winds and seas on Day 3 dispersed the main slick. The only major visual evidence remaining after the storm occurred off marshy areas or areas of heavy seaweed, indicating a leaching effect.

Federal and Local Response:

On 21 March 1972 the Coast Guard was notified of the grounding of the F. L. Hayes at 0345 hrs. The Coast Guard immediately notified officials at the Spentonbush Fuel Transportation Company, dispatchers of the tanker, activated a tug and barge, and monitored offloading of the tanker.

At 1400 hrs the Regional Response Team (RRT) was activated for the purpose of coordinating control and cleanup activities for the oil spill. The RRT consisted of EPA and the US Coast Guard and was assisted by the Connecticut State Department of Environmental Protection.

On Day 2 (22 March 1972), the RRT met with the port captain, the legal counsel, and the port engineer of the Spentonbush Fuel Transportation Company. The EPA activated VAST Inc.'s contract to study the effects of spilled oil on bottom organisms in Niantic Bay, and remained in the area until 3 April 1972 coordinating cleanup and reconnaissance activities. The EPA put two reconnaissance teams in the field, one on Fishers Island one on the Connecticut shoreline. The State of Connecticut responded with wildlife, shellfish, and sportfisheries representatives to assess the immediate damage to shorelines and biota.

Containment and Cleanup Operations:

The first ship's boom was deployed at 0815 hrs on 21 March 1972, 5 hrs after initiation of the spill. It was apparently ineffective in containing the oil due to currents in the area of the reef. After removal of the ship to an area west of Bartlett Reef, booms were still ineffective although seas were relatively calm.

On Day 2 (22 March 1972) the tanker departed and all containment gear was removed. At 1230 hrs on 23 March 1972 a boom was placed across the entrance to the Niantic River and adsorbing booms were deployed by NEPCO to beach areas near Black Point. The complete closing of the river appears to have been effective, as no oil was reported beyond the boomed area. The booms along the beach area were much less effective in the intertidal areas where wave action was high. The adverse weather conditions on this date severely limited the containment and removal operations in contaminated areas.

On 24 March 1972 NEPCO deployed adsorbent booms and bags in the Niantic Bay and Bakers Cove areas, and on 25 March, 150 modified sea serpent logs were placed on the public beach in Niantic. Cleanup of the oil in marshlands behind Crescent Beach was started using both adsorbents and a vacuum haul. Eight boats swept western Niantic Bay with adsorbent logs. Twenty-five (25) sea serpents were added to contain the leaching oil at Jupiter Point and the marshland on the west side of Bakers Cove, bringing the number of logs to one hundred (100) then in place. One hundred (100) adsorbent pillows were also used. Five (5) boats continued to sweep Niantic Bay until 26 March 1972 when the Niantic River was reopened to traffic and sweeping operations were discontinued.

Cleanup continued on the beaches along the western shore of Niantic Bay and at Jupiter Point. Adsorbent material was deployed in the marsh at Niantic and hand-skimmed on 3 April 1972. By 3 April, operations were reduced to minor cleanup as patches of oil were sighted.

Immediate Effects on Biota:

Some effects were observed on intertidal life within the first 3-5 days after the accident. EPA reconnaissance teams reported heavy intertidal mortalities of polychaetes, snails and amphipods at North Point on Fishers Island, an area heavily contaminated with oil. Four other areas on Fishers Island showed either light contamination or no oil, and the intertidal life was reported normal. Subsequent chromatographic analyses performed by the EPA laboratory in Needham, Massachusetts confirmed the presence of No. 2 fuel oil from the F. L. Hayes in the water and intertidal seaweeds at North Point, but water from the Coast Guard Station on the island remained clean.

In the Jupiter Point - Bakers Cove area, dead or distressed polychaetes and amphipods were found in heavy oil contamination. Along the edge of the marsh the *Fucus* was oil-coated and dead. Spawning polychaetes *(Nereis virens)* were observed washing ashore, and small fish, amphipods and shrimp were found dead or dying at the mouth of the Poquonnock River. Again, EPA analyses confirmed the presence of oil in the intertidal sediments at Avery Point and the Poquonnock River area, in seaweeds and mussels at Avery Point, and in mussels from the Poquonnock River. However, they did not find the oil in water samples from these areas.

In the Niantic Bay area, a few clams and 5-6 small lobsters were reported to be washed ashore on the western side of the bay. This could have been a normal effect of the storm. Spawning *Nereis* in dead or moribund condition came ashore on the beach at Black Point, but there was no visible effect on intertidal biota in the Black Point area. Oil was found by chromatographic analyses in the water and intertidal sediments at Black Point and Crescent Beach, but not in those of the Watts Island marsh. Clams from Black Point and Crescent Beach were contaminated but clams and mussels from the Watts Island marsh were not. Both snails and water from the Niantic River Bridge were free of oil. A diving survey of subtidal life by VAST personnel at Bay Point in the Niantic Bay area revealed a well-diversified community with no immediate visible effects from the oil.

All samples taken by the EPA for chromatographic analysis were from intertidal areas within three (3) days after the spill. They were compared with control samples of oysters from Bridgeport and Great Island which were found uncontaminated.

On 3 April VAST personnel responded to a report of lobster mortality at Bob's Fish Market in Niantic. Samples of dead lobsters were autopsied and analysed for *Gaffya homari* virus. No gross abnormalities were found, and other fish markets were checked for mortalities with negative results.

It was later learned that the dead lobsters had been subjected to detergents spilled into the hold in the lobster boat.

On 23 March 1972, state wildlife and conservation officers discovered twenty-five (25) waterfowl dead or oil contaminated. A bird-cleaning station was established. On 24 March a total of twenty-eight (28) dead birds was reported (assumed cumulative total).

Thus, it appears that the immediate effects of the oil on beaches and biota were limited to small areas of heavy oil concentration within the first three days of the spill. Potentially greater damage appears to have been mitigated by the strong tidal currents of the region and the fortuitous circumstances of the storm on 23 March which broke up the heavy concentrations of oil.

The problem remained, however, to determine whether there were further effects on the area. The main thrust of this study by VAST was to determine whether the oil affected the subtidal communities of the Niantic Bay area.

The method employed was a study of the benthic organisms using the features of density and diversity to determine whether a major stress was affecting the area. Samples of sediments and key organisms were analyzed by gas chromatography to determine whether such stress could be caused by the presence of No. 2 fuel oil.

METHODS

Field Methods:

The field surveys were designed to measure possible continuing effects of No. 2 fuel oil on the local marine organisms. Six surveys were conducted according to the following schedule:

Survey I	April 1-7, 1972
Survey II	April 13-18, 1972
Survey III	May 16-22, 1972
Survey IV	June 4-13, 1972
Survey V	June 26-28, 1972
Survey VI	July 12-17, 1972

Samples were taken of the benthos, epibenthos and water column from three prime stations in Niantic Bay. A fourth prime station was established as a control to the west of Black Point. These stations were sampled in six field surveys spaced approximately two weeks apart from April to July, 1972. All samples were collected in duplicate and labelled and logged in the field, initialled by two investigators, and stored on ice for return to the laboratory.

A chain of custody procedure was followed such that each sample contained its survey number in Roman numerals (I-VI) and a sample number in Arabic numbers. When subsamples were drawn they received the entire complement of foregoing numbers and letters, and an additional digit indicating the subsample number. All original labels were filed. Example: A label bearing I-3-A-2 would indicate that it came from Survey I, sample 3, and had undergone two subsampling procedures, one in which it was designated subsample A of Sample 3, and one in which it was designated subsample 2 of subsample A. Upon return from the field, biological samples were frozen. Water and sediment samples were refrigerated in the dark at 4°C.

Glass bottles were used for all water and sediment samples and were cleaned according to procedures designated by the Edison Laboratory. New bottles were first washed with detergent, and rinsed in steam distilled water (APHA spec.). The bottles were rinsed sequentially with acetone, methanol and pentane (all nanograde), dried and capped. Bottles that were reused in subsequent field trips were washed with distilled water and flushed with pentane (nanograde).

Prime Stations:

Water samples were taken by divers from just beneath the surface and from middepth. On the first, third and sixth surveys, samples of bottom water were also taken. Chemically clean and capped amber bottles were taken to the desired depth, uncapped to obtain an uncontaminated sample, then capped for return to the surface. On deck the cap was lined with aluminum foil. Use of divers instead of Van Dorn bottles to collect water samples proved highly satisfactory. Interdepth contamination of the open, descending Van Dorn bottle was avoided as well as the necessity for development of both laboratory and on board methods for cleaning the Van Dorn sampler. Temperature measurements at the surface and bottom were made by boat crew and divers respectively using a mercury thermometer.

Epibenthic sampling was initially attempted using a modified scallop dredge towed over a measured transect. The dredge failed to capture small shrimp and amphipods even when lined with a small mesh bag; and it was difficult to determine actual fishing time on the bottom. For the second survey, a small epibenthic sled was substituted for the scallop dredge and was deployed by a diver on the end of a 50-meter line and carried to the bottom. As the boat crew hauled in the dredge, a diver followed to assess its trapping powers. Although better than the scallop dredge, this sled missed many of the animals. By the third survey, a method was developed whereby a hand-held sampling net, attached to a rigid frame, was carried by a diver along a representative transect of the bottom. The 1 mm net, 50 cm wide x 20 cm high, was pushed over the bottom at approximately 1/2 knot for one minute upcurrent and 1 minute downcurrent. The mouth of the net was closed at the end of the transect and contents brought to the surface. This method yielded satisfactory quantitative and qualitative results and was adopted for the remaining surveys. Only results from the final method were used for the quantitative comparisons.

Four benthic samples were taken by divers from each station. The area was measured off with a meter stick (30 cm x 30 cm x 10-15 cm) and the sediment and infauna scooped into a plastic bag. Two samples were taken at each prime station for the first two surveys. They contained so few organisms that four samples were taken at each station on subsequent surveys.

Photographs were taken of the bottom communities and a diver survey collection of prominent fauna and flora was made to supplement the epibenthic sample.

Finfish were sampled by making three separate traverses of the Niantic Bay transect with a 3-foot otter trawl. Counts of individuals and volume displacements were made for each species. Samples of the winter flounder were retained for gas chromatographic analysis.

Beach Stations:

Three beach stations were established along the western shore of Niantic Bay and sampled at each of the six (6) field surveys. Samples of sand were collected at 10 cm increments to a depth of 30 cm. Each sample was placed in a chemically clean, labelled, glass bottle and capped with aluminum foil under the lid. Samples were collected at both the high and the low tide line at each of the three stations.

Laboratory Methods:

Benthic and epibenthic samples were analyzed for species diversity and numbers of individuals per square meter of bottom. Representative samples of each species were analyzed for dry weight per unit, wet weight or per unit volume to provide a conversion factor for relating laboratory results to field concentrations.

Benthic organisms were separated by screening the samples using fresh water. Unscreened subsamples of the sediment from each station were refrigerated for chemical analyses. The screened fractions were frozen until sorting when the organisms were counted, speciated, and preserved in 5% Formalin.

Individual animals were identified to the species level wherever possible. The worms from the screened samples were often in poor condition from the processing, but frequently could be matched to good specimens at least to the level of the genus. The amphipods are known for identification problems. We, therefore, followed the precedent of Sanders (1956) and identified type specimens by letter, accepting the possibility that we might lump closely allied congeners. Hopefully, since all stations were treated alike, and since we used the same investigator for all amphipod identification, we have a fair comparative appraisal between stations. Type samples have been saved for all specimens.

Epibenthic organisms were handled by the same method as the benthic samples except that aliquots of the original samples were used for determining the numbers and diversity for the smaller organisms. Diver survey samples were speciated and recorded qualitatively as simply the presence or absence of species at a given station over time.

The original plan called for chromatographic analysis of plankton. Plankton hauls were made, but their processing was deferred on the recommendation of WHOI to provide time for a more thorough analysis of the benthic samples. Blumer et al (1972) advocates the close correlation of benthic infauna with hydrocarbon pollution. Since the sediments act as a sink for the pollutant, the continuing impact of an oil spill to an area can best be measured by its effect on the sessile infauna rather than on pelagic members of the community.

Chemical Methods:

The analytical methods used to determine the presence of No. 2 fuel oil were those developed at Woods Hole Oceanographic Institute, (Blumer, 1970). At the beginning of the program, a visit was made to Dr. John Farrington and Dr. Max Blumer at Woods Hole to try to implement the latest developments in the chemical procedure. Additional visits were made during the program to refine our procedures and evaluate our technique.

For the extraction of total lipid components, samples of benthic and beach sediments weighing approximately 200 gm were placed directly in Soxhlet thimbles. Shellfish were shucked and the animal plus its fluids were homogenized in a commercial blender before placement in a thimble. Whole finfish were also homogenized and a portion of the homogenate analyzed. Wet weights were taken, then the samples were Soxhlet-extracted for a minimum of 20 hrs with redistilled, reagent-grade, anhydrous methanol. The extracted thimbles were dried at 110°C overnight and reweighed to obtain the dry weight of the sample. The lipid portion in the methanol extract was filtered to remove solids, and the filters were washed three times with pentane. The methanol extracts were transferred to separatory funnels, where the lipids were extracted with four treatments of 50 ml pentane. Aqueous solutions of NaCl were added to enhance separation of pentane from the methanol. The pentane extracts were dried with anhydrous Na_2SO_4 that had previously been Soxhlet-extracted for 20 hrs in methanol. The pentane was evaporated from the lipid extract on a rotary evaporator under vacuum, and the weight of the residue was recorded as total lipid content of the samples.

The extracted lipids were re-dissolved in a minimum volume of pentane. Hydrocarbons were separated from the remaining lipid fraction by column chromatography. The column, packed in pentane, consisted of three parts silica gel (Davison Grade 923, 100-200 mesh) and two parts alumina (Matheson, Coleman and Bell Chromatographic Grades 80-200 mesh). The silica gel was activated at 120°C and the alumina, at 250°C, then both were deactivated by addition of 5% by weight of water. The silica gel was packed in a lower layer with the alumina over it. The columns were washed with pentane, and the eluate was passed through a column packed with precipitated copper to remove sulfur.

The hydrocarbon residue from the column chromatography was evaporated to dryness under vacuum then taken up in 100 μl of CS_2 for gas chromatography. A Varian Aerograph 2860 Gas Chromatograph with linear temperature programmer and a 1 mv recorder was used. The columns used were ten-foot, eighth-inch outside diameter, packed with three percent Apiezon L in chromosorb W, 80 to 100 mesh, acid washed. The column was cooled to 80°C for injection then programmed for a rise from 80°C to 290°C at 6°C/min. The temperature at the detector was 320°C, that at the injection port was 230°C.

In order to evaluate our laboratory procedure, we weighed samples of No. 2 fuel oil and carried them through our entire laboratory procedure. We found no weathering or loss of fingerprint. We also ran reagent blanks through the entire procedure and found no contamination. Our recovery rate of fuel oil hydrocarbons was 53%. This recovery rate, related to the size of original sample, the concentration of the final sample and the chromatogram of our control sample, indicated that a strong fuel oil fingerprint would have been seen if concentrations at least as low as 1.58 mg fuel oil/100 gm dry weight of sediment samples.

Discussion of Field Results:

The locations of our Prime Stations are given in Figure 3. Sediment profiles of subtidal stations A, B, C, and the control station are given in Figures 4 through 7. Stations A and C were roughly comparable, being composed of coarse sand and cobbles, while Station B and the Control Station were similar in having soft bottoms of fine silt. The general type and location descriptions are summarized in Table 1.

Control Station (Fig. 8):

This station, located in 5 meters of water, sustained tidal currents of about 1 knot in a NW-SE direction. Its bottom was mud with a high silt fraction. There were irregular depression areas (1-2 meters dia.) with a hard, compact surface. Patch areas over this hard bottom consisted of soft, non-compacted silt, 15-20 cm deep, deposited between numerous amphipod cases and polychaete tubes. Assorted detritus and crustacean casts were accumulated at the banks and in the depressions between these elevated, soft patches. Amphipod cases became more exposed and less inflated later in the spring.

Station A - Crescent Beach (Fig. 9):

This station was located in 3 meters of water. The bottom type comprised coarse sand with prominent east-west ripple zones (5-7 cm amplitude and 20-30 cm wave length). It was a comparatively unstable bottom. Shoreward were deposits of cobble (10-15 cm diameter) with coarse sand interspaced. The sand became highly compacted at 5-7 cm depth and contained abundant shell fragments.

Station B - Mid-Bay (Fig. 10):

This station was located in 6.5 - 7.5 meters of water with a 1 - 1.5 knot tidal current running in an east-west orientation. The bottom was a flat, featureless, mud-silt depositional basin, similar to the Control Station. An algal film covered the entire bottom during the first three (3) months of the survey (March - May). The algal film disappeared later in the spring.

TABLE 1

DESCRIPTION OF PRIME STATIONS

CONTROL	LOCATION:	Lat. 41°17'41" Long. 72°14'00"
	DEPTH:	5 m MLW
	SALINITY:	26.5-28 ppt
	SUBSTRATE:	Fine mud and hardpacked sand, Uneven bottom with mud banks approximately five inches high with shell fragments, many amphipod tubes, *Diopatra* tubes.
STATION A	LOCATION:	Lat. 41°18'34" Long. 72°13'58"
	DEPTH:	3 meters MLW
	SALINITY:	27.0-27.5 ppt
	SUBSTRATE:	Coarse sand with shell fragments, large and small cobbles with boulders; *Diopatra* cases.
STATION B	LOCATION:	Lat. 41°18'34" Long. 72°11'13"
	DEPTH:	7 meters MLW
	SALINITY:	26.5-28 ppt
	SUBSTRATE:	Mud, amphipod tubes, worm cases, small shell fragments.
STATION C	LOCATION:	Lat. 41°18'34" Long. 72°10'30"
	DEPTH:	6 meters MLW
	SALINITY:	27-28 ppt
	SUBSTRATE:	Mud and sand with rocks; shell fragments, *Diopatra* cases.

FIGURE 4

Benthic Sediment Profiles (gm retained per 100 gm of sample)

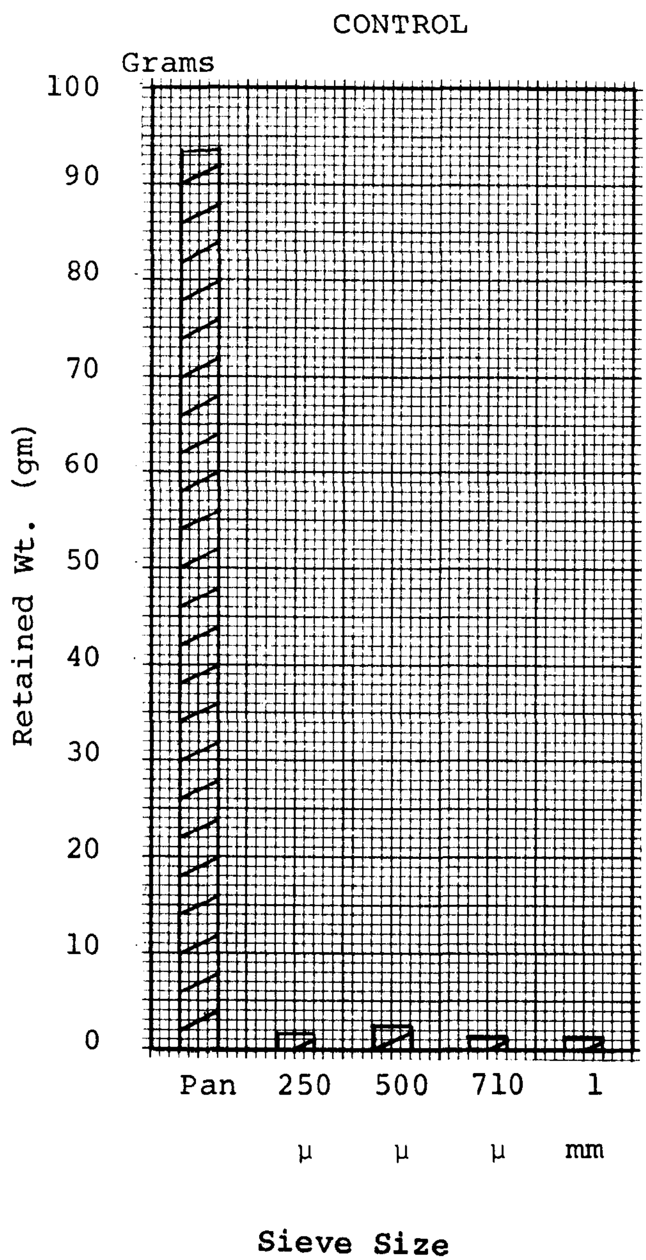


FIGURE 5

Benthic Sediment Profiles (gm retained per 100 gm of sample)

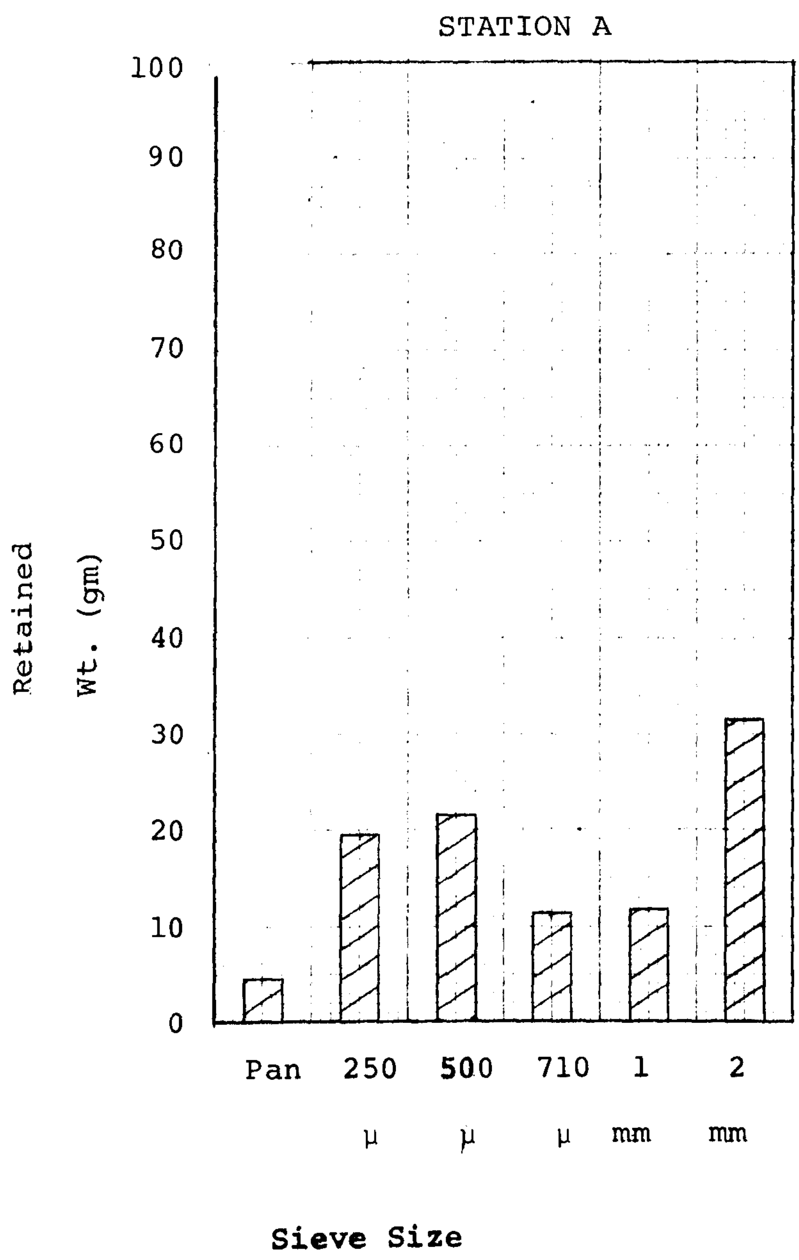


FIGURE 6

Benthic Sediment Profiles (gm retained per 100 gm of sample)

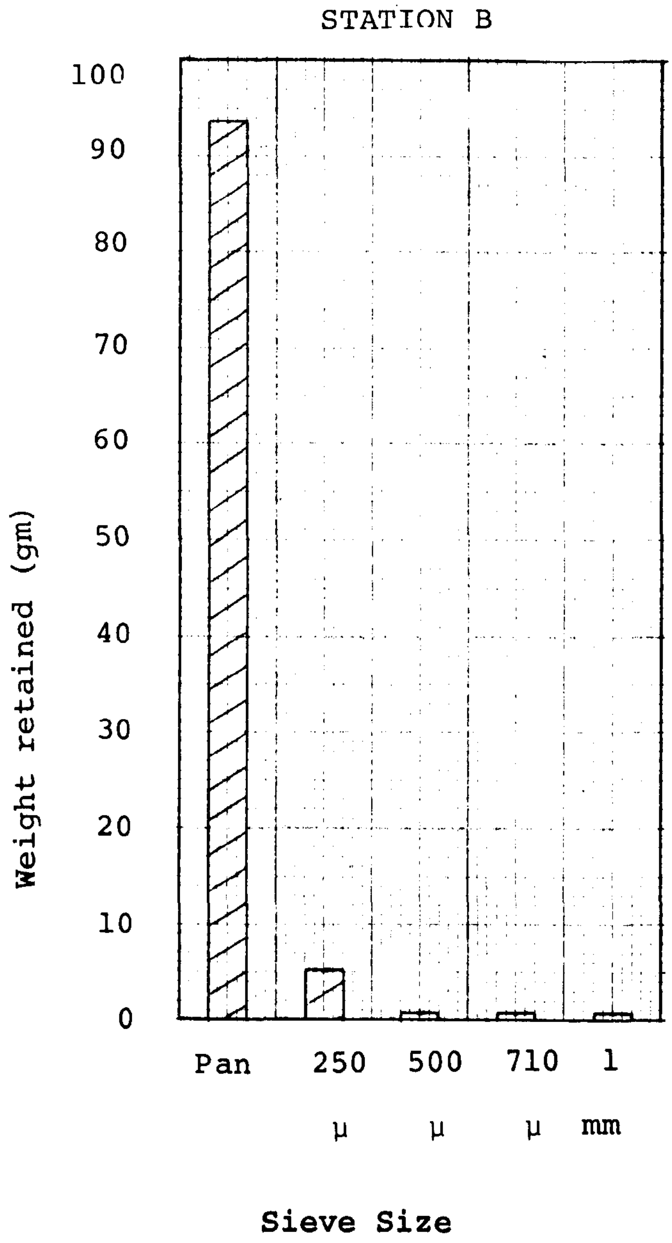
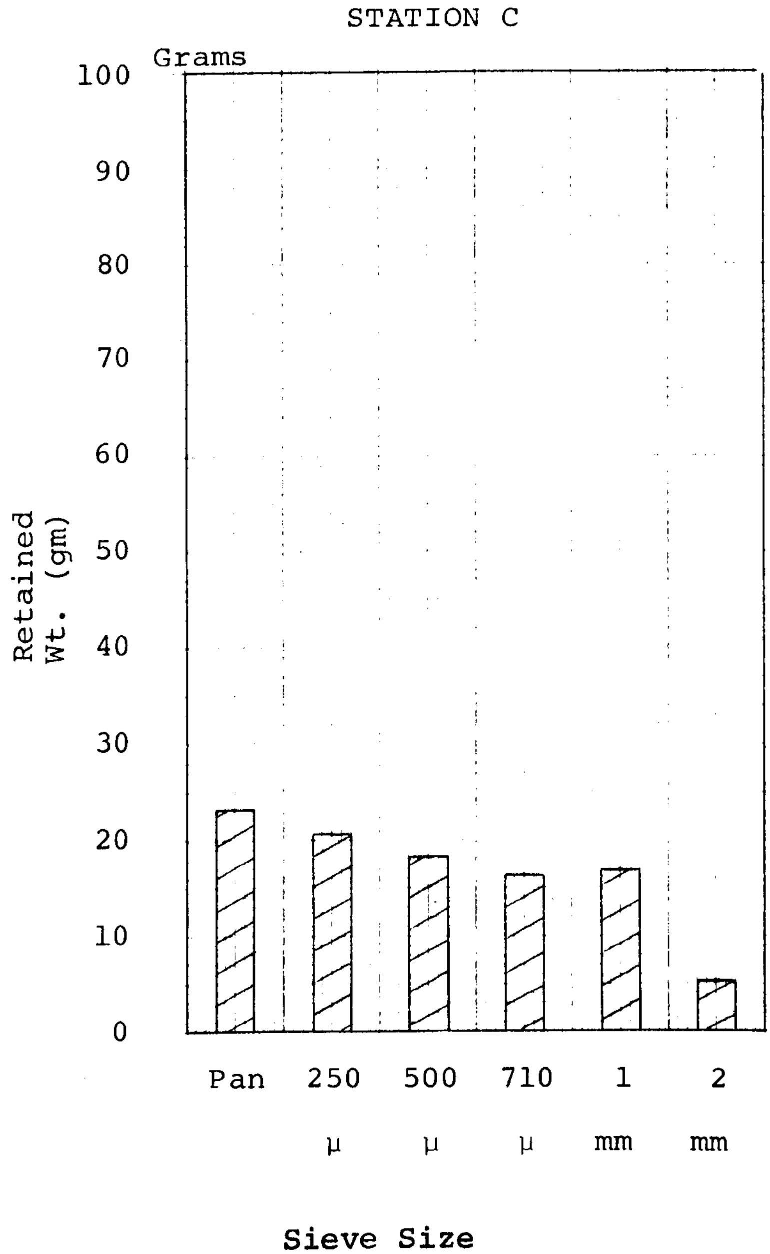
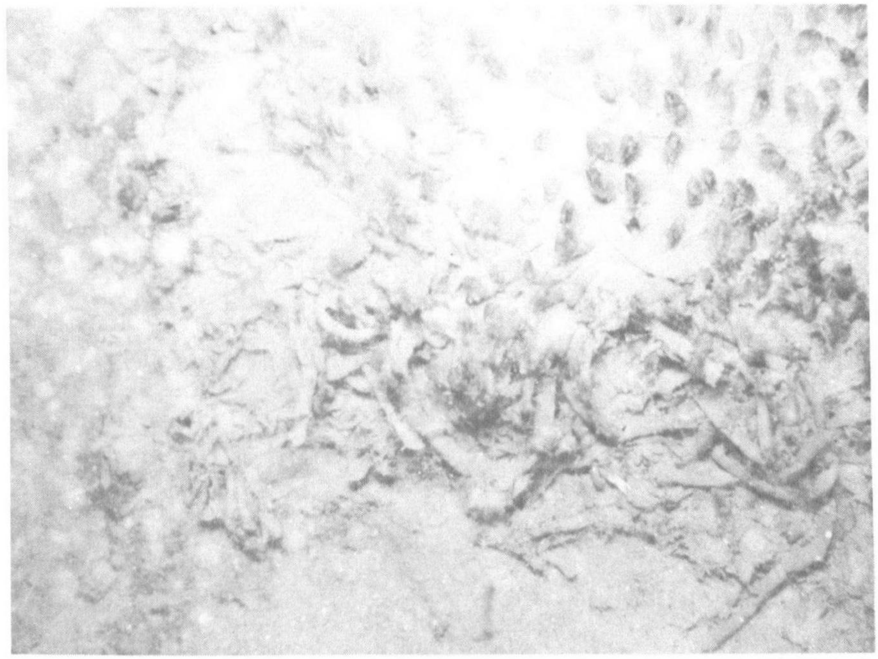


FIGURE 7

Benthic Sediment Profiles (gm retained per 100 gm of sample)



A



B

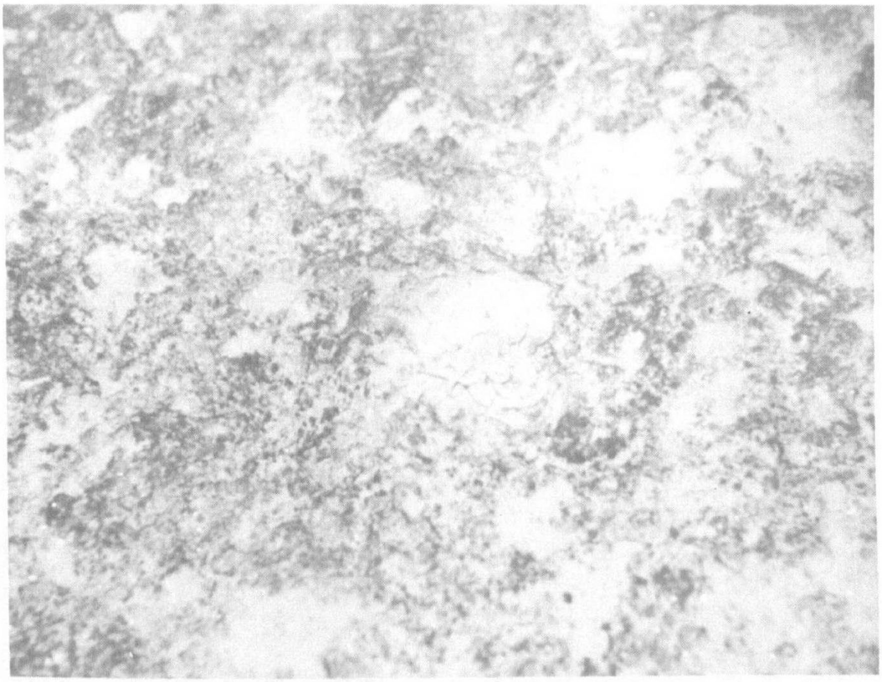
FIGURE 8

A. Control (April) - Edge of Silt and Amphipod Patch Area
B. Control (June)-Silt & Amphipod Patch Area, later in the season-- silt has been eroded away from tubes.

FIGURE 9

Station A - Benthos (June) Coarse Sand and Shell Fragments

A



B

FIGURE 10
A. Station B - Benthos (April) Algal Mat Covering Fine Silt
B. Station B - Benthos (June) Worm Tubes and Fine Silt, Algal Mat has Disappeared.

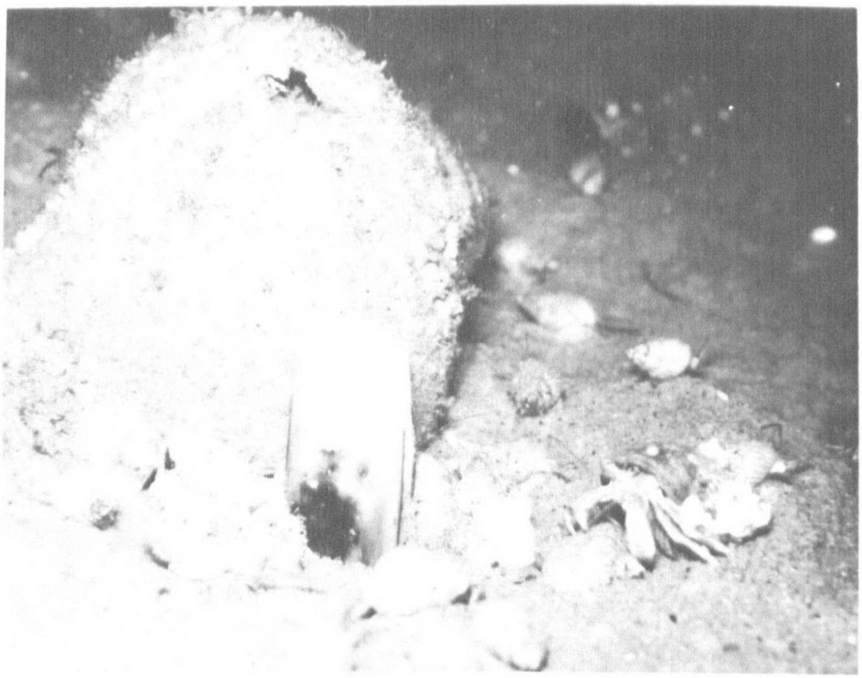


FIGURE 11

Station C - Benthos (June) Coarse Sand and Shell Fragments with *Nassarius* and *Pagurus*.

Station C - Bay Point Area (Fig. 11):

This station was located in 6.5 - 7.5 meters of water with a 1-2 knot north-south current. The bottom featured rock outcroppings from the shore with adjacent boulder and gravel glacial till. Coarse sand graded toward the mud-silt bottom proceeding east to west into Niantic Bay. The poorly sorted sediments contained all fractions of gravel, sand and silt.

Benthic Infaunal Communities:

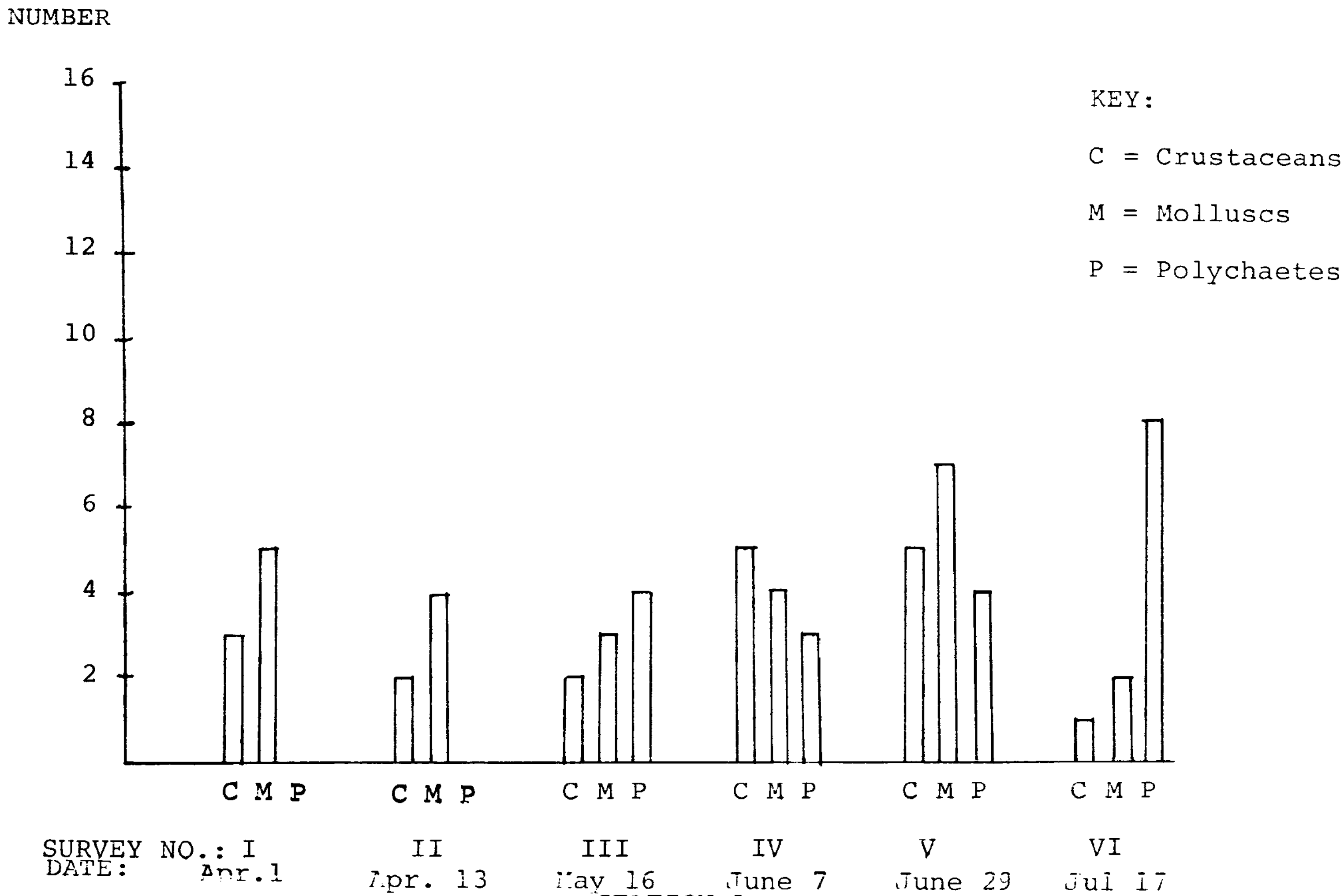
The major effort of our biological investigation was to couple surveys of species density and diversity with chemical analysis for the presence of oil in the sediments and in significant members of the biological community. Blumer and Sass (1972) and Sanders et al. (1972), who have recently completed concurrent biological and chemical studies of the West Falmouth Oil Spill, have demonstrated the power of such complementary efforts, 1) for assessing both short and long term effects of stress, and (2) for establishing causality between the oil and those effects, using sessile bottom animals which are closely associated with the sediments and cannot escape the contaminant.

The numbers of organisms present as infauna per unit area for each station were summed in terms of both species and phylogenetic groupings. The raw data are tabulated in the Appendix, Tables A-2 through A-5. Summary histograms for species diversity at the stations are given in Figures 12 through 15. These histograms show a small general increase in total numbers of species present at all stations but no consistent trends within the phylogenetic groupings of crustaceans, molluscs and polychaetes. Some increase would be expected as the water warmed between Survey I (March) and Survey VI (July).

Summary histograms for numbers of individual animals at each station are given in Figures 16 through 19.

Despite the large variability among stations at a single survey and between surveys at a single station, certain trends were evident. There was a general increase over time in total numbers of individuals of all phylogenetic groups except at Station A. Such increases would be expected as the water warmed with the normal seasonal advance.

BENTHIC SAMPLES - SPECIES

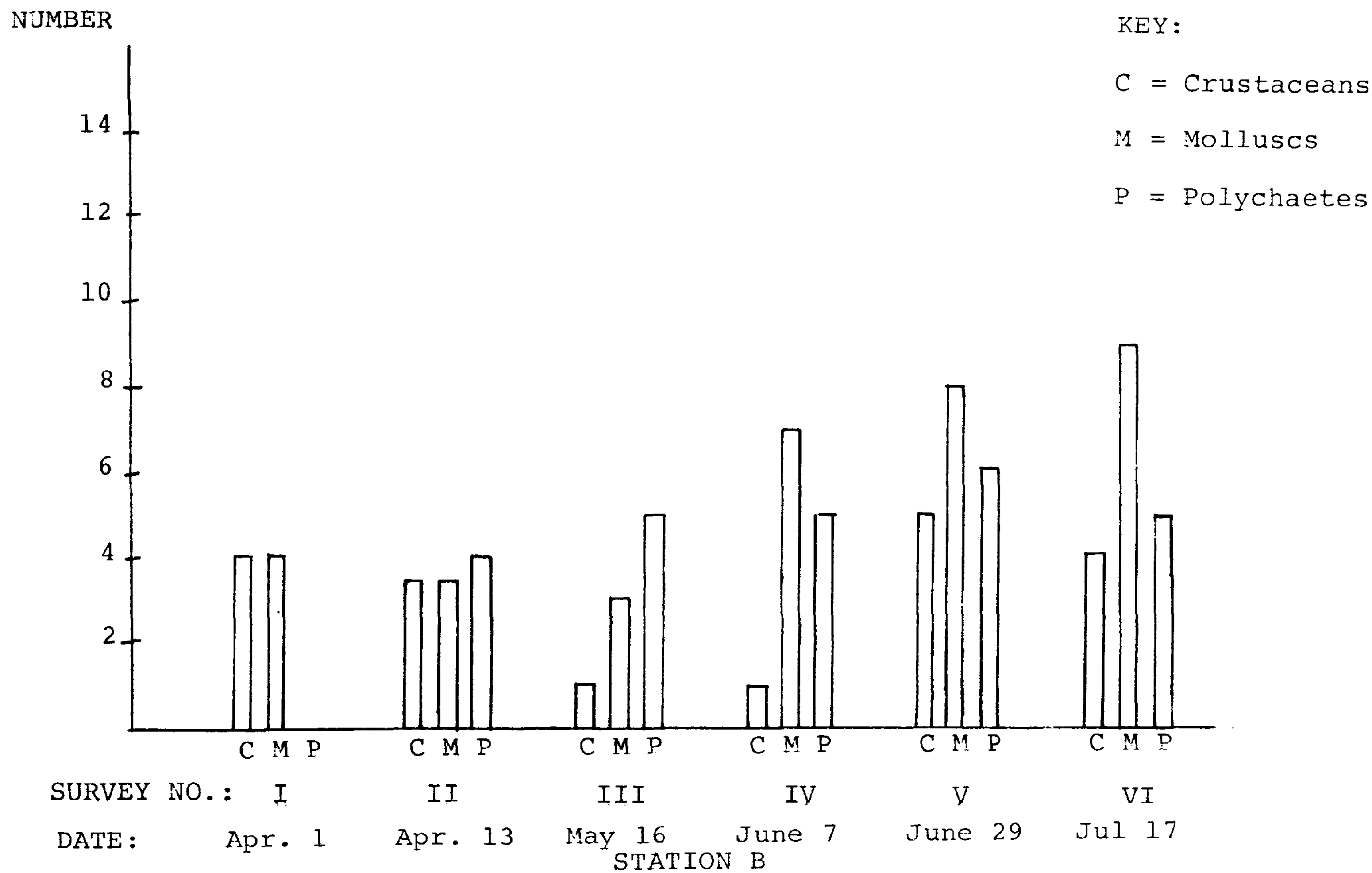


STATION A

NUMBER OF SPECIES PER 0.36 METER^2 BOTTOM

FIGURE 12

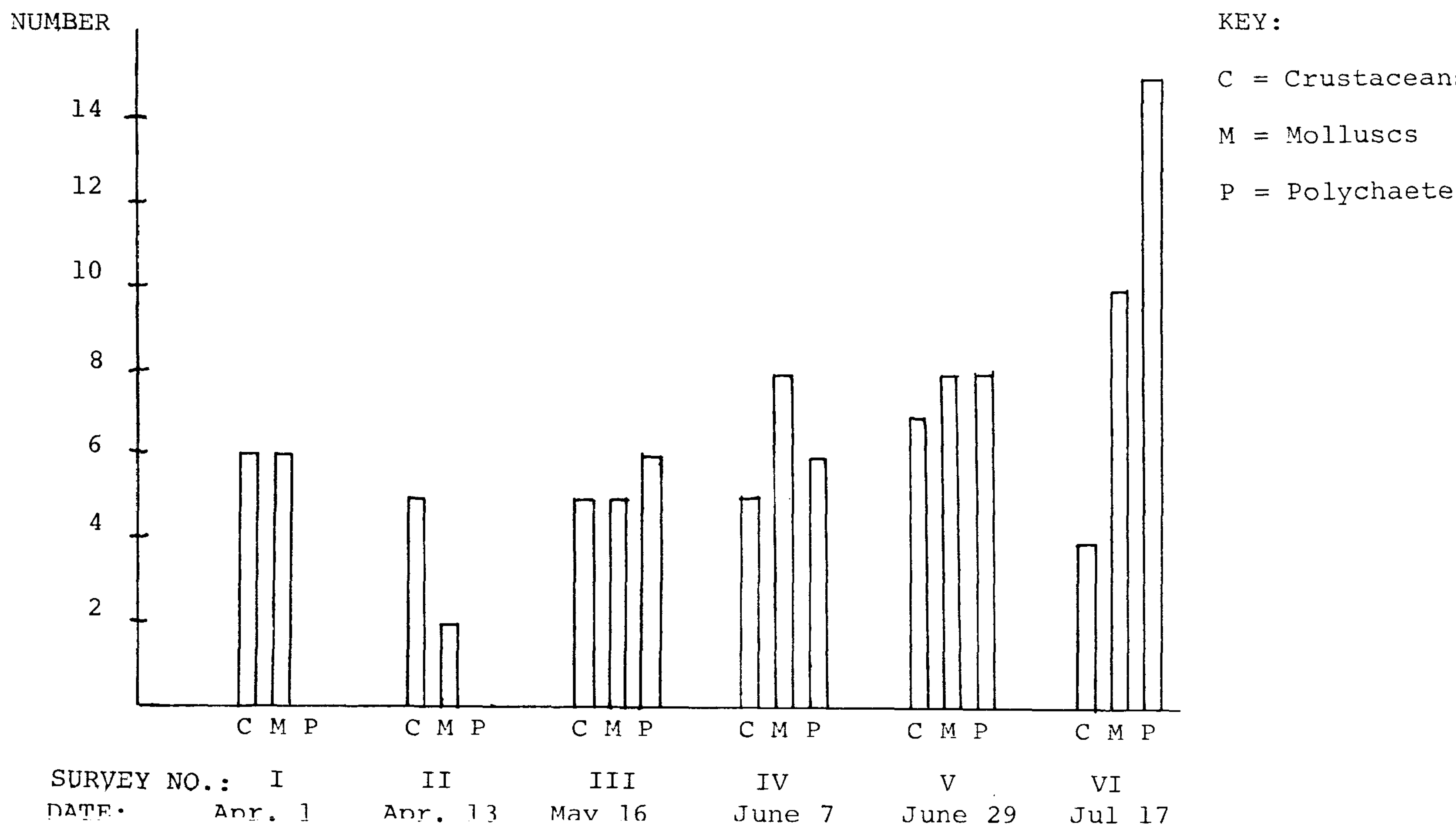
BENTHIC SAMPLES - SPECIES



NUMBER OF SPECIES PER 0.36 METER^2 BOTTOM

FIGURE 13

BENTHIC SAMPLES - SPECIES

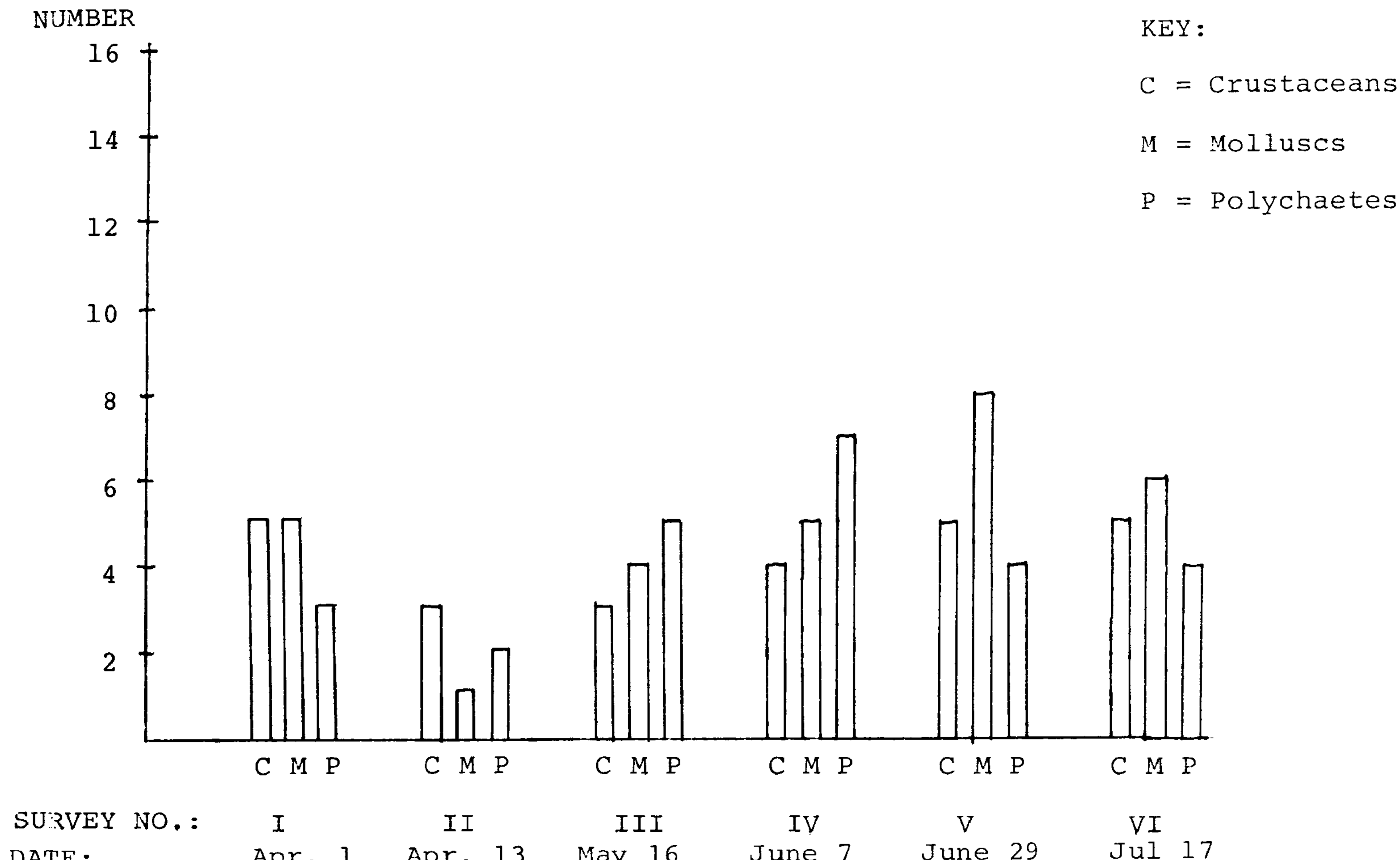


STATION C

NUMBER OF SPECIES PER 0.36 METER^2 BOTTOM

FIGURE 14

BENTHIC SAMPLES - SPECIES

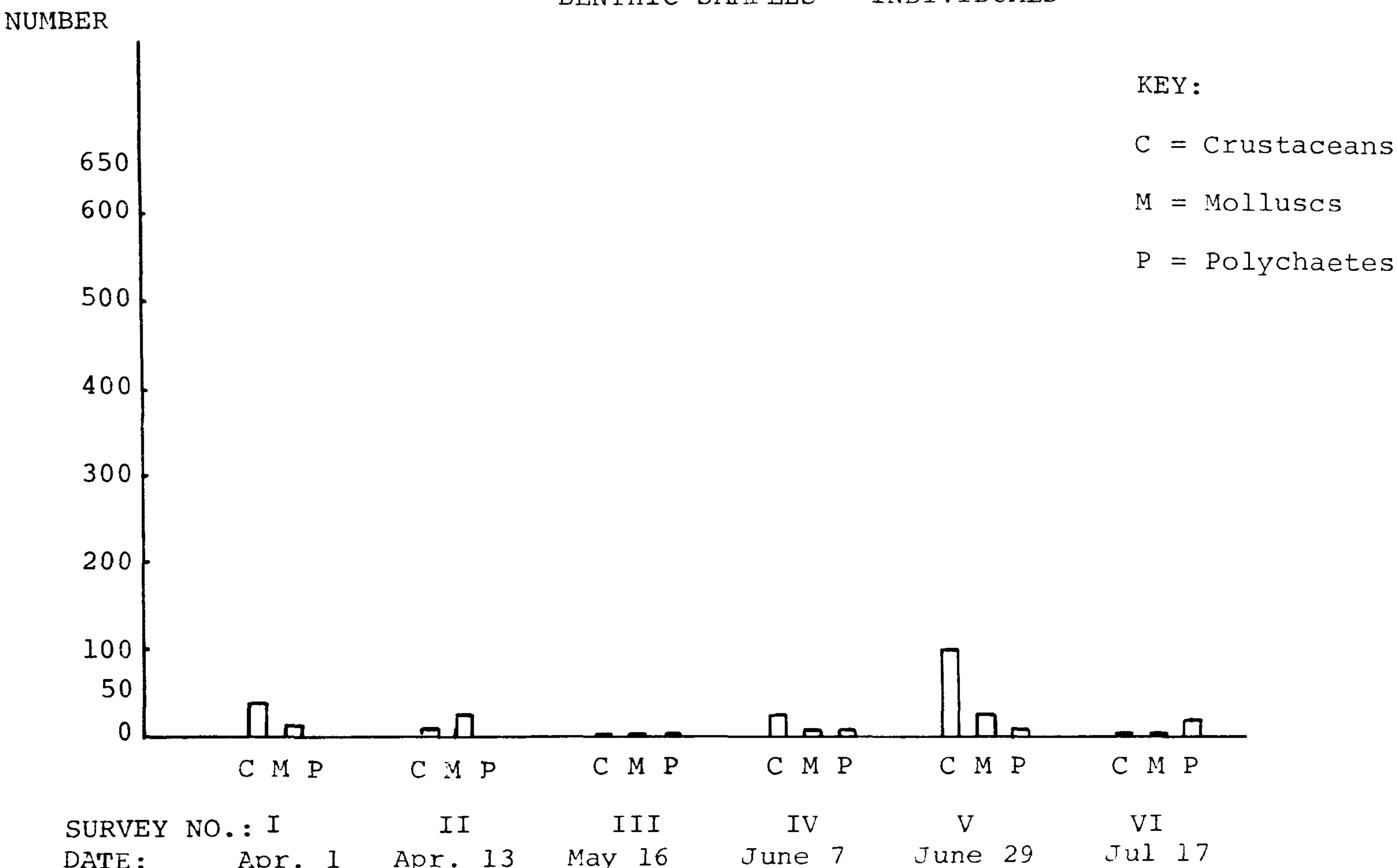


CONTROL STATION

NUMBER OF SPECIES PER 0.36 METER^2 BOTTOM

FIGURE 15

BENTHIC SAMPLES - INDIVIDUALS

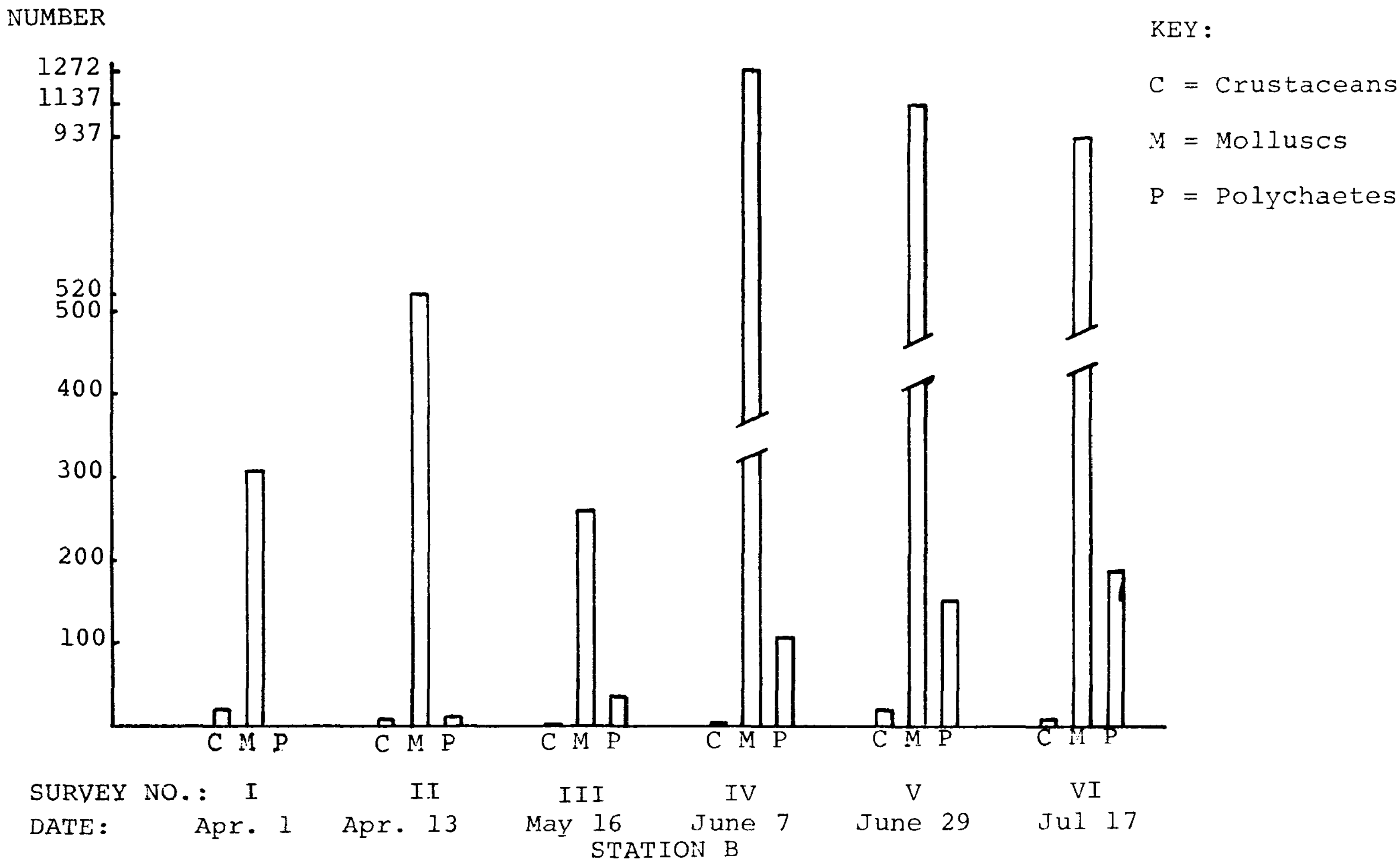


STATION A

NUMBER OF INDIVIDUAL ANIMALS PER 0.36 METER^2 BOTTOM

FIGURE 16

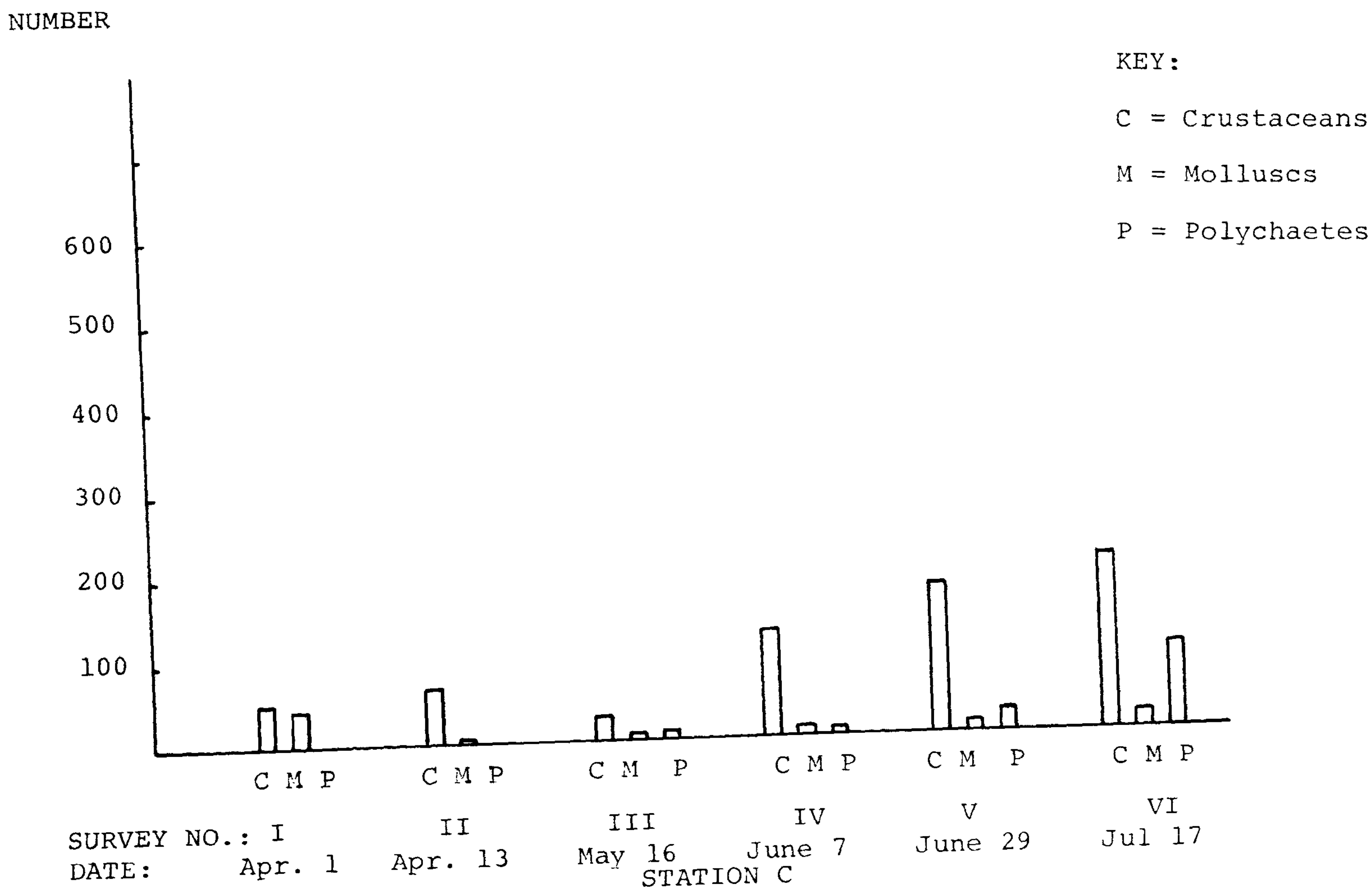
BENTHIC SAMPLES - INDIVIDUALS



NUMBER OF INDIVIDUAL ANIMALS PER 0.36 $METER^2$ BOTTOM

FIGURE 17

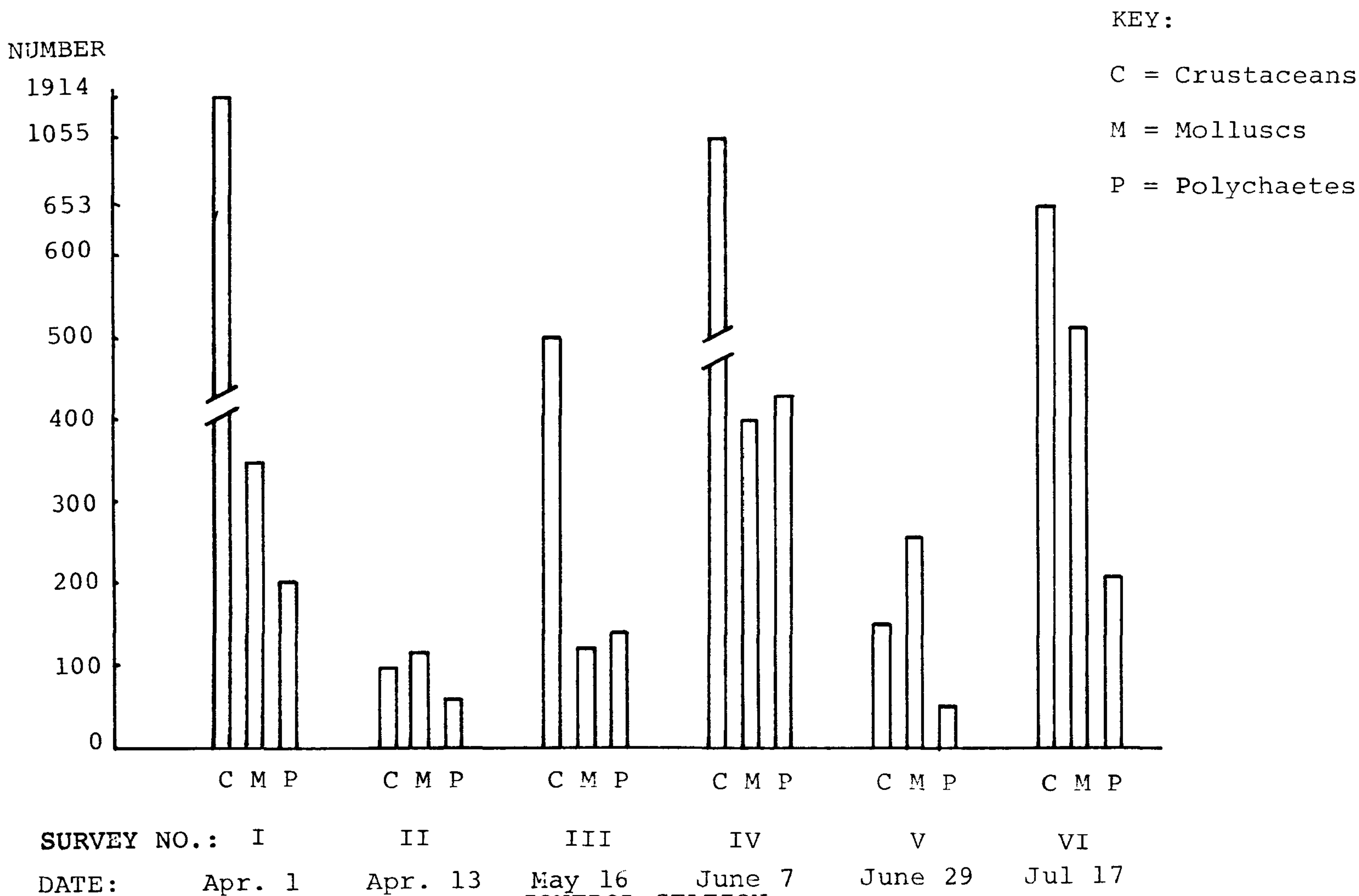
BENTHIC SAMPLES - INDIVIDUALS



NUMBER OF INDIVIDUAL ANIMALS PER 0.36 METER ^{2} BOTTOM

FIGURE 18

BENTHIC SAMPLES - INDIVIDUALS



CONTROL STATION

NUMBER OF INDIVIDUALS PER 0.36 METER^2 BOTTOM

FIGURE 19

Since the species composition of infaunal communities is closely retlated to the sediment type and its size frequency distribution, the logical comparison is between Stations A and C and between B and the Control. Station A was poorer than Station C, both in species diversity (Figs. 12 and 14) and numbers of individuals (Figs. 16 and 18). This could correlate with the higher concentrations of oil sighted along the western shore of the Bay shortly after the spill, but there is no baseline data to imply causality. This area is swept by stronger currents and the bottom is less stable than the Bay Point area which could account for the low numbers of organisms.

Station B compared favorably with the Control in terms of both numbers of species (Figs. 13 and 15) and numbers of individuals (Figs. 17 and 19), but the species composition was quite different. An amphipod community dominated Control while a *Nucula* community dominated Station B. *Nucula proxima* is a lamellibranch ubiquitous to soft sediments in Long Island Sound (Sanders, 1956). Its density can change sharply with changes in the silt-clay fraction of the sediment. Our finest fraction was that which passed a 0.250 screen, and we would not have been able to differentiate the silt-clay fraction from very fine sand as Sanders did. Thus, the ten-fold difference in *Nucula* density could be due to differences in the sediment. The amphipod community, however, undergoes replacement of one species by another with gradations in sediment size. There is, therefore, no explanation for the 100-fold differences in amphipod concentrations between Station B and the Control. Sanders et al (1972) found that amphipods were a very sensitive indicator of fuel oil contamination. The almost total absence of amphipods at Station B might therefore indicate contamination of these sediments.

Epibenthic Communities:

Quantitative sampling of the epibenthic communities commenced with Survey III (See METHODS). These are reported in the Appendix Table A-6 as numbers of individuals per 12 m^2 which was the total area sampled. Comparing the similar stations (A with C and B with Control), these results are similar to those for the infaunal communities. The *Pagurus*- small gastropod community at A was repeated at C, but as an amphipod -*Pagurus*-small gastropod community. The *Nucula*- small gastropod community at B was also found at the Control, but it was an amphipod -*Nucula* - small gastropod community. In both cases, the amphipods would be expected but were absent in areas suspected of contamination.

The numbers of species in the epibenthic communities were variable with no consistent trends between stations or among surveys at the same station. Thus, the hermit crabs, *Pagurus* spp. were very scarce at Station B until Survey VI. This may be significant in the light of the chromatographic analyses as discussed in a later section.

Numbers of individuals within species varied sharply between stations. The small molluscs, especially *Nucula* and *Nassarius*, rose very sharply at Station B compared with the Control. A species increase such as this might be an indication of stress in the manner of the population explosion by *Capitella capitata* in the affected areas in Falmouth (Sanders et al, 1972). The number of amphipods at Station B was very low compared with the Control. This is consistent with the results of the infaunal census and could reflect fuel oil contamination. Amphipods were sparse also at Station A as compared with Station C, but this could reflect the instability of the sediments at Station A, since there is a trend toward more individuals in all categories at Station C than at Station A except for the species *Pagurus* and *Crangon*. The results of a diver survey at each of the stations throughout the six (6) surveys are given in Appendix Table A-8 through A-13. The diver survey was a qualitative collection to provide a general sampling of the epibenthic community at Stations A, B and C, and an intensive search at the control station to find species corresponding to those at the three (3) different communities within the Bay. Station C supported a greater number of large carnivores such as whelks and crabs (*Busycon* and *Cancer*) than did Station A. During the first two surveys, Station B appeared to harbor a greater number of large, highly mobile, carnivores and omnivores (*Callinectes*, *Cancer*, *Busycon*, etc.), but after the second survey, the trend reversed to a degree.

Community Structure:

We used the three (3) types of surveys to form a general picture of community structure at the four (4) sampling stations (Fig. 20). Thus, Station A is generally characterized as one where a sparse epibenthic community dominates. Plankton and macro-algae probably provide the chief energetic source. Station B is primarily an infaunal community with migrant scavenger-type epifauna, utilizing both the detrital and planktonic energy base.

FIGURE 20

Community Profiles for Each of the Prime Stations.

Station A: Coarse, gravel, cobble bottom - Epibenthic community dominates

Algae → *Crangon*, *Nassarius*
Plankton → *Diopatra*, *Mercenaria*, Sponge → *Busycon*, *Nassarius* → Lobsters, Crabs, Starfish

Station B: Mud, fine silt, mid channel very little algae, amphipods not as apparent as Control

Plankton → *Diopatra*, *Mya*, *Nucula* → *Busycon*, *Nassarius*
Detritus → Scavengers, *Pagurus*, *Gammarus*, *Cancer*, *Crangon*

Station C: Sand and boulders, finer than Station A

Algae → *Littorina*, *Crangon*
Plankton → *Diopatra*, *Cliona*, *Mercenaria*, *Anadara* → *Busycon*, *Nassarius* → Crabs, Lobsters

Control Station: Mud and fine silt, amphipod - polychaete community

Algae → *Crangon*, amphipods, *Nassarius* → Lobsters
Plankton → *Mercenaria*, *Anadara* → *Busycon*, *Nassarius* → Lobsters, Crabs
Detritus → Worms, Amphipods → *Crangon*, *Pagurus* → Starfish

Station C is a well diversified community of both epibenthic and infaunal filter feeders and grazers, utilizing primary production as their energy source. The control station, also, appears to be an infaunal and epibenthic community, utilizing the macroalgal planktonic and detrital food chains. If these trophic relationships are correct, it could be assumed that the infaunal community of Station B is the one most intimately associated with sediments. It would, therefore, be highly vulnerable to contamination of the sediments by fuel oil, especially with regard to a sensitive species such as amphipods.

The amphipod community contributes directly as a food source for benthic fishes and invertebrates. Indirectly it accelerates the cycling of detrital energy by breaking down detritus into small particles (fecal pellets) which are enriched by bacteria and high in nutrients for coprophagous members of the community. In fine sediments, the tube-dwelling amphipods tend to stabilize the bottom.

Finfish:

The results of the finfish survey are given in the Appendix, Table A-7. The finfish were so highly mobile and their numbers so variable, that they were not useful in determining immediate effects of the pollutant. Long-term studies might yield information concerning the accumulation of hydrocarbons at the top of the food web.

CHROMATOGRAPHIC RESULTS

Chromatograms of No. 2 Fuel Oil:

The detection of No. 2 fuel oil in the environment by gas chromatography depends upon the interpretation of a number of features. Figure 21 gives the chromatogram of a standard sample of No. 2 fuel oil from WHOI. No. 2 fuel oil is a complex mixture of hydrocarbons consisting of straight-chain n-alkanes, branched alkanes, aromatics and cycloalkanes. The boiling point range is between 170°and 370°C, but most of the oil boils between 200° and 300°. The distinguishing features used for identification of the oil are the homologous series of n-alkanes comprising the progression of tall peaks in Figure 21. These start at C-10 or C-11; the tallest peak is at C-14 or C-15, and the peaks taper to C-22 or C-23. Interspersed among these peaks is a complex of shorter peaks, the most prominent of these comprising a regular homologous series of isoprenoids, a branched isomer. Beneath the peaks is a large unresolved hump or aromatic and cycloalkane compounds called the aromatic envelope which starts at about C-12 and ends at about C-20 or C-21. This aromatic envelope is very stable and does not occur in the natural environment. Its position in the boiling point spectrum distinguishes the No. 2 distillate from other fuel oil mixtures.

Apart from the overall composite picture, several distinguishing characteristics are used to detect the fuel oil when it is mixed with the naturally occurring hydrocarbons from the environment.

The isoprenoid peaks between C-16 and C-18 are highly important. The most prominent one is pristane (C-19), distinguishable on the leading side of the C-17 peak. Next is phytane (C-20) which is poorly resolved and seen only as a wedge on the leading edge of C-18, and lowest is the C-18 homologue which stands alone between C-16 and C-17.

The constancy of these features between different batches of No. 2 fuel oil can be seen by comparing Figure 21 with Figure 22, a sample from the F.L. Hayes. Weathering (dissolution and evaporation) causes the lower boiling portions below n-C-14 to disappear, thus truncating the

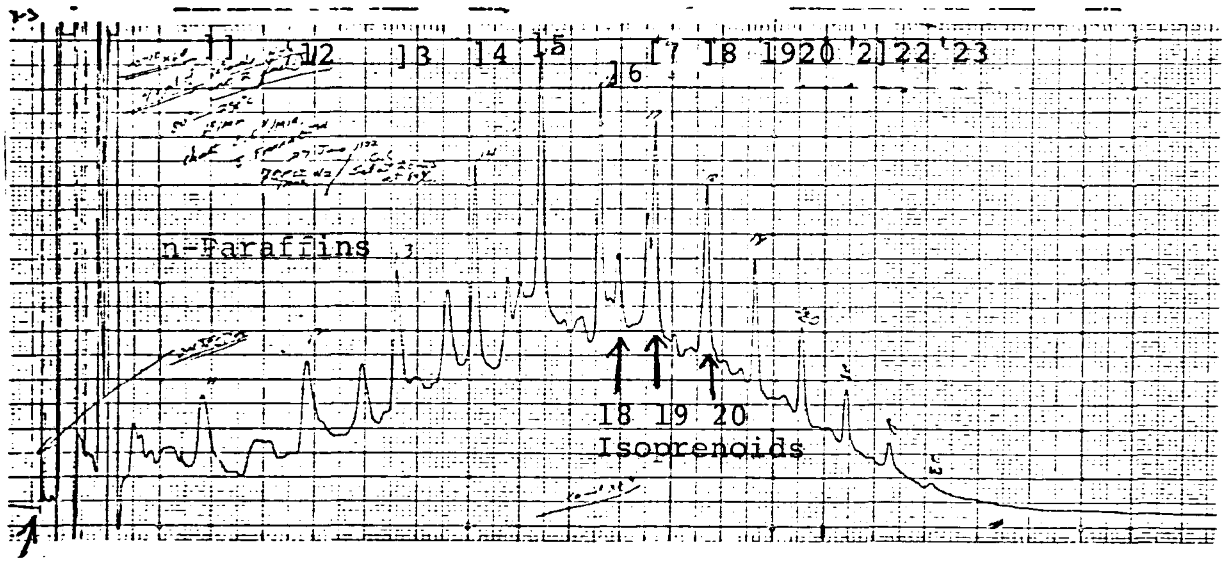


FIGURE 21

Chromatogram of No.2 fuel oil-a standard

from WHOI

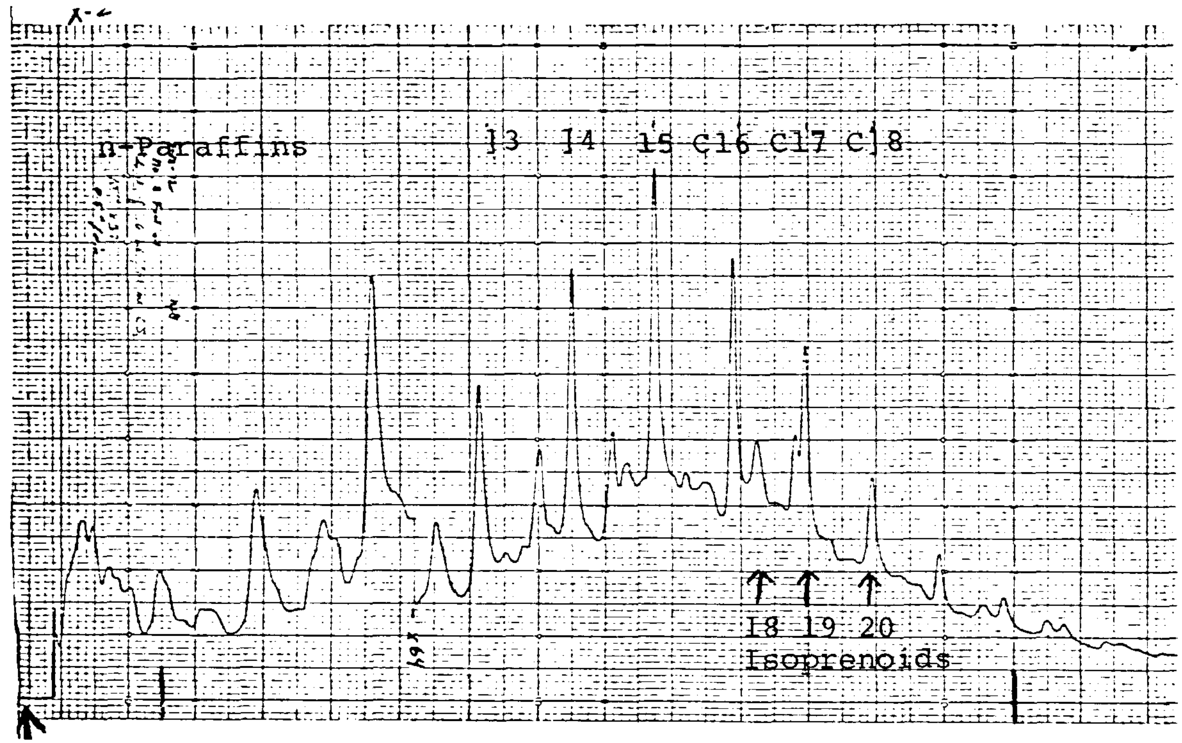


FIGURE 22

Chromatogram of No. 2 fuel oil from F.L. Hayes leading edge of the envelope. Bacterial and chemical degradation causes a lowering of the peaks. The n-alkanes disappear most rapidly, but regularly across the entire boiling range. The isoprenoids disappear more slowly so that this series becomes larger relative to the n-alkanes. The aromatics and cyclo-alkanes disappear only slowly so that the aromatic envelope remains quite stable. Thus, it is a composite of characteristics which are used to determine the presence of the No. 2 fuel oil within the background of natural hydrocarbons.

Chromatograms at Prime Stations:

Figures 23 through 26 are chromatograms of sediments at Station A on Surveys I, III, IV and VI respectively.

Survey I (Fig. 23) showed no evidence of fuel oil. The prominent peak between n-C-16 and n-C-17 was probably of biosynthetic origin and could have been from benthic algae (Youngblood et al 1971). By Survey III (Fig. 24) there was an increase in the unresolved complex mixture which could have been No. 2 fuel oil. If so, the oil was severely water-washed and/or evaporated with loss of the lower boiling components. The prominent peaks of n-C-17 to n-c-21 could have been contributed by biological input such as decaying algae. The chromatogram of Survey IV (Fig. 25) is similar to Survey III but reflected greater input of the fraction which could be considered weathered oil as well as the biological hydrocarbons. Survey VI (Fig. 26) showed a similar picture to Surveys III and IV. The prominent biogenic peaks dominated the mixture and occluded any distinguishing fuel oil characteristics. The spike at C-14 is a tracer injected with the sample, not a part of the natural background.

Chromatograms of water samples at Station A during Surveys I and III (Figs. 27 through 30) failed to show any traces of the fuel oil. The samples chosen for detecting the biological uptake of fuel oil at Station A included the quahog, *Mercenaria mercenaria* from Survey I (Fig. 31) taken eleven (11) days following the spill, and the hermit crab, *Pagurus longicarpus* from Survey II (Fig. 32) taken fourteen (14) days after the spill. The quahog is a filter feeder which would take in material from the water column, but it also lives in close contact with the sediments. The hermit crab is a scavenger which would take in detrital particles mixed with sediment. The quahog (Fig. 31) showed a large peak between n-C-16 and n-C-17,

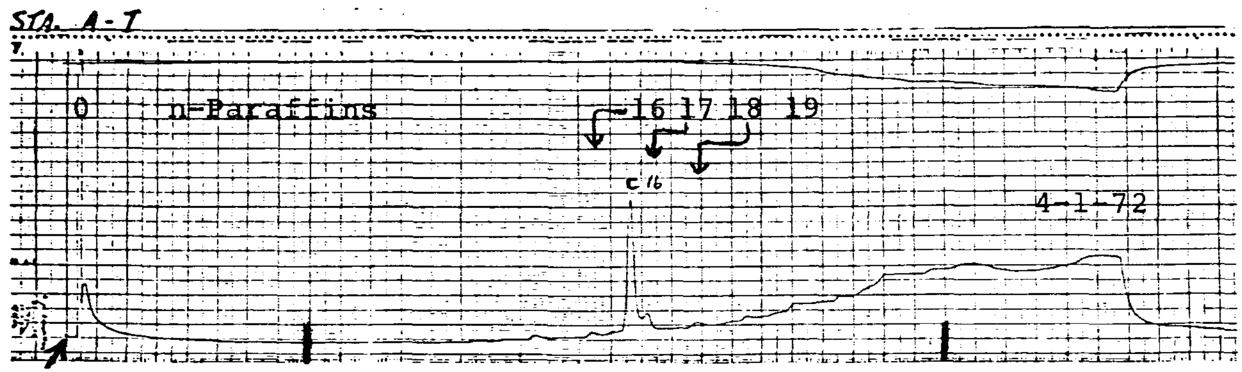


FIGURE 23

Chromatogram of sediment from Station A

Survey I

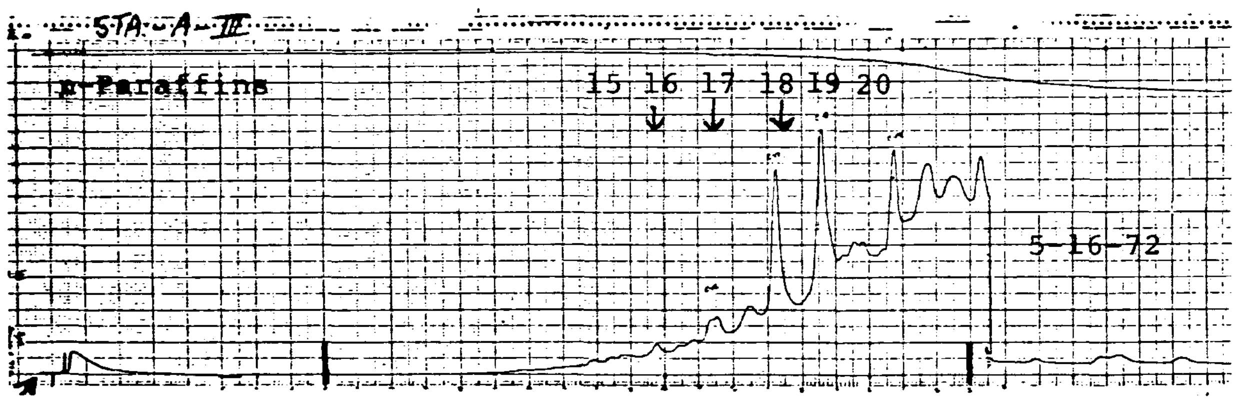


FIGURE 24

Chromatogram of sediment sample from

Station A

Survey III

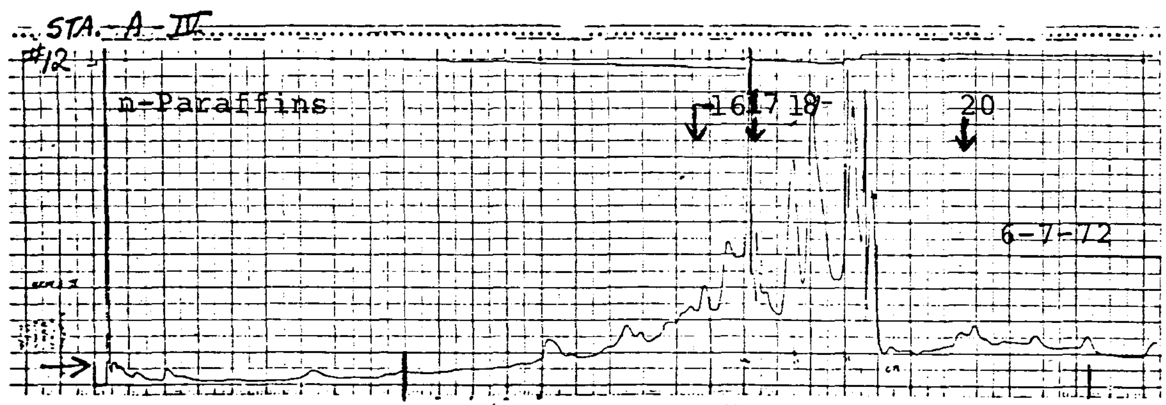


FIGURE 25

Chromatogram of sediment sample from

Station A

Survey IV

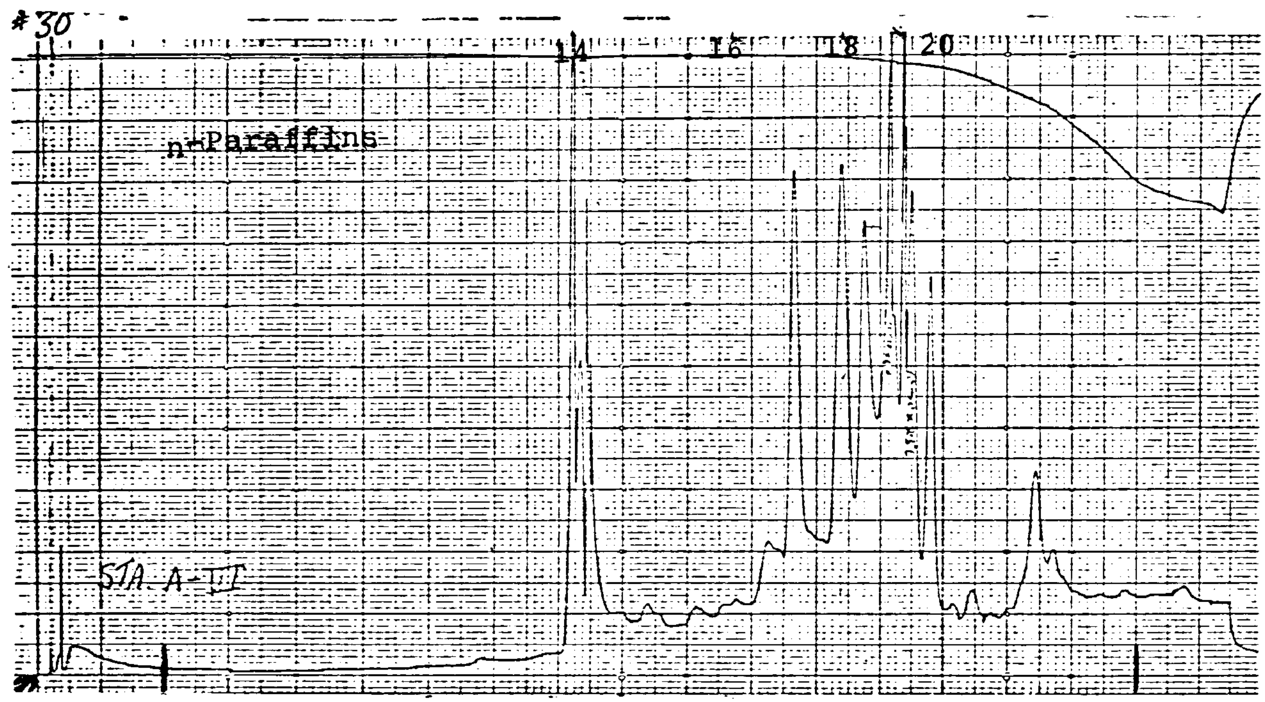


FIGURE 26

Chromatogram of a sediment sample from

Station A

Survey VI

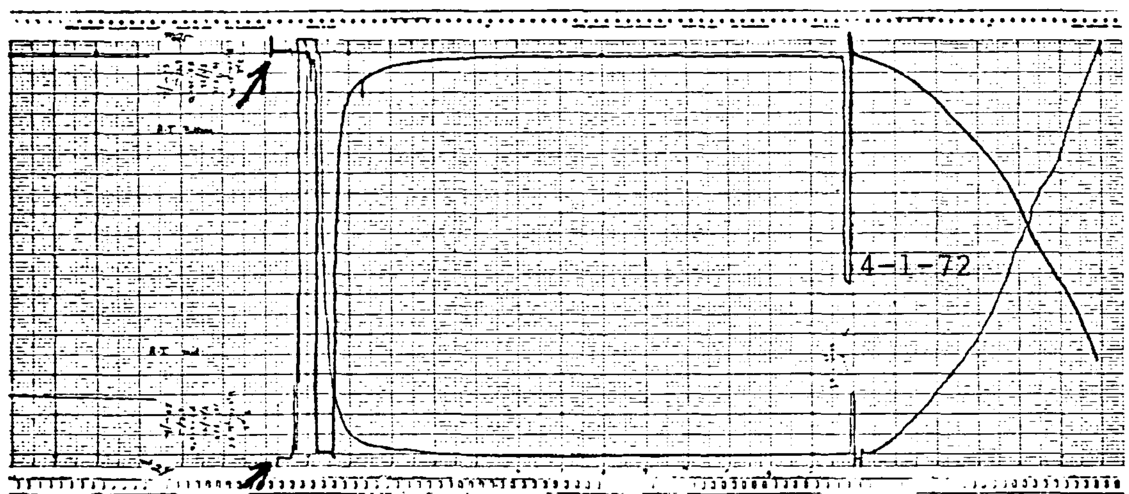


FIGURE 27

Chromatogram of water sample, Station A,

bottom

Survey I

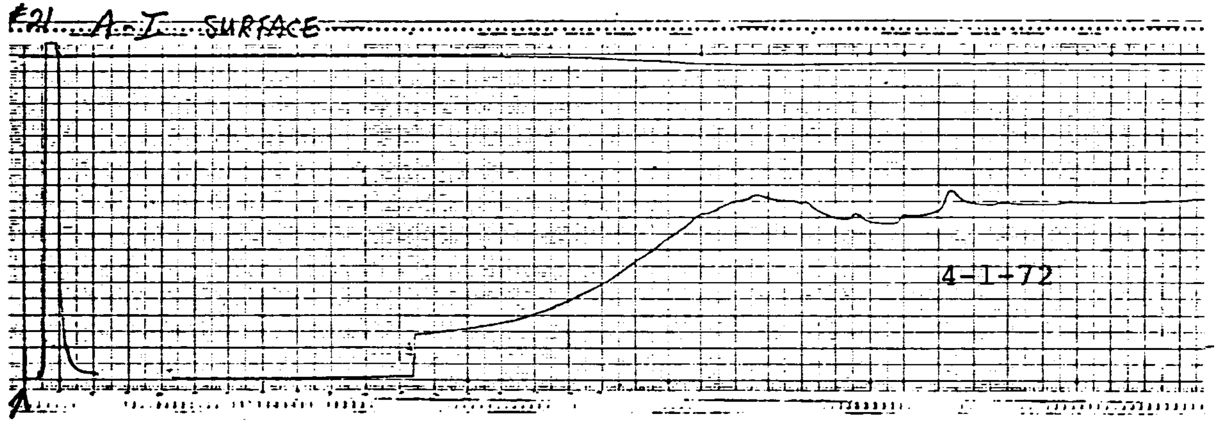


FIGURE 28

Chromatogram of water sample, Station A,

middepth

Survey I

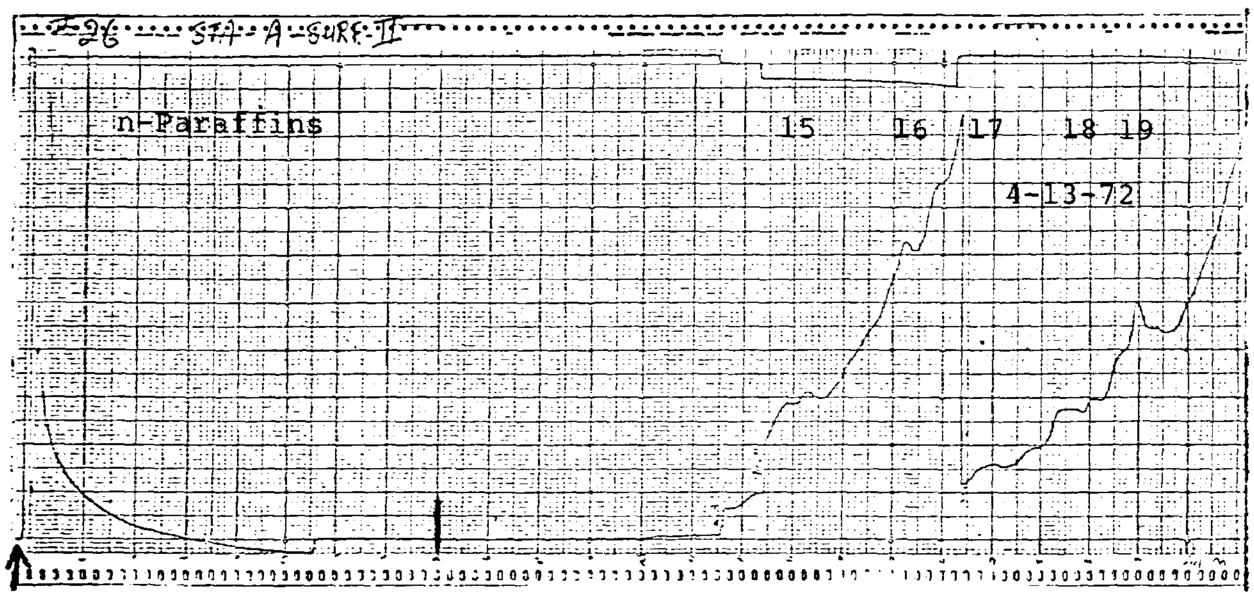


FIGURE 29

Chromatogram of water sample, Station A

surface

Survey II

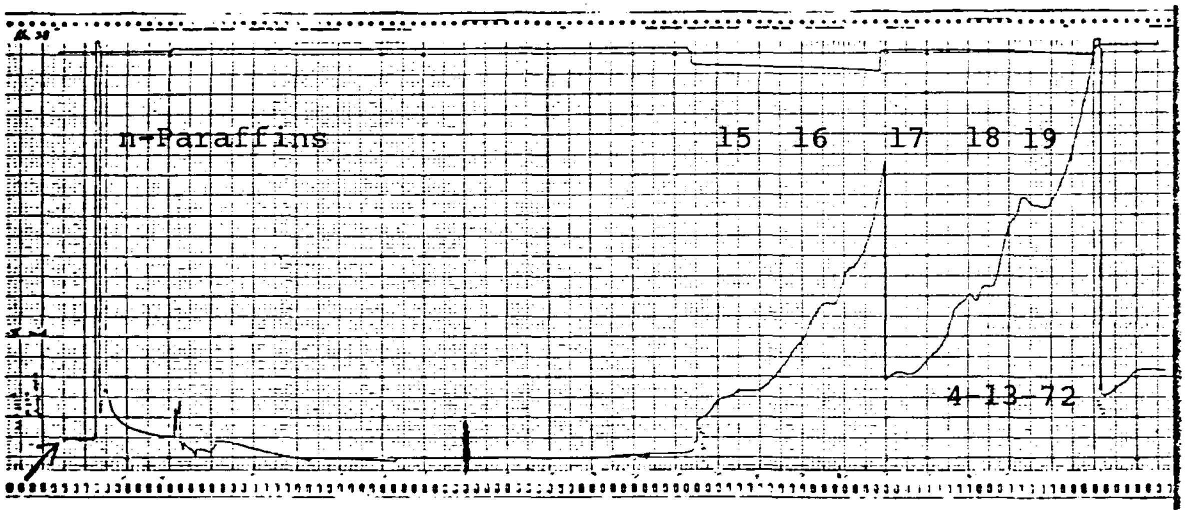


FIGURE 30

Chromatogram of water sample, Station A

middepth

Survey II

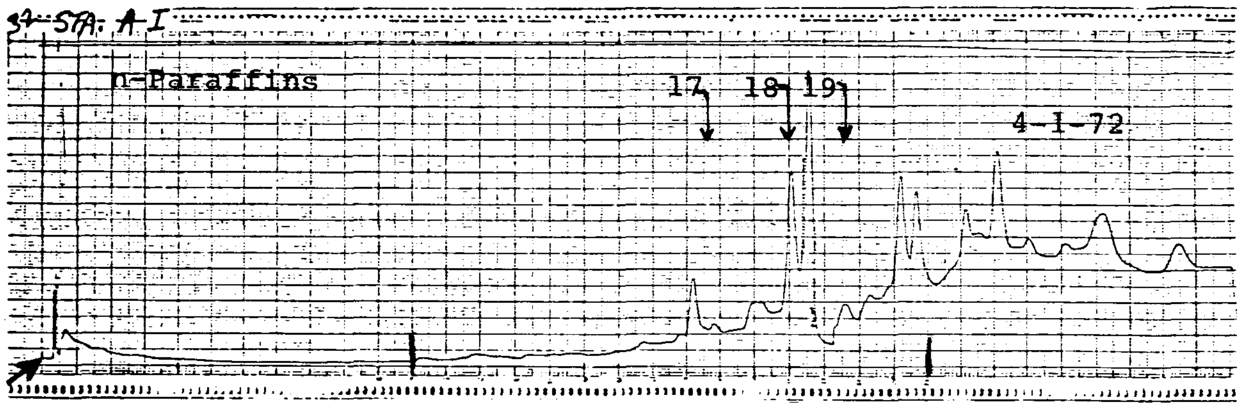


FIGURE 31

Chromatograms of *Mercenaria mercenaria*:

Station A

Survey I

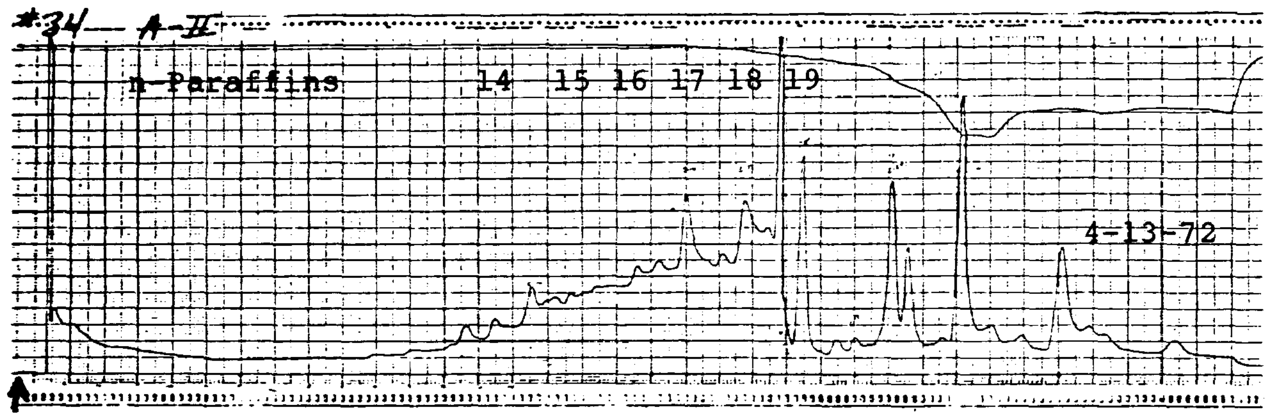


FIGURE 32

Chromatogram of *Pagurus longicarpus*

from Station A

Survey II

reflecting the biogenic peak found in the sediments of Station A at that time. The other large isolated peaks are typical of biogenic hydrocarbons. There was no definitive evidence for the presence of fuel oil in this sample. The hydrocarbon content of the hermit crab (Fig. 32) also showed no definitive evidence for the fuel oil. It lacked the complex series between n-C-16 and n-C-18. The apparent envelope between n-C-14 and n-C-18 was an artifact of the low attenuation setting which was raised between C-18 and C-19 and brought the baseline back to normal.

Hydrocarbon profiles of Station B were made for Survey I (Fig. 33) and Survey III (Fig. 34). The hydrocarbon envelope for Survey I (Fig. 33), eleven (11) days after the spill, was at a boiling range too high to represent No. 2 fuel oil. On Survey III (Fig. 34), however, six (6) weeks after the spill, there was a strong hint of fuel oil contamination, since the aromatic envelope developed sooner than in Fig. 33, and the characteristic n-C-17/pristane complex was present. As at Station A, the hydrocarbon content appeared to increase with time, but any fuel oil component is highly weathered (C-17/pristane ratio is less than 1), especially over the lower boiling points. The large peaks at n-C-19 and above were probably biogenic, possibly the 21:5 and 21:6 components of the *Laminaria* which was abundant there during Survey III.

Chromatographic analysis of water samples was discontinued after the uniformly negative results at Station A where water column contamination was considered most significant. The biological samples analyzed from Station B included the hermit crab, *Pagurus*, from Surveys I and III (Figs. 35 and 37), a lobster, *Homarus americanus*, from Survey II (Fig. 36), and a whelk, *Busycon*, from Survey VI (Fig. 37). The hermit crab taken in Survey I (Fig. 35) was strongly contaminated with No. 2 fuel oil, indicated by the aromatic envelope and typical complex series of n-alkanes and isoprenoids. The oil was chemically degraded (C-17/pristane ratio less than 1), but low boilers were still present (C-11 to C-14).

The lobster taken during Survey II showed a complex background of hydrocarbons, but little to indicate contamination by No. 2 fuel oil. The single large peaks in the low boiling range and the large peak preceding C-17 were typical of biogenic sources. There was little aromatic envelope. The large peak before C-17 was not pristane, and there was no indication of the C-19 isomer between n-C-16

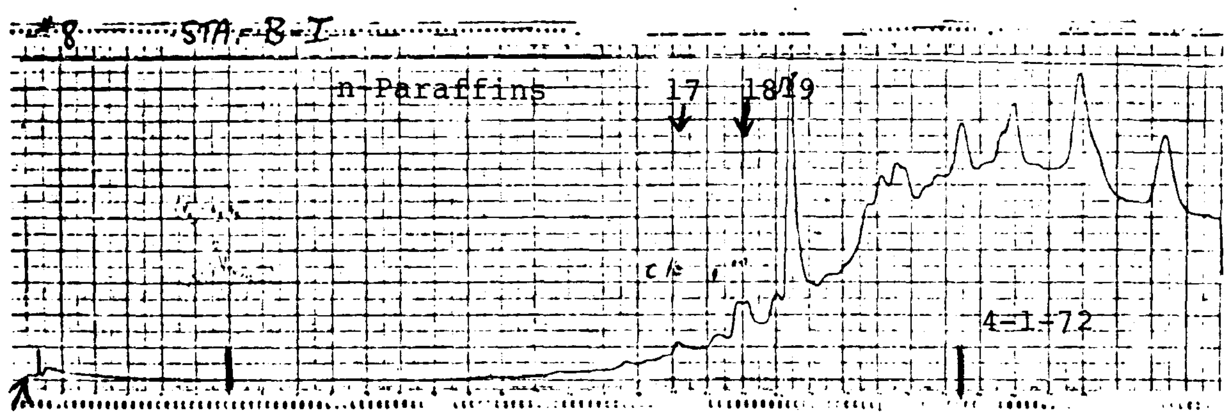


FIGURE 33

Chromatogram of sediment sample from Station B

SURVEY I

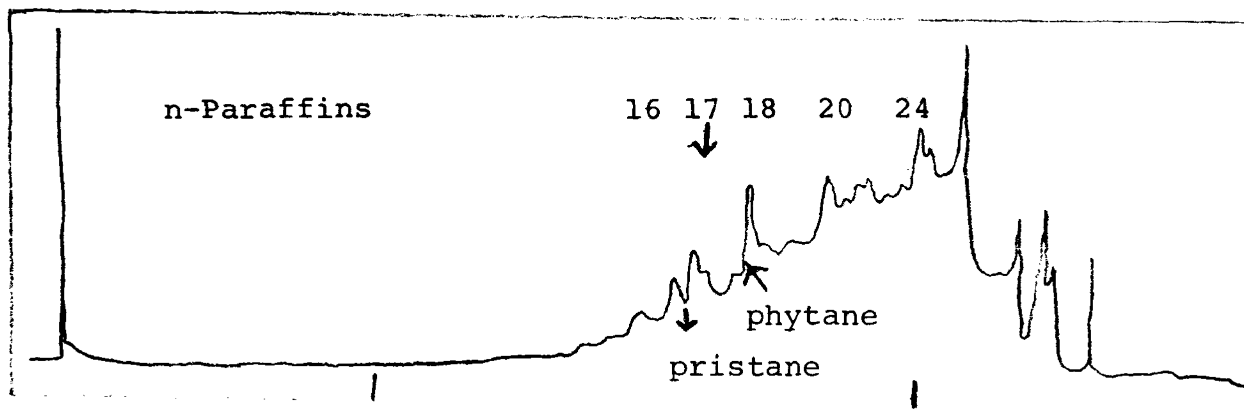


FIGURE 34

Chromatogram of a sediment sample from

Station B

Survey III

Redrawn to facilitate interpretation of right-to-left strip chart record.

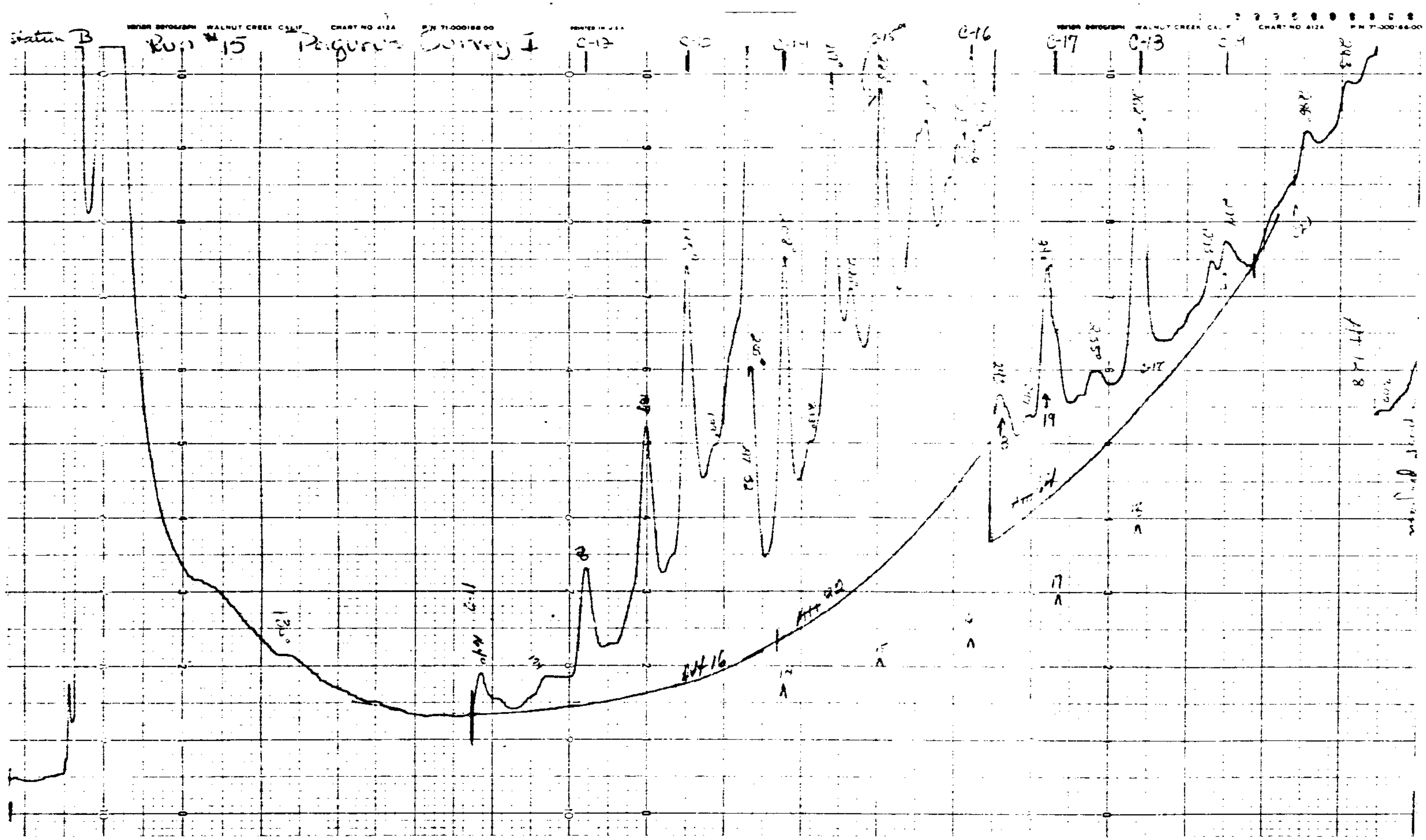


FIGURE 35
Chromatogram of *Pagurus* from Station B, Survey I

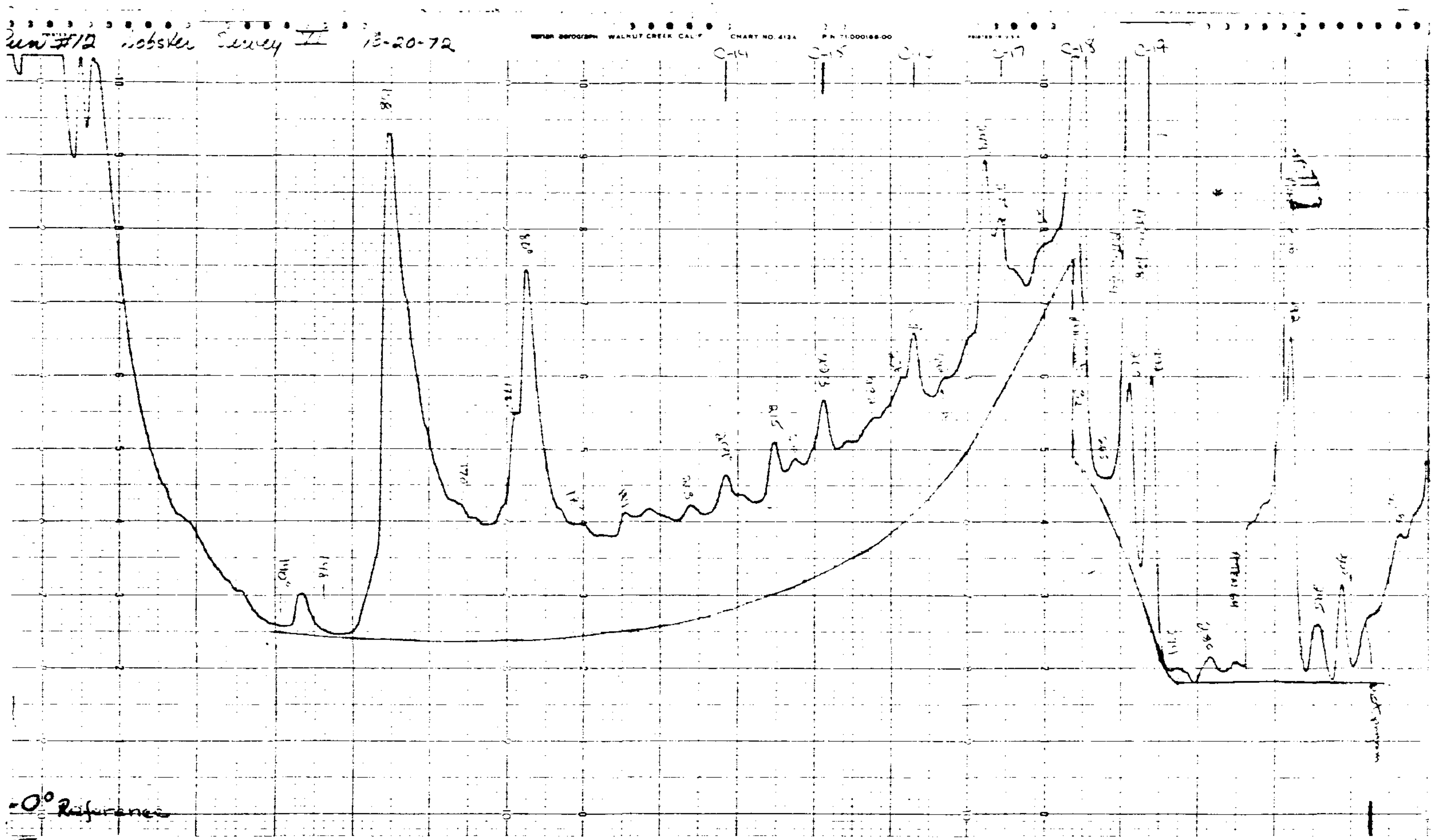


FIGURE 36
Chromatogram of Lobster from Station B, Survey II

and n-C-17.

The hermit crabs taken during Survey III (Fig. 37) appeared to be contaminated with No. 2 fuel oil which was chemically weathered but still exhibited a C-17/pristane ratio greater than 1. The definition of peaks was not so sharp as that in Survey I, but the aromatic envelope was still present in the C-11 to C-14 range indicating chemical degradation.

The whelk taken during Survey VI (Fig. 38) did not appear to contain fuel oil. The aromatic envelope was shallow and only apparent from about C-14 and the peaks from C-16 and C-18 did not follow the complex identifiable as No. 2 fuel oil, especially the single peak at C-17.

In chromatograms of the sediments at Station C during Survey I (Fig. 39) and Survey IV (Fig. 40), most of the hydrocarbons boiled above the range of No. 2 fuel oil and could have been biogenic or of other petroleum origin. The rising baseline in Fig. 40 was due to column bleed.

The chromatogram of the hermit crab, *Pagurus*, however, taken during Survey II (Fig. 41), indicated a hydrocarbon envelope in the low-boiling range (from n-C-14); another in the higher range reflected the sediment background. The complex of peaks from C-16 through C-18 could have been No. 2 fuel oil both weathered and highly degraded chemically (C-17/pristane ratio less than 1). The spike at C-14 was a standard coinjected with the sample and the C-18 peak was apparently a naturally-occurring hydrocarbon in *Pagurus*.

Both chromatographic profiles for the Control Station (Figs. 42 and 43) showed a large hydrocarbon content above the boiling point range of No. 2 fuel oil. The C-19 peak for Survey I (Fig. 42) was probably biogenic. The existence of a background envelope truncated below C-14, and low C-17/pristane and C-18/phytane ratios, make it highly probable that the Control Station received a small dose of highly weathered and chemically degraded fuel oil.

The tracing of a chromatogram from Survey III (Fig. 43) also showed degraded peaks. The n-C-14 spike was a coinjected standard. The quahog, *Mercenaria mercenaria*, collected during Survey I (Fig. 44) reflected a hydrocarbon background, but this could not be identified as No. 2 fuel oil.

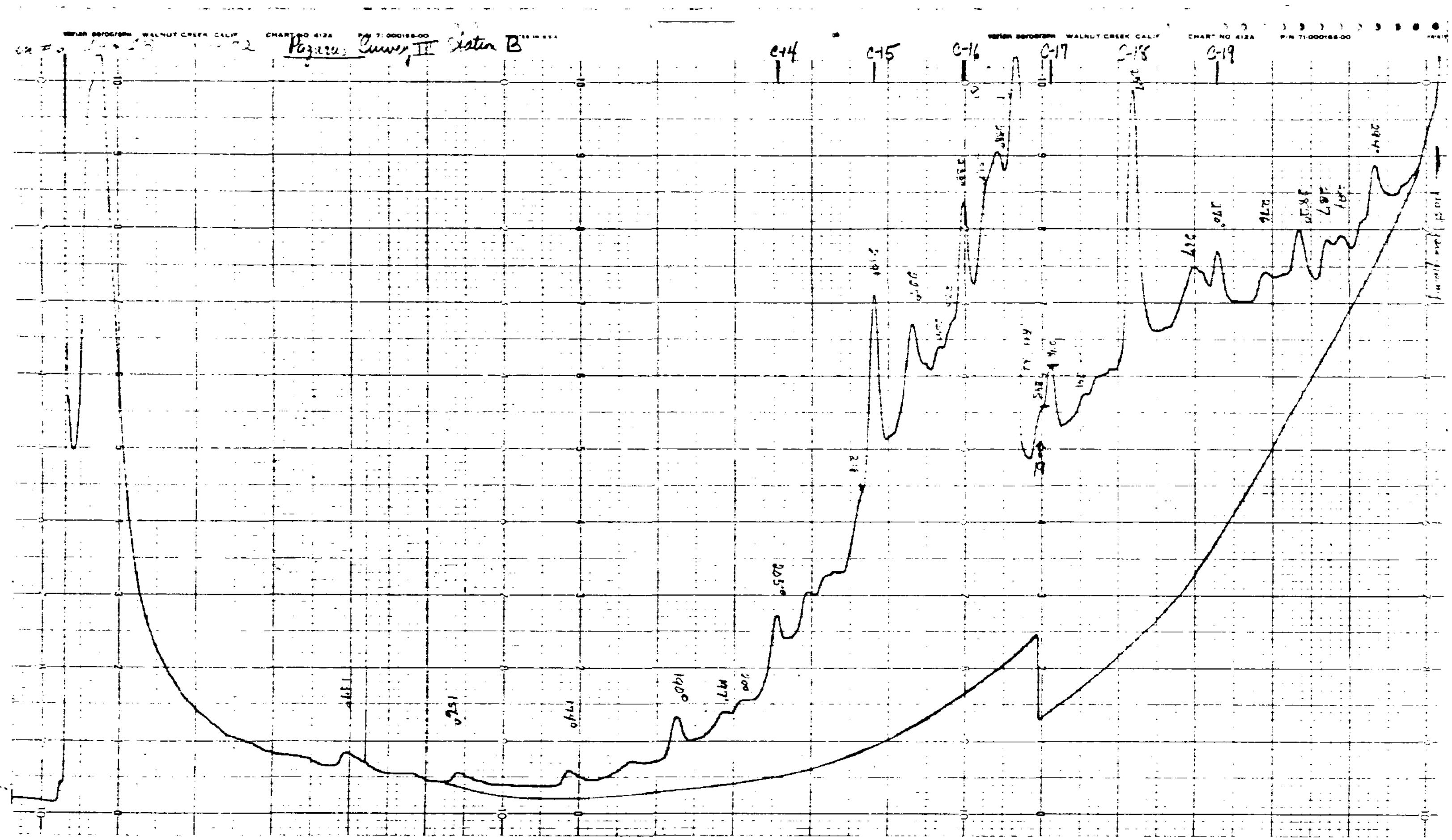


FIGURE 37
Chromatogram of *Pagurus* from Station B, Survey III

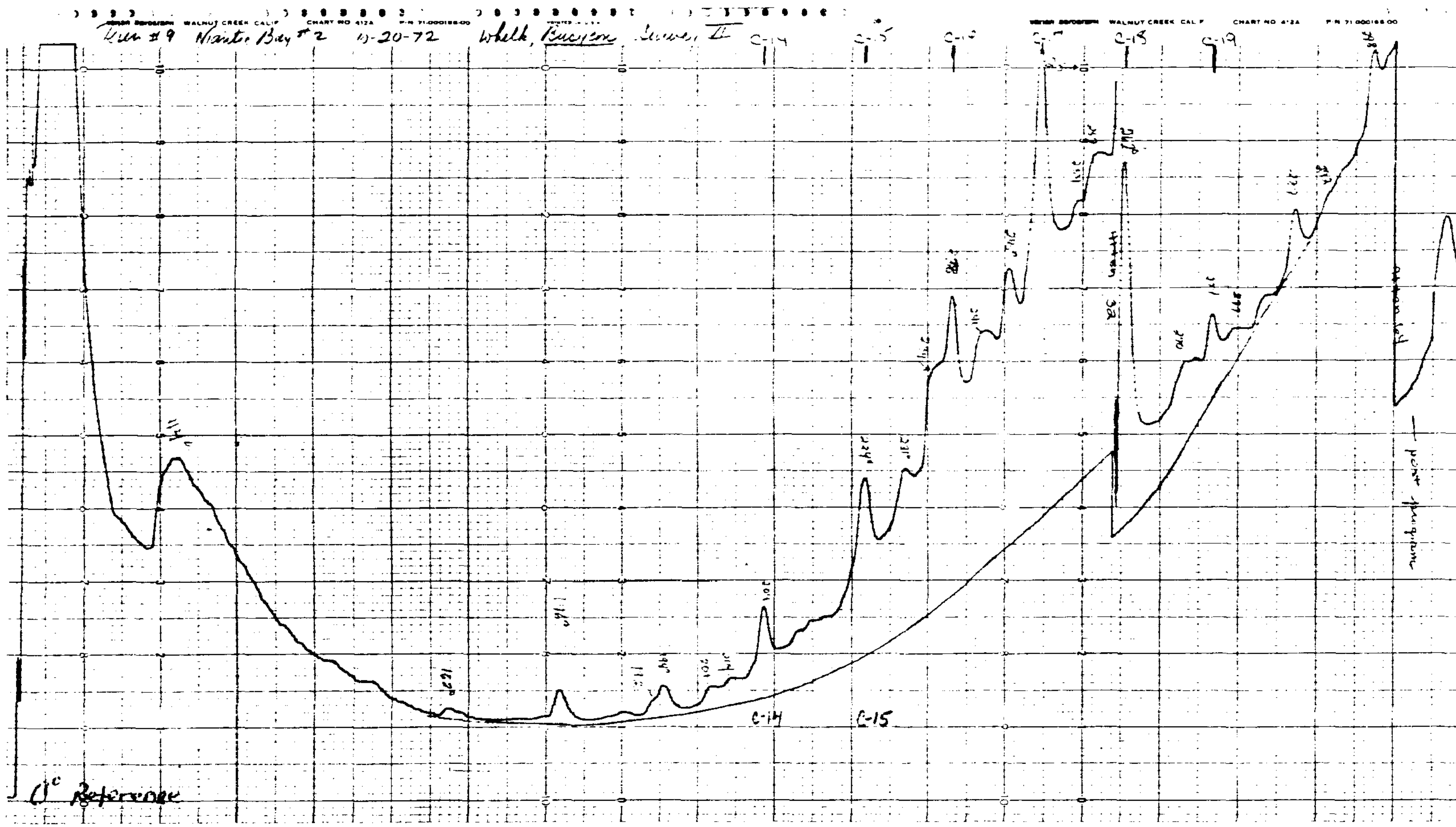


FIGURE 38
Chromatogram of Whelk, *Busycon* from Station B, Survey VI

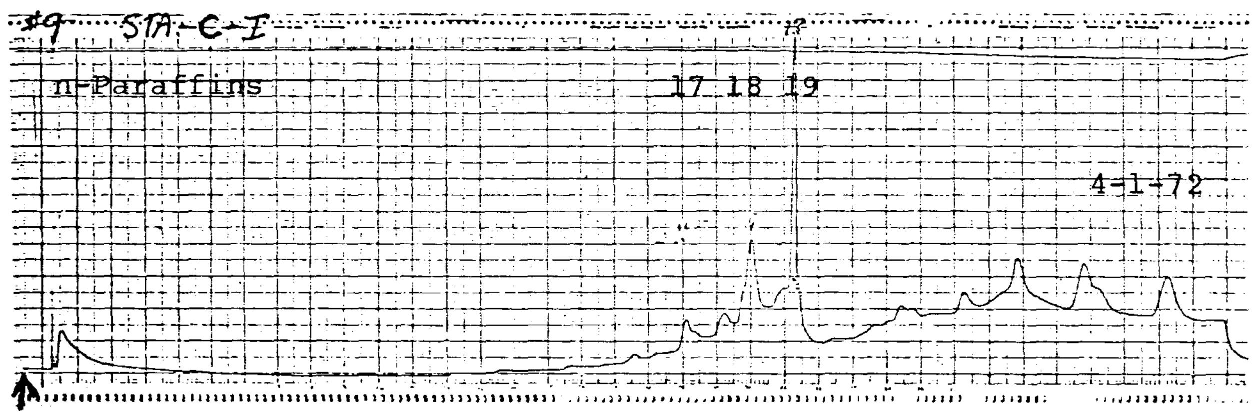


FIGURE 39

Chromatogram of sediment sample, Station C

Survey I

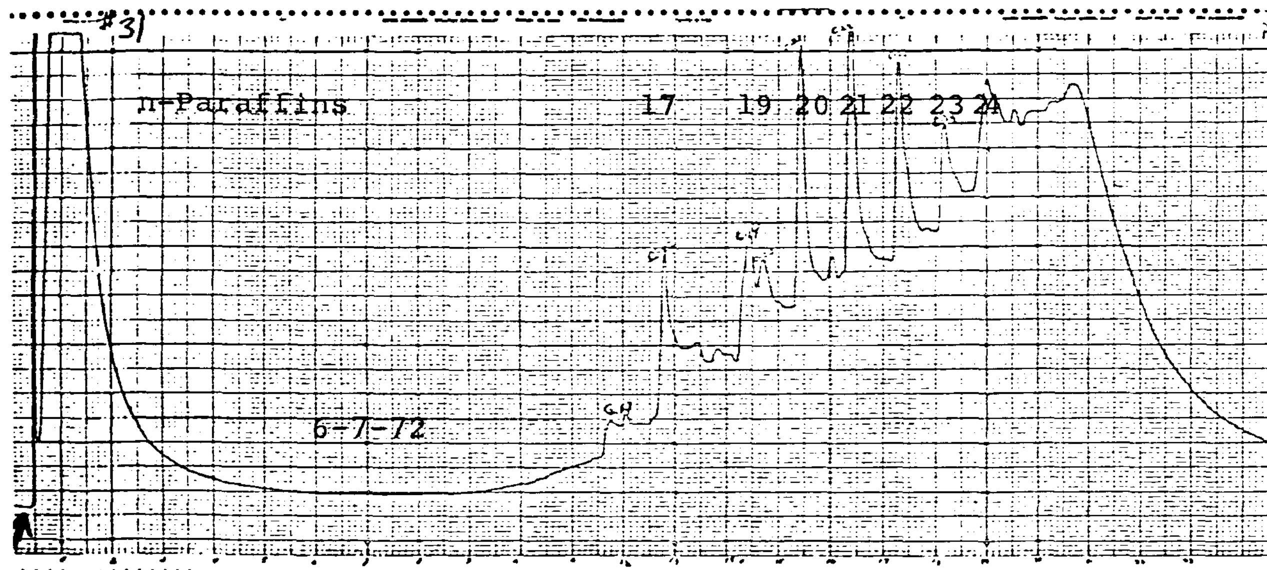


FIGURE 40

Chromatogram of sediment from Station C

Survey IV

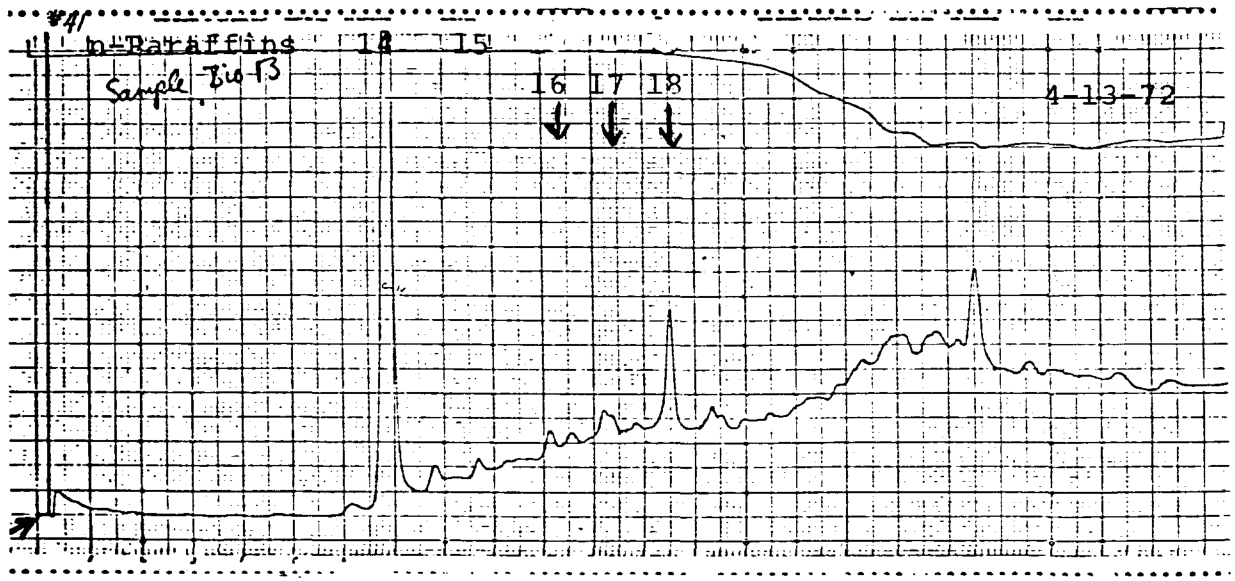


FIGURE 41

Chromatogram of *Pagurus longicarpus*

from Station C

Survey II

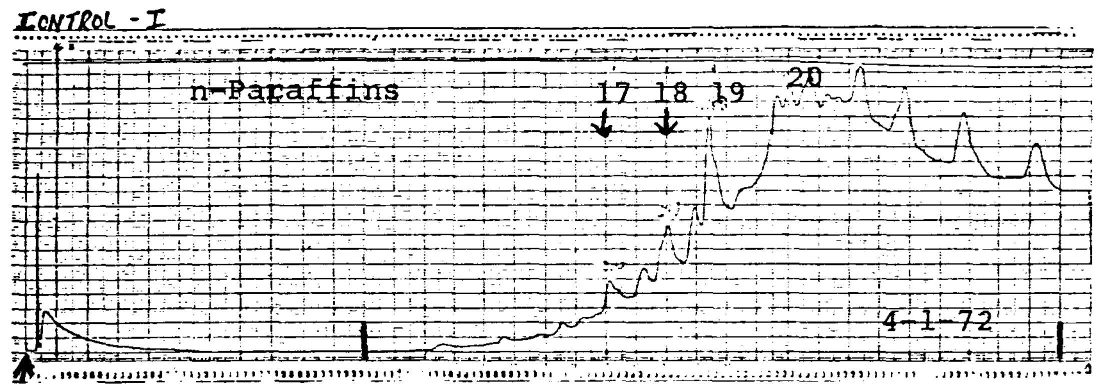


FIGURE 42

Chromatogram of sediment from Control Station

Survey I

Redrawn to facilitate interpretation of right-to-left strip chart record.

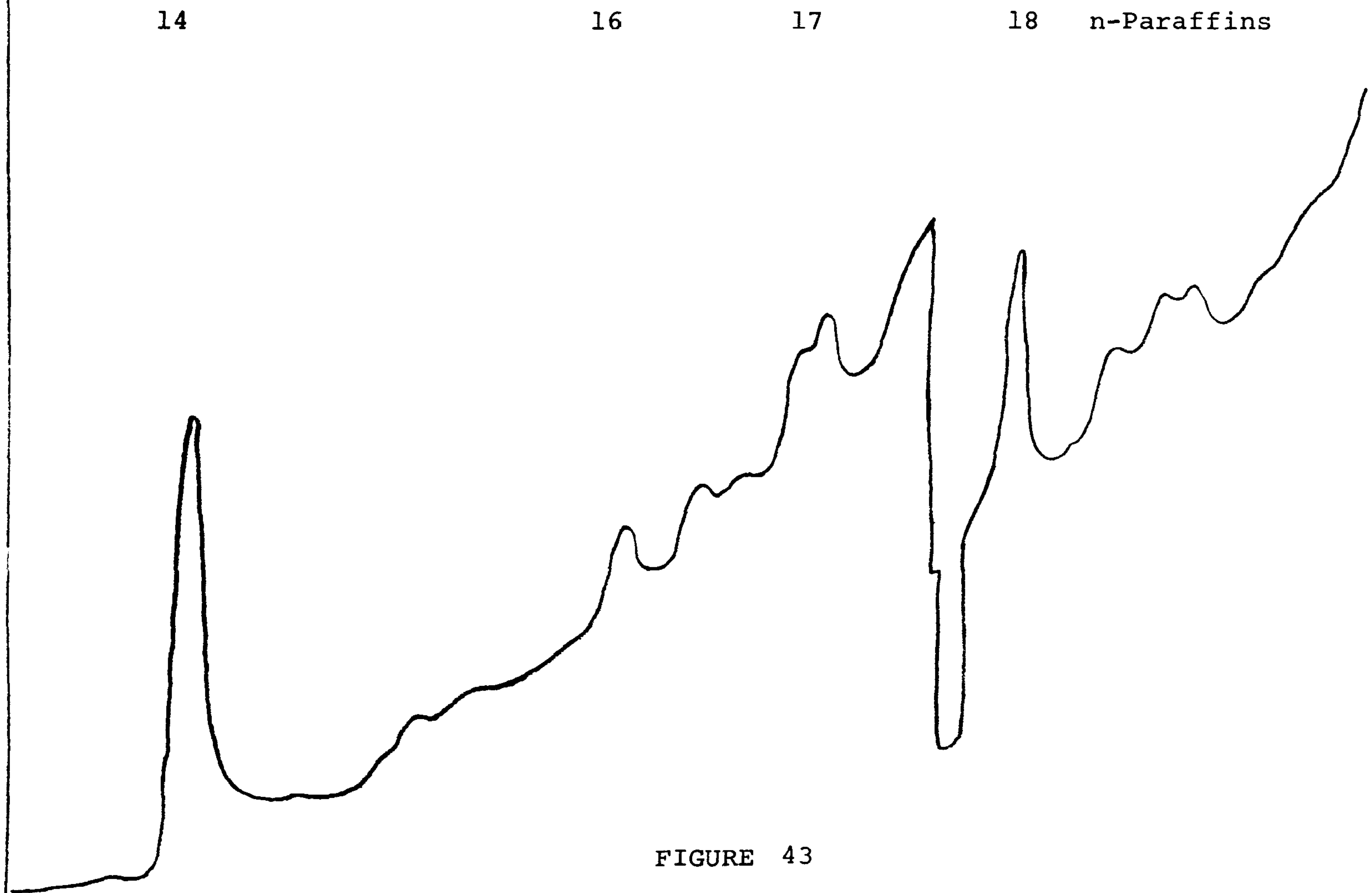


FIGURE 43

Chromatogram of sediment from Control Station

Survey III

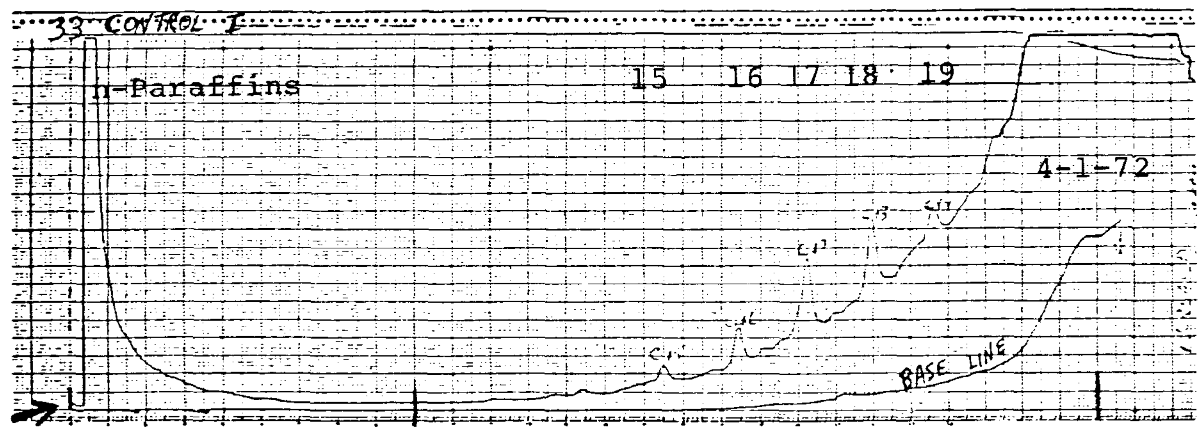


FIGURE 44

Chromatograms of *Mercenaria mercenaria:*

Control Station

Survey I

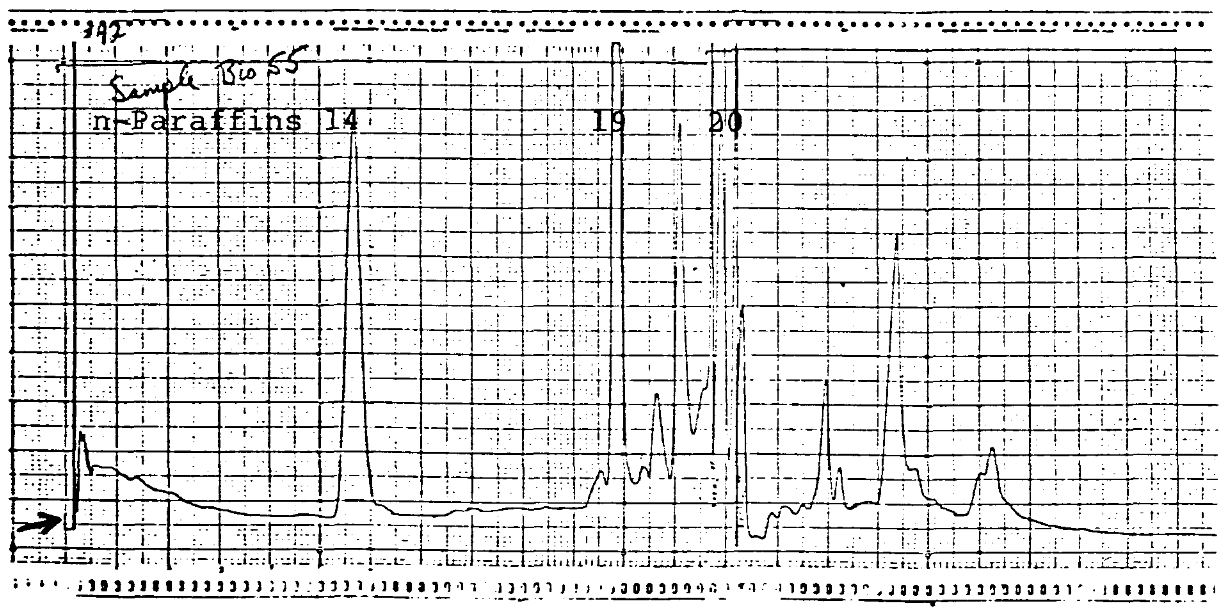


FIGURE 45

Chromatogram of biological sample,

flounder from Niantic Bay

Survey III

A sample of the flounder, *Pseudopleuronectes americanus*, from Survey III (Fig. 45) showed no trace of No. 2 fuel oil. The spike at n-C-14 was a coinjected standard. The large spikes high in the boiling range are typical of biogenic hydrocarbons.

Chromatograms at Beach Stations:

Samples of beach sands from three (3) stations on the Western Shore of Niantic Bay (Fig. 3) were analyzed by gas chromatography. At Station X, situated farthest north, neither the high tide nor the low tide sands within the first 10 cm of the surface bore signs of the No. 2 fuel oil (Figs. 46 and 47). At Station Y, in the vicinity of subtidal Station A, chromatograms of the top 10 cm of sand at both high tide (Fig. 48) and low tide (Fig. 49) showed no evidence of No. 2 fuel oil. Samples were analyzed from the high tide zone at Station Y, 20-30 cm below the surface (Fig. 50) and the low tide at Station Y, 10-20 cm below the surface (Fig. 51). If any No. 2 fuel oil was present, it was highly weathered and chemically degraded, with severe truncations of the lower boilers and chemically altered peaks. The dominant hydrocarbons were most probably biogenic. The peaks at n-C-14 were from the coinjection of a standard. At Station Z, high-tide samples 0-10 cm deep (Fig. 52) and low-tide samples 20-30 cm deep (Fig. 53) showed no definitive evidence of the fuel oil.

The beach sands along the western shore of Niantic Bay were very coarse. The coarsest sands occurred at Station Y, in the low tide area, which is a section of Crescent Beach which appeared to be most heavily contaminated with oil. Profiles for the sand grain size are included in the Appendix, Figures A-1 to A-18. All three of these beach areas were well exposed to wave action, and the oil was apparently washed away by the time these samples were taken sixteen (16) days after the spill.

Synthesis of Results:

The location of residual No. 2 fuel oil in the Niantic Bay area did not coincide with the visual sightings of oil concentrations made on the water surface and shorelines during the first few days following the spill. At that time the western shore of Niantic Bay was believed to be the most heavily contaminated area. The stormy

Redrawn to facilitate interpretation of right-to-left strip chart record.

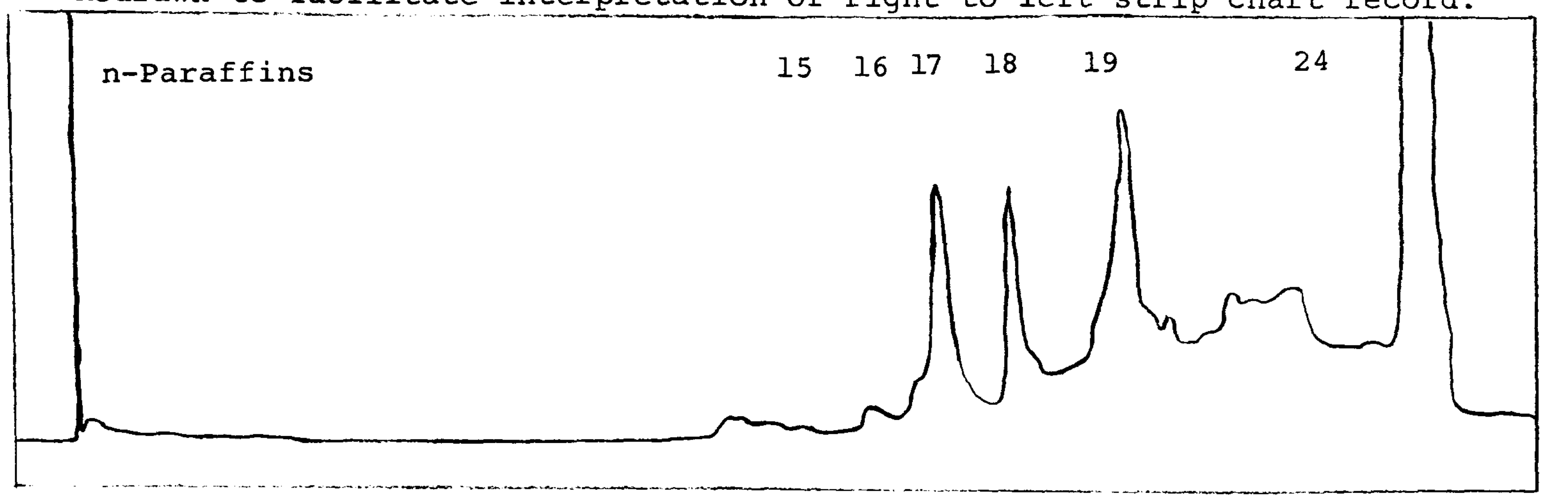


FIGURE 46

Chromatogram of beach sand, Station X,

high tide, surface

Survey I

Redrawn to facilitate interpretation of right-to-left strip chart record.

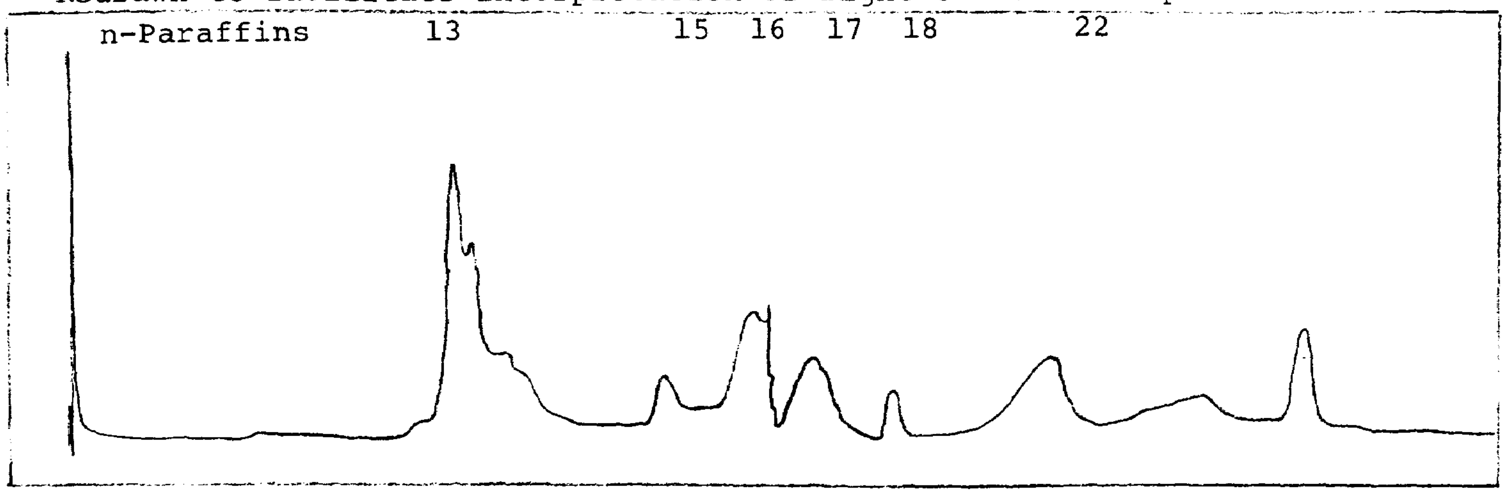


FIGURE 47

Chromatogram of beach sand, Station X, low tide,

surface

Survey I

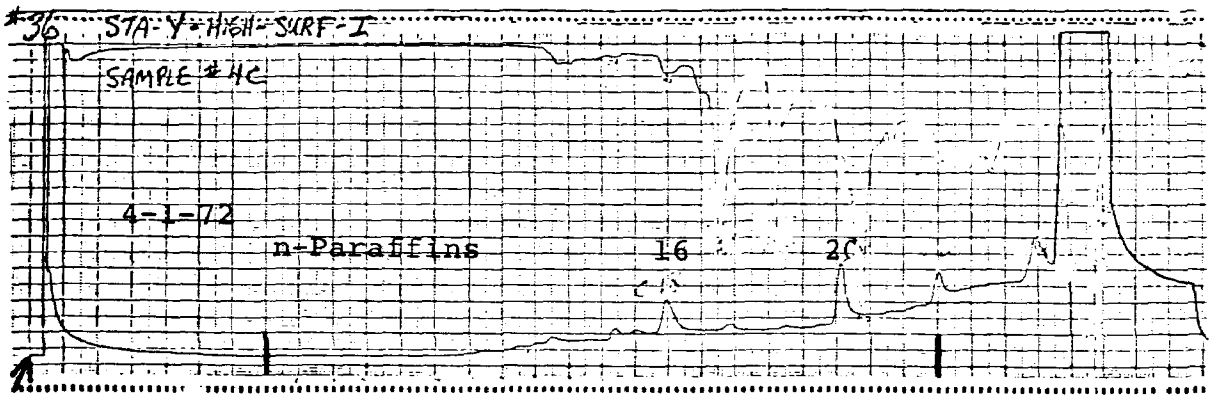


FIGURE 48

Chromatograms of beach sand, Station Y,

high tide, surface

Survey I

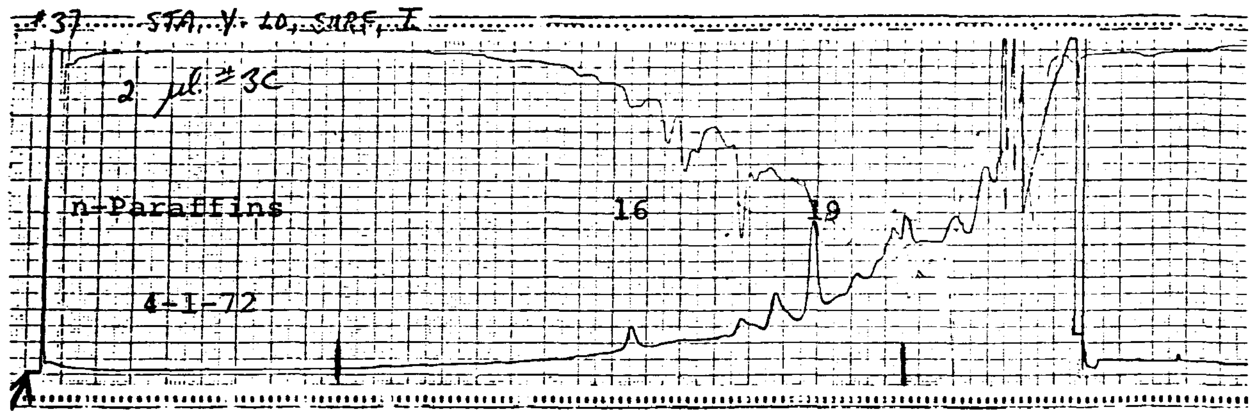
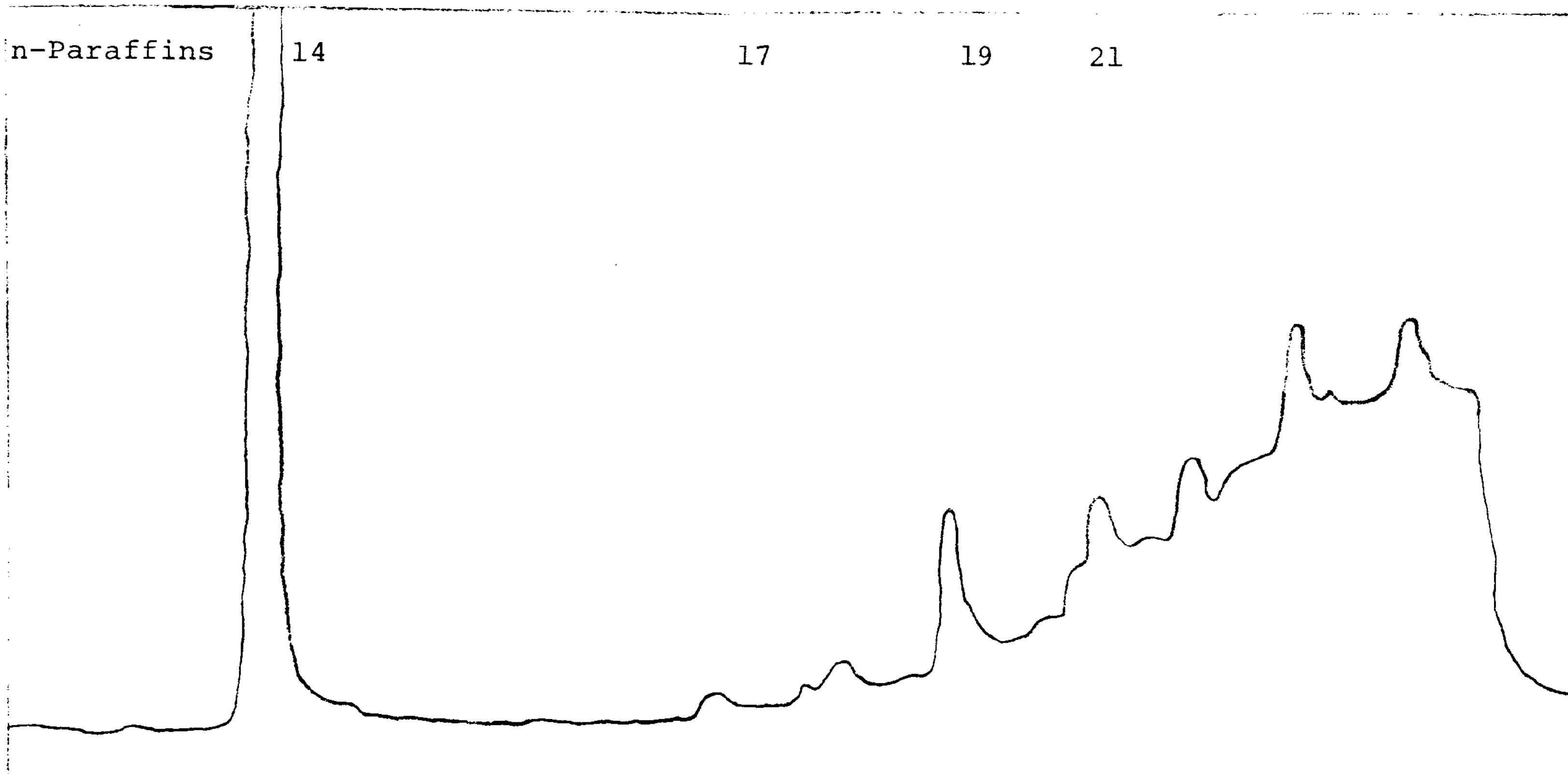


FIGURE 49

Chromatograms of beach sand, Station Y,

low tide, surface

Survey I



Redrawn to facilitate interpretation of right-to-left strip chart record.

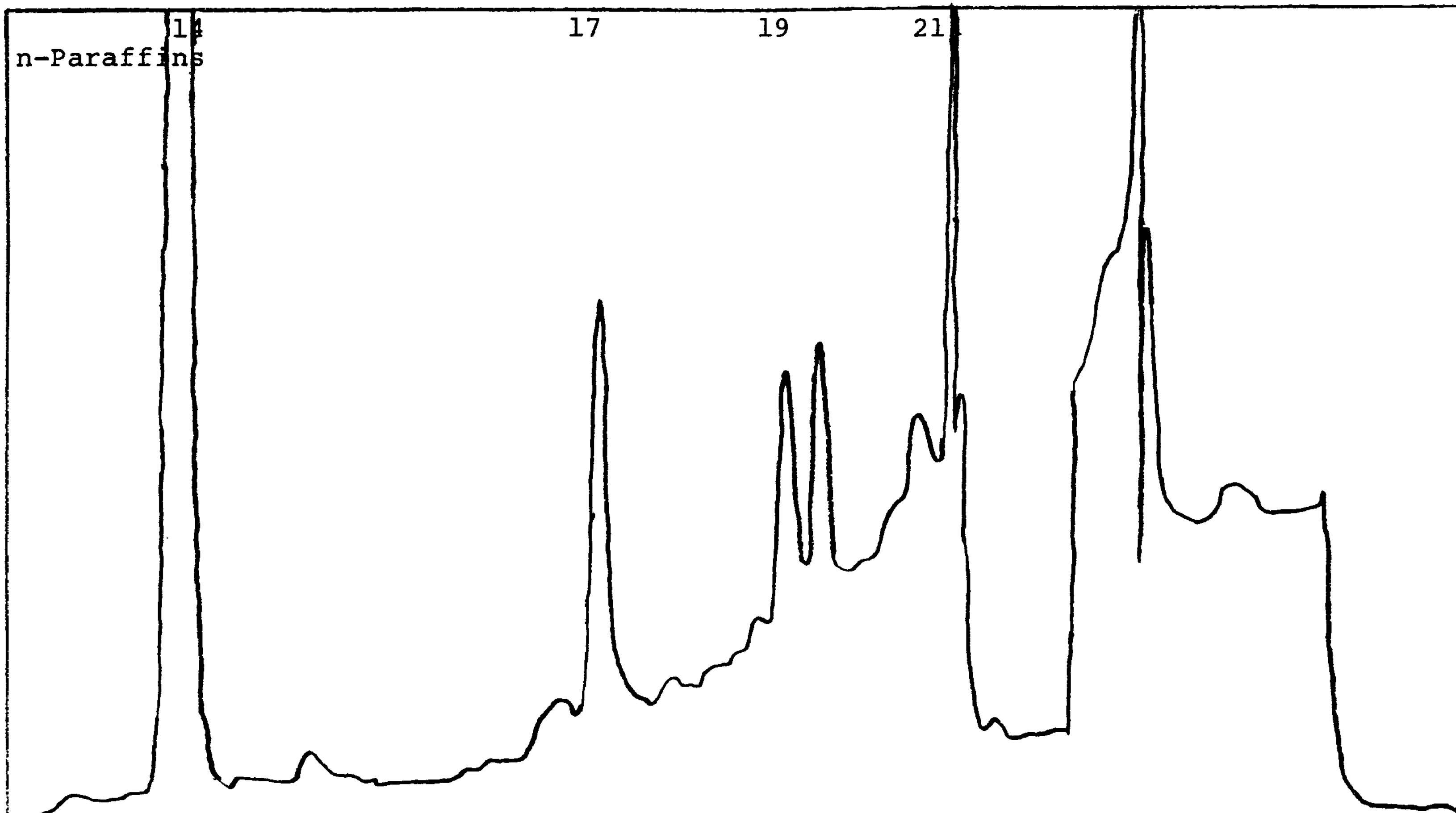
FIGURE 50

Chromatogram of beach sand, Station Y,

high tide, 20-30 cm deep

Spiked with C-14

Survey I



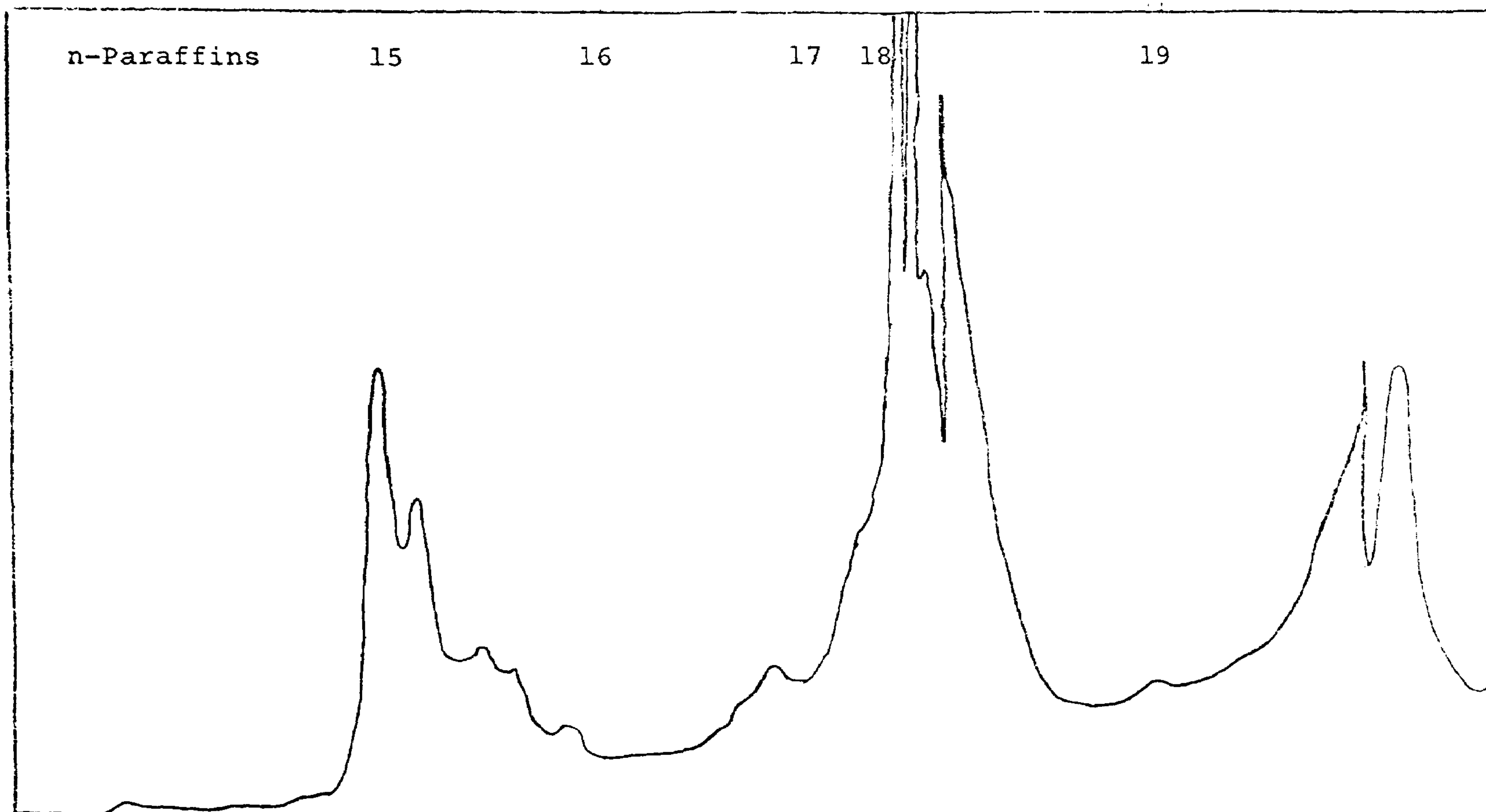
Redrawn to facilitate interpretation of right-to-left strip chart record.

FIGURE 51

Chromatogram of beach sand, Station Y,

low tide, 10 - 20 cm, spiked with C-14

Survey I



Redrawn to facilitate interpretation of right-to-left strip chart record.

FIGURE 52

Chromatogram of sand sample, Station Z

high tide, surface

Survey I

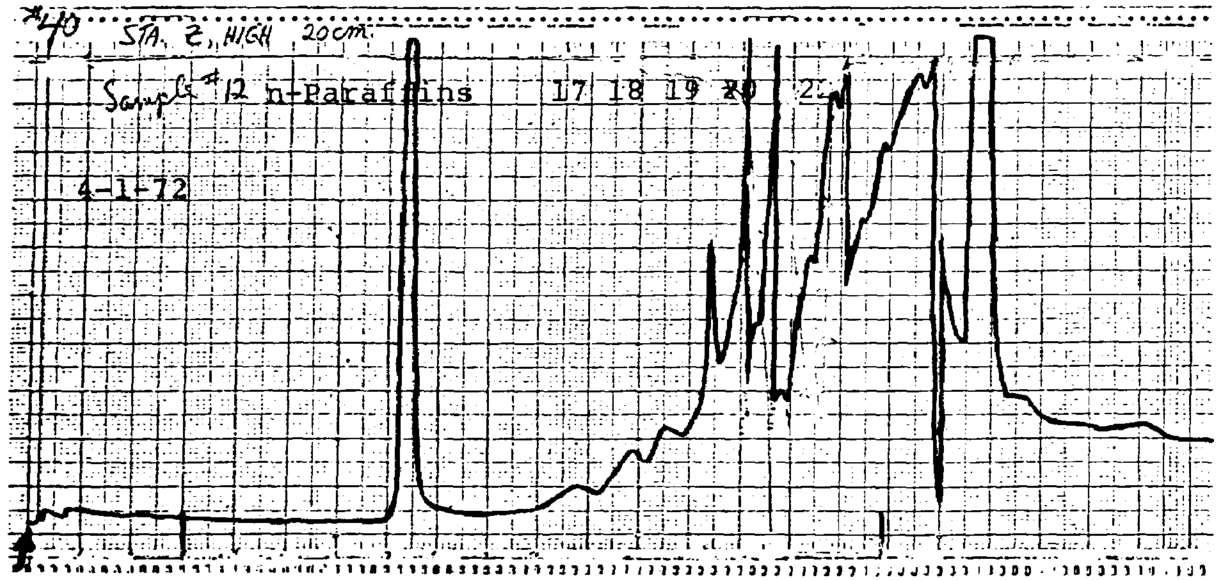


FIGURE 53

Chromatogram of beach sand, Station Z,

low tide, 20 - 30 cm deep

Survey I

weather which occurred within 48 hrs. of the spill was observed to break up and dissipate the heavy concentrations of oil on the surface waters (See Movement of Oil). Coarse sand on both the beaches of the western shore and in the subtidal sediments of the near-shore stations at A and C resulted not only in weathering, but in flushing the fuel oil from the near-shore areas.

The area of greatest residual contamination from the spill was the mid-bay station. This was apparently a result of the current system in the Bay which scoured the shorelines and formed a gyre resulting in a depositional area in mid-bay.

Since we could find no fuel oil in the water column on the first two (2) surveys, yet the hydrocarbon build-up in the sediments continued over the first three (3) surveys, it appeared that the mechanism for continued contamination of Station B was through leaching of intertidal areas and sediment transport. Therefore, the movement of water currents appeared to have ultimately determined the residual concentrations of the pollutant, whereas visual sightings reflected only the immediate effects of the wind.

The severe storm which fortuitously occurred so soon after the spill undoubtedly spared the Niantic Bay area from greater contamination. Although the booms employed to contain the oil and absorbent logs were relatively ineffective, heavy winds and seas dissipated the heavy concentrations of oil. Some heavy intertidal kills were reported immediately after the spill (see Immediate Effects). These coincided with isolated areas of heavy intertidal pollution. There was apparently no ubiquitous uptake of oil in the tissues of the biota of the area. A limited bacteriological survey by a University of Rhode Island group revealed no build-up of oil decomposing bacteria (Cundell, 1972).

The results of the density and diversity studies conducted at the prime stations agreed with the chromatographic results in that only at Station B was there a suspected loss of species (amphipods) attributable to the toxic effects of No. 2 fuel oil. Furthermore, it was apparent from the chromatographic analyses that all organisms did not incorporate No. 2 fuel oil in their tissues to the same degree. *Pagurus* tended to concentrate the oil to a greater extent than *Busycon, Homarus* or *Mercenaria,* and since the presence of the oil was more apparent in the hermit crab tissues than in the sediments, it suggested that this crab would be a good indicator species to detect low levels of pollution by No. 2 fuel oil. The stress of the No. 2 fuel oil may have been the cause of the depleted numbers of hermit crabs in the Epibenthic Survey at Station B during Surveys III, IV and V.

ACKNOWLEDGEMENT

We are most grateful to Dr. John Farrington and Dr. Max Blumer of WHOI for their assistance with our chromatographic techniques, and to Carl Eidam, EPA field coordinator, Region I, for guidance throughout the study.

REFERENCES

Blumer, M., G. Souza and J. Sass, 1970. Hydrocarbon pollution of edible shellfish by an oil spill. Mar. Biol. 5:195-202.

Blumer, M. and J. Sass. 1972. The West Falmouth oil spill. II. Chemistry. WHOI Tech. Rept. 72-19.

Burns, K.A. and J. Teal. 1971. Hydrocarbon incorporation into the salt marsh ecosystem from the West Falmouth oil spill. WHOI Tech. Rept. 71-69.

Cundell, A.M. 1972. A report on the status of oil decomposing bacteria in Niantic Bay, Connecticut. Unpub. ms.

Kollmeyer, Ronald C. 1972. A study of the Niantic River Estuary, Niantic, Connecticut. ONR Rept. #RDCGA 18.

Sanders, H. 1956. Oceanography of Long Island Sound 1952-1954. X. The biology of marine bottom communities. Bull. Bing. Oceanogr. Coll. XV:345-414.

Sanders, H., J. F. Grassle and G. R. Hampson. 1972. The West Falmouth oil spill. I. Biology. WHOI Tech. Rept. 72-20.

Youngblood, W.W., M. Blumer, R. L. Guillard, F. Fiore. 1971. Saturated and unsaturated hydrocarbons in marine benthic algae. Mar. Biol. 8:190-201.

GLOSSARY

ALGAE	Common Name
Ascophyllum nodosum	Knotted Wrack
Chondrus crispus	Irish Moss
Codium fragile	Codium
Fucus sp.	Rockweed
Laminaria sp.	Kelp
Ulva lactuca	Sea Lettuce
ANNELIDA	
Nereis virens	Clam Worm
ARTHROPODA	
Balanus sp.	Barnacles
Callinectes sapidus	Blue Crab
Cancer irroratus	Rock Crab
Crangon septemspinosa	Sand Shrimp
Homarus americanus	American Lobster
Libinia sp.	Spider Crab
Ovalipes ocellatus	Lady Crab
Pagurus sp.	Hermit Crab
CHORDATA	
Anguilla rostrata	Common Eel
Brevoortia tyrannus	Menhaden
Citharichthys sordidus	Sand Dab
Gadas callarias	Cod Fish

Chordata - continued	Common Name
Hippoglossoides platessoides	Sculpin
Paralichtys denatus	Fluke
Pholis gunellus	Rock Eel
Poronotus tricanthus	Butterfish
Prionotus carolinus	Sea Robin
Pseudospleuronectes americanus	Winter Flounder
Raja erinacea	Skate
Stenotomus chrysops	Northern Porgy
Tautoga onitis	Black Fish
Tantogolabrus odspersus	Cunner
COELENTERATA	
Cyanea capillata	Pink Jellyfish
ECHINODERMATA	
Asterias forbesi	Common Starfish
MOLLUSCA	
Anadara ovalis	Blood Ark
Astarte castanea	Astarte
Busycon sp.	Welk
Crepidula sp.	Slipper Shell
Ensis directus	Jackknife Clam
Eupleura caudata	Thick Lipped Drill

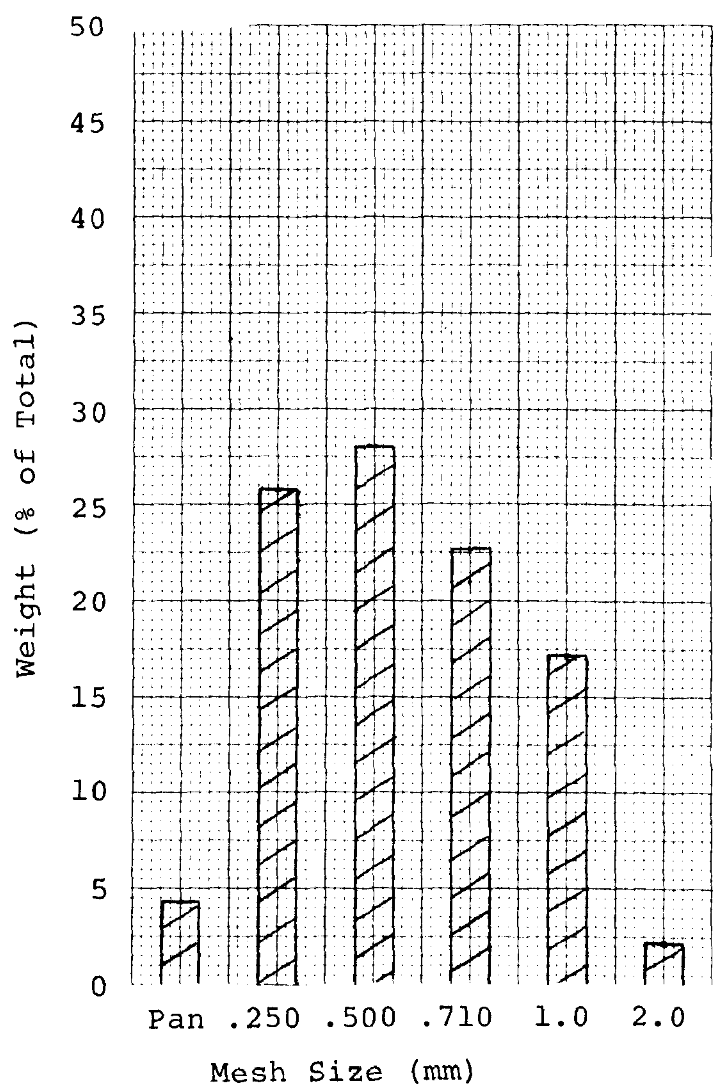
Mollusca - continued	Common Name
Littorina sp.	Periwinkles
Loligo pealei	Squid
Mercenaria mercenaria	Quahog
Mitrella lunata	Lunar Dove-Shell
Mytilus edulis	Blue Mussel
Mya arenaria	Soft Shell Clam
Nassarius trivittatus	New England Nassa
Nucula proxima	Atlantic Nut Clam
Pitar morrhuana	Morrhua Venus
Polinices sp.	Moon Shell
Retusa canaliculata	Channeled Bubble Barrel
Tellina versicolor	Dwarf Tellin
Solemya velum	Common Atlantic Awning Clam
Urosalpinx cinereus	Oyster Drill
PORIFERA	
Haliclona loosanoffi	Sponge
Cliona celata	Boring Sponge

APPENDIX

FIGURE A-1

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION X

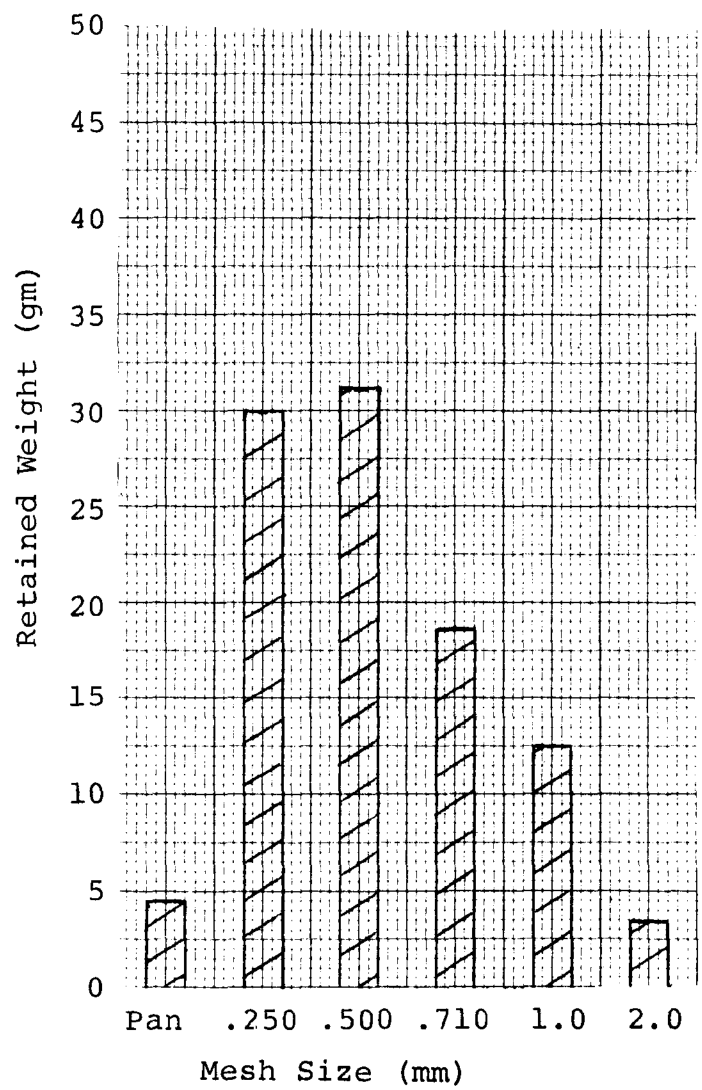


Depth: Low Tide 0-10 cm

FIGURE A-2

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION X

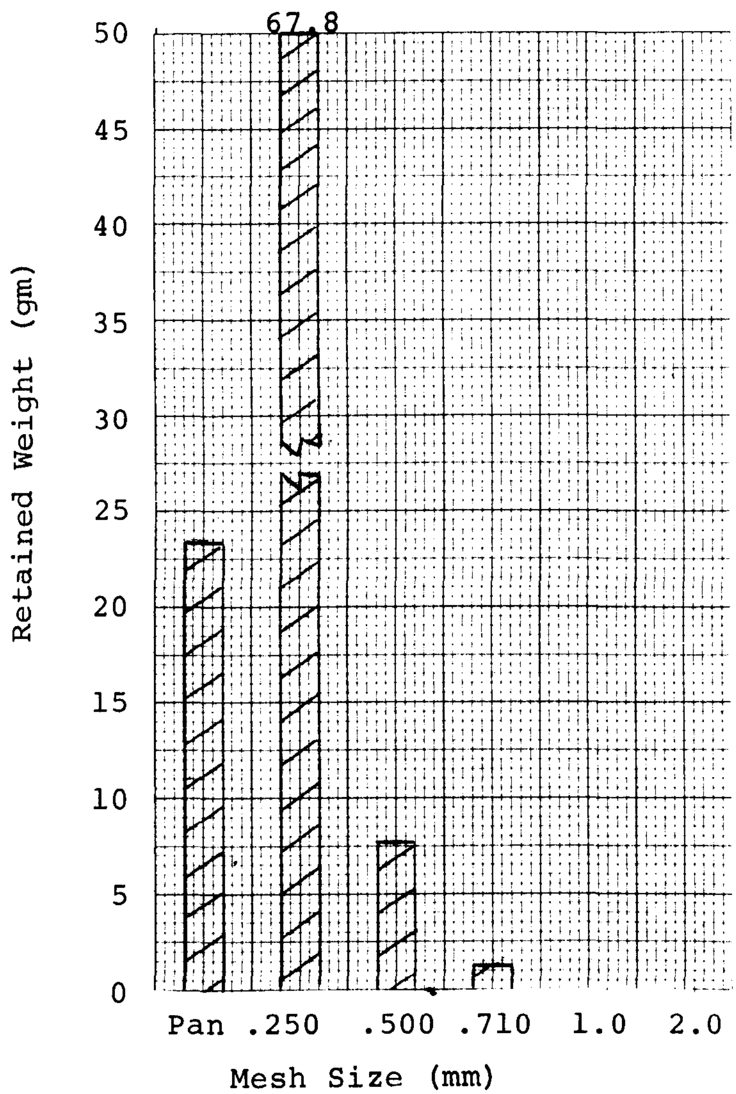


Depth: Low Tide 10-20 cm

FIGURE A-3

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION X

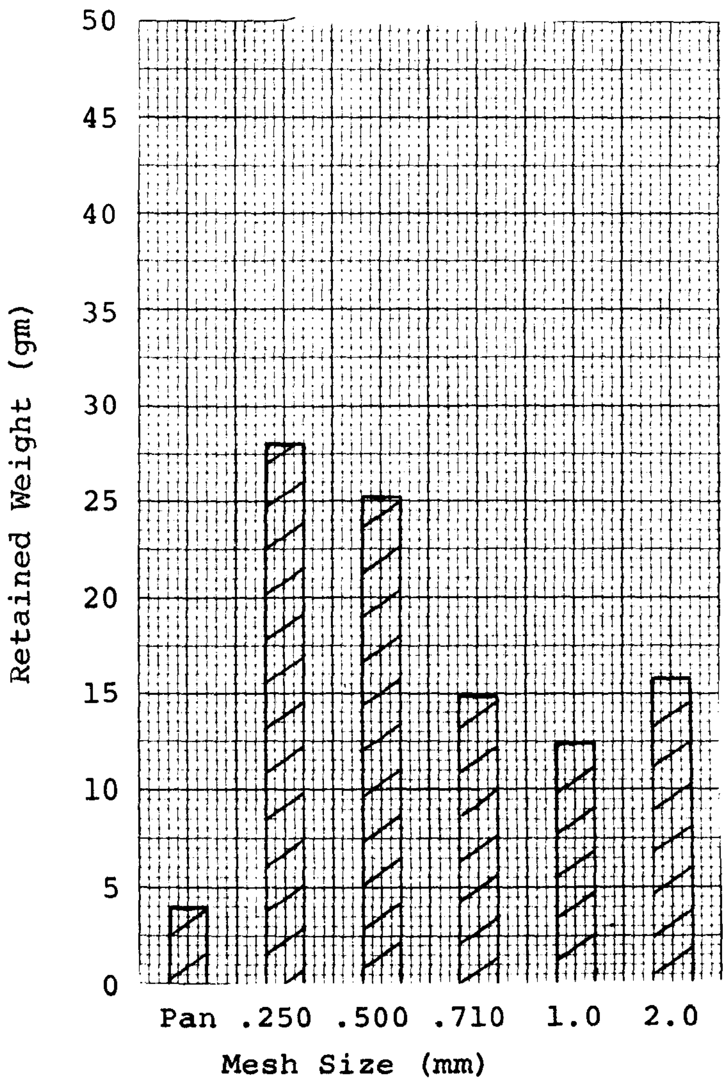


Depth: High Tide 0-10 cm

FIGURE A-4

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION X

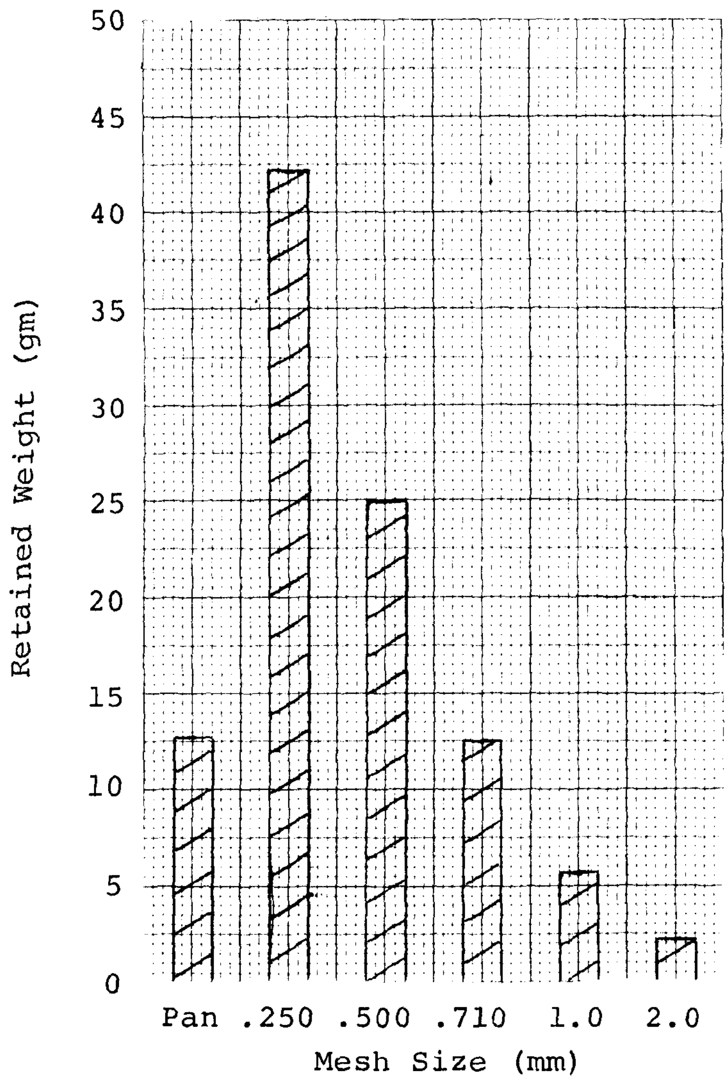


Depth High Tide 10-20 cm

FIGURE A-5

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION X

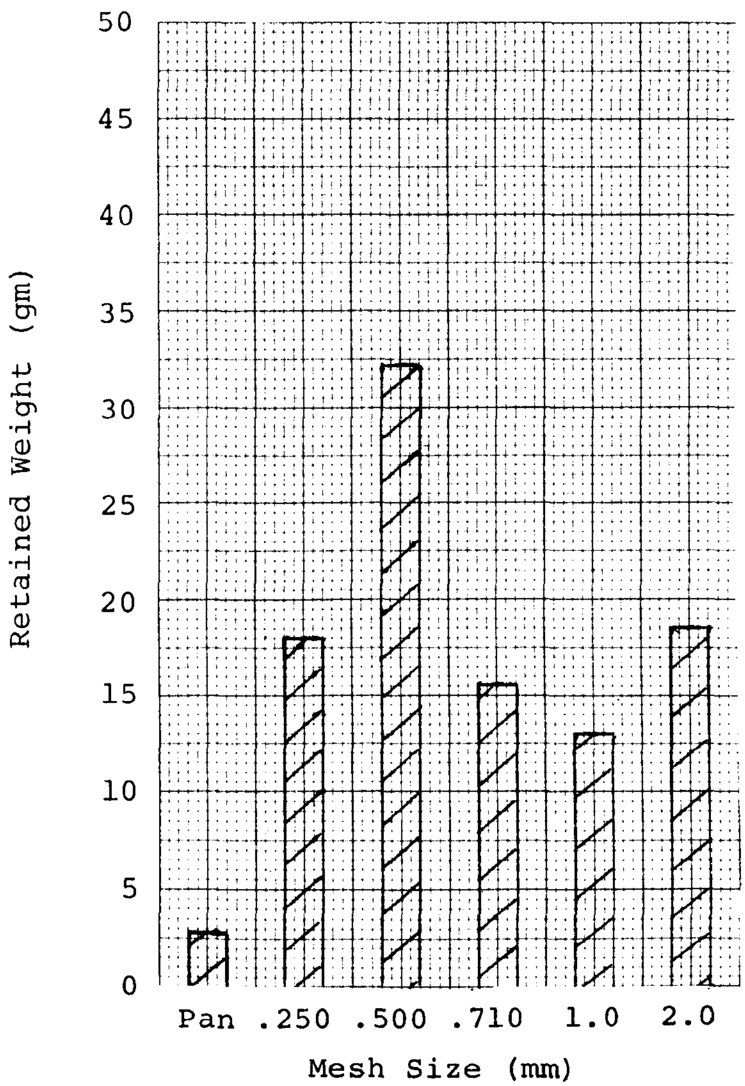


Depth: High Tide 20-30 cm

FIGURE A-6

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Y

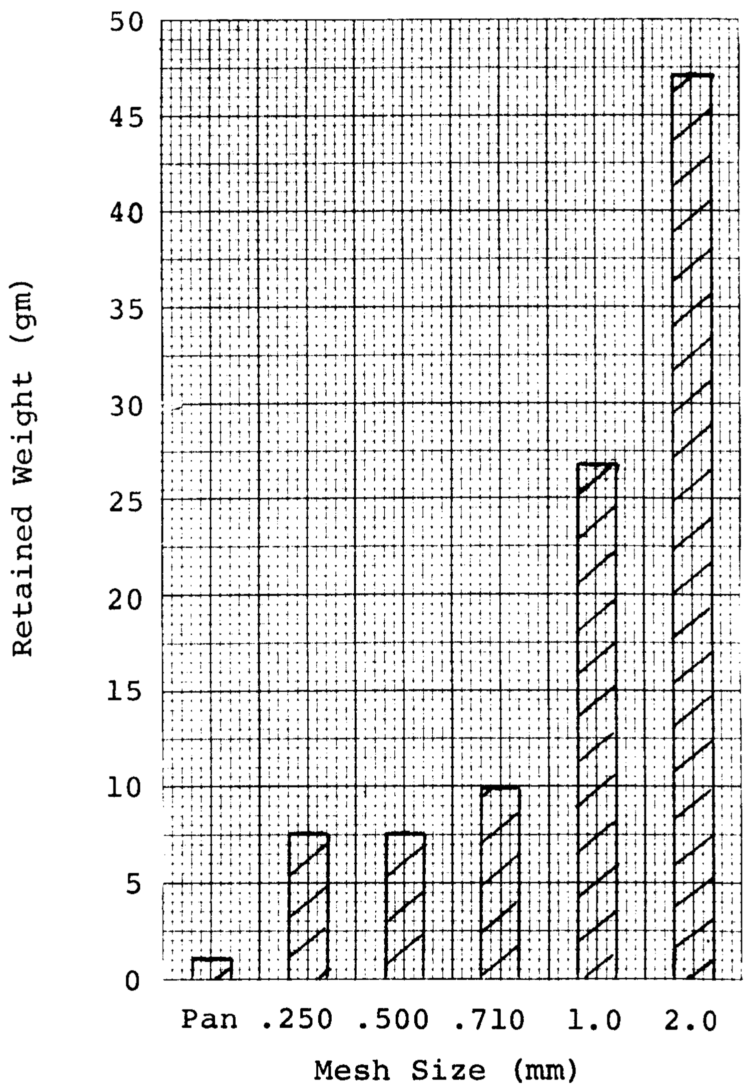


Depth: Low Tide 0-10 cm

FIGURE A-7

Beach Sediment Profiles (gm retained per 100 gm of sample)

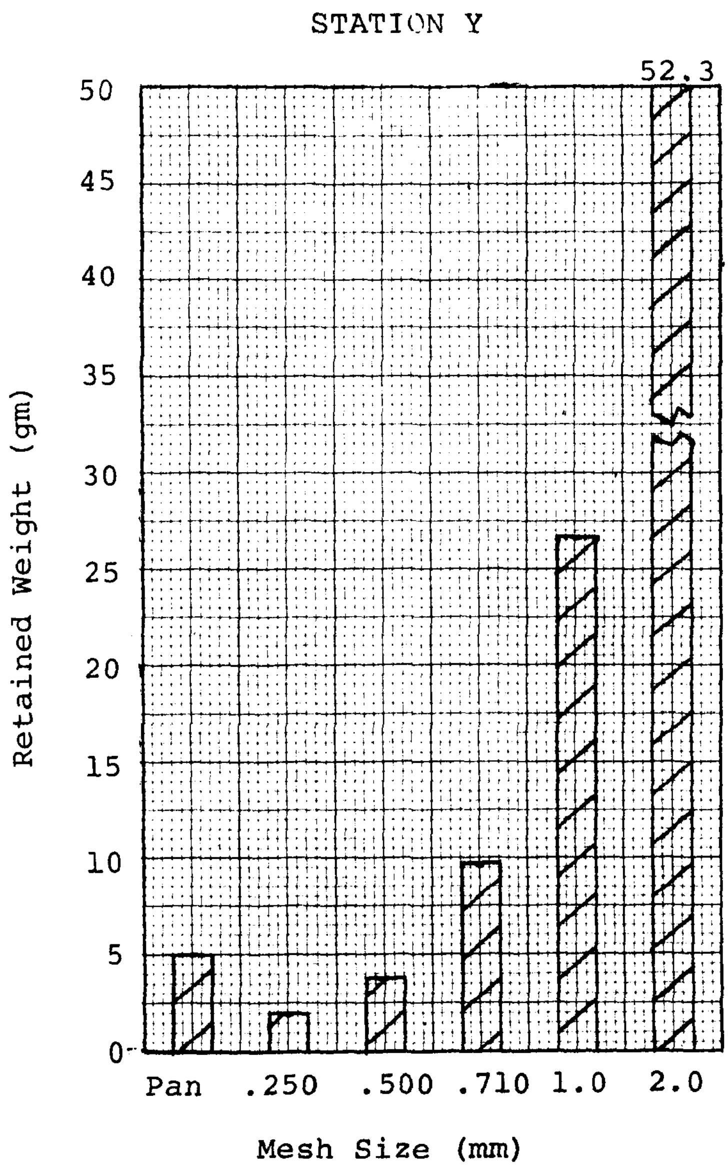
STATION Y



Depth: Low Tide 10-20 cm

FIGURE A-8

Beach Sediment Profiles (gm retained per 100 gm of sample)

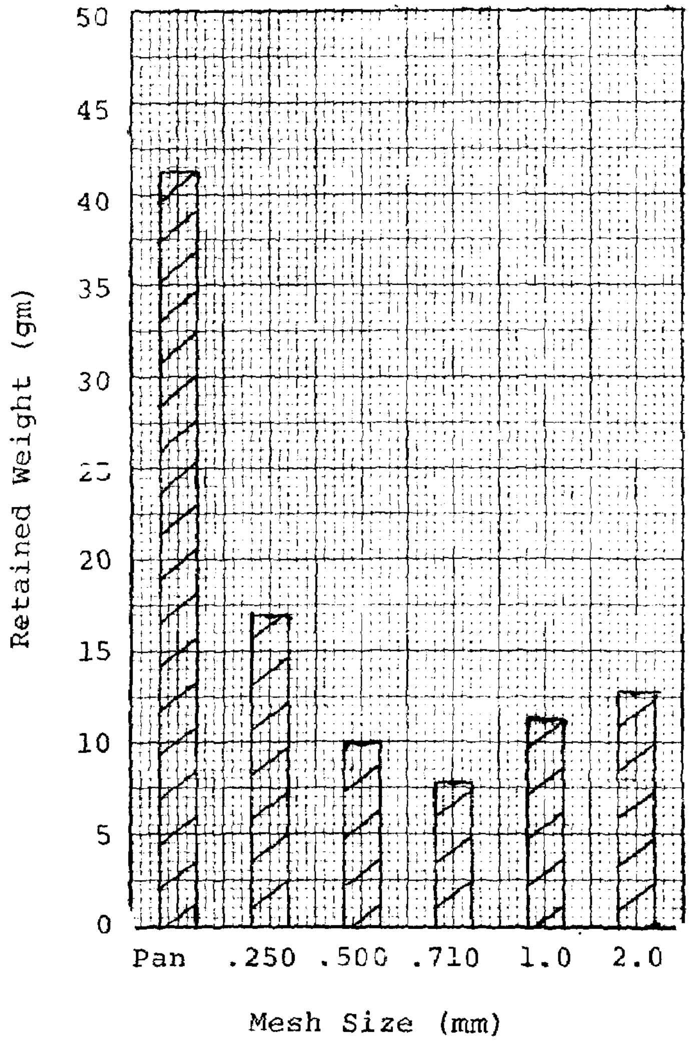


Depth: 20-30 cm Low Tide

FIGURE A-9

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Y

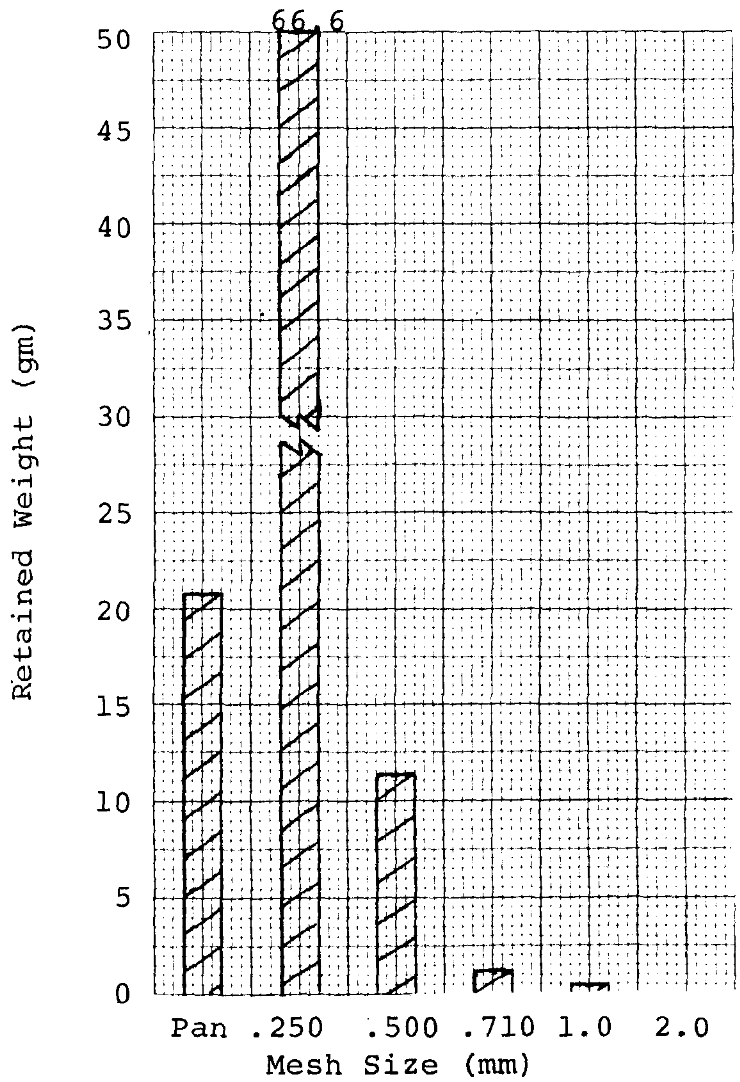


Depth: 30-40 cm Low Tide

FIGURE A-10

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Y

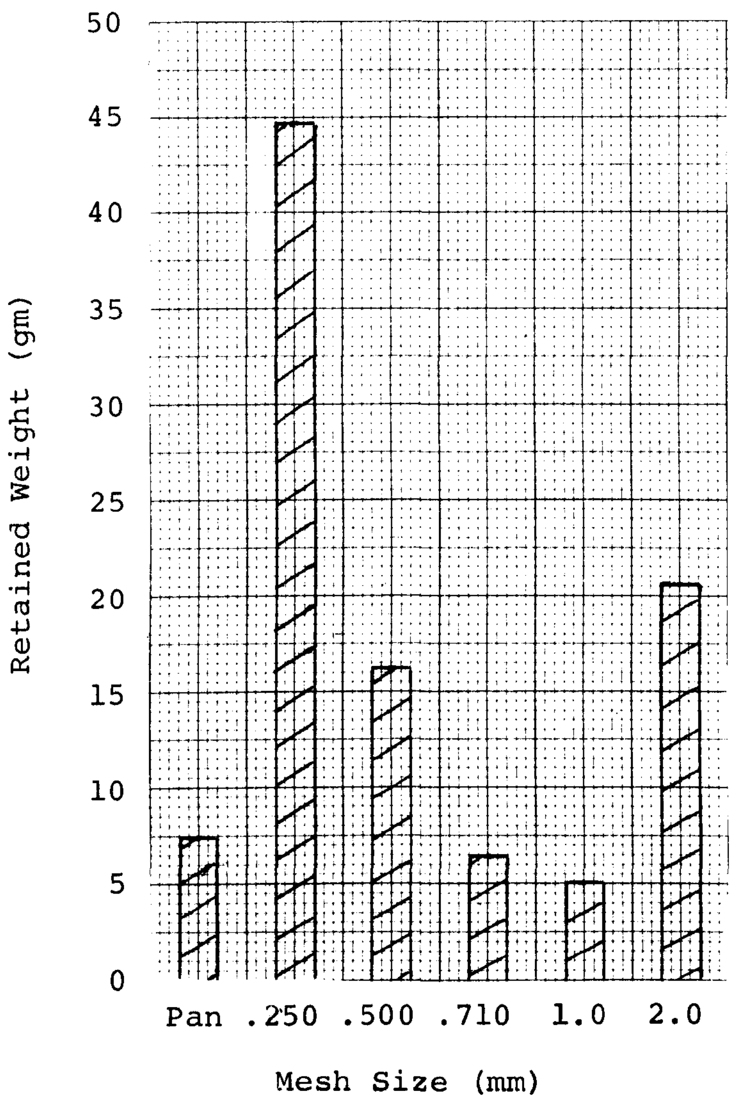


Depth: High Tide 0-10 cm

FIGURE A-11

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Y

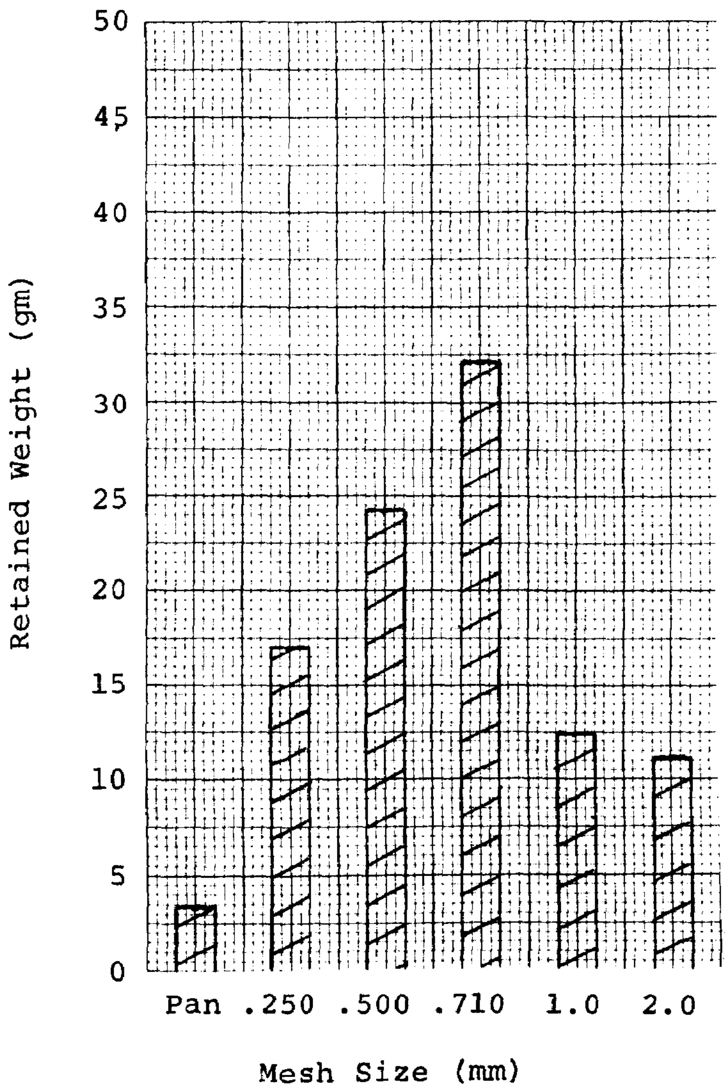


Depth: High Tide 10-20 cm

FIGURE A-12

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Y

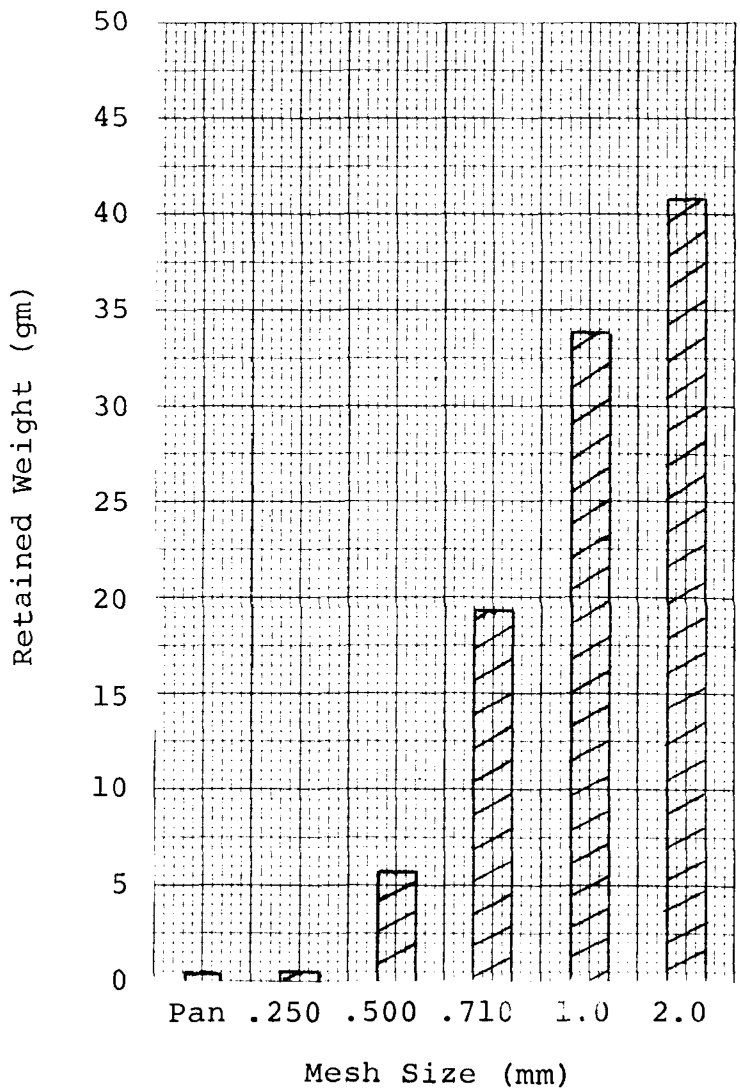


Depth: High Tide 20-30 cm

FIGURE A-13

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Z

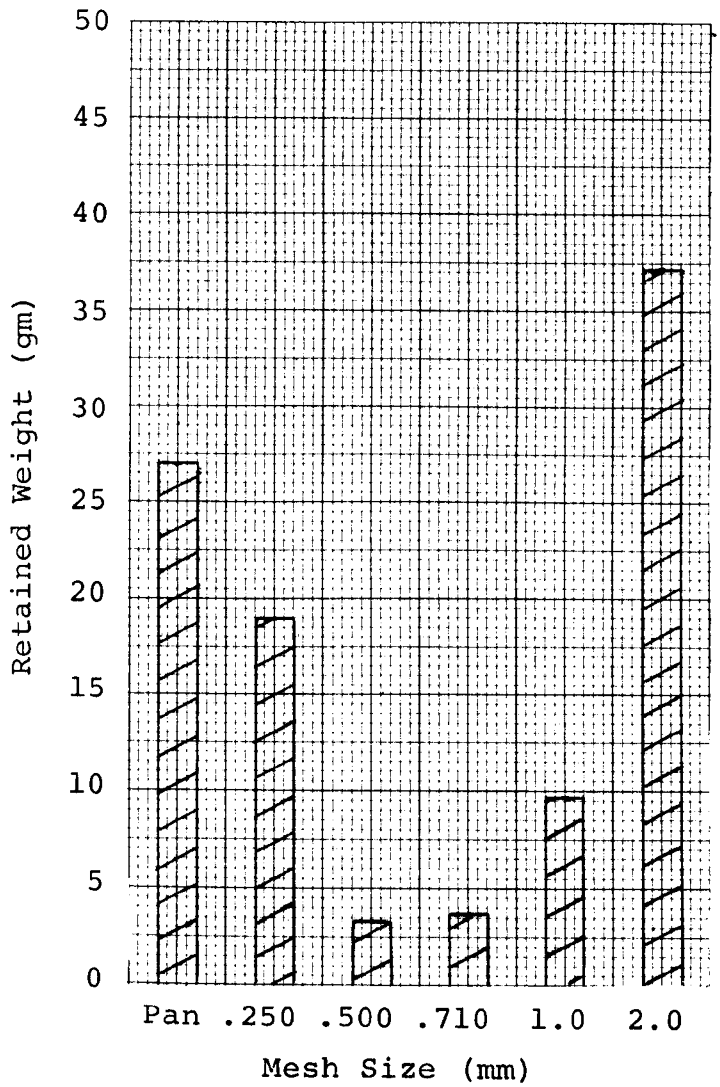


Depth: Low Tide 0--10 cm

FIGURE A-14

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Z

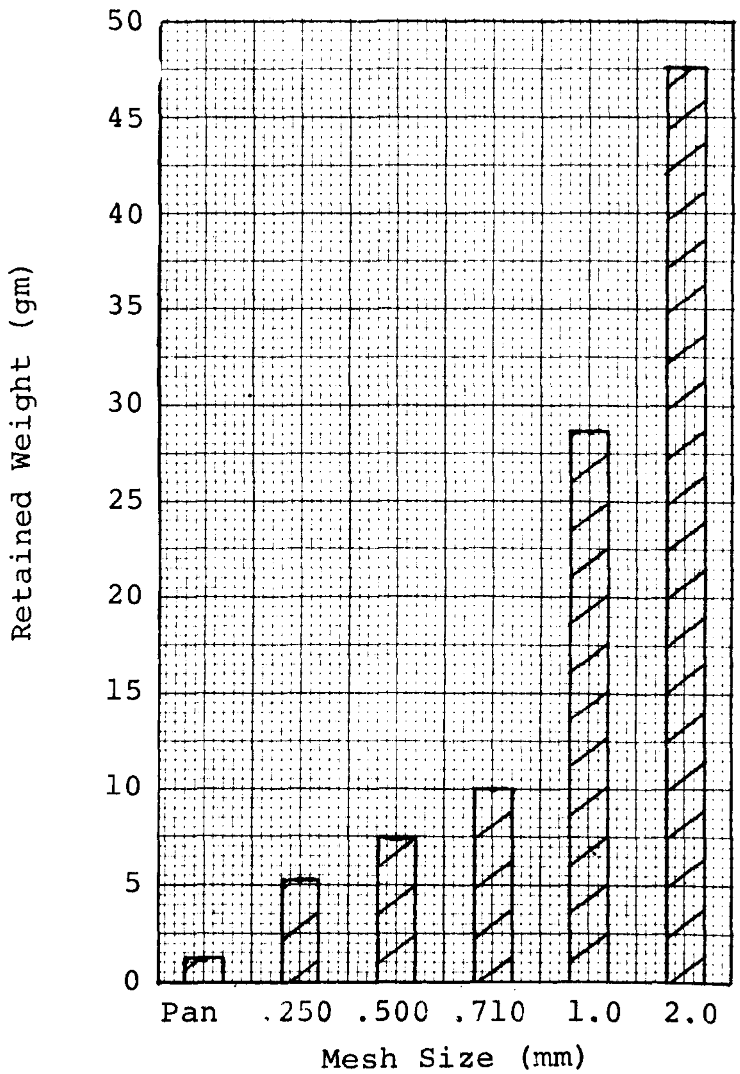


Depth: Low Tide 10-20 cm

FIGURE A-15

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Z

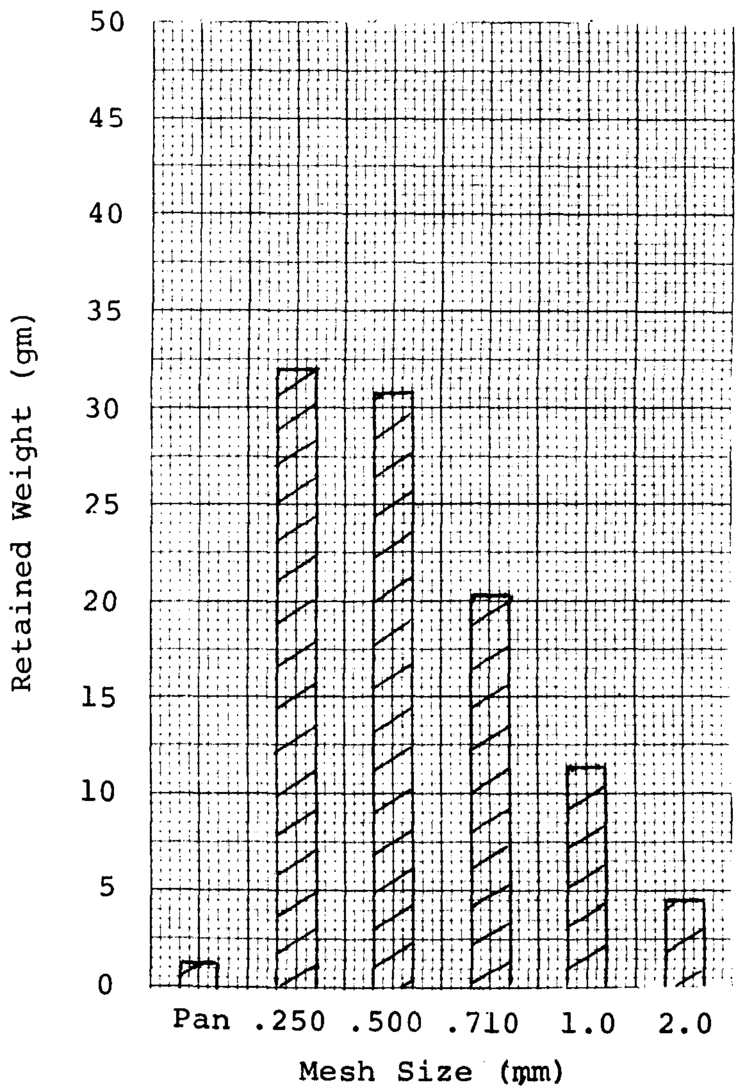


Depth: 20-30 cm Low Tide

FIGURE A-16

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Z

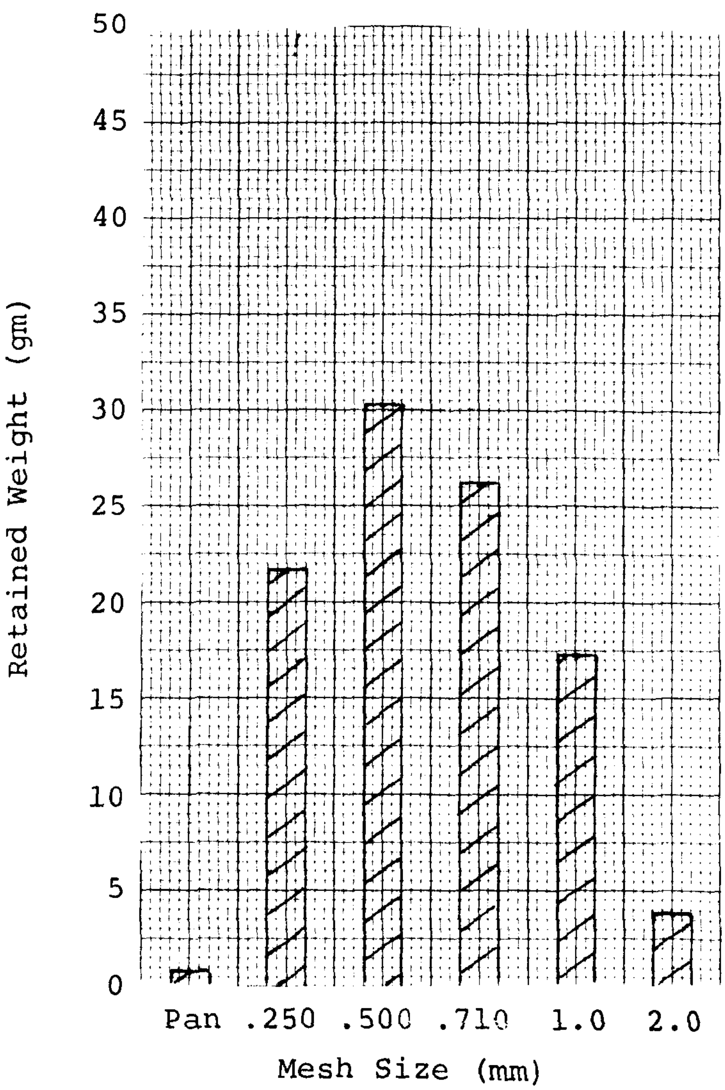


Depth: High Tide 0-10 cm

FIGURE A-17

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Z

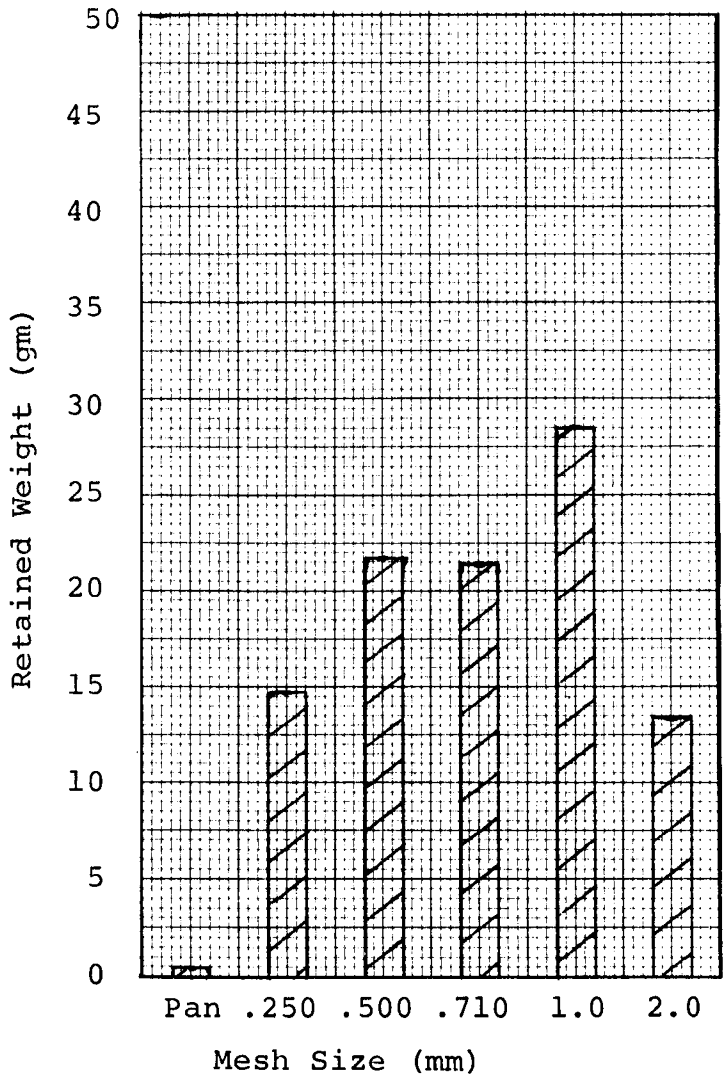


Depth: High Tide 10-20 cm

FIGURE A-18

Beach Sediment Profiles (gm retained per 100 gm of sample)

STATION Z



Depth: 20-30 cm High Tide

TABLE A-1

Temperature and Salinity Measurements at the Prime Stations

Survey			I	II	III	IV	V	VI
Station Control	Surface	°C	4.5	4.5	11.0	13.8	17.8	20.2
		°/oo	26.5	28.0	26.5			25.1
	Bottom	°C	3.9	4.5	8.4	12.2	15.6	18.3
		o/oo	27.5	27.5	25.3			25.0
Station A	Surface	°C	4.5	4.5	11.8	14.2	20.0	23.0
		°/oo	27.5	27.0	23.0			25.1
	Bottom	°C	4.2	4.5	8.4	12.8	16.7	18.9
		°/oo	27.5	27.0	24.8			25.2
Station B	Surface	°C	4.5	4.0	10.0	15.0	16.9	21.7
		°/oo	26.5	28.0	24.5		25.2	
	Bottom	°C	4.5	4.5	8.3	12.0	15.6	17.2
		°/oo	28.0	28.0	25.2			25.3
Station C	Surface	°C	5.3	5.0	11.0	15.5	16.7	22.0
		°/oo	27.0	28.0	25.5			25.2
	Bottom	°C	5.0	4.5	8.9		15.0	17.8
		°/oo	28.0	28.0	26.7			25.3

TABLE A -2
BENTHIC SURVEY
ORGANISMS PRESENT PER 0.36 m^2 AT STATION A

Survey No.:	I	II	III	IV	V	VI
CRUSTACEA						
Amphipod A	10		1		56	4
B				2	10	
C					15	
D	10	2		3	13	
G			2	12		
Libinia emarginata				1		
Pagurus longicarpus	20	8		8	7	
TOTAL	40	10	3	26	101	4
NO. OF SPECIES	3	2	2	5	5	1
MOLLUSCA						
Astarte borealis					2	
Astarte castanea	2					
Bittium alternatum		2			15	
Ensis directus				3	2	1
Eupleura caudata	2					
Macoma tenta			1			
Mercenaria mercenaria		14		1		
Mitrella lunata	2					
Nassarius trivittatus	2		1	1	1	
Nucula proxima		6		1	4	
Polinices triseriata		2	1		1	

Survey No.:	I	II	III	IV	V	VI
Solemya velum					1	1
Urosalpinx cinereus	4					
TOTAL	12	24	3	6	26	2
NO. OF SPECIES	5	4	3	4	7	2
POLYCHAETA						
Cirratulus cirratus			1			
Clymenella torquata			1	5	1	
Eteone sp						1
Nepthys picta						4
Nepthys sp			1	1		4
Nereis grayi				1		5
Pectinaria gouldii			1		1	
Phyllodocid sp					2	2
Platynereis dumerilii						1
Scaled worm						1
Unknown species					2	
TOTAL			4	7	6	19
NO. OF SPECIES			4	3	4	8

TABLE A-3
BENTHIC SURVEY
ORGANISMS PRESENT PER 0.36 m^2 AT STATION B

Survey No.:	I	II	III	IV	V	VI
CRUSTACEA						
Amphipod A	2		1	2	1	1
B	2	2			10	6
C	8					
D	8	2			5	1
G					2	
Pagurus longicarpus		2			1	1
TOTAL	20	6	1	2	19	9
NO. OF SPECIES	4	3	1	1	5	4
MOLLUSCA						
Bittium alternatum	60	190	44	60	41	26
Crepidula fornicata						2
Crepidula plana						1
Macoma tenta	6	4		3	4	4
Mercenaria mercenaria	8				3	1
Nassarius trivittatus				1		
Nucula proxima	224	326	210	1,204	1,065	886
Polinices duplicata					1	
Polinices triseriata				1		2
Retusa canaliculata				1	3	
Tellina versicolor					3	4
Yoldia limatula	8		4	2	17	11

Survey No.:	I	II	III	IV	V	VI
MOLLUSCA						
TOTAL	306	520	258	1,272	1,137	937
NO. OF SPECIES	4	3	3	7	8	9
POLYCHAETA						
Clymenella torquata		4	8	75	108	150
Eteone sp						4
Lepidonotus squamatus			9			
Lumbrineris tenuis		2		7	1	1
Myriochele heeri					1	
Nereis				1		
Nepthys incisa			1	23	33	31
Nepthys picta					7	
Nepthys		4	15			
Phyllodocid sp					1	
Platynereis sp		2				
Sabellid-unknown						1
Unknown sp			1	2		
TOTAL		12	34	108	151	187
NO. OF SPECIES		4	5	5	6	5

TABLE A-4
BENTHIC SURVEY
ORGANISMS PRESENT PER 0.36 m^2 AT STATION C

Survey No.:	I	II	III	IV	V	VI
CRUSTACEA						
Amphipod A	2	12	10	82	51	174
B	4	2		11	51	14
C			1	19	25	11
D	8	2	10		11	
G	30	48	9	11	28	6
Crangon septemspinosa	2					
Isopod					1	
Libinia dubia			1			
Pagurus longicarpus	4	2	1	2	7	
TOTAL	50	66	31	125	174	205
NO. OF SPECIES	6	5	5	5	7	4
MOLLUSCA						
Anadara ovalis			1	2		2
Astarte castanea		2	1	1		3
Bittium alternatum	4	2		1	2	
Crepidula sp						1
Ensis directus			2		2	3
Eupleura caudata	2				1	1
Littorina obtusata				2		
Macoma tenta			4		2	4
Mercenaria mercenaria				1	1	
Nassarius obsoletus					1	

Survey No.:	I	II	III	IV	V	VI
Nassarius trivittatus	2			1	1	
Nucula proxima	18					
Polinices duplicatus					2	1
Polinices triseriata				1		1
Tellina versicolor						2
Urosalpinx cinereus	6			2		1
Yoldia limatula	10					
TOTAL	42	4	9	11	12	19
NO. OF SPECIES	6	2	5	8	8	10
POLYCHAETA						
Clymenella torquata			1		4	19
Diopatra cuprea			2		1	
Drilonereis longa						2
Eteone lactea			1			1
Glycera sp						6
Lumbrineris acuta						2
Lumbrineris tenuis						16
Lumbrineris sp				1	1	
Myriochele heeri						1
Nereis sp				1	2	
Nepthys incisa			7	1	3	15
Nepthys picta				1		21
Nicolea venustula						2
Pectinaria gouldii			1	3	7	2
Pherusa affinis						3
Platyrereis dumerilii					1	
Sphaerodaorum gracilis			1			
Terebellid sp					7	

Survey No.:	I	II	III	IV	V	VI
Bamboo sp						8
Unknown annelid				1	1	2
TOTAL			13	8	26	100
NO. OF. SPECIES			6	6	8	15

TABLE A-5
BENTHIC SURVEY
ORGANISMS PRESENT PER 0.36 m^2 AT STATION CONTROL

Survey No.:	I	II	III	IV	V	VI
CRUSTACEA						
Amphipod A	16	4	12	58	39	402
B	4		1	13	43	72
C				64	46	52
D	1872	86	485	920	13	18
G	2	6			7	109
Crangon septemspinosa	20					
TOTAL	1914	96	498	1,055	148	653
NO. OF SPECIES	5	3	3	4	5	5
MOLLUSCA						
Bittium alternatum	4		1	11	11	5
Macoma tenta					1	3
Mercenaria mercenaria						1
Mitrella lunata					3	
Nassarius trivittatus	2		1	2	2	
Nucula proxima	330	118	112	375	229	471
Pitar morrhuana			1			
Retusa canaliculata	2			2	1	9
Tellina versicolor					1	
Yoldia limatula	4		4	4	6	19
TOTAL	342	118	119	394	254	508
NO. OF SPECIES	5	1	4	5	8	6

Survey No.:	I	II	III	IV	V	VI
POLYCHAETA						
Clymenella torquata	178	46	122	323	32	164
Diopatra cuprea	2				1	
Glycera sp			2			
Lumbrineris fragilis			1			
Lumbrineris tenuis		4			1	
Nepthys incisa			11	77	16	41
Nepthys picta			4	14		
Nepthys sp	20			7		1
Ninoe nigripes				2		
Terebellid sp				1		2
Unknown sp				1		
TOTAL	200	50	140	425	50	208
NO. OF SPECIES	3	2	5	7	4	4

TABLE A-6
EPIBENTHIC SURVEY
STATION A
Numbers of Individuals Per Transect ($12m^2$)

SURVEY NO. / DATE (all in 1972)	III 5/16	IV 6/7	V 6/29	VI 7/17
SPECIES				
MOLLUSCS				
Crepidula fornicata	48	145		91
Crepidula plana				7
Eupleura caudata	7			7
Littorina obtusata				557
Rissoa sp.	11			14
Retusa canaliculata		18		2
Unidentified gastropods	5	27		
POLYCHAETES				4
CRUSTACEANS				
Crangon septemspinosus	105			29
Ovalipes ocellatus				3
Pagurus longicarpus	529	751		16
Pagurus pollicaris				4
Amphipod sp.	13			15
Isopod sp.	10			5
ECHINODERMS				
Asterias forbesi	5			
TOTALS:	733	941		754

TABLE A-6
EPIBENTHIC SURVEY
STATION B
Numbers of Individuals Per Transect ($12m^2$)

SURVEY NO.	III	IV	V	VI
DATE (all in 1972)	5/16	6/7	6/29	7/17
SPECIES				
MOLLUSCS				
Bittium alternatum		4		
Busycon sp.				68
Crepidula fornicata	4		1	
Eupleura caudata			5	21
Mitrella lunata		2		
Nassarius trivittatus			5	2
Rissoa sp.	490	412	435	2520
Retusa canaliculata	95	161	189	1596
Urosalpinx cinerea		1		
Unidentified gastropods		8	20	
Nucula proxima	4480	1673	2039	1575
Yoldia sp.	45	12	9	
POLYCHAETES			5	
CRUSTACEANS				
Crangon septemspinosus	166	5	1	1
Libinia sp.		1		
Pagurus longicarpus		5	1	1
Pagurus pollicaris		1		42
Amphipod sp.		5	369	43
TOTALS:	5280	2296	3058	5869

TABLE A-6
EPIBENTHIC SURVEY
STATION C
Numbers of Individuals Per Transect ($12m^2$)

SURVEY NO.	III	IV	V	VI
DATE: (all in 1972)	5/16	6/7	6/29	7/17
SPECIES				
MOLLUSCS				
Busycon sp.		3		
Crepidula fornicata	109	39	57	77
Crepidula sp.	47	11	50	
Eupleura caudata		11	37	
Littorina obtusata	314	160	311	280
Mitrella lunata			8	
Nassarius trivittatus			1	
Rissoa sp.		60	237	231
Urosalpinx cinerea			2	
Anadara ovalis	1		1	
Nucula proxima	16	3	60	
Yoldia sp.			7	8
Unidentified bivalves				8
POLYCHAETES	16	66	163	
CRUSTACEANS				
Crangon septemspinosus		33		
Libinia sp.	4			
Ovalipes ocellatus		1		8
Pagurus longicarpus	78	59	52	85
Pagurus pollicaris	3	21	22	
Amphipod sp.		49	274	54
Isopod sp.	3			
ECHINODERMS				
Asterias forbesi	1	11	15	
TOTALS:	592	527	1297	751

TABLE A-6
EPIBENTHIC SURVEY
STATION CONTROL
Numbers of Individuals Per Transect ($12m^2$)

SURVEY NO.	III	IV	V	VI
DATE: (all in 1972)	5/16	6/7	6/29	7/17
SPECIES				
MOLLUSCS				
Crepidula fornicata		4		6
Littorina obtusata		2		
Mitrella lunata		3		
Nassarius trivittatus		4		1
Rissoa sp.	253	43	142	11
Retusa canaliculata	121	182	425	114
Unidentified gastropods		128		19
Nucula proxima	3413	88	1322	266
Yoldia sp.	62	285		
Unidentified bivalves		1		
POLYCHAETES		28		2
CRUSTACEANS				
Crangon septemspinosus		276		
Ovalipes ocellatus				19
Pagurus longicarpus	48	91		39
Pagurus pollicares		2		7
Amphipod sp.	3253	5150	283	3693
Isopod sp.	87	140		
TOTALS:	7217	6427	2172	4177

TABLE A-7

FIN FISH SURVEYS

Number Caught and Volume Displaced

Species	I (4/5/72) #	I (4/5/72) vol. (ℓ)	II (4/14/72) #	II (4/14/72) vol. (ℓ)	III (5/19/72) #	III (5/19/72) Vol. (ℓ)
ARTHROPODA						
Callinectes sapidus			1			
Cancer irroratus	1					
Homarus americanus					8	
Libinia emarginata					7	
Pagurus longicarpus					3	
Pagurus pollicaris					2	
CHORDATA						
Anguilla rostrata			1			
Brevoortia tyrannus			1			
Paralichthys dentatus	3(sm.) 6(lg.)	2.25	4	0.5	3 32	 6.67
Gadus callarias			1	15 lbs.		
Scopthalnus aquosus	3	0.13				
Parilichthys dentatus					1	1

Fin Fish Surveys--Number Caught and Volume Displaced

Species	IV (6/4/72)		V (6/28/72)		VI (7/12/72)	
	#	Vol. (ℓ)	#	Vol. (ℓ)	#	Vol. (ℓ)
ARTHROPODA						
Callinectes sapidus						
Cancer irroratus	1				1	
Homarus americanus	2		4		1	
Libinia emarginata	51		9			
Pagurus longicarpus						
Pagurus pollicaris			2		11	
CHORDATA						
Anguilla rostrata					1	
Gadus callarias						
Hippoglossoides platesoides						
Paralichthys dentatus	1	0.25	1	0.33	1	0.5
Brevoortia tyrannus						

Fin Fish Surveys--Number Caught and Volume Displaced

Species	I (4/5/72)		II (4/14/72)		III. (5/19/72)	
	#	Vol. (ℓ)	#	Vol. (ℓ)	#	Vol. (ℓ)
Chordata - continued						
Poronotus tricanthus						
Prionotus carolinus						0.33
Pseudopleuronectes amer.	38(sm.)	4	27	2.13	100	5.5
	5(lg.)		5		31	
Raja erinacea	2	1	1	0.25	5	3.25
Tautoga onitis						
Tantogolabrus adspersus					4	1.45
ECHINODERMATA						
Asterias forbesi					2	
MOLLUSCA						
Busycon canaliculum					1	
Busycon carica						
Loligo pealei						

Fin Fish Surveys--Number Caught and Volume Displaced

Species	IV (6/4/72) #	IV (6/4/72) Vol. (ℓ)	V (6/28/72) #	V (6/28/72) Vol. (ℓ)	VI (7/12/72) #	VI (7/12/72) Vol. (ℓ)
Chordata - continued						
Poronotus tricanthus					3	
Prionotus carolinus	2		16	0.45	1	
Pseudopleuronectes amer.	144 (sm)	9.0	125	6.75	116	5.75
	10 (lg)	7.0	1	3.0	1	
Raja erinacea	5	2.75	1	0.25	1	0.5
Tautoga onitis			1		2	
Tantogolabrus adspersus	25	3.0	12	2.25	6	0.25
ECHINODERMATA						
Asterias forbesi	1		3		5	
MOLLUSCA						
Busycon canaliculum			1			
Busycon carica			1			
Loligo pealei	7	0.5	2		4	

TABLE A-8

DIVERS SURVEY I

April 1, 1972

SPECIES	A	B	C	CONTROL
ALGAE				
Chondrus crispus	X		X	
Codium fragile	X		X	
Laminaria agardhii	X		X	
PORIFERA				
Cliona celata	X	X	X	
Haliclona loosanoffi	X			
MOLLUSCA				
Anadara ovalis			X	
Busycon canaliculatum			X	
Busycon carica			X	
Crepidula convexa		X	X	
Crepidula fornicata		X	X	
Crepidula plana			X	
Littorina littorea			X	
Littorina obtusata			X	X
Mercenaria mercenaria	X		X	X
Mya arenaria		X		
Nassarius trivittatus		X	X	
Nucula proxima	X	X	X	
Yoldia limatula		X		
Yoldia sapotilla		X		X

SURVEY I

SPECIES	A	B	C	CONTROL
ECHINODERMATA				
Asterias forbesi	X		X	
ARTHROPODA				
Balanus crenatus	X	X	X	
Callinectes sapidus		X		
Cancer irroratus		X	X	
Crangon septemspinosa	X	X	X	X
Gammarus sp		X	X	
Libinia emarginata		X		
Pagurus longicarpus	X	X	X	X
Pagurus pollicaris	X	X	X	

TABLE A-9

DIVERS SURVEY II

April 13, 1972

SPECIES	A	B	C	CONTROL
ALGAE				
Ulva lactuca	X			
MOLLUSCA				
Busycon canaliculatum			X	
Busycon carica	X		X	
Littorina littorea			X	
Littorina obtusata			X	X
Nucula proxima			X	
Yoldia sapotilla		X		
ECHINODERMATA				
Asterias forbesi			X	X
ARTHROPODA				
Balanus crenatus	X		X	
Callinectes sapidus				
Cancer irroratus			X	
Crangon septemspinosa	X			
Gammarus		X	X	
Homarus americanus				
Libinia emarginata			X	
Pagurus longicarpus	X	X	X	

TABLE A-10

DIVERS SURVEY III

May 16, 1972

SPECIES	A	B	C	CONTROL
ALGAE				
Ascophyllum nodosum				X
Chondrus crispus	X		X	X
Green alga A	X			
Green alga B (*Enteromorpha*-type)				X
Red alga A	X			X
Ulva lactuca	X			X
MOLLUSCA				
Busycon canaliculatum		X	X	
Busycon carica	X	X	X	X
Crepidula plana	X			X
Littorina obtusata			X	
Mercenaria mercenaria	X			X
Nassarius trivittatus				
Nucula proxima	X			
Urosalpinx cinereus	X			
ECHINODERMATA				
Asterias forbesi	X		X	
ARTHROPODA				
Amphipod A		X		
Balanus sp				X

SURVEY III

SPECIES	A	B	C	CONTROL
Callinectes sapidus				X
Cancer irroratus				X
Homarus americanus				X
Libinia emarginata	X	X	X	X
Pagurus longicarpus	X	X		X
Pagurus pollicaris	X		X	X
ANNELIDA				
Lepidonotus squamatus	X			

TABLE A-11

DIVERS SURVEY IV

June 7, 1972

SPECIES	A	B	C	CONTROL
ALGAE				
Brown filamentous alga		X		
Chondrus crispus	X		X	
Green filamentous alga		X		
Laminaria agardhii		X	X	
Red alga	X	X		
Ulva lactuca	X	X		
MOLLUSCA				
Anadara ovalis			X	X
Busycon canaliculatum	X		X	
Busycon carica		X	X	
Crepidula convexa	X			
Credidula plana	X	X	X	X
Eurpleura caudata	X	X		
Illex illecebrosus				
Mercenaria mercenaria	X		X	X
Nassarius trivittatus	X	X		X
Nucula proxima		X		
Polinices duplicatus				X
Retusa canalicutatus	X			X
ECHINODERMATA				
Asterias forbesi		X	X	X

SURVEY IV

SPECIES	A	B	C	CONTROL
ARTHROPODA				
Amphipod sp				X
Callinectes sapidus				X
Cancer irroratus			X	X
Libinia emarginata		X	X	X
Pagurus longicarpus	X	X		X
Pagurus pollicaris	X	X	X	X
ANNELIDA				
Lepidonotus squamatus	X	X	X	X
EGG CASES				
Busycon carica		X		
Nassarius trivittatus	X		X	
Polinices duplicates	X		X	

TABLE A-12

DIVERS SURVEY V

June 29, 1972

SPECIES	A	B	C	CONTROL
ALGAE				
Chondrus crispus			X	X
Green filamentous alga	X	X		
Laminaria agardhii	X	X	X	X
Porphyra sp	X	X		
Red alga				X
Red filamentous alga				X
Ulva lactuca	X	X	X	X
ARTHROPODA				
Balanus crenateus	X	X	X	X
Libinia emarginata			X	
Pagurus longicarpus	X	X	X	X
Pagurus pollicaris		X	X	X
ANNELIDA				
Lepidonotus squamatus		X	X	X
ECHINODERMATA				
Asterias forbesi	X	X	X	
MOLLUSCA				
Anadara ovalis			X	
Astarte castanea			X	
Busycon canaliculatum	X		X	

TABLE

SPECIES	A	B	C	CONTROL
Busycon carica		X	X	X
Crepidula fornicata			X	
Crepidula plana		X	X	X
Eurpleura caudata		X		
Littorina obtusata				X
Mercenaria mercenaria	X		X	
Nassarius trivittatus		X	X	X
Urosalpinx cinereus			X	
PORIFERA				
Haliclona loosanoffi			X	

TABLE A-13

DIVERS SURVEY VI

July 17, 1972

SPECIES	A	B	C	CONTROL
ALGAE				
Chondrus crispus	X	X	X	X
Green filamentous				X
Laminaria agardhii	X	X	X	X
Red filamentous				X
Red Alga	X			X
Ulva lactuca		X	X	X
ANNELIDA				
Lepidonotus squamatus	X	X	X	X
ARTHROPODA				
Amphipod A				X
Callinectes sapidus				X
Cancer irroratus	X			
Libinia emarginata	X	X	X	X
Pagurus longicarpus	X	X	X	X
Pagurus pollicaris	X	X	X	X
ECHINODERMATA				
Asterias forbesi	X	X		X
MOLLUSCA				
Anadara ovalis			X	
Astarte castanea			X	
Busycon canaliculatum	X		X	X

SURVEY VI

SPECIES	A	B	C	CONTROL
Busycon carica		X	X	X
Crepidula convexa	X	X	X	
Crepidula fornicata		X	X	X
Crepidula plana	X	X	X	X
Ensis directus			X	
Euplenia candata		X		
Littorina obtusata	X		X	X
Mercenaria mercenaria	X	X	X	X
Mytilus edulis	X		X	
Nassarius trivittatus		X		
Polinices duplicatus			X	
Urosalpinx cinereus			X	
EGG Cases				
Polinices sp	X			X
Thais sp	X			X
Urosalpinx sp			X	