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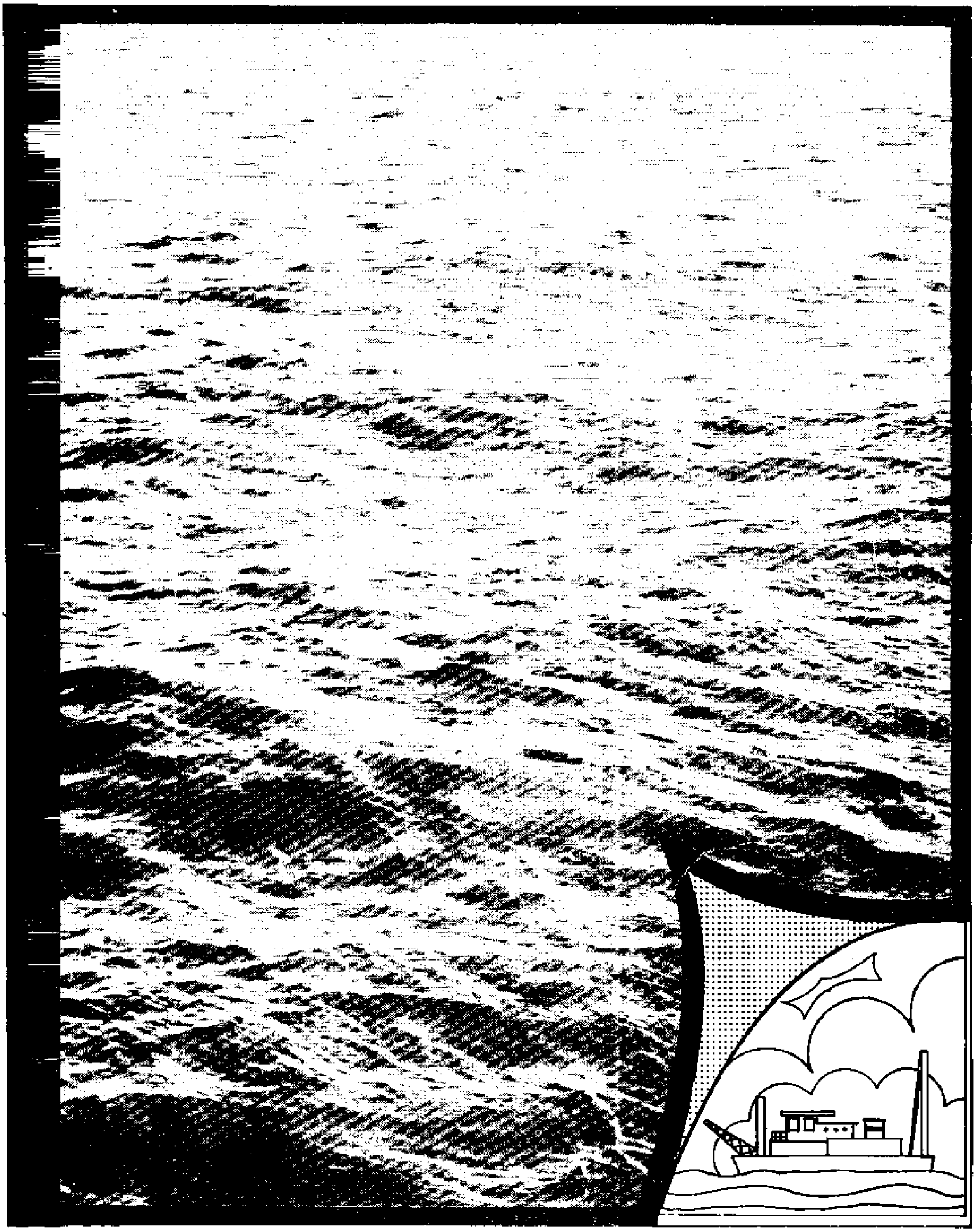

EFFECT of SPOIL DISPOSAL on BENTHIC COMMUNITIES near the MOUTH of DELAWARE BAY

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SUMMARY

Disposition of Spoil on the Dump Site

The disposition of spoil was determined by four bathymetric surveys; one prior to spoil disposal, one immediately after, and one, two, and five months, respectively after disposal.

1. The total volume of spoil detected by the surveys was 138,000 cubic meters including water column. This represents 38.5% of the total amount of spoil dredged.

2. Most of the spoil moved out of the proposed spoil site down a slope 90 meters towards an enclosed basin.

Sediments of the Dredging and Disposal Areas

The sediments from the dredge and dump sites were analyzed for percentage of sand, silt, and clay by wet sieving. Based on these data, a computer program was developed to draw sediment contour maps.

1. In terms of percent sand, sediment patterns were similar at the disposal site for all three sampling periods.

2. In terms of percent silt, there was an increase at the disposal site after dumping. The increase in percent silt was not detected during the June sampling period.

3. In terms of percent clay all values were generally similar from the December and March sampling periods, with a reduction in clay for the June sampling period.

Characteristics of the Environment

General physical characteristics of the disposal site were determined by a review of the literature, hydrographic data (temperature, salinity, dissolved oxygen), dye studies, and drogue studies.

1. Dye injected at the disposal site on an ebb tide moved around Cape Henlopen and then southeast paralleling the beach along the Atlantic Ocean.

2. Dye injected at the disposal site on a flood tide moved southwest toward Lewes Beach. Some dye moved into the ferry basin.

3. Drogues (1 and 2 m below the surface) released at the disposal site on an ebb tide moved around Cape Henlopen and then southeast, paralleling the beach along the Atlantic Ocean. The two-meter drogue tended to move further offshore than the one-meter drogue.

4. Drogues (1 and 2 m) released at the disposal site on a flood tide moved into the bay towards Roosevelt Inlet.

5. Based on current velocities computed from the dye movement, there was evidence to indicate that the tidal currents were capable of maintaining fine particles (<63 microns) in suspension. Fine particles could have been redeposited in the ferry basin on a flood tide.

Effects of Dredging and Spoil Disposal on the Benthic Fauna

Macrobenthic invertebrate assemblages were examined in the dredge, spoil disposal, and undisturbed areas near the mouth of the bay. Analysis was based on 277 quantitative (0.1 m^2) samples distributed over three sampling periods. Data were expressed in terms of number of individuals, principal taxa, redundancy values, Jaccard coefficients, species diversity, biomass, and animal-sediment relationships.

1. One hundred and fifteen live species were identified from the study. Actually 143 species were identified. Some species were not collected live and others collected in the dredge were not quantitatively analyzed. The density of individuals was low and the number of species rarely exceeded 10/0.1 m^2.

2. There was a significant reduction in density of benthos at the dredge and disposal sites after dredging.

3. The abundance of two dominant species, *Nucula proxima* and *Tellina agilis*, declined significantly at the disposal site after dredging.

4. Reduction in density and community disruption of benthic invertebrates was restricted to the dredge and areas of spoil accumulation.

5. There were data to suggest that some recruitment of benthic invertebrates occurred at the spoil site between disposal in March and benthic sampling conducted in June.

Ecological Implications

Any study which assesses the effect of dredging and dumping must include the environmental setting of the particular area. The fact that high natural turbidity occurs in Delaware Bay together with a variety of pollutants must also be considered in comparing this area with another.

1. All dredging and disposal projects will cause some environmental damage; however, this damage can be reduced by consideration for spawning areas, fishing grounds, and the time of the year. In lower Delaware Bay the period of least harm for benthic invertebrates from dredging and spoil disposal would be between December and March.

2. A total of 115 live species was collected from the study area; however, the density ($<10/0.1\ m^2$) prior to dredging and disposal was extremely low, particularly at the disposal site. Such a low density made it difficult to detect changes between natural and disturbed conditions. The relative density of benthic populations should be definitely considered when selecting sites for future disposal projects.

3. Depending on initial ecological conditions, season, nature of biota, and the duration, frequency, and scope of dredging and dumping, benthic invertebrates may recover rapidly. Under certain conditions, recolonization of disposal sites and dredged areas may begin as early as the next

spawning period. Results of this study indicate that following dredging and disposal in March and prior to sampling in June, some recruitment probably occurred.

4. Lower Delaware Bay receives heavy loads of suspended material from the Delaware River watershed and adjacent tributaries throughout the year. Secchi disc readings made in the study area indicated that the change in suspended sediment following dredging and dumping was insignificant compared to the natural load. The addition of small volumes of suspended matter from this operation probably did not significantly affect the fauna.

5. Since the disposal operation occurred near the mouth of Delaware Bay where the current velocity reaches 4.3 km/hr on an ebb tide, this flushing rate probably also helped to reduce the damage to benthic invertebrates from oxygen depletion and suspended sediment.

6. Spoil disposal may distribute material over a large area. In this project the proximity of the disposal site to a trough (13.6 m) probably reduced the spread of dredged material. If a disposal site is selected to contain the spoil in a natural depression, special attention should be given to the benthic invertebrates in the basin.

7. Dredging and disposal projects which are relatively small, such as this one, have limited influence outside the action areas. Projects in Chesapeake Bay and Rhode Island involved 10 million and 8.2 million cubic yards of material,

respectively. Since both projects far exceeded the volume of this study, much more ecological disturbance was reported. For purposes of emphasis, it deserves repeating that regardless of the volume of material dredged and dumped, the effect of these operations should be interpreted in light of the natural conditions of the given area.

Based on the results and ecological implications of this project, the following recommendations are offered:

1. All dredging and spoil disposal operations associated with any coastal engineering projects should implement ecological feasibility studies prior to or concurrently with economic and engineering studies.

2. These studies should not be restricted to but should include: hydrography, geology, and biology (phytoplankton, zooplankton, benthos, nekton). Chemical analyses for pollutants in the water column, sediments and animals should also receive special emphasis. Laboratory studies should include bioassay tests on important local ecological and commercial species. Field experiments using live-car techniques should be applied where feasible.

3. For a comprehensive review of guidelines for dredging and spoil disposal related to research needs and ecological implications, the reader is urged to review Cronin (1969), Cronin, et al. (1970), Sherk (1971 a), Saila, et al. (1972) and miscellaneous papers on dredged material research published by the U.S. Army Engineering Waterways Experiment

Station. These sources go into considerable detail concerning research procedures associated with dredge and spoil disposal projects. Rather than directly repeat their comments we preferred to offer ecological implications based on this project. In some cases, our comments included those expressed by earlier workers.

ACKNOWLEDGMENTS

It is appropriate to thank those people who have contributed to this work. Dr. Kent Price was instrumental in initiating early consideration of this problem. Mr. Joel Goodman served an important role as liaison between the College of Marine Studies (CMS) and the Delaware River and Bay Authority (DRBA). Mr. John Bryson and Dr. Harry Otto, Delaware Department of Natural Resources and Environmental Control, aided in planning the dye study and Dr. Otto and his staff performed the dye study. In addition, Dr. Klemas took aerial photographs of the dye study and provided the photos to further document that phase of the project. We would like to thank Drs. S. Kupferman, D. Polis, and K. Szekielda for permitting us access to unpublished information on water chemistry. Mr. John Volk, DRBA, has been most helpful throughout the study. Mr. Clarence Wicker has also provided informed commentary. Dr. Albert Sherk, University of Maryland, provided manuscript copies of his research on the effects of suspended sediment and a critical review of this manuscript. A special thanks to Captain Tom White and the crew of the R.V. Skimmer for facilitating our field work. Other laboratory staff who helped included April Morris who typed the manuscript, Pam Ferneyhaugh, Lori Fisher, Janice Palmer, Joanne Tschantre, and Susan Wilkins who worked in the field and laboratory during the summer months.

Finally, to our young associates, Messrs. Wayne Leathem, Peter Kinner, William Treasure, Michael Otley, and Les Watling, who carried the principal work load, we owe our thanks.

Don Maurer and Robert Biggs
January 1974

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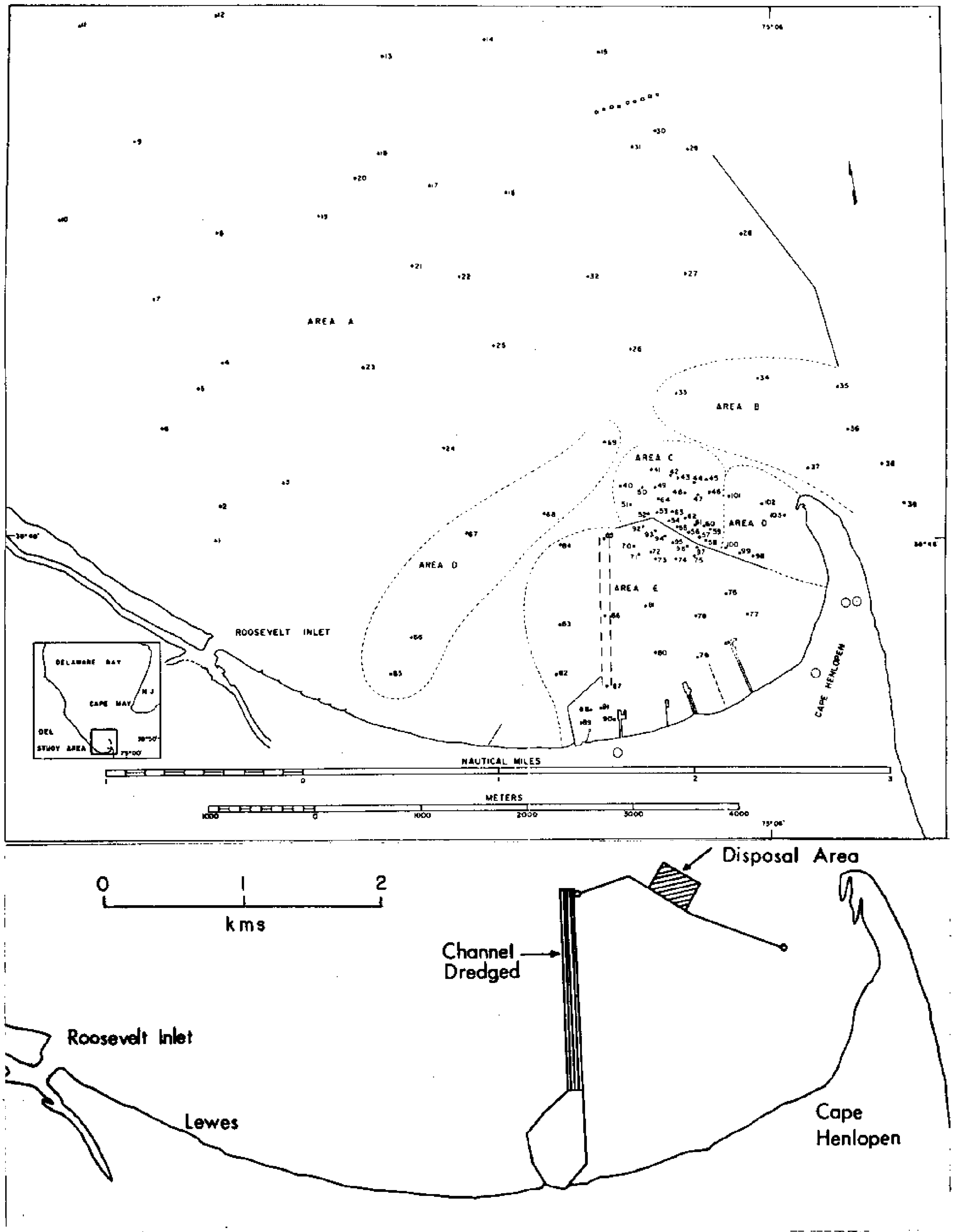

Figure 1. Map of Hydrographic and Geological Stations, Breakwater Harbor, Lewes, Delaware

INTRODUCTION

Purpose

The purpose of this study was to evaluate the gross (community disruption, mortality) biological effects of dredging and overboard spoil disposal in the Breakwater Harbor, Lewes, Delaware (Figure 1) on benthic marine invertebrates. The study consisted of three interdisciplinary aspects: 1) physical oceanography and aerial photography, 2) marine geology, and 3) marine biology.

Objectives

Specific objectives were: 1) to determine the relatively short-term dispersion of spoils from dredging, 2) to determine the relatively short-term biological effect of spoil disposal from dredging.

Project Background

Public notice was given by the U.S. Corps of Engineers, Philadelphia District on January 27, 1971, that the Delaware River and Bay Authority had applied for permission to deposit maintenance dredging material from the Lewes ferry terminal approach, in an area on the northeast side of the inner breakwater in the Harbor of Refuge, Lewes, Delaware. The applicant proposed to hydraulically dispose of approximately 191,150 cubic meters of sandy material in an open disposal area 213.4 m wide and 304.8 m long (Figure 1). Concern by authorities of the State of Delaware was expressed as to possible effects of spoil disposal on the biota and movements of the material from the designated disposal site to other areas. Because there is a diversity of views concerning the effects of dredging and spoil disposal on the biota, the study described herein was designed to provide information for this project. Hopefully, some of the information can be applied to other geographic areas.

LITERATURE REVIEW

Many engineering projects in or near coastal areas involve temporary or permanent changes in suspended loads and deposition of sediments (Sherk, 1971 a). Such projects as maintenance of waterways, opening new channels, removal of material for beach replacement, and spoil disposal are commonplace. The present project evaluated the effects of maintenance dredging on an access channel and subsequent spoil disposal on the benthic community.

The benthic community was selected for study for several reasons: 1) Benthic communities are more sensitive to environmental perturbations from dredging and spoil disposal than other types of communities (Sherk, 1971 a; Rounsefell, 1972); 2) We have acquired experience with local benthic communities (Watling and Maurer, 1972 a; Maurer and Watling, 1973 a, 1973 b).

An early paper (Lunz, 1938) reported that dredging operations in South Carolina were not injurious to oysters and killed only those actually buried by spoil. Reish (1961) found no indication of succession following dredging in a boat harbor in southern California. In a Texas bay, Hellier and Kornicker (1962) observed that dredged sediment was deposited more than 0.8 km but less than 1.6 km from the spoil bank. A report on the effect of overboard spoil disposal in upper Chesapeake Bay concluded that the most economic and least harmful way of disposing channel spoil was to place it along the bottom near the middle of the open bay because the suspended sediment would remain only as long as the flushing time, and resuspension would be negligible except in violent storms. Claims made about dangers to spawning grounds of striped bass and damage to valuable shellfish beds were also discounted if the spoil was disposed of in the deep areas of the bay (Gunter, et al., 1964). In a study of shell dredging as a factor in sedimentation of Galveston Bay, Texas, it was found that dredging for shell produced an order-of-magnitude increase in suspended sediment over that caused by currents, wind, wave action, and ship traffic. The report cited suggested that all dredging near oyster reefs should cease when deposition was discovered (James, et al., 1972). Cronin (1969) provided an outline for biological aspects of coastal waste disposal. These included assessments of toxicity and estimation of concentrations of waste, biostimulation by wastes, health risks from pathogens, quantitative measure of community health, improved models of toxicity, and sublethal responses to toxicants.

In Virginia waters of Chesapeake Bay, Haven and Loesch (1970) described the effect of a hydraulic dredge on hard clam beds. Results showed that within sample plots the bottom was changed. Eel grass and other aquatic plants were uprooted, buried shell was unearthed, and silts and clay were washed away. Oysters located at 22 to 45 meters from the dredged area were not injured or covered by the action of the hydraulic dredge. Maximum distance that sediments accumulated was 30.5 meters from the site of operation. However, they also pointed out that following dredging, it will require four or five years in the James and York Rivers for clams to grow to commercial size. Once hard clams reached a size of 12 mm, mortality was low from dredging.

In a survey of benthic molluscs in Boca Ciega Bay, Florida, there was a much smaller number (1.1 individuals) and variety (0.6 species) in the soft sediments in dredged canals than in the predominantly sand and shell sediments (60.5 individuals, 3.8 species) in undredged areas (Sykes and Hall, 1970). Another study in the same area showed that there was no recolonization by sea grasses one year after dredging with a commercial hydraulic clam dredge (Godcharles, 1971). Along the northern New York Bight, Gross, et al. (1971) have demonstrated serious damage to benthic communities from waste deposits. Howell and Shelton (1970) in England reported that the deposition of china clay waste had a profound effect upon the bottom fauna of the bays. Near the place of discharge, the rate of silt deposition has caused a near sterile situation. In a Florida bay Taylor, et al. (1970) reported that the diversity and abundance of molluscs was affected by bottom conditions which were influenced in varying degrees by dredging. Nineteen stations had no living molluscs and 18 stations had one or more of the four mollusc species that were predominant. In Anaheim Bay, California, Reish and Kauwling (1971) found that the average number of species from dredged and undredged areas was 12 and 10 respectively, whereas the number of specimens averaged only 100 from the dredged region as compared to 430 from the undisturbed area.

Several other important papers related to dredging and spoil disposal include Cronin, et al., 1970; Sherk, 1971 a; and Saila, et al., 1972. The former was a three year study in Chesapeake Bay involving the gross effect of overboard spoil disposal on phytoplankton, zooplankton, nekton, and the benthos. In regard to the benthos there was a 71% reduction in average number of individuals and about 65% in the biomass in the spoil area following dredging and spoil disposal. After one and a half years, abundance, biomass, and species diversity had recovered to approximately pre-disposal levels in the disposal area. The greatest decrease in biomass occurred in the channel or dredge site.

Saila, et al. (1972) reported on the effects of dredge spoil disposal in Rhode Island Sound. They found that a few benthic species were able to reach the surface after deep burial ($>$ 20 cm). Most of the species colonizing the spoil were members of the surrounding sand bottom assemblage. Some spoil samples had relatively high diversity indices suggesting little disturbance, while others had extremely low values suggesting considerable disturbance.

Sherk's paper (1971 a) is a review of the literature on the effects of suspended and deposited sediments on estuarine organisms. It is recommended reading for those interested in the scope and background of studies involving dredging and the biota. Sherk recognized several major categories: loss of habitat, oxygen demand, community disruption, mortality and other gross effects.

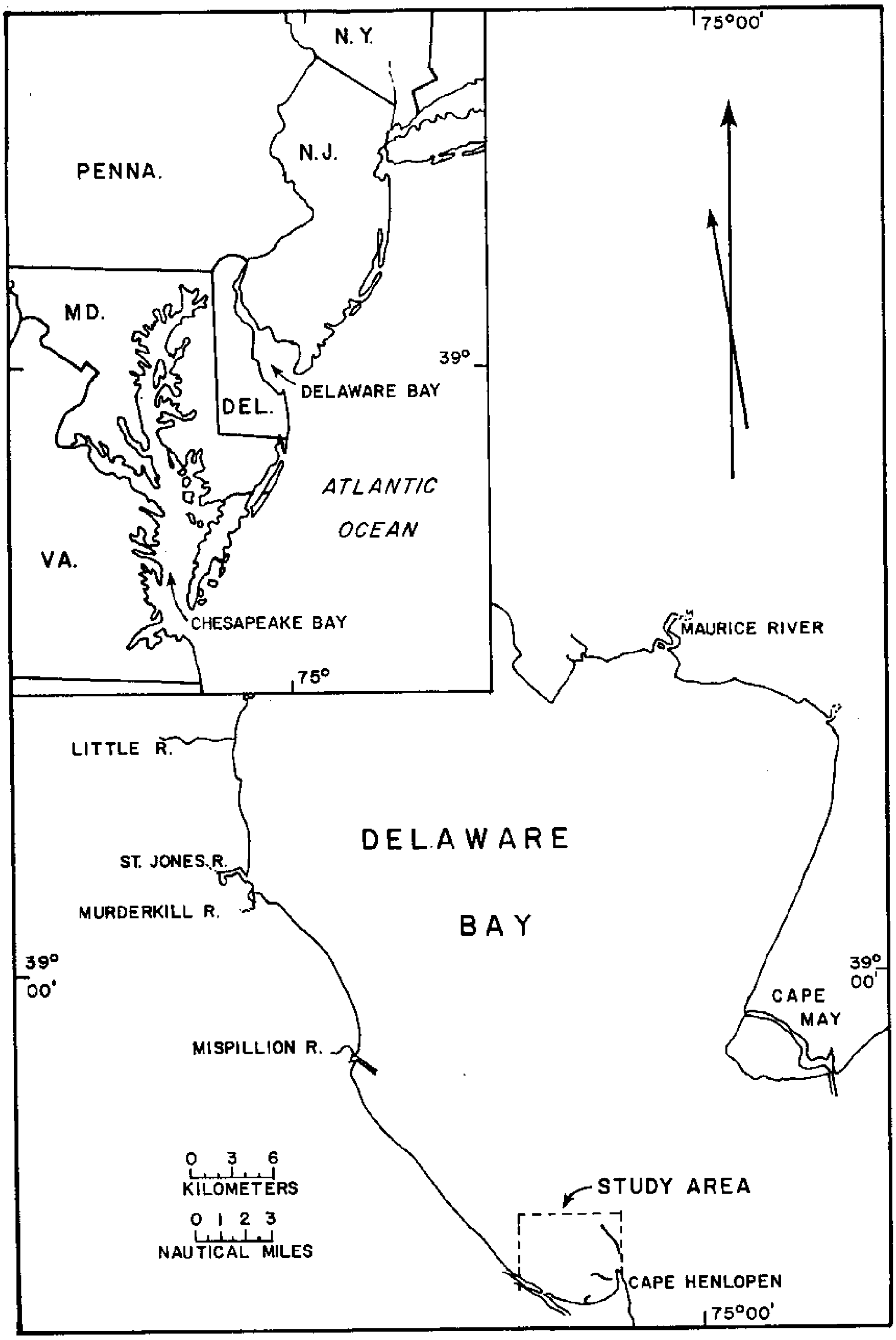

Figure 2
Delaware Bay, including the Breakwater Harbor in the southeast corner

LOCATION AND DESCRIPTION OF THE AREA

Delaware Bay is an estuary on the east coast of the United States, bordered by the States of New Jersey and Delaware and is situated between the major estuaries of New York Harbor and Chesapeake Bay (Figure 2). The Delaware Bay is a drowned river valley. Its shape is that of a flattened funnel with extensive tidal flats along the lower New Jersey shore. The deepest areas (up to 150 feet, 46 m) lie in an area immediately north and east of the Harbor of Refuge. The length of the Bay is 46.7 miles (75.2 km) with mean and maximum widths of 15.3 miles (24.6 km) and 27.1 miles (43.6 km) respectively. The Bay encompasses approximately 720 square miles (1864.8 sq. km) and has a volume of about 2.7×10^{12} gallons (1.78×10^{13} l). A detailed description of the morphometry of Delaware Bay may be found in Shuster (1959).

The Lewes ferry channel is located near the mouth of Delaware Bay at 38° 47' 30" north latitude and 75° 07' west longitude. The area is protected on the east by Cape Henlopen and on the northeast by two breakwaters (Figure 1). The depth within the undredged portion of Breakwater Harbor ranged from 3-12 feet (0.9-3.6 m) while the depth within the spoil disposal site ranged from 19-22 feet (5.8-6.8 m). The northwest end of the disposal site slopes steeply toward a 44 foot (13.6 m) hole (Figure 1).

Tides and Currents

Tides are of the semi-diurnal type and their range at the mouth of the Bay is 4.1 feet (1.3 meters). Maximum flood and ebb currents 0.3 miles (1.5 km) north of Cape Henlopen are 2.0 (3.7 km/hr) and 2.3 knots (4.3 km/hr), respectively. In general, the waters of Delaware Bay circulate in a rotary current due to the influence of Coriolis force on tidal currents.

Salinity

The salinity in the Bay increases with depth and distance from the Delaware River. The range of salinity near the mouth of the Bay is approximately 26-31 o/oo.

Water Temperature

The range in water temperature is approximately 0-28° C. Changes in the water temperature are most rapid during the spring and fall periods. The extreme temperatures are usually associated with the shallow area because they are affected more by seasonal air temperatures. Thermoclines may develop in the Bay, particularly in deep areas; however, they are not as pronounced as outside the Bay.

Water Chemistry

A winter cruise throughout Delaware Bay in January 1972 yielded a number of measurements for some of the substances in the water column (Kupferman, personal communication; Maurer and Wang, 1973). Phosphorus concentrations were higher near shore (2.5 mg/l) than in the center of the Bay (1.0 mg/l). Concentrations of phosphorus were also higher upstream than downstream. Copper concentrations were generally lower than 0.1 mg/l with the highest concentrations near the Bay mouth. Manganese also was generally less than 0.1 mg/l except at confluences of a few tributaries where concentrations reach 0.2 mg/l. Chromium concentrations were negligible and lead was found to be moderate throughout the Bay. Nickel (generally <0.12 mg/l) was higher along the shore than in the middle of the Bay. Between the capes and at the confluences of rivers, zinc was found at concentrations of 0.4 mg/l.

Trace Metals in Sediments

Studies were conducted by Bopp and Biggs (1972) to typify the trace metal geochemical aspects of sedimentary environments which support oysters in Delaware Bay. The philosophy behind the study was to identify those trace metals that were available to the food web by normal biological and chemical processes. Two sources are believed to be responsible for fine-grained materials which may carry trace metals: shoreline sources and deposition from Delaware River sediments. Those sediments being eroded from tidal marshes showed low concentrations of active metals. The deposition of riverborne sediments occurred near the New Jersey shore in the upper reaches of the Bay, around the ship channel in the middle of the Bay, and then approached the Delaware shore between Port Mahon and the mouths of the Murderkill and St. Jones Rivers. These areas were higher in active metal concentration.

Results of the study revealed iron, zinc, lead, cadmium, mercury, and nickel have their primary sources in the Delaware River, while magnesium, chromium, copper, and strontium have mainly seaborne sources. It also is apparent that the distributions of the metals, regardless of the sources, are influenced greatly by the water currents.

Two areas were identified as problem areas with regard to trace metals. At the mouth of the Cohansey River, chromium ($>$ 250 ppm), copper (75-100 ppm), lead ($>$ 200 ppm), and strontium (400 ppm) were found in high concentrations. Similarly a "sink" for trace metals was detected offshore from the mouths of the Murderkill and St. Jones Rivers. Higher values of these trace metals were also found in oysters from the same areas.

PHYSICAL OCEANOGRAPHY

Methods

Dye Study

This phase of the dye study was conducted by Dr. Harry Otto and his associates, Delaware Department of Natural Resources and Environmental Control. Rhodamine WT dye was injected into the water column on the bottom to establish the surface flow pattern in the area of the disposal site.

Two dye insertions were made near the center of the spoil disposal site. One insertion was made January 6, 1972 at 1230 (predicted high water slack 1343), the second was made January 6, 1972 at 0830 (predicted low water slack 0843). Approximately 105 liters of 40% Rhodamine WT dye in acetic acid were used each time.

Water samples for dye analysis were collected continuously approximately 1 m below the surface of the sea from the R.V. Delaware. Samples were pumped via a flex-i-liner pump without cavitation from undisturbed water under the boat to a modified Turner fluorometer. The location of the dye readings was established by radar and compass. Radar was used to determine distances from known points

(Coast and Geodetic Survey Chart 411) and the compass was employed in the steering of predetermined courses. A number of courses were run to find the fringes of the dye area and the location of the maximum concentrations.

Aerial photography was applied as another means of following the path of the dye mass. Dr. Vytautas Klemas, College of Marine Studies, supervised the aerial photography using color-band and infrared film. Several overflights on both days provided motion-time sequence of the movement and dispersion of the dye mass. Because there was poor contrast between Rhodamine WT dye and the turbid water background, special filters were used throughout the experiment to emphasize the dye mass outline and deemphasize the background.

Drogue Study

To supplement the dye study, a drogue study was planned to provide information on subsurface current flow.

Two drogues were designed and constructed. One drogue weighted with 11.3 kg had a fixed distance of one meter from the water's surface to the top of the cross and a biplane area of 0.19 m^2. The second drogue weighted with 45.3 kg had a fixed distance of two meters below the surface and a biplane area of 1.5 m^2. The drogues were equipped with a radar screen of 0.65 cm mesh for tracking by the R.V.

Delaware. The drogues were also tracked in a small boat taking sextant readings from alongside each drogue. Local landmarks on CGS Chart 411 were used for sightings and the angles and times were recorded for plotting onto maps (Figures 9 and 10). The first four readings were taken every 15 minutes. Thereafter, the time interval was 30 minutes. To provide a check of the sextant readings on the drogues, replicate readings were made. The drogues were tracked from the R.V. *Delaware* by applying the angle and distance of the drogues from the vessel's radar scope and establishing the boat's position via sextant readings.

Hydrographic Study

Hydrographic data were taken at 103 stations during the three sampling periods with a nansen bottle (Figure 1). The nansen bottle was lowered to approximately 1 m from the bottom for a period of five minutes. Water temperature was recorded from the reversing thermometer and the water sample was preserved for dissolved oxygen and salinity analysis in the laboratory. The concentration of dissolved oxygen was determined by the Winkler Method and salinity was measured by an induction salinometer. A secchi disc (diameter 30.5 cm) was used to measure light transmission.

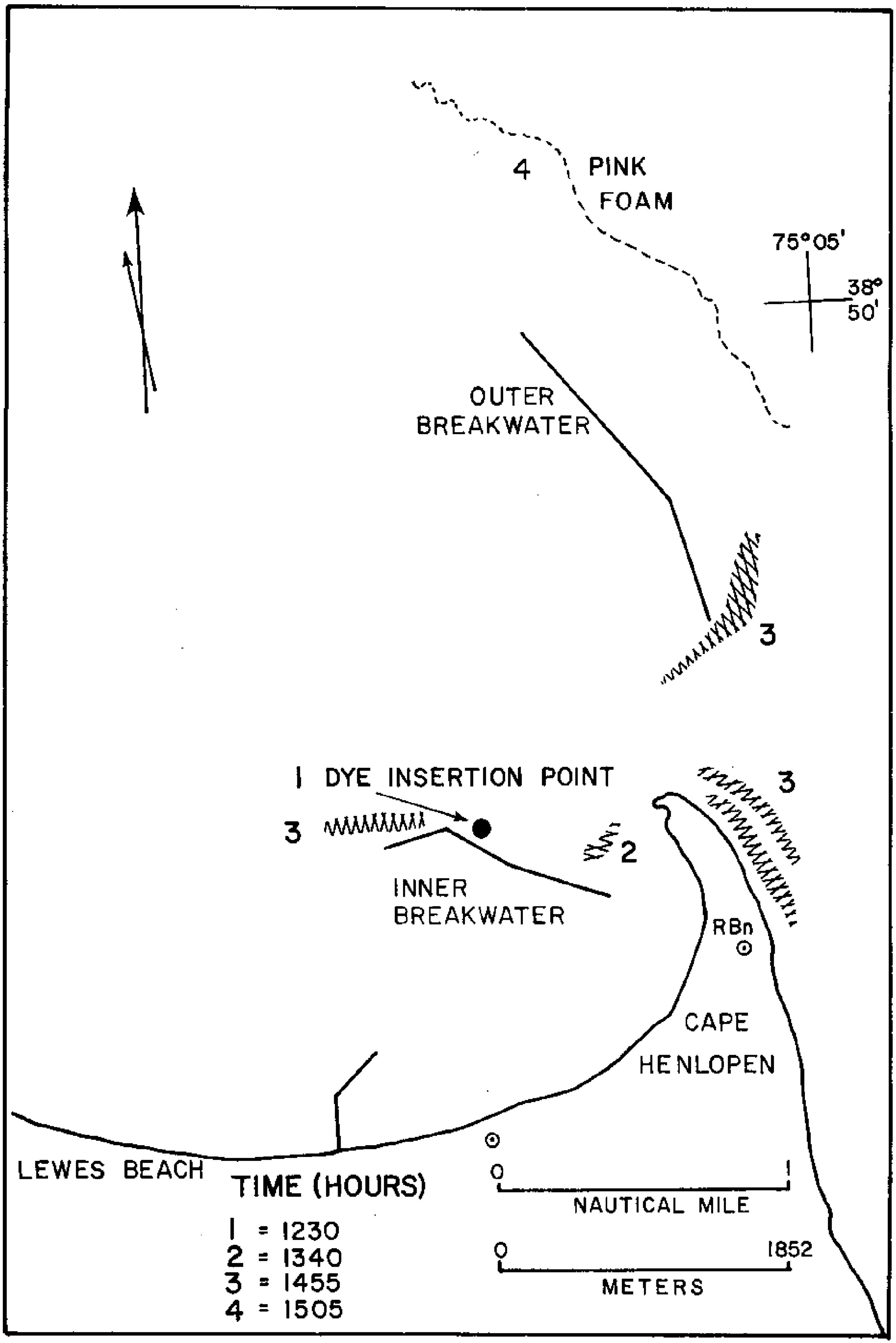

Figure 3
Map of Dye Pattern
Lewes Breakwater Area--Ebb Tide, January 6, 1972

Results

Dye Study

Thursday, January 6, 1972

Dye was injected near the inner breakwater at 1230 (Figure 3). At 1340 distinct discoloration was observed at Point 2 (Figure 3) and at 1405 long streaks of dye were seen hugging the Atlantic shoreline of Cape Henlopen and crossing the outer breakwater. These elongated dye patches traveled about 1800 meters southward, then stopped abruptly and lingered there approximately 100 meters from shore. Final dye distribution observed at 1455 is shown in Figure 3. Some dye remained near the inner breakwater and a tongue of dye extended past the outer breakwater. A portion of lower Delaware Bay showed pinkish discoloration with normally white foam along the boundaries turning strongly pink. Oil slicks were observed to respond in a similar manner.

Friday, January 7, 1972

Dye was injected at the inner breakwater at 0830 (Figure 4). At 0900 the dye patch was clearly visible. It tended to remain together as one long slick around the inner breakwater towards Lewes Harbor (Figures 5, 6, and 7). By 1050 a horseshoe-shaped patch had formed in Lewes Harbor (Figure 4) with legs of lower concentration extending northward from the closed end of the horseshoe. At 1310 the long

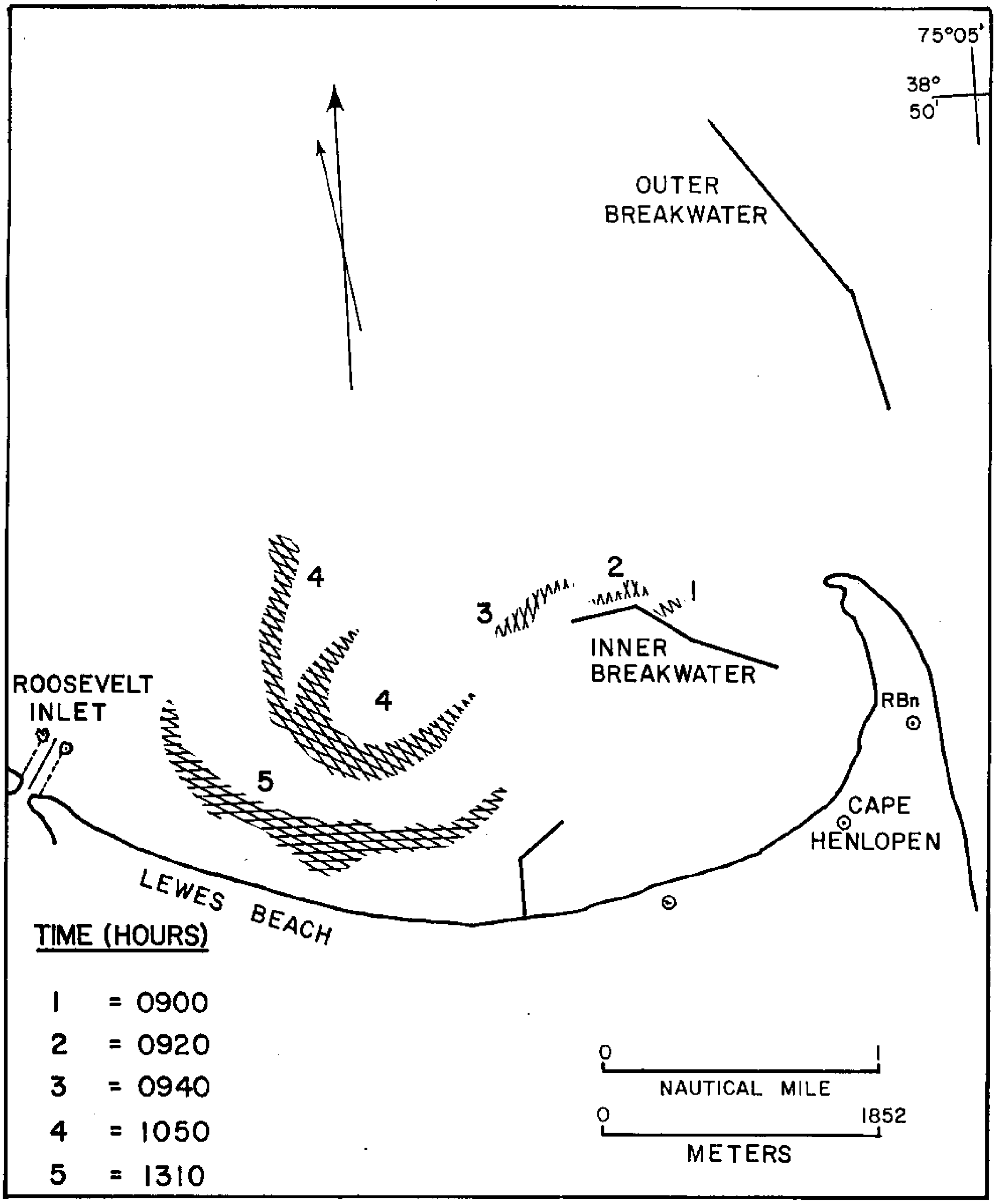

Figure 4

Map of Dye Pattern
Lewes Breakwater Area--Flood Tide, January 7, 1972

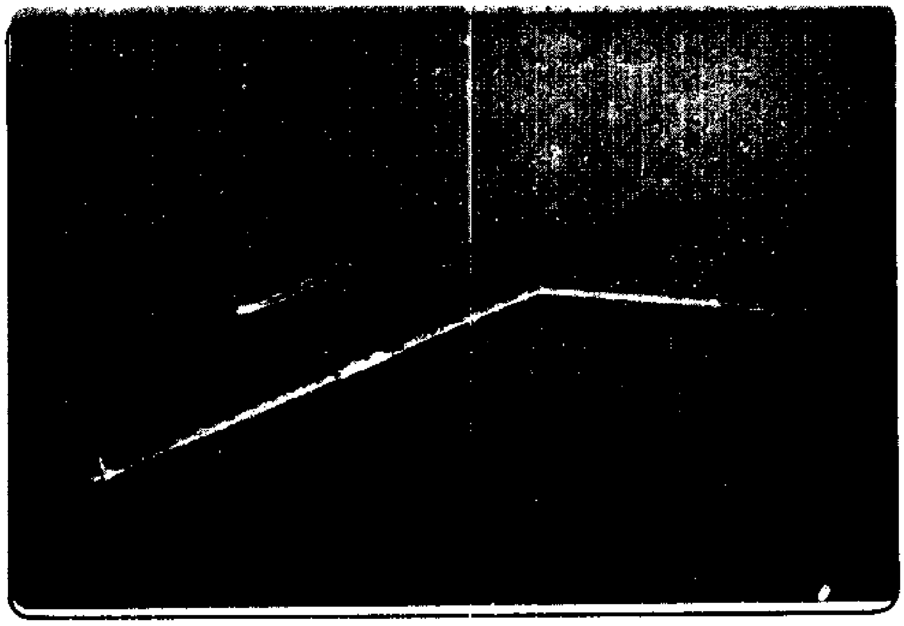

Figure 5. Dye patch is carried around inner breakwater by incoming tide (0920).

Figure 6. Dye patch passes northern end of inner breakwater on its way toward Lewes Harbor (0940).

Figure 7. Dye forms horseshoe pattern halfway between inner breakwater and Roosevelt Inlet (1050).

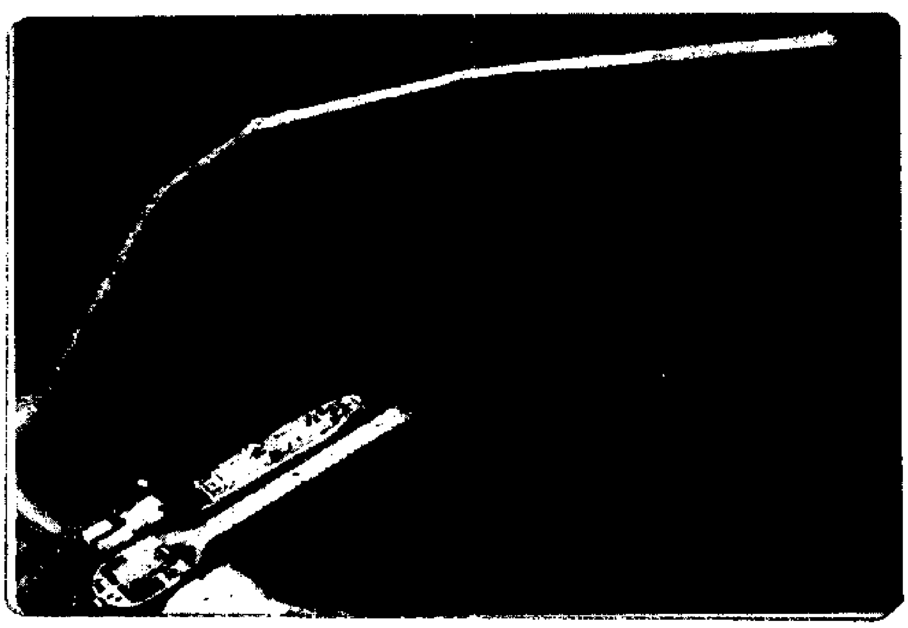

Figure 8. Dye near the Lewes-Cape May ferry terminal (1310).

dye patch was following the contour of Lewes Harbor extending from near the ferry terminal to a few hundred yards past Roosevelt Inlet. Some dye moved into the vicinity of the pier by the Lewes-Cape May Ferry (Figure 8).

The dye movement during the flood tide study was deemed more environmentally significant than the ebb tide study because of its final position. In order to estimate the effect the ebb tidal currents would have on suspended sediment, the velocity of the dye mass was calculated and compared with standards established by Postma (1967). A mean value of 30.6 cm/sec. was computed for flood tide. This velocity would be able to maintain silt and clay-size ($<$63 microns) particles in suspension.

Drogue Study

Thursday, January 6, 1972

At 1245 the drogues were placed in the water with wind blowing 3-5 knots from the northeast. Their routes can be traced in Figure 9. At 1445 the one meter drogue was removed from the rocks of the breakwater and reset in the channel adjacent to the east end of the breakwater. After rounding Cape Henlopen the two meter drogue moved south rapidly. Since this drogue had established a definite path into the ocean, it was removed from the water east of Hen and Chickens shoal at 1525. After the one

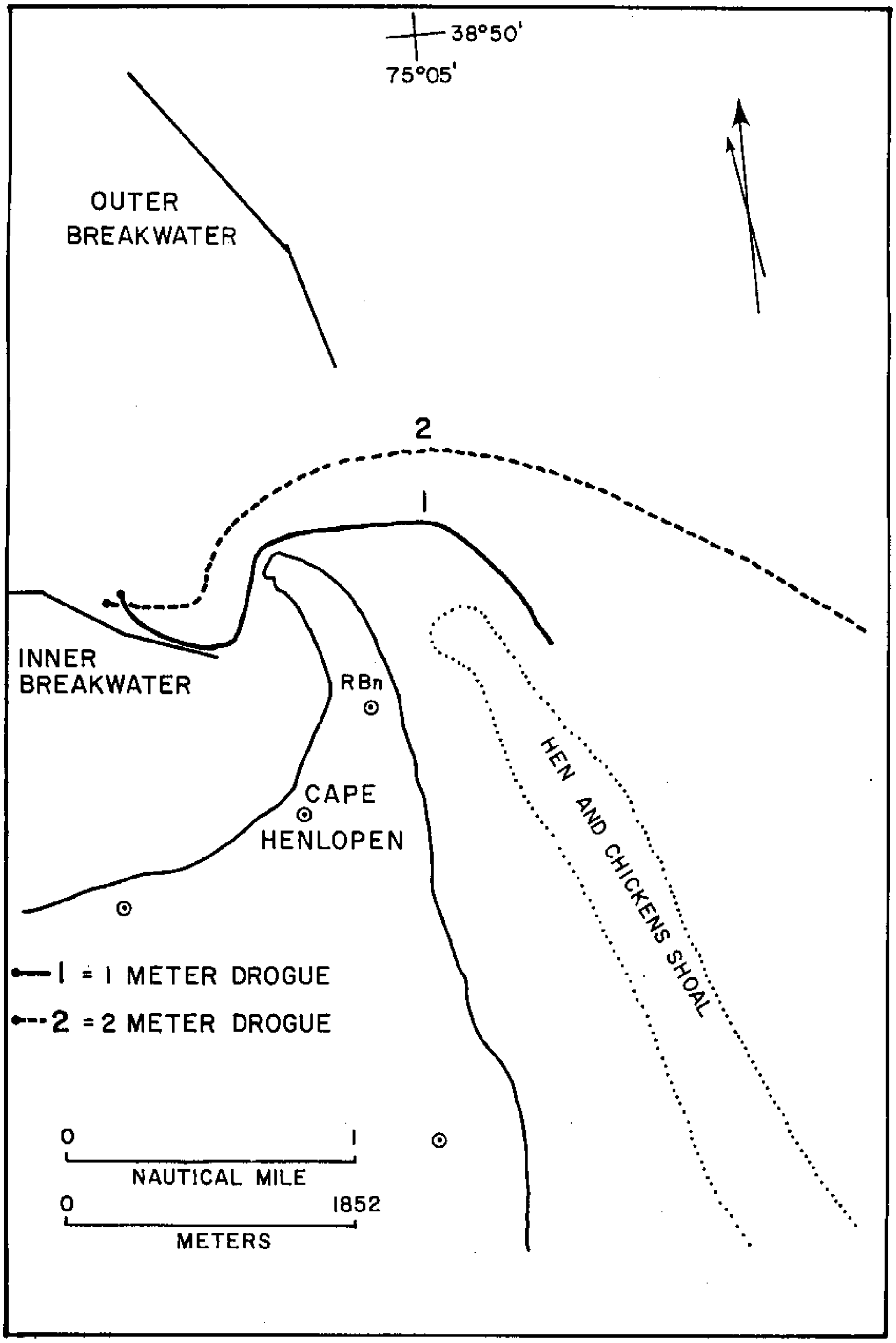

Figure 9
Current Study--Lewes Breakwater Area, Ebb Tide
January 6, 1972

meter drogue was repositioned it followed a path similar to the two meter drogue and was removed from the water east of Cape Henlopen at 1545.

Friday, January 7, 1972

The drogues were placed in the water at 0845 with the wind blowing 11-17 knots from the southwest. The drogues assumed parallel paths and moved west along the breakwater. Their routes can be traced in Figure 10. The one meter drogue was affected by the wind as evidenced by its erratic path to the northwest. Both drogues were removed from the water opposite Roosevelt Inlet at 1145 because increasing wind velocity made it hazardous for the small boat to track the drogues and the radar aboard the R.V. Delaware began to malfunction in the low distance scales. Sextant readings for the drogue studies are included in the Appendix.*

Hydrographic Study

Hydrographic data collected in this study are included in the Appendix.

December 1971 hydrographic samples revealed a constant water temperature throughout the sampling area. The mean temperature for all the stations was 7.3° C with a range of 6.1° C to 7.8° C. Salinity measurements also showed

* Appendix includes all sampling data (physical oceanography, marine geology, marine biology) plus computer contour maps of sediments and fauna.

small variation with a mean value of 26.9 o/oo and a range of 25.3 to 28.7 o/oo.

Dissolved oxygen values were pooled into three groups (Table I). Areas A, B, and D (Figure 1) comprised one group which had a mean value of 10.35 ± 1.56 SD, Area C had a slightly lower mean value of 9.57 ppm ± .795 SD and the lowest mean value (8.38 ppm ± 1.33 SD) was recorded in Area E. Mean value for all the stations in December was 9.63 ppm ± 1.57 SD. The computed oxygen percent saturation value for December revealed 94.4% saturation for the entire area.

Mean temperature for the March 1972 samples was 5.9° C with a range of 5.4° - 6.8° C (Table I). This was 1.4° C lower than the December temperature mean. The mean salinity value (27.6 o/oo) was (0.7 o/oo) slightly higher in March than December.

Dissolved oxygen values for March were substantially lower than earlier samples. The mean value for all stations was 3.88 ppm lower than the same value in December (9.63 ppm). More important is the fact that the percent saturation dropped to 55.4%. Each area showed similar reductions (Table I). Values for Areas A, B, and D decreased to 6.05 ppm (± 1.33 SD), Area C decreased to 5.47 ppm (± .820 SD), and Area E declined to 5.37 ppm (± 1.20 SD). The spoil areas, Area C and Area E showed lower percent saturations of 52.5% and 51.6% respectively than that of the total average value (Table I).

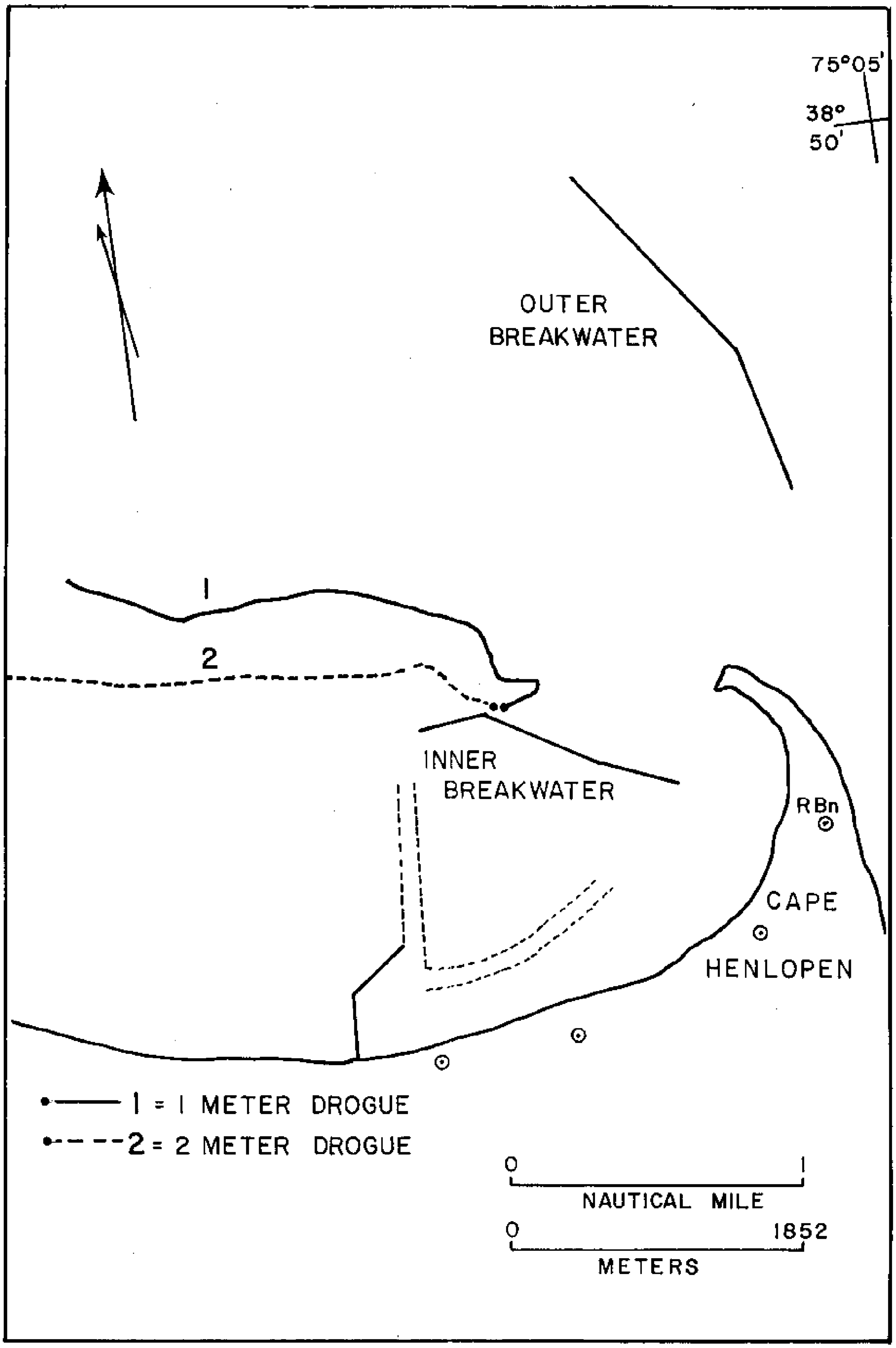

Figure 10
Current Study--Lewes Breakwater Area, Flood Tide
January 7, 1972

Table I

Hydrographic Data for each Period by Areas

December 1971

	All Stations			Areas A, B, D			Area C			Area E		
	Mean	SD	Range	Mean	SD	% Sat.	Mean	SD	% Sat.	Mean	SD	% Sat.
DO ppm	9.63	1.57	6.73-14.87	10.35	1.56	100	9.57	.795	94.3	8.38	1.33	82.6
Salinity o/oo	26.93	.698	25.32-28.74									
Temp. ° C	7.28	.377	6.1 - 7.8									

March 1972

	All Stations			Areas A, B, D			Area C			Area E		
	Mean	SD	Range	Mean	SD	% Sat.	Mean	SD	% Sat.	Mean	SD	% Sat.
DO ppm	5.75	1.20	4.17- 9.06	6.05	1.33	58.2	5.47	.820	52.5	5.37	1.20	51.6
Salinity o/oo	27.64	1.24	23.22-29.45									
Temp. ° C	5.92	.389	5.4 - 6.8									

June 1972

	All Stations			Areas A, B, D			Area C			Area E		
	Mean	SD	Range	Mean	SD	% Sat.	Mean	SD	% Sat.	Mean	SD	% Sat.
DO ppm	7.91	2.32	2.82-17.01	7.74	2.27	96.8	9.35	2.38	100	6.65	1.46	83.1
Salinity o/oo	26.57	1.31	24.49-29.36									
Temp. ° C	17.06	1.53	14.1 -19.6									

SD --Standard Deviation
% Sat.--Percent Oxygen Saturation Value
DO --Dissolved Oxygen

June 1972 temperature values reflected the change in the season (Table I). A mean value of 17.1° C was found for all stations with the highest temperature (19.6° C) at Station 79 inside Breakwater Harbor and the lowest temperature (14.1° C) at Station 26. The mean salinity value (26.6 o/oo) was similar to readings from December and March.

Oxygen saturation values were higher than the December values (Table I). The mean value was 7.91 ppm (± 2.32 SD) or 96.7% saturated. Values from each area were similar (± 1.4 ppm) to this value.

A t-test was used to determine if there was a significant (from here on significance is at the .05 probability level, unless otherwise noted) difference between the means of the oxygen concentrations for each of the areas and for the three sampling periods. The results showed that only Area D and December-June comparisons of Area C were not significantly different.

December sediment temperatures closely paralleled water temperatures. The mean value was 7.1° C and the range was 4.5° to 9.5° C. However, the difference between the high and low values of the sediment temperature (5.0° C) was more than double that of the water temperature (1.7° C). In March the mean sediment temperature decreased to 6.6° C. The range of sediment temperature was 6.0°-9.0° C. The mean of June temperatures was 17.1° C which was identical to the mean water temperature. The ranges for sediment and water temperatures were also similar (14.5-19.5° C).

Secchi disc measurements were taken during each of the three sampling periods. However, no trend was discerned.

MARINE GEOLOGY

Introduction

The geological study was designed to measure the distribution of spoil material and to provide background data for assessment of gross biological effects. This section includes the geological observations of overboard shallow water spoil disposal.

Geological Setting

Since 1965 there has been considerable research in the geology of the Delaware Bay area. This research includes suspended sediment (Oostdam, 1971), sedimentation of shell beds (Biggs, 1972), trace metal distribution (Bopp and Biggs, 1972; Bopp, et al., 1972), sediment distribution in southwestern Delaware Bay (Strom, 1972), and the geological history of the region (Kraft, 1971). A summary of this research provides the geological setting for the spoil disposal project.

Geologic History

Delaware Bay is underlaid by a thick wedge of semiconsolidated and unconsolidated sediments constituting the modern Atlantic Coastal Plain. Although the bulk of the sediments is of non-marine Cretaceous origin, the post-Cretaceous sequence consists largely of paralic and neritic deposits. The effect of alternating regression and transgression of the sea is reflected in both the textures and structures of the Pleistocene sediment of southern Delaware. Relative sea level changes for the Delaware Coast during the Holocene have been documented (Kraft, 1971).

Regional differences in subsidence rates determined the series of alternating structural highs and lows along the east coast. Delaware Bay occupies a tectonic low, the Salisbury Embayment, the axis of which trends approximately at right angles to the coast line. The age of the present mouth of the Delaware River probably does not exceed one million years (Oostdam, 1971).

Sediment Distribution

The ultimate source of most bottom sediments in the Bay is the varied assemblage of igneous, metamorphic, and sedimentary rocks constituting the Appalachian upland drainage area of the Delaware River and its tributaries. Sediment from shoals consists of clean sands (Strom, 1972). More than 50% of the sediments consists of non-clay crystalline minerals (35 to 75% quartz, 11-15% feldspar, minor amounts of mica); the remainder contains mainly clay minerals, but also 7 to 12% organic material. Heavy minerals in the Bay are characterized by hornblende, epidote, and chloritoid. Clays are mainly illite, chlorite, and lesser amounts of kaolinite (Oostdam, 1971). Trace metal concentrations (Cu, Pb, Zn, Cd, Hg, Ni, etc.) have also been found in sediments throughout the Bay (Bopp and Biggs, 1972; Bopp, et al., 1972).

Most of the sediments in the Bay are medium grained sands, coarsening towards the Bay mouth and generally decreasing in size in both upriver and shoreward directions. Off the Bay mouth gravel patches are relatively abundant on the shoals, indicating strong erosion or non-deposition. Several dump or spoil areas are of interest because the associated patches of muds in their vicinity may represent dispersion shadows which could be used to determine prevailing directions of bottom sediment transport. For example, sediments from the dump site near the Harbor of Refuge may have been dispersed and redeposited at the end of ebb periods (Oostdam, 1971). Fines are either not deposited, or else preferentially removed from the bottom sediments in the center part of the Bay (where currents are stronger), leaving a relatively coarse (lag) deposit. Some of these fines may be flushed from the Bay, others may be deposited preferentially in the quieter waters along the shore and upriver.

Strom (1972) studied in detail sediment distribution in southwestern Delaware Bay which includes the spoil area. He found muddy sand, sandy mud, and mud in the basin region off the mouth of Roosevelt Inlet. He concluded that deposition from suspension in quiet water is clearly the origin of the deposits of mud and sandy mud in Breakwater Harbor.

Average median grain size of suspended sediment was 2.5 μ and the gross textural composition was 55% clay, 40% silt, and 5% fine sand. Clay mineralogy was similar throughout the estuary with the following order of abundance: illite, chlorite, kaolinite, and montmorillonite (Oostdam, 1971).

Geological Processes

Cape Henlopen is an actively growing spit built by longshore transport of beach sands eroded from the coastline immediately south of the Cape. Erosion rates up to 0.4 meters (Kraft, 1971) per year for the Atlantic Beach at Cape Henlopen have been estimated and northward longshore transport past the Cape was estimated at 114,690 cubic meters per year. The principal features of the bathymetry of Delaware Bay are: 1) shoals off Cape May Point which are analogous to bay-mouth shoals in other estuaries; 2) a series of shoals parallel to the axis of the estuary; 3) finger-like channels, extending into and shoaling in upriver direction, constituting flood channels; 4) shallow mud-flats which fringe almost the entire Bay shore, especially in the bight on the New Jersey side; 5) the center channel.

In summary (Oostdam, 1971), the geology of Delaware Bay demonstrates: 1) the important long-term effects of Pleistocene sea level changes, reflected in the relation between buried and present day channels and in the gross distribution of the sediments; 2) the shorter term effects of tidal currents expressed in the relation of shoals and minor channels, together with the distribution, composition, and texture of the surface sediments.

Project Background

In the earliest days when ships traveled into Delaware Bay, they lacked a sheltered area to protect them from storms. Due to the heavy loss of ships in these waters, a breakwater in the Harbor of Refuge was finally constructed in 1828. The breakwater originally consisted of two parts. Shortly after the construction of these sea walls, deep troughs formed at each end of these two segments. These troughs were apparently formed from the deflection of currents by the breakwaters. It was later realized that the existing breakwater configuration did not provide adequate protection. To arrest this effect, the two parts were joined by a third section, which was completed in 1898.

The two end troughs are still "active" because they are continuously scoured by currents. The two inner troughs became "inactive" when the two breakwaters were joined. The trough on the southeast corner was filled by spoil deposited as a result of former dredging projects.

Methods

Sediment Type

Sediment sample stations are given in Figure 1. One hundred and three stations were sampled prior to dredging. Only 71 of the 103 were sampled immediately after dredging; all of the original stations were resampled three months later. A 0.1 m^2 Petersen grab was used to take samples. Two aliquots of sediment were taken at each station and Eh readings were recorded immediately. One aliquot was analyzed for total percentage of sand, silt, clay, and carbon content. The second aliquot was frozen for future analysis.

To determine the percent sand, silt, and clay, approximately 10 g of sediment was washed through a 62 μ mesh sieve into a one liter graduated cylinder. Sand was dried and weighed, and the filtrate was diluted to one liter and agitated. Twenty minutes after agitation, 20 ml was pipetted from a depth of 2 cm, placed into a beaker and dried. The dried material was weighed to obtain the clay fraction. No dispersing agent was used. To determine the weight of silt, the weight of clay was subtracted from the total weight of silt-clay. These weights were converted to percentages. The carbon content of the silt-clay fraction was determined on a Coleman Carbon-Hydrogen Analyzer.

Distribution of Spoil

This study was designed to evaluate the amount of settling of the spoil, its total volume and its distribution. Four bathymetric surveys were performed in the disposal area with a Raytheon precision depth recorder Model D 719. Six points, established by sextant, were located on the middle section of the inner breakwater. At each of these locations a $0.74 m^2$ marker was erected. A tide staff was also erected on the breakwater and water depths were corrected to mean sea level. Accuracy of the depth recordings was 0.15 meters. A small boat was anchored approximately 900 meters from the breakwater and its location was determined by sextant readings. Transect lines were formed between the anchored boat and each of the markers. A 200 kilohertz transducer was used and the results plotted on graph paper. Constant speed was maintained throughout each transect and the time of day was also recorded. Each bathymetric survey contained from 24 to 42 transect lines. A depth survey was performed immediately before (February) and after dredging (March) and

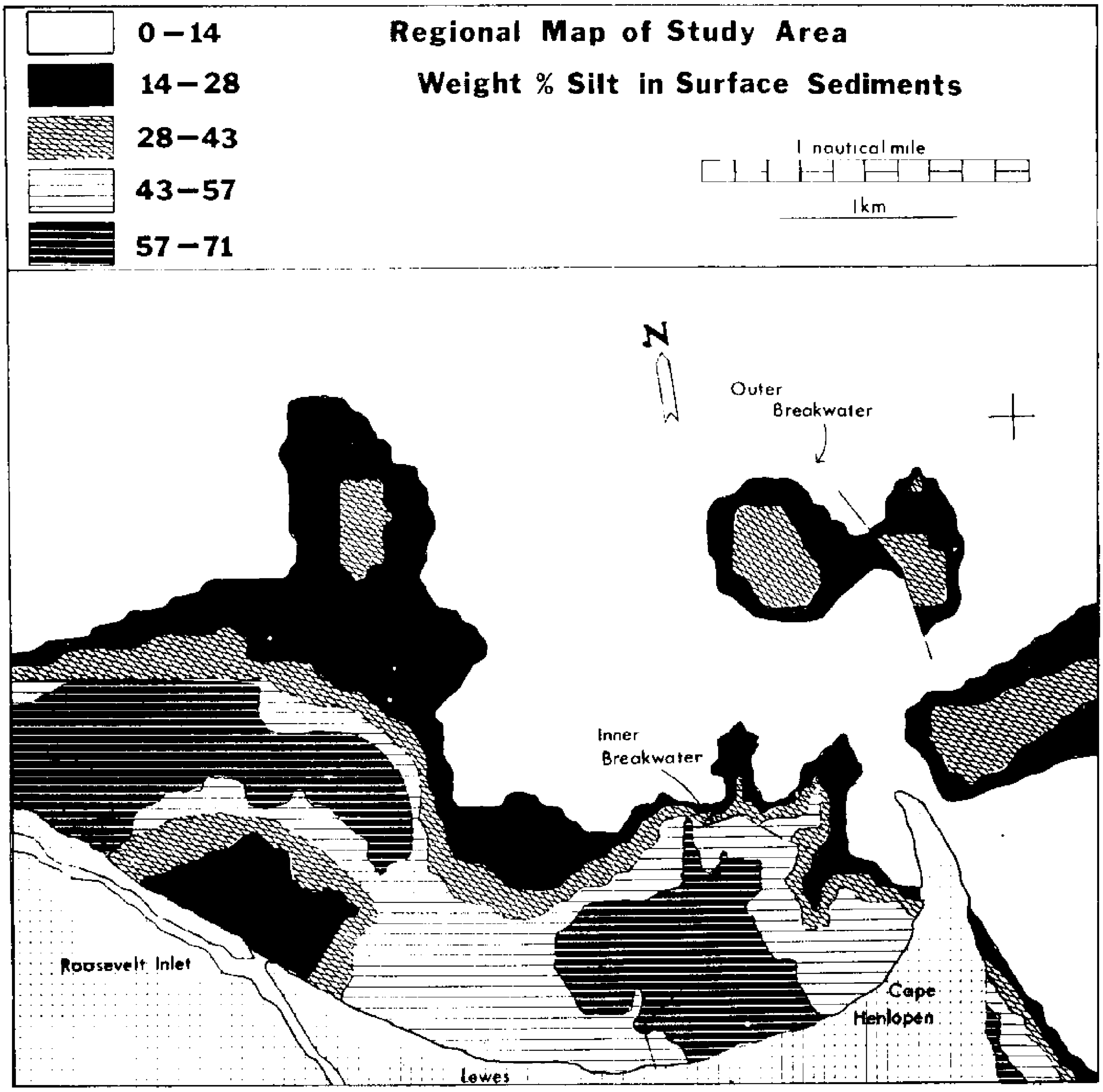

Figure 11
Percent Silt, December 1971

two months (April) and five months (July) after dredging. Data from the survey two months after dredging were not included because of technical trouble. Data were collated and continuous depth contour maps were made. Based on isopach maps, differences in sediment thickness and distribution of spoil before and after disposal can be determined.

To estimate the settling rate of the spoil, a sediment sample was obtained from the dredging discharge pipe and put into a 3.6 m transparent plastic tube (10.2 cm in diameter). The water column was vigorously agitated. The spoil material was predominantly a mixture of silt and clay with a high percentage of organics. The settling rate, which represents loss of water as the spoil gradually compacts, was recorded.

Results

Sediment Type

A computer program was developed for sediment data to provide printout contour maps of sand, silt, and clay. The majority of these maps are included in the Appendix.

In terms of percent sand, the contour maps for December and March sampling periods showed almost no variation between them. The map developed for June varied somewhat from the other sampling periods. However, ranges of percent sand in and around the spoil area were similar for all three periods.

The maps of percent silt for the December and March sampling periods were also similar (Figure 11). However, there was an increase in percentage of silt in the spoil disposal area in March (Figure 12). This increase in silt was not recorded during the June sampling period (Figure 13).

Contours of the percentage clay were similar from the December and March sampling periods with a reduction in the amount of clay recorded for June sampling periods.

Distribution of Spoil

Contour maps of the bathymetric surveys indicate that the majority of the spoil moved out of the proposed disposal site down a slope 90 meters towards a dead trough. The second survey accounted for approximately 99,000 cubic meters of spoil (Figure 14). The fourth survey revealed an additional 39,000 cubic meters around the west end of the inner breakwater (Figure 15). The dredging operation removed 142,000 cubic meters of sediment from the channel (DRBA) which contained 40% water by volume. The total volume of spoil detected by the project bathymetric survey was 138,000 cubic meters, including 74% water by volume. Calculations were made to determine the dry weight of the spoil material and the sediment in the channel before dredg-

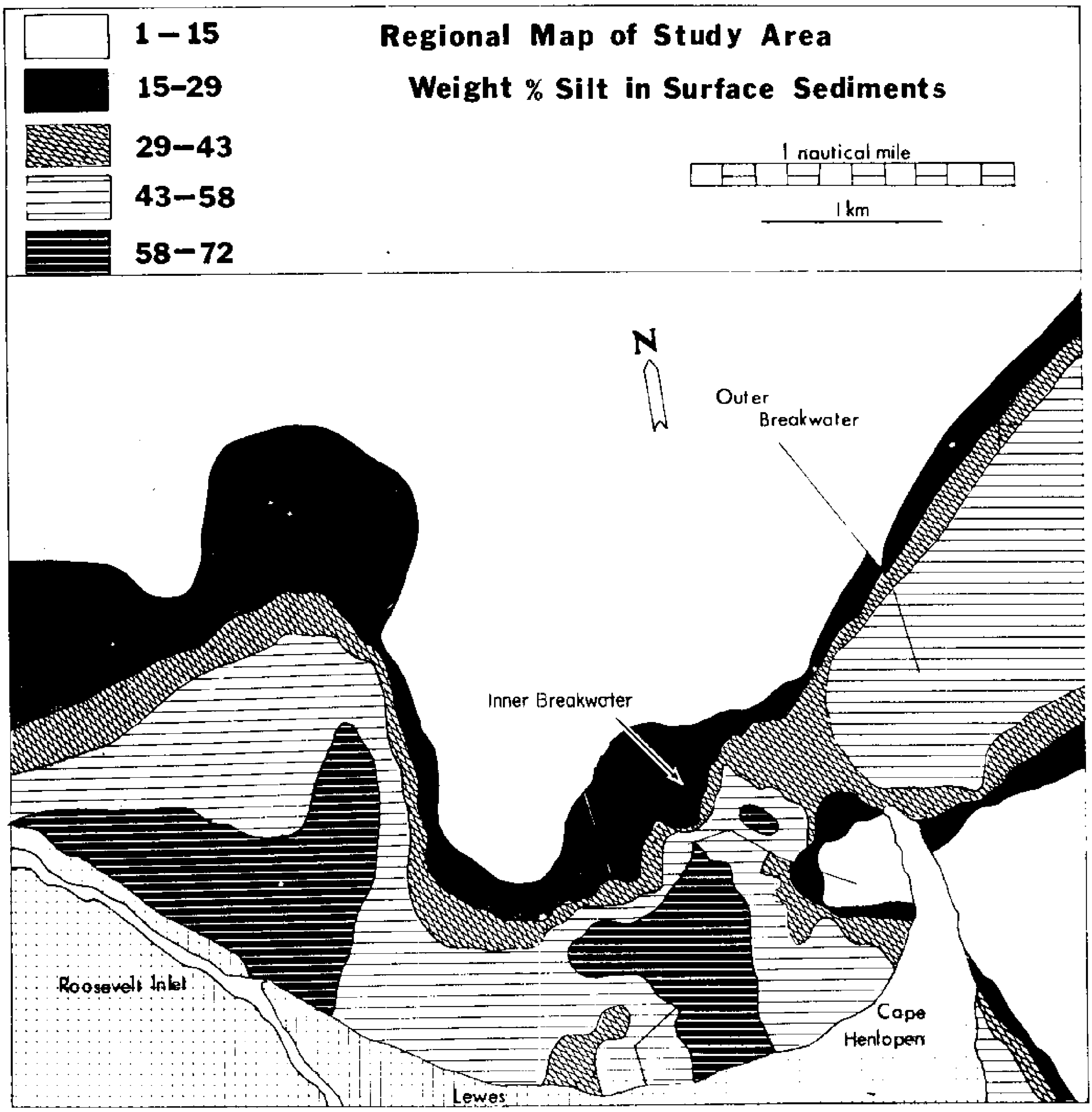

Figure 12
Percent Silt, March 1972

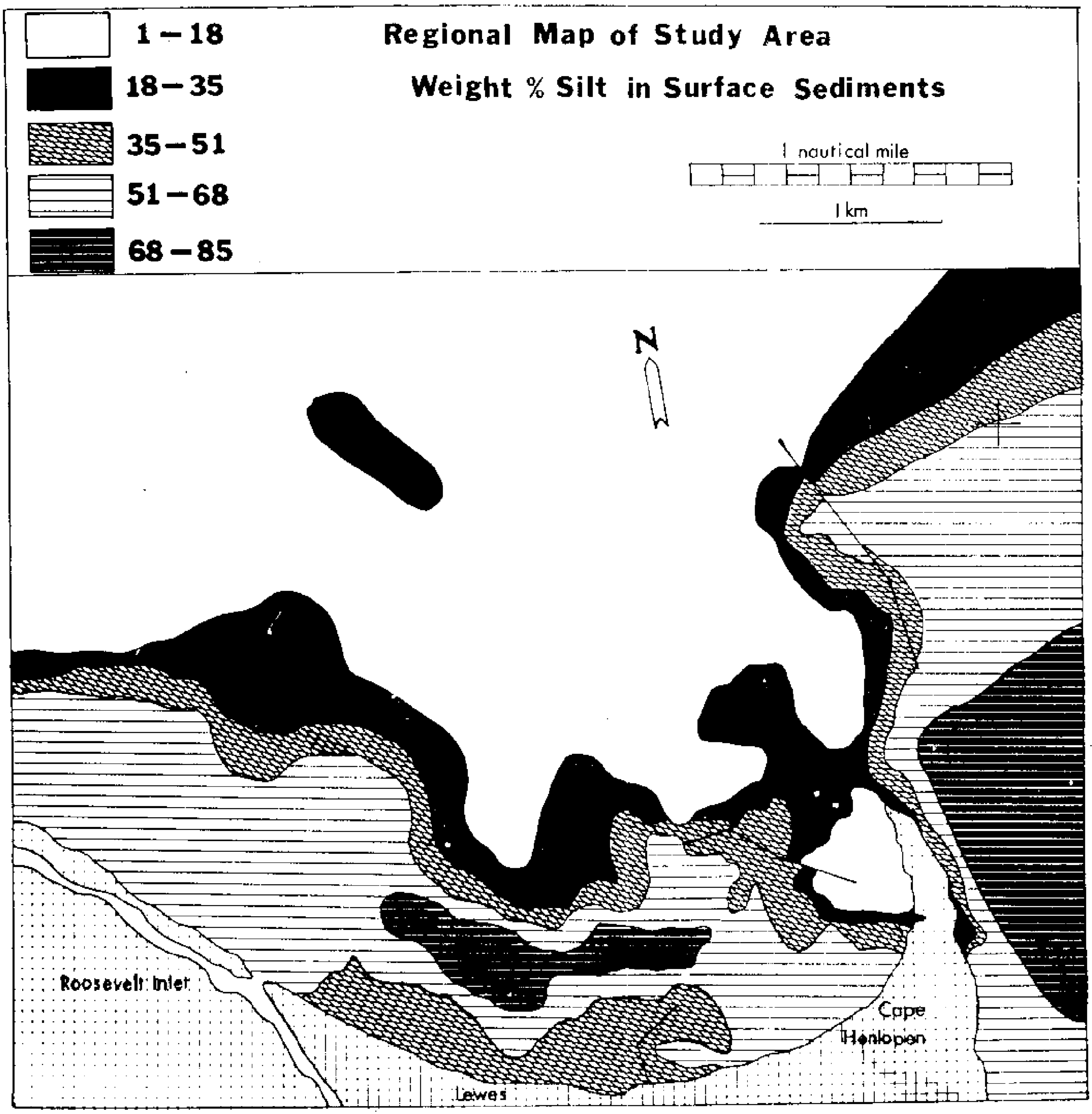

Figure 13

Percent Silt, June 1972

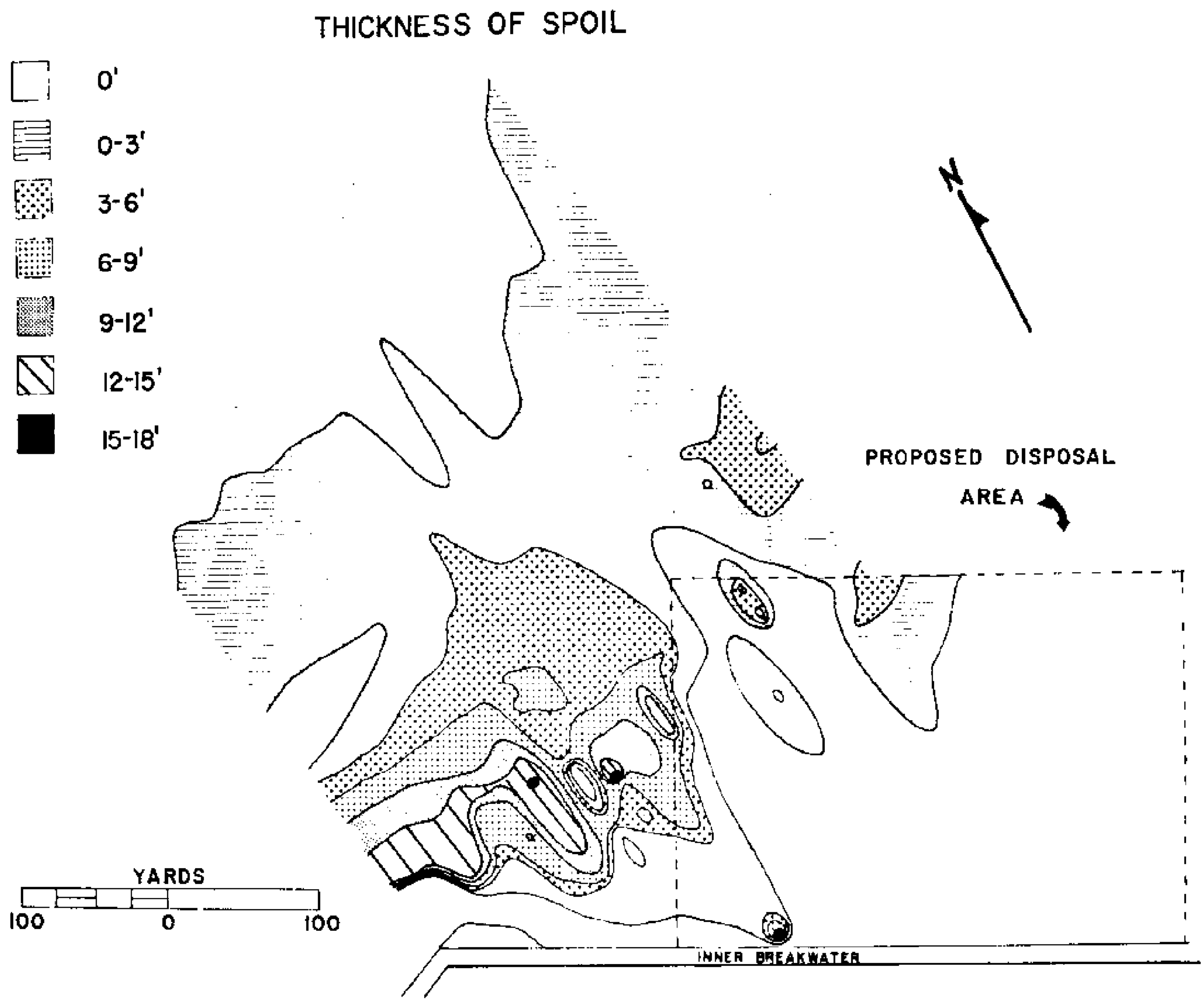

Figure 14

Isopach Map Constructed from Bathymetric Surveys of February 9, 1972 and March 21, 1972 ing. The results showed that the amount of spoil detected by bathymetry represented 38.5% of the amount of sediment (dry weight) dredged. The remainder was unaccounted for.

The subbottom profile was markedly different after dredging (Figure 16). The trough at the west end of the spoil disposal area was completely filled. Because the spoil was able to fill the trough it was not distributed over as large an area as it might have been if no trough existed. Layers of silt were discovered on Cape Henlopen beaches indicating that fine spoil materials may have been suspended and transported to sea or up into the bay, depending on the tides.

Data on the settling rate are included in the Appendix. The spoil was found to settle only 34.6 mm during a period of 64 days. The material failed to settle further in the next 69 days. This was particularly significant because this material was not subject to wind, tidal currents, and faunal reworking, and therefore had ideal conditions for settling. The settling tube experiment supported the field data that much of the spoil material (< 63 microns) would remain in suspension for an indefinite period when agitated by the slightest wind or tidal action. These laboratory data provided a possible explanation for the loss of approximately 61% of the spoil.

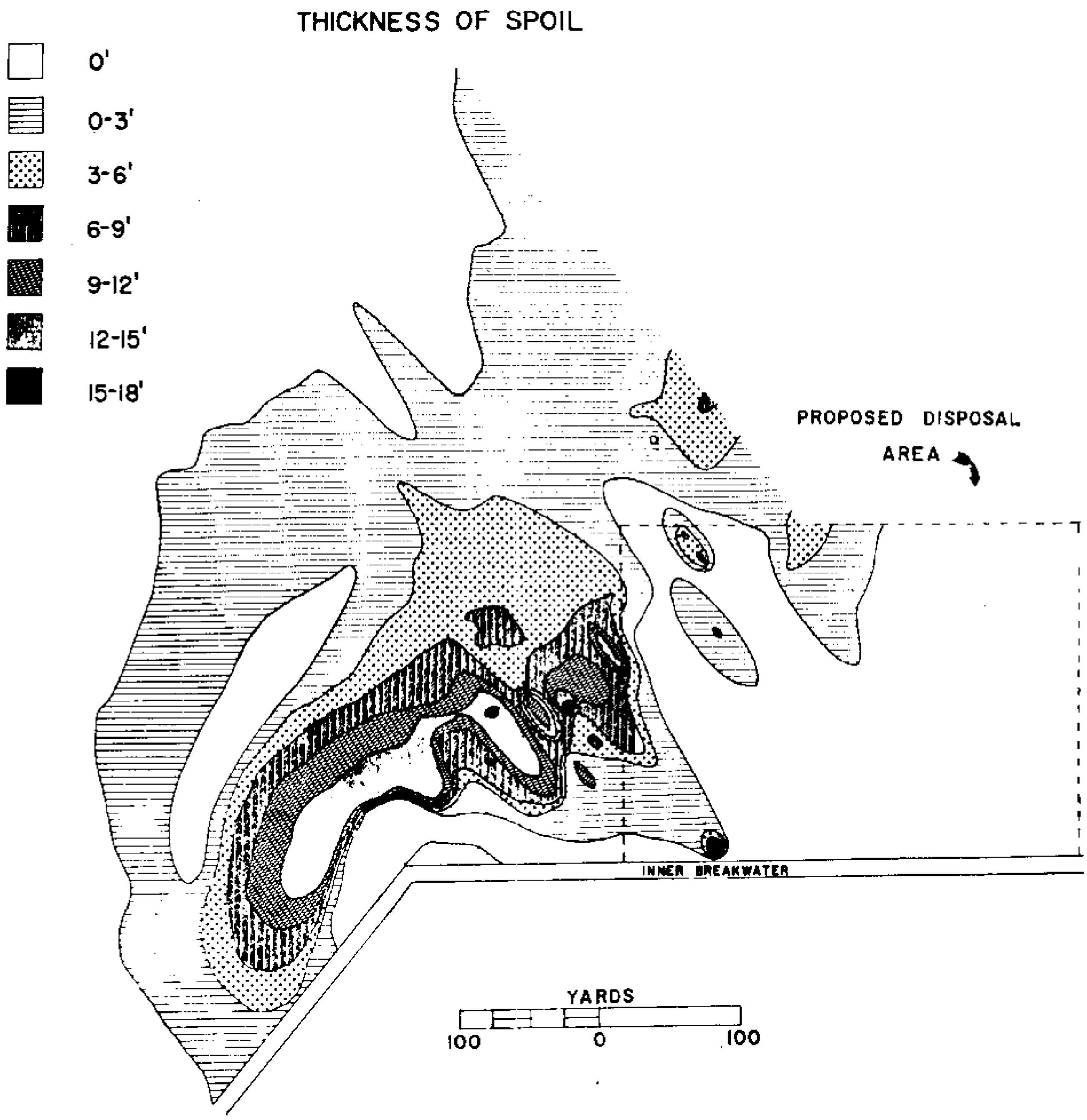

Figure 15

Isopach Map Constructed from Bathymetric Surveys, February 9, 1972 and July 10, 1972

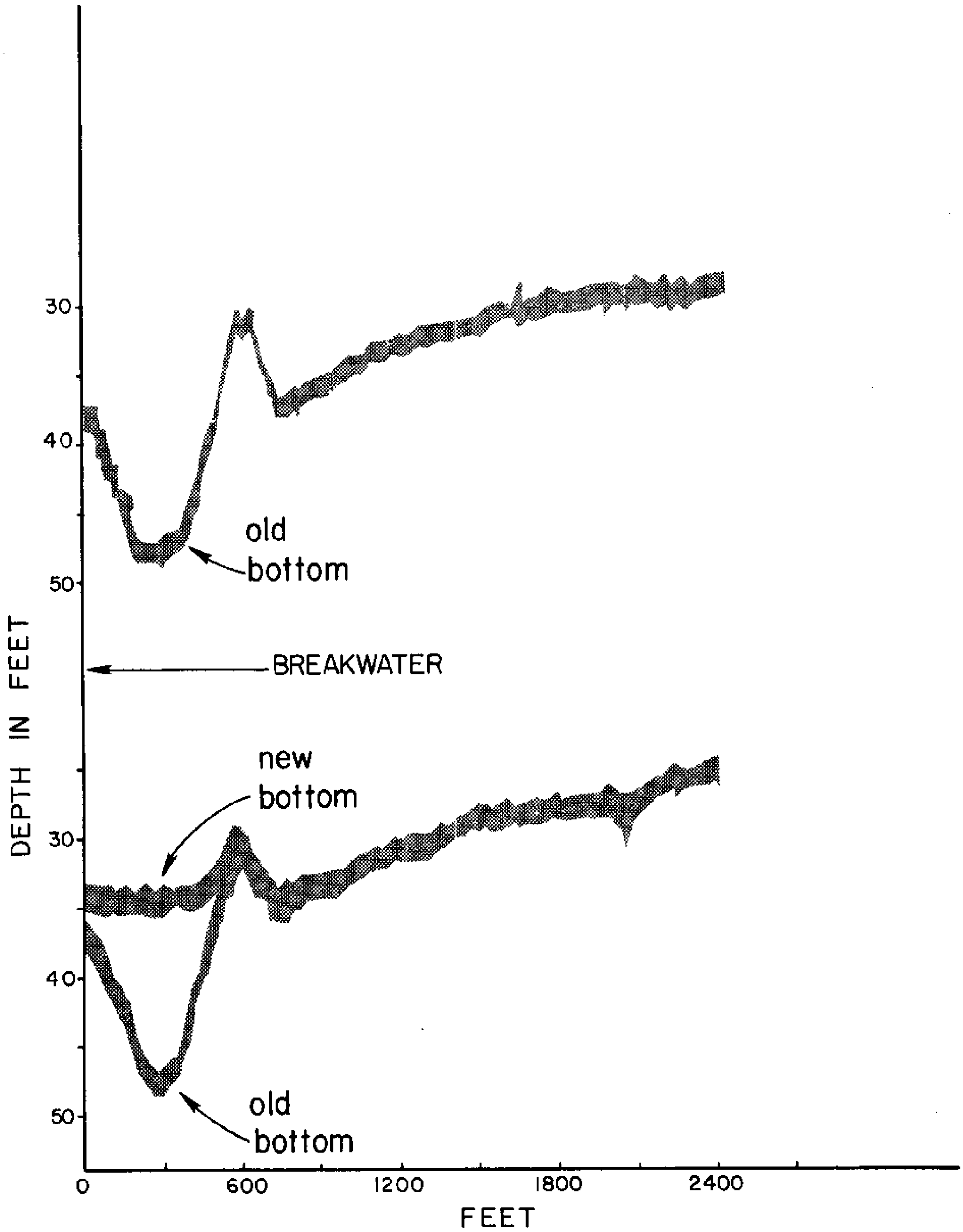

Figure 16

Subbottom Profile of Trough near the Spoil Area Before and After Dredge

MARINE BIOLOGY

The purpose of the benthic survey was to determine the effect of dredging and spoil disposal on bottom dwelling invertebrates in the project area. A secondary objective was to assess short-term recruitment. This section includes data and biological observations.

Biological Setting

The Delaware Bay area has been the subject of many biological studies. The most complete listing of these studies occurs in the Governor's Task Force (1972) and Polis (1972). Both references contain annotated bibliographies. Based on the above and other studies, a great deal is known about finfish and a few commercial invertebrates such as the oyster, hard clam, and blue crab (DeSylva, et al., 1962; Abbe, 1967; Daiber and Smith, 1971; Haskin, 1949, 1952, 1954, 1964; Cronin, 1954; Porter, 1956; Shuster, 1959; Hidu and Haskin, 1971; Maurer, et al., 1971; Keck, et al., 1973). Other studies have been conducted which include larger taxonomic or ecologic groups--xanthid crabs, amphipods, hydroids, nudibranchs, isopods, and pelecypods (McDermott, 1960; Franz, 1968; Bousfield, 1969;

Watling and Maurer, 1972 a, b; Watling, et al., 1973; Maurer, et al., 1973). Moreover, there has been some effort to document the fauna of the oyster community where 152 species were collected from Delaware's oyster beds (Maurer and Watling, 1973 a, b). Finally, approximately 350 species of macroscopic invertebrates are included in a guidebook for the Delaware Bay area (Watling and Maurer, 1973).

Methods

In December 1971 a benthic survey was conducted. One hundred and three quantitative samples were taken with a 0.1 m^2 weighted Petersen grab and located with sextant and loran readings (Figure 1). The grab was emptied into a pan of known volume. Preliminary observations concerning sediment type, oxidation zone, odor (H_2S), burrows, and tubes were noted. The sediment temperature was recorded, the material was leveled in the pan, and the depth of the sediment was measured to determine the volume for that particular sample. Two aliquots of sediment were retained for geological analysis as described in the previous section. The remainder of the sediment was washed through a 1.0 mm sieve using sea water. The residue on the sieve was placed in a bottle and fixed with methenamine buffered 10% formalin for biological analysis in the laboratory.

The second set of benthic samples was collected in March 1972 immediately following the completion of the dredging operation. To determine immediate gross changes from the spoil disposal, 71 of the original 103 stations were selected because of their proximity to the spoil disposal area. To obtain some data on short-term recolonization by benthic organisms, a complete (103) set of benthic samples was taken in June.

Based on the current study and the initial disposition of the spoil, areas that would demonstrate differing effects of the spoil on the biota were outlined (Figure 1). Area A was farthest from the effect of the spoil. Areas B and D were those stations which might be subject to turbid conditions caused by tidal currents resuspending the spoil. Area C was in the disposal site and included that area where initial shifting of the spoil occurred. Area E included stations behind the inner breakwater which might be subject to disturbance by the dredge itself.

Results

Invertebrate Species

A total of 115 live species of benthic invertebrates was collected. A complete species list is included in Table VI. Data on their distribution and abundance at each station and sampling period are included in the Appendix.

Phyla which had the greatest number of species represented were: arthropods 35.2%, annelids 22.8%, molluscs 20.9%, and ectoprocts 10.4%. The remaining 10.4% included four minor phyla.

Seventy-four species were categorized as infaunal. The other 31 species contained both vagile forms (*Neomysis americana*, *Crangon septemspinosa*, *Ovalipes ocellatus*, *Oxyurostylis smithi*) and attached epifaunal species (*Conopeum tenuissimum*, *Sertularia argentea*, *Membranipora tenuis*). In brief, this area essentially contains a soft bottom community (Thorson, 1957) with contributions of epifaunal species (hydroids and ectoprocts) from the surrounding hard rock jetty and breakwater.

Six species were collected more frequently than any others. These included the bivalve molluscs, *Tellina agilis*, *Nucula proxima*; the arthropods, *Ampelisca verrilli*, *Protohaustorius wigleyi*, *Trichophoxus epistomus*; and the polychaete worm, *Heteromastus filiformis*.

The two bivalves are common species in the Delaware Bay area. *Tellina agilis* is extremely abundant on the Henlopen tide flat, subtidal sand bottoms, and enclosed smaller bays, Rehoboth and Indian River Bay (Maurer, unpublished). *Nucula proxima* is locally more common in the subtidal than intertidal. It is uncommon in the smaller bays, but is most frequent at the high salinity end of the estuary in sandy silt or mud. Among the arthropods Ampelisca verrilli is one of five species of local ampeliscids. Ampelisca verrilli may occur abundantly in a given area but is normally not as abundant or widespread as Ampelisca abdita and A. vadorum (Maurer, unpublished). The latter species are characteristic of soft bottoms in the smaller bays. Protohaustorius wigleyi is just one of several species of local haustoriid amphipods known to occur in clean sand bottoms under oceanic conditions. Trichophoxus epistomus is similar to A. verrilli in that it is not usually common but may occur in high numbers in the smaller bays. Finally, Heteromastus filiformis is one of the most common polychaetes; however, it occurs in abundance under special conditions which will be discussed later.

Dredging and Spoil Disposal Effects on the Benthos

Several methods were used to examine the effects of dredging and spoil disposal upon the macrobenthos. These methods were: changes in abundance, principal taxa, Jaccard coefficient, species diversity index, animal-sediment relationships, and biomass. Each of these will be discussed separately.

Abundance

Samples were pooled into areas (Figure 1). In December, Area A had the greatest abundance of individuals (587) with an average density of 18.3 individuals per 0.1 m^2. Hereafter, density will refer to the number of individuals per 0.1 m^2. Area C, the spoil disposal site, had the second largest number (499) of individuals, but had a slightly higher density of 19.9 (Table II B). Areas B, D, and E had densities of 8.7, 16.8, and 7.1, respectively (Table IIB).

In March there was a marked reduction in the abundance of individuals in Area C. The density (3.1) was only 16% of the density recorded in December. Comparison of Area C between December and March showed a significant decrease. In contrast, during March, Area A showed a marked increase in density from 18.3 to 71.5 individuals (Table II B). This increase can be attributed to 820 bivalves (Gemma gemma) found in Station 7 (Table II A). Without these bivalves, there would have been a reduction in density to 16.8. Area E also showed a reduction in density to 1.7 individuals representing only 2.3% of the December value. T-tests for Area E between December and March showed a significant decline in density. Area D also had a reduction in density (11.4), but density (22.5) in Area B increased sharply.

In general, samples from the March sampling period or post disposal period revealed an expected pattern. There was a significant reduction in density in Area C

Table II A

Abundance and Number of Species
for the Three Sampling Periods by Station

AREA A

	December 1971		March 1972		June 1972	
Station	Abundance	No. Species	Abundance	No. Species	Abundance	No. Species
1	8	4	5	3	12	1
2	16	3	3	3	0	0
3	13	5	16	7	9	4
4	16	4	-	-	16	4
5	5	2	12	1	13	5
6	7	2	-	-	31	6
7	15	3	844 (24)	16 (15)	17	5
8	22	4	-	-	11	6
9	7	7	-	-	3	2
10	6	4	-	-	4	2
11	34	8	5	2	26	8
12	14	6	18	5	4	4
13	10	5	-	-	8	5
14	26	6	-	-	16	9
15	20	8	-	-	160	6
16	2	1	51	5	28	3
17	36	6	-	-	2	1
18	5	4	13	4	10	7
19	66	4	39	8	14	4
20	15	4	-	-	11	4
21	56	6	6	5	14	5
22	19	3	-	-	7	5
23	13	7	-	-	5	3
24	19	5	15	4	13	2
25	4	3	-	-	4	3
26	12	8	7	7	11	7
27	6	4	8	7	14	14
28	18	4	-	-	9	9
29	22	6	-	-	2	2
30	60	8	-	-	31	6
31	7	4	30	7	29	5
32	8	6	-	-	16	6
Total	587	154	1072	84	536	153
Average	18.3	4.8	71.5	5.6	16.8	4.8
			(252)*	(83)*		
			(16.8)*	(5.5)*		

Note: * Total and average exclude 820 Gemma gemma in Station 7.

Table II A (cont.)

Abundance and Number of Species
for the Three Sampling Periods by Station

AREA B

	December 1971		March 1972		June 1972	
Station	Abundance	No. Species	Abundance	No. Species	Abundance	No. Species
33	3	3	9	6	9	5
34	22	7	-	-	7	7
35	3	3	49	9	4	2
36	15	8	6	3	7	5
37	4	4	53	3	4	4
38	6	6	12	8	12	7
39	8	3	6	3	0	0
Total	61	34	135	32	43	30
Average	8.7	4.9	22.5	5.3	6.1	4.3

AREA C

	December 1971		March 1972		June 1972	
Station	Abundance	No. Species	Abundance	No. Species	Abundance	No. Species
40	12	4	16	6	17	5
41	10	2	-	-	48	5
42	26	6	16	4	5	3
43	27	8	6	5	30	6
44	21	5	0	0	42	5
45	23	6	4	3	3	2
46	6	2	1	1	5	2
47	3	3	4	3	2	2
48	17	2	-	-	5	4
49	14	5	0	0	17	5
50	7	4	-	-	14	3
51	16	3	4	3	1	1
52	10	7	8	5	2	2
53	4	4	0	0	4	3
54	1	1	0	0	5	5
55	1	1	1	1	5	2
56	4	4	-	-	10	3
57	8	5	0	0	10	6
58	16	2	0	0	3	3
59	19	1	2	2	6	3
60	12	1	0	0	13	6
61	2	1	1	1	4	2

Table II A (cont.)

Abundance and Number of Species
for the Three Sampling Periods by Station

AREA C (continued)

	December 1971		March 1972		June 1972	
Station	Abundance	No. Species	Abundance	No. Species	Abundance	No. Species
62	0	0	2	2	27	1
63	209	4	1	1	14	3
64	30	7	0	0	1	1
Total	499 (293)*	88 (87)*	66	37	293	83
Average	19.9 (11.7)*	3.5 (3.5)*	3.1	1.8	11.7	3.3

Note: * Total and average exclude 206 <u>Nucula proxima</u> in Station 63.

AREA D

	December 1971		March 1972		June 1972	
Station	Abundance	No. Species	Abundance	No. Species	Abundance	No. Species
65	10	1	22	1	31	2
66	3	1	34	2	8	2
67	4	4	10	4	3	2
68	72	9	12	5	2	2
69	16	5	11	3	3	3
98	40	7	9	4	10	3
99	1	1	5	5	11	4
100	19	3	13	4	8	5
101	4	2	3	2	14	6
102	15	4	5	2	14	3
103	1	1	1	1	0	0
Total	185	38	125	33	104	32
Average	16.8	3.5	11.4	3.0	9.5	2.9

Table II A (cont.)

Abundance and Number of Species
for the Three Sampling Periods by Station

AREA E

	December 1971		March 1972		June 1972	
Station	Abundance	No. Species	Abundance	No. Species	Abundance	No. Species
70	3	1	0	0	1	1
71	3	2	-	-	5	2
72	7	4	5	1	3	2
73	1	1	-	-	7	1
74	4	3	1	1	12	3
75	11	5	-	-	7	2
76	36	5	5	1	58	4
77	351	2	0	0	5	3
78	4	2	3	2	1	1
79	3	2	1	1	0	0
80	6	2	1	1	3	2
81	0	0	3	2	4	1
82	2	2	0	0	16	4
83	3	3	0	0	11	3
84	10	5	1	1	9	4
85	5	1	1	1	1	1
86	3	1	0	0	1	1
87	0	0	1	1	0	0
88	1	1	-	-	1	1
89	0	0	-	-	0	0
90	0	0	-	-	0	0
91	0	0	-	-	1	1
92	1	1	4	2	4	2
93	5	2	-	-	7	3
94	24	3	2	1	7	4
95	8	3	-	-	5	2
96	18	5	3	3	17	2
97	5	4	1	2	17	6
Total	198	60	32	20	203	56
Average	7.1	2.1	1.7	1.1	7.3	2.0

Table II B

Mean Abundance and Number of Species for the Three Sampling Periods by Area

Area	December 1971 Abundance	December 1971 No. Species	March 1972 Abundance	March 1972 No. Species	June 1972 Abundance	June 1972 No. Species
	Observations at all Stations					
A	18.3	4.8	71.5	5.6	16.8	4.8
B	8.7	4.9	22.5	5.3	6.1	4.3
C	19.9	3.5	3.1	1.8	11.7	3.3
D	16.8	3.5	11.4	3.0	9.5	2.9
E	7.1	2.1	1.7	1.1	7.3	2.0
	Excludes Observations at Certain Stations (See Note)					
A	18.3	4.8	16.8*	5.5*	16.8	4.8
B	8.7	4.9	22.5	5.3	6.1	4.3
C	11.7**	3.5**	3.1	1.8	11.7	3.3
D	16.8	3.5	11.4	3.0	9.5	2.9
E	7.1	2.1	1.7	1.1	7.3	2.0

Note: * Excludes Station 7 = 820 <u>Gemma gemma</u> & 1 Species.
** Excludes Station 63 = 206 <u>Nucula proxima</u> & 1 Species.

and in Area E. The area surrounding the dump site showed a much smaller decline in the density of the benthos. The density in Areas A and B, furthest from the spoil site, showed no significant changes.

June samples revealed an increase in density for Areas C and E (Table II B). In the spoil area there was a significant increase in density from 3.1 (March) to 11.7 (June). Area D, surrounding the spoil site, showed a decrease in density from 11.4 to 9.5 individuals. Density of stations within Breakwater Harbor (Area E) were similar to December or predredging values (7.3) indicating a significant increase from March to June. Stations in Areas A and B both had densities of 16.8 and 6.1, respectively in June. These values were not significantly different from those densities recorded in December and March.

Principal Taxa

In December, two species of bivalves, Tellina agilis (473 individuals) and Nucula proxima (423 individuals) were the dominant taxa in the fauna. Together they represented over 50% of the total individuals. Ampelisca verrilli (86 individuals) and Protohaustorius wigleyi (81 individuals) were the dominant arthropods but occurred in only 12 and 11 stations, respectively. Among polychaetes, Heteromastus filiformis (68 individuals) was the most abundant.

Samples from March revealed some changes from December. Tellina agilis and N. proxima were still the most dominant species and H. filiformis remained the dominant polychaete, occurring in 11 stations. Ampelisca verrilli appeared in only four stations, but this was due to the elimination of some of the sampling stations on the periphery of the study area where it was frequent prior to dredging. Among the arthropods, P. wigleyi remained a dominant species. The relative frequency of two epifaunal species, the ectoprocts, Conopeum tenuissimum and Membranipora tenuis declined in the spoil area. Membranipora tenuis occurred in ten stations in Area C in December and none in March. Conopeum tenuissimum occurred in only 33% of the stations in Area C that it was found in during December.

During June, Mulinia lateralis emerged as the third major bivalve when it was recorded in 39 stations. Mulinia lateralis was not recorded from Area C in December, but occurred at two stations in March and eight in June. Nucula proxima showed an increase in abundance and occurrence from December to June. Exclusive of the 206 individuals from Station 63 (December), there was an increase from 217 individuals in December to 351 in June. Moreover, Nucula proxima occurred in 15 more stations in June than it did in December. The relative frequency of the ectoprocts, M. tenuis and C. tenuissimum was also lower in June than December.

The Mann-Whitney test was used to determine if differences in abundance existed between sampling periods for the two major species, T. agilis and N. proxima. The sample population of T. agilis and N. proxima was found to be significantly greater in December than in March in Area C, the dump site. Other differences in abundance of T. agilis occurred in Areas A and E where December samples were found to be significantly larger than June samples. The test also revealed that December samples of N. proxima were significantly greater than March samples in Area E.

Jaccard Coefficient

In addition to studying the gross effects of dredging and spoil disposal, attempts were also made to evaluate any community changes that might have occurred. Jaccard's binary coefficient (Sokal and Sneath, 1963) was used to compare the species present in each of the stations for all the sampling periods (Table III). In 62 comparisons computed for Area A, only 8 had no similarity at all for two sampling periods. Areas B and D showed a slightly higher number of zero similarities with 9 of 19 and 10 of 33 comparisons, respectively. Sixty-five coefficients were computed for the spoil disposal area (Area C)

Table III

Jaccard Coefficient

Area A

Station	Dec.-March	Mar.-June	Dec.-June
1	.750	.333	.250
2	.500	.000	.000
3	.250	.222	.333
4			.600
5	.500	.200	.400
6			.333
7	.059	.053	.333
8			.250
9			.125
10			.000
11	.100	.091	.214
12	.222	.125	.250
13			.182
14			.231
15			.182
16	.000	.143	.000
17			.000
18	.125	.100	.333
19	.273	.200	.250
20			.286
21	.222	.111	.222
22			.143
23			.286
24	.500	.200	.167
25			.000
26	.333	.429	.272
27	.100	.300	.077
28			.333
29			.000
30			.250
31	.375	.500	.333
32			.091

Area B

Station	Dec.-March	Mar.-June	Dec.-June
33	.125	.222	.000
34			.413
35	.111	.111	.000
36	.222	.333	.300
37	.000	.200	.000
38	.182	.500	.333
39	.200	.000	.000

Table III (cont.)

Jaccard Coefficient

Area C

Station	Dec.-March	Mar.-June	Dec.-June
40	.099	.200	.250
41			.333
42		.400	.285
43	.182	.100	.076
44			.111
45	.000	.000	.000
46	.000	.000	1.00
47	.200	.250	.250
48			.200
49	.000	.000	.111
50			.166
51	.200	.000	.000
52	.200	.000	.000
53	.000	.000	.000
54	.000	.000	.000
55	.000	.000	.000
56			.000
57	.000	.000	.000
58	.000	.000	.000
59	.500	.667	.333
60	.000	.000	.142
61	.000	.000	.500
62	.000	.500	.000
63	.250	.333	.167
64	.000	.000	.200

Area D

Station	Dec.-March	Mar.-June	Dec.-June
65	.250	.200	.500
66	.333	.500	.333
67	.333	.333	.333
68	.167	1.00	.167
69	.333	.200	.167

Area E

Station	Dec.-March	Mar.-June	Dec.-June
70	.000	.000	1.000
71			.500
72	.250	.500	.200

Table III (cont.)

Jaccard Coefficient

Area E

Station	Dec.-March	Mar.-June	Dec.-June
73			.000
74	.000	.333	.200
75			.167
76	.200	.250	.500
77	.000	.000	.000
78	.000	.000	.000
79	.500	.000	.000
80	.000	.500	.000
81	.000	.500	.000
82	.000	.000	.500
83	.000	.000	.500
84	.000	.000	.125
85	.000	.000	.000
86	.000	.000	.000
87	1.000	.000	.000
88			.000
89			.000
90			.000
91			.000
92	.333	.333	.500
93			.333
94	.333	.250	.400
95			.666
96	.167	.250	.000
97	.000	.000	.000

Area D

Station	Dec.-March	Mar.-June	Dec.-June
98	.375	.167	.250
99	.000	.000	.000
100	.400	.167	.200
101	.000	.143	.333
102	.000	.000	.000
103	.000	.000	.000

and 32 of these had no similar species. Within Area C it was noted that stations farthest from the spoil area had the highest coefficients of similarity. Coefficients for December-June comparisons were consistently greater than December-March comparisons in Area C. Area E had an even greater number of zero comparisons (38 of 56 computed) than Area C. No trend was discerned in this area.

Diversity Index

The formula $\bar{H} = \frac{C}{N}$ [N $\log_{10}$ N - Σn $\log_{10}$ ni] (Lloyd, et al., 1968) which was derived from Brillouin (1956) was used to provide additional analysis of changes of community structure due to dredge and spoil disposal (Table IV). Redundancy coefficients [R = 100 (1-H_r) (where (H_r) is the ratio of the observed to the maximum diversity)] were also calculated to assess the dominance of one or more species and provide a further measure of community change (Lie, 1968). Unlike ($\bar{H}$), however, the R value is unaffected by variation in the number of species and represents the distribution of the individuals among the species (Table IV).

In December the highest abundance of individuals (209) in the dump site occurred at Station 63. This was primarily due to 206 N. proxima. Stations 42, 43, and 64 had 27, 26, and 30 individuals, respectively. The highest abundance (16) of individuals occurred at Stations 40 and 42 in March.

Table IV

Diversity ($\bar{H}$) and % Redundancy (R) Values
for the Three Sampling Periods by Stations
(Pelecypods, polychaetes, arthropods were used to compute $\bar{H}$ and R)

\- Station Not Sampled

o/o Station Sampled--No Species Present

Area A

	December 1971		March 1972		June 1972	
Station	$\bar{H}$ Diversity	% R Redundancy	$\bar{H}$ Diversity	% R Redundancy	$\bar{H}$ Diversity	% R Redundancy
1	1.90	4.95	1.37	13.44	0.00	100.00
2	.87	45.18	1.59	0.0	0/0	0/0
3	1.10	30.82	1.63	29.85	1.89	5.40
4	1.58	20.99	-	-	1.91	4.70
5	.97	2.89	0.00	100.0	2.04	12.12
6	.86	13.68	-	-	1.47	43.23
7	.70	55.83	.24	93.77	1.74	25.14
8	1.40	30.26	-	-	2.37	8.37
9	2.00	0.00	-	-	.92	8.17
10	1.37	13.45	-	-	.81	18.87
11	2.47	22.13	.72	27.79	1.66	16.94
12	1.42	29.09	1.95	15.99	0.00	100.00
13	1.32	16.58	-	-	1.84	7.87
14	.91	8.78	-	-	2.29	11.51
15	.99	50.33	-	-	.25	87.47
16	.92	8.16	1.51	34.79	.89	43.94
17	1.56	32.74	-	-	0.00	100.00
18	1.44	37.94	1.49	25.58	2.28	11.76
19	1.75	12.36	2.08	25.86	1.52	23.91
20	1.81	22.03	-	-	1.28	38.62
21	1.27	50.98	2.25	2.90	1.55	22.66
22	1.14	20.05	-	-	1.79	10.37
23	2.75	8.21	-	-	1.52	3.98
24	1.50	24.96	1.71	14.70	.39	60.88
25	1.50	5.36	-	-	.92	8.16
26	2.32	10.17	0.00	100.0	1.45	27.67
27	1.92	3.90	1.50	5.36	1.95	24.55
28	1.09	31.46	-	-	.98	2.11
29	.09	95.56	-	-	1.00	0.00
30	1.75	41.56	-	-	1.89	18.63
31	1.95	2.48	2.30	17.96	1.96	15.29
32	2.24	3.57	-	-	1.91	17.76

Table IV (cont.)

Area B

	December 1971		March 1972		June 1972	
Station	$\bar{H}$ Diversity	% R Redundancy	$\bar{H}$ Diversity	% R Redundancy	$\bar{H}$ Diversity	% R Redundancy
33	1.00	0.00	0.00	100.00	1.75	12.51
34	2.42	32.65	-		1.50	5.36
35	0/0	0/0	1.93	25.10	1.00	0.00
36	2.05	11.41	.35	77.80	1.92	4.00
37	1.00	0.00	.14	86.29	1.59	0.00
38	.92	8.16	2.37	8.27	1.97	1.25
39	.86	13.67	.72	27.79	0/0	0/0

Area C

	December 1971		March 1972		June 1972	
Station	$\bar{H}$ Diversity	% R Redundancy	$\bar{H}$ Diversity	% R Redundancy	$\bar{H}$ Diversity	% R Redundancy
40	1.21	39.62	1.09	45.55	1.33	33.77
41	0.00	100.00	-	-	0.41	74.28
42	0.72	64.02	1.40	11.70	0.81	18.88
43	1.66	28.35	1.92	3.90	1.63	37.11
44	0.85	57.62	-	-	0.76	67.40
45	0.99	50.29	0.92	8.17	0.92	8.17
46	1.00	0.0	0.00	100.00	0.72	27.80
47	0/0	0/0	0.92	8.17	0.00	100.00
48	0.32	67.72	-	-	0.92	8.17
49	0.82	48.47	0/0	0/0	1.44	38.02
50	1.46	7.94	-	-	1.20	24.41
51	1.01	36.03	0.92	8.17	0/0	0/0
52	1.67	16.75	0.97	2.91	1.00	0.00
53	0.99	0.0	0/0	0/0	1.50	5.36
54	0.00	100.00	0/0	0/0	1.59	0.00
55	0.00	100.00	0.00	100.00	0.00	100.00
56	0.99	0.00	-	-	0.92	41.84
57	0.72	27.80	0/0	0/0	1.79	10.40
58	0.34	66.27	0/0	0/0	1.59	0.00
59	0.00	100.00	1.00	0.00	1.58	0.00
60	0.00	100.00	0/0	0/0	2.60	11.52
61	0.00	100.00	0/0	0/0	1.00	0.00
62	0/0	0/0	1.00	0.00	0.00	100.00
63	0.04	96.02	0.00	100.00	0.74	53.66
64	1.49	74.70	0/0	0/0	0/0	0/0

Table IV (cont.)

Area D

Station	December 1971 $\bar{H}$ Diversity	December 1971 R % Redundancy	March 1972 $\bar{H}$ Diversity	March 1972 R % Redundancy	June 1972 $\bar{H}$ Diversity	June 1972 R % Redundancy
65	0.00	100.00	1.79	10.37	.21	79.43
66	0.00	100.00	1.48	6.35	.81	18.87
67	1.59	0.00	1.69	15.46	1.57	21.50
68	1.33	57.94	.92	7.79	1.00	0.00
69	1.91	4.51	.47	53.09	1.59	0.00
98	1.10	60.73	1.97	1.25	.50	49.62
99	0.00	100.00	2.32	0.00	1.62	19.14
100	.77	22.51	1.15	42.72	1.46	7.93
101	0.00	100.00	.92	8.16	1.91	17.46
102	1.53	23.34	0.00	100.00	.95	5.35
103	0.00	100.00	0.00	100.00	0/0	0/0

Area E

Station	December 1971 $\bar{H}$ Diversity	December 1971 R % Redundancy	March 1972 $\bar{H}$ Diversity	March 1972 R % Redundancy	June 1972 $\bar{H}$ Diversity	June 1972 R % Redundancy
70	0.00	100.00	0/0	0/0	0.00	100.00
71	.92	8.16	-	-	.72	27.79
72	1.66	16.76	0.00	100.00	.92	8.16
73	0.00	100.00	-	-	0.00	100.00
74	1.48	6.35	0.00	100.00	1.19	25.00
75	1.97	17.33	-	-	.59	40.82
76	.95	40.92	0.00	100.00	.70	65.09
77	.32	68.40	0/0	0/0	.81	18.87
78	1.01	0	.92	8.16	0.00	100.00
79	.92	8.16	0.00	100.00	0/0	0/0
80	.65	34.99	0.00	100.00	.92	8.16
81	0.00	100.00	.92	8.16	0.00	100.00
82	1.00	0.00	0/0	0/0	.99	50.33
83	1.59	0.00	0/0	0/0	1.31	17.39
84	2.25	3.13	0.00	100.00	1.66	17.11
85	0.00	100.00	0.00	100.00	0.00	100.00
86	0.00	100.00	0/0	0/0	0.00	100.00
87	0/0	0/0	0/0	0/0	0/0	0/0
88	0/0	0/0	-	-	0/0	0/0
89	0/0	0/0	-	-	0/0	0/0
90	0/0	0/0	-	-	0/0	0/0
91	0/0	0/0	-	-	0.00	100.00
92	.92	8.16	.81	18.87	.81	18.87
93	.72	27.80	-	-	1.15	27.50
94	.50	68.64	0.00	100.00	1.84	7.87
95	1.06	33.04	-	-	.72	27.80
96	1.88	19.07	1.59	0.00	.52	47.74
97	1.92	3.90	0.00	0.00	.39	60.88

For the June sampling period the highest abundance of individuals was 48 and 42 at Stations 41 and 44, respectively.

The highest abundance of species recorded in Area C in December was eight at Station 43 (Table II A). In March the abundance of species declined with a high of six at Station 40 and five at 43 and 52. A high of six species occurred at Stations 43, 57, and 60 in June.

In terms of diversity ($\bar{H}$) per station in Area C, six values were higher in December than March and three were lower (Table IV). Five values were higher in June than March and four were lower. Comparison between $\bar{H}$ values in December and June showed that thirteen values were higher (June) and seven were lower (Table IV).

In terms of redundancy (R) values per station, six were higher in December than March and three were lower (Table IV). Five values were higher in June than March and three were lower. Comparison between redundancy values in December and June showed that nineteen were higher (December) and six were lower.

T-tests performed on the diversity and redundancy values for Area C showed that the June sampling period had significantly greater diversity than December at the 0.01 probability level and significantly lower redundancy also at the 0.01 probability level. No significance was discerned between December and March or March and June.

Areas other than the dumping site showed no change or pattern for any of the samplings. Diversity and redundancy values tended to be higher in Areas A, B, and D than in Areas C and E throughout all the sampling periods.

Animal-Sediment Relationships

Sediment Correlations

Within the project area, sediment composition was variable. For example, Stations 12, 13, and 14, farthest from the dump site, contained sediment with 100% sand. In contrast, sediment from two stations directly behind the inner breakwater contained 12% and 13% sand. In general, sediments in Area E were high in silt and clay concentration. Stations with the highest percents of sand were located in Area A which is subject to rapid current flow in and out of the mouth of the bay. Those areas with silty sand and sandy mud form transition zones between the two extremes. These observations on sediment distribution provide an important background upon which to assess the introduction of foreign sediment (spoil).

Based on abundance data from December samples, six species were selected for comparison with sediment data: *Tellina agilis*, *Nucula proxima*, *Ampelisca verrilli*, *Trichophoxus epistomus*, *Protohaustorius wigleyi*, and *Heteromastus filiformis*. Scatter diagrams relating abundance to fractions

Table V

Sediment Correlations for Selected Species of the Sample Area Using Kendall's Tau

	December 1971			March 1972			June 1972		
	Silt-Clay	Silt	Clay	Silt-Clay	Silt	Clay	Silt-Clay	Silt	Clay
Nucula proxima	.0609	.0731	.0853	-.2890 *	-.1421	-.2578	.2797 *	.2601 *	.3521 *
Tellina agilis	-.3050 *	-.2758 *	-.2866 *	-.2036	-.1451	-.1875	-.1946 *	-.1946 *	.0976
Heteromastus filiformis	.2000	.1952	.2619	.0909	.1515	.2121	.5555	.8518	.0277
Ampelisca verrilli	-.5909	-.7121 *	-.4090 *	.5000	.5000	.5000	0.0	.6666	0.0
Trichophoxus epistomus	-.2564	-.2307	-.1025	-.2777	-.3333	-.2222	-.2857	-.3809	.0952
Protohaustorius wigleyi	.3454	.2363	.4181 *	-.2666	0.0	-.5333	1.000 *	1.000 *	1.000 *

* 0.05 significance

of silt-clay, silt, and clay were made for preliminary analysis. The diagrams suggested some general associations, but were not included in the report. To supplement this analysis, correlation coefficients (Kendall's Tau, Table V). were computed to determine the association between abundance and sediment fractions.

Silt-Clay

Tellina agilis occurred in sediment with a range of 1-93% silt-clay. There was a progressive increase in abundance with decreasing amounts of silt-clay for all sampling periods. There was a statistically significant negative correlation between abundance of *T. agilis* and silt-clay for December (-.305) and June (-.195) (Table V).

Maximum density of *Nucula proxima* occurred in sediment with 50-80% silt-clay. In contrast to *T. agilis* there was an increase in abundance for *Nucula proxima* with higher percentages of silt-clay (Table V). This was particularly clear in March and June samples. December samples were inordinately affected by two stations, one of which contained 206 individuals and occurred in low percentage of silt and clay. Sediment association of abundance and high silt and clay was insignificant for June samples.

The highest abundance of *Ampelisca verrilli* occurred in sediment with less than 35% silt-clay. There was a significant negative association (-.591) with December samples (Table V). In general, Trichophoxus epistomus was associated with low silt-clay. Only one sample with five individuals was found in sediment with more than 30% silt-clay. The third amphipod, Protohaustorius wigleyi, was associated with sand. In March, one station with P. wigleyi had sediment with 31% silt-clay. In June, P. wigleyi did not occur in sediment containing silt-clay. Correlation coefficients for all sampling periods were not statistically significant.

Silt

Tellina agilis occurred in sediment with as much as 75% silt. However, there was an inverse relationship between abundance and increasing percentage of silt. There was a significant negative association in December (-.276) and June (-.195) (Table V). Nucula proxima occurred in sediment with as much as 50% silt. There was a significant positive association with abundance and increasing silt in June.

Ampelisca verrilli occurred in sediment with a range in silt of 7-12%. There was a statistically significant negative correlation (-.712) between abundance and increasing silt in December (Table V). Trichophoxus epistomus was found in sediment with a range of 2-41%. No correlation coefficients were statistically significant. The third amphipod, P. wigleyi, inhabited sediment with a range of 1-26% silt. The highest abundance appeared in silt concentrations of 1% or less.

For Heteromastus filiformis there were no statistically significant correlations.

Clay

Tellina agilis inhabited sediment with as much as 38% clay. In general there were negative associations between abundance and increasing clay. Based on these and previous data, Tellina agilis was best developed in fine sand with a range of silt and clay of 0-26% and 0-15%, respectively. Abundance of Nucula proxima was probably associated with increasing percentages of clay. This species was best developed in silty sand with 50% silt.

Correlation coefficients for A. verrilli and clay revealed the same pattern that was found with the silt-clay and silt fractions (Table V). There was a significant negative association between abundance and increasing clay in December. Ampelisca verrilli lived best in low amounts of silt (7-12%) and clay. There was a decrease in abundance with increases in these fractions to approximately 76% silt-clay, above which it did not occur. Trichophoxus epistomus occurred in sediment with clay of 5-9%. There

Table VI

Faunal Lists from Three Sampling Periods in Delaware Bay, Lewes Breakwater Area

Phylum Porifera
Order Halichondrida

Halichondria bowerbanki Burton

Phylum Cnidaria
Class Anthozoa

Diadumene leucolena (Verrill)

Class Hydrozoa

Halecium gracile Verrill
Hydractinia echinata (Fleming)
Sertularia argentea (L.)

Class Scyphozoa

Cyanea capillata (L.)

Phylum Platyhelminthes
Class Turbellaria

Stylochus ellipticus (Girard)

Phylum Rhynchocoela
Class Anopla

Cerebratulus lacteus (Leidy)
Micrura rubra Verrill
Tubulanus pellucidus (Coe)
Zygeupolia rubens (Coe)

Phylum Mollusca
Class Bivalvia

Abra aequalis (Say)
Aequipecten irradians (Lamarck)

Table VI (cont.)
Phylum Mollusca
Class Bivalvia

*Anadara ovalis Bruguiere
Anomia simplex Orbigny
Barnea truncata (Say)
*Cardita borealis (Conrad)
Cardita tridentata (Say)
Cerastoderma pinnulatum (Conrad)
Corbula contracta Say
Cyrtopleura costata (L.)
Donax fossor Say
*Ensis directus Conrad
*Gemma gemma (Totten)
Macoma baltica (L.)
*Mercenaria mercenaria (L.)
*Mulinia lateralis (Say)
Mya arenaria (L.)
Mysella planulata Stimpson
*Mytilus edulis L.
Noetia ponderosa (Say)
*Nucula proxima Say
*Pandora gouldiana Dall
*Petricola pholadiformis Lamarck
Siliqua costata (Say)
Solen viridis Say
*Spisula solidissima (Dillwyn)
Tagelus plebeius (Solander)
*Tellina agilis Stimpson
*Yoldia limatula (Say)

Class Gastropoda

*Busycon caniculatum (L.)
*Busycon carica (Gmelin)
*Crepidula convexa Say
*Crepidula fornicata (L.)
*Crepidula plana Say
Epitonium rupicolum (Kurtz)
Eupleura caudata (Say)
Haminoea solitaria (Say)
*Lunatia heros (Say)
Mangelia cerina (Kurtz and Stimpson)
*Mitrella lunata (Say)

*collected alive

Table VI (cont.)
Phylum Mollusca
Class Gastropoda

Nassarius obsoletus (Say)
*Nassarius trivittatus (Say)
*Nassarius vibex (Say)
Natica pusilla Say
Odostomia gibbosa Bush
*Polinices duplicatus (Say)
Prunum cf. bellum (Conrad)
Pyramidella fusca C.B. Adams
Retusa canaliculata (Say)
Seila adamsi (H.C. Lea)
Skenea planorbis Fabricius
Turbonilla interrupta Totten
*Urosalpinx cinerea (Say)

*collected alive

Phylum Annelida
Class Polychaeta

Ampharete acutifrons (Grube)
Asabellides oculata Webster
Diopatra cuprea (Bosc)
Drilonereis filum (Claparede)
Glycera americana Leidy
Glycera dibranchiata Ehlers
Glycinde solitaria Webster
Harmothoe (Lagisca) extenuata (Grube)
Heteromastus filiformis (Claparede)
Hydroides (Eupomatus) dianthus (Verrill)
Hypaniola grayi Pettibone
Lepidonotus sublevis (Verrill)
Lumbrineris tenuis Verrill
Nephtys picta Ehlers
Nereis (Neanthes) succinea (Frey and Leuckart)
Ophelia bicornis Savigny
Owenia fusiformis Delle Chiaje -- tubes only
Paraprionospio pinnata Ehlers
Polydora ligni Webster
Sabellaria vulgaris Verrill
Scolecolepides viridis (Verrill)
Scolelepis squamata (Muller)
Scoloplos fragilis (Verrill)
Spiochaetopterus oculatus Webster -- tubes only
Spiophanes bombyx (Claparede)
Sthenlais limicola (Ehlers)
Streblospio benedicti Webster

Table VI (cont.)

Phylum Arthropoda
Class Crustacea
Order Isopoda

Ancinus depressus (Say)
Chiridotea tuftsi (Stimpson)
Cirolana concharum (Stimpson)
Cirolana polita (Stimpson)
Edotea triloba (Say)

Order Mysidacea

Neomysis americana (S.I. Smith)

Order Amphipoda

Acanthohaustorius intermedius Bousfield
Acanthohaustorius millsi Bousfield
Ampelisca abdita Mills
Ampelisca vadorum Mills
Ampelisca verrilli Mills
Batea cartharinensis Fr. Muller
Corophium tuberculatum Shoemaker
Gammarus palustris Bousfield
Haustorius canadensis Bousfield
Lysianopsis alba Holmes
Orchomene pinguis (Boeck)
Parahaustorius attennatus Bousfield
Parahaustorius holmesi Bousfield
Parahaustorius longimerus Bousfield
Parapleustes n. sp.
Protohaustorius deichmannae Bousfield
Protohaustorius wigleyi Bousfield
Trichophoxus epistomus Shoemaker
Unciola dissimilis Shoemaker
Unciola serrata Shoemaker

Order Cumacea

Leucon americanus Zimmer
Oxyurostylis smithi Calman

Table VI (cont.)

Order Decapoda

Cancer irroratus Say
Crangon septemspinosa (Say)
Hexapanopeus angustifrons (Benedict and Rathbun)
Libinia emarginata Leach
Neopanope texana sayi (Smith)
Ovalipes ocellatus (Herbst)
Pagurus longicarpus Say
Pagurus pollicaris Say
Pinnixa sayana Stimpson
Upogebia affinis (Say)
Xanthidae spp.

Class Merostomata

Limulus polyphemus (L.)

Phylum Ectoprocta
Class Gymnolaenata

Aeverillia setigera (Hincks)
Alcyonidium polyoum (Hassall)
Alcyonidium verrilli Osborn
Conopeum tenuissimum (Canu)
Cryptosula pallasiana (Moll)
Electra hastingsae Marcus
Hippoporina porosa (Verrill)
Membranipora tenuis Desor
Schizoporella biaperta (Michelin)
Schizoporella errata (Johnston)

Phylum Echinodermata
Class Echinoidea

Arbacia punctulata (Lamarck)

Class Asterozoa

Asterias forbesi (Desor)

Class Ophiuroidea

Amphioplus abditus (Verrill)

were no significant associations between abundance and increasing clay and all but one association was negative. This species was best developed in sand with 0-12% silt and less than 5% clay. Correlation coefficients for abundance of *Protohaustorius wigleyi* and clay varied considerably. Nevertheless, this species was characteristic of clean sand.

Heteromastus filiformis lived in sediment with as much as 38% clay. This species was characteristic of sandy-silt or mud.

In summary, *P. wigleyi*, *T. epistomus*, *Ampelisca verrilli*, and *T. agilis* were found in clean, fine sand and *H. filiformis* and *N. proxima* generally inhabited sediment high in clay and silt.

Contour Maps

Data from the 103 stations were used in a computer program to construct contour maps of the distributions of the species. These maps aided in determining the effect of the spoil on the individual species and the faunal aggregations. Most of these maps are included in the Appendix, but a few are presented here. *Nucula proxima* and *H. filiformis* were concentrated mainly in the area within the Breakwater Harbor and the area surrounding the mouth of the Roosevelt Inlet. *Tellina agilis* also showed small numbers

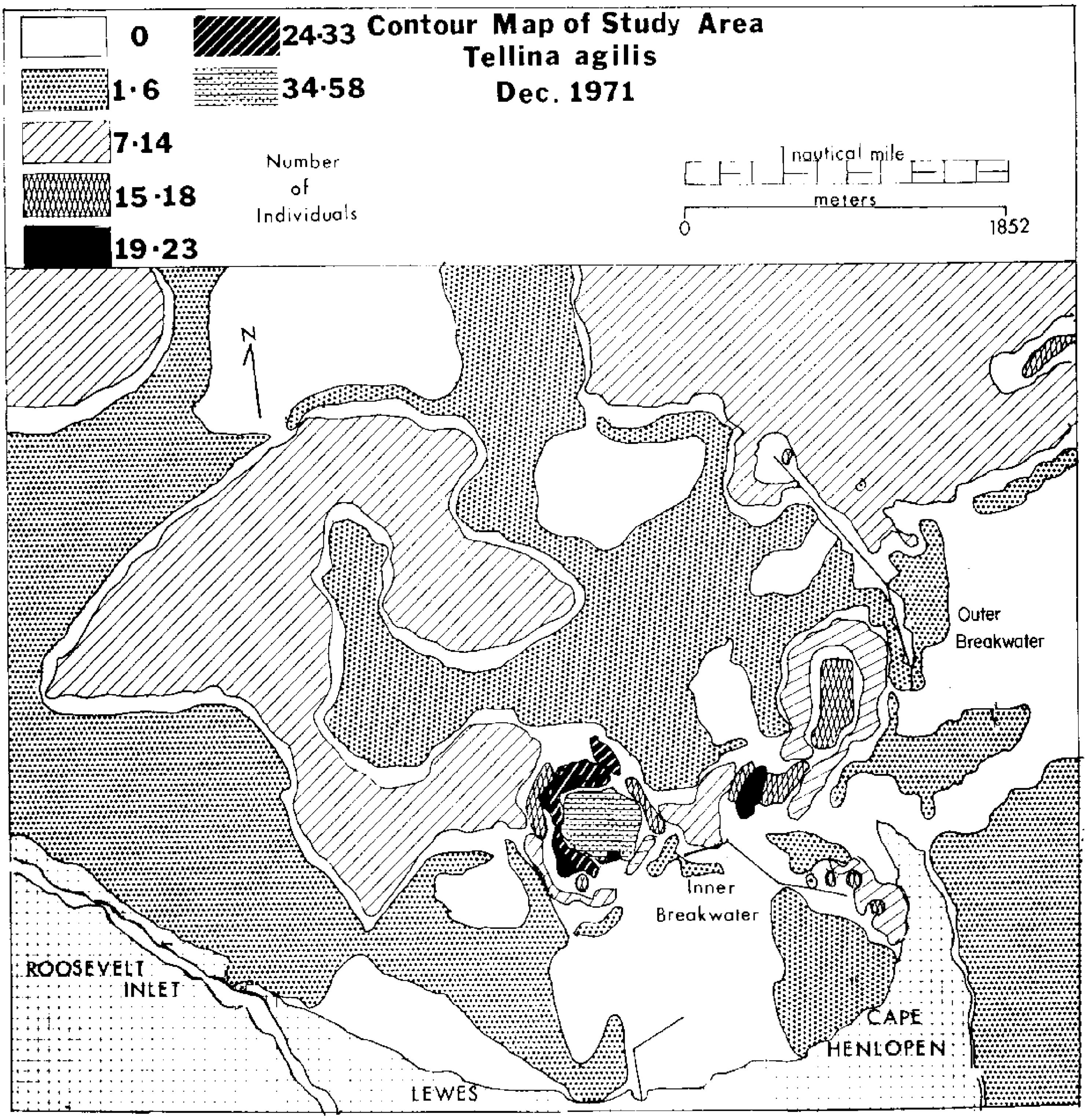
0
24·33
Contour Map of Study Area
Tellina agilis
Dec. 1971
1·6
34·58
7·14
15·18
19·23
Number
of
Individuals
nautical mile
meters
0
1852
N
Outer
Breakwater
Inner
Breakwater
ROOSEVELT
INLET
LEWES
CAPE
HENLOPEN

Figure 17

of individuals in these areas (Figures 17, 18, and 19). Sediment correlations indicated both N. proxima and H. filiformis were associated with higher concentrations of silt and clay. Comparisons with contour maps for fractions of silt and clay support this. The area surrounding the spoil area indicates a slight reduction in H. filiformis in March and June. Nucula proxima showed low densities in the spoil area during December and March; however, June densities showed an increase in the immediate area of the spoil deposition (Figures 20, 21, and 22). Nucula proxima and H. filiformis may have benefited as a result of the addition of silt-clay material deposited by the dredge. The greater number of stations in which N. proxima occurred in June would also indicate this fact.

Tellina agilis had a wide range of occurrences throughout the study area. The highest density contours indicated that the optimum condition for T. agilis was in the sandy areas. Based on the contour maps, there was some decrease in abundance between December and June.

Contour maps of Trichophoxus epistomus and Protohaustorius wigleyi indicate that they occur in almost identical areas in similar concentrations of sand. Distributions of these species were not affected by the spoil. Any changes that occurred in population densities were probably not attributable to the spoil.

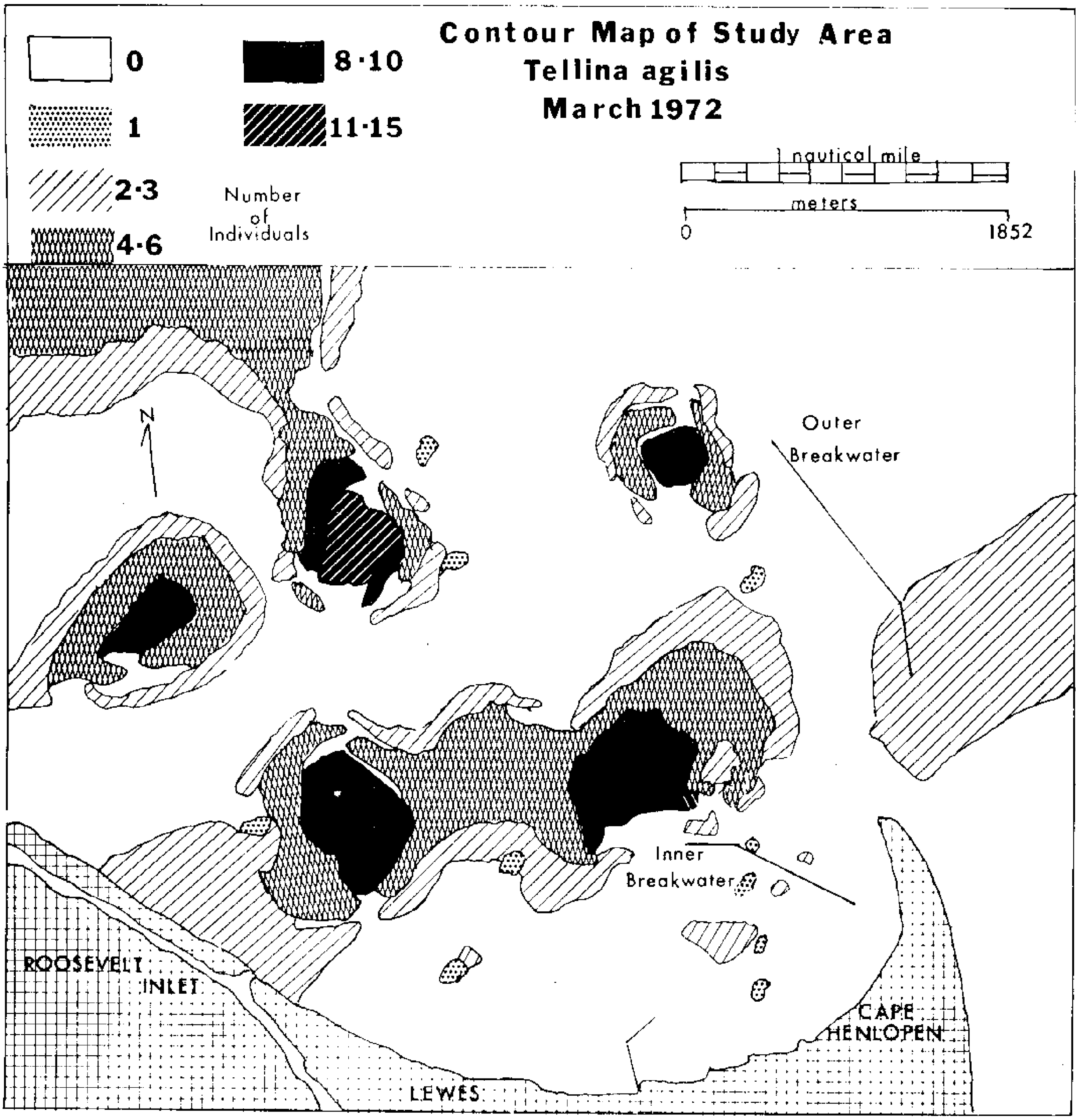
Contour Map of Study Area
Tellina agilis
March 1972
0
1
2·3
4·6
8·10
11·15
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
CAPE HENLOPEN
LEWES

Figure 18

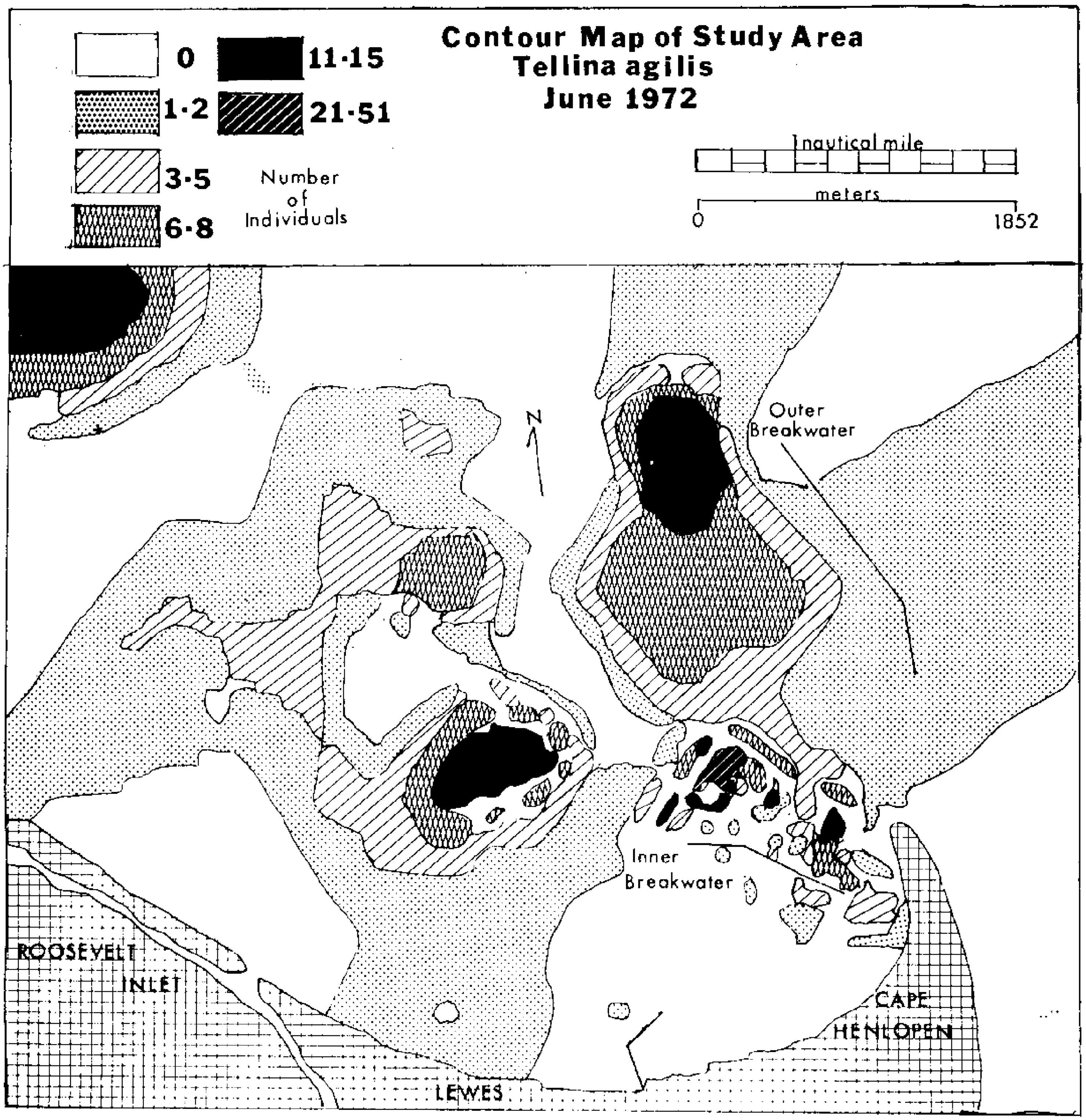
Contour Map of Study Area
Tellina agilis
June 1972
0
11-15
1-2
21-51
3-5
6-8
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
CAPE HENLOPEN
LEWES

Figure 19

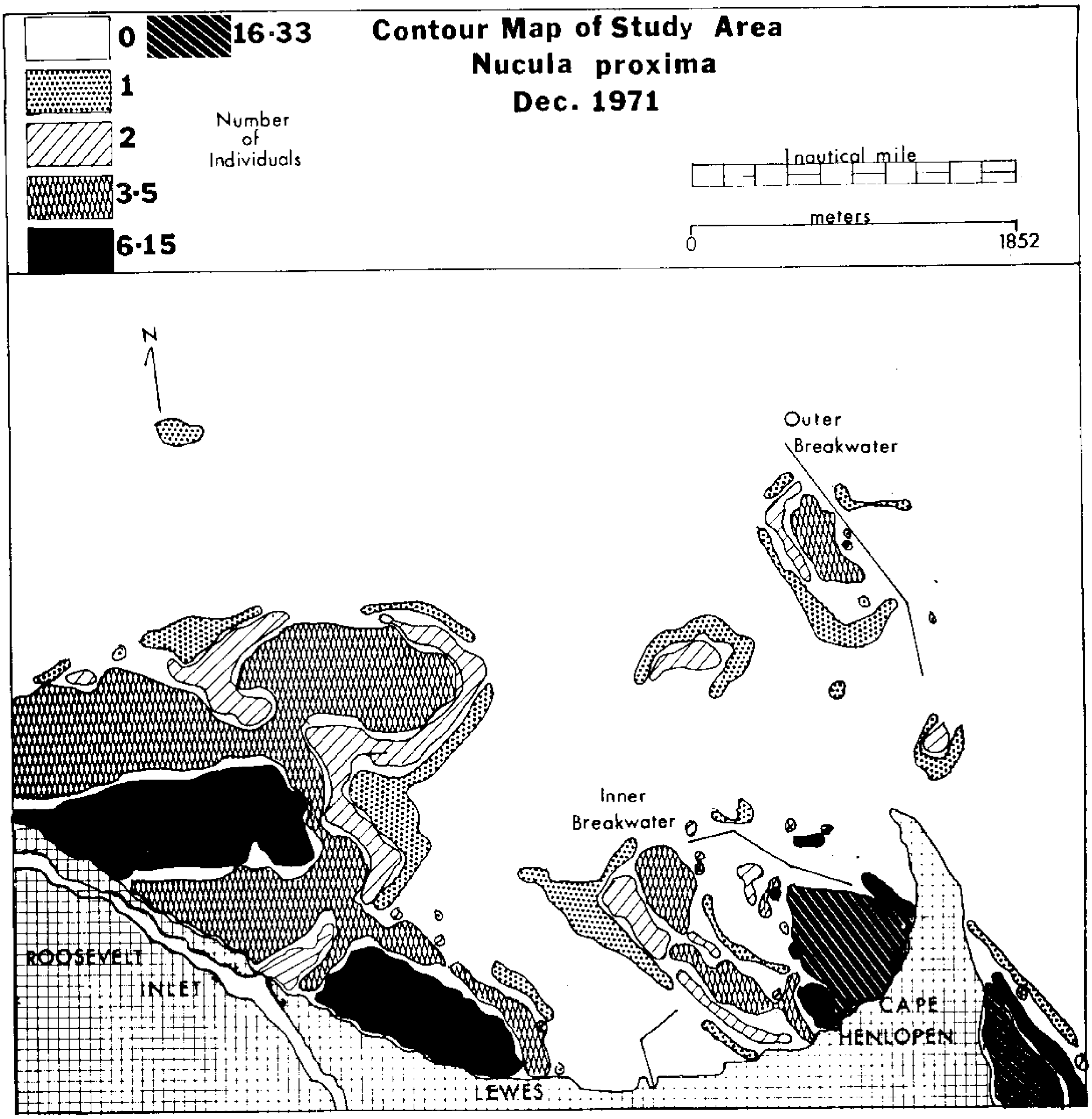
Contour Map of Study Area
Nucula proxima
Dec. 1971
0
16-33
1
2
3-5
6-15
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
LEWES
CAPE HENLOPEN

Figure 20

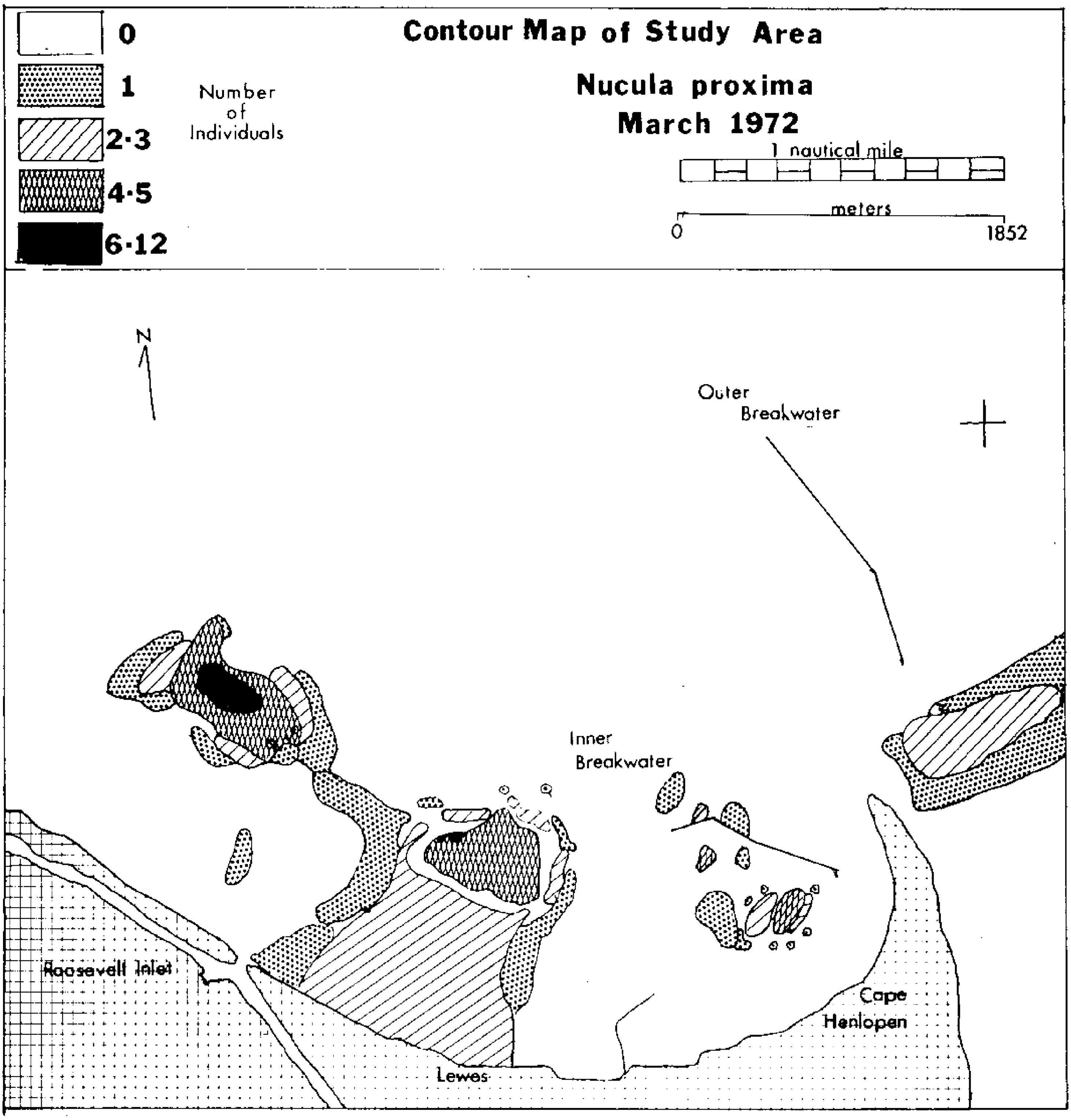
Contour Map of Study Area
Nucula proxima
March 1972
0
1
2-3
4-5
6-12
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
Roosevelt Inlet
Lewes
Cape Henlopen

Figure 21

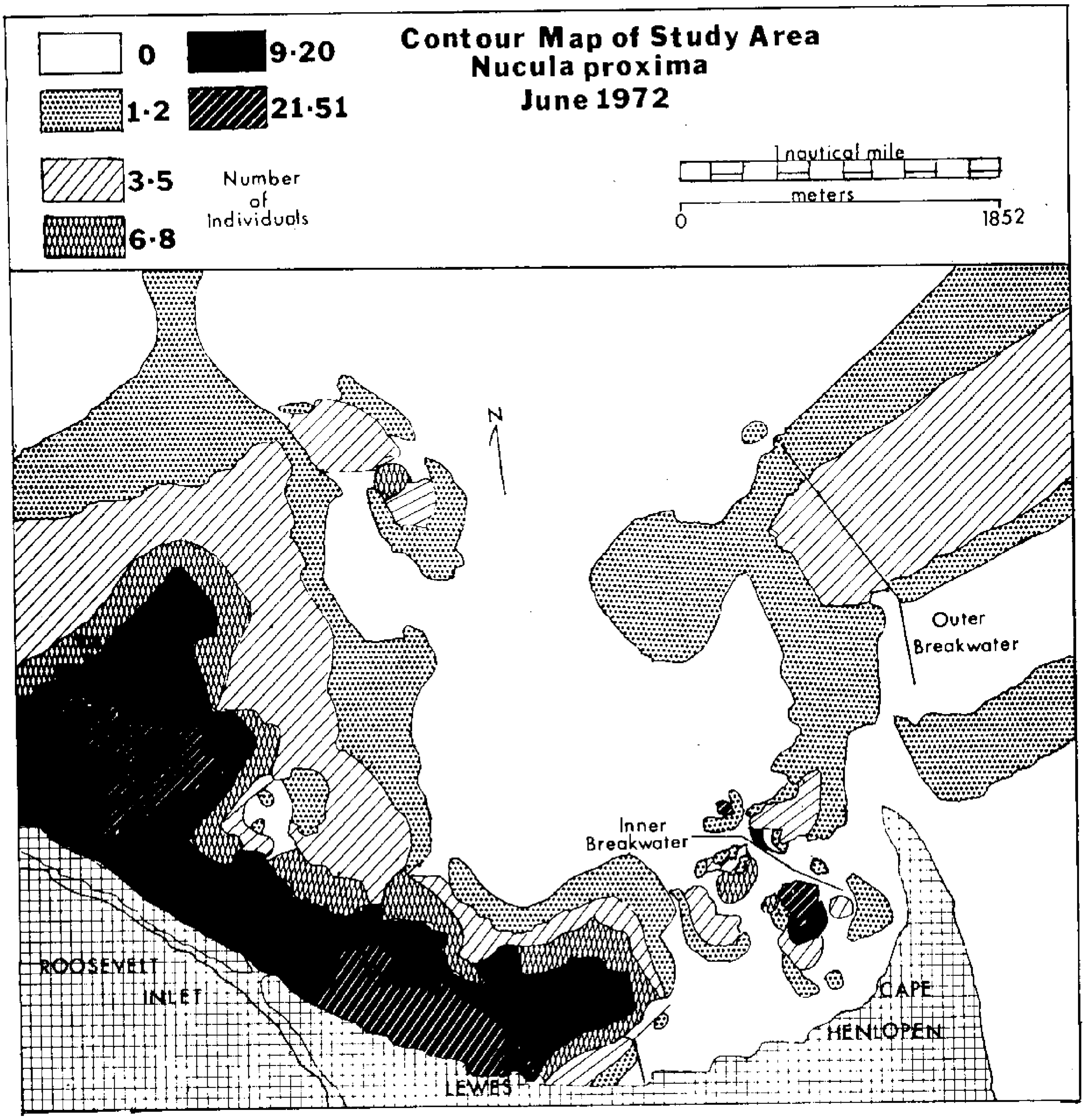
Contour Map of Study Area
Nucula proxima
June 1972
0
9·20
1·2
21·51
3·5
6·8
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
LEWES
CAPE HENLOPEN

Figure 22

Ampelisca verrilli occurred in slightly different areas from the other amphipods. The silt concentrations were higher in the areas where this species was found. With the exception of December, the species was located far from the spoil area. A few *A. verrilli* occurred directly behind the inner breakwater in December. The absence of this species in March and June samples may indicate that the influence of the turbidity from the dredge was detrimental to the amphipod.

The contour maps indicate that several key species form two aggregations--a mud facies with *N. proxima* and *H. filiformis* and a sand facies of *P. wigleyi* and *T. epistomus*. The mud community appeared to become more prevalent due to the spoil disposal. The sand group seemed to remain unchanged, probably due largely to the distance it was located away from the spoil area.

Biomass

Determinations of biomass were also used to examine whether there were significant changes due to dredging and spoil disposal. Nine species were compared from area to area to determine if there were differences in wet and dry weights. For all five areas dry weight was higher in December than in either March or June except for those samples taken in Area E during the third sampling period. Dry weight was higher in March than June for Areas A and B, but this trend was reversed for Areas C, D, and E. Area A contained samples with the highest dry weight, Area B with the lowest. Difference in dry weight for each area for each sampling period is summarized in the Appendix.

In terms of species, N. proxima, T. agilis, and G. dibranchiata showed reductions in dry weight from December to March in Area A. Tellina agilis and G. dibranchiata revealed similar reduction in Area C. Only in Areas B and C did all the species have larger dry weight in December than June. T. agilis was the only species to follow this pattern in Area A. The other species all indicate that June had greater dry weights than December. Area E revealed H. filiformis to have greater biomass in December and N. proxima was larger in June. For all the areas June biomass for individual species was greater than March; Ampelisca verrilli in Area A was the only exception to this trend. For this species, June represented only 25% of the biomass recorded in March.

DISCUSSION

Discussion of the effects of dredging and spoil disposal in general follows the sequence established earlier in this report: hydrographic, marine geology, and marine biology. These sections have been integrated wherever possible.

General

In coastal areas, marshes, and estuaries, and in navigable rivers of the world, one of the major forces altering the environment is exercised by the dredging industry (Hann and Hutton, 1970). The subsequent need for spoil disposal and associated effects must also be considered. This situation is further complicated because the dredged material may be seriously contaminated and its disposal spreads these contaminants (MacKay, et al., 1972; Gross, et al., 1971; Horne, et al., 1971).

Construction and associated dredging in coastal areas is expected to increase considerably with offshore power plants, airports, and deepwater ports (Rounsefell, 1972). Indeed the latter activity would involve removal of huge volumes (1.1×10^6 - 1.9×10^6 cubic meters) of sediment at proposed deepwater port sites in Raritan Bay, New Jersey and Delaware Bay (McHugh, 1972; Maurer and Wang, 1973). Similar volumes of dredging would be involved at proposed sites in the Gulf of Mexico off Texas and Louisiana (James, et al., 1972; Stone, 1972). Serious environmental damage from the dredging expected in the smaller bays (Raritan and Delaware) was not anticipated for the larger Gulf area.

The environmental problems of the lower Delaware Bay area are just beginning to be recognized (Buelow, 1968; Buelow, et al., 1968; Bopp and Biggs, 1972; Bopp, et al., 1972; Davey, 1972; DuPont, 1972). Recent dredging of the Chesapeake-Delaware Canal by the Corps and the Mispillion and Broadkill Rivers by the State of Delaware, together with widespread distribution of high levels of trace metals in sediments (Bopp and Biggs, 1972; Bopp, et al., 1972), indicate the type and scope of man's activity in the area (Maurer, 1973).

Other examples of man's impact near the study area include: 1) the first Philadelphia sewage sludge dump site was approximately 14 miles east of the present study (Buelow, 1968; Buelow, et al., 1968; Davey, 1972). Sediments and marine organisms (shellfish) from the area were known to contain trace metals; 2) approximately 35 miles southeast of Delaware Bay an acid waste dump site has been established (DuPont, 1972).

Hydrographic

Based on hydrographic data, the most important change was a reduction in dissolved oxygen following spoil disposal (Table I). In Areas A, B, and D, there was a reduction from 100% saturation to 58.2%. In Area C the saturation level dropped from 94.3% (December) to 52.5% (March) and in Area E it dropped from 82.6% (December) to 51.6% (March). All of the saturation values returned to predredging levels by June. The 51.6% saturation value recorded in Area E in March is extremely close to the 50% saturation level of dissolved oxygen which is the minimum water quality standard for the State of Delaware (EPA, 1971). It cannot be concluded from this study that spoil disposal was the only factor involved in reducing oxygen saturation values. The oxygen saturation values in June averaged higher than December or predredging values. Values from each area were similar to values from the spoil disposal site. The oxygen concentration increased rapidly after the spoil disposal.

Depression in dissolved oxygen concentration associated with dredging projects has been noted by many (Sherk, 1971 a; Saila, et al., 1972; and Cronin, et al., 1971). Depending on the season, the duration of low dissolved oxygen, and the fauna, the effect of low values may be significant or negligible. In this case, benthic invertebrates were exposed to low values in March for a very short time increment. Compared to the almost permanently low dissolved O_2 values described by Reish (1959), the invertebrates in the present study were probably not exposed to levels of stress. A number of infaunal bivalves and tube dwelling polychaetes can tolerate oxygen concentrations as low as 2 ppm (Reish, 1959; Richards, 1969).

Although there was a significant reduction in oxygen concentration at the spoil site following dredging, we do not consider this a limiting factor for the corresponding reduction in the benthos.

Marine Geology and Marine Biology

Suspended Sediment

The drogue and dye studies showed it is possible that silt (< 63 microns) and particularly clay-size (< 2 microns) sediment particles can be maintained in suspension and transported by tidal currents (Figures 3-6). The average velocity of the dye mass during flood tide was calculated to be 30.6 cm/sec. Postma (1967) stated that velocities of 10 cm/sec. were sufficient to maintain fine silt and clay-size particles in suspension. Based on the water content of sediments collected from the spoil material, it was considered improbable that erosion occurred once the material was deposited. However, there was evidence that clay-size particles could be redeposited in the ferry terminal turning basin on a flood tide (Figure 8). This suggests that the basin may be an area of continuous sedimentation, a point which has already been reported in a larger study of sediment distribution for the southwest corner of Delaware Bay (Strom, 1972). Future shoaling here remains a practical consideration.

Results from the dye and drogue studies indicated that clay might be transported at least as far south as the region off Roosevelt Inlet. The sediment here already is organic mud with high percentages of silt-clay and changes in sediment type would not be anticipated with the deposition of resuspended clay from the dredge and spoil sites. There was a definite veneer of silt and clay deposited on the Cape Henlopen Flat beach during dredging. The major concern would be the spread of contaminants (hydrocarbons, trace metals, phenols) with the clay from the ferry terminal area. No data on these pollutants were obtained in this study. Bopp and Biggs (1972), however, discovered high concentrations of trace metals in sediments and oysters of lower Delaware Bay. In many cases levels in shellfish exceeded public health standards. It is possible that an area like the turning basin and channel might accumulate pollutants such as trace metals because the Breakwater Harbor area acts as a sediment trap for upper bay suspended matter.

Evidence for the dispersion of clay and particulate debris from dredging is well documented (Sherk, 1971 a). However, what is not generally accepted is the distance the material travels during overboard spoil disposal and the effect it has on the biota. There are so many provisions (season, original composition of sediment, hydrography, magnitude of dredging, frequency of dredging, type of dredging, number of dredges operating) that generalizations are difficult to make. Estimates of dispersion of suspended sediments related to dredging and disposal include values of 22.5 m (Manning, 1957), 30 m (Haven and Loesch, 1970); 270 m (Wilson, 1950), 390 m (Mackin, 1961), 1584 m (Hellier and Kornicker, 1962; Saila, et al., 1972), 5000 m (Cronin, et al., 1970), and 3 km (Jenkinson, 1972).

As the suspended sediment moves through the water, it decreases light penetration. This in turn produces a whole host of new problems for the biota (Sherk, 1971 a). In areas with normally low turbidity values, increased turbidity from dredging and spoil disposal could be biologically harmful to the biota within a few hours. However, in estuaries with naturally high turbidity values (20-400 mg/l), it is difficult to document causal relationships between these activities and the response of the biota. Exclusive of smothering due to burial, which will be described in the next section, estuarine organisms have lived in highly turbid conditions for millions of years (Hedgpeth, 1957). Intensive laboratory studies (Sherk, 1971 b) reported that prediction of the effects of any one sediment load (most estuaries contain three or four types of clay and a variety of particulate debris) must at least account for the duration of exposure, the species affected, their life history stage, sediment concentration, sediment type, and the indigenous habitat of the species. Laboratory tests such as Sherk and O'Connor (1971 b) and others (Loosanoff and Tommers, 1948; Loosanoff, 1961; Davis, 1960; Davis and Hidu, 1969) together with critical laboratory-field tests will be necessary to accurately assess the effect of suspended material on estuarine organisms.

Sediment and Spoil Distribution

The effect of the mechanical removal of sediments is well known. Complete oyster and clam mortality in the path of a commercial soft shell clam dredge was reported by Manning (1957). Sykes (1971) attributed the basic cause of ecological stress in Boca Ciega Bay, Florida to hydraulic dredging of the bottom. Godcharles (1971) also found the commercial soft shell dredge extremely destructive to the bottom in grassy areas. Dredge tracks remained visible from 1 to 86 days and some spots remained soft for over 500 days. Similar results to vegetation were described by Haven and Loesch (1970).

The sediment data and maps for lower Delaware Bay indicated there was little change in sediment type for the sampling area following dredging. However, there was a definite increase in percentage of silt in the spoil disposal area. This increase in silt was not recorded in June.

The contour and isopach maps from the bathymetric survey accounted for approximately 138,000 cubic meters (including the water volume) of spoil. The true dry weight volume of the spoil found was only 38.5% of the spoil dredged. The spoil essentially moved down the slope towards the northwest, filling a 13.6 meter "hole" or trough.

A mechanical effect of sediment deposition involves burial. This aspect has been studied by many (Wilson, 1950; Dunnington, 1968; Maurer, 1967; Stanley, 1970; Saila, et al., 1972; Kranz, personal communication). In most cases weak burrowers, epifaunal species, and suspension feeders are more susceptible to rapid deposition or burial than strong burrowers, infaunal species, and deposit feeders. Experiments cited by Saila, et al. (1972) showed that some animals established "blow holes" to the surface and smaller animals of any type had the greatest chance of being destroyed. Intensive experiments conducted by Stanley (1970) and Kranz (personal communication) indicate that some marine organisms are much more tolerant to conditions of burial than originally considered. In particular, Kranz found that mortality varied considerably depending whether in situ sediment or foreign sediment was used in the experiments. Among 30 species of bivalves many survived deeper burials in indigenous sediment than lesser amounts of foreign material.

Effect on the Benthos

Since many invertebrates are sessile they have commonly been used to determine the effect of dredge studies. In some cases the number of species may be too large to facilitate easy and accurate analysis. As a result, diversity indices have become a convenient means of summarizing and comparing large amounts of data on abundance and occurrence of species. Reviews of these indices can be found in Lie (1968), Sanders (1969), Boesch (1970), Cronin, et al. (1970), Saila, et al. (1972). For example, Boesch (1970) used $\bar{H}$ values computed from the Shannon-Weaver formula for comparing samples from a variety of sources. He found $\bar{H}$ values between 1 and 2 in the brackish parts of estuaries and in polluted areas. Saila, et al. (1972) also used $\bar{H}$ values in their work. They reported that differences in species richness and diversity were not correlated in a simple way with disturbance of the bottom by spoil dumping. They commented that further sampling and analysis would be necessary to determine the utility of changes in subdominant groups as indicators of disturbance.

We share their concern for several reasons. Although there were 115 live species collected in the present study, individual stations rarely exceeded ten species and abundance was normally very low (1-5 individuals) with a few exceptions for a few species (N. proxima, T. agilis, P. wigleyi, T. epistomus, H. filiformis, M. lateralis, G. gemma) (Table II A). The diversity index $\overline{H}$ is closely related to number of individuals and may be inappropriate and insensitive for comparing the structure of communities with irregular or clustered abundances (Fager, 1972). Finally, we believe that $\overline{H}$ may be misleading as a measure of community structure unless the function of the principal species and their response to natural or artificial environmental conditions are known. $\overline{H}$ values may be similar in two different communities, but this reveals nothing about their structure.

Because of these reservations we also computed redundancy values (R) defined by Shannon and Weaver (1963). R is the measure of the level of dominance (abundance) in the community. In calculating redundancy (R), a value of zero is obtained if each individual belongs to a different species and a value of one is obtained if all individuals belong to the same species. Since R is dimensionless and is not correlated closely with number of individuals, it was a useful index, particularly for an area with small numbers of organisms.

T-tests were calculated on diversity and redundancy values; both showed significant (0.01) differences existed in comparisons of June with December in Area C. Diversity values were greater in June than December and redundancy values were greater in December than June. This may indicate that recruitment began to occur before June and that community changes were negligible after the dredging operation.

Another closely related measure of change was simply the density of individuals per area. In March there was a significant reduction in density in Area E and Area C. The density in Areas A and B farthest from the spoil site showed no significant changes. June samples resulted in an increase in density for Areas C, D, and E. Stations in Areas A and B had densities similar to December values.

In general, dry weight was higher in December than March or June. Dry weight was higher in March than June for Areas A and B, but the trend was reversed for Areas C, D, and E. For all areas, June showed greater biomass for selected species than did March. Biomass data did not provide as definitive a picture as did density. This can best be attributed to the small number of individuals in the area. It is important to recognize, however, that all of the biological factors must be considered collectively and not as separate entities.

Recruitment

Since the project encompassed December through June, and since July through early September is the prime time for maximum setting, we are reluctant to offer conclusions on local recruitment. Nevertheless, we believe that the density data tentatively suggest some recruitment between early March and June. The emergence of *M. lateralis* as a third major pelecypod also seems to indicate some recruitment. Calabrese (1969) outlined spawning temperatures which indicated that setting and new growth of *M. lateralis* were possible prior to the June sampling period. This suggestion remains to be locally corroborated.

Recruitment of the benthos following dredging shows considerable geographic variation. In one study, abundance, biomass, and species diversity recovered in one and a half years to approximately predisposal levels in the disposal area (Cronin, et al., 1970). Another study indicated that much of the spoil in their study area was recent and had few species in it. Nevertheless, surfaces which had been exposed for one to three years yielded large numbers of species (Saila, et al., 1972). Still another study showed little or no recruitment in areas dredged 15 or 20 years ago (Sykes, 1971).

Principal Taxa

The principal species in this study were: Tellina agilis, Nucula proxima, Ampelisca verrilli, Protohaustorius wigleyi, Trichophoxus epistomus, and Heteromastus filiformis. A species which was also important in June was Mulinia lateralis. The animal-sediment relationships of several of these species have been studied by others and a brief comparison between their results and ours may be informative. Sanders (1958) recognized two faunal assemblages which included one present in muddy sediments and dominated by the bivalve Nucula proxima. This bivalve was a dominant species in the present study and was most common in mud and silty sand with 50% silt-clay. The contour maps also indicate this association.

Capitella capitata, a marine worm belonging to the Family Capitellidae has commonly been cited as an indicator of polluted bottom, mud rich in organic content and low in dissolved oxygen (Wilhelmi, 1916; Reish, 1971). Wass (1967) stated that members of the Capitellidae replace species of

Tubifex as pollutant indicators in estuarine environments. Heteromastus filiformis, another capitellid, has been recognized as occurring abundantly under similar conditions (Dean and Haskin, 1964; Saila, et al., 1972). Tenore (1972) found this species in non-polluted areas with high levels of organic matter but suggested that H. filiformis should be investigated as an indicator species.

Based on the present study and past experience throughout the Delaware area, Heteromastus filiformis is a frequent inhabitant of fine-grained sediment with high silt-clay and low dissolved oxygen. Nucula proxima and H. filiformis form a definite mud bottom facies in relatively high salinity areas (> 20 o/oo).

Tellina tenera and Ampelisca macrocephala (T. agilis and A. verrilli of this study) were associated with sandy sediment in Buzzards Bay (Sanders, 1958). These species were mainly limited to sediments with small amounts of silt and clay. In fact, a whole series of parallel or iso-communities of species of Tellina living in sand bottoms were proposed by Thorson (1957). In general, our data agree with Sanders' (1958) associations as both T. agilis and A. verrilli show negative association with increasing silt-clay. However, the sediment range of Tellina agilis was 1-93% silt-clay and that of Ampelisca verrilli was 1-35% silt-clay. Another amphipod, Protohaustorius wigleyi, has been described as inhabiting clean, fine sand (Bousfield, 1965; Sameoto, 1969). This species is one of many species of haustoriids which occur along the Atlantic coast just offshore of the surf zone. Thus it was not unexpected that P. wigleyi occurred at stations with sand bottoms and low (< 5%) silt-clay. Haustoriid amphipods also occur further up bay (15 miles) on sand shoals or lenses.

Mulinia lateralis was described as a characteristic species of the polyhaline zone in a North Carolina estuary (Tenore, 1972). The same species was used as a pollution indicator in a Florida bay (Taylor, et al., 1970). This species was locally collected live at 39 stations in June. It was not recorded from Area C in December, but was recorded at two stations and eight stations in March and June, respectively. Moreover, thousands of valves were collected in the study area. This species is probably extremely abundant in the surrounding area and is transported into the study area after death.

The amphipod, Trichophoxus epistomus was reported by Watling and Maurer (1972 a) and is a common and abundant inhabitant of the enclosed soft bottom bays (Rehoboth and Indian River). In the present study, T. epistomus was associated with sediment containing low silt clay. In contrast to N. proxima and H. filiformis, P. wigleyi, T. epistomus, A. verrilli, and T. agilis form a sand bottom facies.

Protohaustorius wigleyi and *T. epistomus* were recorded in almost identical locations and in very low concentrations of silt-clay. *Ampelisca verrilli* was recorded in slightly greater concentrations of silt-clay than the other amphipods which may be attributed to its deposit-feeding habits. Among the bivalves, *T. agilis* has the widest silt-clay range (1-93%) and may be a transitional species.

The relative decline of two ectoprocts in the spoil area after dumping may be significant since there was no decline in the other areas. Both species are among the most abundant epifaunal organisms in Delaware Bay (Maurer and Watling, 1973 a, b). *Membranipora tenuis* occurred at ten stations in December and none in March. *Conopeum tenuissimum* occurred in only 33% of the stations of Area C that it was found in during December. Epifaunal organisms are probably more sensitive to environmental stresses including turbidity than infaunal organisms. The decline of these ectoprocts was associated with dredging and spoil disposal.

Indicator Species

Several marine species (polychaetes--*Capitella capitata*, *Heteromastus filiformis*, *Spiochaetopterus oculatus*, *Chaetopterus variopedatus*, *Streblospio benedicti*, *Nereis succinea*, *Polydora ligni*; bivalve--*Mulinia lateralis*; xanthid crab, *Rhithropanopeus harrisi*) have been suggested as indicator species of domestic and industrial pollution, particularly in mud bottoms with high organic content and low oxygen (Wilhelmi, 1916; Reish, 1957; Filice, 1959; Wass, 1967; Saila, et al., 1972; Wade, et al., 1972). All these species occur in the Delaware Bay region and most were collected in the spoil disposal project. In addition, large numbers of *Spiochaetopterus oculatus* tubes were obtained. These tubes were primarily found in the turning basin, the dredge channel, and soft bottom with greater than 50% silt-clay. In most cases the tubes were stained a dark black indicating reducing conditions. This situation agrees with the findings of McNulty (1970) and Wade, et al. (1972). For the Delaware Bay area we suggest that the polychaete, *Heteromastus filiformis* is an indicator species of reducing conditions and that *S. oculatus* is a good candidate for the same. Confirmation of the remaining species as local indicator organisms is left for further study.

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APPENDIX

This appendix contains supporting field and laboratory data for the study involving the "Effect of Spoil Disposal on Benthic Communities Near the Mouth of Delaware Bay." The basic purpose of this appendix is to enhance the readers' knowledge of the main report by providing access to all the data. The appendix is divided into three major sections which are: Physical Oceanography, Marine Geology, and Marine Biology. All three sections contain detailed figures and maps not included in the main report.

PHYSICAL OCEANOGRAPHY

Table I

Sextant Readings for Current Study, Breakwater Harbor, Lewes Delaware

SEXTANT READINGS January 6, 1972

3 m drogue		Time		1 m drogue	
HORN-EIN 130° 45'	EIN-TOW 46° 6'	1300	1310	Horn-Ein 87° 31'	Ein-Tow 71° 29'
RAD-EIN 31° 33'	EIN-Chim 53° 32'	1325	1333	HORN-EIN 87° 21'	EIN-Chim 96° 21'
RAD-TOW 23° 51'	TOW-Chim 45° 35'	1345	1350	EIN-TOW 31° 18'	TOW-Chim 65° 40'
RAD-EIN 34° 10'	EIN-WIN 46° 16'	1400	1412	Horn-RAD 90° 29'	RAD-Chim 100° 34'
RAD-EIN 28° 50'	EIN-WIN 26° 47'	1430	1437	Ice-Horn 39° 19'	Horn-RAD 90° 42' Stuck on Rocks
			1445	moved to RAD-TOW 36° 16'	TOW-Chim 57° 11'
RAD-WIN 24° 44'	WIN-Horn 35° 4'	1455	1530	RAD-EIN 34° 1'	EIN-WIN 24° 2'
WT-RAD 43° 53'	RAD-Horn 38° 55'	1515	1545	RAD-EIN 30° 3'	EIN-TOW 58° 29'

Horn - east end of outer breakwater
Ein - east end of inner breakwater
Tow - army lookout tower on Cape
RAD - radio speaking station on Cape
Chim - Smith's smoke stack on fish factory
Win - west end of inner breakwater
Ice - middle of ice breakers adjacent to outer breakwater
WT - water tower, Lewes, Delaware

Table I (cont.)

SEXTANT READINGS January 7, 1972

1 Meter		Time		2 Meter	
RAD TOW 22° 42'	TOW CHIM 53° 24'	9:00	9:01	RAD TOW 22° 40'	TOW CHIM 53° 23'
RAD TOW 21° 2'	TOW CHIM 50° 37'	9:15	9:19	RAD TOW 20° 34'	TOW CHIM 52° 19'
HORN RAD 66, 10'	RAD CHIM 70° 50'	9:30	9:33	HORN RAD 72° 14'	RAD CHIM 67° 1'
HORN RAD 63° 26'	RAD CHIM 62° 41'	9:52	9:46	HORN RAD 58° 33'	RAD CHIM 64° 56'
HORN RAD 51° 51'	RAD CHIM 59° 58'	10:02	10:06	HORN EIN 48° 58'	EIN CHIM 58° 2'
HORN RAD 43° 18'	RAD CHIM 50° 13'	10:30	10:35	HONR EIN 35° 53'	EIN CHIM 48° 29'
HORN WIN 40° 13	WIN CHIM 33° 24'	11:02	11:11	HORN WIN 27° 49'	WIN CHIM w/o° 0'
HORN WIN 34° 49'	WIN CHIM 28° 40'	11:32	11:45	HORN WIN 24° 53'	WIN CHIM 34° 10'

Horn - east end of outer breakwater
Ein - east end of inner breakwater
Tow - army lookout tower on Cape
Rad - radio speaking station on Cape
Chim - Smith's smoke stack on fish factory
Win - west end of inner breakwater
Ice - middle of ice breakers adjacent to outer breakwater
Stations taken from Coast and Geodetic Survey Chart 411.

Table II

Spoil Disposal
December 1971

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp. °C	Eh	Sed. Temp. °C
SD. 1	12/21/71	27.96	10.54	7.7	-200	9
SD. 2	12/21/71	27.74	11.36	7.7	-230	9
SD. 3	12/21/71	27.93	*6.10	7.7	-240	8.5
SD. 4	12/21/71	27.35	10.30	7.7	-270	8.5
SD. 5	12/21/71	27.73	8.26	7.8	-280	8.5
SD. 6	12/21/71	27.92	9.34	7.8	-250	8.5
SD. 7	12/21/71	27.50	8.92	7.8	-220	8.5
SD. 8	12/21/71	27.90	11.40	7.8	-180	9.0
SD. 9	12/21/71	27.33	14.87	7.8	-100	8.5
SD.10	12/21/71	27.06	13.73	7.6	+020	8.5
SD.11	12/21/71	26.62	11.10	7.5	+080	7.5
SD.12	12/21/71	26.72	13.94	7.5	+050	7.5
SD.13	12/21/71	26.72	11.72	7.6	+080	7.5
SD.14	12/21/71	26.88	11.11	7.5	+070	7.5
SD.15	12/21/71	27.00	11.19	7.6	+070	7.5
SD.16	12/21/71	27.12	9.29	7.6	+070	7.5
SD.17	12/21/71	26.73	13.83	7.5	+070	7.5
SD.18	12/21/71	26.88	9.61	7.5	+070	7.5
SD.19	12/23/71	26.12	10.35	6.1	-170	9.5
SD.20	12/23/71	26.26	11.15	6.1	-230	5
SD.21	12/23/71	26.38	10.20	6.1	-160	5
SD.22	12/29/71	26.03	8.43	7.0	-170	6.5
SD.23	12/23/71	26.60	8.80	6.8	-280	5.2
SD.24	12/23/71	26.70	11.06	6.8	-200	5.0
SD.25	12/23/71	26.90	11.52	6.8	-170	5.5
SD.26	12/23/71	26.39	10.56	6.8	+080	5
SD.27	12/23/71	26.09	9.24	7.0	-290	4.5
SD.28	12/23/71	27.32	11.09	7.0	-300	5.2
SD.29	12/23/71	25.65	9.56	7.0	+020	5.0
SD.30	12/23/71	27.22	10.56	6.5	+030	4.8
SD.31	12/23/71	27.15	10.38	6.5	+050	5.0
SD.32	12/23/71	27.28	10.46	7.1	+050	4.9
SD.33	12/23/71	27.72	9.54	7.3	+080	5.5
SD.34	12/23/71	27.62	10.38	6.8	-040	5.5
SD.35	12/23/71	28.05	10.91	7.5	+060	5.5
SD.36	12/23/71	28.22	9.75	7.3	--	5.0
SD.37	12/23/71	27.51	8.56	7.0	+100	5.5
SD.38	12/23/71	27.51	11.49	6.5	--	4.5
SD.39	12/23/71	27.65	10.91	7.2	+090	5.5
SD.40	12/28/71	27.33	9.34	7.6	-175	7.0
SD.41	12/28/71	26.50	9.85	7.6	-190	7.0
SD.42	12/28/71	26.79	10.80	7.6	-230	6.5
			*cloudy			

Table II (cont.)

Spoil Disposal
December 1971

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp. °C	Eh	Sed. Temp. °C
SD.43	12/28/71	26.99	11.70	7.0	-165	6.5
SD.44	12/28/71	27.19	10.12	7.5	-105	7.0
SD.45	12/28/71	27.06	9.82	7.5	+ 20	8.0
SD.46	12/28/71	26.56	9.19	7.5	-295	6.5
SD.47	12/28/71	26.57	9.64	7.5	-330	7.0
SD.48	12/28/71	27.14	8.43	7.6	-230	8.5
SD.49	12/28/71	26.57	10.10	7.4	-180	7.5
SD.50	12/28/71	26.66	8.31	7.4	-205	8.0
SD.51	12/28/71	26.62	9.38	7.4	-215	8.5
SD.52	12/28/71	27.19	9.64	7.6	-270	8.5
SD.53	12/28/71	26.85	10.62	7.6	-340	8.5
SD.54	12/28/71	26.81	8.92	7.5	-375	8.5
SD.55	12/28/71	26.90	9.45	7.6	-375	9.0
SD.56	12/28/71	26.48	*7.97	7.7	-420	8.5
SD.57	12/28/71	26.53	9.72	7.5	-420	8.5
SD.58	12/28/71	26.60	9.63	7.7	-460	8.5
SD.59	12/28/71	26.89	8.16	7.7	-460	8.5
SD.60	12/28/71	27.81	9.85	7.7	-450	8.5
SD.61	12/28/71	26.17	9.93	7.7	-445	8.5
SD.62	12/28/71	27.18	9.09	7.6	-425	8.4
SD.63	12/28/71	27.23	9.19	7.5	-390	8.5
SD.64	12/28/71	27.69	8.87	7.7	-180	8.2
SD.65	12/29/72	25.42	7.68	6.9	-350	7.0
SD.66	12/29/72	26.47	8.10	7.0	-320	7.0
SD.67	12/29/72	26.19	8.56	7.2	-210	7.5
SD.68	12/29/72	25.32	8.16	7.1	-070	7.3
SD.69	12/29/72	27.08	7.85	6.9	-090	7.5
SD.70	12/29/72	26.71	7.82	7.1	-290	7.0
SD.71	12/29/72	26.72	7.37	7.1	-290	6.8
SD.72	12/29/72	26.71	7.68	7.1	-325	6.5
SD.73	12/29/72	26.26	8.10	7.1	-330	7.0
SD.74	12/29/71	26.26	6.89	7.1	-330	7.0
SD.75	12/29/71	26.14	11.07	7.1	-290	7.1
SD.76	12/29/71	26.42	7.44	7.1	-390	7.2
SD.77	12/29/71	26.56	7.60	7.1	-270	7.2
SD.78	12/29/71	26.50	6.94	7.2	-325	7.2
SD.79	12/29/71	27.08	7.00	7.1	-270	7.4
SD.80	12/29/71	26.32	6.73	7.2	-300	7.0
SD.81	12/29/71	26.33	8.03	7.2	-280	7.5
SD.82	12/29/71	26.22	10.43	7.1	-280	7.5
SD.83	12/29/71	26.03	9.45	7.1	-320	8.0
SD.84	12/29/71	25.70	11.15	7.1	-220	7.2
SD.85	12/29/71	26.11	7.47	7.1	-250	7.5
SD.86	12/29/71	26.08	7.37	7.1	-330	7.3

*cloudy

Table II (cont.)

Spoil Disposal
December 1971

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp. °C	Eh	Sed. Temp. °C
SD.87	12/29/71	25.94	10.33	7.3	-340	7.5
SD.88	12/29/71	26.51	7.24	7.2	-350	8.0
SD.89	12/29/71	26.73	7.47	7.4	-330	7.5
SD.90	12/29/71	26.83	8.39	7.3	-350	8.0
SD.91	12/29/71	26.55	8.69	7.1	-350	7.5
SD.92	12/30/71	26.62	10.00	7.1	-400	8.0
SD.93	12/30/71	27.02	7.15	7.1	-400	7.5
SD.94	12/30/71	26.96	8.84	7.1	-450	8.0
SD.95	12/30/71	26.81	9.53	7.1	-435	8.0
SD.96	12/30/71	27.68	9.32	7.1	-445	8.0
SD.97	12/30/71	26.79	9.32	7.1	-440	7.8
SD.98	12/30/71	26.71	10.29	7.4	- 60	8.2
SD.99	12/30/71	27.65	10.27	7.2	-400	8.2
SD.100	12/30/71	28.54	9.14	7.7	- 90	8.0
SD.101	12/30/71	28.74	10.45	7.7	-435	8.3
SD.102	12/30/71	28.69	10.62	7.7	-205	8.0
SD.103	12/30/71	27.09	10.78	7.7	+ 40	8.0

Table III

Spoil Disposal
March 1972

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp. °C	Eh	Sed. Temp. °C
SD. 1	3/21/72	23.22	*6.44	6.3	-310	7.0
SD. 2	3/21/72	24.91	6.86	6.2	-370	7.0
SD. 3	3/21/72	25.97	5.97	5.8	-325	6.3
SD. 4	--	--	--	--	--	--
SD. 5	3/21/72	25.06	6.31	6.1	-360	6.0
SD. 6	--	--	--	--	--	--
SD. 7	3/21/72	25.89	5.39	5.6	-210	6.2
SD. 8	--	--	--	--	--	--
SD. 9	--	--	--	--	--	--
SD.10	--	--	--	--	--	--
SD.11	3/21/72	26.08	6.31	5.6	+ 50	6.0
SD.12	3/21/72	26.04	5.92	5.5	+ 80	6.0
SD.13	--	--	--	--	--	--
SD.14	--	--	--	--	--	--
SD.15	--	--	--	--	--	--
SD.16	3/21/72	27.70	5.25	5.6	+ 60	6.0
SD.17	--	--	--	--	--	--
SD.18	3/21/72	26.58	7.58	5.5	+ 90	--
SD.19	3/21/72	26.88	7.40	5.6	-240	--
SD.20	--	--	--	--	--	--
SD.21	3/21/72	27.06	5.34	5.6	-230	--
SD.22	--	--	--	--	--	--
SD.23	--	--	--	--	--	--
SD.24	3/21/72	27.62	8.93	5.5	-280	--
SD.25	--	--	--	--	--	--
SD.26	3/21/72	28.18	6.16	5.5	+ 80	--
SD.27	3/21/72	27.89	6.33	5.5	+ 70	--
SD.28	--	--	--	--	--	--
SD.29	--	--	--	--	--	--
SD.30	--	--	--	--	--	--
SD.31	3/21/72	27.87	4.88	5.5	- 20	--
SD.32	--	--	--	--	--	--
SD.33	3/21/72	28.37	5.17	5.4	- 60	--
SD.34	--	--	--	--	--	--
SD.35	3/21/72	28.79	5.68	5.4	-200	--
SD.36	3/21/72	28.05	7.37	5.5	-220	--
SD.37	3/21/72	28.69	5.63	5.4	-150	--
SD.38	3/21/72	28.81	4.67	5.5	-250	--
SD.39	3/21/72	28.83	5.09	5.4	+170	--
SD.40	3/23/72	26.64	5.49	6.0	-230	6.0
SD.41	--	--	--	--	--	--
SD.42	3.23.72	27.02	4.30	6.1	-340	6.5

*cloudy

Table III(cont.)

Spoil Disposal
March 1972

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp. °C	Eh	Sed. Temp. °C
SD.43	3/23/72	27.05	5.20	6.0	-310	6.5
SD.44	--	--	--	--	--	--
SD.45	3/22/72	28.99	5.25	5.6	-470	6.5
SD.46	3/22/72	29.16	4.84	5.5	-470	7.0
SD.47	3/22/72	29.41	4.94	5.6	-510	7.0
SD.48	--	--	--	--	--	--
SD.49	3/23/72	27.17	4.80	6.1	-230	6.0
SD.50	--	--	--	--	--	--
SD.51	3/22/72	28.54	6.15	5.6	-300	8.0
SD.52	3/22/72	29.08	5.13	5.7	-360	7.0
SD.53	3/22/72	29.32	6.28	5.6	-370	9.0
SD.54	3/22/72	28.78	5.92	5.8	-360	7.5
SD.55	3/22/72	28.83	5.96	5.7	-400	6.5
SD.56	--	--	--	--	--	--
SD.57	3/22/72	29.21	6.00	5.6	-440	7.0
SD.58	3/22/72	29.32	5.31	5.6	-420	6.0
SD.59	3/22/72	28.70	7.76	5.8	-570	7.0
SD.60	3/22/72	27.43	6.53	5.9	-530	7.0
SD.61	3/22/72	28.61	4.59	5.9	-550	7.0
SD.62	3/22/72	28.78	4.84	5.6	-260	7.0
SD.63	3/22/72	28.12	5.42	5.6	-250	7.0
SD.64	3/22/72	28.69	4.67	5.6	-320	8.0
SD.65	3/22/72	27.18	9.06	6.2	-460	8.0
SD.66	3/22/72	27.29	8.42	6.2	-400	6.0
SD.67	3/23/72	26.46	5.22	6.8	-270	7.0
SD.68	3/23/72	26.93	5.12	6.4	-185	6.0
SD.69	3/23/72	26.87	4.44	6.1	-230	6.0
SD.70	3/23/72	26.42	*3.90	6.6	-400	6.0
SD.71	--	--	--	--	--	--
SD.72	3/23/72	27.32	5.39	6.5	-400	6.0
SD.73	--	--	--	--	--	--
SD.74	3/23/72	26.54	4.61	6.3	-400	6.0
SD.75	--	--	--	--	--	--
SD.76	3/23/72	27.58	4.70	6.2	-350	6.0
SD.77	3/23/72	25.99	5.25	6.3	-340	6.0
SD.78	3/23/72	27.53	4.64	6.1	-410	6.0
SD.79	3/23/72	27.16	4.91	6.3	-380	6.0
SD.80	3/23/72	27.37	4.73	6.3	-360	6.0
SD.81	3/23/72	27.33	4.56	6.3	-365	6.0
SD.82	3/22/72	26.06	4.64	6.2	-300	7.0
SD.83	3/22/72	28.19	7.15	6.4	-370	7.0
SD.84	3/22/72	27.09	7.57	6.4	-390	7.0

*cloudy

Table III (cont.)

Spoil Disposal
March 1972

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp. °C	Eh	Sed. Temp. °C
SD.85	3/22/72	27.55	5.71	6.5	-260	6.0
SD.86	3/22/72	27.66	5.71	6.4	-380	6.5
SD.87	3/22/72	28.55	8.60	6.2	-290	6.0
SD.88	--	--	--	--	--	--
SD.89	--	--	--	--	---	--
SD.90	--	--	--	--	--	--
SD.91	--	--	--	--	--	--
SD.92	3/23/72	26.65	4.33	6.8	-360	6.0
SD.93	--	--	--	--	--	--
SD.94	3/23/72	27.17	4.46	6.6	-420	6.0
SD.95	--	--	--	--	--	--
SD.96	3/23/72	27.17	4.99	6.4	-390	6.0
SD.97	3/23/72	26.89	4.78	6.4	-390	6.0
SD.98	3/22/72	29.22	4.52	5.7	+ 70	7.0
SD.99	3/22/72	29.45	5.78	5.6	+ 70	7.0
SD.100	3/22/72	28.51	8.21	5.7	- 20	8.0
SD.101	3/22/72	29.21	5.33	5.8	-640	6.0
SD.102	3/22/72	29.28	4.17	5.7	-540	6.5
SD.103	3/22/72	28.88	5.09	5.7	-240	8.0

Table IV

Spoil Disposal
June 1972

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp.	Eh	Sed. Temp.
SD. 1	6/5/72	25.01	8.55	18.6	--	20
SD. 2	6/5/72	25.71	4.02	19.3		17
SD. 3	6/5/72	26.06	9.44	17.4		17
SD. 4	6/5/72	25.65	10.20	18		18
SD. 5	6/5/72	25.89	9.84	18.4		18
SD. 6	6/5/72	25.54	10.75	19.4		17
SD. 7	6/5/72	25.66	8.80	19.5		18
SD. 8	6/5/72	25.62	9.74	18.8		19
SD. 9	6/5/72	25.86	7.99	18.7		17.5
SD. 10	6/5/72	25.83	9.72	18.2		18.5
SD. 11	6/5/72	25.76	10.15	18.5		19
SD. 12	6/5/72	25.41	10.09	17.6		18.5
SD. 13	6/5/72	24.86	10.39	17.8		18.5
SD. 14	6/5/72	24.49	10.00	17.5		17
SD. 15	6/5/72	25.02	9.58	16.9		20
SD. 16	6/5/72	27.33	9.15	16.4		19
SD. 17	6/5/72	26.37	9.03	18		18.5
SD. 18	6/5/72	26.83	8.96	16.7		17.5
SD. 19	6/5/72	26.83	9.44	17.2		19.5
SD. 20	6/5/72	27.80	9.12	17.2		19
SD. 21	6/5/72	28.32	8.92	16.5		17
SD. 22	6/5/72	28.49	8.71	15.4		18
SD. 23	6/5/72	28.15	9.05	15.5		17
SD. 24	6/5/72	28.17	9.01	16.3		16
SD. 25	6/5/72	28.93	9.03	15.1		16.5
SD. 26	6/5/72	29.36	8.50	14.5		17
SD. 27	6/5/72	28.92	9.22	14.3		16
SD. 28	6/5/72	28.91	8.75	14.3		17.5
SD. 29	6/5/72	29.07	6.09	14.5		17.5
SD. 30	6/5/72	28.85	8.94	14.6		16.5
SD. 31	6/5/72	28.42	8.89	14.9		16
SD. 32	6/5/72	28.75	8.84	14.6		17.5
SD. 33	6/5/72	28.18	3.12	14.7	-310	16
SD. 34	6/5/72	29.01	2.82	14.2	-60	15
SD. 35	6/5/72	28.25	5.11	14.7	-190	--
SD. 36	6/6/72	29.22	3.79	14.1	-140	16
SD. 37	6/6/72	28.28	5.74	14.2	+ 75	16
SD. 38	6/6/72	28.72	3.95	14.2	-180	15.5
SD. 39	6/6/72	28.19	4.05	14.6	- 35	16
SD. 40	6/6/72	25.84	8.72	17.4	-245	17
SD. 41	6/6/72	24.99	8.65	17.3	-195	17
SD. 42	6/6/72	26.18	8.52	17.3	-300	16.5

Table IV (cont.)

Spoil Disposal
June 1972

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp.	Eh	Sed. Temp.
SD. 43	6/6/72	25.88	8.65	17.1	-260	17
SD. 44	6/6/72	25.80	8.57	17.1	- 50	17
SD. 45	6/6/72	26.51	5.25	16.6	-265	16
SD. 46	6/6/72	25.81	8.72	17.2	-350	17
SD. 47	6/6/72	24.99	8.75	17.2	-325	17
SD. 48	6/6/72	26.08	8.75	17.2	-190	17
SD. 49	6/6/72	25.78	8.77	17.3	-240	17
SD. 50	6/6/72	25.49	8.63	17.3	-250	17
SD. 51	6/6/72	25.53	8.86	17.5	-410	17
SD. 52	6/6/72	26.44	8.94	17.2	-395	17.5
SD. 53	6/6/72	27.07	8.86	16.7	-360	15.5
SD. 54	6/6/72	26.73	9.12	16.9	-335	15
SD. 55	6/6/72	26.76	9.01	16.9	-315	15.5
SD. 56	6/6/72	26.58	9.51	16.9	-440	16
SD. 57	6/6/72	26.34	9.56	17.1	- 90	16.5
SD. 58	6/6/72	25.36	16.38	17.2	- 75	16.5
SD. 59	6/6/72	26.11	17.01	17.1	-440	16
SD. 60	6/6/72	26.01	9.51	16.9	-400	16
SD. 61	6/6/72	25.84	8.68	17.3	-405	16
SD. 62	6/6/72	27.03	9.55	16.5	-380	16
SD. 63	6/6/72	25.85	11.85	17.2	-420	16.5
SD. 64	6/6/72	25.66	8.94	17.5	-410	17
SD. 65	6/8/72	27.27	6.30	15.8	-415	17
SD. 66	6/8/72	28.06	8.46	15.4	-380	17
SD. 67	6/8/72	24.89	8.71	15.2	-450	17.5
SD. 68	6/8/72	25.68	6.99	18	- 75	18
SD. 69	6/8/72	26.08	8.53	17.8	+ 50	19
SD. 70	6/8/72	25.31	5.86	19	-460	17
SD. 71	6/8/72	25.64	8.14	19.4	-425	18
SD. 72	6/8/72	28.73	5.72	19	-455	19
SD. 73	6/8/72	24.82	6.62	19.5	-430	18.5
SD. 74	6/8/72	25.22	8.98	19.5	-425	19
SD. 75	6/6/72	26.24	4.90	17.2	-460	17
SD. 76	6/8/72	25.57	8.61	19.5	-390	19
SD. 77	6/8/72	25.86	7.97	18.3	---	18
SD. 78	6/8/72	25.85	7.49	18.9	-460	17.5
SD. 79	6/8/72	25.52	8.02	19.6	-420	18
SD. 80	6/8/72	25.40	8.61	19.4	-390	17
SD. 81	6/8/72	25.58	6.60	19.1	-450	18
SD. 82	6/8/72	25.57	7.61	19.0	-400	18
SD. 83	6/8/72	25.44	6.96	18.9	-425	17
SD. 84	6/8/72	25.26	7.03	19.1	-390	17
SD. 85	6/8/72	25.70	8.37	18.3	-420	18.5

Table IV (cont.)

Spoil Disposal
June 1972

Hydrographic Data

Station	Date	Sal.	DO	H_2O Temp.	Eh	Sed. Temp.
SD. 86	6/8/72	26.09	5.42	18.4	-390	14.5
SD. 87	6/8/72	27.52	6.87	16.2	-355	17
SD. 88	6/8/72	25.68	8.07	18.2	-350	17
SD. 89	6/8/72	25.54	4.80	16.4	-460	16
SD. 90	6/8/72	27.43	6.59	16.8	-445	16.5
SD. 91	6/8/72	25.93	4.80	17.4	-360	17
SD. 92	6/6/72	25.33	4.05	17.4	-310	17
SD. 93	6/6/72	25.75	5.33	17.7	-280	17.5
SD. 94	6/6/72	25.94	4.05	14.4	-400	17
SD. 95	6/6/72	26.43	4.83	17.1	-400	17.5
SD. 96	6/6/72	25.48	6.92	17.5	-410	17
SD. 97	6/6/72	26.22	7.03	17.4	-425	17
SD. 98	6/6/72	29.19	6.69	16.8	- 20	17
SD. 99	6/6/72	25.25	5.47	17.3	- 90	16.5
SD.100	6/6/72	25.65	6.06	17.4	0	16
SD.101	6/6/72	27.01	3.88	15.4	-275	17
SD.102	6/6/72	25.45	4.50	16.2	-330	16.5
SD.103	6/6/72	28.66	5.29	14.3	+ 45	15.5

Table V

Secchi Disc Readings
(in cm)

Station	December Samples	March Samples	June Samples	Station	December Samples	March Samples	June Samples
1		84	--	44	122	--	.127
2		81	--	45	120	200	117
3		120	--	46	100	118	121
4		--	90	47	125	200	123
5		115	120	48	117	--	110
6		--	100	49	95	65	104
7		124	115	50	94	--	117
8		--	105	51	85	110	106
9		--	124	52	94	114	126
10		--	97	53	87	101	103
11		95	160	54	92	104	89
12		165	141	55	121	93	77
13		--	137	56	110	--	84
14		--	164	57	102	100	101
15		--	200	58	126	93	100
16		121	121	59	110	120	100
17		--	122	60	100	110	76
18		177	180	61	160	100	109
19		131	127	62	177	100	130
20		--	180	63	150	103	110
21		107	153	64	170	102	121
22	119	--	141	65	50	121	70
23		--	138	66	50	98	94
24		114	108	67	65	60	105
25		--	169	68	65	65	103
26		200+	134	69	65	100	185
27		170	149	70	60	65	101
28		--	152	71	50		103
29		--	130	72	55	65	73
30		--	151	73			78
31		200+	147	74	55	60	81
32			177	75	50		140
33		74	151	76	50	125	72
34		--	152	77	50	130	92
35		200+	135	78	50	104	96
36		174	160	79	50	118	57
37		174	150	80	40	130	79
38		200+	175	81	40	60	90
39		174	144	82	40	75	79
40	120	60	121	83	40		75
41	105	--	110	84	40	50	91
42	115	60	102	85	50	60	88
43	102	87	115	86	40	60	96

Table V (cont.)

Secchi Disc Readings
(in cm)

Station	December Samples	March Samples	June Samples	Station	December Samples	March Samples	June Samples
87	60	70	92	96	123	70	126
88	63		79	97	124	99	126
89	50		86	98	140	94	69
90	55		87	99	142	70	94
91	63		92	100	142	75	87
92	123	13	127	101	153	132	120
93	109			102	150	98	124
94	123	70	128	103	100	125	96
95	120		137				

Table VI

Results of T-test for Differences in Means of Dissolved Oxygen

Monthly Comparison	T Values	Level of Significance
Area A		
Dec. -March	7.898	.05
March-June	5.212	.05
Dec. -June	4.79	.05
Area B		
Dec. -March	7.779	.05
March-June	2.386	.05
Dec. -June	11.269	.05
Area C		
Dec. -March	16.704	.05
March-June	6.797	.05
Dec. -June	0.120	---
Area D		
Dec. -March	1.684	---
March-June	1.203	---
Dec. -June	.536	---
Area E		
Dec. -March	7.023	.05
March-June	3.747	.05
Dec. -June	4.976	.05

MARINE GEOLOGY

Table I

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand			% Silt			% Clay			Eh		
		Dec.	March	June	Dec.	March	June	Dec.	March	June	Dec.	March	June
1	38°47'57" 75°09'38"	72	19	28	20	70	60	8	11	12	-200	-310	--
2	38°48'07" 75°09'36"	26	31	32	56	51	52	18	19	16	-230	-370	--
3	38°48'15" 75°09'11"	19	21	20	61	59	58	20	22	22	-240	-325	--
4	38°48'52" 75°09'37"	67	--	73	24	--	21	9	--	6	-270	--	--
5	38°48'44" 75°09'54"	18	46	77	61	51	22	21	2	1	-280	-360	--
6	38°48'31" 75°10'04"	17	--	19	65	--	64	18	--	17	-250	--	--
7	38°49'11" 75°10'04"	79	76	78	14	15	16	7	9	7	-220	-210	--
8	38°49'33" 75°09'39"	85	--	81	12	--	15	4	--	5	-180	--	--
9	38°50' 0" 75°10'14"	94	--	82	5	--	13	1	--	5	-100	--	--
10	38°49'36" 75°10'43"	97	--	83	2	--	15	1	--	2	+020	--	--
11	38°50'39" 75°10'43"	99	99	99	0	1	1	1	1	0	+080	+ 50	--

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand			% Silt			% Clay			Eh		
		Dec.	March	June	Dec.	March	June	Dec.	March	June	Dec.	March	June
12	38°50'42" 75°09'42"	99	95	98	1	3	1	1	1	1	+050	+ 80	--
13	38°50'29" 75°08'34"	100	--	100	0	--	0	0	0	--	+080	--	--
14	38°50'34" 75°07'54"	100	--	100	0	--	1	0	--	0	+070	--	--
15	38°50'31" 75°07'08"	100	--	100	0	--	0	0	--	0	+070	--	--
16	38°49'45" 75°07'45"	99	99	100	0	1	0	1	0	0	+070	+ 60	--
17	38°49'48" 75°08'15"	99	--	100	0	--	0	1	--	0	-070	--	--
18	38°49'58" 75°08'35"	87	97	98	8	1	1	5	3	1	-170	+ 90	--
19	38°49'38" 75°08'59"	51	69	91	31	26	8	18	5	1	-230	-240	--
20	38°49'50" 75°08'44"	85	--	58	11	--	33	4	--	9	-210	--	--
21	38°49'23" 75°08'21"	83	86	97	11	9	2	6	5	1	-160	-230	--
22	38°49'19" 75°08'04"	86	--	98	9	--	1	5	--	1	-170	--	--

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand			% Silt			% Clay			Eh		
		Dec.	March	June	Dec.	March	June	Dec.	March	June	Dec.	March	June
23	38°48'51" 75°08'40"	76	--	80	17	--	16	7	--	4	-280	--	--
24	38°48'26" 75°08'08"	89	90	100	7	5	0	5	5	0	-200	-280	--
25	38°48'26" 75°07'49"	80	--	100	12	--	0	8	--	0	-170	--	--
26	38°48'57" 75°06'55"	98	96	99	0	4	1	2	1	1	+080	+ 80	--
27	38°49'20" 75°06'34"	36	92	98	41	6	1	22	2	1	-290	+ 70	--
28	38°49'33" 75°06'11"	78	--	34	14	--	54	7	--	12	-300	--	--
29	38°49'59" 75°06'33"	96	--	89	2	--	8	2	--	3	+020	--	--
30	38°50' 5" 75°06'45"	97	--	100	1	--	0	1	--	0	+030	--	--
31	38°50' 0" 75°06'54"	98	94	100	1	4	0	1	2	0	+050	- 20	--
32	38°49'20" 75°07'12"	99	--	86	1	--	12	1	--	2	+050	--	--
33	38°48'44" 75°06'37"	98	99	49	1	0	33	1	1	19	+080	- 60	-310

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand			% Silt			% Clay			Eh		
		Dec.	March	June	Dec.	March	June	Dec.	March	June	Dec.	March	June
34	38°48'48" 75°06'06"	94	--	100	3	--	1	3	--	0	-040	--	- 60
35	38°48'46" 75°05'34"	98	46	41	2	52	58	1	1	1	+060	-200	-190
36	38°48'32" 75°05'34"	30	39	27	40	49	73	30	11	0	*	-220	-140
37	38°48'20" 75°05'45"	98	46	100	1	53	0	1	1	0	+100	-150	+ 75
38	38°48'20" 75°05'08"	23	17	14	43	50	85	34	32	0	*	-250	-180
39	38°48'09" 75°05'08"	99	99	100	1	1	0	1	0	0	+ 90	+170	- 35
40	38°48'15" 75°06'59"	85	78	86	10	17	11	4	4	3	-175	-230	-245
41	38°48'20" 75°06'46"	51	--	97	29	--	2	12	--	1	-190	--	-195
42	38°48'18" 75°06'40"	79	44	83	14	41	11	7	15	7	-230	-340	-300
43	38°48'17" 75°06'36"	93	61	86	3	21	10	3	18	4	-165	-310	-260
44	38°48'16" 75°06'30"	91	--	100	5	--	0	3	--	0	-105	--	- 50

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand Dec.	% Sand March	% Sand June	% Silt Dec.	% Silt March	% Silt June	% Clay Dec.	% Clay March	% Clay June	Eh Dec.	Eh March	Eh June
45	38°48'17" 75°06'25"	95	50	53	3	38	33	2	12	15	- 10	-470	-265
46	38°48'13" 75°06'24"	76	27	53	18	58	33	6	20	14	-295	-470	-350
47	38°48'12" 75°06'28"	31	24	52	52	54	42	17	22	6	-330	-510	-325
48	38°48'12" 75°06'34"	83	--	100	11	--	0	6	--	0	-230	--	-190
49	38°48'14" 75°06'50"	87	25	97	9	65	2	4	10	1	-180	-230	-240
50	38°48'14" 75°06'50"	81	--	93	14	--	6	6	--	1	-205	--	-250
51	38°48'09" 75°06'55"	91	33	47	5	47	48	4	20	10	-215	-300	-410
52	38°48'06" 75°06'47"	51	70	44	34	25	40	14	4	16	-270	-360	-395
53	38°48'06" 75°06'44"	30	42	33	56	45	34	13	13	34	-340	-370	-360
54	38°48'04" 75°06'40"	62	57	23	28	42	62	10	1	15	-375	-360	-385
55	38°48'02" 75°06'37"	34	21	42	46	50	44	21	39	14	-375	-400	-315

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand			% Silt			% Clay			Eh		
		Dec.	March	June	Dec.	March	June	Dec.	March	June	Dec.	March	June
56	38°48' 0" 75°06'32"	26	--	67	52	--	26	21	--	7	-420	--	-440
57	38°47'59" 75°06'28"	21	24	23	56	59	57	23	17	20	-420	-440	- 90
58	38°47'58" 75°06'25"	22	25	28	55	51	48	23	24	24	-460	-420	- 75
59	38°48'02" 75°06'24"	21	28	38	55	56	35	24	16	26	-460	-570	-440
60	38°48'03" 75°06'26"	27	28	63	32	57	30	40	15	7	-450	-530	-400
61	38°48'03" 75°06'30"	26	24	23	54	56	50	19	20	26	-445	-550	-405
62	38°48'05" 75°06'30"	17	15	25	62	65	58	21	20	17	-425	-260	-380
63	38°48'07" 75°06'39"	83	16	33	13	65	49	4	19	29	-390	-250	-420
64	38°48'10" 75°06'44"	98	50	26	1	44	43	1	5	31	-180	-320	-410
65	38°47'17" 75°08'29"	38	31	47	44	57	41	18	13	12	-350	-460	-415
66	38°47'28" 75°08'20"	38	25	7	48	43	85	15	33	8	-320	-400	-380

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand			% Silt			% Clay			Eh		
		Dec.	March	June	Dec.	March	June	Dec.	March	June	Dec.	March	June
67	38°48' 0" 75°08' 0"	65	82	80	21	12	17	14	5	3	-210	-270	-450
68	38°48' 0" 75°07'29"	97	74	100	2	18	0	2	9	0	-070	-185	- 75
69	38°48'28" 75°07'06"	96	74	100	2	16	0	2	11	0	-090	-230	+ 50
70	38°47'56" 75°06'54"	33	25	15	50	68	65	17	7	20	-290	-400	-460
71	38°47'54" 75°06'51"	13	--	16	57	--	55	30	--	29	-290	--	-425
72	38°47'55" 75°06'47"	42	27	22	43	63	57	14	10	21	-325	-400	-455
73	38°47'52" 75°06'45"	11	--	40	71	--	43	18	--	17	-330	--	-430
74	38°47'52" 75°06'37"	26	28	31	55	55	55	19	17	14	-330	-400	-425
75	38°47'53" 75°06'30"	23	--	51	55	--	42	22	--	7	-290	--	-460
76	38°47'42" 75°06'18"	73	57	44	21	37	37	6	6	20	-390	-350	-390
77	38°47'35" 75°06'09"	25	41	41	54	48	56	21	11	3	-270	-340	--

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand			% Silt			% Clay			Eh		
		Dec.	March	June	Dec.	March	June	Dec.	March	June	Dec.	March	June
78	38°47'35" 75°06'30"	20	33	32	55	54	52	25	13	16	-325	-410	-460
79	38°47'22" 75°06'29"	19	20	16	56	55	57	25	25	26	-270	-380	-420
80	38°47'24" 75°06'45"	22	29	21	59	64	56	20	8	23	-300	-360	-390
81	38°47'38" 75°06'49"	24	18	17	57	66	68	18	16	15	-280	-365	-450
82	38°47'38" 75°07'24"	23	21	22	57	41	40	20	37	38	-280	-300	-400
83	38°47'32" 75°07'23"	14	10	8	67	72	81	19	18	11	-320	-370	-425
84	38°47'57" 75°07'23"	51	77	63	38	21	36	12	4	2	-220	-390	-390
85	38°47'58" 75°07'06"	23	29	14	59	54	67	17	17	19	-250	-260	-420
86	38°47'35" 75°07'05"	16	15	9	60	67	70	25	18	21	-330	-380	-390
87	38°47'13" 75°07'05"	12	18	29	62	59	21	26	23	50	-340	-290	-355
88	38°47'06" 75°07'10"	7	--	8	68	--	60	25	--	32	-350	--	-350

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand Dec.	% Sand March	% Sand June	% Silt Dec.	% Silt March	% Silt June	% Clay Dec.	% Clay March	% Clay June	Eh Dec.	Eh March	Eh June
89	38°47'02" 75°07'15"	17	--	60	51	--	30	31	--	9	-330	--	-460
90	38°47'03" 75°07'02"	8	--	13	59	--	50	34	--	37	-350	--	-445
91	38°47'07" 75°07'07"	10	--	20	63	--	68	27	--	11	-350	--	-360
92	38°48'02" 75°06'50"	20	31	26	60	51	50	20	18	24	-400	-360	-310
93	38°48'01" 75°06'45"	18	--	12	58	--	74	25	--	14	-400	--	-280
94	38°47'59" 75°06'42"	29	27	33	55	59	62	17	13	6	-450	-420	-400
95	38°47'57" 75°06'38"	35	--	39	49	--	55	17	--	7	-435	--	-400
96	38°47'56" 75°06'38"	33	38	53	49	39	36	18	22	11	-445	-390	-410
97	38°47'56" 75°06'29"	34	29	39	45	57	52	21	14	8	-440	-390	-425
98	38°47'53" 75°06'08"	99	98	98	1	1	1	1	1	1	-060	+ 70	- 20

Table I (cont.)

Sample Locations and Sediment Characteristics for December, March, and June Samplings

Sample No.	Latitude & Longitude	% Sand			% Silt			% Clay			Eh		
		Dec.	March	June	Dec.	March	June	Dec.	March	June	Dec.	March	June
99	38°47'54" 75°06'12"	62	95	97	32	3	2	6	2	1	-400	+ 70	- 90
100	38°47'56" 75°06'18"	69	96	99	27	2	1	4	2	0	- 90	- 20	0
101	38°48'11" 75°06'17"	23	49	77	58	31	14	19	20	9	-435	-640	-275
102	38°48'09" 75°06'04"	83	73	71	13	19	23	4	8	6	-205	-540	-330
103	38°48'06" 75°05'55"	99	99	99	1	1	1	1	1	1	+040	-240	+ 45

Table II

Settling Rate of Spoil Material Taken from the Dredge

Day	Centimeters Settled	Day	Centimeters Settled
1	2.9	27	----
2	5.2	28	25.1
3	6.8	29	25.6
4	8.1	30	25.9
5	----	31	26.3
6	----	32	26.7
7	12.1	33	----
8	13.0	34	----
9	14.1	35	27.6
10	14.8	36	28.2
11	15.6	37	28.4
12	16.5	38	28.9
13	----	39	29.2
14	17.9	40	----
15	18.5	41	----
16	19.2	42	30.1
17	19.6	43	30.5
18	20.2	44	30.8
19	----	45	31.1
20	----	46	31.4
21	21.6	47	----
22	22.2	48	----
23	22.7	49	32.2
24	23.2	50	32.5
25	23.8	56	33.0
26	----	64	34.6
		133	34.6

Table III

Percent Total Carbon in Bottom Sediments for December and June Sampling Periods

Sample No.	% C of 1/72	% C of 7/72
1	2.0	3.3 +
2	2.2	7.4 +
3	2.3	2.7 +
5	3.3	69.9 +
6	2.3	3.1 +
7	2.9	2.5 -
8	2.3	50.8 +
19	3.1	2.2 -
27	3.0	27.3 +
36	2.0	1.6 -
38	1.6	1.9 +
40	3.0	3.3 +
41	2.8	3.7 +
42	2.5	3.0 +
43	2.6	2.7 +
45	2.9	3.6 +
46	2.8	3.3 +
47	2.2	2.7 +
50	1.9	1.9
51	2.9	3.0 +
52	3.5	3.6 +
53	1.4	6.3 +
54	1.5	2.5 +
55	1.7	2.7 +
56	1.6	2.7 +
57	3.3	3.9 +
58	2.5	4.5 +
59	2.3	4.9 +
60	2.3	3.3 +
61	2.4	3.5 +
62	2.2	2.4 +
63	3.1	5.2 +
65	3.2	2.7 -
66	1.8	1.9 +
70	1.4	3.3 +
71	3.2	3.6 +
72	2.8	3.6 +
73	2.3	---
74	2.4	---
75	2.6	---

Table III (cont.)

Sample No.	% C of 1/72	% C of 7/72
77	2.4	---
78	3.9	---
82	2.0	---
83	2.5	---
85	2.5	---
86	3.0	---
92	1.9	---
94	1.7	---
101	3.5	---

+ = Increase December-June
− = Decrease December-June

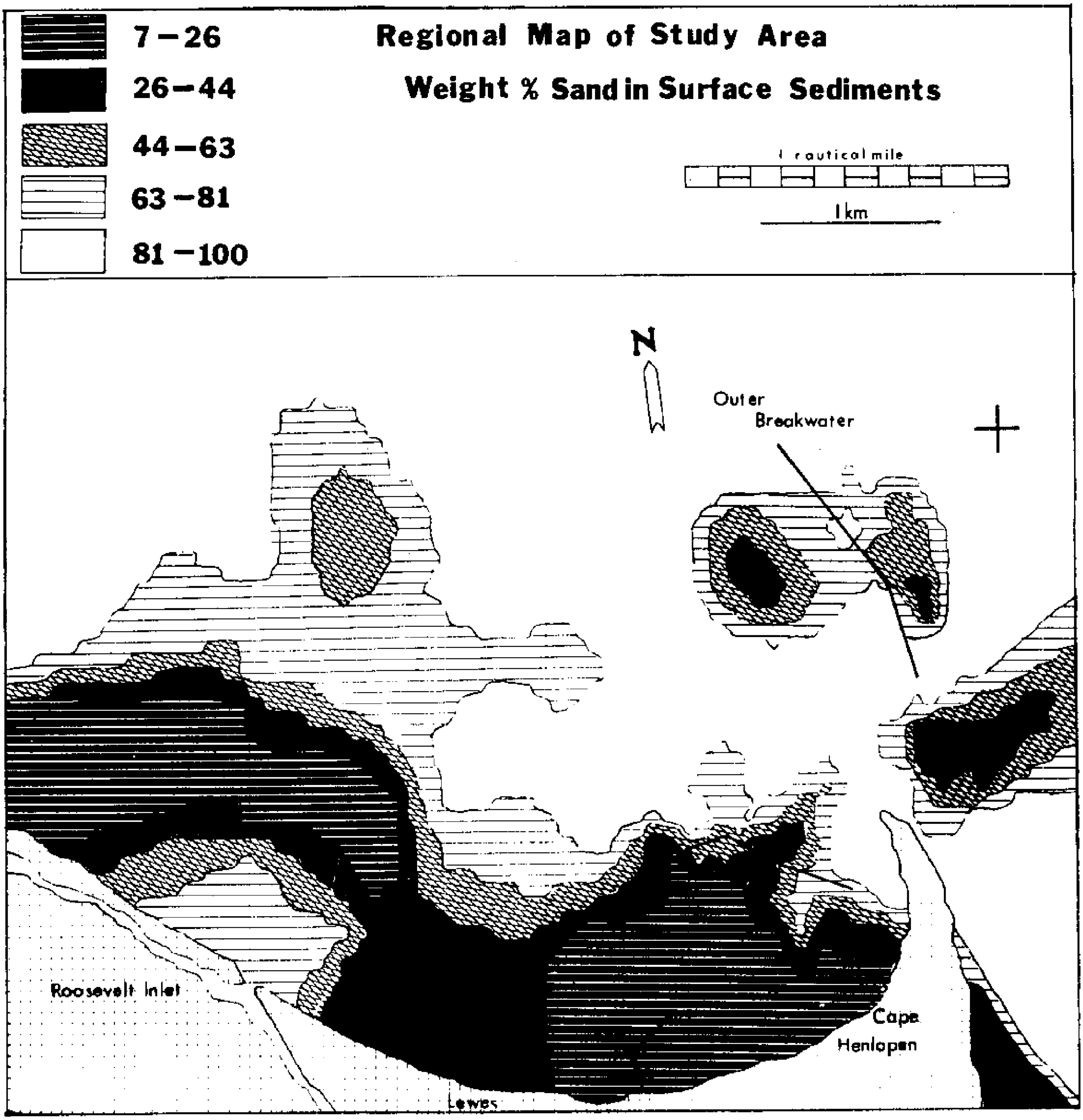

Figure 1
Percent Sand, December 1971

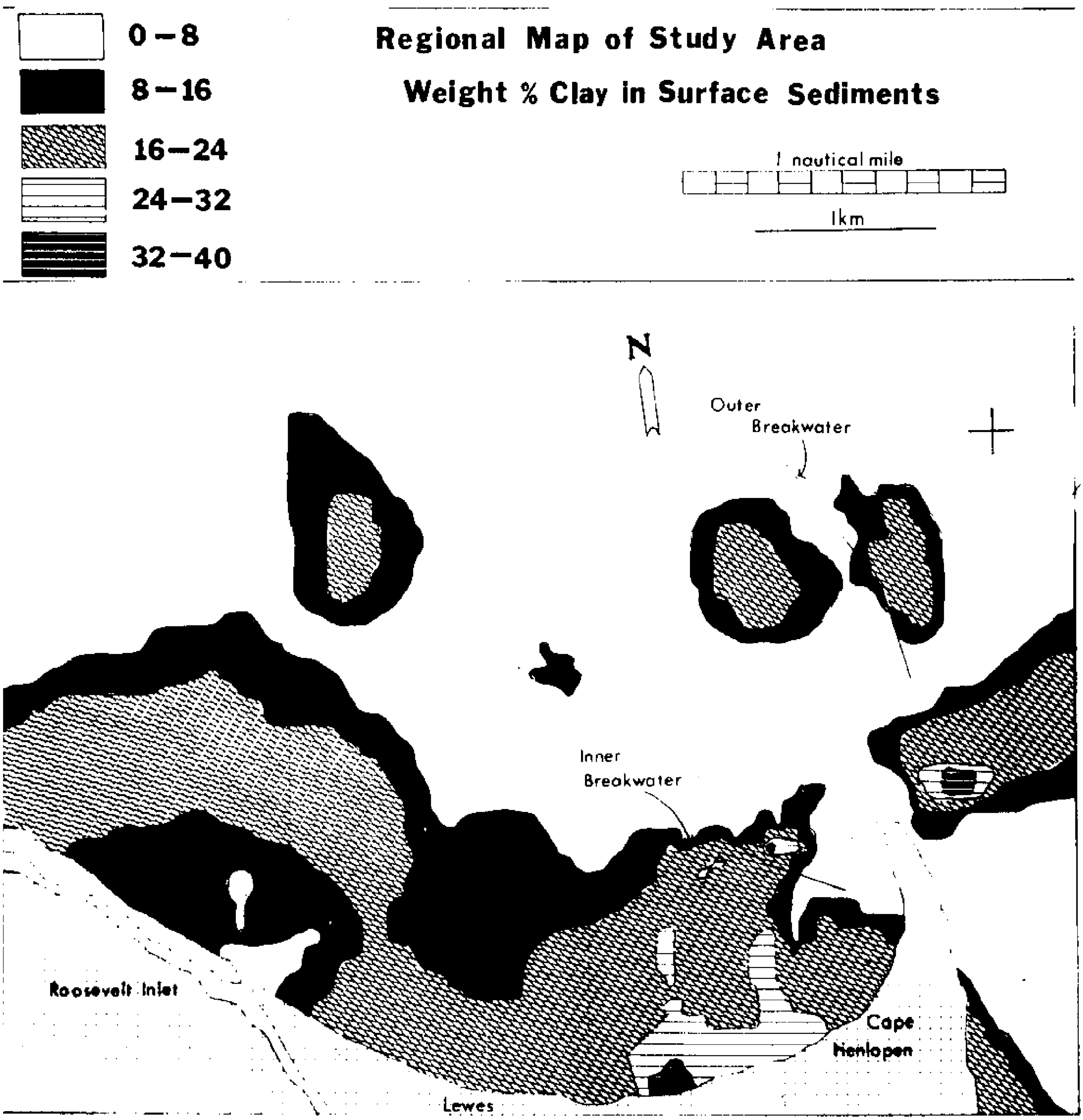

Figure 2
Percent Clay, December 1971

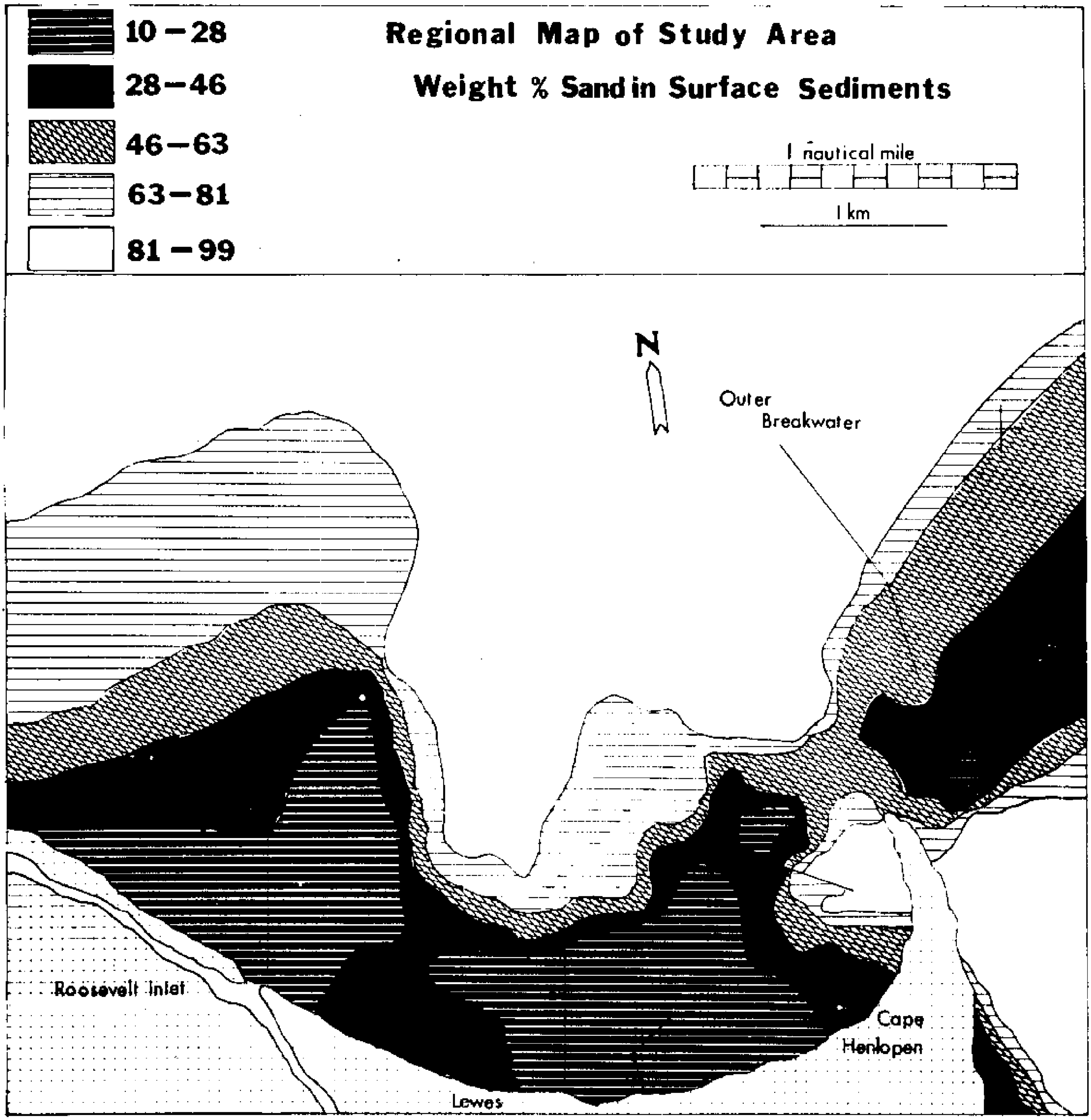

Figure 3
Percent Sand, March 1972

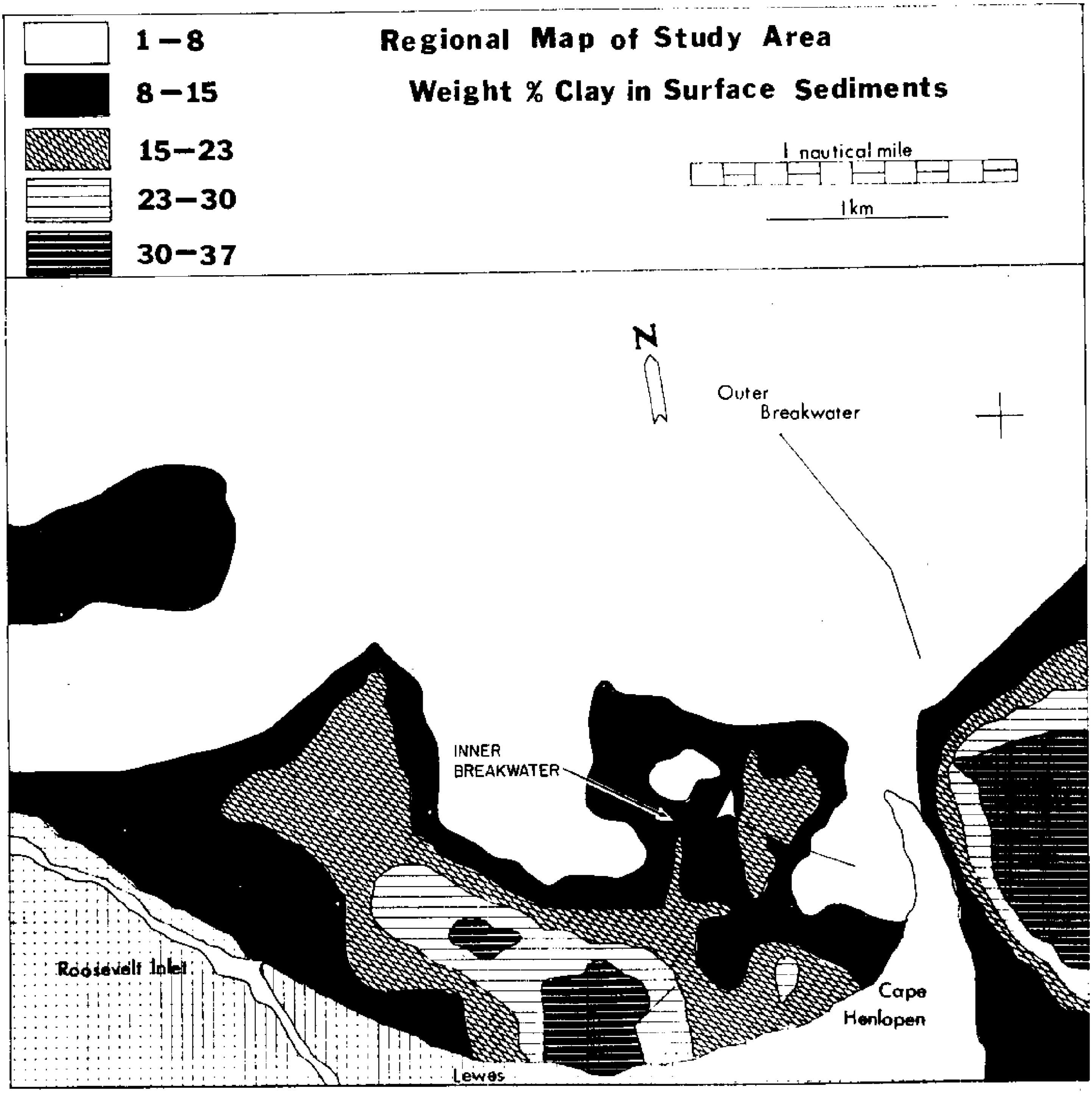

Figure 4
Percent Clay, March 1972

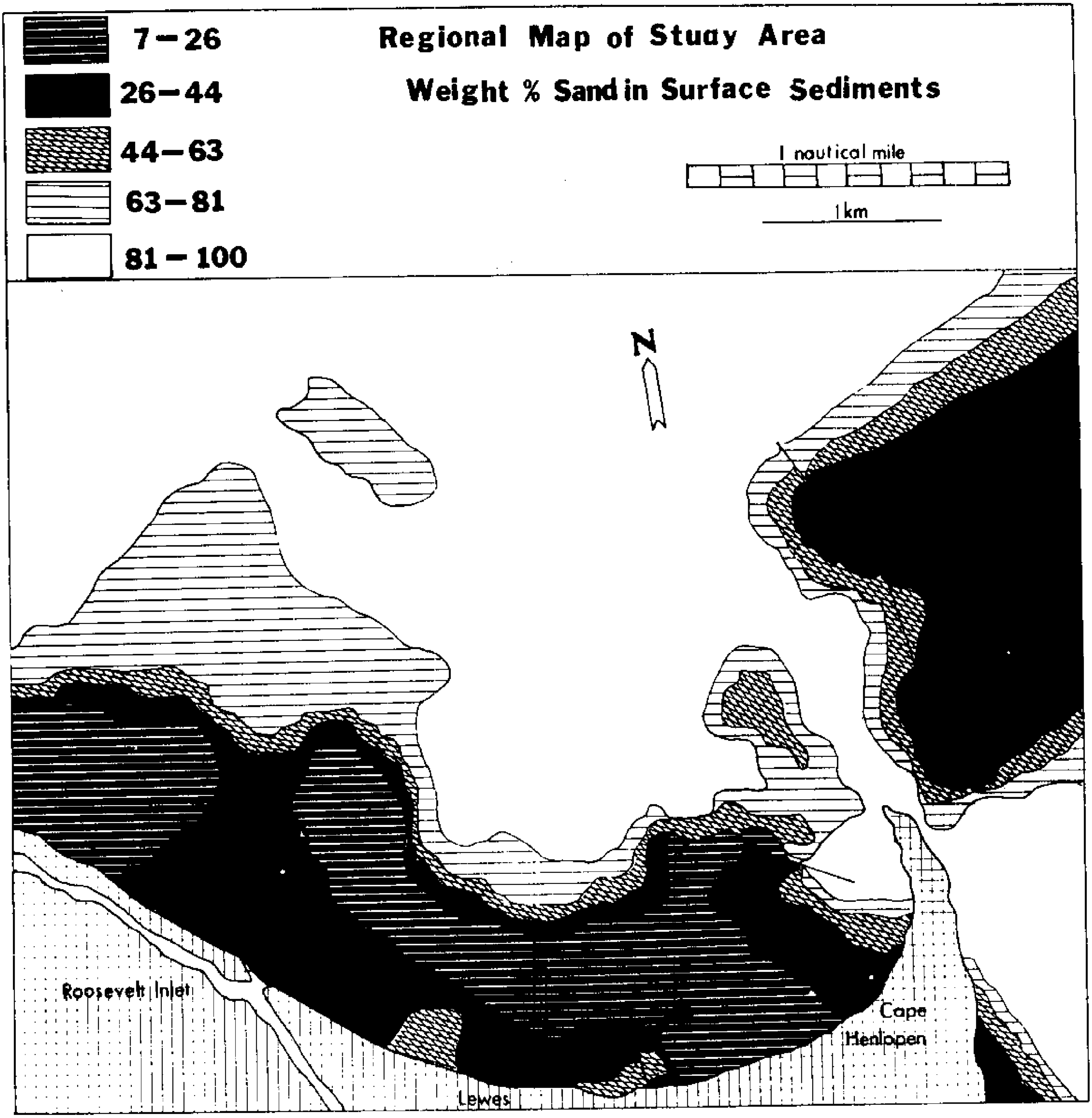

Figure 5
Percent Sand, June 1972

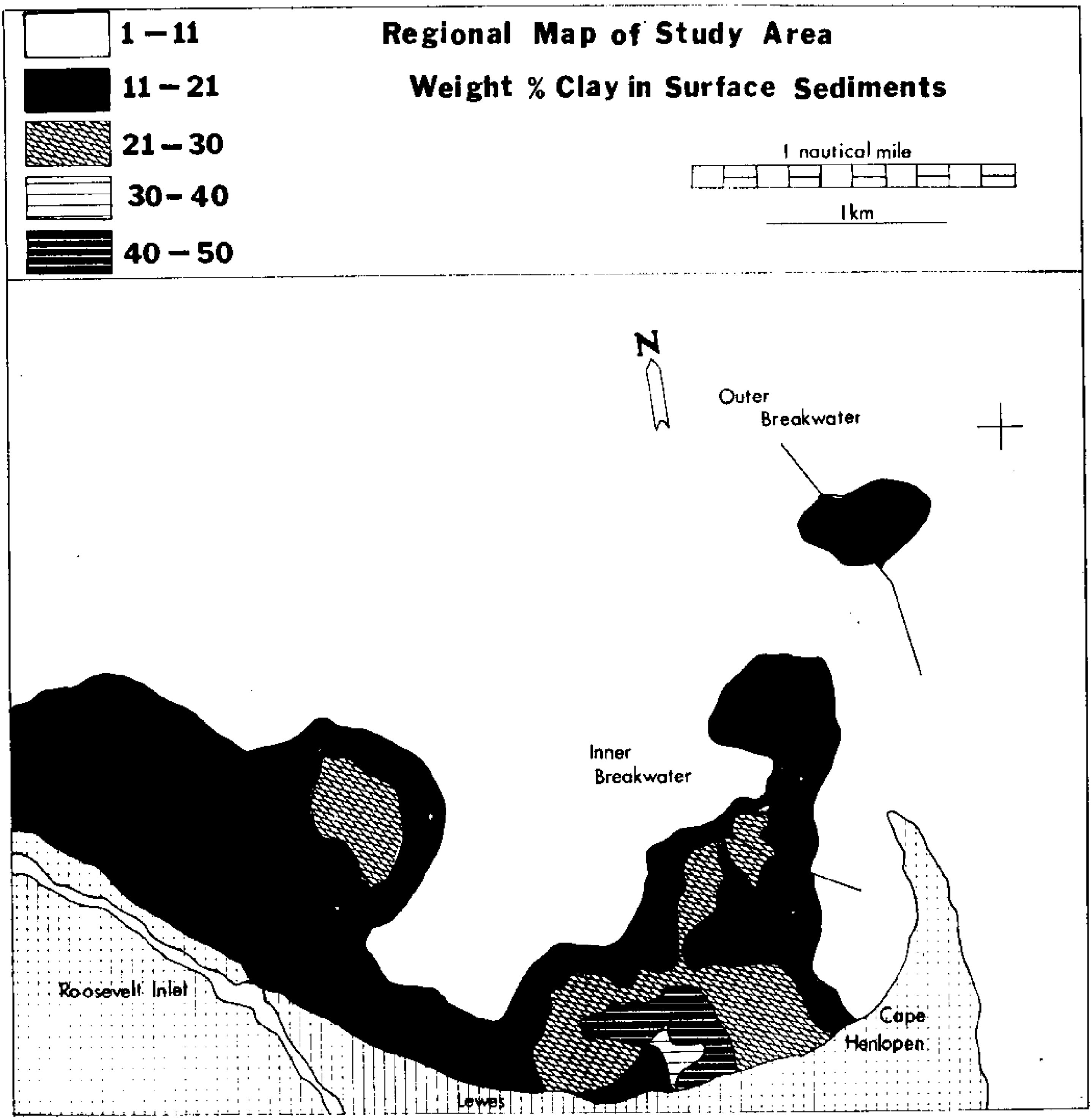

Figure 6
Percent Clay, June 1972

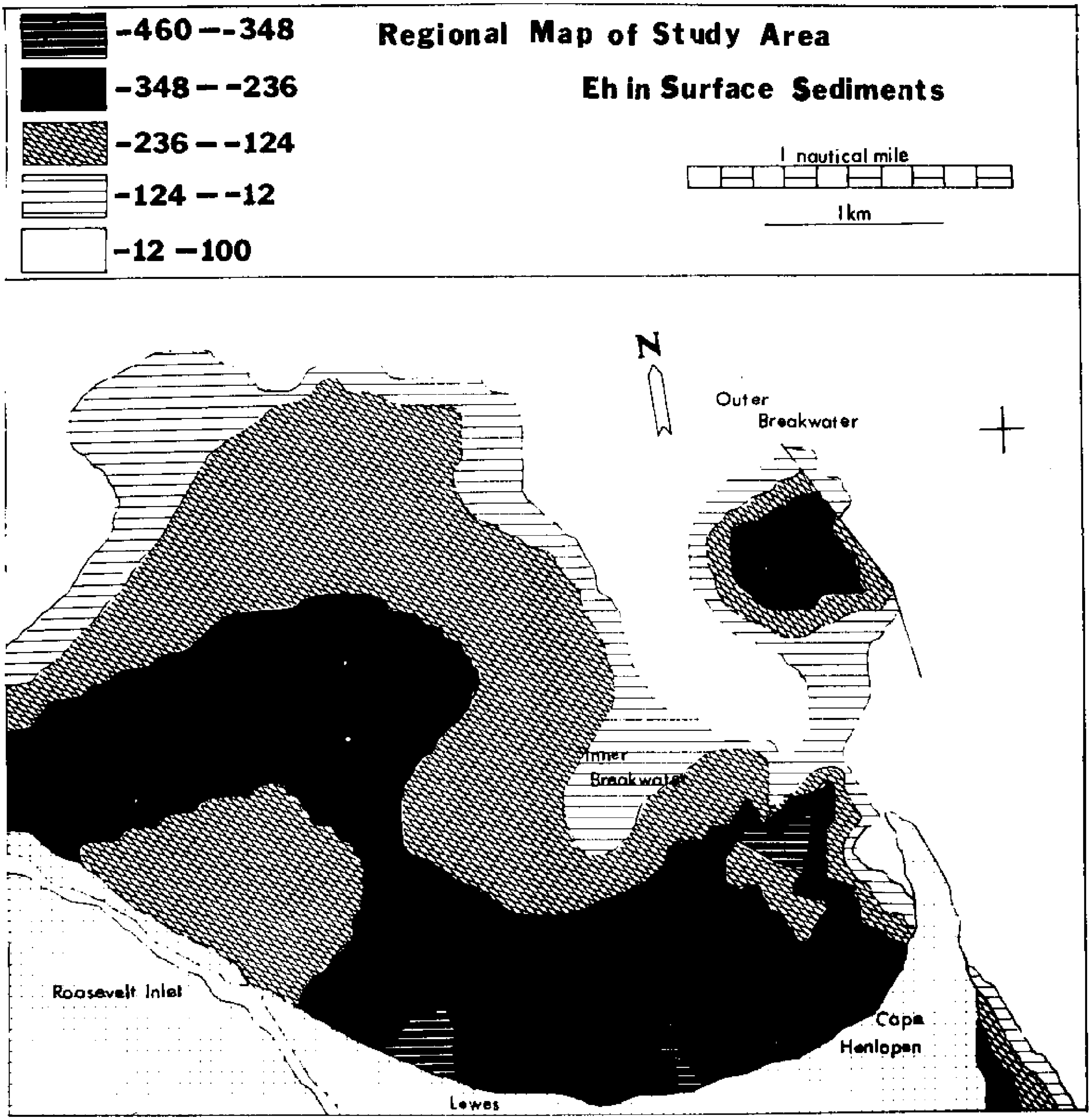

Figure 7

Eh Reading in Surface Sediments
of Study Area

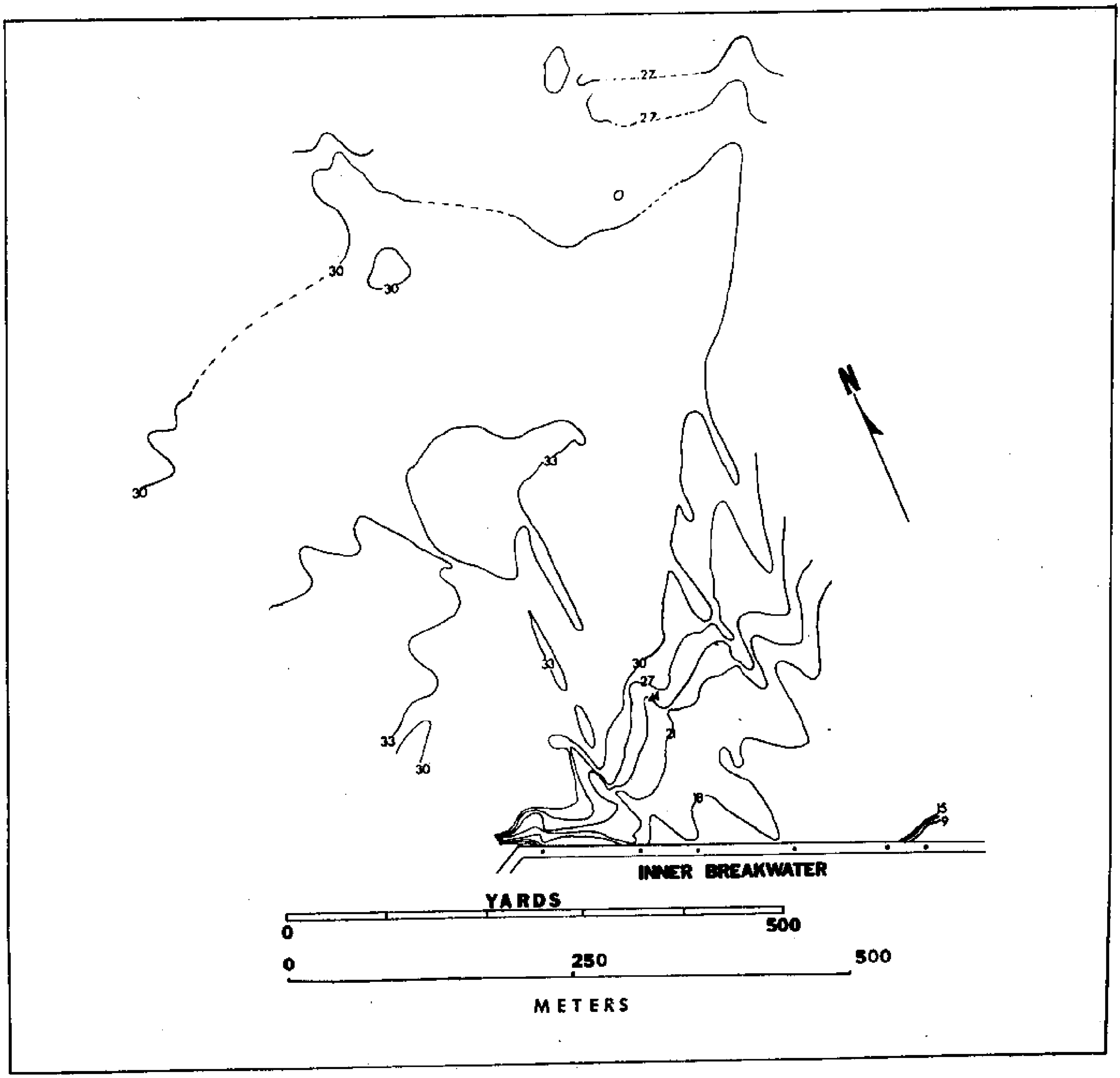

Figure 8

Continuous Contour Map of Bathymetric Survey
Conducted on February 9, 1972.

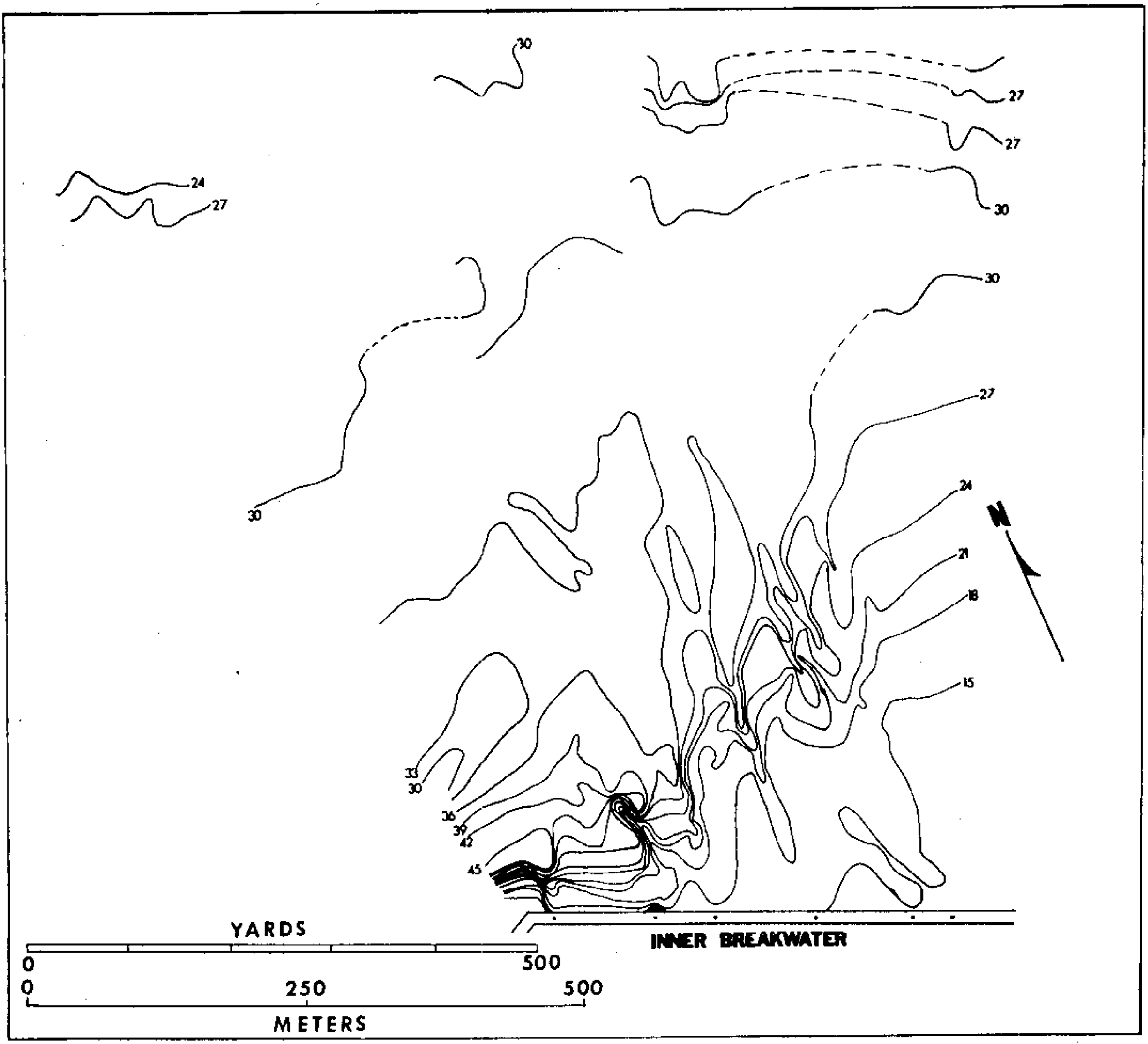

Figure 9

Continuous Contour Map of Bathymetric Survey Conducted March 21, 1972.

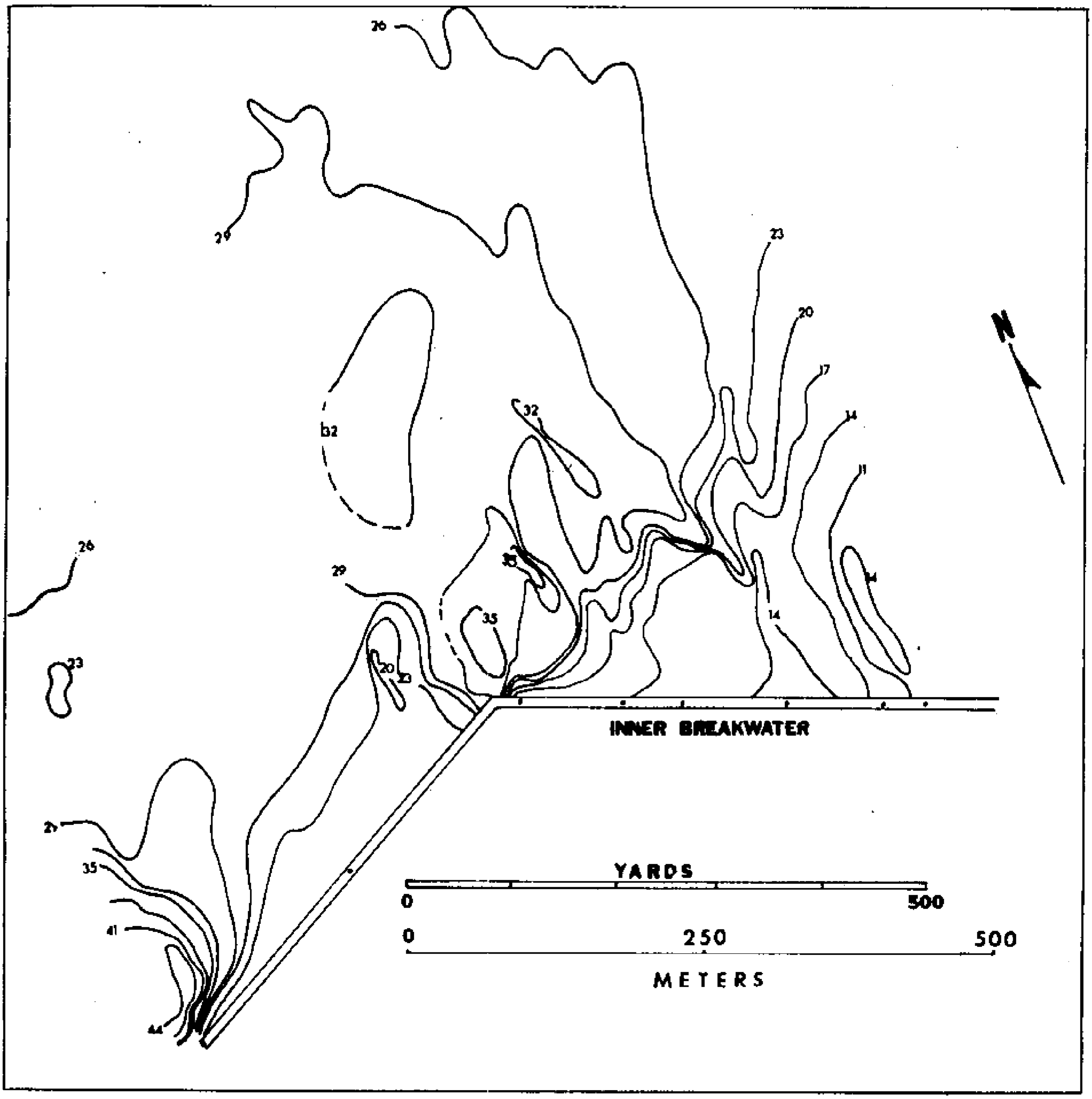

Figure 10
Continuous Contour Map of Bathymetric Survey Conducted on July 10, 1972.

MARINE BIOLOGY

Table I

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

December 1971

Pelecypods Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Cardita borealis											2		4													
Ensis directus																		1		1	1					1
Gemma gemma									1		8	1	6													
Mercenaria mercenaria																										
Mulinia lateralis																										
Nucula proxima	3	13	2	3	2	5	1		1														3			2
Pandora gouldiana										1				1									1			
Tellina agilis	2	2	8	9	3	2	13	13	1	3	10			4	13		3	12	4	12	13	12	2	11	2	1
Yoldia limatula				1															1		1		1			
Gastropods																										
Crepidula convexa											1															
Crepidula fornicata															1											
Crepidula plana											1															
Nassarius trivittatus																										
Nassarius vibex																							1			
Total/Station	5	15	10	13	5	7	14	13	3	4	22	1	10	5	14	0	3	13	5	13	15	12	8	11	2	4

December 1971

Pelecypods Stations	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Cardita borealis																										
Ensis directus				1																						
Gemma gemma																										
Mercenaria mercenaria																										
Mulinia lateralis			2			1																				
Nucula proxima		4						1		2										3						
Pandora gouldiana																										
Tellina agilis	1	1	14	4		2		16		5			2	9	9	22	15	17	17	3		16	10	3	12	1
Yoldia limatula																										
Gastropods																										
Crepidula convexa																										
Crepidula fornicata																										
Crepidula plana																										
Nassarius trivittatus																		1					1			
Nassarius vibex																									3	
Total/Station	1	5	16	5	0	3	0	17	0	7	0	0	2	9	9	22	15	18	17	6	0	16	11	3	15	1

Table I (cont.)

Pelecypods	December 1971																									
Stations	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Cardita borealis																										
Ensis directus																1										
Gemma gemma																										
Mercenaria mercenaria																										
Mulinia lateralis																										
Nucula proxima				1	4	15	19	12	2		206	12	10		1			3	1	4		2	1	30	33	
Pandora gouldiana																										
Tellina agilis	1											12		3	1	58	3						1	3	2	
Yoldia limatula																						1				
Gastropods																										
Crepidula convexa																										
Crepidula fornicata																										
Crepidula plana																										
Nassarius trivittatus															1	2										
Nassarius vibex																										
Total/Station	1	0	0	1	4	15	19	12	2	0	206	24	10	3	3	61	3	3	1	4	0	3	2	33	35	0

Pelecypods	December 1971																								
Stations	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Cardita borealis																									
Ensis directus																									
Gemma gemma																									
Mercenaria mercenaria																1									
Mulinia lateralis					1																				
Nucula proxima	2	5			1	2	5	3									1		1	2					
Pandora gouldiana																		1							
Tellina agilis	1			1										1						32		16	3		
Yoldia limatula																									
Gastropods																									
Crepidula convexa																									
Crepidula fornicata																									
Crepidula plana																									
Nassarius trivittatus																									
Nassarius vibex																									
Total/Station	3	5	0	1	2	2	5	3	0	0	0	0	0	1	0	1	1	1	1	34	0	16	3	0	0

Table I (cont.)

Pelecypods December 1971	Total/Occurrence
Cardita borealis	6/ 2
Ensis directus	6/ 6
Gemma gemma	16/ 4
Mercenaria mercenaria	1/ 1
Mulinia lateralis	4/ 3
Nucula proxima	423/ 40
Pandora gouldiana	4/ 4
Tellina agilis	472/ 50
Yoldia limatula	5/ 5
Gastropods	
Crepidula convexa	1/ 1
Crepidula fornicata	1/ 1
Crepidula plana	1/ 1
Nassarius trivittatus	5/ 4
Nassarius vibex	4/ 2
Total/Station	949/132

Table I (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

Polychaetes	December 1971																								
Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Asabellides oculata																									
Diopatra cuprea																									
Glycera americana										1									1	1			1		
Glycera dibranchiata															1			1			1	1			
Glycinde solitaria																									
Harmothoe extenuata																									
Heteromastus filiformis	2	1																							
Hydroides dianthus													1												
Hypaniola grayi								1																	
Lumbrineris tenuis																									
Nephtys picta									1		1	2			1		1							1	
Nereis succinea																									
Ophelia bicornis														18											
Paraprionospio pinnata																									
Polydora ligni																									
Sabellaria vulgaris											1														
Scolecolepides viridis																									1
Scolelepis squamata																									
Scoloplos fragilis	1							1									1								
Sthenelais limicola																							1		
Streblospio benedicti																									
Total	3	1	0	0	0	0	0	2	1	1	2	2	1	18	2	0	2	1	1	1	1	1	2	1	1

Table I (cont.)

Polychaetes	December 1971																								
Stations	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Asabellides oculata																									
Diopatra cuprea																									
Glycera americana		1																							
Glycera dibranchiata												1			1		1		1						
Glycinde solitaria									1																
Harmothoe extenuata											1														
Heteromastus filiformis								1							1										2
Hydroides dianthus											3														
Hypaniola grayi																									
Lumbrineris tenuis																								1	
Nephtys picta					1	1									1			2	1	2					
Nereis succinea													1												
Ophelia bicornis	1							1																	
Paraprionospio pinnata																									
Polydora ligni											1														
Sabellaria vulgaris																									
Scolecolepides viridis																									
Scolelepis squamata					1																				
Scoloplos fragilis																		3					1		
Sthenelais limicola																									
Streblospio benedicti																									
Total	1	1	0	0	2	1	0	2	1	0	5	1	1	0	3	0	1	5	2	2	0	0	1	1	2

Table I (cont.)

Polychaetes / Stations	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
December 1971																									
Asabellides oculata								1																	
Diopatra cuprea		1																							
Glycera americana																									
Glycera dibranchiata																		2							1
Glycinde solitaria																		2				1			
Harmothoe extenuata																									
Heteromastus filiformis		4	1											2							2	1			
Hydroides dianthus																									3
Hypaniola grayi																									
Lumbrineris tenuis																						1			
Nephtys picta																			2						
Nereis succinea																									
Ophelia bicornis																									
Paraprionospio pinnata																								1	
Polydora ligni																									
Sabellaria vulgaris																									
Scolecolepides viridis																									
Scolelepis squamata																									
Scoloplos fragilis																									
Sthenelais limicola																									
Streblospio benedicti						1																			
Total	0	5	1	0	0	1	0	1	0	0	0	0	0	2	0	0	0	4	2	0	2	3	0	1	4

Table I (cont.)

Polychaetes	December 1971																								
Stations	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Asabellides oculata																									
Diopatra cuprea																									
Glycera americana																									
Glycera dibranchiata									2											1					
Glycinde solitaria																									
Harmothoe extenuata																									
Heteromastus filiformis	1		2				1		2								2	4	22	6	9	1	1		
Hydroides dianthus																									
Hypaniola grayi																									
Lumbrineris tenuis																									
Nephtys picta																								1	
Nereis succinea																									
Ophelia bicornis																									
Paraprionospio pinnata								1																	
Polydora ligni																									
Sabellaria vulgaris																									
Scolecolepides viridis																									
Scolelepis squamata																									
Scoloplos fragilis	1																				3	1			
Sthenelais limicola																									
Streblospio benedicti																									
Total	2	0	2	0	0	0	1	1	4	0	0	0	0	0	0	0	2	4	22	7	12	2	1	1	0

Table I (cont.)

Polychaetes	December 1971			
Stations	101	102	103	Total/Occurrence
Asabellides oculata				1/ 1
Diopatra cuprea				1/ 1
Glycera americana				5/ 5
Glycera dibranchiata				14/12
Glycinde solitaria				4/ 3
Harmothoe extenuata				1/ 1
Heteromastus filiformis				68/21
Hydroides dianthus				7/ 3
Hypaniola grayi				1/ 1
Lumbrineris tenuis				2/ 2
Nephtys picta			1	19/15
Nereis succinea				1/ 1
Ophelia bicornis				20/ 3
Paraprionospio pinnata				2/ 2
Polydora ligni				1/ 1
Sabellaria vulgaris				1/ 1
Scolecolepides viridis				1/ 1
Scolelepis squamata				1/ 1
Scoloplos fragilis				12/ 8
Sthenelais limicola				1/ 1
Streblospio benedicti				1/ 1
Total	0	0	1	164/85

Table I (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

Arthropods	December 1971																							
Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Acanthohaustorius millsi																2								
Ampelisca abdita			1				1																	
Ampelisca verrilli				3				7											3	4	39	5	4	
Batea catharinensis																								
Cancer irroratus																								
Chiridotea tuftsi																								
Cirolana concharum																								
Cirolana polita																								
Corophium tuberculatum																				9				
Edotea triloba																								
Gammarus palustris																								
Hexapanopeus angustifrons																								
Leucon americanus																								
Lysianopsis alba																								
Neomysis americana																								
Ovalipes ocellatus																								
Oxyurostylis smithi																		1						
Parahaustorius holmesi																								
Parahaustorius longimerus																								
Parapleustes sp.																								
Pagurus longicarpus																					1			
Pagurus pollicaris																								
Pinnixa sayana												1						2						
Protohaustorius wigleyi											1					1	21							2
Trichophoxus epistomus											11						11							4
Unciola dissimilis																								
Upogebia affinis																								
Total	0	0	1	3	0	0	1	7	0	0	12	1	0	0	0	3	32	3	3	13	40	5	4	6

Table I (cont.)

Arthropods / Stations	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	December 1971																							
Acanthohaustorius millsi																								
Ampelisca abdita																								
Ampelisca verrilli				12																				
Batea catharinensis																								
Cancer irroratus																								
Chiridotea tuftsi							2														1			
Cirolana concharum																								
Cirolana polita		1																						
Corophium tuberculatum																								
Edotea triloba																								
Gammarus palustris																								
Hexapanopeus angustifrons			1							2														
Leucon americanus																								
Lysianopsis alba										13														
Neomysis americana										1														
Ovalipes ocellatus						1																		
Oxyurostylis smithi																								
Parahaustorius holmesi		4				7		1							5									
Parahaustorius longimerus								1																
Parapleustes sp.										1														
Pagurus longicarpus										1											1			
Pagurus pollicaris																		1						
Pinnixa sayana	2				2																			
Protohaustorius wigleyi						39	2	2																
Trichophoxus epistomus					2	6	2											1	3					
Unciola dissimilis										10				2					1					
Upogebia affinis			2							1														
Total	2	5	3	12	4	53	6	4	0	29	0	0	0	2	5	0	0	2	4	0	2	0	0	0

Table I (cont.)

Arthropods	December 1971																							
Stations	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Acanthohaustorius millsi																								
Ampelisca abdita						1	1																	
Ampelisca verrilli																								
Batea catharinensis				1																				
Cancer irroratus																1								
Chiridotea tuftsi			1																	2				
Cirolana concharum																								
Cirolana polita																								
Corophium tuberculatum																								
Edotea triloba																								
Gammarus palustris																								
Hexapanopeus angustifrons																								
Leucon americanus	1																							
Lysianopsis alba																								
Neomysis americana																								
Ovalipes ocellatus																								
Oxyurostylis smithi																								
Parahaustorius holmesi																								
Parahaustorius longimerus																								
Parapleustes sp.																								
Pagurus longicarpus																								
Pagurus pollicaris																								
Pinnixa sayana																				1				
Protohaustorius wigleyi																				2	5			
Trichophoxus epistomus																				3	5			
Unciola dissimilis																								
Upogebia affinis															1									
Total	1	0	1	1	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	8	10	0	0	0

Table I (cont.)

Arthropods	December 1971																							
Stations	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Acanthohaustorius millsi																								
Ampelisca abdita	1		5			2																1		
Ampelisca verrilli									1			1												4
Batea catharinensis																								
Cancer irroratus																								
Chiridotea tuftsi																								
Cirolana concharum				1																				
Cirolana polita																								
Corophium tuberculatum																								
Edotea triloba								1																
Gammarus palustris																					1			1
Hexapanopeus angustifrons																								
Leucon americanus																								
Lysianopsis alba																								
Neomysis americana																								
Ovalipes ocellatus																								
Oxyurostylis smithi																								
Parahaustorius holmesi																								
Parahaustorius longimerus																								
Parapleustes sp.																								
Pagurus longicarpus																								
Pagurus pollicaris																								
Pinnixa sayana												3												
Protohaustorius wigleyi																								
Trichophoxus epistomus																								
Unciola dissimilis																								
Upogebia affinis																								
Total	1	0	5	1	0	2	0	1	1	0	0	4	0	0	0	0	0	0	0	0	1	1	0	5

Table I (cont.)

Arthropods	December 1971							
Stations	97	98	99	100	101	102	103	Total/Occurrence
Acanthohaustorius millsi								2/ 1
Ampelisca abdita								13/ 7
Ampelisca verrilli	2							85/12
Batea catharinensis								1/ 1
Cancer irroratus								1/ 1
Chiridotea tuftsi						1		7/ 5
Cirolana concharum								1/ 1
Cirolana polita								2/ 2
Corophium tuberculatum								9/ 1
Edotea triloba								1/ 1
Gammarus palustris								2/ 2
Hexapanopeus angustifrons								3/ 2
Leucon americanus								1/ 1
Lysianopsis alba								13/ 1
Neomysis americana								1/ 1
Ovalipes ocellatus		1						2/ 2
Oxyurostylis smithi								1/ 1
Parahaustorius holmesi		2						19/ 6
Parahaustorius longimerus						1		2/ 2
Parapleustes sp.								1/ 1
Pagurus longicarpus								3/ 3
Pagurus pollicaris								1/ 1
Pinnixa sayana				2				13/ 7
Protohaustorius wigleyi		1				5		81/11
Trichophoxus epistomus		1		1		8		58/13
Unciola dissimilis								13/ 3
Upogebia affinis								4/ 3
Total	2	5	0	3	0	15	0	340/92

Table I (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

Miscellaneous — December 1971

Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Alcyonidium polyoum													x	x			x									
Amphioplus abditus																										
Arbacia punctulata																										
Asterias forbesi																										
Cerebratulus lacteus			1																1							
Conopeum tenuissimum									x			x	x	x	x		x					x				
Cryptosula pallasiana																										
Electra hastingsae									x					x	x											x
Hippoporina porosa																										
Membranipora tenuis									x			x	x	x	x											x
Micrura rubra																										
Schizoporella errata																										
Sertularia argentea																										
Stylochus ellipticus																										
Tubulanus pellucidus										1					1				1							
Zygeupolia rubens			1																					1		
Total/Station	0	0	2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	2	0	0	0	0	1	0	0

Miscellaneous — December 1971

Stations	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Alcyonidium polyoum								x		x		x												x		x
Amphioplus abditus										1																
Arbacia punctulata											x														x	
Asterias forbesi												1														
Cerebratulus lacteus																					1					
Conopeum tenuissimum				x				x	x			x	x		x	x	x		x		x				x	x
Cryptosula pallasiana								x																		
Electra hastingsae																										
Hippoporina porosa									x																	
Membranipora tenuis							x	x			x					x	x		x		x		x		x	x
Micrura rubra						1																				
Schizoporella errata								x																		
Sertularia argentea																										
Stylochus ellipticus										1																
Tubulanus pellucidus		1															2	1								
Zygeupolia rubens			5																				1			
Total/Station	0	1	5	0	0	1	0	0	0	2	0	1	0	0	0	0	2	1	0	0	1	0	1	0	0	0

x indicates occurrence of colonial organism (not included in totals).

Table I (cont.)

Miscellaneous — December 1971

Stations	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Alcyonidium polyoum																										
Amphioplus abditus																										
Arbacia punctulata																										
Asterias forbesi																										
Cerebratulus lacteus				1											1		6									
Conopeum tenuissimum											x	x														
Cryptosula pallasiana																										
Electra hastingsae												x														
Hippoporina porosa																										
Membranipora tenuis											x	x														
Micrura rubra																										
Schizoporella errata																										
Sertularia argentea																										
Stylochus ellipticus																										
Tubulanus pellucidus				1																						
Zygeupolia rubens																										
Total/Station	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	6	0	0	0	0	0	0	0	0	0

Miscellaneous — December 1971

Stations	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Alcyonidium polyoum																									
Amphioplus abditus																									
Arbacia punctulata																									
Asterias forbesi																									
Cerebratulus lacteus																									
Conopeum tenuissimum																							x		
Cryptosula pallasiana																									
Electra hastingsae																									
Hippoporina porosa																									
Membranipora tenuis																									
Micrura rubra																									
Schizoporella errata																									
Sertularia argentea									x	x															
Stylochus ellipticus																									
Tubulanus pellucidus																									
Zygeupolia rubens																									
Total/Station	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

x indicates occurrence of colonial organism (not included in totals).

Table I (cont.)

Miscellaneous	December 1971
	Total/Occurrence
Alcyonidium polyoum	/ 8
Amphioplus abditus	1/ 1
Arbacia punctulata	2/ 2
Asterias forbesi	1/ 1
Cerebratulus lacteus	11/ 6
Conopeum tenuissimum	/23
Cryptosula pallasiana	/ 1
Electra hastingsae	/ 6
Hippoporina porosa	1/ 1
Membranipora tenuis	/19
Micrura rubra	1/ 1
Schizoporella errata	/ 1
Sertularia argentea	/ 2
Stylochus ellipticus	1/ 1
Tubulanus pellucidus	8/ 7
Zygeupolia rubens	8/ 4
Total/Station	34/84

Table II

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

March 1972

Pelecypods Stations	1	2	3	5	7	11	12	16	18	19	21	24	26	27	31	33	35	36	37	38	39	40	42	43	45
Ensis directus										2															2
Gemma gemma					820																				
Mulinia lateralis										1														1	
Nucula proxima	1		1	12														3		3		1			
Pandora gouldiana																									
Petricola pholadiformis																			51	1					
Spisula solidissima								1																	
Tellina agilis	3	1	9		8	4	4		1	15	1	6	4	1	9	4	3	2				11	8	2	
Yoldia limatula		1																							
Gastropod																									
Crepidula plana					4																				
Total/Station	4	2	10	12	832	4	4	1	1	18	1	6	4	1	9	4	3	5	51	4	0	12	8	3	2

March 1972

Pelecypods Stations	46	47	49	51	52	53	54	55	57	58	59	60	61	62	63	64	65	66	67	68	69	70	72	74	76
Ensis directus	1			1																1					
Gemma gemma																									
Mulinia lateralis											1														
Nucula proxima					3			1			1			1	1		3	2	5				5		5
Pandora gouldiana																		1	3						
Petricola pholadiformis																									
Spisula solidissima																									
Tellina agilis				2	2									1				1	1	8	9			1	
Yoldia limatula		1																							
Gastropod																									
Crepidula plana																									
Total/Station	1	1	0	3	5	0	0	1	0	0	2	0	0	2	1	0	3	4	9	9	9	0	5	1	5

Table II (cont.)

Pelecypods Stations	March 1972 77	78	79	80	81	82	83	84	85	86	87	92	94	96	97	98	99	100	101	102	103	Total/Occurrence
Ensis directus																		1				8/ 6
Gemma gemma																						820/ 1
Mulinia lateralis				1															1			5/ 5
Nucula proxima		2			1									1				1				53/20
Pandora gouldiana																						4/ 2
Petricola pholadiformis																						52/ 2
Spisula solidissima																						1/ 1
Tellina agilis		1	1	2												2		10				137/32
Yoldia limatula																			2			4/ 3
Gastropod																						
Crepidula plana																						4/ 1
Total/Station	0	3	1	3	1	0	0	0	0	0	0	0	0	1	0	2	0	12	3	0	0	1088/73

Table II (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

March 1972

Polychaetes Stations	1	2	3	5	7	11	12	16	18	19	21	24	26	27	31	33	35	36	37	38	39	40	42	43
Ampharete acutifrons																				1				
Drilonereis filum											1													
Glycera americana																		1						
Glycera dibranchiata			1							1														1
Glycinde solitaria					1		1															1		
Heteromastus filiformis	1	1			1						1						1							
Lepidonotus sublevis					1																			
Nephtys picta							4		1			1			3									
Nereis succinea																	3		1	1				
Paraprionospio pinnata																								
Sabellaria vulgaris																	15							
Scoloplos fragilis			1		1																	1		
Total/Station	1	1	2	0	4	0	5	0	1	1	2	1	0	0	3	0	19	1	1	2	0	2	0	1
Arthropods																								
Ampelisca abdita																								
Ampelisca verrilli			2			1				13	2													
Ancinus depressus					1																			
Chiridotea tuftsi																							2	
Crangon septemspinosa											1				1									
Haustorius canadensis												6												
Leucon americanus					1																			
Neomysis americana								1						2							1			
Neopanope texana sayi					1																			
Oxyurostylis smithi																								
Parahaustorius attenuatus															1									
Parahaustorius holmesi															2									
Parahaustorius longimerus														1										
Photidae																								
Pinnixa sayana					1		1																	
Protohaustorius deichmannae								4																
Protohaustorius wigleyi								23	3	5					11									1
Trichophoxus epistomus					1		8	7	8	1		2			3								5	
Unciola serrata																	3			3	4			
Xanthidae																	21			1				
Total/Station	0	0	2	0	5	1	9	35	11	19	3	8	0	3	18	0	24	0	0	4	5	0	7	1

Table II (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

March 1972

Polychaetes Stations	45	46	47	49	51	52	53	54	55	57	58	59	60	61	62	63	64	65	66	67	68	69	70	72
Ampharete acutifrons																								
Drilonereis filum																								
Glycera americana																		1						
Glycera dibranchiata																								
Glycinde solitaria																								
Heteromastus filiformis	1		2																					
Lepidonotus sublevis																								
Nephtys picta																		1			1	1		
Nereis succinea																								
Paraprionospio pinnata																								
Sabellaria vulgaris																								
Scoloplos fragilis																								
Total/Station	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	0	0
Arthropods																								
Ampelisca abdita																								
Ampelisca verrilli																								
Ancinus depressus																								
Chiridotea tuftsi																								
Crangon septemspinosa																								
Haustorius canadensis																								
Leucon americanus																								
Neomysis americana																								
Neopanope texana sayi																								
Oxyurostylis smithi																								
Parahaustorius attenuatus																								
Parahaustorius holmesi																								
Parahaustorius longimerus																		1						
Photidae																								
Pinnixa sayana																				1				
Protohaustorius deichmannae																								
Protohaustorius wigleyi																								
Trichophoxus epistomus																								
Unciola serrata																								
Xanthidae																								
Total/Station	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0

Table II (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

March 1972

Polychaetes Stations	74	76	77	78	79	80	81	82	83	84	85	86	87	92	94	96	97	98	99	100	101	102	103
Ampharete acutifrons																							
Drilonereis filum																							
Glycera americana																	1						
Glycera dibranchiata											1												
Glycinde solitaria																							
Heteromastus filiformis														3	2	1						4	
Lepidonotus sublevis																							
Nephtys picta																							
Nereis succinea																							
Paraprionospio pinnata										1													
Sabellaria vulgaris																							
Scoloplos fragilis																							
Total/Station	0	0	0	0	0	0	0	0	0	1	1	0	0	3	2	1	1	0	0	0	0	4	0
Arthropods																							
Ampelisca abdita														1		1							
Ampelisca verrilli																							
Ancinus depressus																							
Chiridotea tuftsi																			1				
Crangon septemspinosa																							
Haustorius canadensis																							
Leucon americanus																							
Neomysis americana																			1				
Neopanope texana sayi																							
Oxyurostylis smithi																			1				
Parahaustorius attenuatus																			1				
Parahaustorius holmesi																		2	1				
Parahaustorius longimerus																		2					
Photidae																							1
Pinnixa sayana																							
Protohaustorius deichmannae																							
Protohaustorius wigleyi																		3					
Trichophoxus epistomus																				1			
Unciola serrata																							
Xanthidae																							
Total/Station	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	7	5	1	0	0	1

Table II (cont.)

Polychaetes	March 1972 Total/Occurrence
Ampharete acutifrons	1/ 1
Drilonereis filum	1/ 1
Glycera americana	3/ 3
Glycera dibranchiata	4/ 4
Glycinde solitaria	3/ 3
Heteromastus filiformis	18/11
Lepidonotus sublevis	1/ 1
Nephtys picta	12/ 7
Nereis succinea	5/ 3
Paraprionospio pinnata	1/ 1
Sabellaria vulgaris	15/ 1
Scoloplos fragilis	3/ 3
Total/Station	67/39
Arthropods	
Ampelisca abdita	2/ 2
Ampelisca verrilli	18/ 4
Ancinus depressus	1/ 1
Chiridotea tuftsi	3/ 2
Crangon septemspinosa	2/ 2
Haustorius canadensis	6/ 1
Leucon americanus	1/ 1
Neomysis americana	5/ 4
Neopanope texana sayi	1/ 1
Oxyurostylis smithi	1/ 1
Parahaustorius attenuatus	2/ 2
Parahaustorius holmesi	5/ 3
Parahaustorius longimerus	4/ 3
Photidae	1/ 1
Pinnixa sayana	3/ 3
Protohaustorius deichmannae	4/ 1
Protohaustorius wigleyi	46/ 6
Trichophoxus epistomus	36/ 9
Unciola serrata	10/ 3
Xanthidae	22/ 2
Total/Station	173/52

Table II (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

Miscellaneous	March 1972																								
Stations	1	2	3	5	7	11	12	16	18	19	21	24	26	27	31	33	35	36	37	38	39	40	42	43	45
Arbacia punctulata																									
Alcyonidium polyoum					x															x					
Alcyonidium verrilli					x												x								x
Cerebratulus lacteus																1									
Conopeum tenuissimum					x								x	x		x	x		x	x	x				
Cryptosula pallasiana														x											
Diadumene leucolena			x																						
Electra hastingsae													x	x		x									
Halichondria bowerbanki																									
Membranipora tenuis													x	x		x	x								
Micrura rubra																1									
Sertularia argentea																									
Tubulanus pellucidus										1															
Total/Station	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0

x indicates occurrence of colonial organism (not included in totals).

Table II (cont.)

March 1972

Miscellaneous Stations	46	47	49	51	52	53	54	55	57	58	59	60	61	62	63	64	65	66	67	68	69	70	72	74	76
Arbacia punctulata					1																				
Alcyonidium polyoum																									
Alcyonidium verrilli																									
Cerebratulus lacteus														1											
Conopeum tenuissimum		x		x	x															x					
Cryptosula pallasiana																									
Diadumene leucolena																									
Electra hastingsae					x																				
Halichondria bowerbanki																									
Membranipora tenuis																				x	x				
Micrura rubra																									
Sertularia argentea																									
Tubulanus pellucidus																									
Total/Station	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

March 1972

Miscellaneous Stations	77	78	79	80	81	82	83	84	85	86	87	92	94	96	97	98	99	100	101	102	103	Total Occurrence
Arbacia punctulata																						1/ 1
Alcyonidium polyoum																						/ 2
Alcyonidium verrilli																						/ 3
Cerebratulus lacteus															1							3/ 3
Conopeum tenuissimum																						/12
Cryptosula pallasiana																						/ 1
Diadumene leucolena																						/ 1
Electra hastingsae																						/ 5
Halichondria bowerbanki																				1		1/ 1
Membranipora tenuis																						/ 6
Micrura rubra																						1/ 1
Sertularia argentea											x											/ 1
Tubulanus pellucidus																						1/ 1
Total/Station	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	7/ 7

Table III

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

June 1972

Pelecypods / Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Anadara ovalis							1																		
Cardita borealis															153										
Ensis directus																									
Gemma gemma											6			2											
Mercenaria mercenaria																									
Mulinia lateralis				6	4	2	2	2	1					5				1			2	3	2	1	2
Mytilus edulis														3											
Nucula proxima	12		3	4	5	22	10	4	2	3	4									8	1		1		
Petricola pholadiformis																									
Spisula solidissima																									
Tellina agilis			3	4	1	1	3	1			11	1			2			4	4	1	8	1		12	
Yoldia limatula			2	2	2	1															2		2		
Gastropods																									
Mitrella lunata																									
Nassarius trivittatus							1															1			
Nassarius vibex																									
Polinices duplicatus													1												
Polinices immaculatus															2										
Urosalpinx cinerea																									
Total/Station	12	0	8	16	12	26	17	7	3	3	21	1	1	10	157	0	0	5	4	9	13	5	5	13	2

Table III (cont.)

Pelecypods	June 1972																								
Stations	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Anadara ovalis												1													
Cardita borealis		1																							
Ensis directus																			1					2	
Gemma gemma																									
Mercenaria mercenaria																									
Mulinia lateralis	1				8														1						
Mytilus edulis									1											1					
Nucula proxima	1	1	5	1			2		2		2		2							2	4		1		
Petricola pholadiformis													2												
Spisula solidissima						2												20							
Tellina agilis	6	8	2		1	15	8	4	1	2	2	1			11	43	3		37	1		1	2	12	
Yoldia limatula		2																							
Gastropods																									
Mitrella lunata												1													
Nassarius trivittatus															1										
Nassarius vibex																									4
Polinices duplicatus																									
Polinices immaculatus																									
Urosalpinx cinerea																									9
Total/Station	8	12	7	1	9	17	10	4	4	2	4	3	4	0	12	43	3	20	39	4	4	1	3	14	13

Table III (cont.)

Pelecypods	June 1972																								
Stations	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Anadara ovalis																									
Cardita borealis																									
Ensis directus									1										1						
Gemma gemma																									
Mercenaria mercenaria								1																	
Mulinia lateralis		1	1	1	4	1			2	5							1				1	1		3	1
Mytilus edulis										1			1												
Nucula proxima		2	1					2	3	2	27	12		22	30	6				1	4	2	7	8	6
Petricola pholadiformis																									
Spisula solidissima																									
Tellina agilis				1			3	1	2	1					1	2	2	1	1					1	
Yoldia limatula																									
Gastropods																									
Mitrella lunata																									
Nassarius trivittatus			1				1																		
Nassarius vibex																									
Polinices duplicatus																									
Polinices immaculatus																									
Urosalpinx cinerea																									
Total/Station	0	3	3	2	4	1	4	4	8	9	27	12	1	22	31	8	3	1	2	1	5	3	7	12	7

Table III (cont.)

Pelecypods / Stations	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
	June 1972																								
Anadara ovalis																									
Cardita borealis																									
Ensis directus																									
Gemma gemma																									
Mercenaria mercenaria																									
Mulinia lateralis	4	1	1		2		1	2	1								1		1		2				1
Mytilus edulis																									
Nucula proxima	51					4	13	7	2										2	1	15	12		1	
Petricola pholadiformis																									
Spisula solidissima																									
Tellina agilis	2						1		1							1		1					8	6	3
Yoldia limatula								2	5																
Gastropods																									
Mitrella lunata																									
Nassarius trivittatus										1												1			
Nassarius vibex																									
Polinices duplicatus																									
Polinices immaculatus																									
Urosalpinx cinerea																									
Total/Station	57	1	1	0	2	4	15	11	9	1	0	0	0	0	0	1	1	1	3	1	17	13	8	7	4

Table III (cont.)

Pelecypods	June 1972			
Stations	101	102	103	Total/Occurrence
Anadara ovalis				2/ 2
Cardita borealis				154/ 2
Ensis directus				5/ 4
Gemma gemma				8/ 2
Mercenaria mercenaria				1/ 1
Mulinia lateralis				82/ 39
Mytilus edulis				7/ 5
Nucula proxima	5	1		351/ 52
Petricola pholadiformis				2/ 1
Spisula solidissima				22/ 2
Tellina agilis	5	11		272/ 55
Yoldia limatula	1	2		23/ 11
Gastropods				
Mitrella lunata				1/ 1
Nassarius trivittatus	1			8/ 8
Nassarius vibex				4/ 1
Polinices duplicatus				1/ 1
Polinices immaculatus				2/ 1
Urosalpinx cinerea				9/ 1
Total/Station	12	14	0	954/189

Table III (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

June 1972

Polychaetes Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Asabellides oculata																								
Diopatra cuprea																								
Drilonereis filum			1																					
Glycera americana																				1				
Glycera dibranchiata														1				1						
Glycinde solitaria																								
Heteromastus filiformis										1														
Hydroides dianthus						4																		
Hypaniola grayi																								
Lepidonotus sublevis																								
Nephtys picta														1		1				1				
Nereis succinea																								
Scolecolepides viridis														1					1					
Scoloplos fragilis													2											
Sthenelais limicola															1									
Total/Station	0	0	1	0	0	4	0	0	0	1	0	0	2	3	1	1	0	1	1	2	0	0	0	0
Arthropods																								
Acanthaustorius intermedius																	2							
Ampelisca verrilli								1										1	8					
Crangon septemspinosa								1										1	1					
Edotea triloba					1																			
Gammarus palustris																						1		
Libinia emarginata																								
Neomysis americana						1		2																
Oxyurostylis smithi																		1						
Pagurus longicarpus																								
Parahaustorius holmesi													1											
Pinnixa sayana																								
Protohaustorius deichmannae																5								
Protohaustorius wigleyi																22								
Trichophoxus epistomus											1		3											
Unciola dissimilis																								
Total/Station	0	0	0	0	1	1	0	4	0	0	1	0	4	0	0	27	2	3	9	0	0	1	0	0

Table III (cont.)

Polychaetes	June 1972																							
Stations	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Asabellides oculata									2															
Diopatra cuprea								1																
Drilonereis filum					1																			
Glycera americana																	1							
Glycera dibranchiata									1										1					
Glycinde solitaria		1																						
Heteromastus filiformis																								
Hydroides dianthus																								
Hypaniola grayi								2									2		4					
Lepidonotus sublevis														3										
Nephtys picta	1		1				1	2																
Nereis succinea											2			2					2					
Scolecolepides viridis									1										2					
Scoloplos fragilis																								
Sthenelais limicola																								
Total/Station	1	1	1	0	1	0	1	5	4	0	2	0	0	5	0	0	3	0	9	0	0	0	0	0
Arthropods																								
Acanthaustorius intermedius																								
Ampelisca verrilli																								
Crangon septemspinosa																								
Edotea triloba																								
Gammarus palustris																								
Libinia emarginata												1												
Neomysis americana						1																		
Oxyurostylis smithi																								
Pagurus longicarpus												1												
Parahaustorius holmesi																								
Pinnixa sayana																								
Protohaustorius deichmannae																								
Protohaustorius wigleyi						11	4													1				
Trichophoxus epistomus						9	7													2				
Unciola dissimilis			1																					
Total/Station	0	0	1	0	1	21	11	0	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0	0

Table III (cont.)

Polychaetes	June 1972																							
Stations	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Asabellides oculata																					1			
Diopatra cuprea																								
Drilonereis filum																								
Glycera americana																								
Glycera dibranchiata	1			1					1															
Glycinde solitaria																								
Heteromastus filiformis																								
Hydroides dianthus																								
Hypaniola grayi		1						1																
Lepidonotus sublevis																								
Nephtys picta									1															
Nereis succinea																				1				
Scolecolepides viridis																								
Scoloplos fragilis																								
Sthenelais limicola																								
Total/Station	1	1	0	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Arthropods																								
Acanthaustorius intermedius																								
Ampelisca verrilli																								
Crangon septemspinosa																								
Edotea triloba																								
Gammarus palustris																								
Libinia emarginata																								
Neomysis americana																								
Oxyurostylis smithi																								
Pagurus longicarpus									1															
Parahaustorius holmesi																								
Pinnixa sayana																								
Protohaustorius deichmannae																								
Protohaustorius wigleyi																								
Trichophoxus epistomus	1																							
Unciola dissimilis																								
Total/Station	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table III (cont.)

Polychaetes	June 1972																							
Stations	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Asabellides oculata																								
Diopatra cuprea																								
Driloncreis filum																								
Glycera americana								1														1		
Glycera dibranchiata																								
Glycinde solitaria																								
Heteromastus filiformis				1	3					1										3	5	3	4	
Hydroides dianthus																								
Hypaniola grayi																								
Lepidonotus sublevis																								
Nephtys picta																								
Nereis succinea																								
Scolecolepides viridis																								
Scoloplos fragilis																								
Sthenelais limicola																								
Total/Station	0	0	0	1	3	0	0	1	0	1	0	0	0	0	0	0	0	0	0	3	5	4	4	0
Arthropods																								
Acanthaustorius intermedius																								
Ampelisca verrilli																								
Crangon septemspinosa														1										
Edotea triloba																								
Gammarus palustris																								
Libinia emarginata																								
Neomysis americana																								
Oxyurostylis smithi																								
Pagurus longicarpus																					1			
Parahaustorius holmesi																								
Pinnixa sayana																								
Protohaustorius deichmannae																								
Protohaustorius wigleyi																								
Trichophoxus epistomus																								
Unciola dissimilis																								
Total/Station	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0

Table III (cont.)

Polychaetes	June 1972							
Stations	97	98	99	100	101	102	103	Total/Occurrence
Asabellides oculata								3/ 2
Diopatra cuprea								1/ 1
Drilonereis filum								2/ 2
Glycera americana								4/ 4
Glycera dibranchiata								7/ 7
Glycinde solitaria		1	1					3/ 3
Heteromastus filiformis					1			22/ 9
Hydroides dianthus								4/ 1
Hypaniola grayi								10/ 5
Lepidonotus sublevis								3/ 1
Nephtys picta								9/ 8
Nereis succinea			3	2				12/ 6
Scolecolepides viridis								5/ 4
Scoloplos fragilis								2/ 1
Sthenelais limicola								1/ 1
Total/Station	0	1	4	2	1	0	0	88/55
Arthropods								
Acanthaustorius intermedius								2/ 1
Ampelisca verrilli								10/ 3
Crangon septemspinosa								4/ 4
Edotea triloba								1/ 1
Gammarus palustris								1/ 1
Libinia emarginata								1/ 1
Neomysis americana								4/ 3
Oxyurostylis smithi								1/ 1
Pagurus longicarpus								2/ 2
Parahaustorius holmesi								1/ 1
Pinnixa sayana								1/ 1
Protohaustorius deichmannae								5/ 1
Protohaustorius wigleyi								38/ 4
Trichophoxus epistomus		1						24/ 7
Unciola dissimilis								1/ 1
Total/Station	0	1	0	0	0	0	0	96 /32

Table III (cont.)

Faunal lists from the 103 sampling stations from Delaware Bay's Lewes breakwater spoil disposal area. Numbers of species and individuals per 0.1 m^2.

Miscellaneous — June 1972

Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Aeverillia setigera																										
Alcyonidium polyoum											x	x		x				x								
Cerebratulus lacteus																										
Conopeum tenuissimum											x	x	x	x	x										x	x
Diadumene leucolena															x											
Electra hastingsae											x															
Membranipora tenuis											x	x		x								x				x
Schizoporella biaperta																										
Schizoporella errata																										
Sertularia argentea																					x					
Total/Station	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

x indicates occurrence of colonial organism (not included in totals).

Miscellaneous — June 1972

Stations	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Aeverillia setigera																									x	
Alcyonidium polyoum	x							x		x		x														
Cerebratulus lacteus							1																			
Conopeum tenuissimum	x	x						x			x	x		x	x	x					x	x				
Diadumene leucolena																										
Electra hastingsae	x																									
Membranipora tenuis	x	x		x		x		x				x			x							x				
Schizoporella biaperta																										
Schizoporella errata	x																									
Sertularia argentea																										
Total/Station	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table III (cont.)

Miscellaneous — June 1972

Stations	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Aeverillia setigera																										
Alcyonidium polyoum																										
Cerebratulus lacteus																										
Conopeum tenuissimum			x																							
Diadumene leucolena																										
Electra hastingsae																										
Membranipora tenuis		x										x														
Schizoporella biaperta		x																								
Schizoporella errata																									x	
Sertularia argentea																										
Total/Station	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Miscellaneous — June 1972

Stations	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Aeverillia setigera																			x						
Alcyonidium polyoum																									
Cerebratulus lacteus																									
Conopeum tenuissimum																			x				x		
Diadumene leucolena																									
Electra hastingsae																						x			
Membranipora tenuis																									
Schizoporella biaperta																									
Schizoporella errata																			x						
Sertularia argentea																									
Total/Station	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Miscellaneous — June 1972

	Total/Occurrence
Aeverillia setigera	/ 2
Alcyonidium polyoum	/ 8
Cerebratulus lacteus	1/ 1
Conopeum tenuissimum	/20
Diadumene leucolena	/ 2
Electra hastingsae	/ 2
Membranipora tenuis	/ 5
Schizoporella biaperta	/ 2
Schizoporella errata	/ 3
Sertularia argentea	/ 1
Total/Station	1/ 1

Table IV

T-test of average number of individuals per area

Months	t-Value	Level of Significance
	Area A	
Dec. - March	.337	--
March - June	1.078	0.3
Dec. - June	.206	--
	Area B	
Dec. - March	1.727	0.2
March - June	1.786	0.1
Dec. - June	.775	--
	Area C	
Dec. - March	1.873	0.1
March - June	2.394	0.05
Dec. - June	1.211	0.3
	Area D	
Dec. - March	.950	0.4
March - June	.140	--
Dec. - June	.823	0.5
	Area E	
Dec. - March	2.775	0.05
March - June	2.339	0.05
Dec. - June	.064	--

Table V

Mann-Whitney Tests by Areas for
T. agilis and *N. proxima*
at .05 Confidence Level

Sampling Period	Dec. vs. Mar.	Mar. vs. June	Dec. vs. June
Area A			
Tellina agilis	1=2	2=3	1> 3
Nucula proxima	1=2	2< 3	1< 3
Area B			
Tellina agilis	1=2	2=3	1=3
Nucula proxima	1=2	2=3	1=3
Area C			
Tellina agilis	1> 2	2=3	1=3
Nucula proxima	1> 2	2< 3	1=3
Area D			
Tellina agilis	1=2	2=3	1=3
Nucula proxima	1=2	2=3	1=3
Area E			
Tellina agilis	1=2	2=3	1> 3
Nucula proxima	1> 2	2< 3	1=3

Table VI

Biomass Data by Areas for the Three Sampling Periods

Area A

Stations 1-32

Species	December 1971			March 1972			June 1972		
	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight
Glycera dibranchiata	2	1.149	.260	2	1.604	.144	-	0	0
Glycera americana	1	.009	.007	-	0	0	2	.060	.020
Heteromastus filiformis	-	0	0	4	.140	.022	-	0	0
Ampelisca verrilli	39	.435	.042	16	.170	.080	8	.140	.060
Trichophoxus epistomus	-	0	0	15	.040	.015	12	.050	.015
Parahaustorius holmesi	4	.057	.008	-	0	0	2	.020	.010
Protohaustorius wigleyi	-	0	0	34	.075	.025	31	.105	.025
Nucula proxima	13	.068	.013	3	.08	.02	22	.155	.035
Tellina agilis	67	.489	.169	43	.199	.055	52	.780	.119
TOTAL	126	2.207	.449	117	2.308	.361	129	1.310	.284

Table VI (cont.)

Area B

Stations 33-39

Species	December 1971			March 1972			June 1972		
	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight
Glycera dibranchiata	1	.663	.150	-	0	0	1	.02	.005
Glycera americana	-	0	0	1	.25	.05			
Heteromastus filiformis	-	0	0	1	.01	.004			
Ampelisca verrilli	-	0	0	-	0	0	-	0	0
Trichophoxus epistomus	-	0	0	-	0	0	-	0	0
Parahaustorius holmesi	5	.035	.005	-	0	0	-	0	0
Protohaustorius wigleyi	-	0	0	-	0	0	-	0	0
Nucula proxima	-	0	0	6	.21	.025	-	0	0
Tellina agilis	-	0	0	-	0	0	-	0	0
TOTAL	6	.698	.155	8	.47	.079	1	.02	.005

Table VI (cont.)

Area C

Stations 40-64

Species	December 1971			March 1972			June 1972		
	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight
Glycera dibranchiata	2	1.52	.190	1	.035	.007	3	.130	.040
Glycera americana	0	--	--	0	--	--	--	0	0
Heteromastus filiformis	0	--	--						
Ampelisca verrilli	0	--	--	0	--	--	0	--	--
Trichophoxus epistomus	0	--	--	5	.035	.010	0	--	--
Parahaustorius nolmesi	0	--	--	0	--	--	0	--	--
Protohaustorius wigleyi	0	--	--	0	--	--	0	--	--
Nucula proxima	252	2.307	.090	0	--	--	38	.123	.021
Tellina agilis	97	.606	.097	18	.190	.019	27	.310	.050
TOTAL	351	4.433	.377	24	.260	.036	68	.563	.111

Table VI (cont.)

Area D

Stations 65-69 and 98-103

Species	December 1971			March 1972			June 1972		
	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight
Glycera dibranchiata	2	.418	.065	--	0	0	--	0	0
Glycera americana	0	--	--	--	0	0	--	0	0
Heteromastus filiformis	0	--	--	--	0	0	--	0	0
Ampelisca verrilli	0	--	--	--	0	0	--	0	0
Trichophoxus epistomus	13	.042	.007	--	0	0	--	0	0
Parahaustorius holmesi	0	--	--	--	0	0	--	0	0
Protohaustorius wigleyi	10	.040	.006	--	0	0	--	0	0
Nucula proxima	10	.033	.004	--	0	0	54	.195	.085
Tellina agilis	106	.467	.062	--	0	0	19	.110	.026
TOTAL	141	1.000	.144	0	0	0	73	.305	.111

Table VI (cont.)

Area E

Stations 70-97

Species	December 1971			March 1972			June 1972		
	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight	# Ind.	Wet Wgt.	Ash Free Dryweight
Glycera dibranchiata	--	0	0	--	0	0	--	0	0
Glycera americana	--	0	0	--	0	0	2	.27	.033
Heteromastus filiformis	28	.206	.079	--	0	0	10	.190	.15
Ampelisca verrilli	--	0	0	--	0	0	--	0	0
Trichophoxus epistomus	--	0	0	--	0	0	--	0	0
Parahaustorius holmesi	--	0	0	--	0	0	--	0	0
Protohaustorius wigleyi	--	0	0	--	0	0	--	0	0
Nucula proxima	32	.360	.055	--	0	0	124	.548	.148
Tellina agilis	--	0	0	--	0	0	--	0	0
TOTAL	60	.566	.134	--	0	0	136	.765	.196

Table VII

Percent Difference of Dry Weight (Biomass) among each of the Sampling Periods

Area	Station	December-March	December-June	March-June
		1st-2nd	1st-2nd	2nd-3rd
		Dry Wgt. %	Dry Wgt. %	Dry Wgt. %
A.	1-32	19.5 1 > 2	36.7 1 > 3	21.3 2 > 3
B.	33-39	49.0 1 > 2	96.7 1 > 3	93.6 2 > 3
C.	40-64	90.4 1 > 2	70.5 1 > 3	67.5 3 > 2
D.	65-69 98-103	--	22.9 1 > 3	--
E.	70-97	--	31.6 3 > 1	--

Table VIII

Percent Difference in Biomass Determinations of Dry Weights for each Area and for each Key Species

Area A
(1-32)

Species	December-March Dry Wgt.	December-June Dry Wgt.	March-June Dry Wgt.
G. dibranchiata	44.6% 1 < 2	--	--
G. americana	--	65.0% 3 > 1	--
A. verrilli	47.5% 2 < 1	30.0% 3 < 1	25.0% 2 3
T. epistomus	--	--	00.00% 3 = 2
P. holmesi	--	20.0% 3 < 1	--
P. wigleyi	--	--	00.00% 3 = 2
N. proxima	84.6% 1 > 2	62.8% 3 > 1	94.2% 3 > 2
T. agilis	67.4% 1 > 2	29.5% 1 < 3	53.7% 3 > 2

Area B
(33-39)

Species	December-March Dry Wgt.	December-June Dry Wgt.	March-June Dry Wgt.
G. dibranchiata	--	96.6% 1 > 3	--

Table VIII (cont.)

Area C
(40-64)

G. dibranchiata	96.3% 1 > 2	78.9% 1 > 3	82.5% 3 > 2
N. proxima	--	76.6% 1 > 3	--
T. agilis	80.4% 1 > 2	48.4% 1 > 3	62.0% 3 > 2

Area D
(65-69) (98-103)

Species	December-March Dry Wgt.	December-June Dry Wgt.	March-June Dry Wgt.
N. proxima	--	95.2% 3 > 1	--
T. agilis	--	58.0% 3 > 1	--

Area E
(70-97)

H. filiformis	--	81.0% 1 > 3	--
N. proxima	--	62.8% 3 > 1	--

BIOLOGICAL CONTOUR MAPS

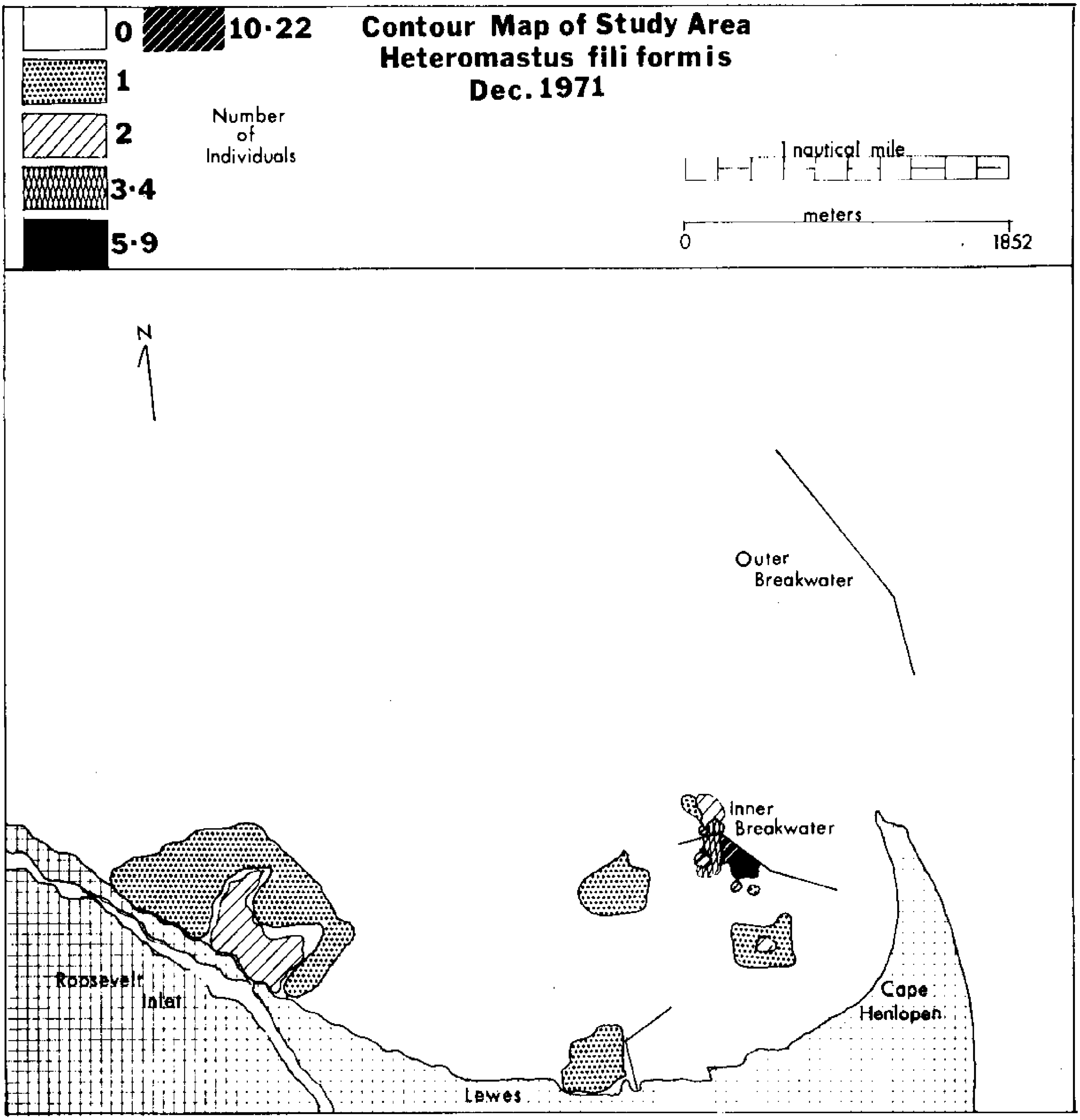
0
10·22
1
2
3·4
5·9
Number of Individuals
Contour Map of Study Area
Heteromastus fili formis
Dec. 1971
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
Roosevelt Inlet
Lewes
Cape Henlopen

Figure 1

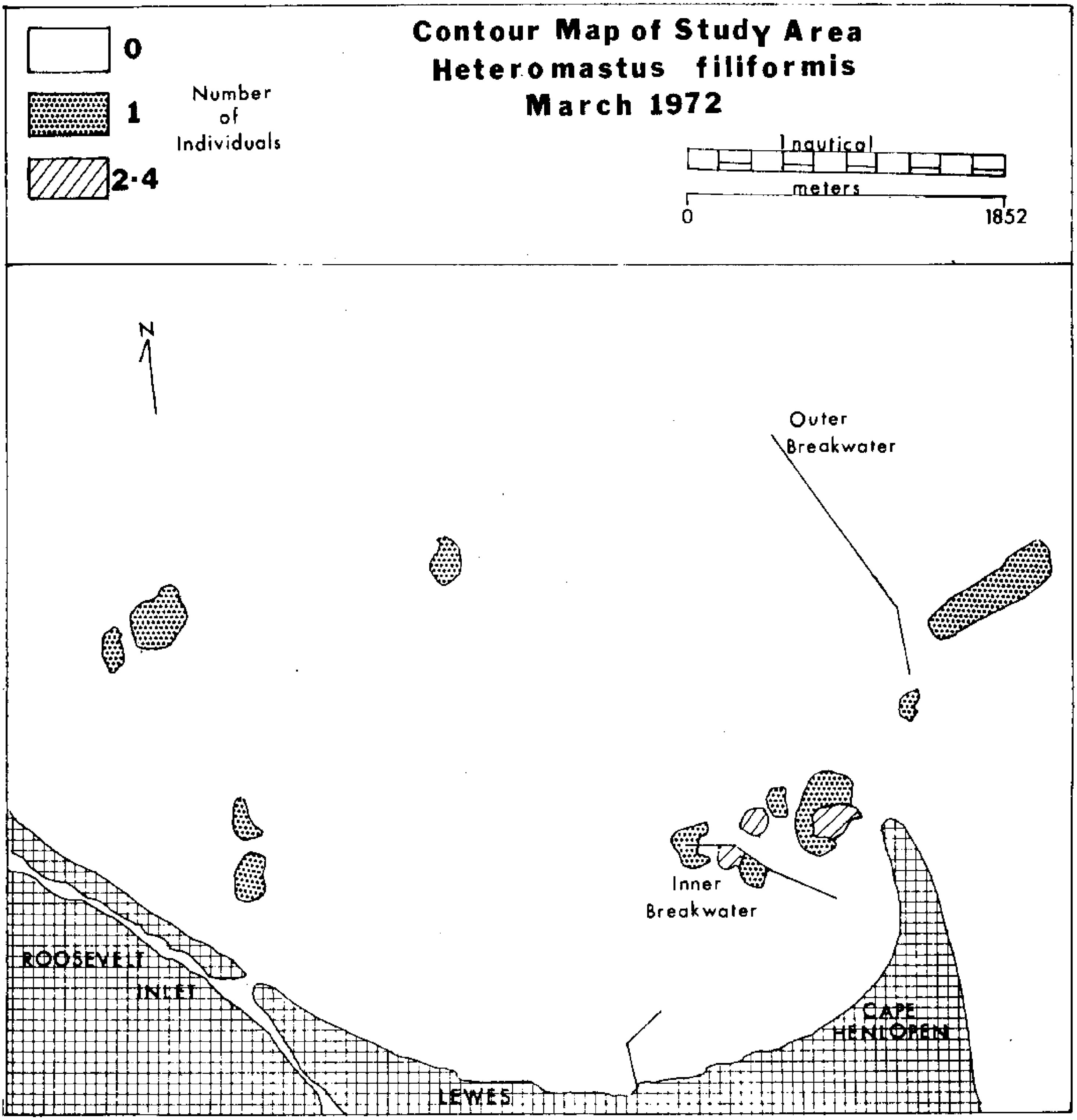
Contour Map of Study Area
Heteromastus filiformis
March 1972
0
1
2-4
Number of Individuals
1 nautical
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
LEWES
CAPE HENLOPEN

Figure 2

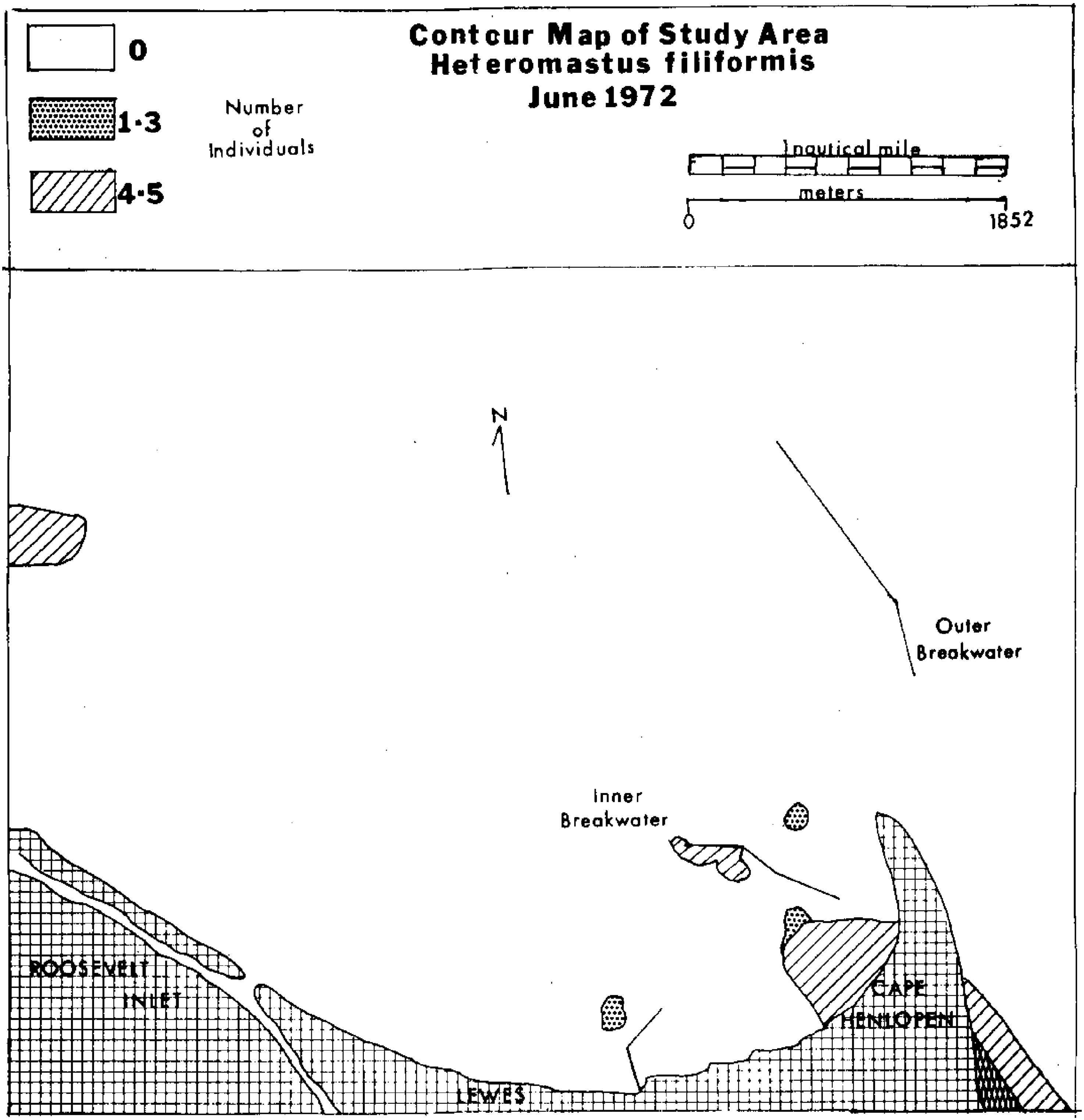
Contour Map of Study Area
Heteromastus filiformis
June 1972
0
1-3
4-5
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
LEWES
CAPE HENLOPEN

Figure 3

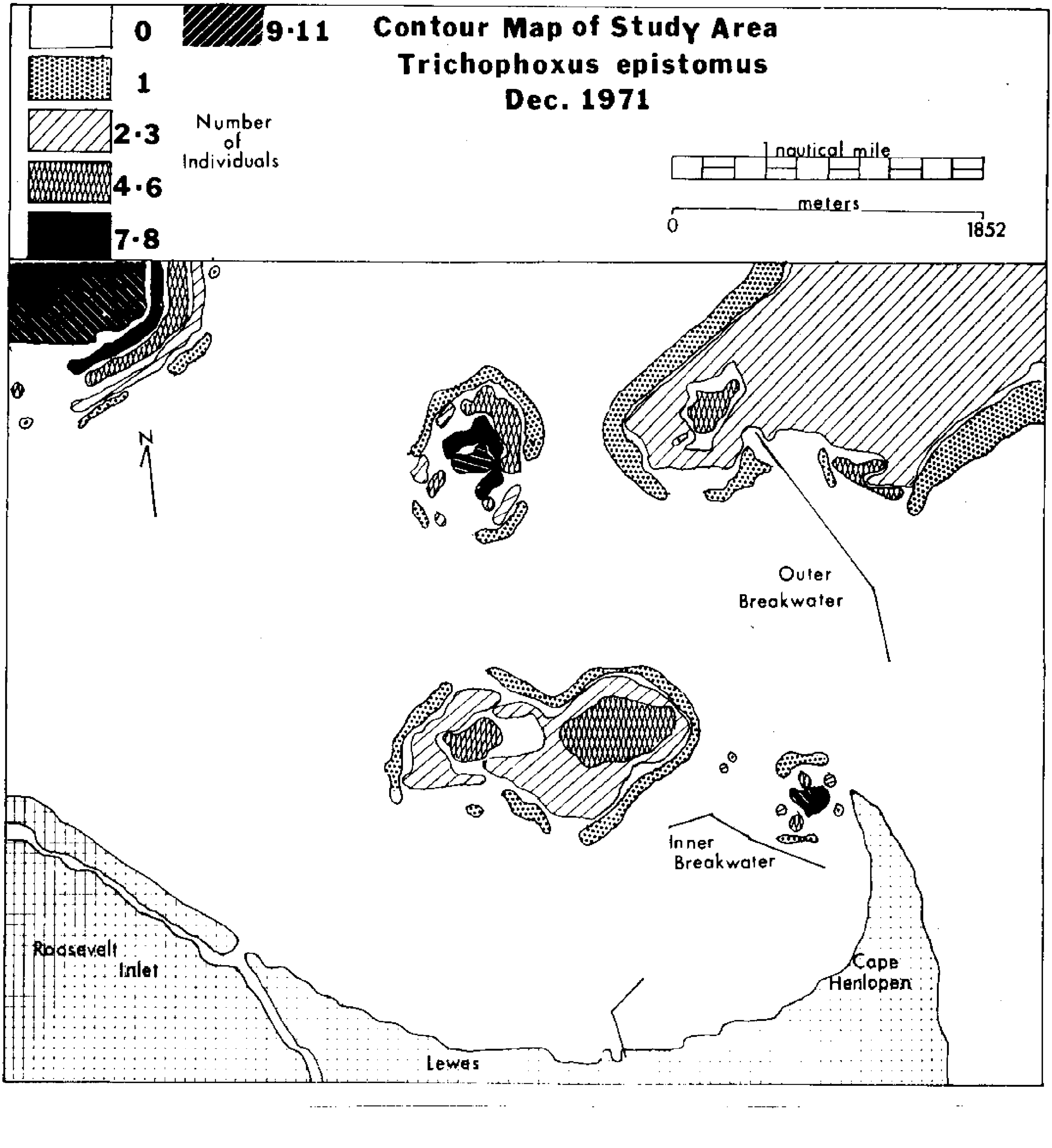
0
1
2·3
4·6
7·8
9·11
Number of Individuals
Contour Map of Study Area
Trichophoxus epistomus
Dec. 1971
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
Roosevelt Inlet
Cape Henlopen
Lewes

Figure 4

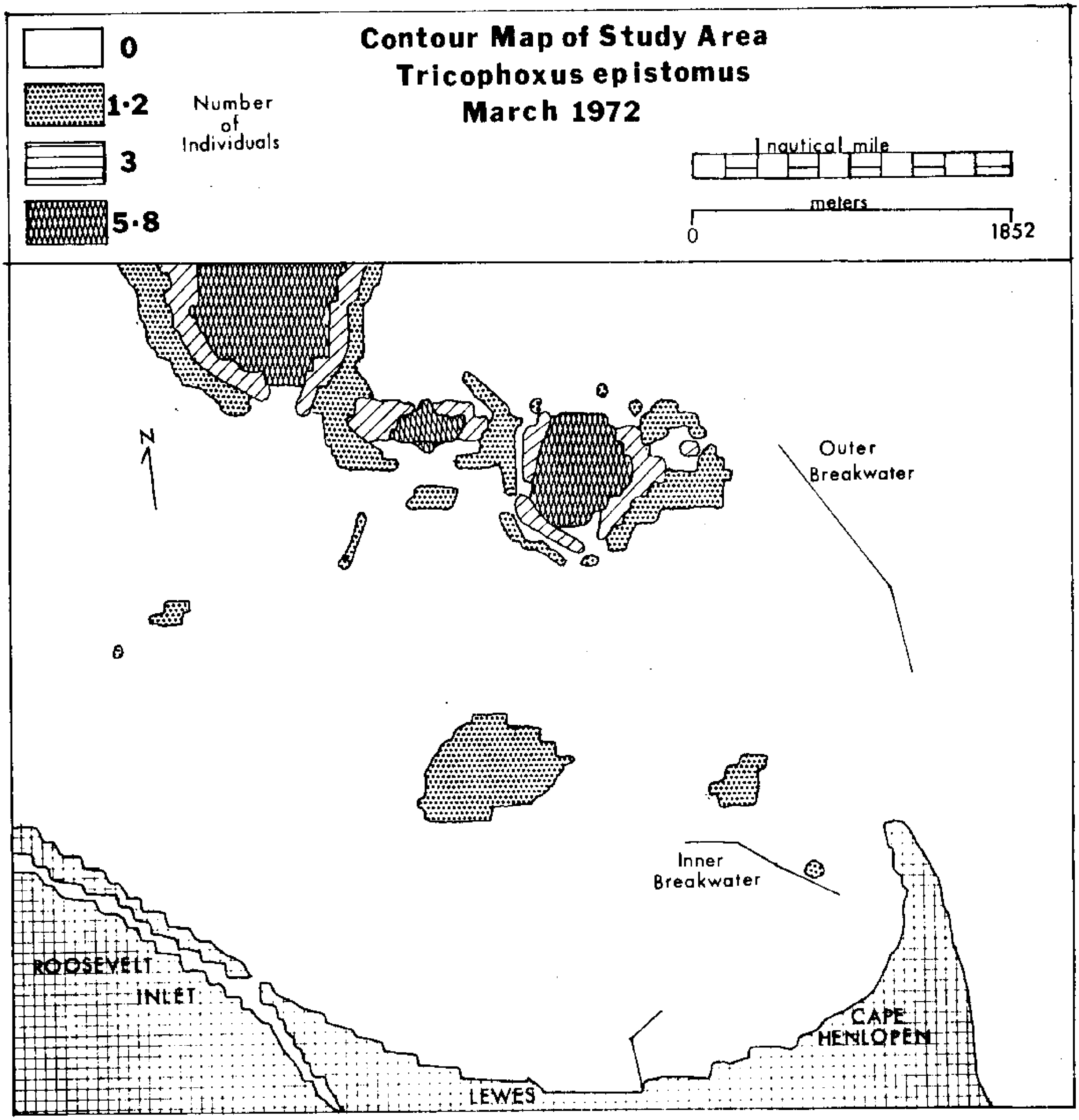
Contour Map of Study Area
Tricophoxus epistomus
March 1972
0
1·2
3
5·8
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
LEWES
CAPE HENLOPEN

Figure 5

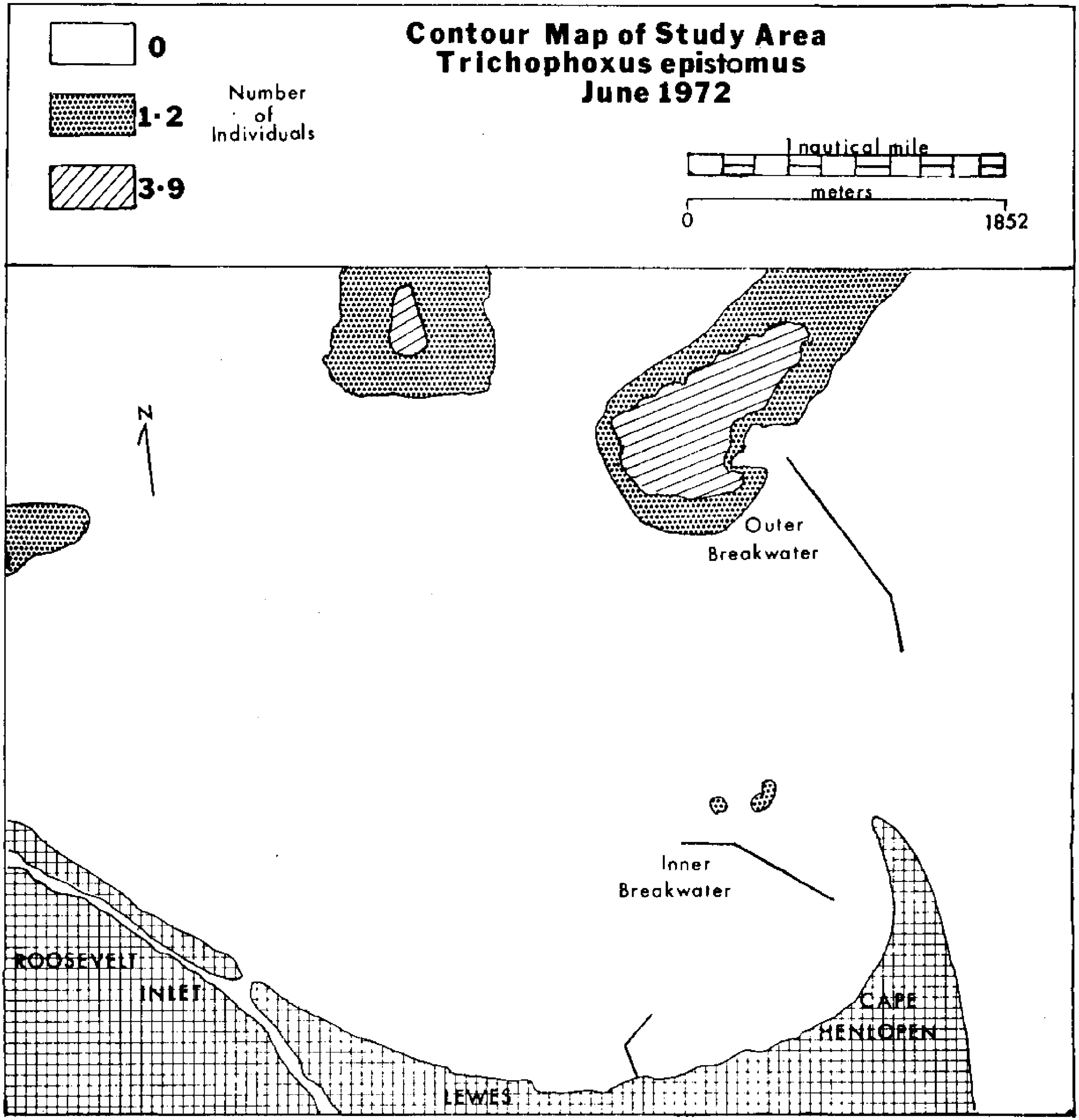
Contour Map of Study Area
Trichophoxus epistomus
June 1972
0
1-2
3-9
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
LEWES
CAPE HENLOPEN

Figure 6

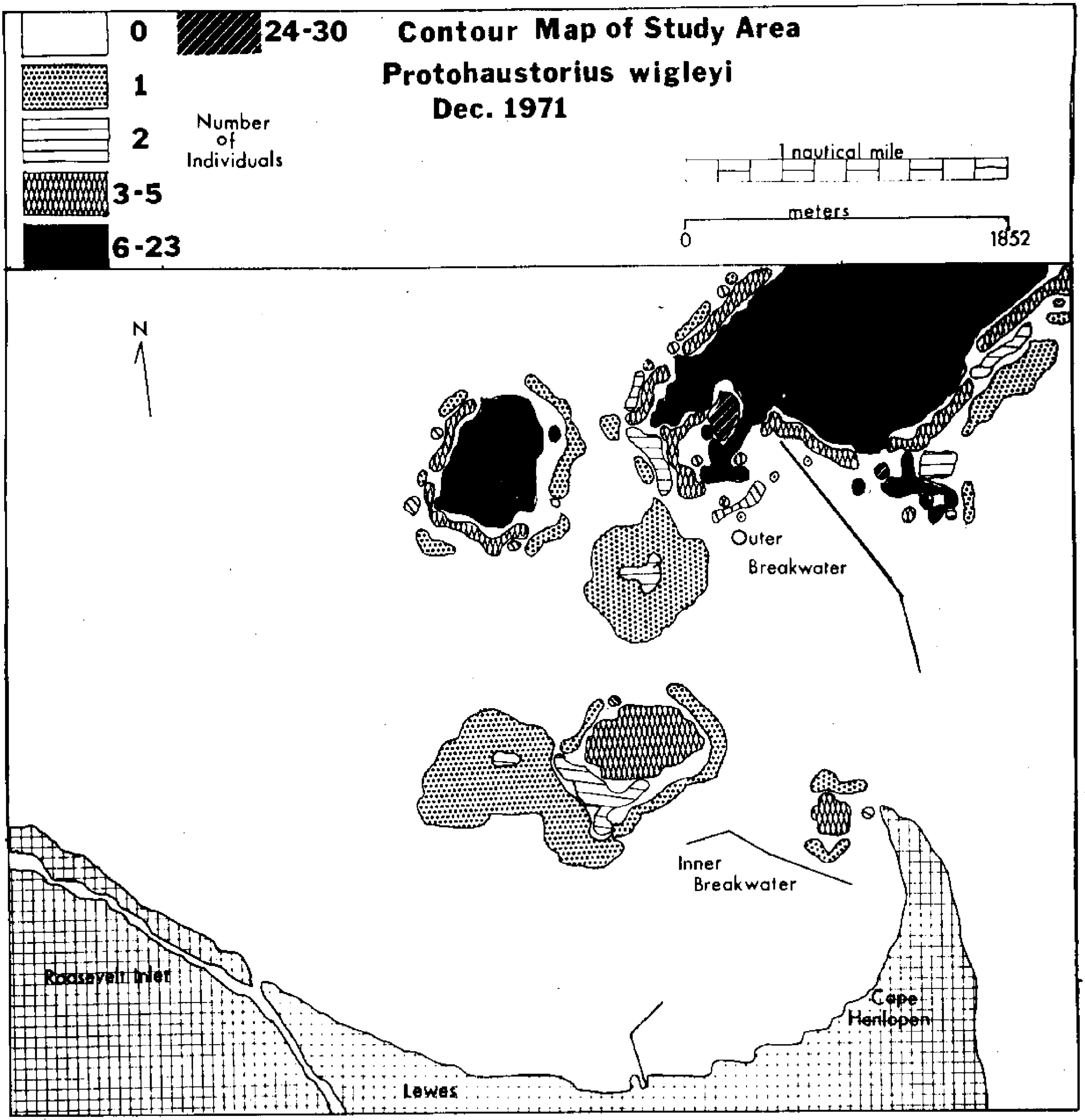
0
24-30
Contour Map of Study Area
Protohaustorius wigleyi
Dec. 1971
1
2
Number of Individuals
3-5
6-23
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
Roosevelt Inlet
Cape Henlopen
Lewes

Figure 7

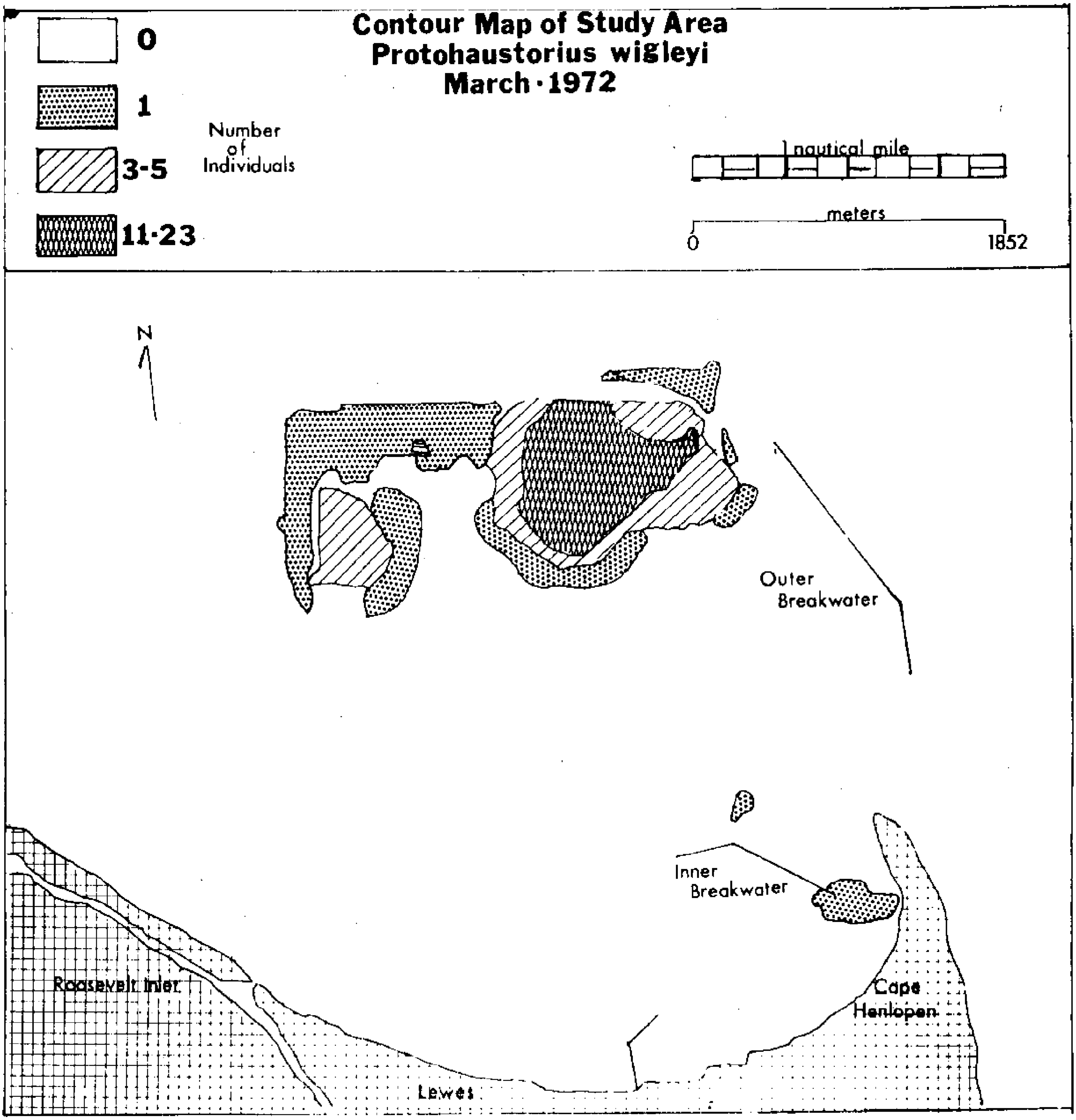
Contour Map of Study Area
Protohaustorius wigleyi
March · 1972
0
1
3-5
11-23
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
Roosevelt Inlet
Lewes
Cape Henlopen

Figure 8

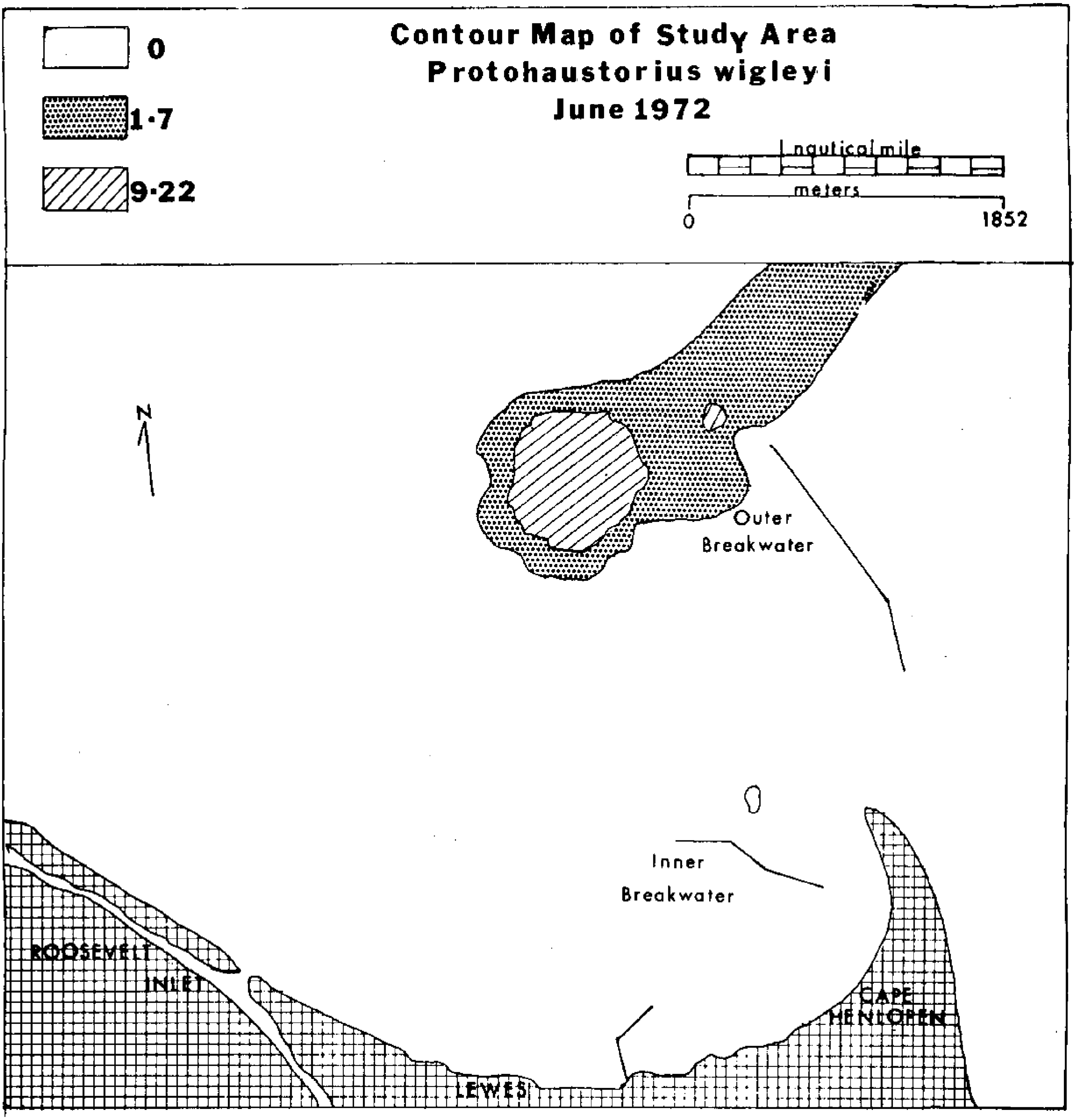
Contour Map of Study Area
Protohaustorius wigleyi
June 1972
0
1·7
9·22
1 nautical mile
meters
0
1852
N
Outer
Breakwater
Inner
Breakwater
ROOSEVELT
INLET
LEWES
CAPE
HENLOPEN

Figure 9

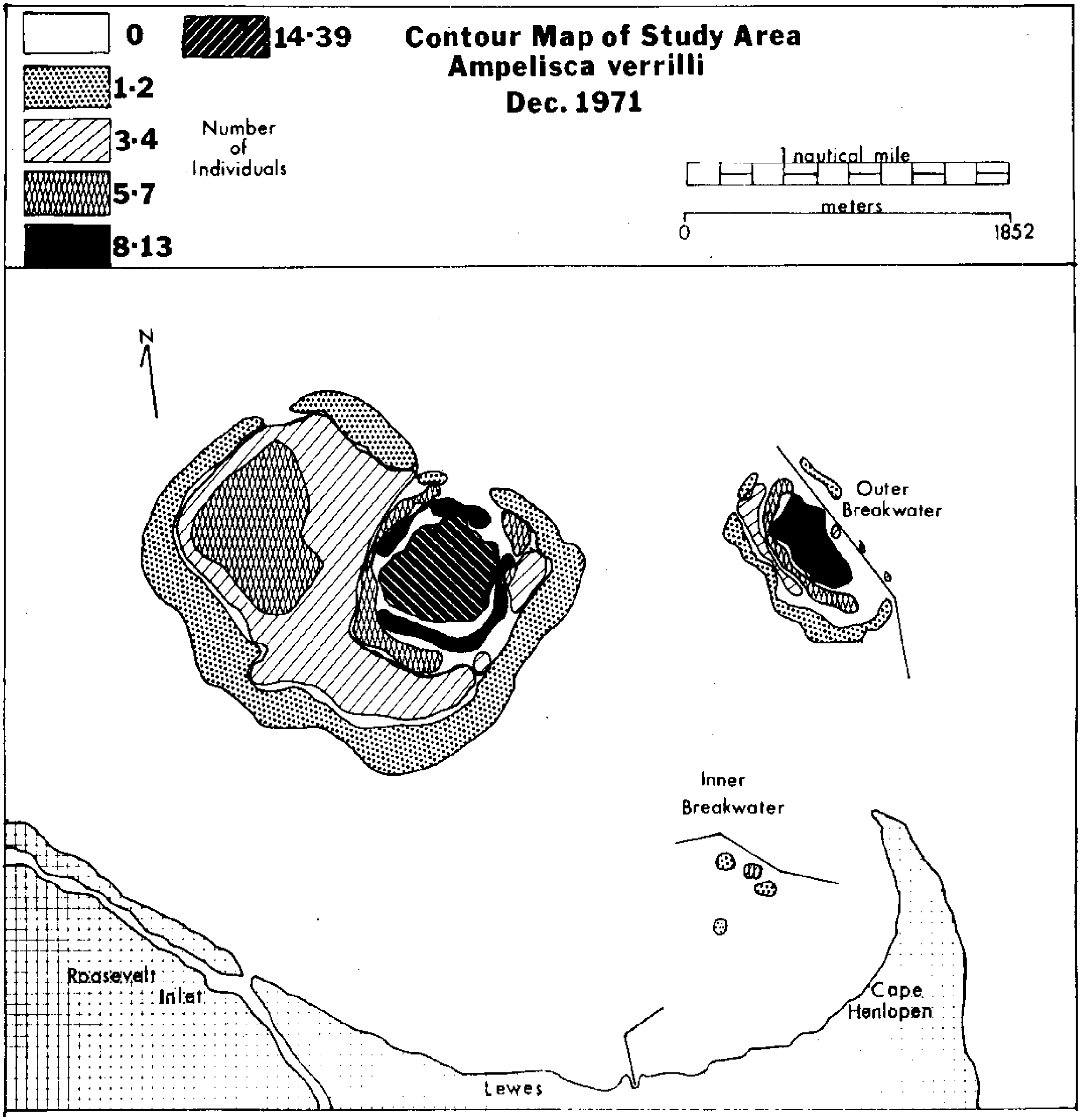
0
14·39
1·2
3·4
5·7
8·13
Number of Individuals
Contour Map of Study Area
Ampelisca verrilli
Dec. 1971
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
Roosevelt Inlet
Cape Henlopen
Lewes

Figure 10

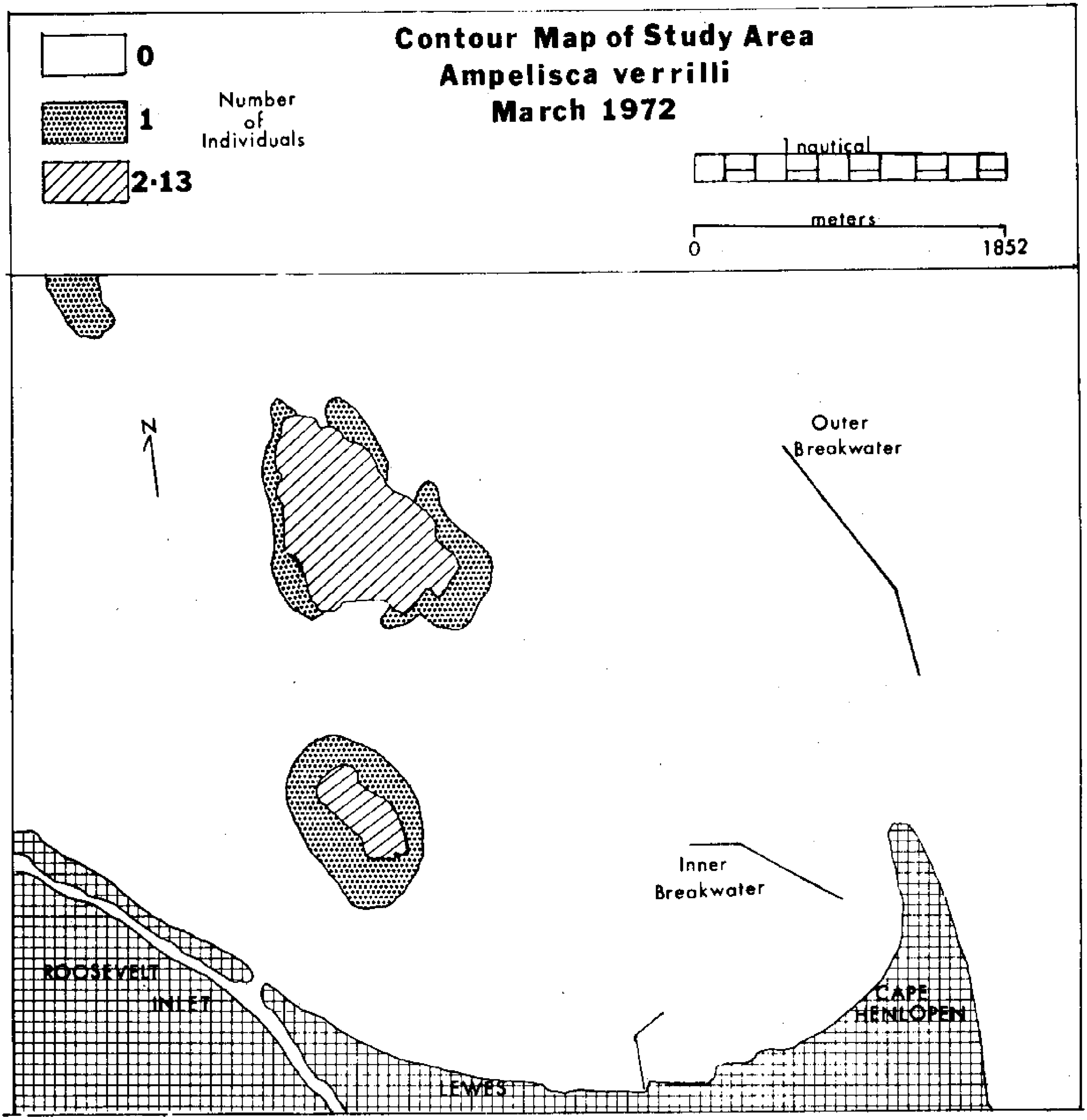
Contour Map of Study Area
Ampelisca verrilli
March 1972
0
1
2-13
Number of Individuals
1 nautical
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
LEWES
CAPE HENLOPEN

Figure 11

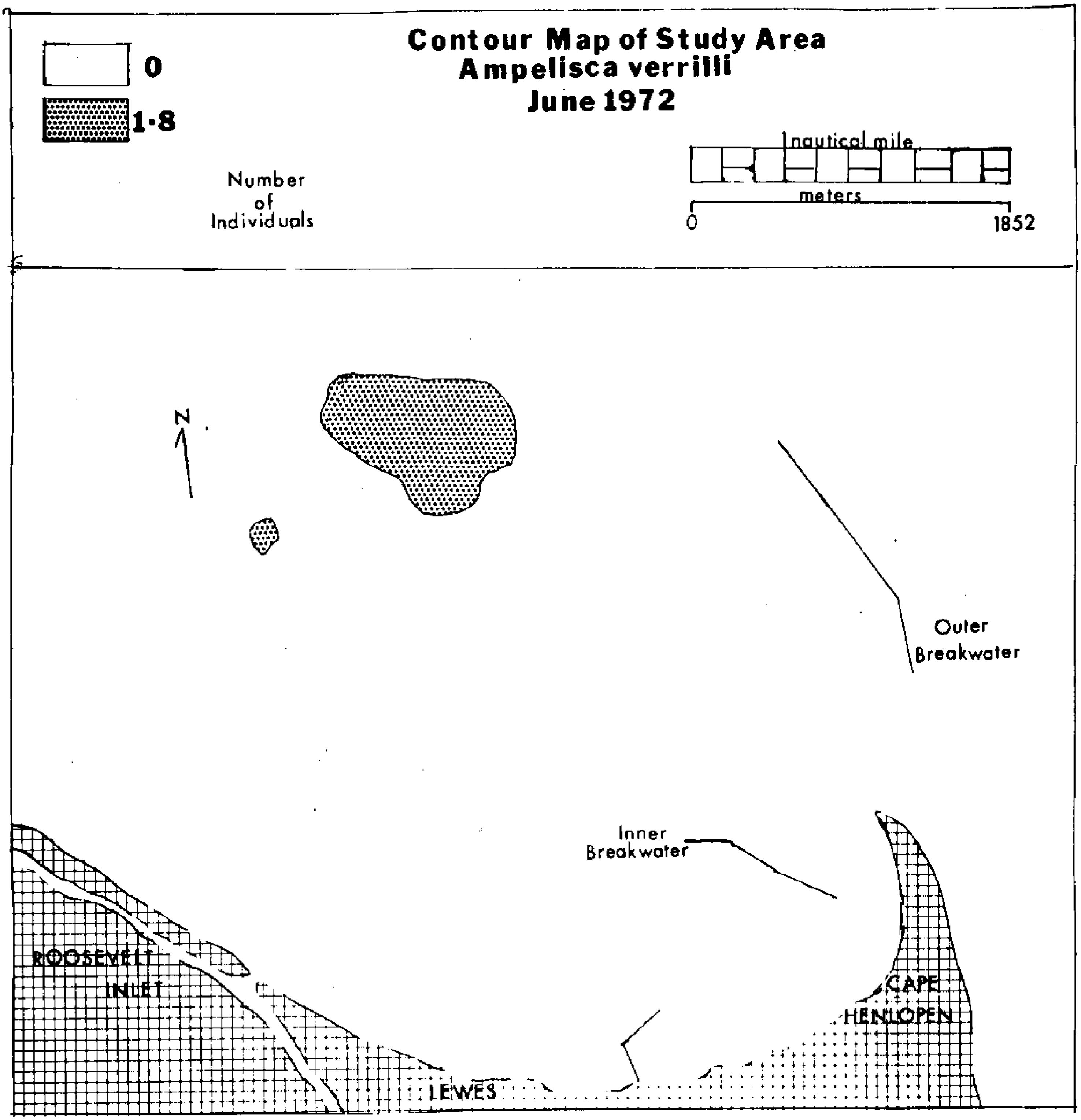
Contour Map of Study Area
Ampelisca verrilli
June 1972
0
1·8
Number of Individuals
1 nautical mile
meters
0
1852
N
Outer Breakwater
Inner Breakwater
ROOSEVELT INLET
LEWES
CAPE HENLOPEN

Figure 12