THE BENTHIC FAUNA AT FOUR POTENTIAL CONTAINMENT/WETLANDS STABILIZATION AREAS IN THE NEW YORK HARBOR REGION

by

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Special Report #73

MARINE SCIENCES RESEARCH CENTER
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STONY BROOK, NEW YORK 11794

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August 1986

Sponsored by the
New York Sea Grant Institute
through a contract with the
New York District, U.S. Army Corps of Engineers

Special Report 73

Reference 86-10

Approved for Distribution

J.R. Schubel

J.R. Schubel, Dean

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ACKNOWLEDGEMENTS

This work was supported by the New York Sea Grant Institute through a contract with the New York District of the U.S. Army Corps of Engineers. We would like to thank C. Jones, C.L. Arnold, M Zimmerman-Berger, R. Eppi, R. Castaneda, and F. Scheier for carrying out the field sampling and laboratory analyses.

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ABSTRACT

A one-time benthic survey was conducted at four potential containment/wetlands stabilization areas in the New York Harbor region. These areas were located in Raritan Bay, Newark Bay, Flushing Bay, and Bowery Bay. Results showed that the Raritan Bay area had the highest and the Bowery Bay area the lowest benthic resources. The Newark Bay area appeared to be intermediate between these two sites. The Flushing Bay area was subdivided into two distinct habitats. Benthic resources in one portion of the Flushing Bay area exceeded that of Raritan Bay, while the other portion was more comparable to Bowery Bay.

Introduction

In 1984, the Dredged Material Disposal Management Program's Joint Steering Committee identified four areas in the New York Harbor region as potential sites for the containment of dredged sediment. These were in Raritan Bay, Newark Bay, Flushing Bay, and Bowery Bay (Figure 1). This report presents the results of a one-time survey undertaken to characterize the benthic fauna in each of these potential containment/wetlands stabilization areas. More specifically, the goals of this study were to 1) obtain a quantitative but first order estimate of the benthic resources in each of the four areas, and 2) collect a site specific data set which could be used later to design a more comprehensive seasonal study.

In this report, comparative information is presented since managers ultimately needed to decide on which, if any, of these areas were suitable for the containment of dredged material. However, as will be emphasized throughout this report, the study areas are geographically separated, and they perhaps represent distinctly different environments. In addition, because of the limited scope of this survey, no attempt was made here to evaluate the relative contribution of these areas to the local resources. The significance of these areas to resources in Raritan Bay, Newark Bay, and the East River would have required a much larger, longer term effort.

Methods

1. Sampling Procedures

Benthic samples were collected within each of the four potential containment/wetlands stabilization areas during September 1984. Sampling was carried out aboard the R/V SIOME. The exact sampling dates for each area were 25 September 1984 for Raritan Bay, 27 September 1984 for Newark and Flushing bays, and 28 September 1984 for Bowery Bay.

The four potential containment/wetlands stabilization areas are fairly small ($\leq$ 200 acres), and we estimated that eight stations within each area would be sufficient for this first order survey. In our original design, stations were to be systematically located along two to three transects within each area. This was altered in the field for two reasons. First, access to some portions of the areas was limited by water depth. Second, because of the small size of the areas, change in orientation or drifting of the vessel during the sampling could introduce a displacement from the intended station that was relatively large compared to the size of each study area. As a result, stations were first located based on visual navigational aids but when the sample was actually taken, an exact location was determined by Loran.

Both Loran coordinates and a direct readout of latitude and longitude for each sampling station were obtained using a Texas Instruments 9900 II Loran C. Direct readout of latitude and longitude requires calibrating the unit using a reference point of known location. This was done for each area. The accuracy of the TI 9900 II is about 20 yards. The latitude and longitude of each station is given in Table 1. Station locations are shown in Figures 2-5.

Benthic samples were collected using a 0.04 square meter Shipek grab. At each station, three replicate grabs were taken for biological study. In addition, a portion of a fourth grab was saved untreated for sediment analysis. A Martek instrument package was used to measure depth and dissolved oxygen concentration in the bottom water.

Grab samples for biological study were wet-sieved onboard immediately after collection. Sieves were constructed of 1 mm diameter Nitex screening. After washing, all material retained on the screen (e.g., animals, detritus, sand, gravel, shell fragments, etc.) was transferred to labelled sample jars. These samples were preserved for later analysis in 5% buffered formalin.

2. Laboratory Procedures

In the laboratory, biological samples were transferred to 70% ethyl alcohol and stained with rose bengal. Samples were analyzed using a two stage process. In the first stage, animals were picked from the sediments, detritus, etc., under an illuminated magnifier and sorted to phylum level. In the second stage, animals were sorted to species level whenever possible and enumerated. All results were initially entered on log sheets and later transferred to a computer.

For the sediment analysis, each sample was homogenized, and a subsample of approximately 10 g was taken. Particle size distributions were determined by wet sieving and pipette analysis (Folk, 1964). Subsamples were dispersed with a 1% Calgon solution (sodium hexametaphosphate) and mechanically agitated for one hour to disaggregate the particles. The subsample was wet sieved into a 1000 ml graduated cylinder using a combination of a 2 mm mesh sieve and a 63 μm mesh sieve to separate the gravel, sand, and mud fractions. The mud fraction remaining in the graduated cylinder was separated into silt and clay by taking two pipette withdrawals. The gravel, sand, silt, and clay fractions were then dried in an oven at 80-90 degrees C, cooled to room temperature, and weighed. Weights of the silt and clay fractions were corrected for the amount of Calgon added. Mass percentages of the four particle size categories were calculated as percentages of the total subsample weight. No correction was made for salt content in the pipetted samples because the error introduced was considered insignificant.

3. Data Analysis

A number of derived parameters or indices (abundance, species richness, Sorenson's index of affinity, Shannon-Wiener diversity, equitability, and rarefaction diversity) were computed from the biological data. To maintain consistency throughout, nonenumerable species (e.g. colonial organisms such as sponges and hydrozoans) were excluded from all computations. The occurrence of these species is reported on the data sheets at the end of this report.

Abundances are reported as the number of individuals per square meter. These estimates were obtained by dividing the sample results by the sampling unit area (0.04 square meter). Species richness is presented as the number of species per 0.04 square meter. Because the relationship between the number of species and sampling unit area is nonlinear, normalization to a standard unit such as number per square meter is not possible for this parameter. Station and area results for both abundance and species richness represent per sample values averaged for that station or area.

Pairwise station comparisons of faunal similarity were made by using Sorenson's index of affinity (Sorenson, 1948; Sanders, 1960). This index is expressed as

$$S = \frac{2c}{a + b}$$

where the two compared stations contain a and b species respectively, and there are c species in common. This index is essentially the ratio of the number of species in common (c) to the average number present ((a + b)/2). Values of S range from 0 to 1. For convenience, values are reported as percentages by multiplying S by 100. S was computed from the total number of species present at each station after pooling the three replicate grabs.

Three indices of diversity were used to analyze the biological data. The first index is the Shannon-Wiener information function:

$$H'(s) = \sum_{i=1}^{s} p_i \log_2 p_i$$

where s is the total number of species and p_i is the proportion of individuals in the sample belonging to the ith species (i = 1, 2,3,...,s). Shannon-Wiener diversity measures both species richness (i.e. the number of species in a sample) and the distribution of individuals among species (termed evenness or equitability). This index is sample size dependent (Sanders et al., 1980); Shannon-Wiener diversity for a sample of size 10 will almost always be lower than the diversity for a sample of size 1000. This index was computed for each sample in the study. Station and area results represent per sample values averaged for that station or area.

The second index of diversity is the equitability or evenness function:

$$V' = H'(s)/H'_{max}$$

where $H'_{max} = \log_2 s$. This index has a maximum value of 1. The higher the value of V', the more evenly individuals in a sample are distributed among the s species. Equitability was computed for each sample. Station and area results represent per sample values averaged for that station or area.

The third index of diversity is Hurlbert's (1971) modification of the rarefaction technique. Given the species-abundance distribution observed in a population, the rarefaction method predicts the expected number of species in a random sample of size m taken without replacement. The combinatoric function for rarefaction diversity is of the form

$$E[S_m|N] = \sum_{i=1}^{s} \left[1 - \frac{\binom{N - N_i}{m}}{\binom{N}{m}} \right]$$

where N_i is the number of individuals of species i, N is the total number of individuals in the population, and S_m is a random variable representing the number of species in a subsample of size m. This index, except at very low densities, is independent of sample size (Sanders, 1980). Rarefaction diversity was computed for each area after pooling the results of all stations within the area.

RESULTS

1. Sediment Characteristics

A total of 32 sediment samples were analyzed for grain size distribution. The results are given in Figures 6-21. In this section, station and area summaries are reported in detail.

a. Percent Gravel

Gravel content in the surface sediments ranged from 0 to 3.4% (Figures 6-9). Gravel was not found at a majority of the stations sampled. All sites averaged less than 1% in gravel content (Table 2).

b. Percent Sand

Sand content in the samples analyzed ranged from 0.66% to 67.92% (Figures 10-13). The highest average percent sand occurred at the Raritan Bay area, followed by Newark, Flushing, and Bowery Bays, respectively (Table 2). Systematic trends within areas were generally not evident. However, it does appear that the northern portion of the Newark Bay area (Stations 9 and 10) had a lower sand content relative to the rest of this site (Figure 11). Also, the highest percent sand values in the Flushing Bay area (Stations 17 and 18) were found at the two stations nearest to shore (Figure 12).

c. Percent Silt

Percent silt in the surface sediments ranged from 3.37% to 70.96% (Figures 14-17). Average silt content was very similar for all areas (Table 2). There was no evidence for systematic trends in this parameter within the areas.

d. Percent Clay

Percent clay ranged from 8.59% to 90.36% in the samples analyzed (Figures 18-21). The lowest average clay content was found in the Raritan Bay area, followed by Newark, Flushing, and Bowery Bays, respectively in increasing order (Table 2). Within areas there were generally no systematic trends in clay content. However, it does appear that the lowest clay values in the Flushing Bay area (Stations 17 and 18) occurred near shore.

2. Depth

All four areas are fairly shallow (Figures 22-25). Station depths ranged from 2 to 15 feet. The Raritan Bay area had the lowest average depth, followed by Newark, Flushing, and Bowery bays, respectively (Table 2). These results, however, were not adjusted for tidal factors. The northern portion of Newark Bay (Stations 9 through 12) appears to be somewhat deeper than the rest of this area (Figure 23). The other sites did not show any obvious depth trends.

3. Dissolved Oxygen (DO)

Dissolved oxygen concentrations at each station are given in Figures 26-29. Values ranged from 1.98 to 6.70 ml/l. As a reference, the EPA approved water quality standard for New York/New Jersey is 4 ml/l during the July-September period. Most of the stations had dissolved oxygen concentrations which were close to or below this standard. The Raritan Bay area had the highest average value, followed by Newark, Flushing, and Bowery

Bays, respectively (Table 2). In Raritan Bay, Stations 1, 2, and 7 had higher dissolved oxygen concentrations than the remaining stations. This suggests that DO levels may increase with distance from the mouth of the Raritan River (Figure 26). Also, within the Flushing Bay area (Figure 28), the highest DO values were found at the two nearshore stations (17 and 18). The other two areas, Newark Bay and Bowery Bay, showed no obvious spatial gradients in dissolved oxygen concentrations. The low values of dissolved oxygen in Bowery Bay, however, may indicate that the tidal flushing of the bay is poor. There is also a sewage treatment plant nearby that may be affecting the oxygen demand here.

4. Biological Characteristics

Station and area summaries are reported in detail in this section. Information on individual grab samples is, however, included in this report as appendices. Data from each sample are tabulated in Appendix A. Abundance, species richness, Shannon-Wiener diversity, and equitability results for each sample may be found in Appendix B.

Three replicate grabs at each of the 32 sampling stations were analyzed. From these, a total of 1713 individuals and 52 taxa were obtained. A composite species list is given in Table 3. Of the 52 taxa, 24 (46%) were Polychaetes, 11 (21%) were Crustacea, and 10 (19%) were Molluscs. The remaining taxa were distributed among seven other groups: Porifera, Cnidaria, Platyhelminthes, Rhynchocoela, Sipuncula, Ectoprocta, and Chordata.

a. Species Composition

The percentage composition of the fauna in each area is given in Table 4. This table was constructed by pooling the sample data within each area. The highest number of species collected was 32 at the Flushing Bay area. The next highest was the Raritan Bay area with 25. The remaining two areas, Newark Bay and Bowery Bay, had 15 and 12 species, respectively.

In this report, we defined a dominant species as one which represents 5% or more of the total number of individuals collected within an area. Table 5 lists these species. Using this criterion, each area had four or five dominant species. The polychaete Streblospio benedicti was a dominant within all four areas. Capitellidae sp. A represented greater than 5% of the total number in two of the four areas. The remaining species in Table 5 were dominant in only one area. Most of these were found at two or more areas although they represented greater than 5% of the total number at only one area. Exceptions were Nereis virens and Macoma balthica, which were collected only in Newark Bay, and Haploscoloplos fragilis, which was found only in Raritan Bay.

In the Raritan Bay area, the soft-shelled clam, Mya arenaria, was by far the most abundant species, representing almost 43% of the total fauna. Other dominant taxa include the polychaetes Streblospio benedicti, Haploscoloplos fragilis, and Pectinaria gouldii. Most soft-shelled clams were collected at the offshore stations (Figure 30). Streblospio benedicti was found only at Stations 2 and 7 within the area (Figure 31). Haploscoloplos fragilis and Pectinaria gouldii occurred at most sampling stations but showed considerable variations in abundance (Figures 32-33).

Within the Newark Bay area, Streblospio benedicti was the most abundant species accounting for about 52% of the total fauna. The distribution of this species was quite patchy (Figure 34). The mud crab Rhithropanopeus harrisii, the polychaete Nereis virens, and the bivalve Macoma balthica were also dominants in this area. Two of these, Rhithropanopeus harrisii and Macoma balthica were found at the majority of sampling stations (Figures 35 and 37). Nereis virens was restricted mainly to Station 12 (Figure 36). In general, very few individuals were collected at stations 9 and 15.

The five dominant species in the Flushing Bay area were the polychaetes Streblospio benedicti, Nereis succinea, Polydora ligni, Capitellidae sp. A, and the amphipod Melita nitida (Figures 38-42). All of these appear to be abundant mainly nearshore (Stations 17, 18, and 19).

The Bowery Bay area was dominated by Capitellidae sp. A. Individuals of this taxa represented about 69% of the total fauna. Most of the Capitellidae sp. A individuals were collected at Stations 30 and 31 (Figure 43). Other dominant species in this area include Ilyanassa obsoleta, Eteone sp., and Streblospio benedicti. All of these were found at only two or three of the eight stations (Figures 44-46).

One striking feature of Table 5 is that there is very little overlap in the dominant species among areas. In addition, as reported above, many of the dominant species are patchily distributed within an area. This suggests that there may be significant differences both within and among these areas. To examine this further, Sorenson's index of affinity was calculated for each pairwise combination of stations. The results are presented as a trellis diagram (Table 6). In this table, elements above the diagonal are the affinity index values for each pair of stations. These values are expressed as percentages, and the range of possible outcomes is from 0 to 100%. A high index value indicates substantial overlap in the species composition between a pair of stations. In the elements below the diagonal, the same information is presented, but the index values have been grouped into four classes. Class intervals were determined by dividing the set of results into four approximately equal sized groups based on the frequency distribution of the index values. The trellis diagram is subdivided into blocks consisting of eight stations on a side to facilitate comparisons within and among areas.

Blocks along the diagonal show pairwise comparisons of stations within an area. Stations within Raritan Bay exhibit a high degree of affinity among themselves. The Raritan Bay area appears, therefore, to be fairly homogeneous in terms of species composition. With the exception of Station 9, the Newark Bay area also appears to be fairly homogeneous. At Station 9, we collected only one species, the mysid shrimp Neomysis americana. This species was not found at any of the other stations within Newark Bay. The Flushing Bay area can be subdivided into two groups of stations based on the affinity index. One group consists of Stations 17-20 and the other of Stations 21-24. When stations between these groups are compared, there is very little overlap in species composition. Finally, the Bowery Bay area appears to be the least homogeneous. One group of stations (26, 27, 28, 30, and 31) appears to show some degree of affinity. The remaining stations (25, 29, and 32) exhibit very little affinity among themselves or to any of the other stations within this area.

Table 7 lists the average values of the affinity index for each block. Entries along the diagonal are the average affinities for pairs of stations within an area. These diagonal entries tend to confirm the findings presented above. That is, the Raritan Bay area appears to be the most homogeneous in terms of species composition, followed by Newark Bay, Flushing Bay, and Bowery Bay, respectively.

Blocks arranged off of the diagonal in Table 6 show pairwise comparisons of stations between areas. As expected, affinity values for blocks of stations between areas were found to be generally lower than values obtained for station comparisons within areas. An exception to this occurs when Raritan and Flushing Bays are compared. Stations in these two areas show a fairly high degree of species overlap. Note that in Table 7, the average affinity obtained in the Raritan-Flushing Bay comparison is the only between area value which exceeds any of the diagonal entries.

b. Abundance

Spatial patterns in abundance for each area are given in Figures 47-50. Station abundances ranged from a low of eight individuals per square meter to a high of 2283 animals per square meter (Table 8). Overall, the Raritan Bay area had the highest average abundance, followed by Flushing Bay, Newark Bay, and Bowery Bay, respectively. The Raritan Bay area had no obvious spatial trends in abundance (Figure 47). Within the Newark Bay area, abundances were distinctly lower at Stations 9 and 15 when compared to the remaining stations at this site (Figure 48). Highest abundances occurred at nearshore stations (17-19) in the Flushing Bay area (Figure 49). In Bowery Bay, abundances were generally low, except at Station 30 (Figure 50).

c. Species Richness

The number of species per 0.04 square meter ranged from 0.3 to 7.7 (Table 8). Overall, numbers of species were highest in the Raritan Bay area, followed by Flushing, Newark, and Bowery Bays, respectively. The Raritan and Bowery Bay areas showed no obvious spatial trends (Figures 51 and 54). Within Newark Bay, Stations 9 and 15 had distinctly lower values than the remaining stations (Figure 52). In Flushing Bay, Stations 18 and 19 had distinctly higher values than the other stations in this area (Figure 53).

d. Shannon-Wiener Diversity

Shannon-Wiener diversity values for each station are presented in Figures 55-58. Diversities ranged from 0 to 2.72 (Table 8). Of the four areas, Raritan Bay had the highest average value (Table 8). Flushing Bay was the next highest, followed by Newark and Bowery Bays, respectively. No spatial trends in diversity were evident at the Raritan Bay area (Figure 55). Within the Newark Bay area, lowest values of diversity were found at Station 9 near Port Newark Channel and at Stations 13-15 near Elizabeth Channel (Figure 56). Figure 57 shows two distinct groups of stations within the Flushing Bay area. Stations 17-20 had higher diversity values than the remaining stations within this area. Diversity values in Bowery Bay were very low in general (Figure 58).

e. Equitability

Equitability values for each station are given in Figures 59-62. This index ranged from 0.0 to 0.97 (Table 8). Raritan Bay had the highest mean equitability value, followed by Newark, Flushing, and Bowery Bays, respectively (Table 8). Generally, no spatial trends were evident for this index.

f. Rarefaction Diversity

The rarefaction method allows one to compare populations in a manner that is independent of the numbers of individuals collected. Rarefaction computations were carried out on the total pooled data set for each area. The results are shown in Figure 63. Based on these curves, Flushing Bay has the highest diversity, followed by the Raritan Bay area. Newark Bay and Bowery Bay are about equivalent and have the lowest rarefaction diversity.

DISCUSSION

Table 9 presents an overview of the results. In this table, areas have been ordered or ranked according to the physical and biological parameters measured in this study. Ranks were determined from the mean values listed in Tables 2, 7, and 8, and the results in Figure 63. While not quantified in this report, there appears to be some general correspondence between the observed physical characteristics and benthic resources in the areas. Raritan Bay is sandier and shallower than the other areas, and it had the highest dissolved oxygen concentrations. Based on the rankings in Table 9, the benthic resources in Raritan Bay are clearly greater than the other areas.

Bowery Bay is at the opposite end of the spectrum. It is the deepest and muddiest of the four sites, and it had the lowest dissolved oxygen levels. The information on Table 9 suggests that the benthic resources at the time of the sampling were lower in Bowery Bay relative to the other sites.

Station specific information for Newark Bay suggests that there are some gradients in the characteristics of this site. The northern portion near Port Newark Channel was deeper and had a lower sand content when compared to the rest of this area. Many of the biological parameters (e.g. abundance, species richness, and Shannon-Wiener diversity) were low at stations near Port Newark Channel on the north and near Elizabeth Channel on the south. Overall, Newark Bay appears to be intermediate between Raritan and Bowery Bays according to the rankings in Table 9.

Flushing Bay is the most difficult of the four areas to classify. Station specific information suggests that two distinct habitats are present (Stations 17-20 and 21-24). Because of this, the ranks in Table 9 are not very representative of this area. Table 10 lists some of the biological parameters separately for the two groups of stations. When compared to Table 8, it is apparent that the parameters for Stations 17-20 exceed those for Raritan Bay. On the other hand, those for Stations 21-24 are comparable to or lower than the values for Bowery Bay.

Table 11 compares some of the results of the present study to several local nearshore environments. With the exception of one East Bank Study (i.e. Woodward and Clyde, 1975a,b), abundances in the four areas are similar to that found in previous surveys in the Lower Bay. Abundances are, however, substantially lower than the values reported for the other nearshore benthic environments.

Pearson and Rosenberg (1978) have compiled a list of species which were found to be "dominant or prominent in areas polluted or enriched by organic material." The authors state that this list is not exhaustive, but it was compiled after a review of the general literature. Of the 13 species listed as dominants in Table 5, nine are cited in the list assembled by these authors. This observation combined with low abundances and levels of dissolved oxygen suggests that the four areas are stressed. There is, of course, no evidence at the present time to indicate whether the source of the stress is due to natural or anthropogenic factors.

Finally, we wish to emphasize again that the trends reported here are based on a one-time survey at each of the potential containment/wetlands stabilization areas. Seasonal variations were not examined, and no attempt was made to evaluate the relative contribution of these areas to local resources. Nevertheless, the results of this study were sufficient to document differences in the physical and biological characteristics of the areas.

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Table 1. Station Latitude and Longitude.

STATION	LATITUDE	LONGITUDE
1	40 28' 70"	74 15' 40"
2	40 28' 81"	74 15' 65"
3	40 29' 14"	74 15' 65"
4	40 29' 36"	74 16' 01"
5	40 29' 30"	74 16' 08"
6	40 29' 17"	74 16' 02"
7	40 28' 95"	74 15' 85"
8	40 29' 19"	74 15' 77"
9	40 41' 29"	74 08' 14"
10	40 41' 27"	74 08' 26"
11	40 41' 14"	74 08' 21"
12	40 41' 02"	74 08' 13"
13	40 40' 93"	74 08' 53"
14	40 40' 84"	74 08' 38"
15	40 40' 72"	74 08' 30"
16	40 40' 87"	74 08' 33"
17	40 46' 88"	73 52' 13"
18	40 47' 10"	73 52' 28"
19	40 47' 04"	73 52' 27"
20	40 47' 04"	73 52' 16"
21	40 46' 98"	73 52' 16"
22	40 46' 98"	73 52' 07"
23	40 46' 90"	73 52' 02"
24	40 46' 86"	73 51' 95"
25	40 46' 64"	73 53' 40"
26	40 46' 66"	73 53' 28"
27	40 46' 66"	73 53' 21"
28	40 46' 77"	73 53' 22"
29	40 46' 77"	73 53' 32"
30	40 46' 75"	73 53' 44"
31	40 46' 84"	73 53' 44"
32	40 46' 96"	73 53' 33"

Table 2. Minimum, maximum, and mean values for the physical characteristics of each area.

PARAMETER	MINIMUM	MAXIMUM	MEAN
1) PERCENT GRAVEL			
Raritan Bay	0	3.40	.74
Newark Bay	0	1.34	.34
Flushing Bay	0	3.16	.64
Bowery Bay	0	0	0
2) PERCENT SAND			
Raritan Bay	19.55	67.92	38.68
Newark Bay	2.08	34.20	19.86
Flushing Bay	2.66	44.38	17.43
Bowery Bay	.66	15.61	7.45
3) PERCENT SILT			
Raritan Bay	16.57	63.00	34.60
Newark Bay	12.63	55.75	37.86
Flushing Bay	3.37	58.24	36.33
Bowery Bay	6.69	70.96	37.11
4) PERCENT CLAY			
Raritan Bay	8.59	54.77	25.98
Newark Bay	19.62	85.28	41.94
Flushing Bay	17.68	84.36	45.60
Bowery Bay	13.43	90.36	55.44
5) DISSOLVED OXYGEN (ml/l)			
Raritan Bay	3.40	6.70	4.45
Newark Bay	3.96	4.42	4.20
Flushing Bay	2.70	5.40	3.20
Bowery Bay	1.98	3.30	2.88
6) DEPTH (ft)			
Raritan Bay	2	7	4.88
Newark Bay	5	15	7.25
Flushing Bay	3	13	8.25
Bowery Bay	5	13	9.75

Table 3. Species List.

- PORIFERA
  - HYDROMERIDA
    - CLIONIDAE
      - Cliona sp.
- CNIDARIA
  - HYDROZOA
      - Hydrozoa sp.
- PLATYHELMINTHES
  - TURBELLARIA
    - POLYCLADIA
      - Turbellaria sp.
- RHYNCHOCOELA
      - Nemertea sp.
- SIPUNCULA
      - Sipuncula sp.
- ANNELIDA
  - POLYCHAETA
    - CAPITELLIDAE
      - Capitellidae sp. A
    - CIRRATULIDAE
      - Tharyx acutus
    - GLYCERIDAE
      - Glycera americana
      - Glycera capitata
      - Glycera dibranchiata
      - Glycera sp.
    - NEREIDAE
      - Nereis succinea
      - Nereis virens
      - Nereis sp.
    - ORBINIIDAE
      - Haploscoloplos fragilis
    - PARAONIDAE
      - Paraonidae sp.
    - PECTINARIIDAE
      - Pectinaria gouldii
    - PHYLLODOCIDAE
      - Eteone heteropoda
      - Eteone sp.
      - Eumida sanguinea
      - Phyllodoce sp.
    - POLYNOIDAE
      - Lepidonotus squamatus
      - Polynoidae sp.
    - SABELLARIIDAE
      - Sabellaria vulgaris
    - SPIONIDAE
      - Polydora ligni
      - Scolelepis squamata
      - Scolecolepides viridis
      - Streblospio benedicti
    - SYLLIDAE
      - Syllidae sp.
- ARTHROPODA
  - CRUSTACEA
    - AMPHIPODA
      - AMPELISCIDAE
        - Ampelisca sp.
      - AORIDAE
        - Lembos websteri
      - COROPHIIDAE
        - Corophiidae sp.
      - GAMMARIDAE
        - Gammarus mucronatus
      - MELITIDAE
        - Melita nitida
      - CAPRELLIDEA
        - Caprellidea sp.
    - CIRRIPEDIA
      - THORACICA
        - Thoracica sp.
    - ISOPODA
      - IDOTEIDAE
        - Edotea montosa
    - DECAPODA
      - XANTHIDAE
        - Neopanope texana sayi
        - Rhithropanopeus harrisii
    - MYSIDACEA
        - Neomysis americana
- MOLLUSCA
  - GASTROPODA
    - CREPIDULIDAE
      - Crepidula plana
      - Crepidula sp.
    - NASSARIDAE
      - Nassarius trivittata
      - Ilyanassa obsoleta
  - BIVALVIA
    - MACTRIDAE
      - Mulinia lateralis
    - MYIDAE
      - Mya arenaria
    - OSTREIDAE
      - Crassostrea virginica
    - SOLENIDAE
      - Ensis directus
    - TELLINIDAE
      - Macoma balthica
      - Tellina agilis
- ECTOPROCTA
      - Ectoprocta sp.
- CHORDATA
  - ASCIDIACEA
    - PLEUROGONA
      - MOLGULIDAE
        - Molgula manhattensis

Table 4. Percentage composition by abundance of the fauna at each area.

	Raritan Bay	Newark Bay	Flushing Bay	Bowery Bay
PORIFERA				
Cliona sp.			*	
CNIDARIA				
Hydrozoa sp.	*			
PLATYHELMINTHES				
Turbellaria sp.	.13			
RHYNCHOCOELA				
Nemertea sp.	.13	4.58		
SIPUNCULA				
Sipuncula sp.	.13			
POLYCHAETA				
Capitellidae sp. A	1.70	1.91	6.71	68.85
Tharyx acutus			1.77	
Glycera americana	.13		1.59	
Glycera capitata	1.57			
Glycera dibranchiata	.92			
Glycera sp.			.35	
Nereis succinea	1.18	1.15	16.96	3.28
Nereis virens		9.92		
Nereis sp.		3.44		
Haploscoloplos fragilis	10.09			
Paraonidae sp.		.38		
Pectinaria gouldii	8.13		2.12	
Eteone heteropoda	.66	.76		.82
Eteone sp.	.39		.71	5.74
Eumida sanguinea			.53	
Phyllodoce sp.			1.24	
Lepidonotus squamatus			.71	
Polynoidae sp.			.35	
Sabellaria vulgaris			3.00	
Polydora ligni	4.59		7.24	
Scolelepis squamata	.66			
Scolecolepides viridis			.35	
Streblospio benedicti	19.40	51.53	33.22	5.74
Syllidae sp.	.13			
AMPHIPODA				
Ampelisca sp.				.82
Lembos websteri			2.83	.82
Corophiidae sp.			1.77	
Gammarus mucronatus				.82
Melita nitida			8.83	.82
CAPRELLIDEA				
Caprellidea sp.		.38	.18	
CIRRIPEDIA				
Thoracica sp.		*	*	
ISOPODA				
Edotea montosa			3.00	.82
DECAPODA				
Neopanope texana sayi			.71	
Rhithropanopeus harrisii	.13	14.89	.88	

Table 4 (continued)

	Raritan Bay	Newark Bay	Flushing Bay	Bowery Bay
MYSIDACEA				
Neomysis americana	.39	.38		3.28
GASTROPODA				
Crepidula plana			.18	
Crepidula sp.			.18	
Nassarius trivittata	.13			
Ilyanassa obsoleta	2.36			8.20
BIVALVIA				
Mulinia lateralis	.13	.38	.18	
Mya arenaria	42.86	3.05	3.00	
Crassostrea virginica			.71	
Ensis directus	.13		.35	
Macoma balthica		7.25		
Tellina agilis			.35	
ECTOPROCTA				
Ectoprocta sp.			*	
CHORDATA				
Molgula manhattensis	3.93			
CUMULATIVE PERCENT	100	100	100	100
NUMBER OF SPECIES	25	15	32	12
NUMBER OF INDIVIDUALS COLLECTED	763	262	566	122
AVERAGE ABUNDANCE (per sq. m)	795	273	590	127

Note: * Indicates presence of a nonenumerable species.

Table 5. Rank abundance of those species representing 5% or more of the total number of individuals collected in an area. Percentages are from Table 4.

	RARITAN BAY		NEWARK BAY		FLUSHING BAY		BOWERY BAY	
	RANK	%	RANK	%	RANK	%	RANK	%
Mya arenaria	1	(42.86)						
Streblospio benedicti	2	(19.40)	1	(51.53)	1	(33.22)	4	(5.74)
Haploscoloplos fragilis	3	(10.09)						
Pectinaria gouldii	4	(8.13)						
Rhithropanopeus harrisii			2	(14.89)				
Nereis virens			3	(9.92)				
Macoma balthica			4	(7.25)				
Nereis succinea					2	(16.96)		
Melita nitida					3	(8.83)		
Polydora ligni					4	(7.24)		
Capitellidae sp. A					5	(6.71)	1	(68.85)
Ilyanassa obsoleta							2	(8.20)
Eteone sp.							3	(5.74)
CUMULATIVE PERCENT		(80.48)		(83.59)		(72.96)		(88.53)

Table 6. Trellis diagram of affinity indices.

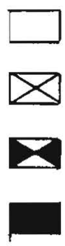
Key:

0

1 - 18%

19 - 33%

34 - 100%



	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	27	28	29	30	31	32	
1		36	50	52	45	40	62	30	13	30	10	27	36	29	33	36	40	33	38	26	33	22	12	11	0	13	50	33	12	32	33	13	Raritan Bay
2			25	27	29	50	33	17	0	33	15	29	43	46	20	43	24	14	17	13	20	0	0	0	0	25	33	40	0	36	20	25	
3				82	75	43	50	71	0	14	0	0	13	0	17	13	32	20	23	35	17	33	18	33	0	0	14	33	0	0	0	20	
4					80	46	42	77	22	15	0	0	13	0	18	13	33	21	24	38	18	36	20	36	0	0	31	36	20	0	0	22	
5						50	44	67	0	17	0	0	14	0	20	14	35	21	33	40	20	40	22	40	0	0	17	40	0	0	0	25	
6							50	60	0	0	0	0	33	18	50	33	27	15	18	15	25	25	29	25	0	33	20	25	0	22	25	0	
7								50	0	13	12	22	33	24	29	33	38	31	36	32	29	29	15	29	0	17	38	14	0	40	43	0	
8									0	0	0	0	17	0	25	17	27	15	18	31	25	25	29	50	0	0	0	0	0	0	0	0	
9										0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	67	0	0	0	Newark Bay
10											55	67	67	73	25	67	40	23	27	31	25	25	0	0	0	0	40	25	0	22	0	0	
11												46	62	50	22	46	13	7	9	0	0	22	0	0	0	0	0	0	0	0	0	0	
12													57	77	20	71	24	21	17	13	20	0	0	0	0	0	17	0	0	18	20	0	
13														77	60	86	35	21	25	13	40	20	22	20	0	25	33	20	0	36	20	0	
14															44	92	38	22	26	14	22	0	0	0	0	29	36	22	0	40	22	0	
15																60	31	17	20	0	33	33	40	33	0	50	25	33	0	29	33	0	
16																	35	21	25	13	40	20	22	20	0	25	33	20	0	36	20	0	
17																		52	59	56	15	15	0	15	15	18	40	31	0	29	15	0	Flushing Bay
18																			74	48	8	8	9	17	8	9	31	17	9	32	17	0	
19																				56	10	10	0	20	10	11	36	20	11	38	20	0	
20																					18	18	0	36	18	0	31	18	0	17	0	0	
21																						33	40	33	0	0	25	0	0	29	0	0	
22																							40	33	0	0	25	33	0	0	0	0	
23																								40	0	0	0	0	0	0	0	0	
24																									0	0	0	0	0	0	0	0	
25																										0	0	0	0	0	0	0	Bowery Bay
26																											33	50	0	40	50	0	
27																												50	29	67	50	0	
28																													0	29	33	50	
29																														0	0	0	
30																															57	0	
31																																0	
32																																	

Raritan Bay — Newark Bay — Flushing Bay — Bowery Bay

Table 7. Average affinities for blocks shown in Table 6.

	Raritan Bay	Newark Bay	Flushing Bay	Bowery Bay
Raritan Bay	49	16	25	14
Newark Bay		44	16	13
Flushing Bay			27	10
Bowery Bay				19

Table 8. Minimum, maximum, and mean values for the biological characteristics of each area.

PARAMETER	MINIMUM	MAXIMUM	MEAN
1) ABUNDANCE			
Raritan Bay	233	1417	795
Newark Bay	8	642	273
Flushing Bay	33	2283	590
Bowery Bay	8	608	127
2) SPECIES RICHNESS			
Raritan Bay	3.0	7.7	5.38
Newark Bay	.3	4.7	2.95
Flushing Bay	1.0	12.0	4.75
Bowery Bay	.3	2.3	1.40
3) SHANNON-WIENER DIVERSITY			
Raritan Bay	.96	2.39	1.52
Newark Bay	0	2.14	1.14
Flushing Bay	0	2.72	1.21
Bowery Bay	0	1.01	.39
4) EQUITABILITY			
Raritan Bay	.54	.82	.65
Newark Bay	0	.97	.62
Flushing Bay	0	.90	.53
Bowery Bay	0	.83	.31

Table 9. Area rankings based on observed physical and biological parameters. Order of ranking is from highest (1) to lowest (4) for each parameter.

	% GRAV.	% SAND	% SILT	% CLAY	DO	DEPTH	ABUND.	SPECIES RICH.	DIV. (H')	EQUIT.	RAREF. DIV.	AFF. INDEX
Raritan Bay	1	1	4	4	1	4	1	1	1	1	2	1
Newark Bay	2	2	1	3	2	3	3	3	3	2	3.5	2
Flushing Bay	3	3	3	2	3	2	2	2	2	3	1	3
Bowery Bay	4	4	2	1	4	1	4	4	4	4	3.5	4

Table 10. Mean values of several biologcal parameters for the two station groups within Flushing Bay.

	Stations 17-20	Stations 21-24
ABUNDANCE	1125	54
SPECIES RICHNESS	8.2	1.3
SHANNON-WIENER DIVERSITY	2.10	.33
EQUITABILITY	.73	.33

Table 11. Abundances of benthic invertebrates compared to some local nearshore environments.

	Mean Abundance (#/m^2)	Reference
Current Study		
Raritan Bay	795	
Newark Bay	273	
Flushing Bay	590	
Bowery Bay	127	
New York Harbor		
West Bank	536	Cerrato and Scheier (1983)
Old Orchard Shoal	400	Gandarillas and Brinkhuis (1981)
Romer Shoal	400	" "
East Bank	250	" "
East Bank	5,406	Woodward and Clyde (1975a,b)
Lower Bay	110	McGrath (1974)
Lower Bay	766	Walford (1971)
Port Jefferson Harbor	3,413	Klein (1976)
Buzzard's Bay	4,430	Sanders (1958)
Long Island Sound	16,443	"
Moriches Bay	5,402	O'Connor (1972)
South Shore of Long Island		
(9 - 18 m)	1,630	Cerrato (1983)
(5 - 25 m)	1,521	Steime and Stone (1973)
Southern New England (0-24 m)	2,429	Wigley and Theroux (1981)
New York Bight (0-24 m)	2,430	" "
Chesapeake Bight (0-24 m)	1,742	" "

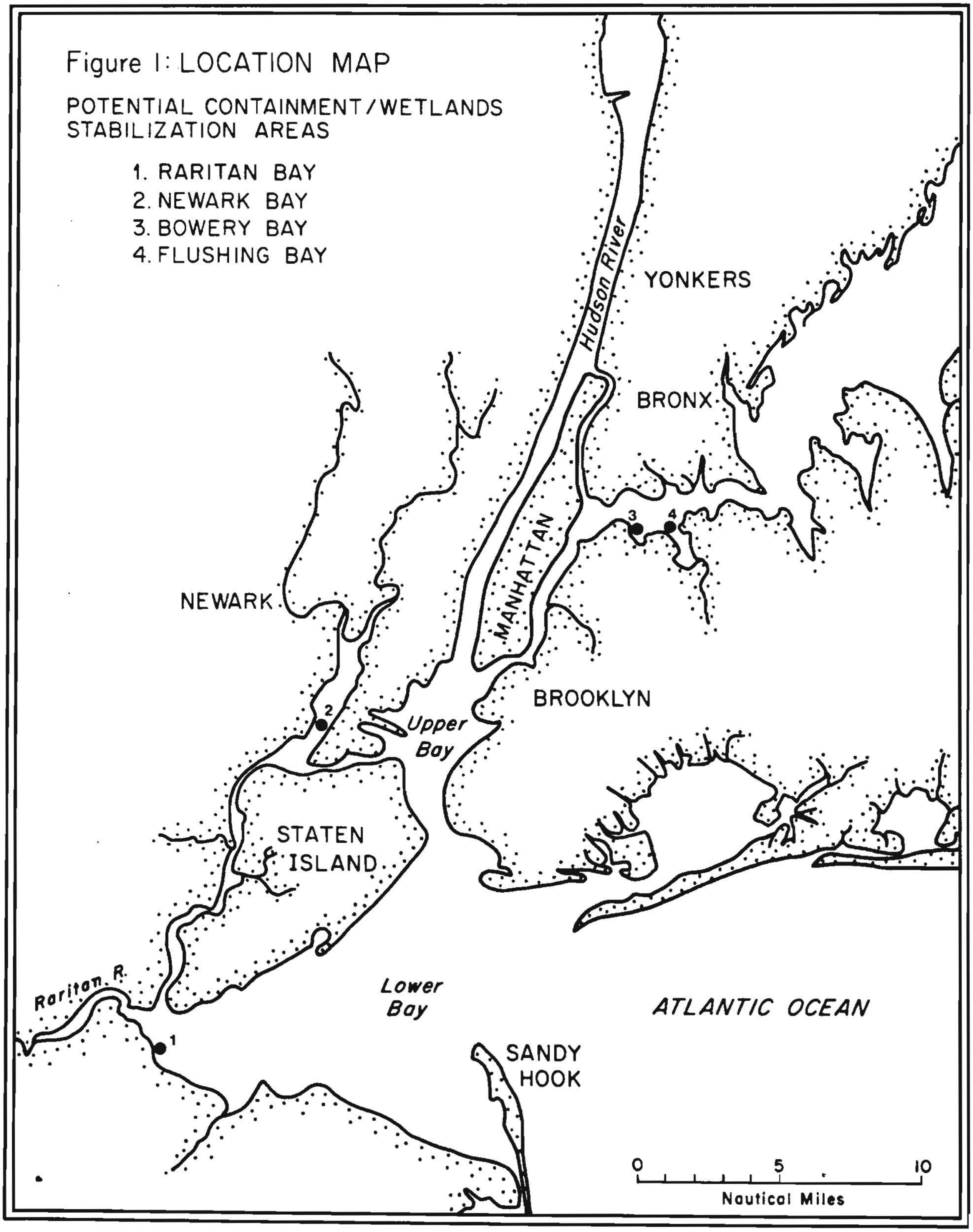
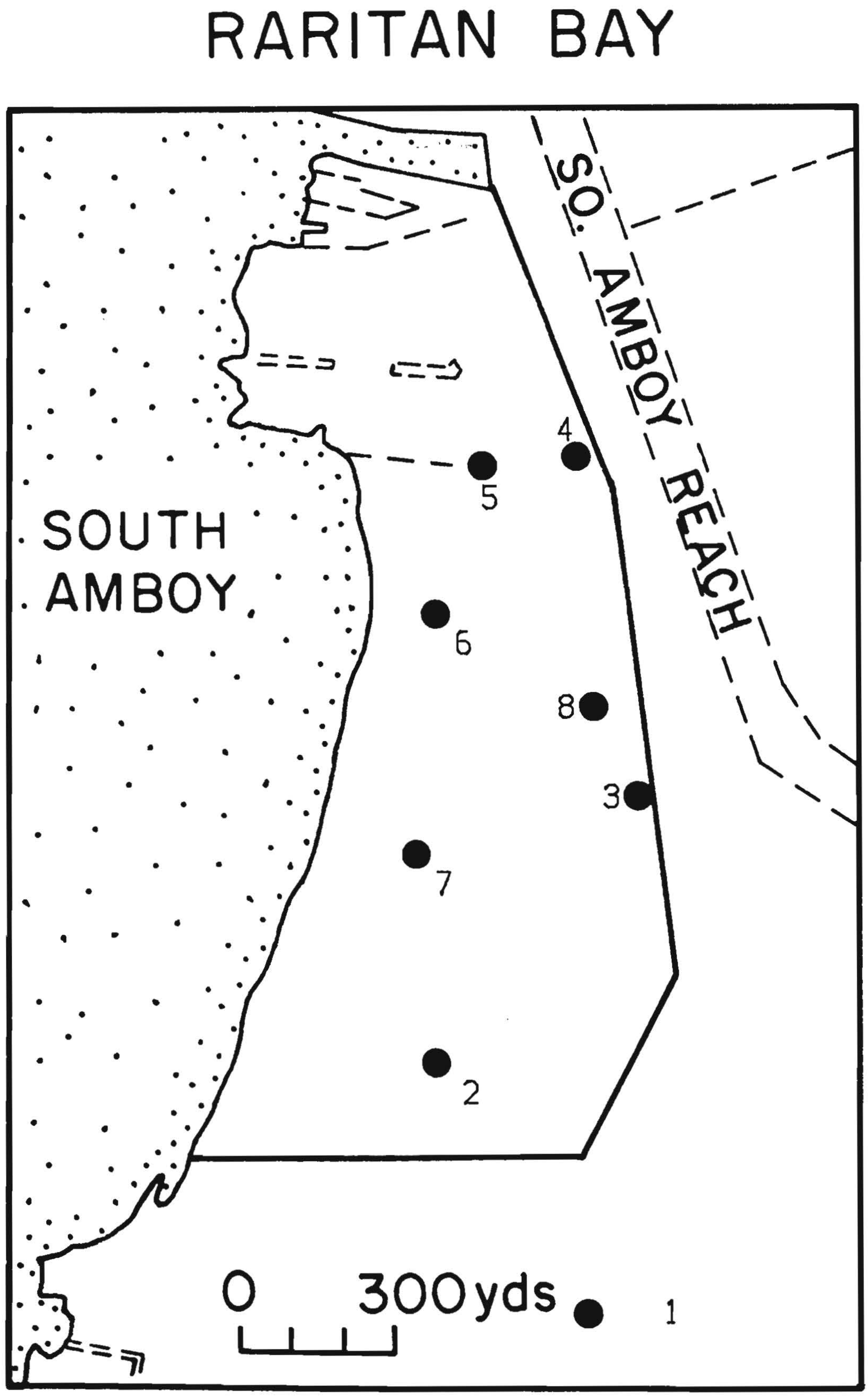


Figure 1: LOCATION MAP

POTENTIAL CONTAINMENT/WETLANDS STABILIZATION AREAS

1. RARITAN BAY
2. NEWARK BAY
3. BOWERY BAY
4. FLUSHING BAY



Station Locations

Figure 2

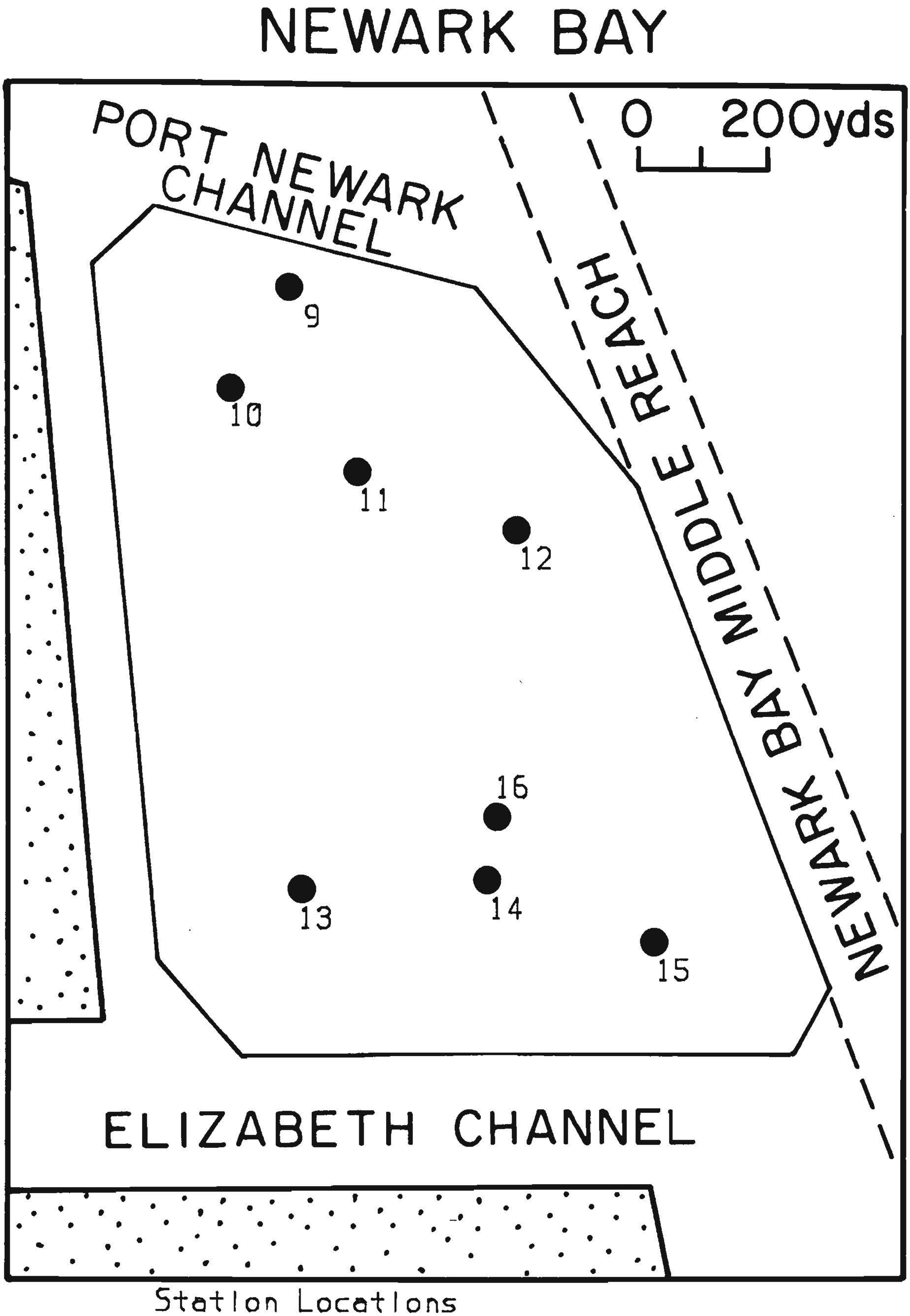
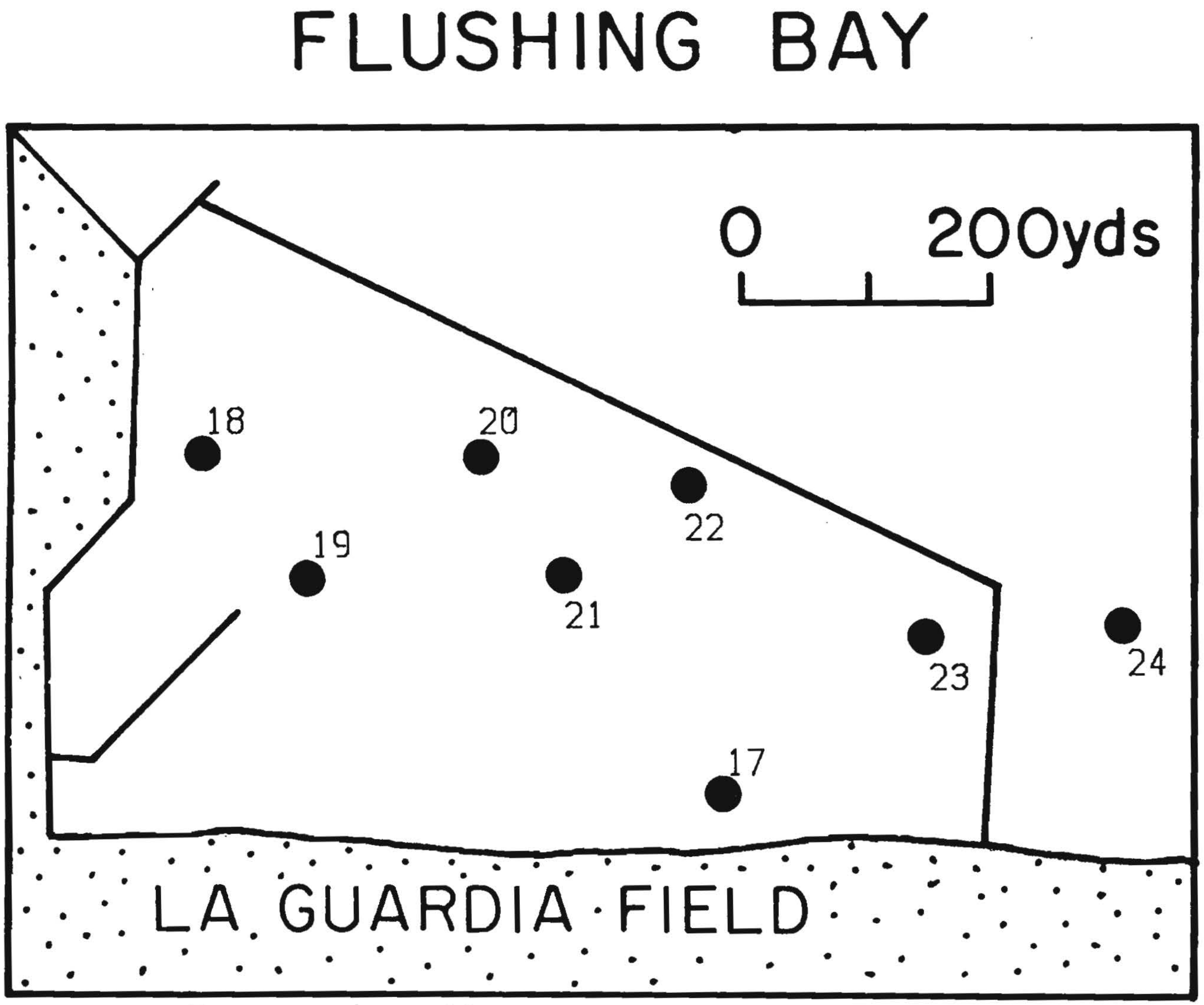

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
9
10
11
12
16
13
14
15
ELIZABETH CHANNEL
Station Locations

Figure 3



Station Locations

Figure 4

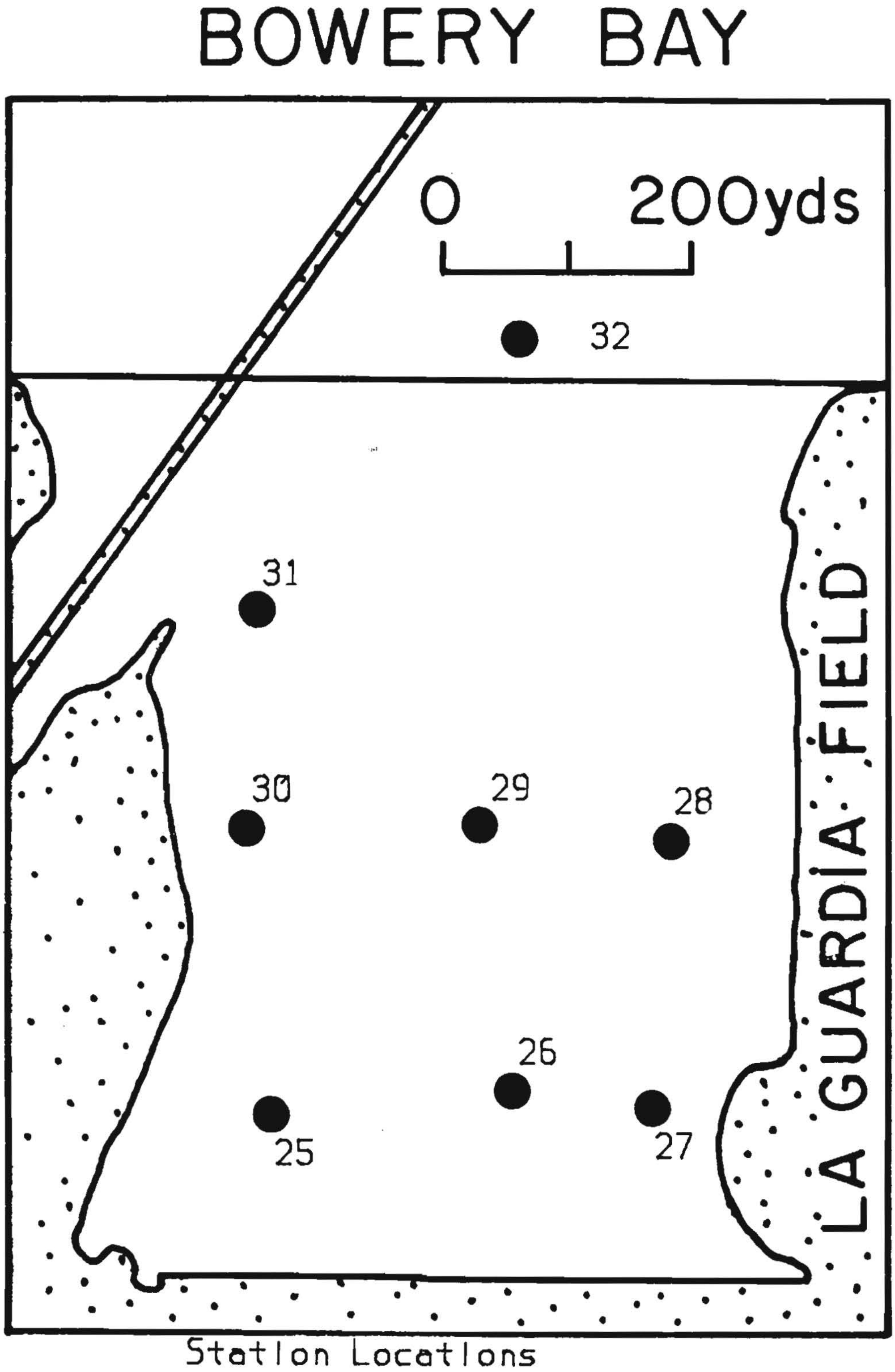

BOWERY BAY
0
200yds
32
31
30
29
28
26
25
27
LA GUARDIA FIELD
Statlon Locatlons

Figure 5

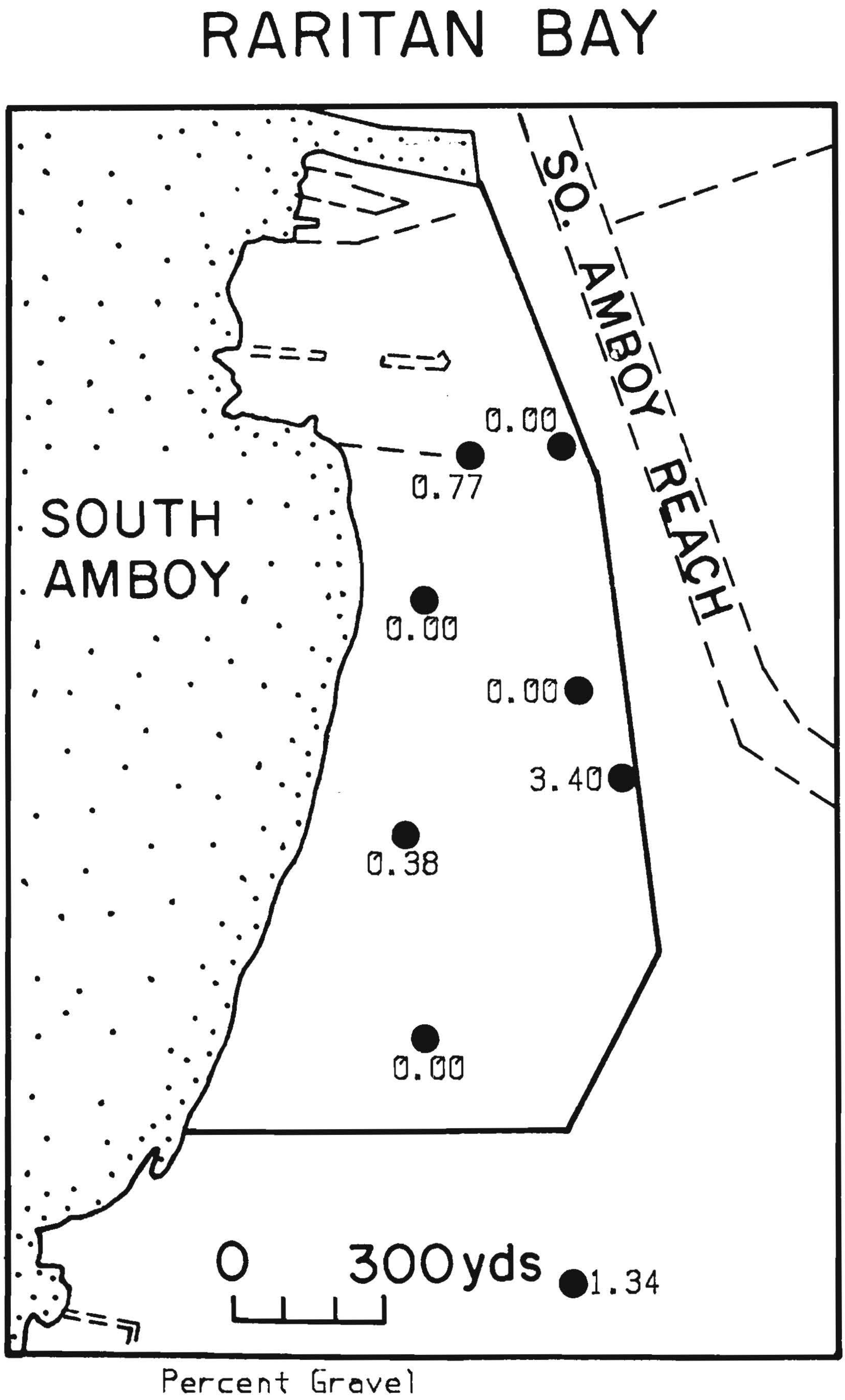

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
0.00
0.77
0.00
0.00
3.40
0.38
0.00
0 300yds
1.34
Percent Gravel

Figure 6

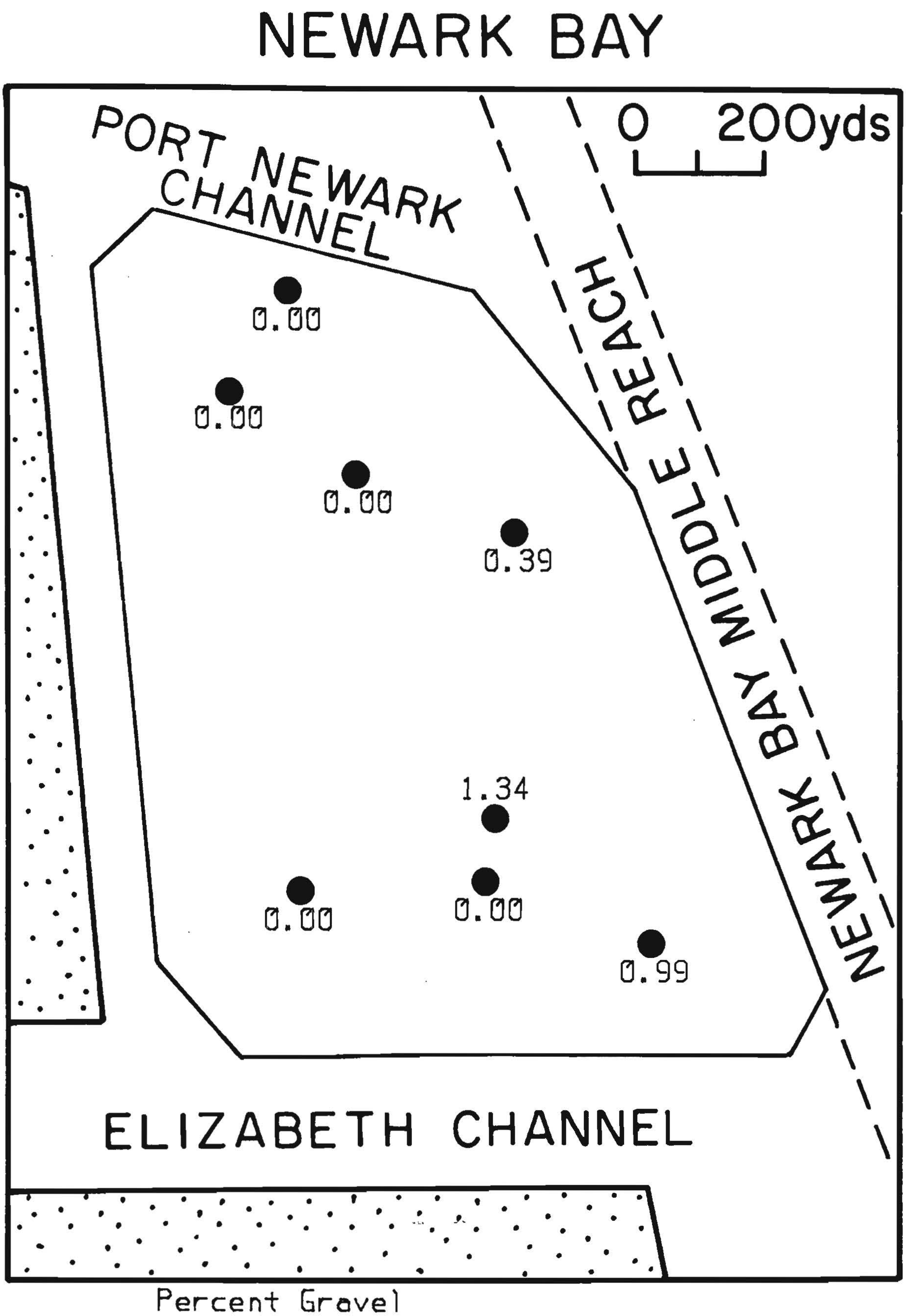
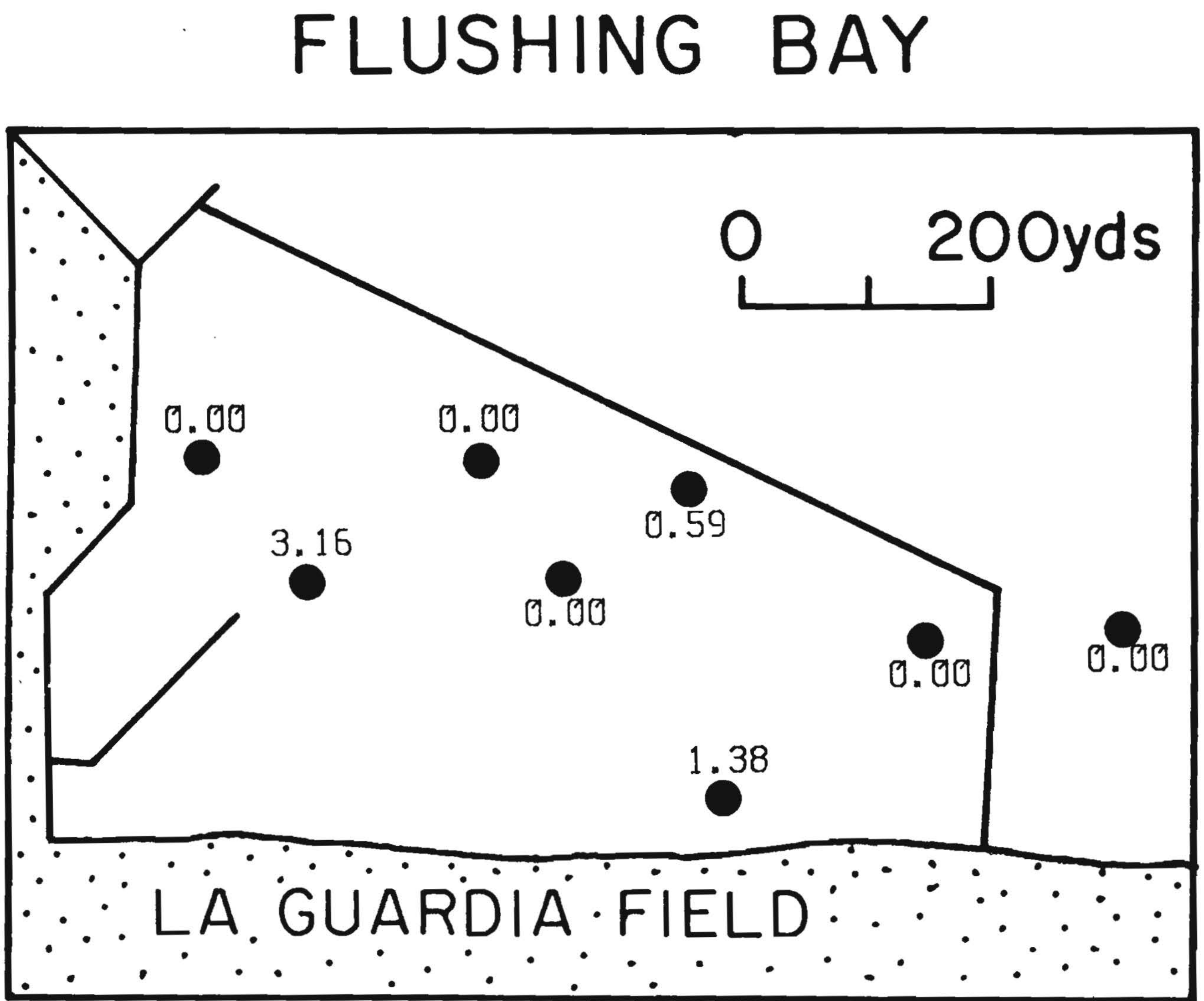

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
0.00
0.00
0.00
0.39
1.34
0.00
0.00
0.99
ELIZABETH CHANNEL
Percent Gravel

Figure 7



Percent Gravel

Figure 8

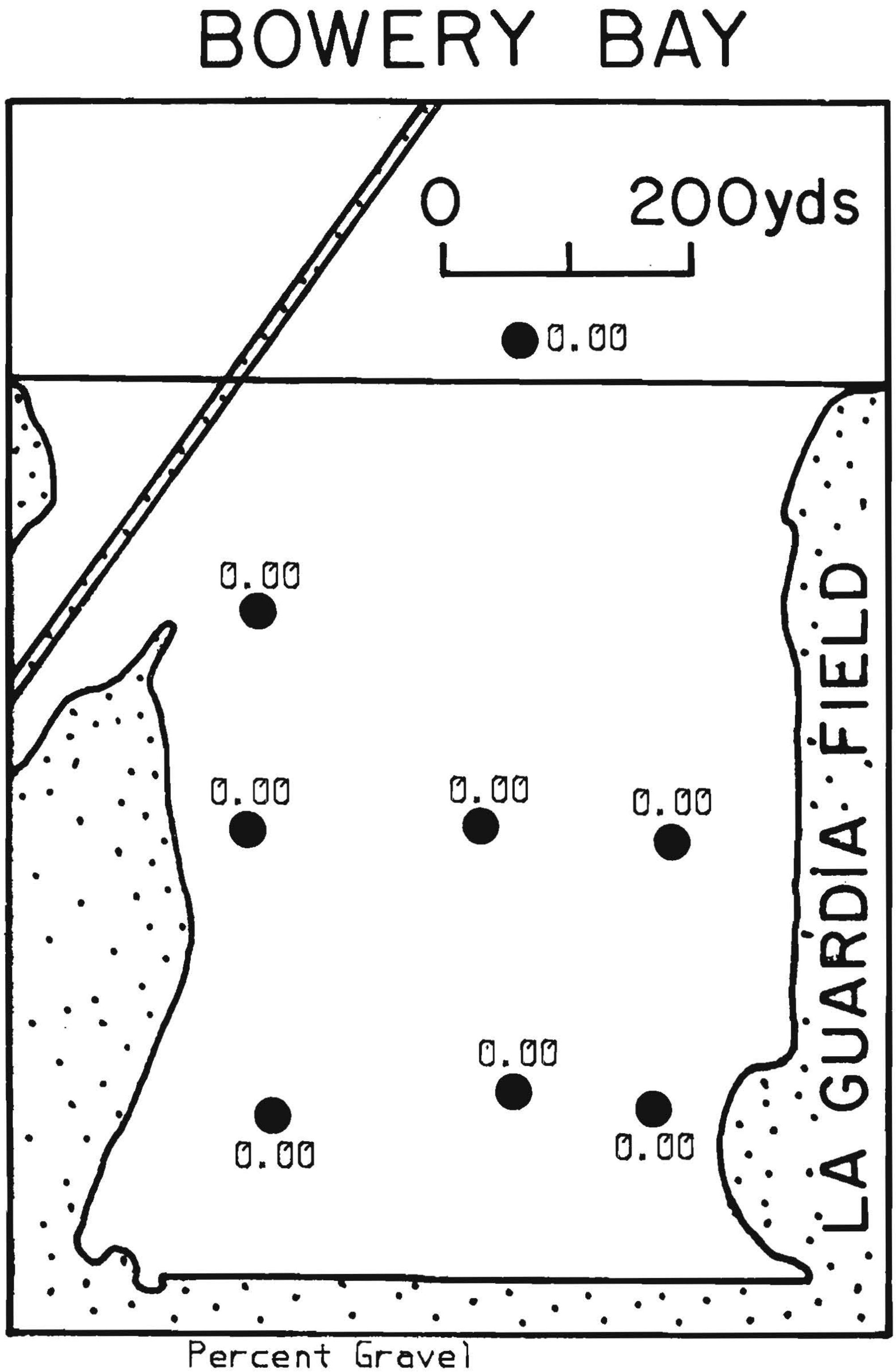

BOWERY BAY
0 200yds
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
LA GUARDIA FIELD
Percent Gravel

Figure 9

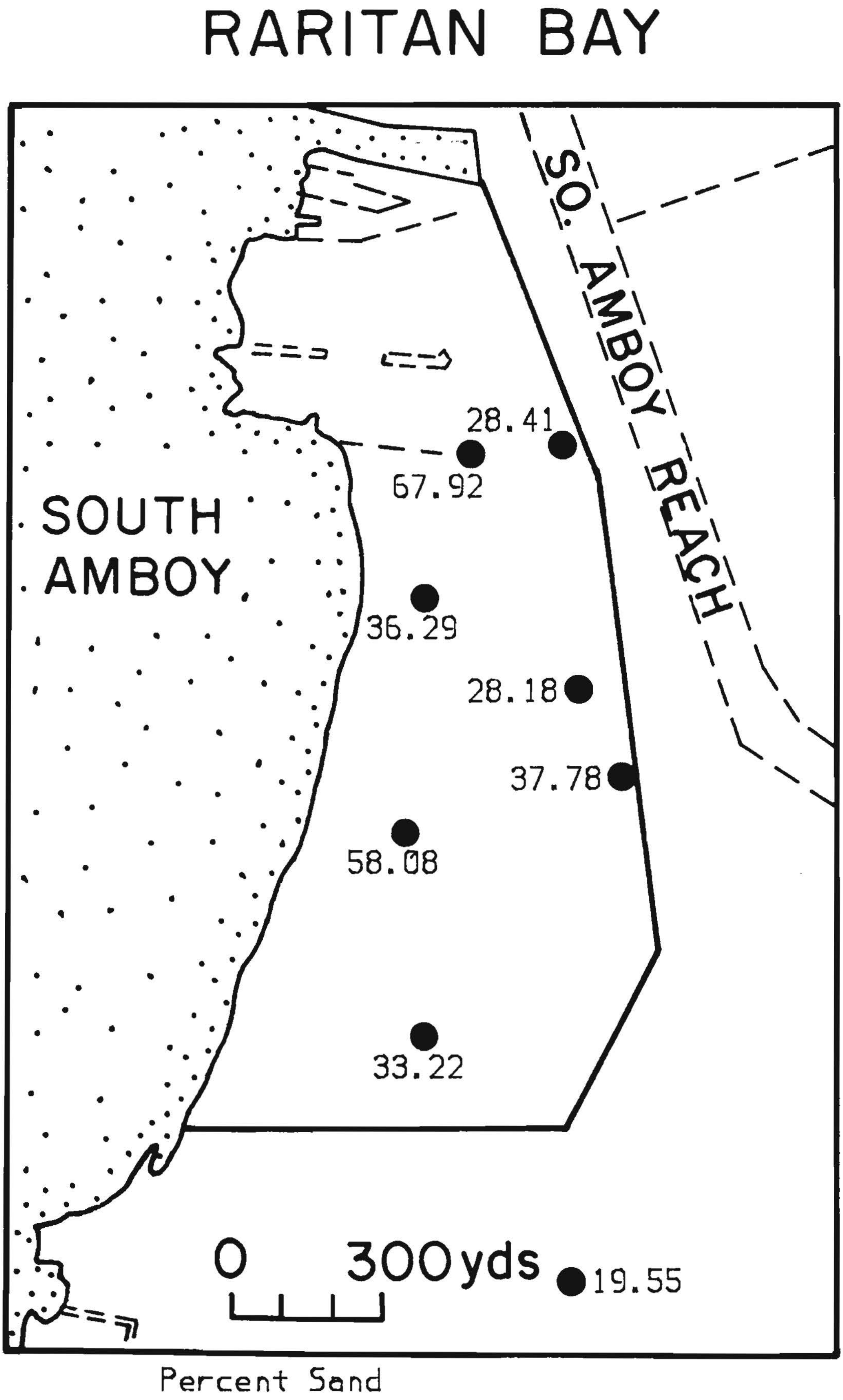

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
28.41
67.92
36.29
28.18
37.78
58.08
33.22
0
300yds
19.55
Percent Sand

Figure 10

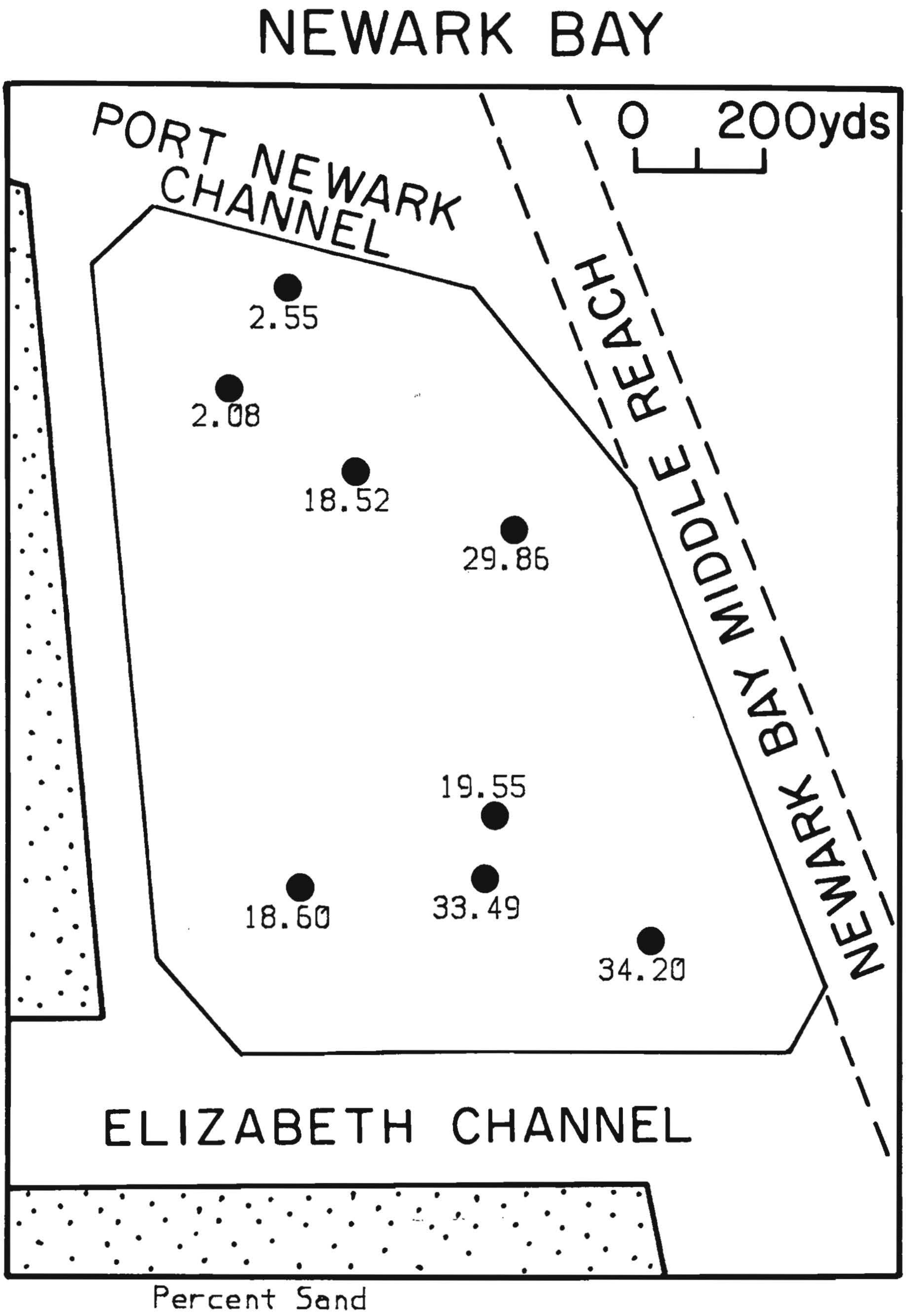

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
2.55
2.08
18.52
29.86
19.55
18.60
33.49
34.20
ELIZABETH CHANNEL
Percent Sand

Figure 11

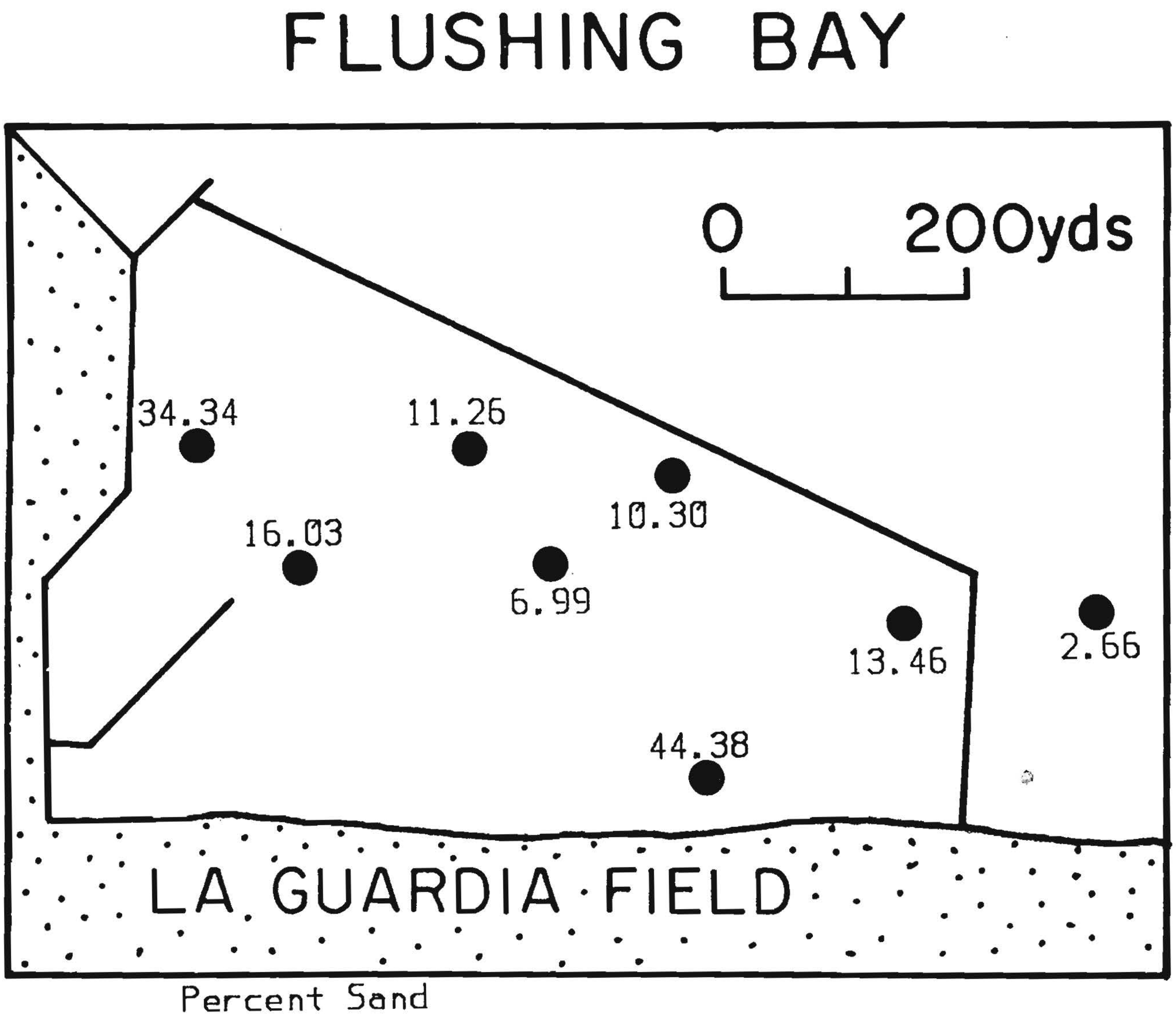

FLUSHING BAY
0
200yds
34.34
11.26
10.30
16.03
6.99
13.46
2.66
44.38
LA GUARDIA FIELD
Percent Sand

Figure 12

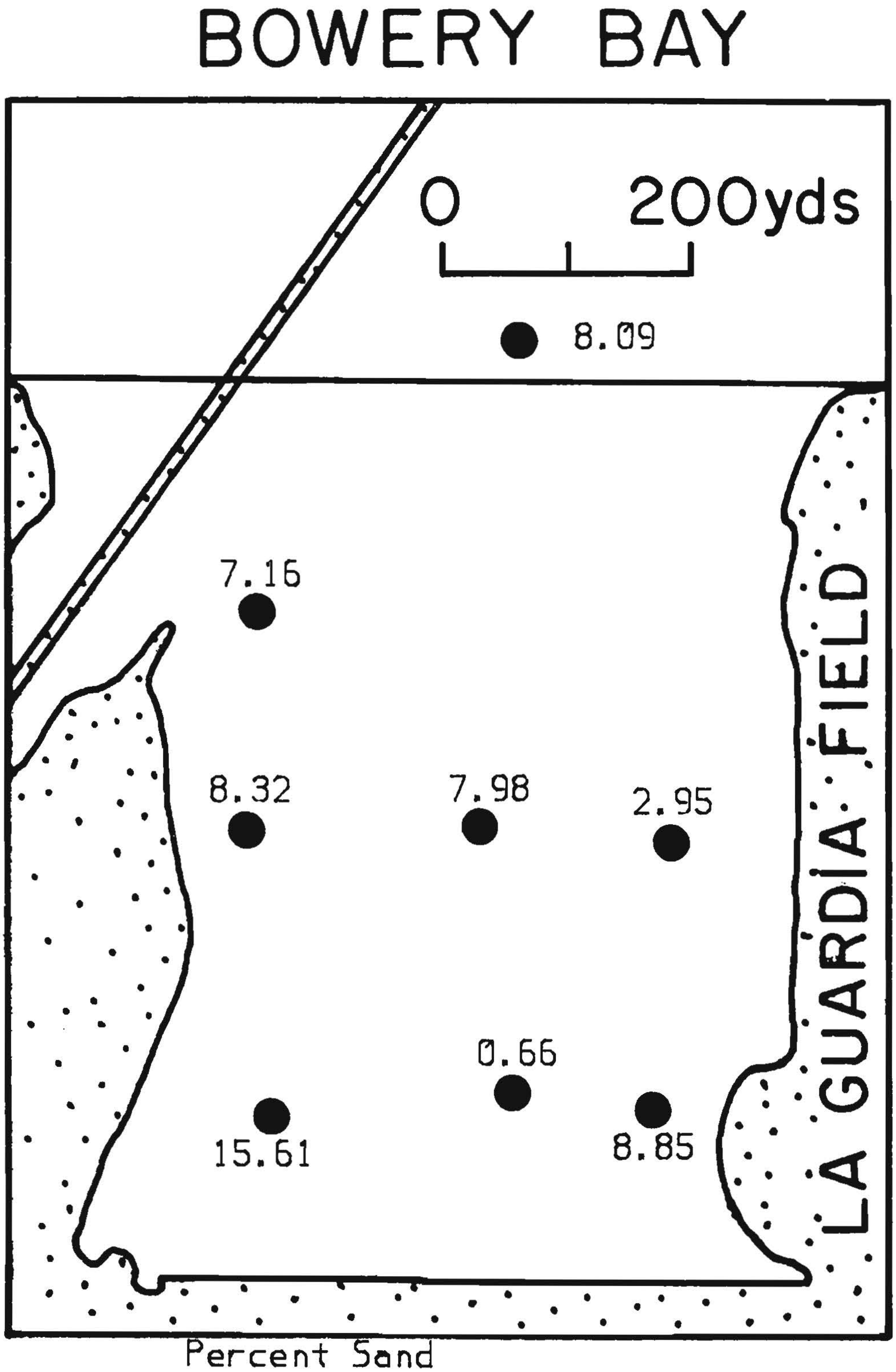

BOWERY BAY
0
200yds
8.09
7.16
8.32
7.98
2.95
0.66
15.61
8.85
LA GUARDIA FIELD
Percent Sand

Figure 13

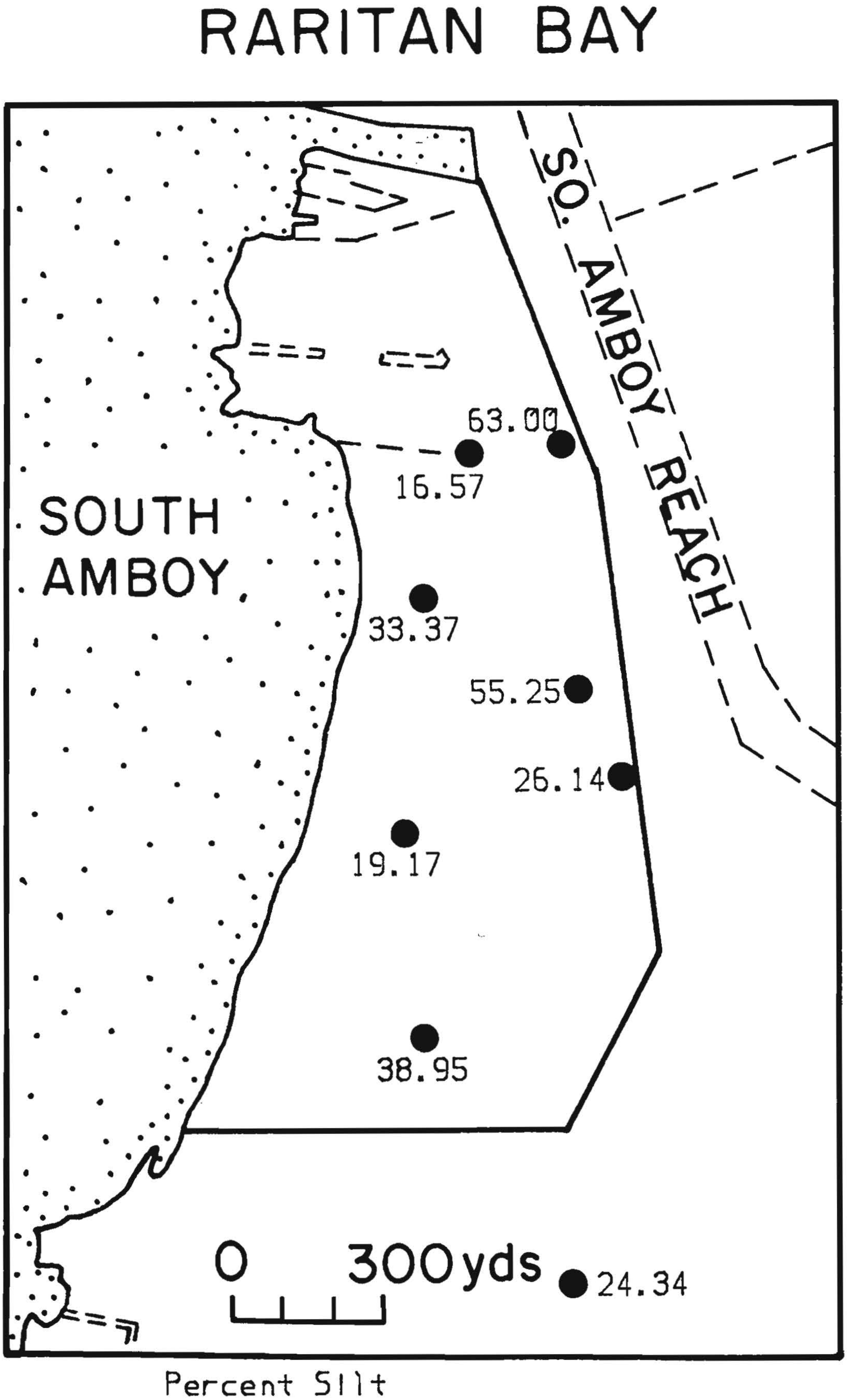

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
63.00
16.57
33.37
55.25
26.14
19.17
38.95
24.34
0 300yds
Percent Silt

Figure 14

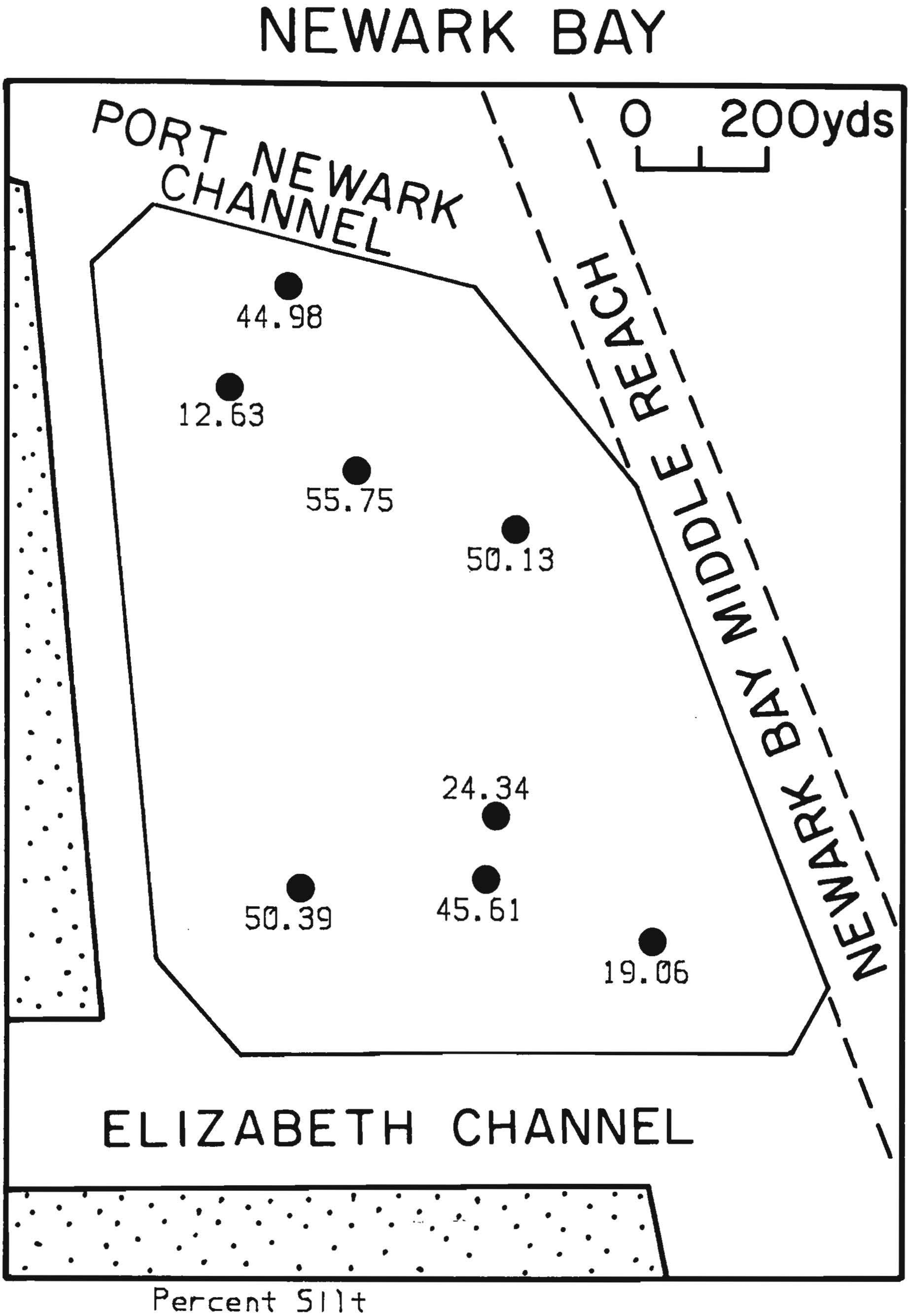
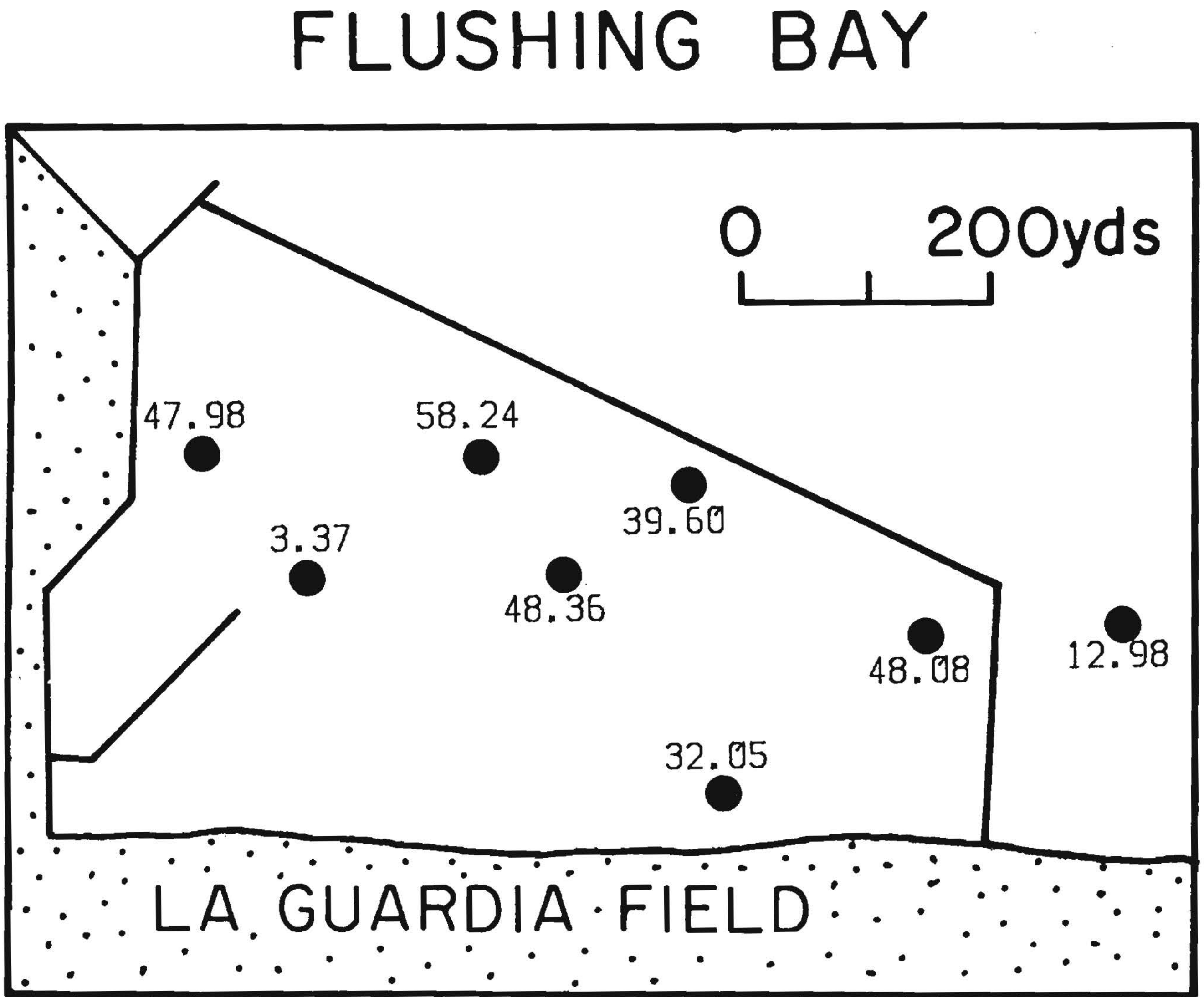

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
44.98
12.63
55.75
50.13
24.34
50.39
45.61
19.06
ELIZABETH CHANNEL
Percent Silt

Figure 15



Percent Silt

Figure 16

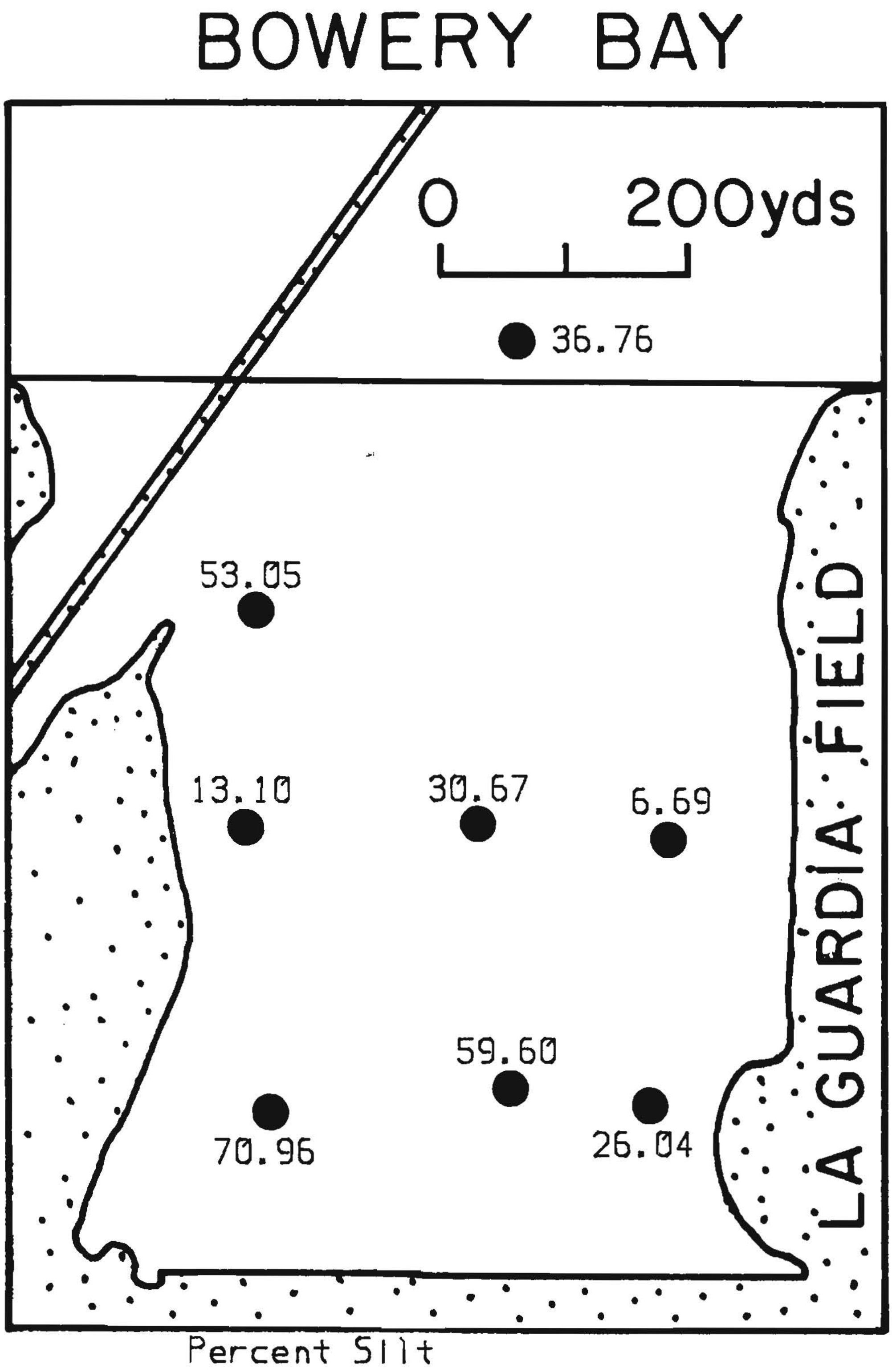

BOWERY BAY
0
200yds
36.76
53.05
13.10
30.67
6.69
59.60
70.96
26.04
LA GUARDIA FIELD
Percent Silt

Figure 17

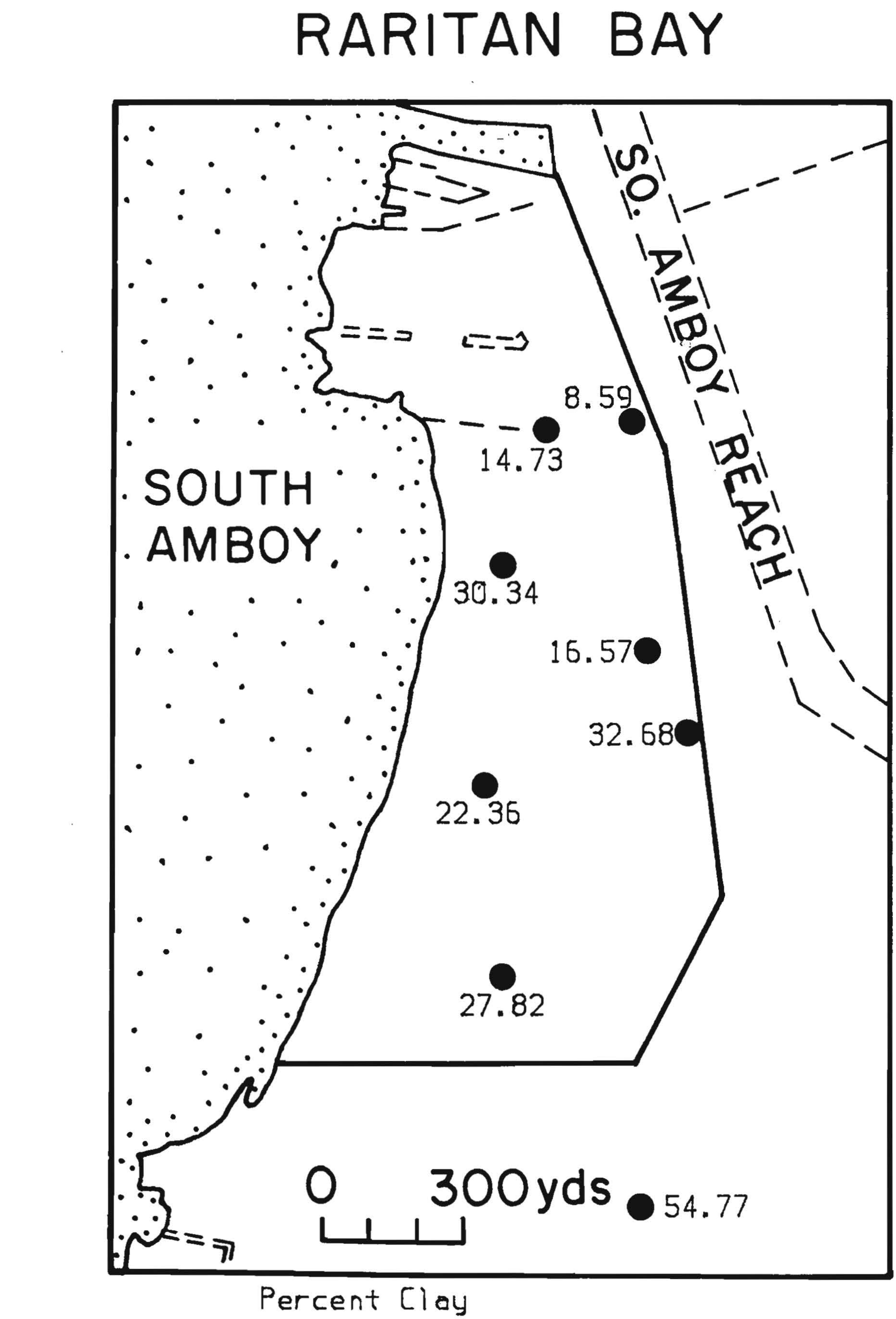

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
8.59
14.73
30.34
16.57
32.68
22.36
27.82
0 300yds
54.77
Percent Clay

Figure 18

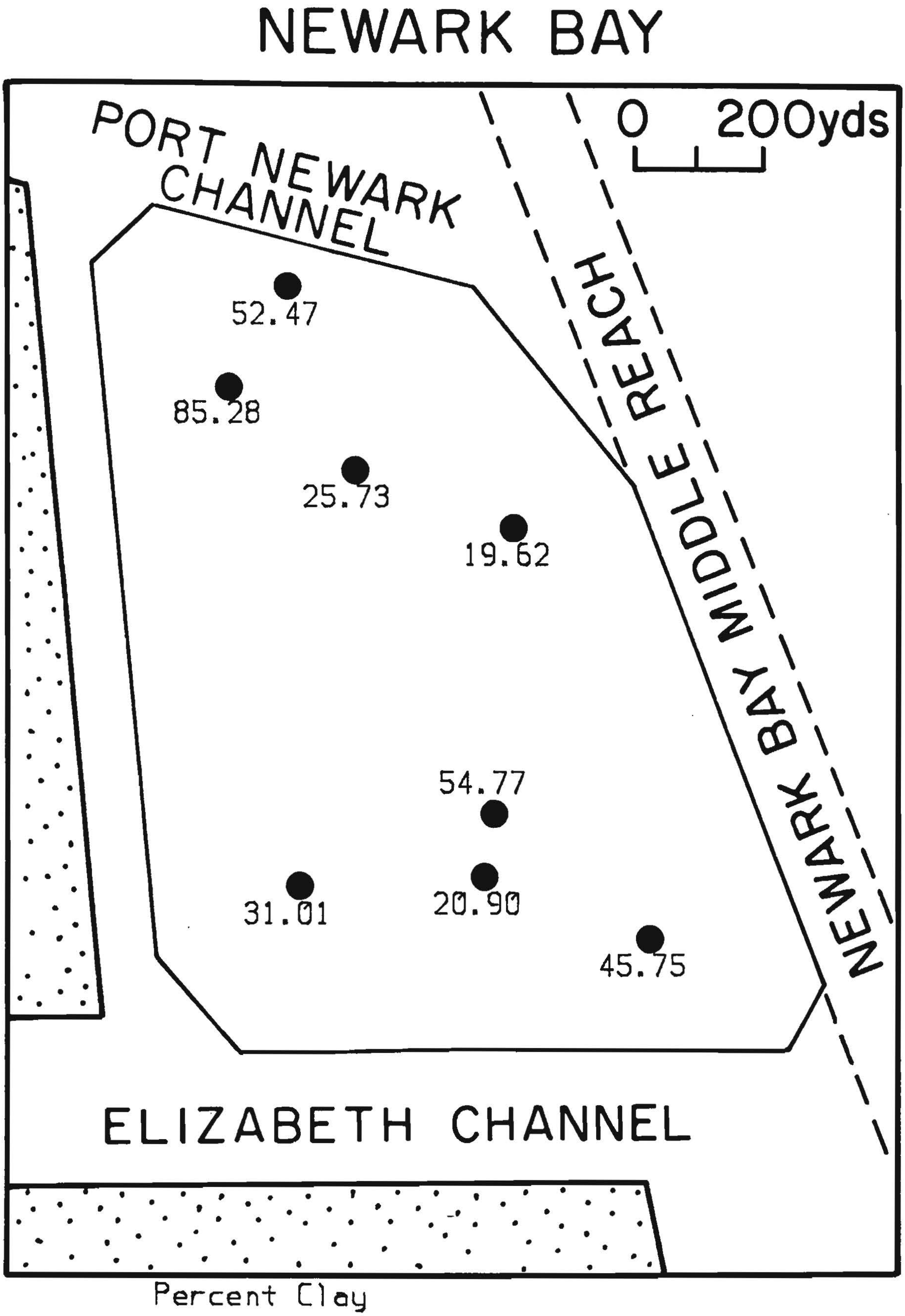

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
52.47
85.28
25.73
19.62
54.77
31.01
20.90
45.75
ELIZABETH CHANNEL
Percent Clay

Figure 19

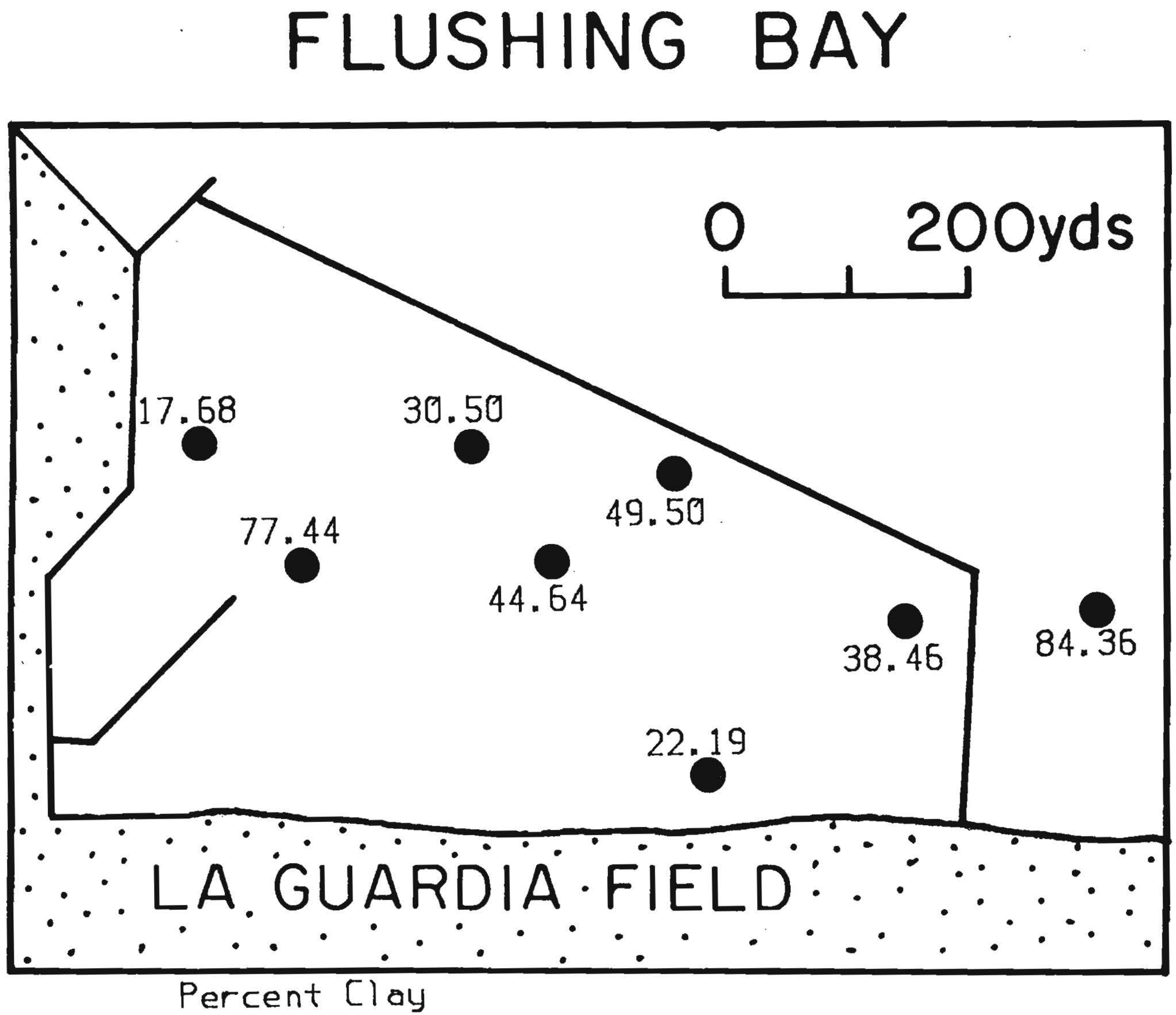

FLUSHING BAY
0
200yds
17.68
30.50
49.50
77.44
44.64
38.46
84.36
22.19
LA GUARDIA FIELD
Percent Clay

Figure 20

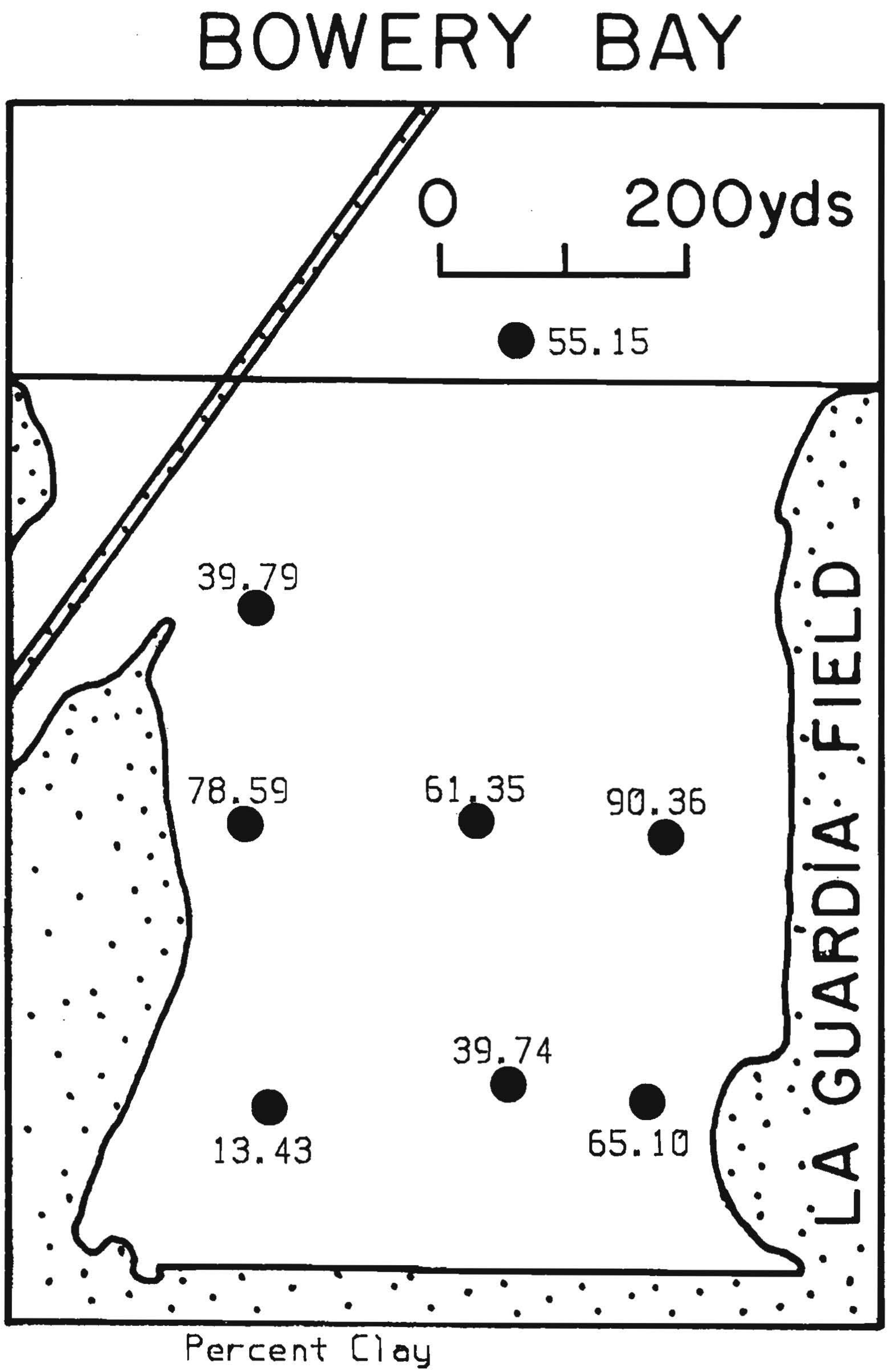

BOWERY BAY
0
200yds
55.15
39.79
78.59
61.35
90.36
39.74
13.43
65.10
LA GUARDIA FIELD
Percent Clay

Figure 21

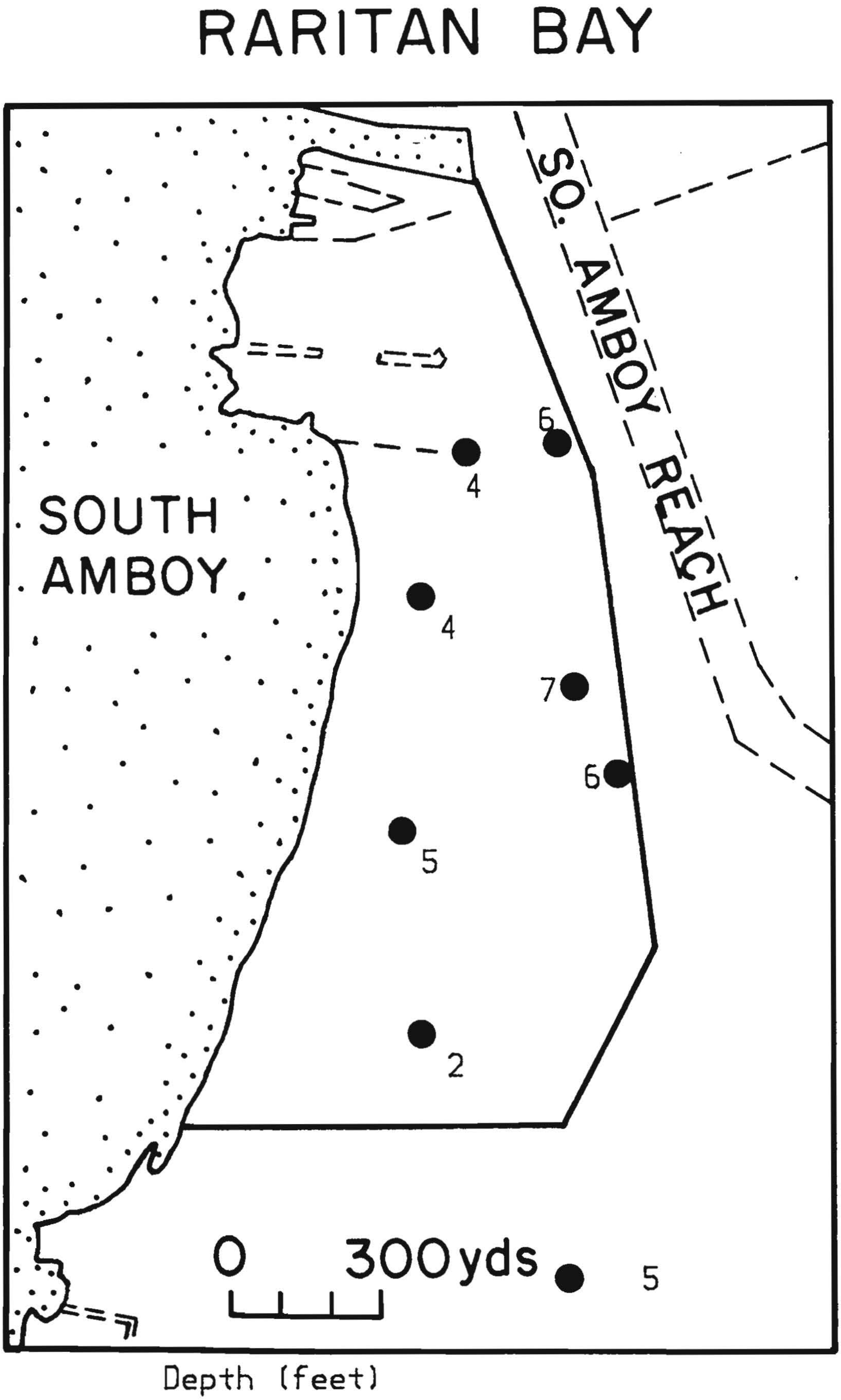

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
6
4
4
7
6
5
2
5
0 300yds
Depth (feet)

Figure 22

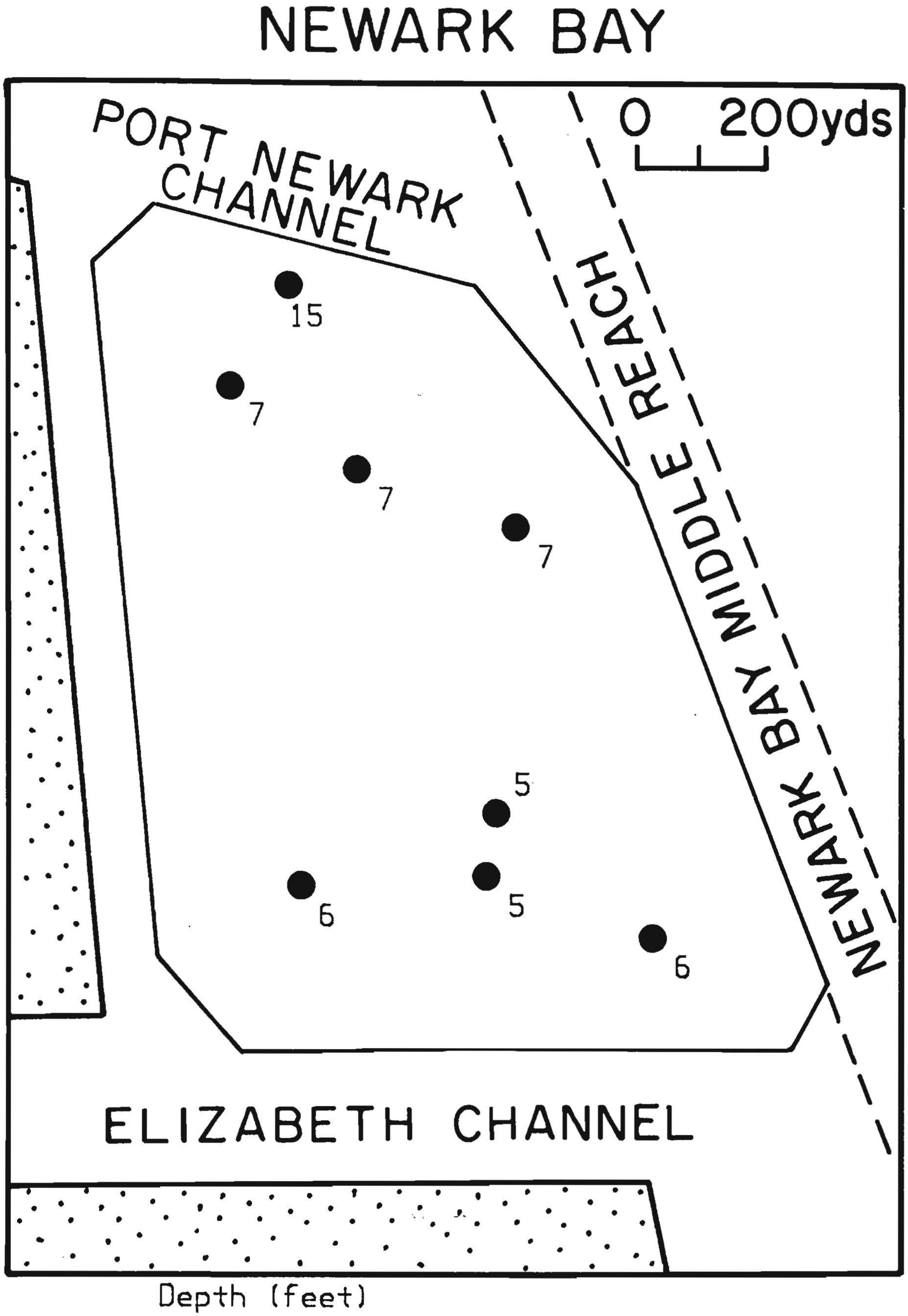

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
15
7
7
7
5
5
6
6
ELIZABETH CHANNEL
Depth (feet)

Figure 23

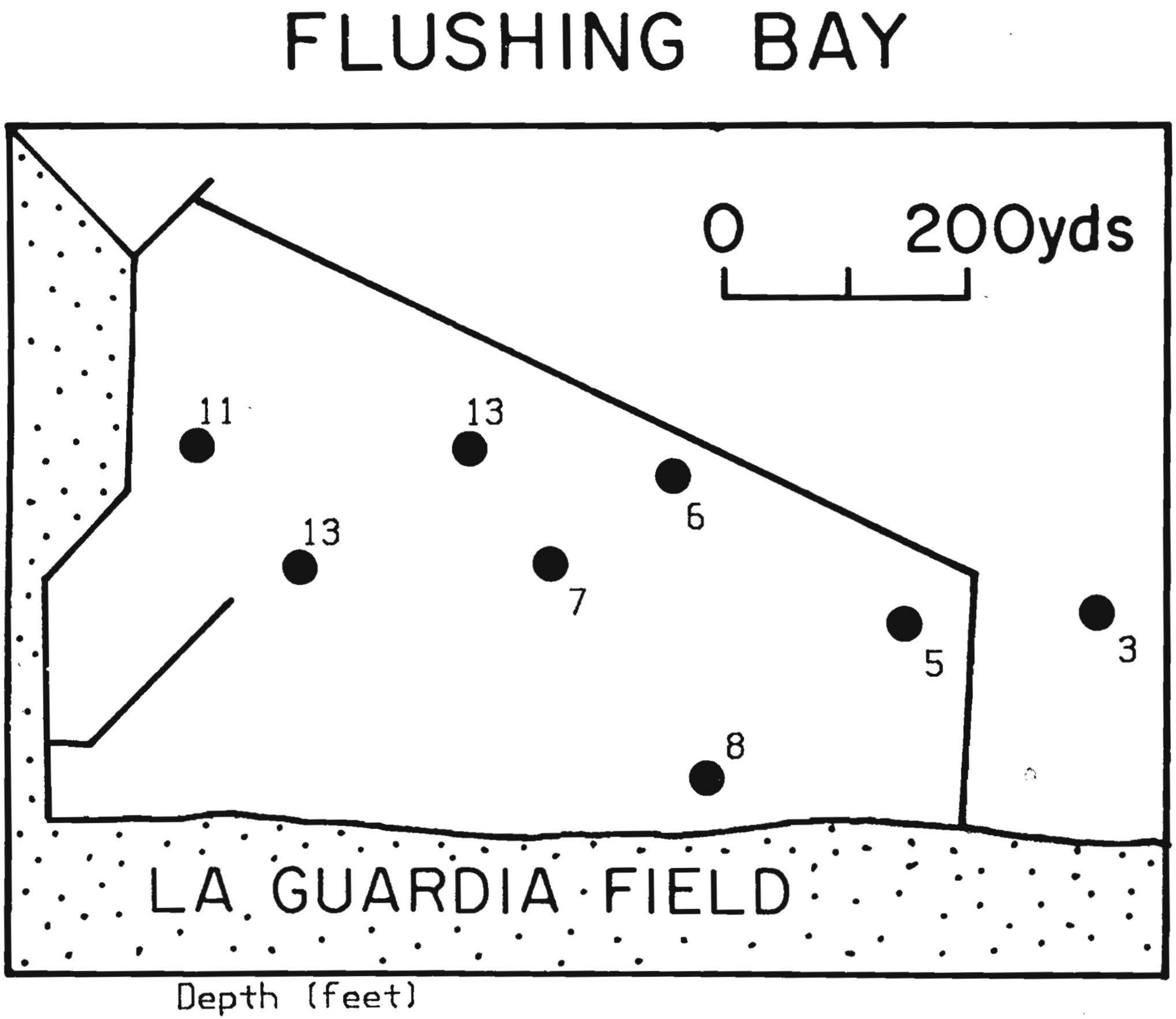

FLUSHING BAY
0
200yds
11
13
6
13
7
5
3
8
LA GUARDIA FIELD
Depth (feet)

Figure 24

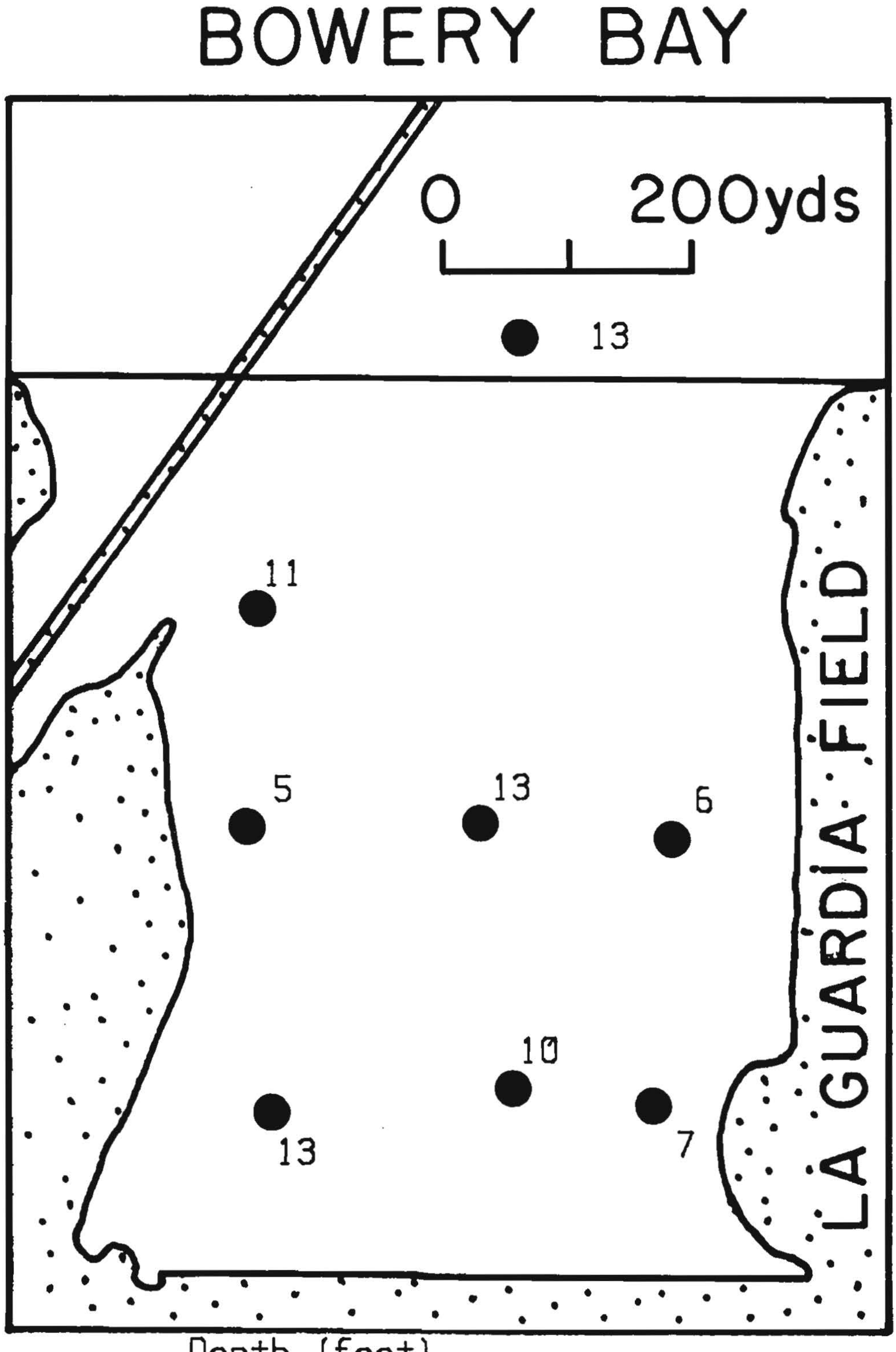

BOWERY BAY
0
200yds
13
11
5
13
6
10
13
7
LA GUARDIA FIELD
Depth (feet)

Figure 25

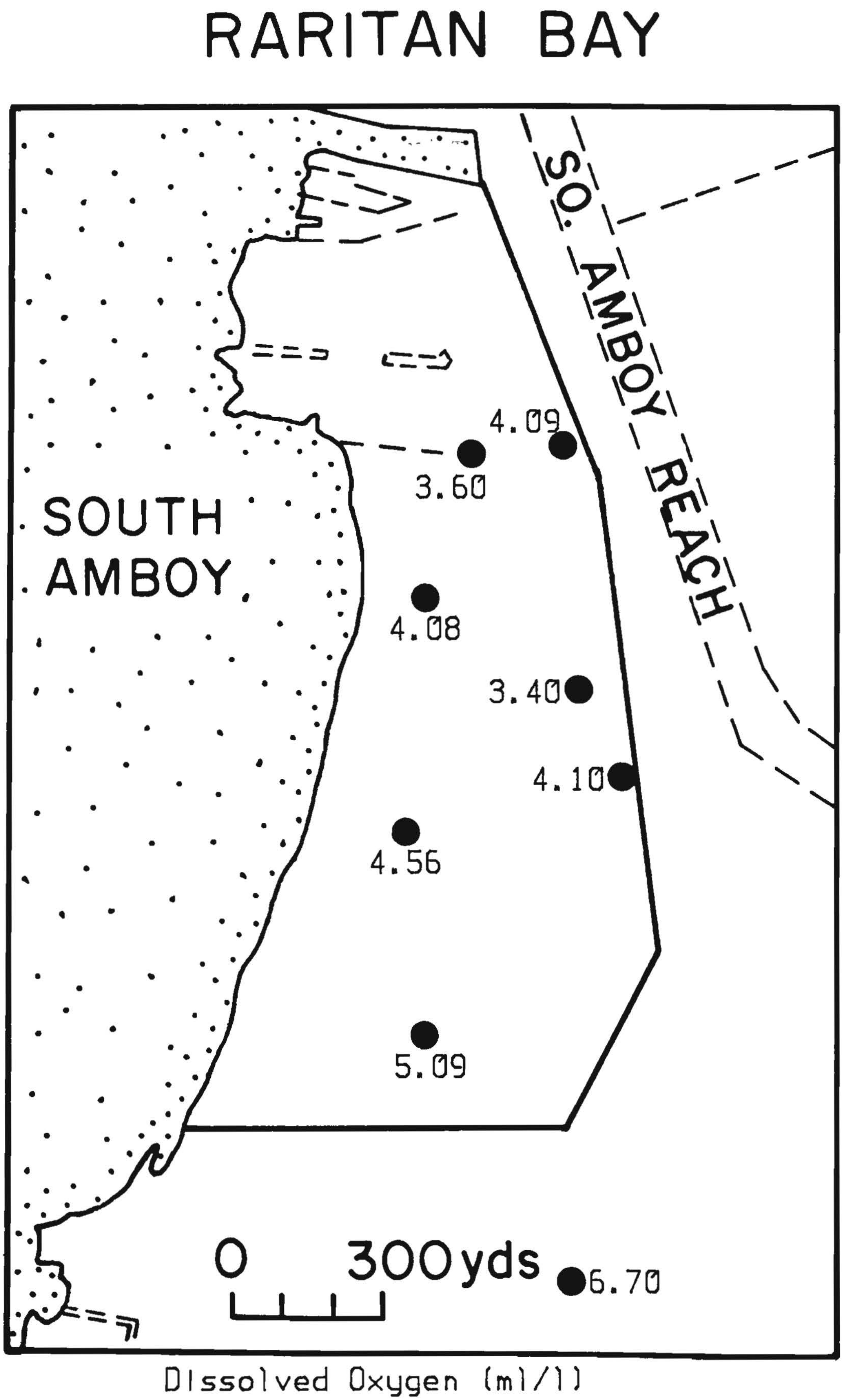
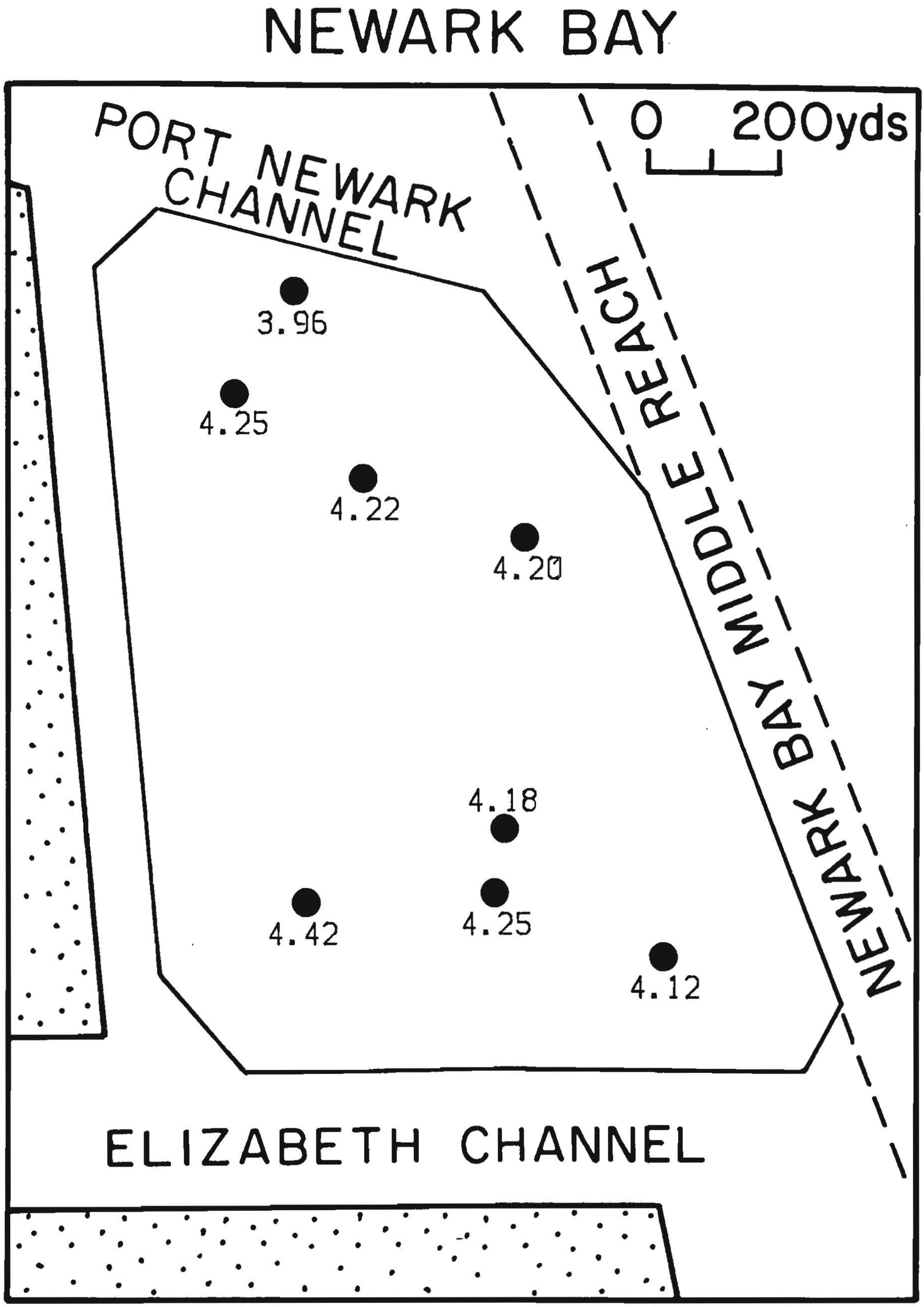

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
4.09
3.60
4.08
3.40
4.10
4.56
5.09
0 300yds
6.70
Dissolved Oxygen (ml/l)

Figure 26



Dissolved Oxygen (ml/l)

Figure 27

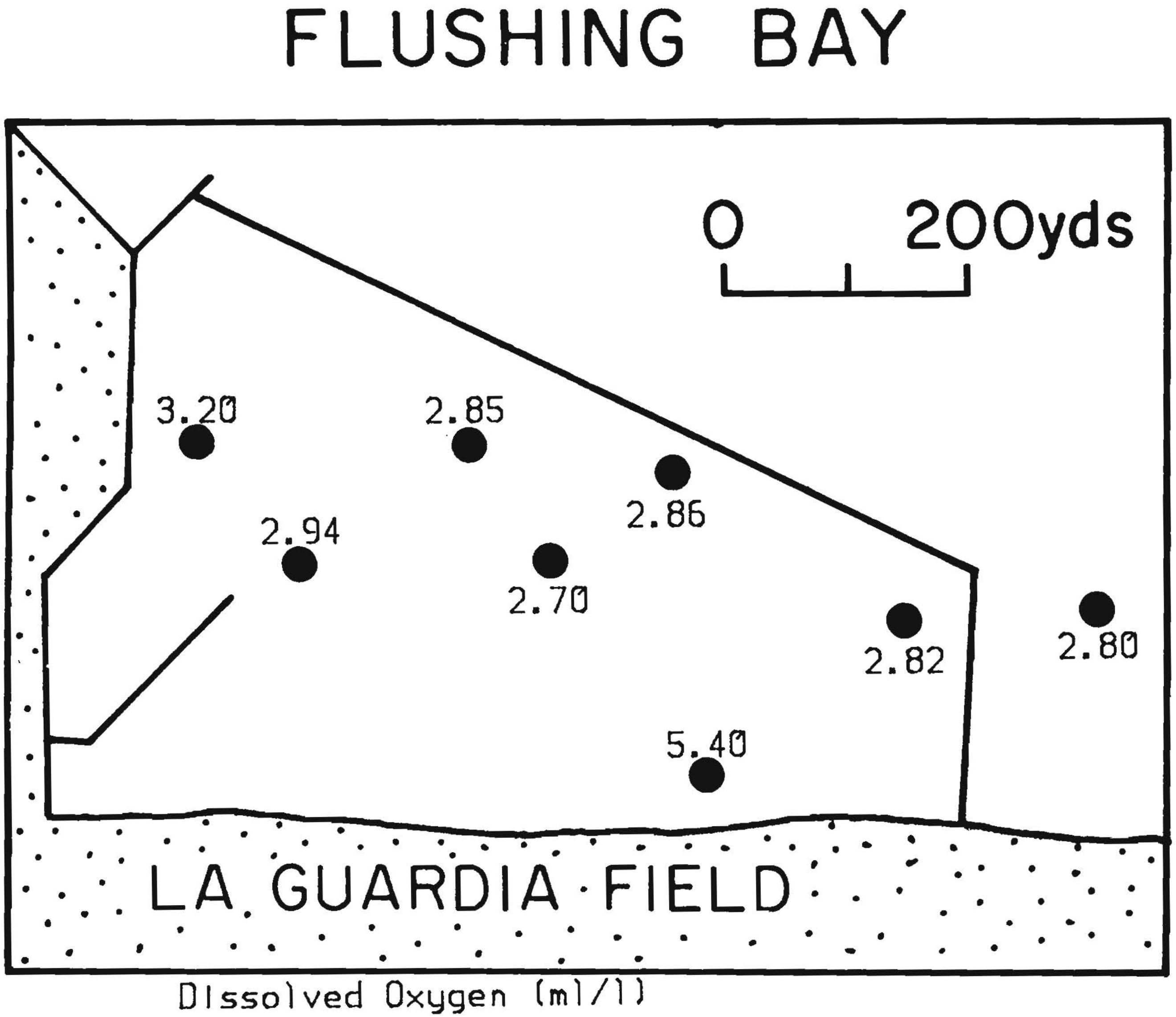

FLUSHING BAY
0
200yds
3.20
2.85
2.86
2.94
2.70
2.82
2.80
5.40
LA GUARDIA FIELD
Dissolved Oxygen (ml/l)

Figure 28

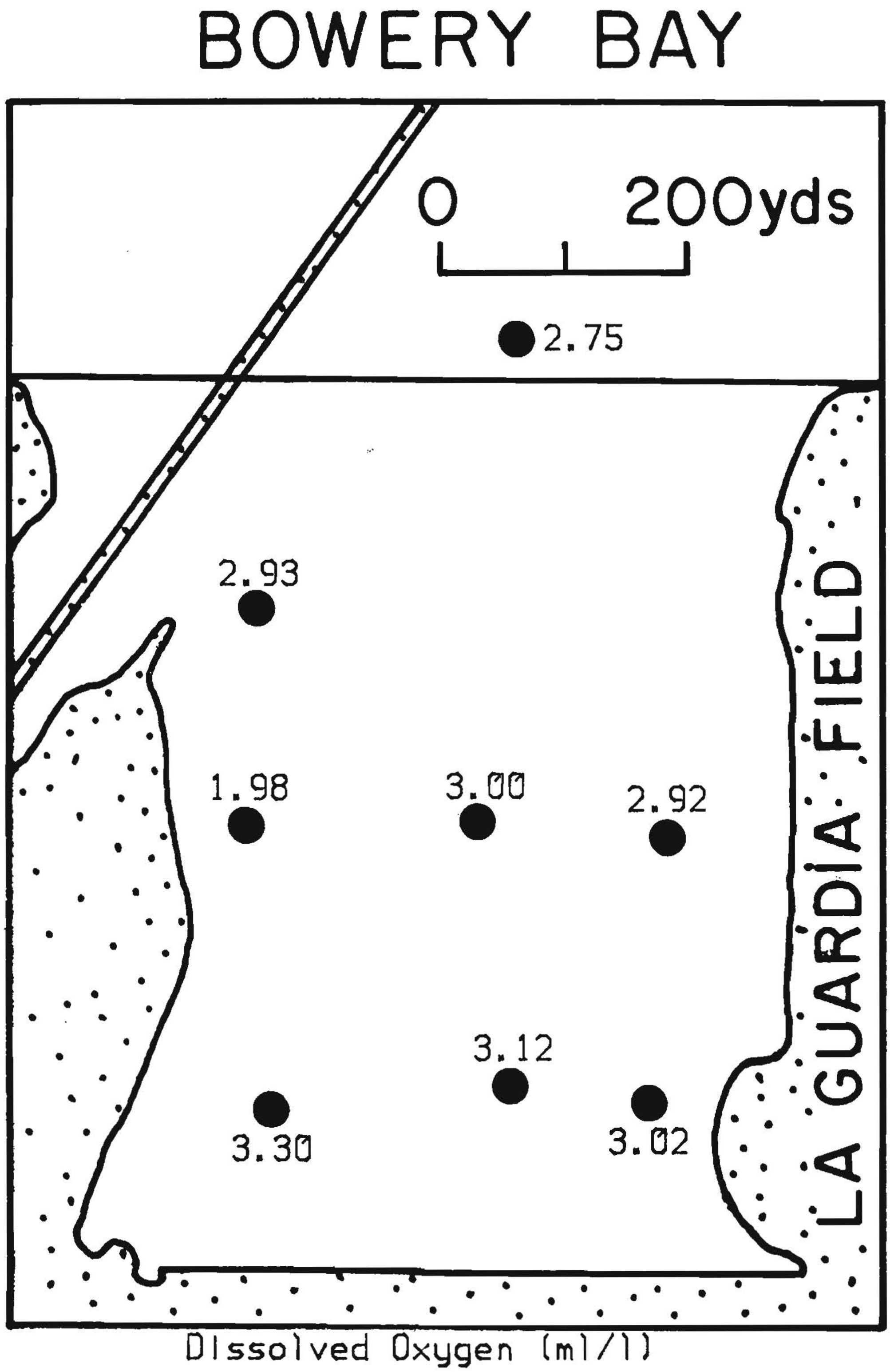

BOWERY BAY
0
200yds
2.75
2.93
1.98
3.00
2.92
3.12
3.30
3.02
LA GUARDIA FIELD
Dissolved Oxygen (ml/l)

Figure 29

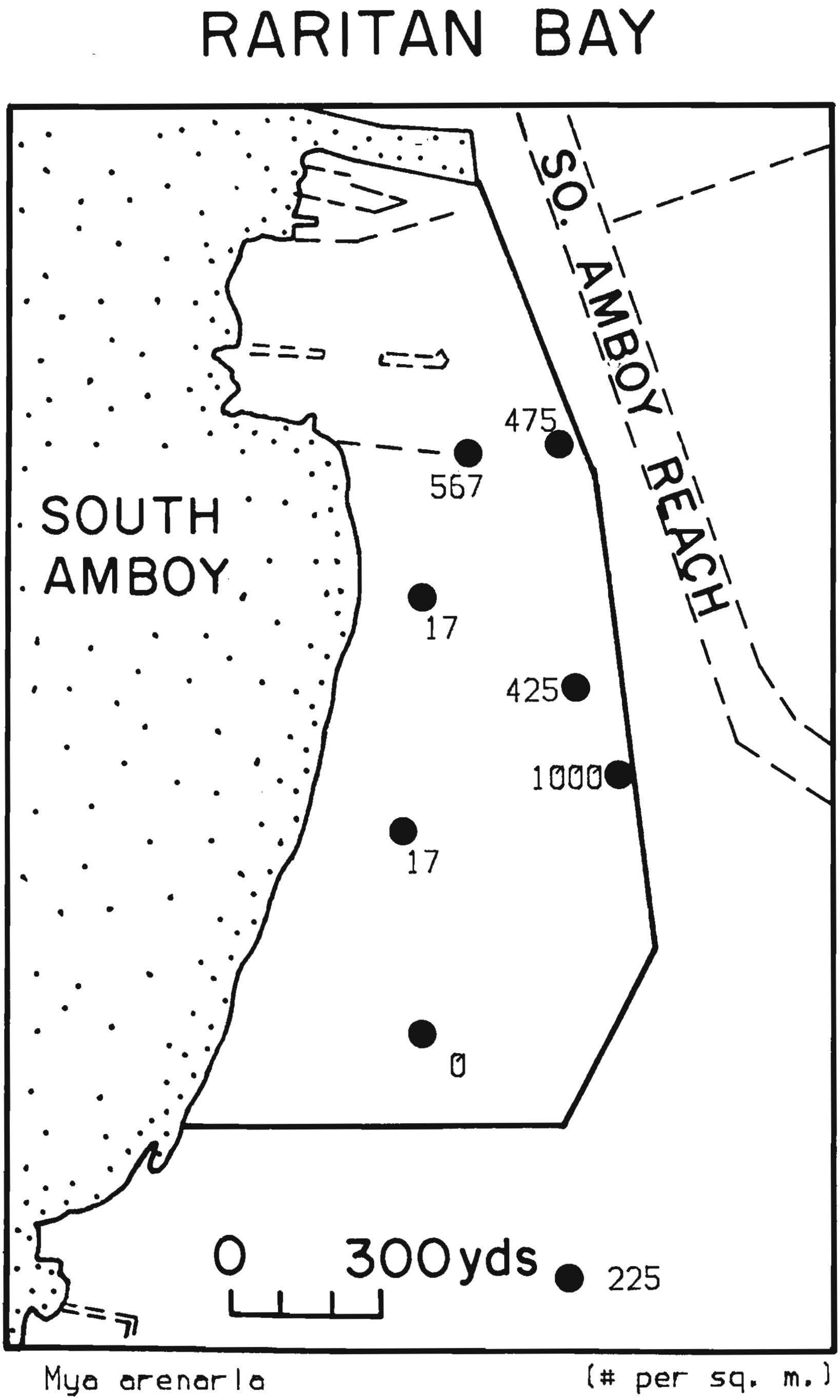
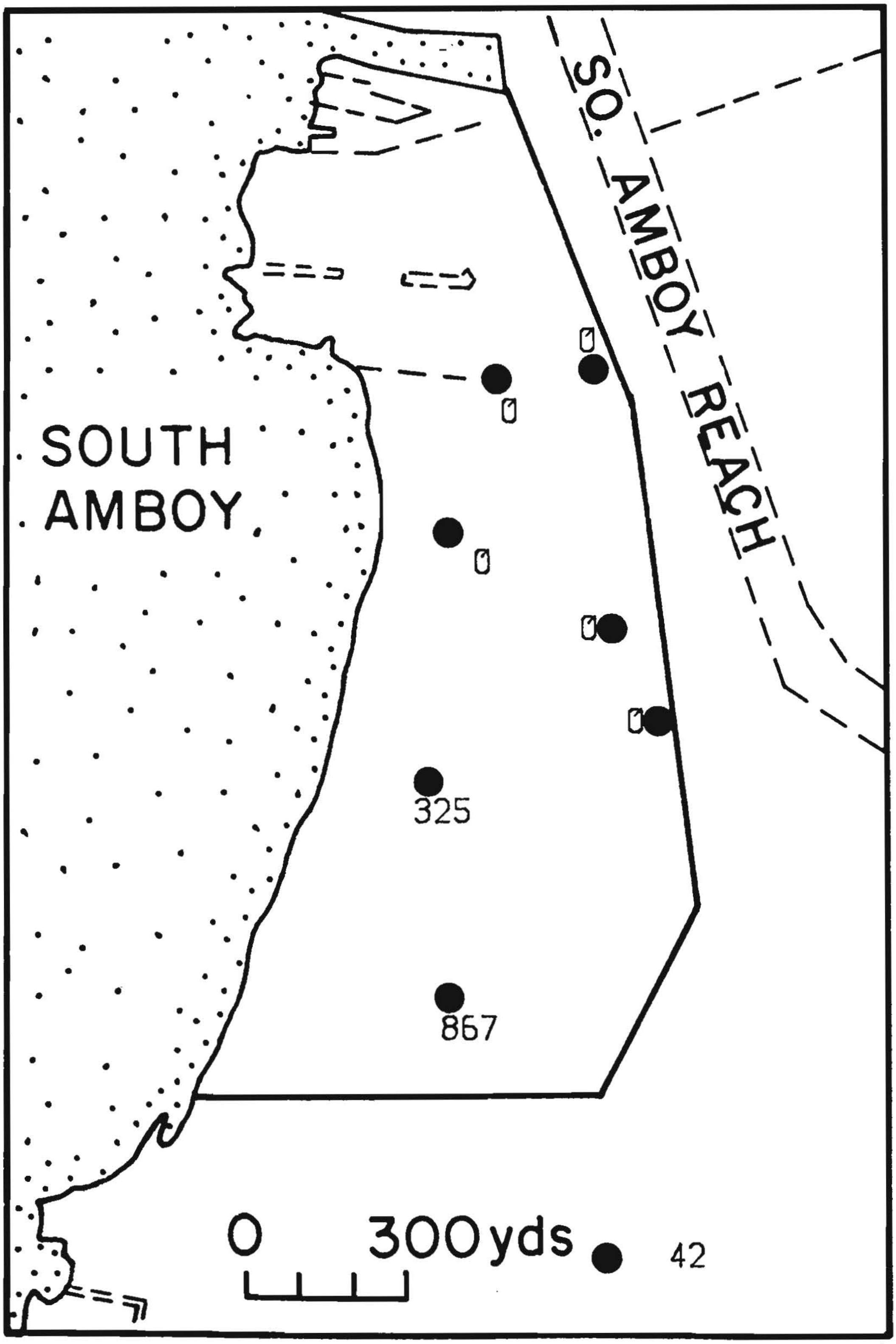

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
475
567
17
425
1000
17
0
0 300yds
225
Mya arenaria
(# per sq. m.)

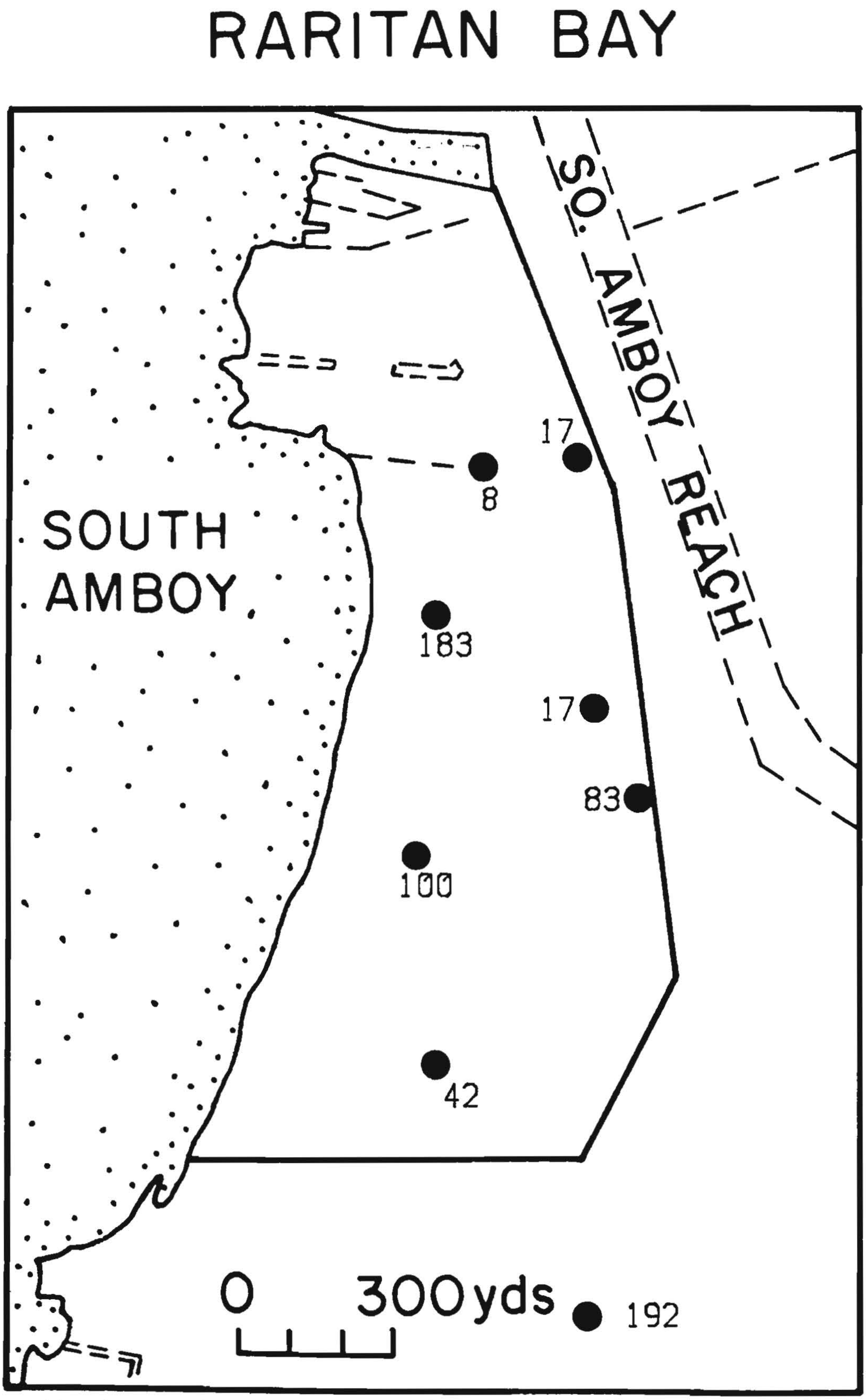
Figure 30

RARITAN BAY



Streblosplo benedlctl (# per sq. m.)

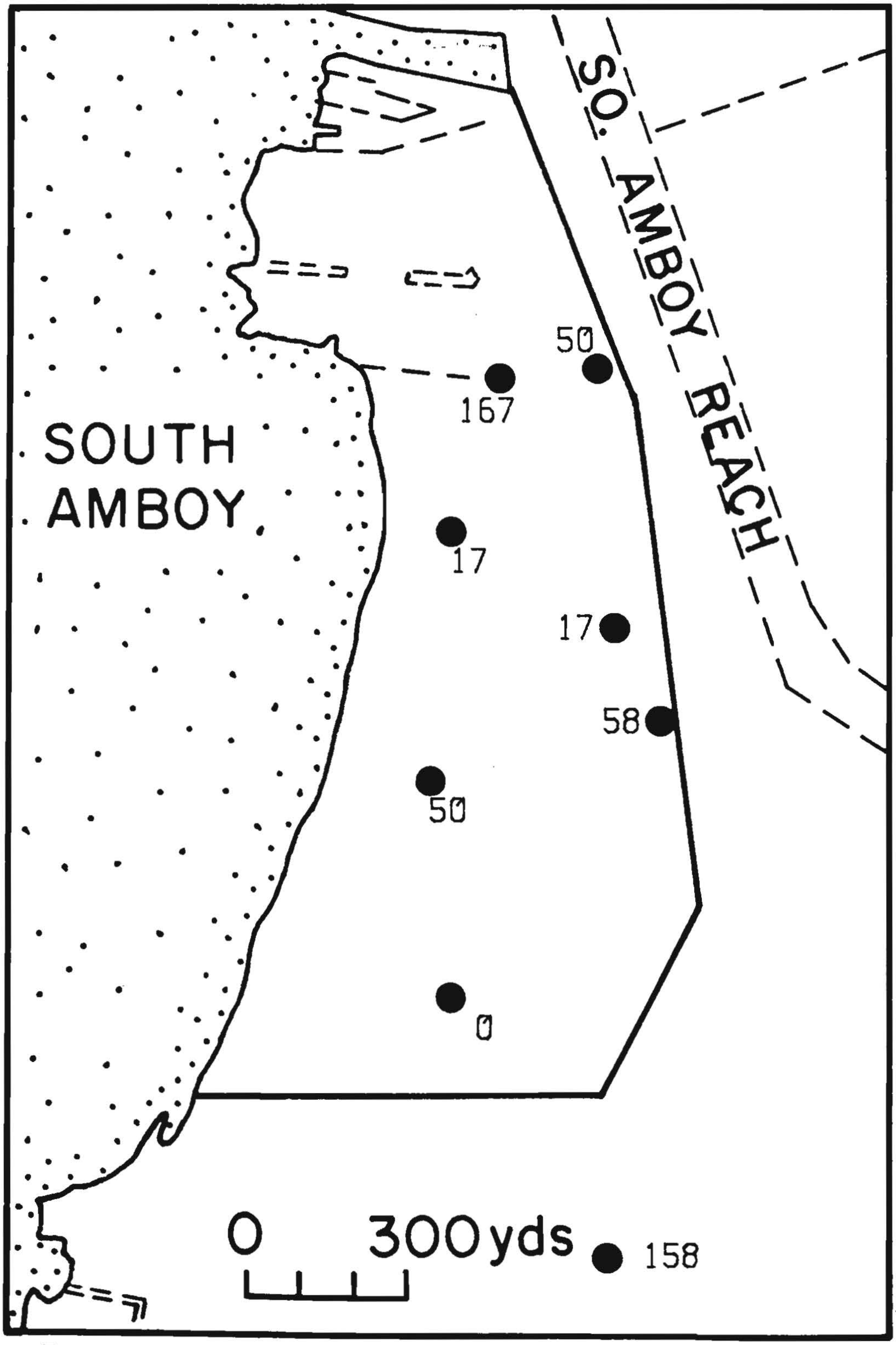
Figure 31



Haploscoloplos fragilis (# per sq. m.)

Figure 32

RARITAN BAY



Pectinaria gouldii (# per sq. m.)

Figure 33

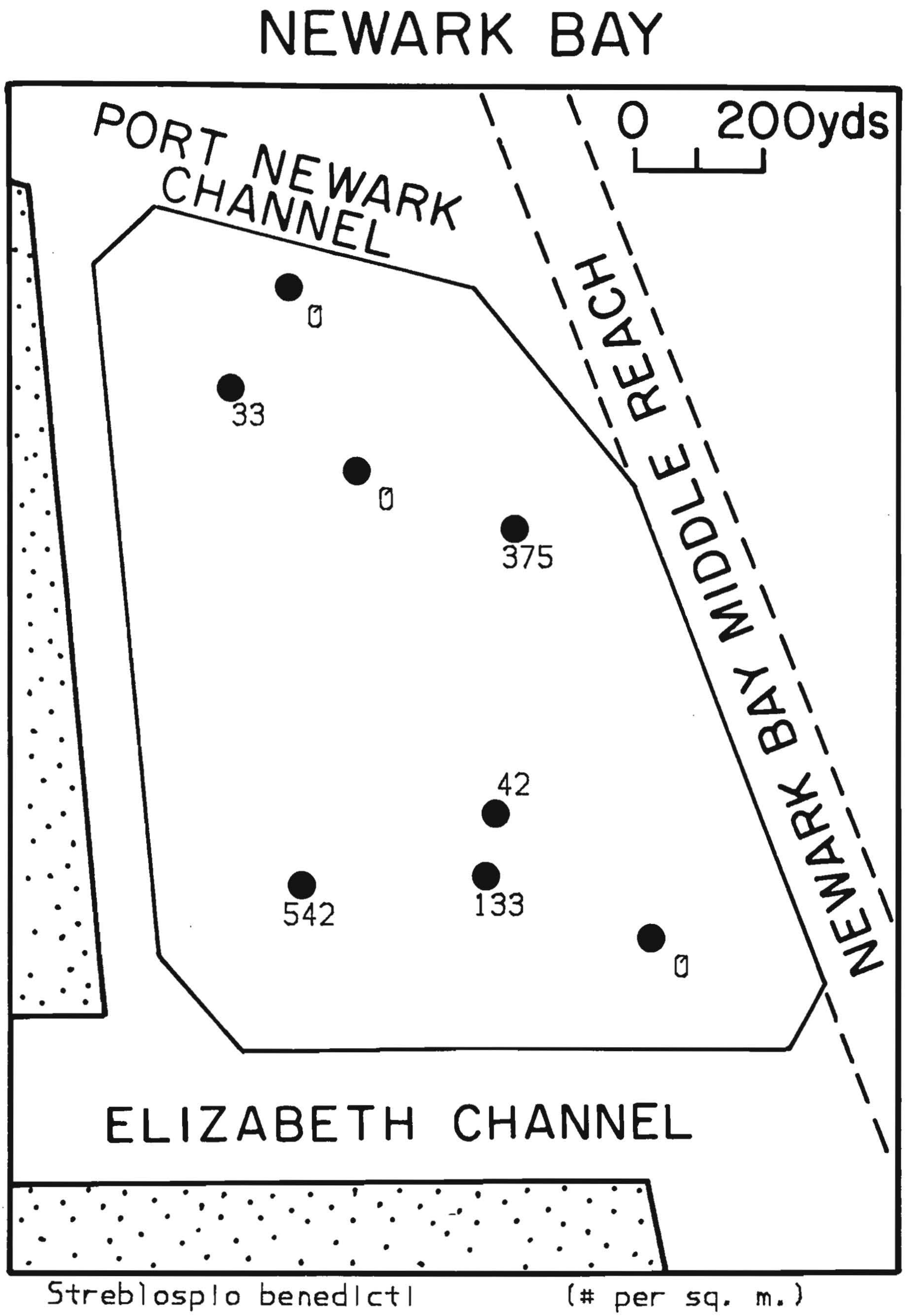

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
0
33
0
375
42
542
133
0
ELIZABETH CHANNEL
Streblospio benedicti (# per sq. m.)

Figure 34

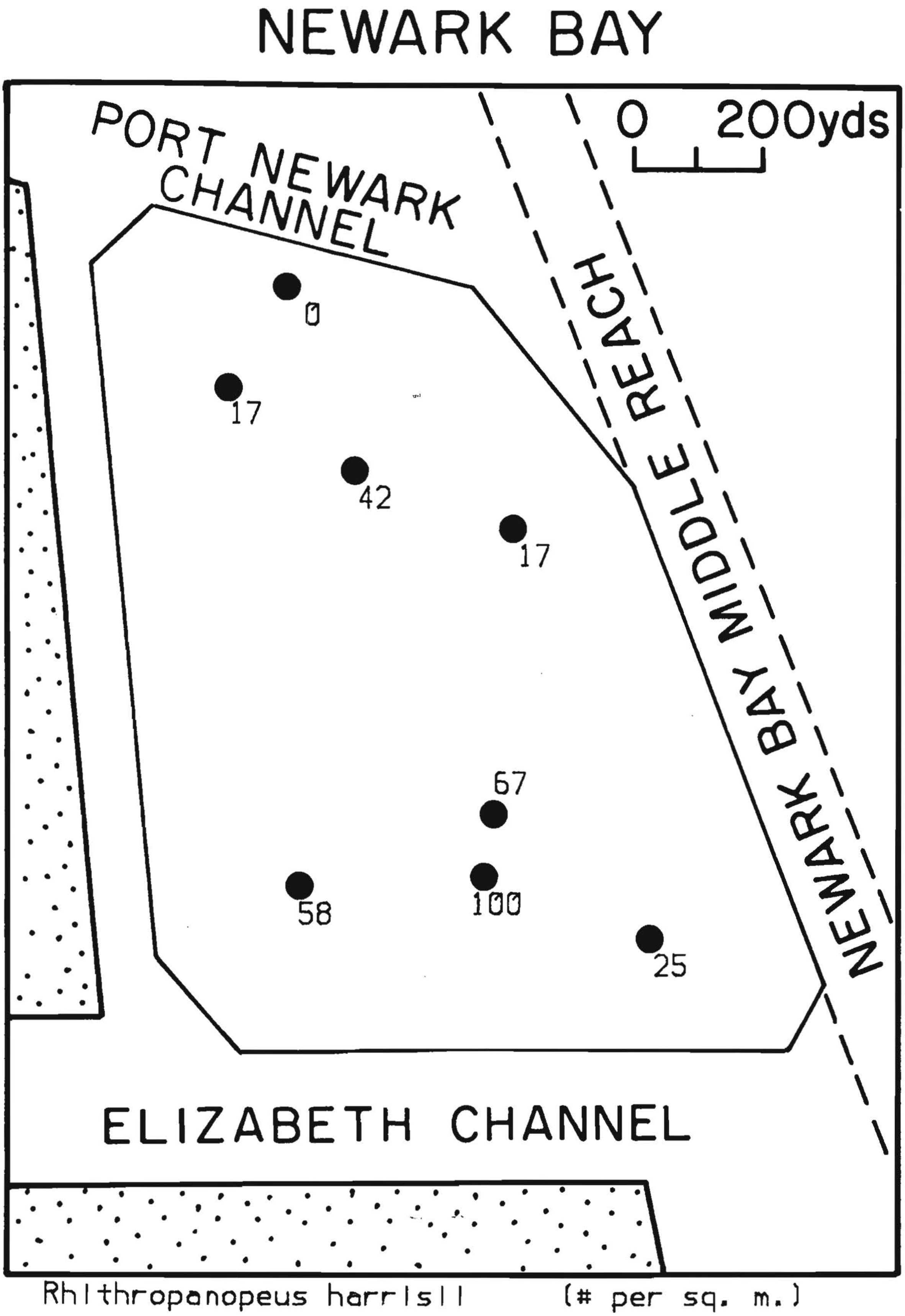

NEWARK BAY
0 200yds
PORT NEWARK CHANNEL
NEWARK BAY MIDDLE REACH
0
17
42
17
67
58
100
25
ELIZABETH CHANNEL
Rhithropanopeus harrisii (# per sq. m.)

Figure 35

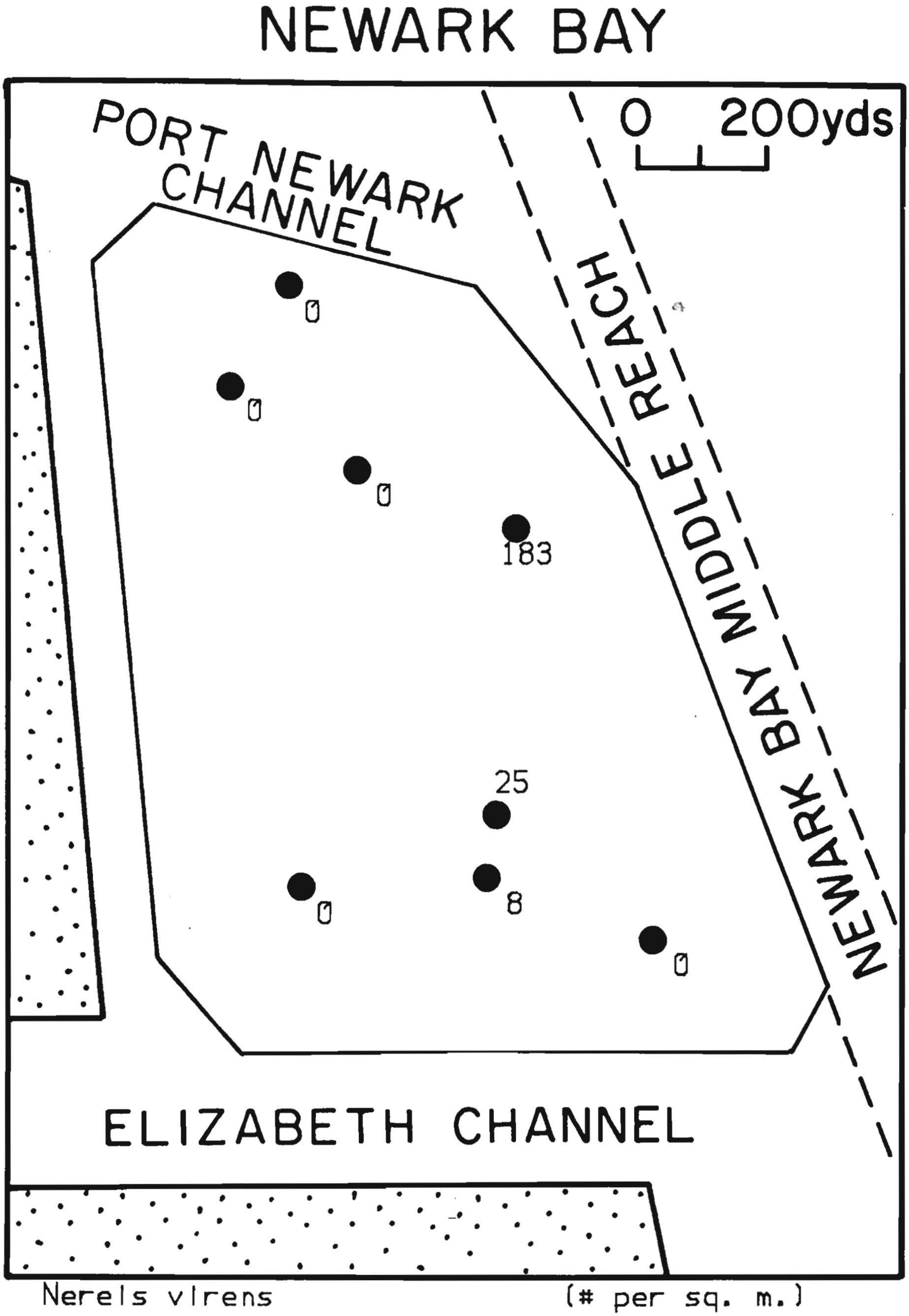

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
0
0
0
183
25
8
0
0
ELIZABETH CHANNEL
Nereis virens
(# per sq. m.)

Figure 36

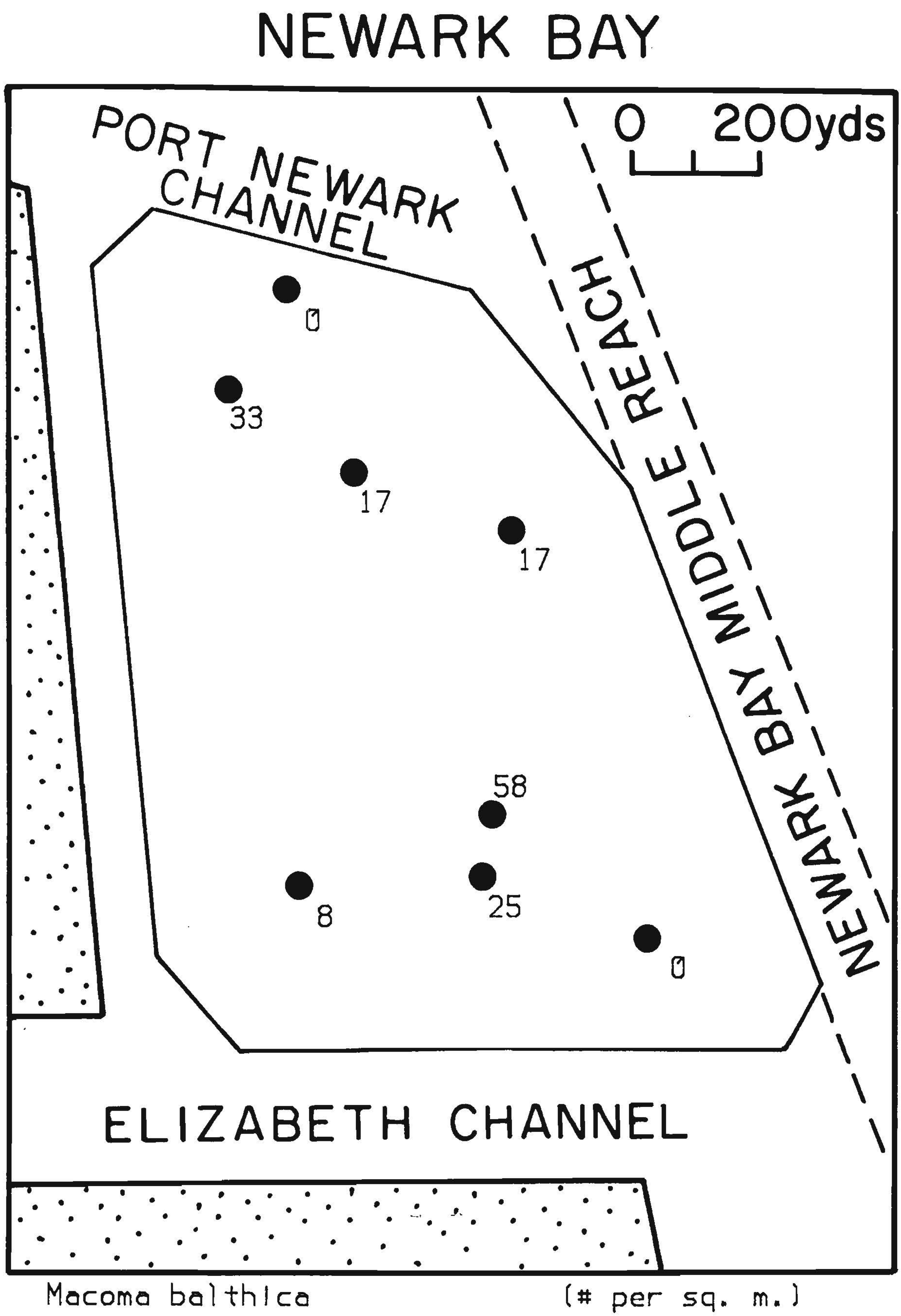
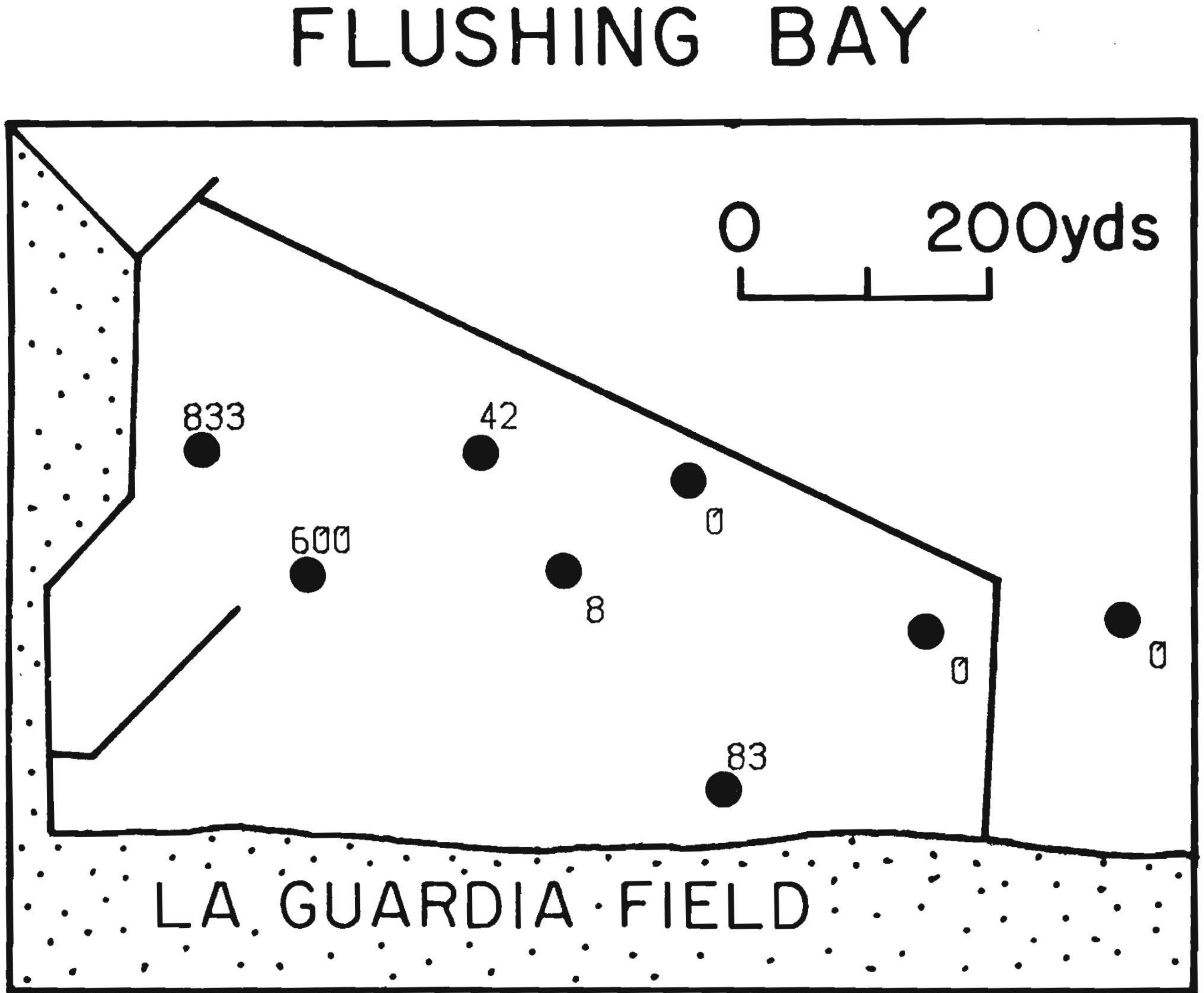
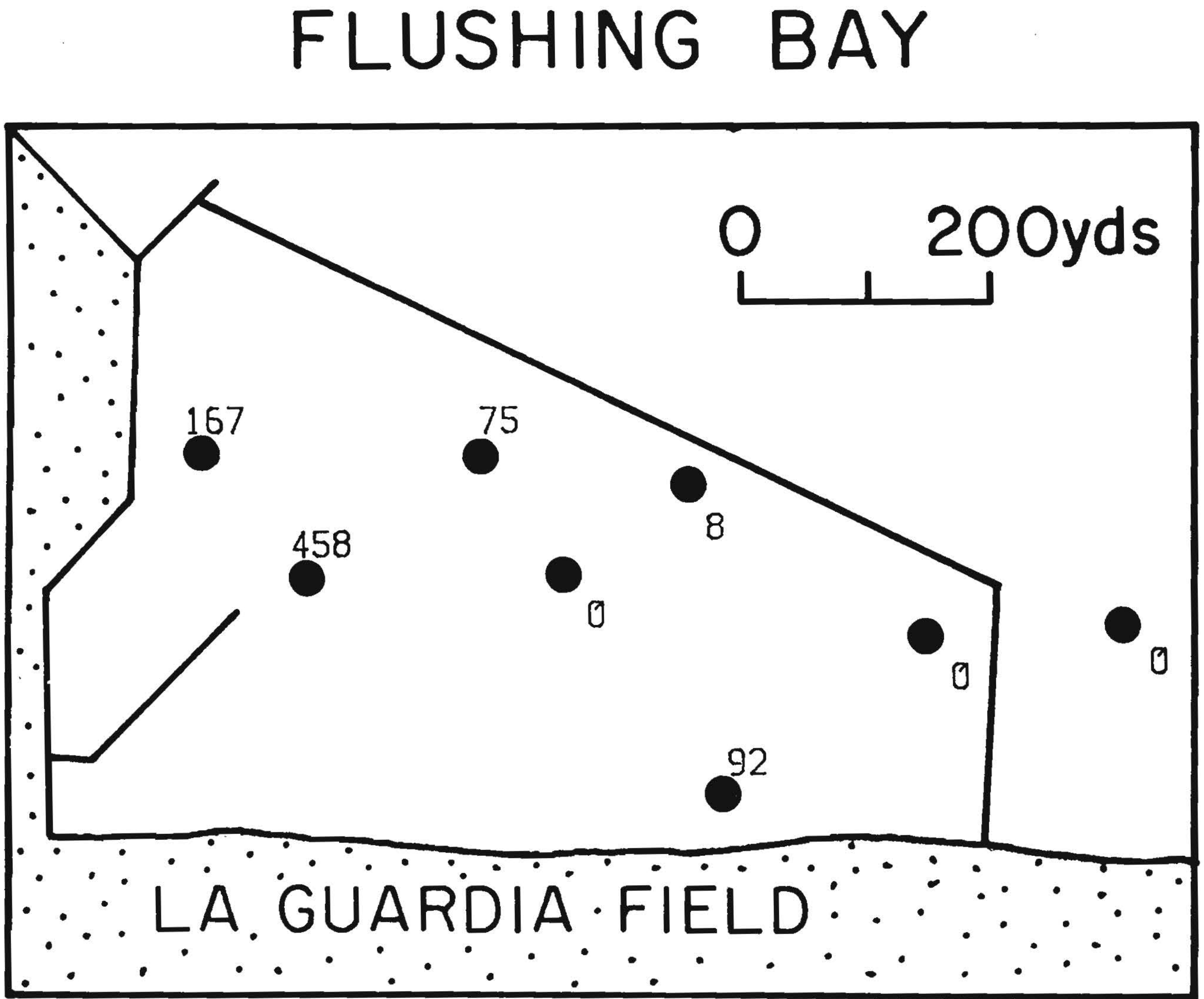

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
0
33
17
17
58
8
25
0
ELIZABETH CHANNEL
Macoma balthica
(# per sq. m.)

Figure 37



Streblospio benedicti (# per sq. m.)

Figure 38



Nereis succinea (# per sq. m.)

Figure 39

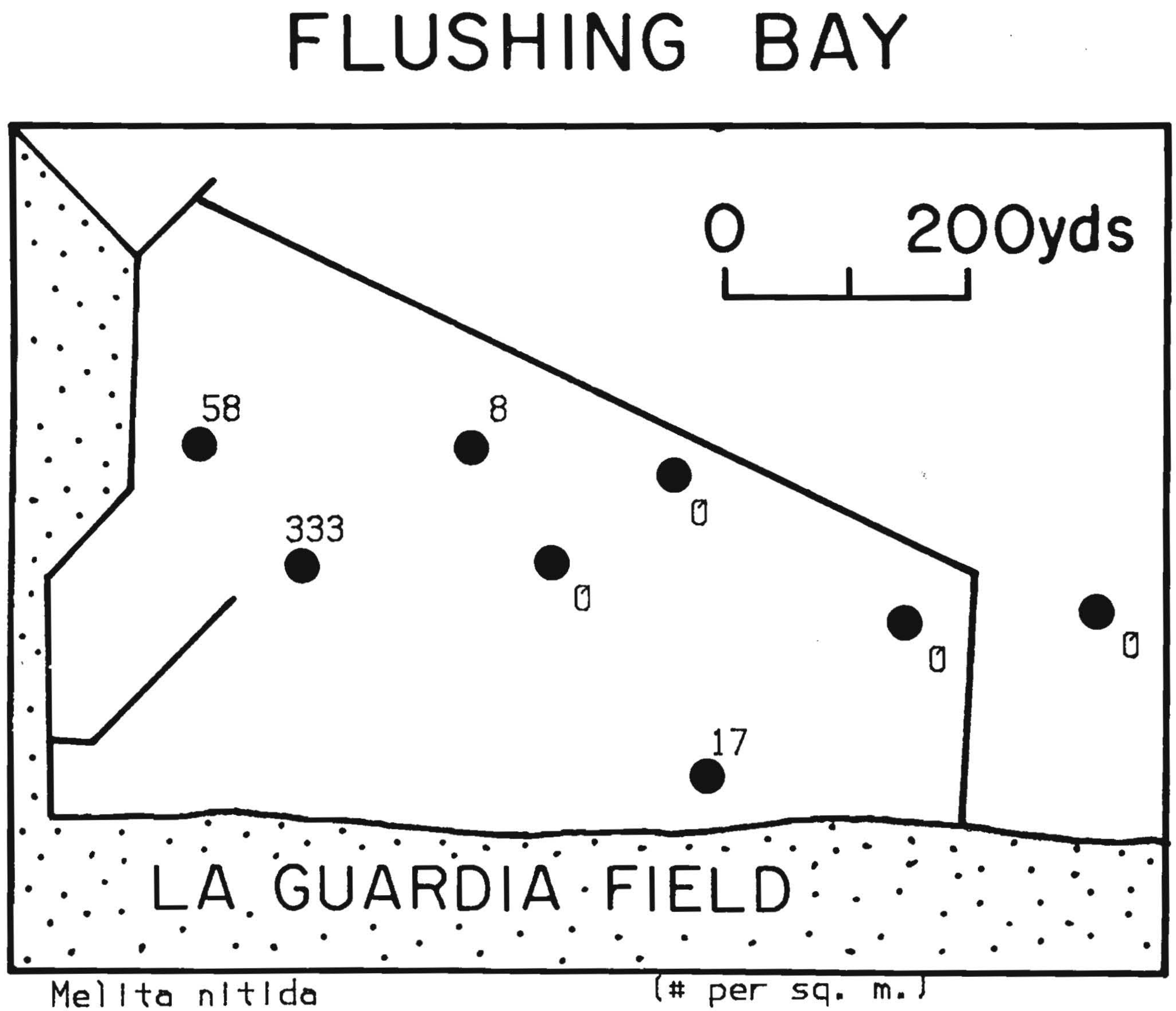

FLUSHING BAY
0 200yds
58
8
0
333
0
0
0
17
LA GUARDIA FIELD
Melita nitida
(# per sq. m.)

Figure 40

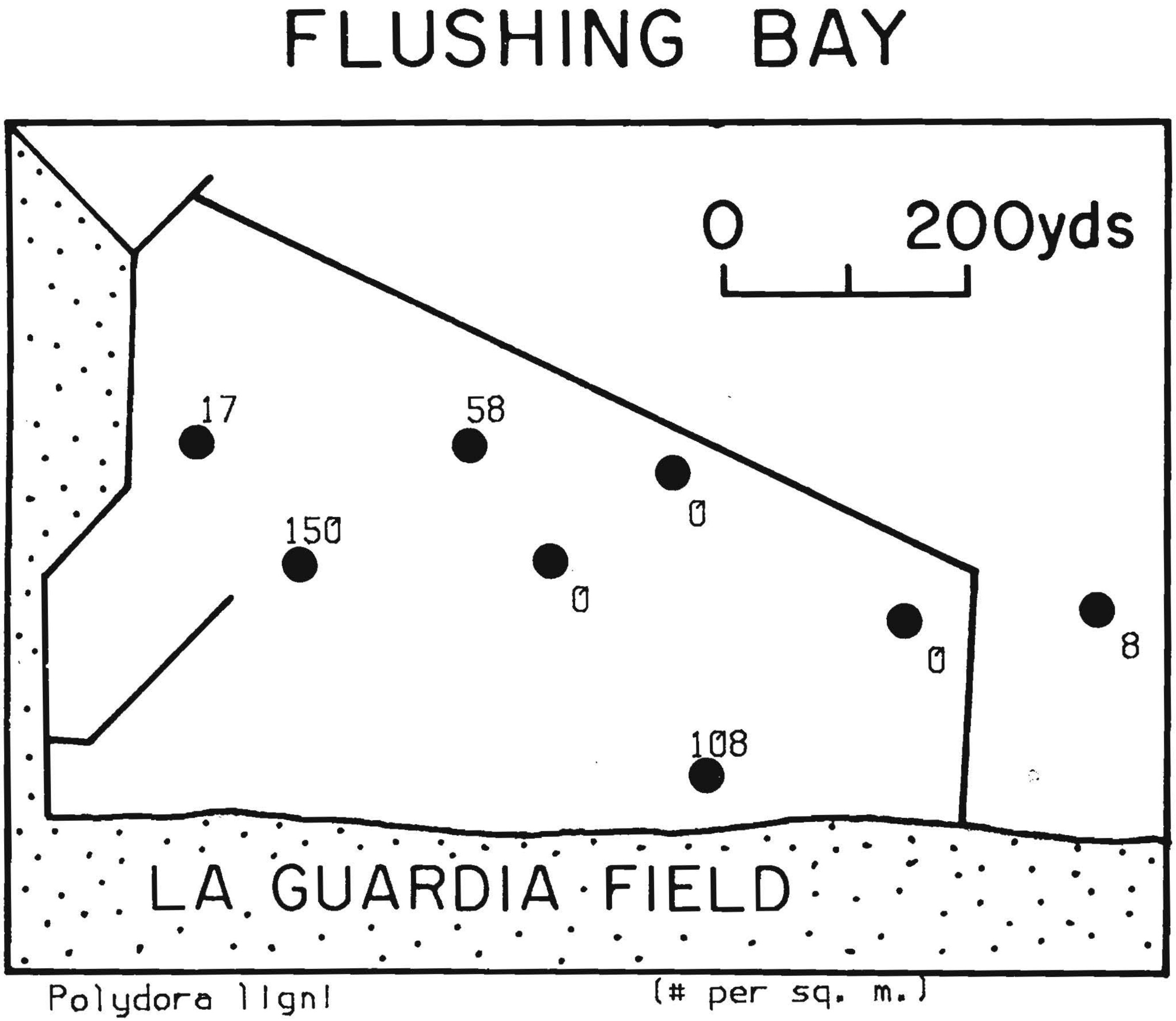

FLUSHING BAY
0 200yds
17
58
0
150
0
0
8
108
LA GUARDIA FIELD
Polydora ligni
(# per sq. m.)

Figure 41

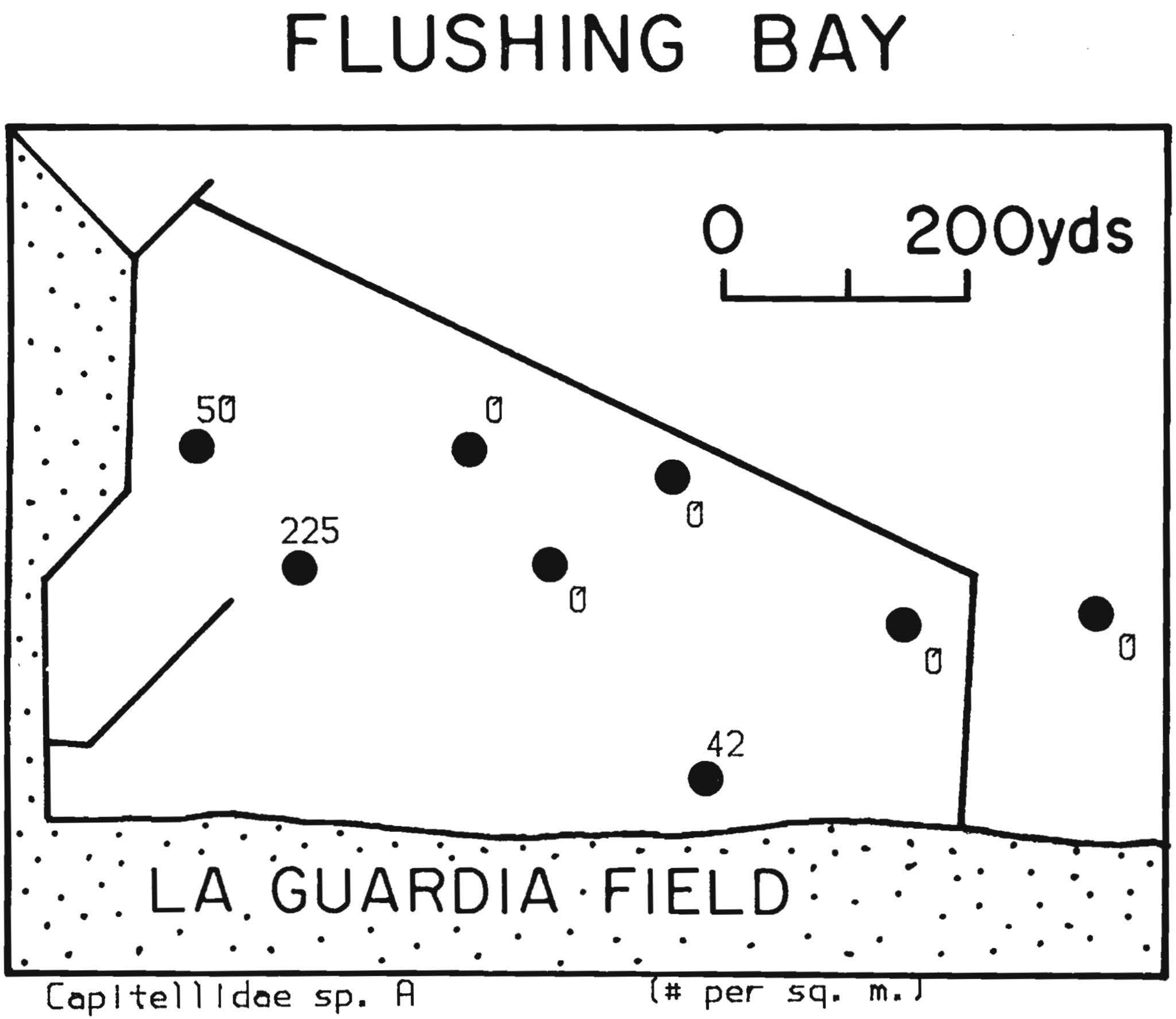

FLUSHING BAY
0
200yds
50
0
0
225
0
0
0
42
LA GUARDIA FIELD
Capitellidae sp. A
(# per sq. m.)

Figure 42

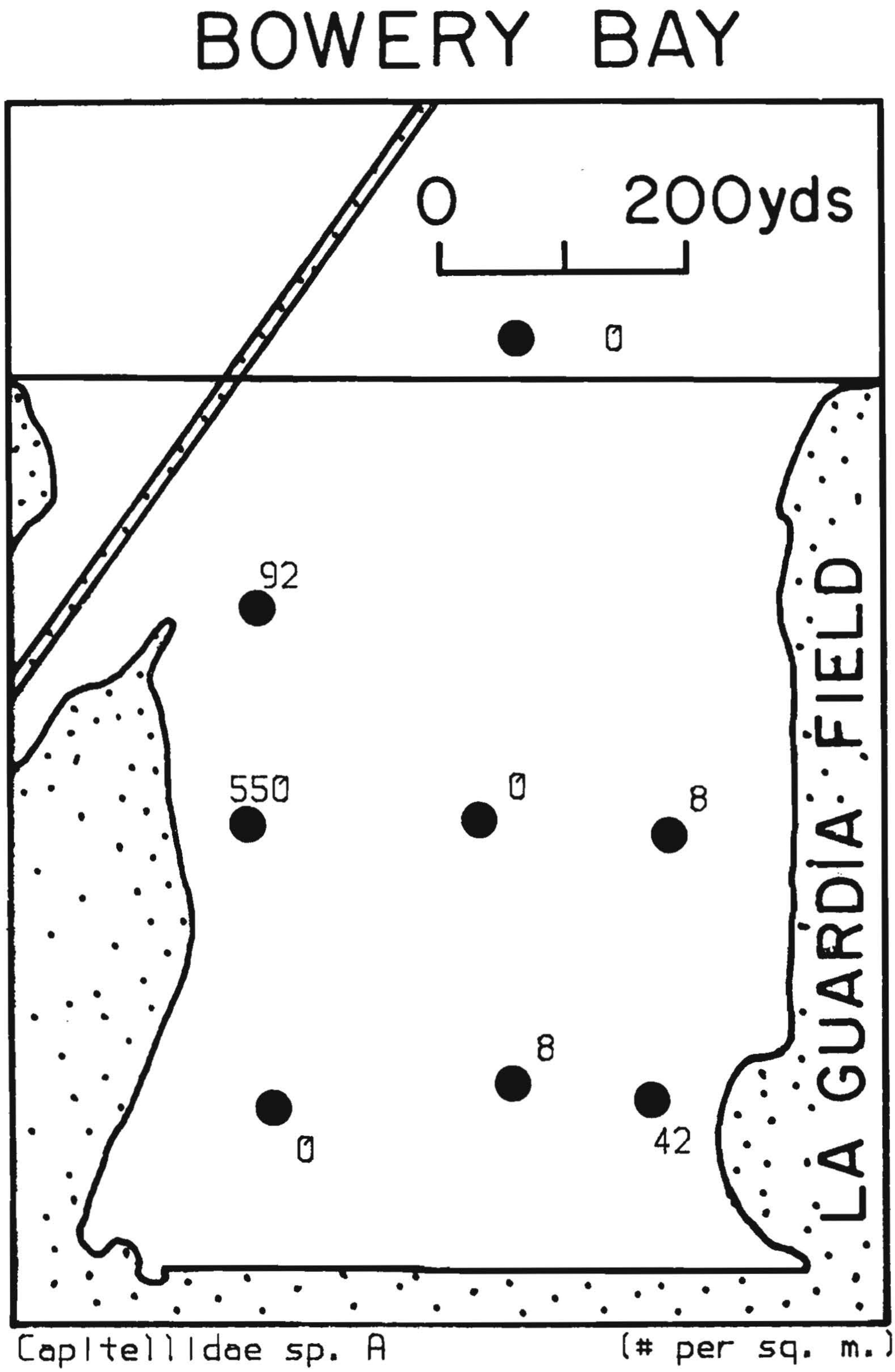

BOWERY BAY
0
200yds
0
92
550
0
8
8
0
42
LA GUARDIA FIELD
Capltelllidae sp. A
(# per sq. m.)

Figure 43

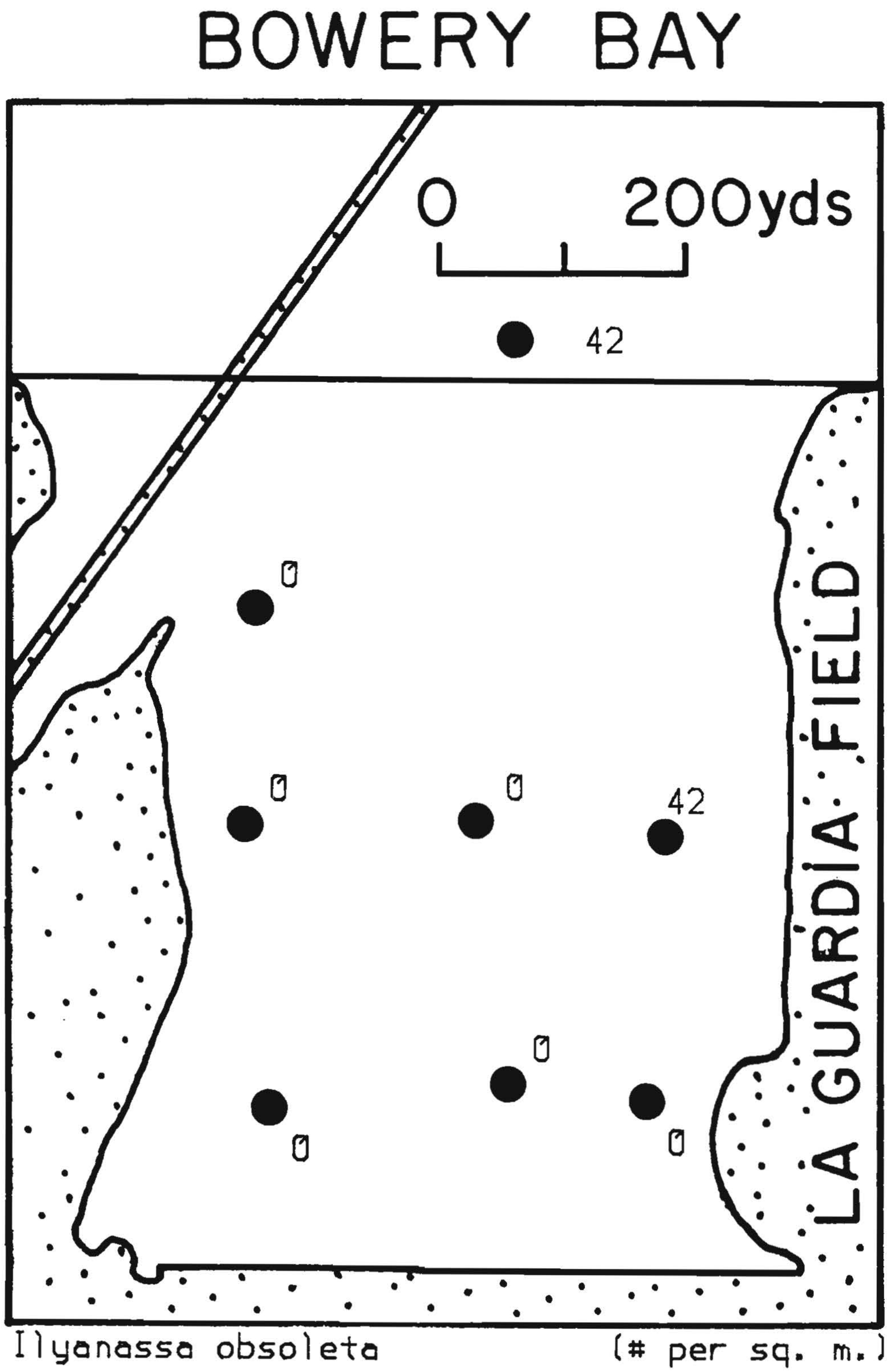

BOWERY BAY
0
200yds
42
0
0
0
42
0
0
0
LA GUARDIA FIELD
Ilyanassa obsoleta
(# per sq. m.)

Figure 44

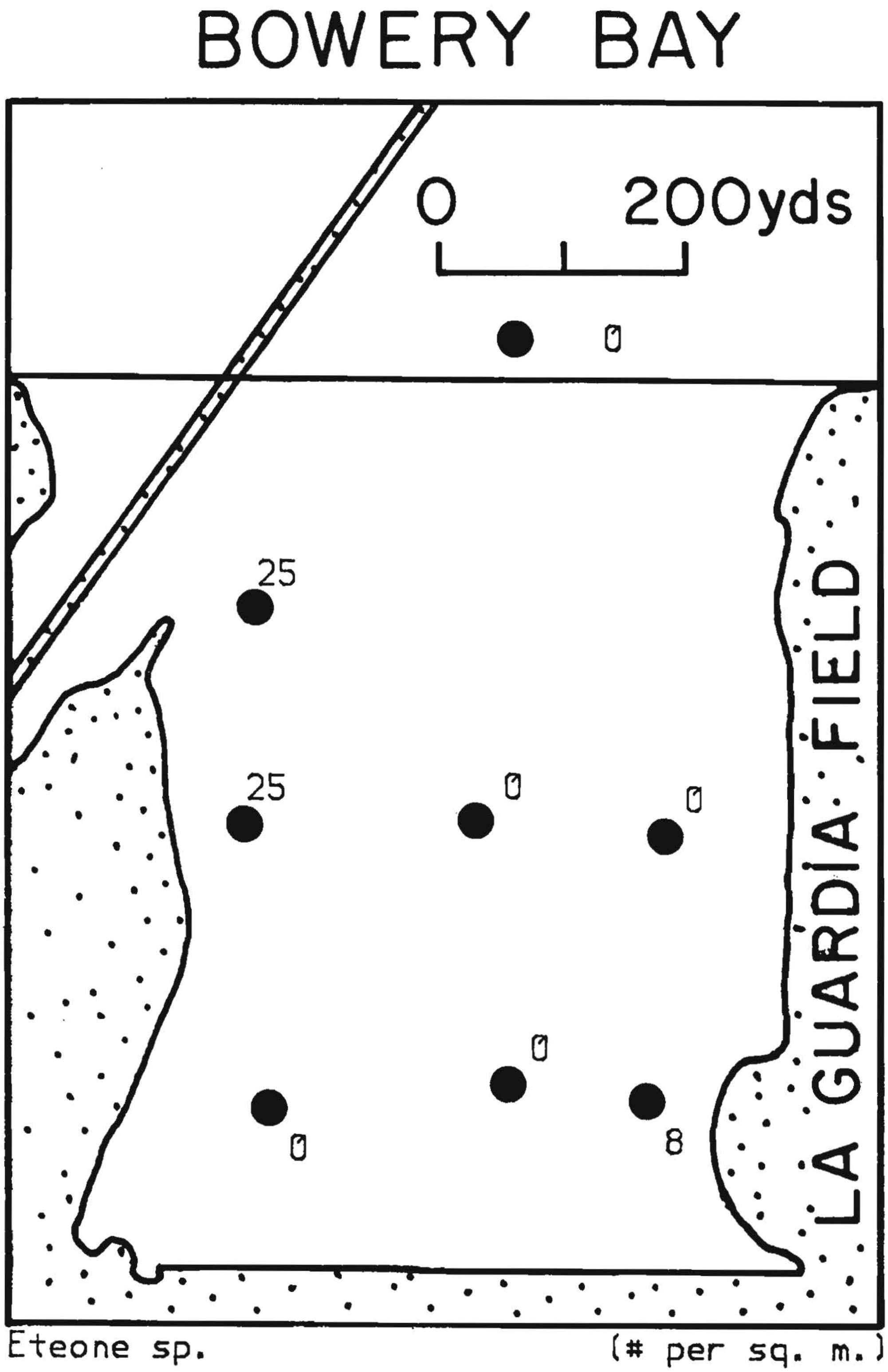

BOWERY BAY
0
200yds
0
25
25
0
0
0
0
8
LA GUARDIA FIELD
Eteone sp.
(# per sq. m.)

Figure 45

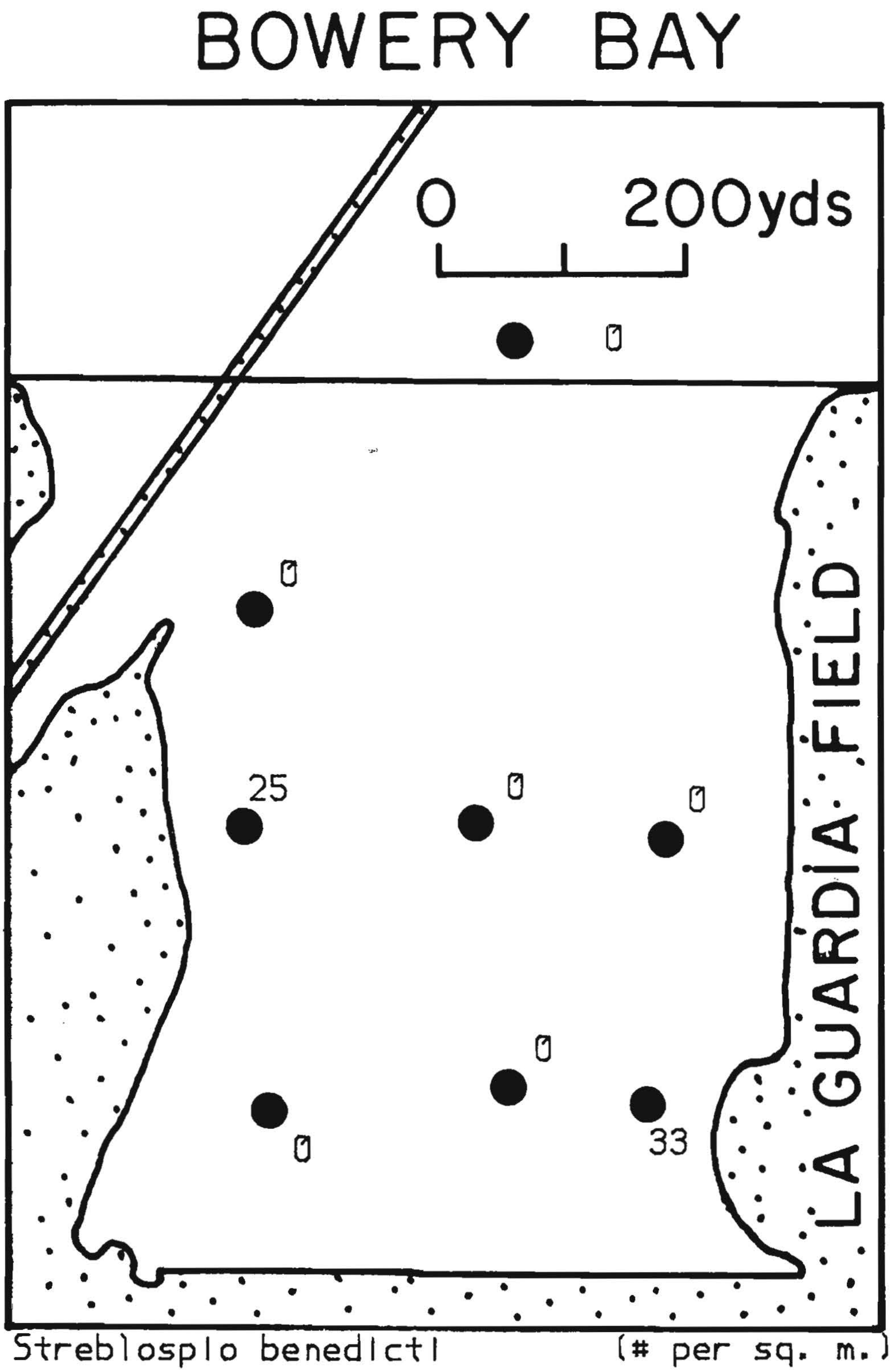

BOWERY BAY
0 200yds
0
0
25
0
0
0
0
33
LA GUARDIA FIELD
Streblosplo benedlctl (# per sq. m.)

Figure 46

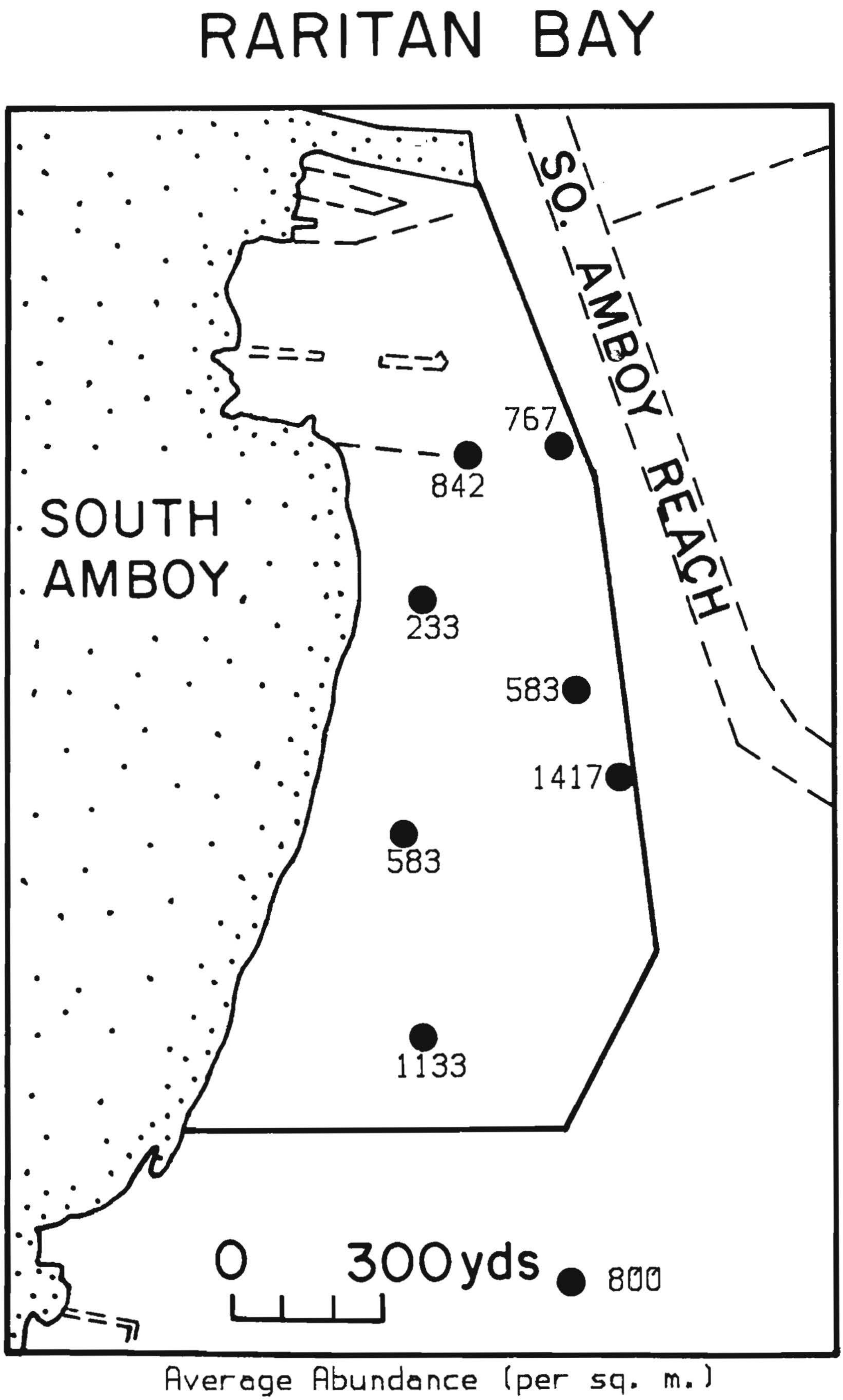

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
767
842
233
583
1417
583
1133
0 300yds
800
Average Abundance (per sq. m.)

Figure 47

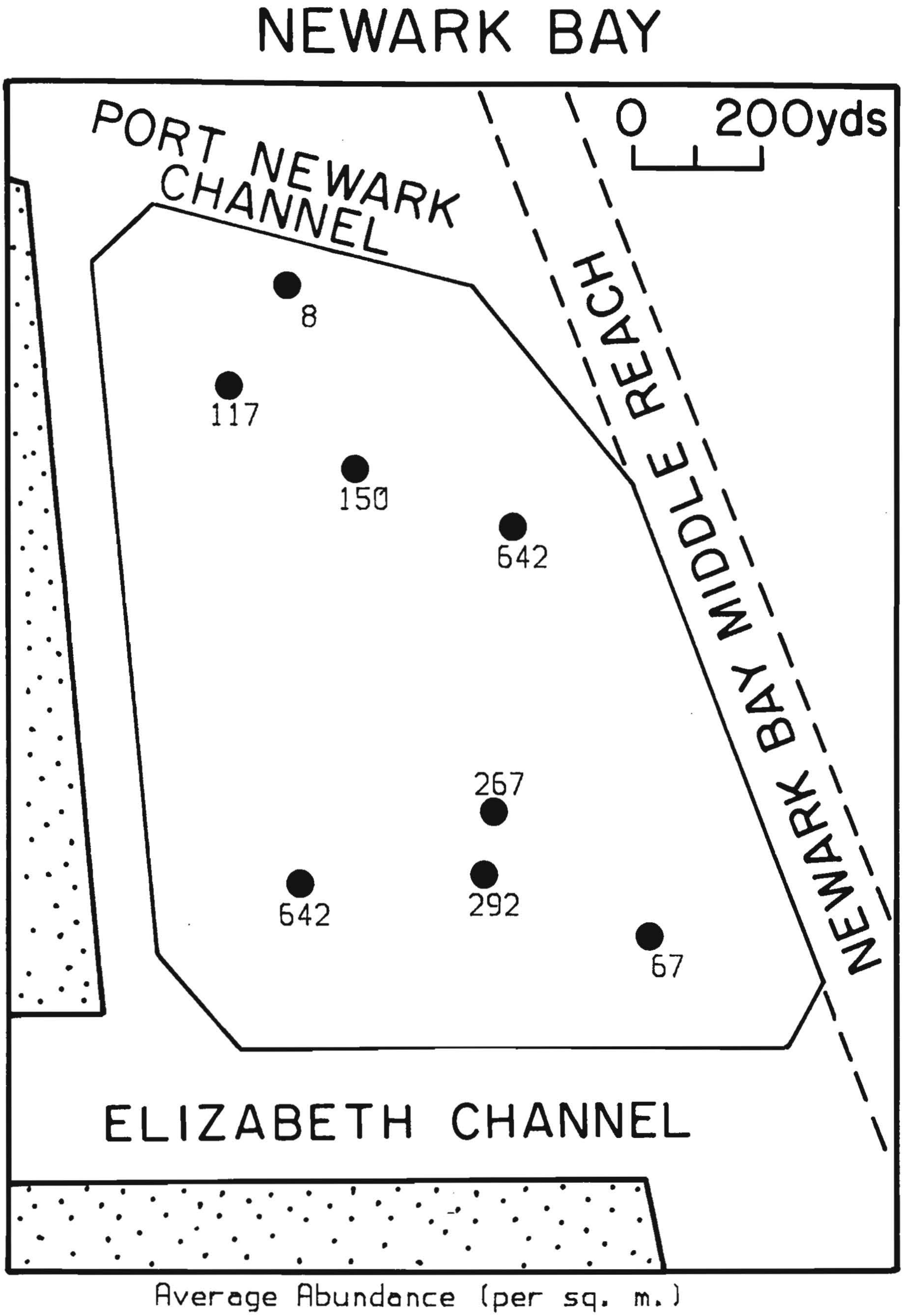
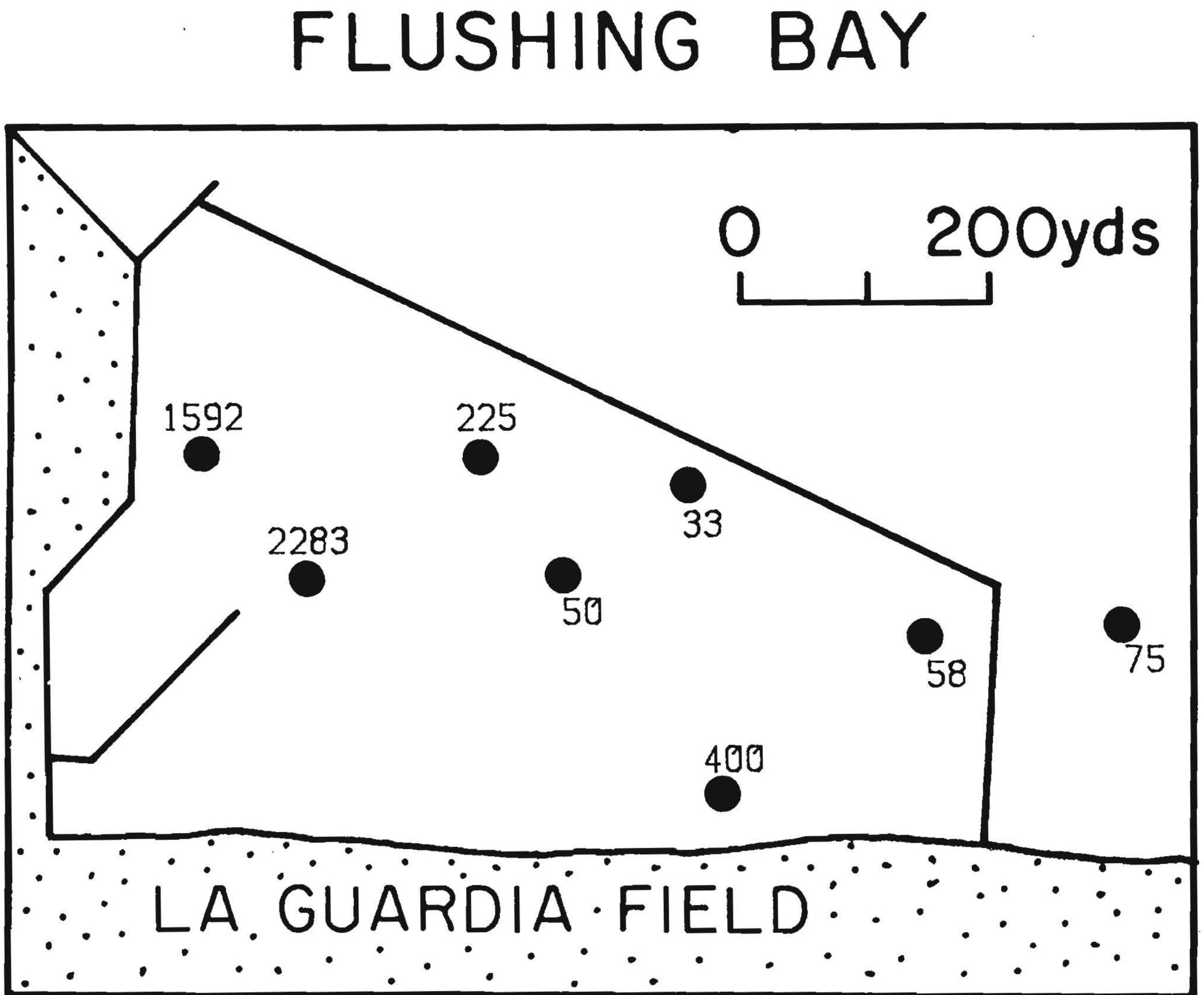

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
8
117
150
642
267
642
292
67
ELIZABETH CHANNEL
Average Abundance (per sq. m.)

Figure 48



Average Abundance (per sq. m.)

Figure 49

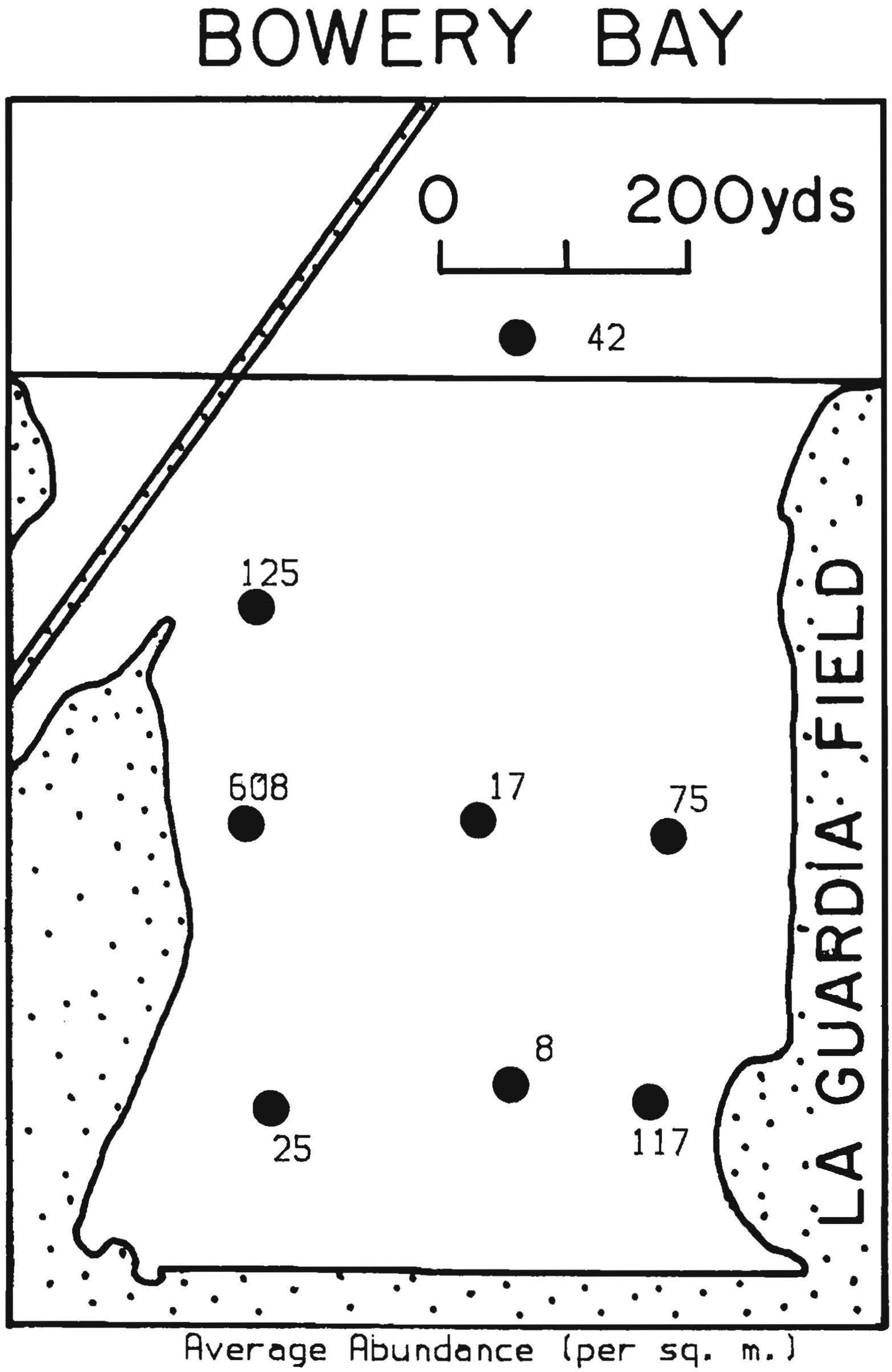

BOWERY BAY
0 200yds
42
125
608
17
75
8
25
117
LA GUARDIA FIELD
Average Abundance (per sq. m.)

Figure 50

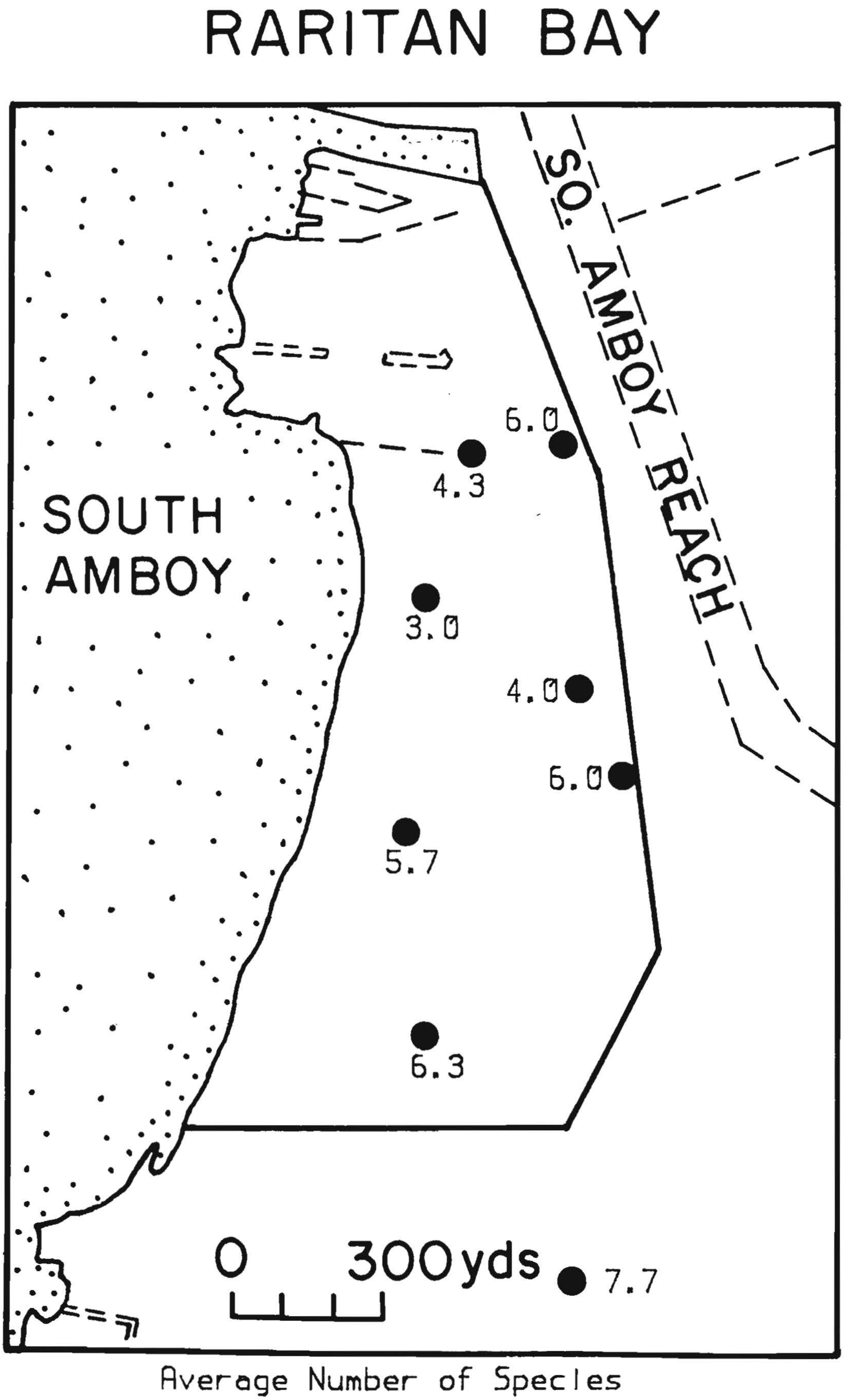

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
6.0
4.3
3.0
4.0
6.0
5.7
6.3
0 300yds
7.7
Average Number of Species

Figure 51

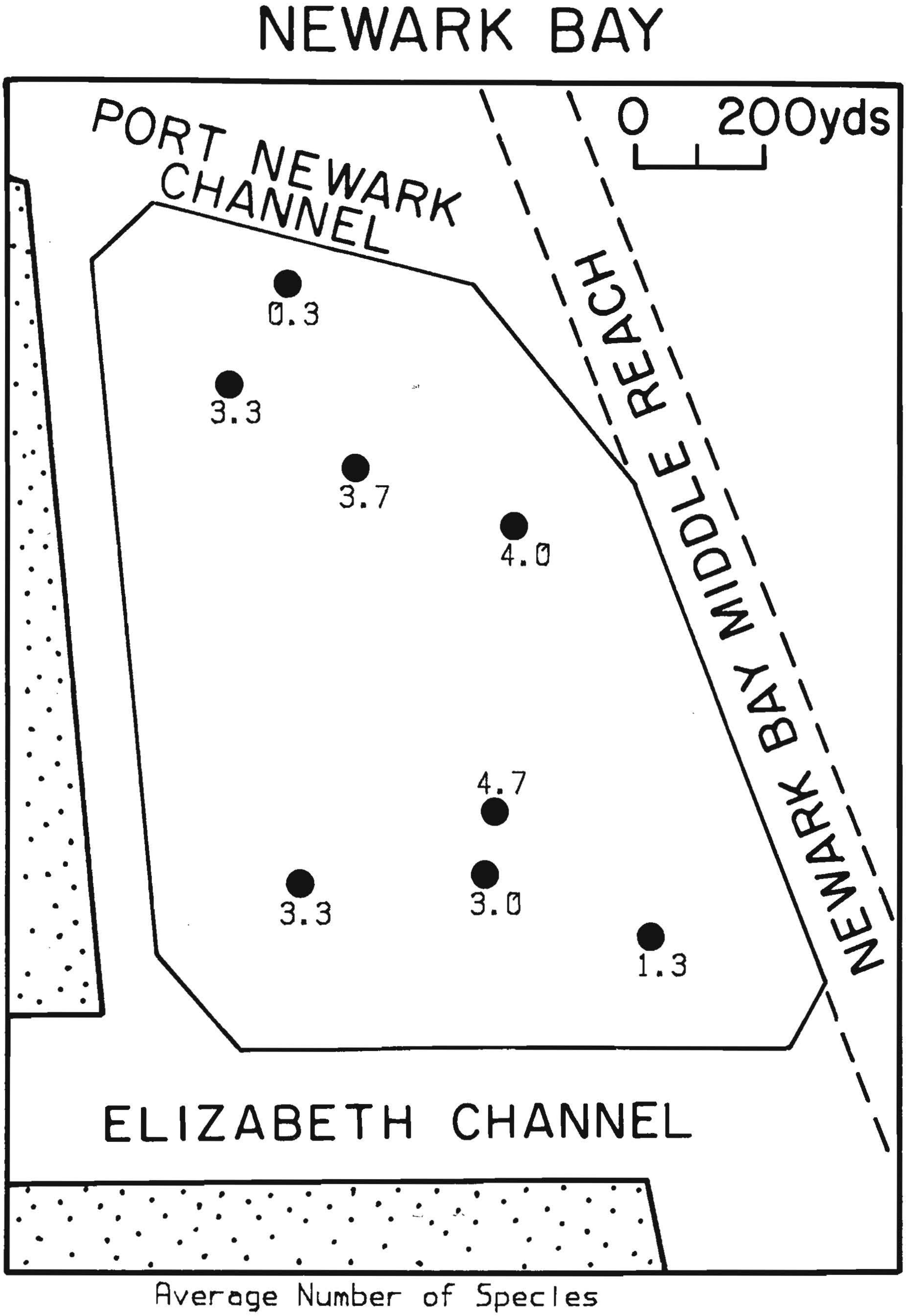
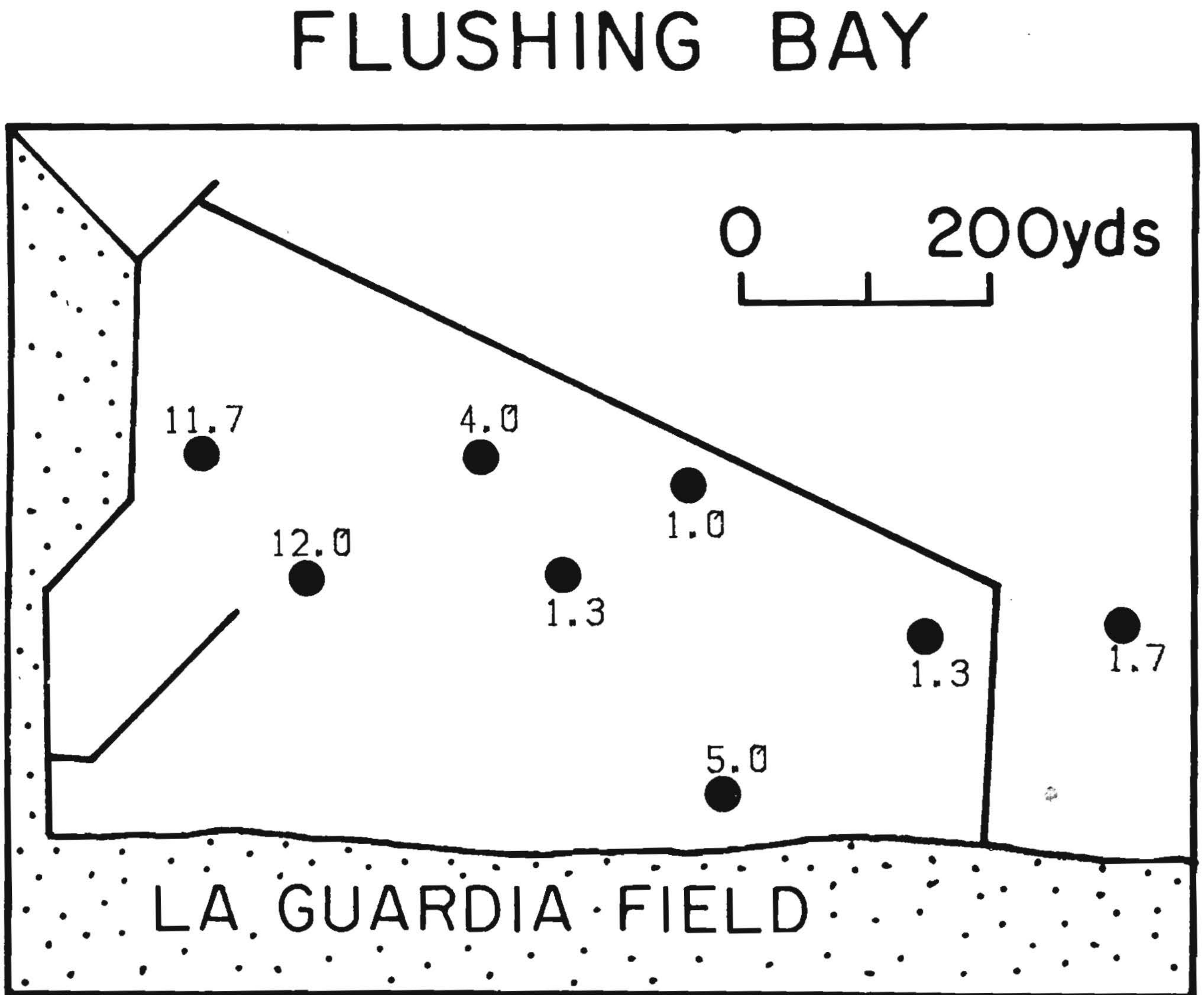

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
0.3
3.3
3.7
4.0
4.7
3.3
3.0
1.3
ELIZABETH CHANNEL
Average Number of Species

Figure 52



Average Number of Species

Figure 53

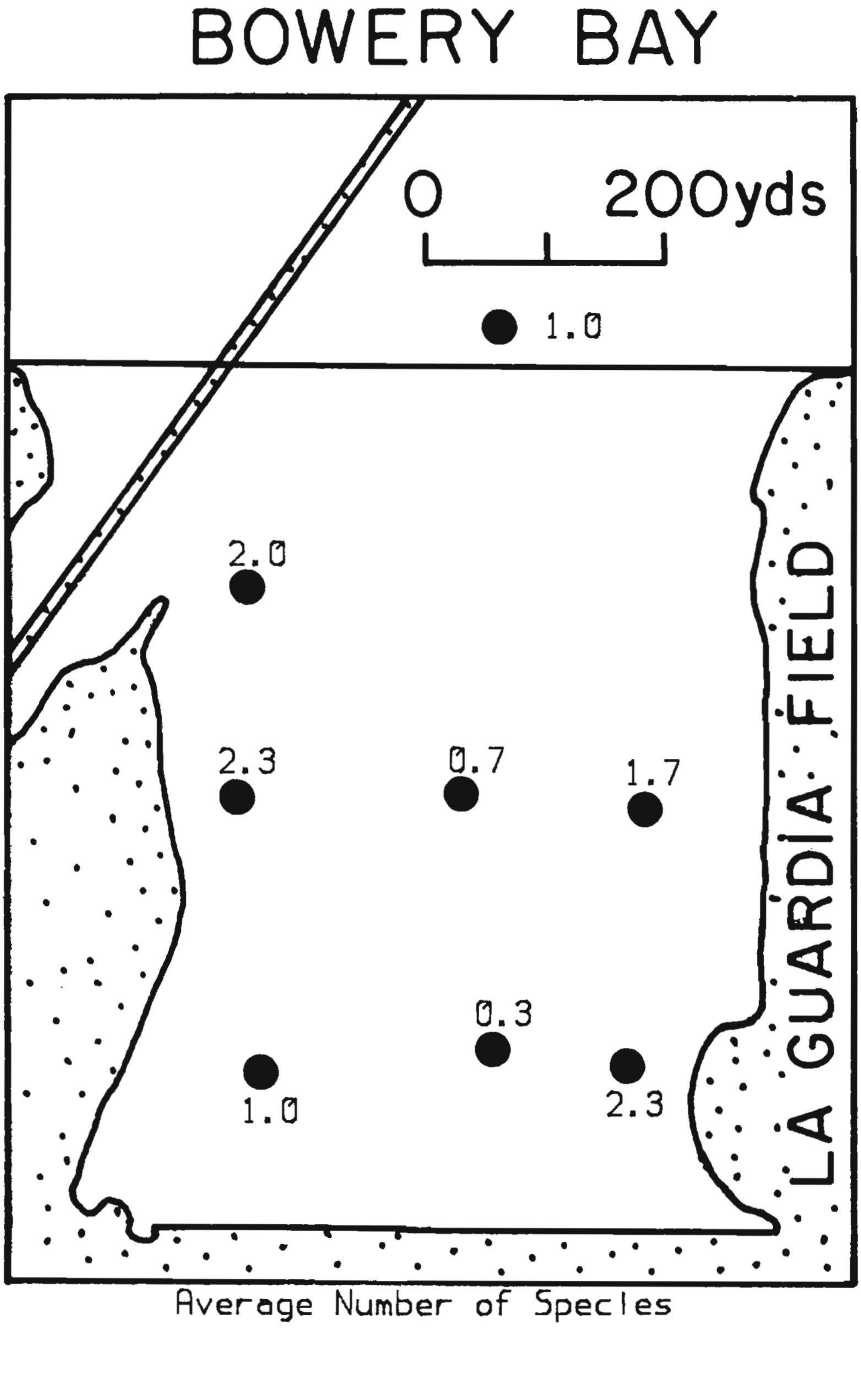

BOWERY BAY
0
200yds
1.0
2.0
2.3
0.7
1.7
0.3
1.0
2.3
LA GUARDIA FIELD
Average Number of Species

Figure 54

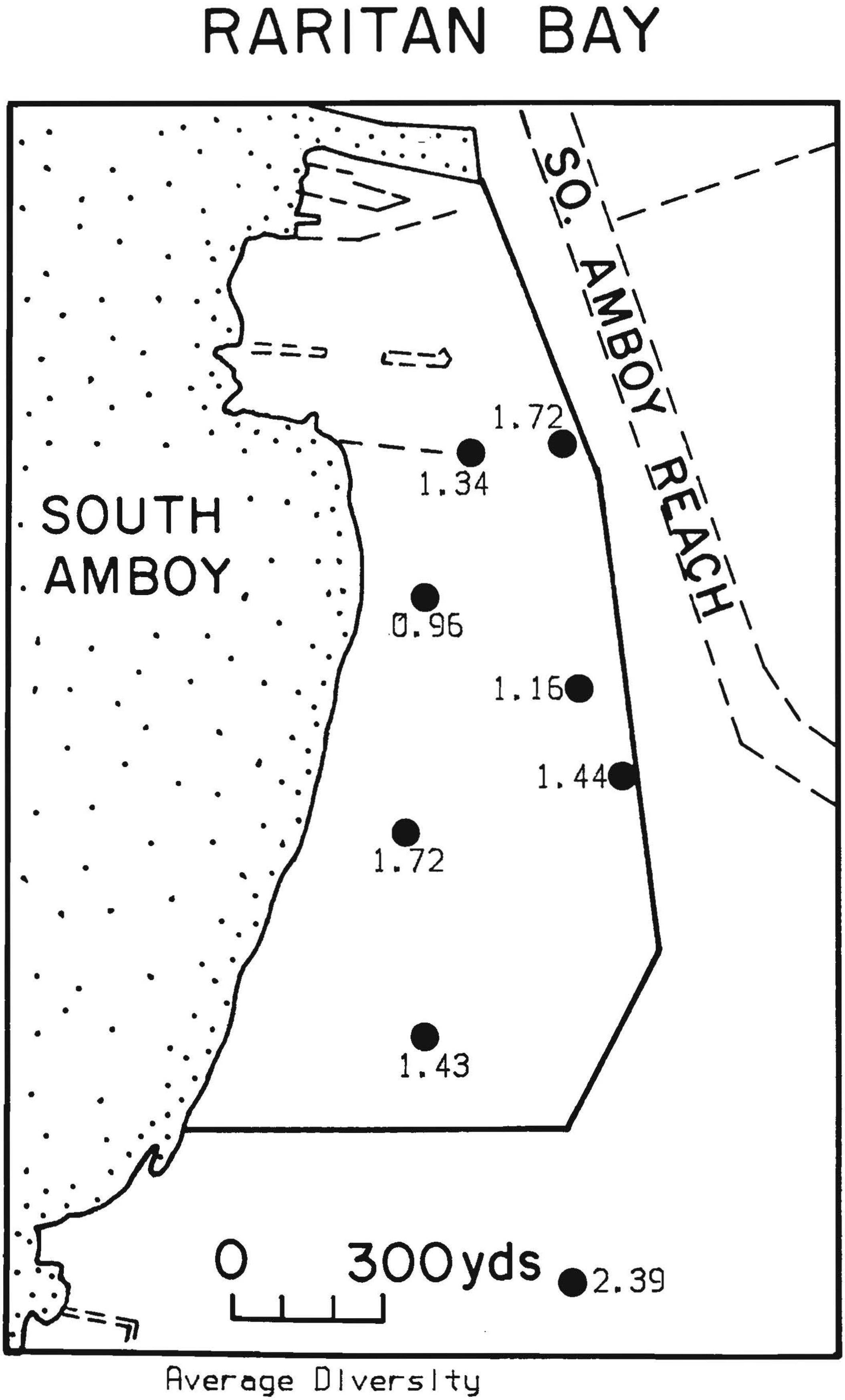

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
1.72
1.34
0.96
1.16
1.44
1.72
1.43
0 300yds
2.39
Average Diversity

Figure 55

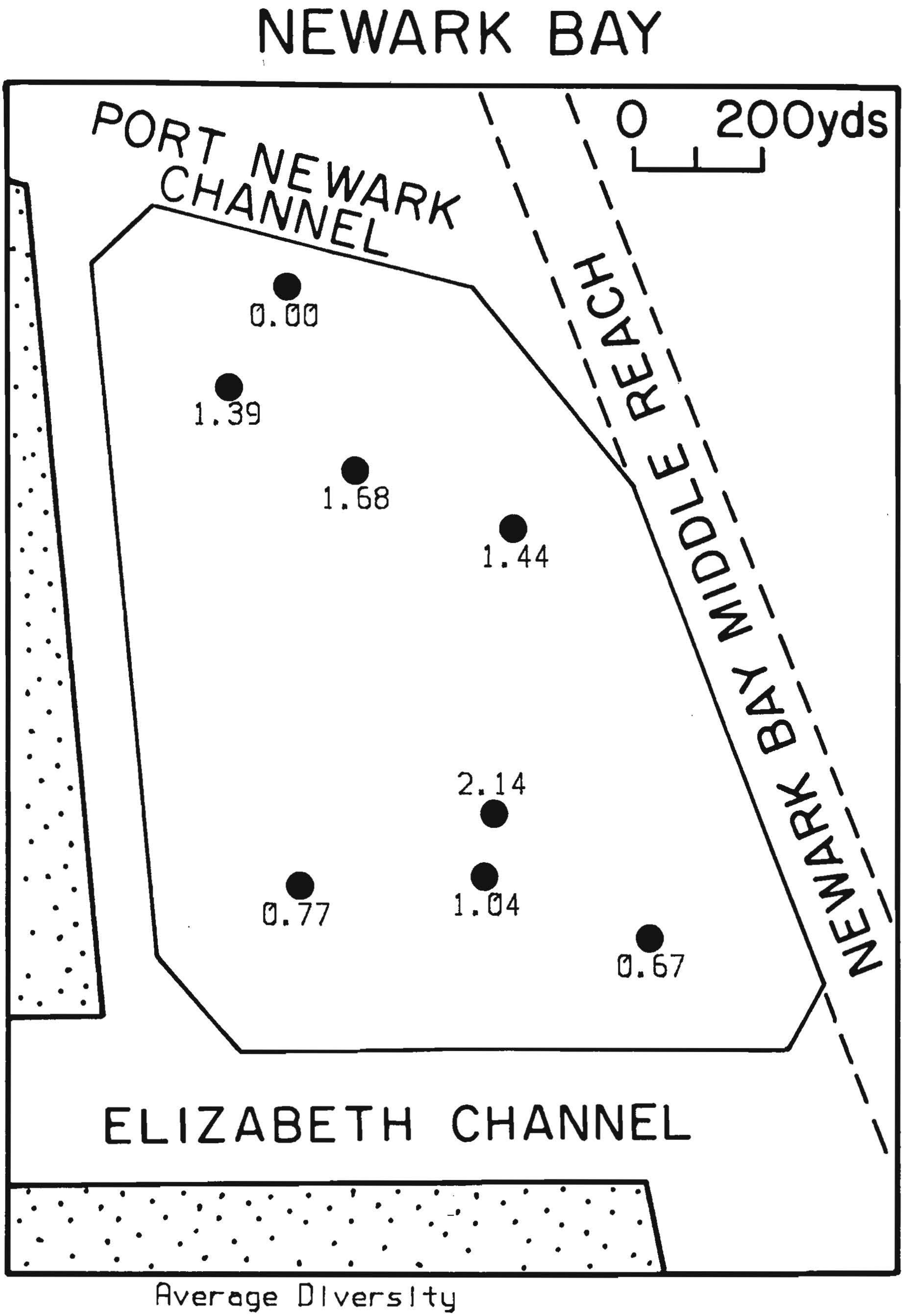
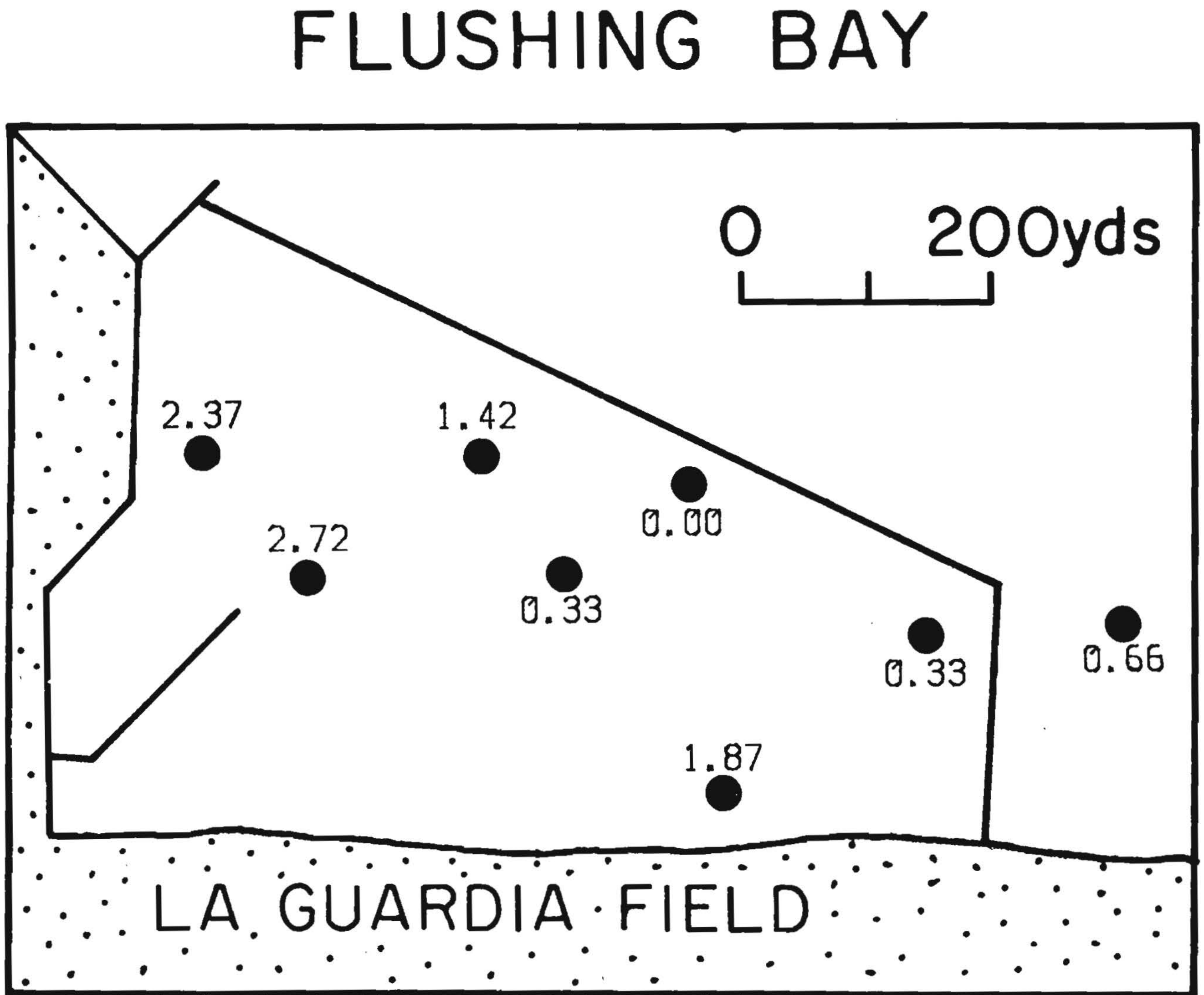

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
0.00
1.39
1.68
1.44
2.14
0.77
1.04
0.67
ELIZABETH CHANNEL
Average Diversity

Figure 56



Average Diversity

Figure 57

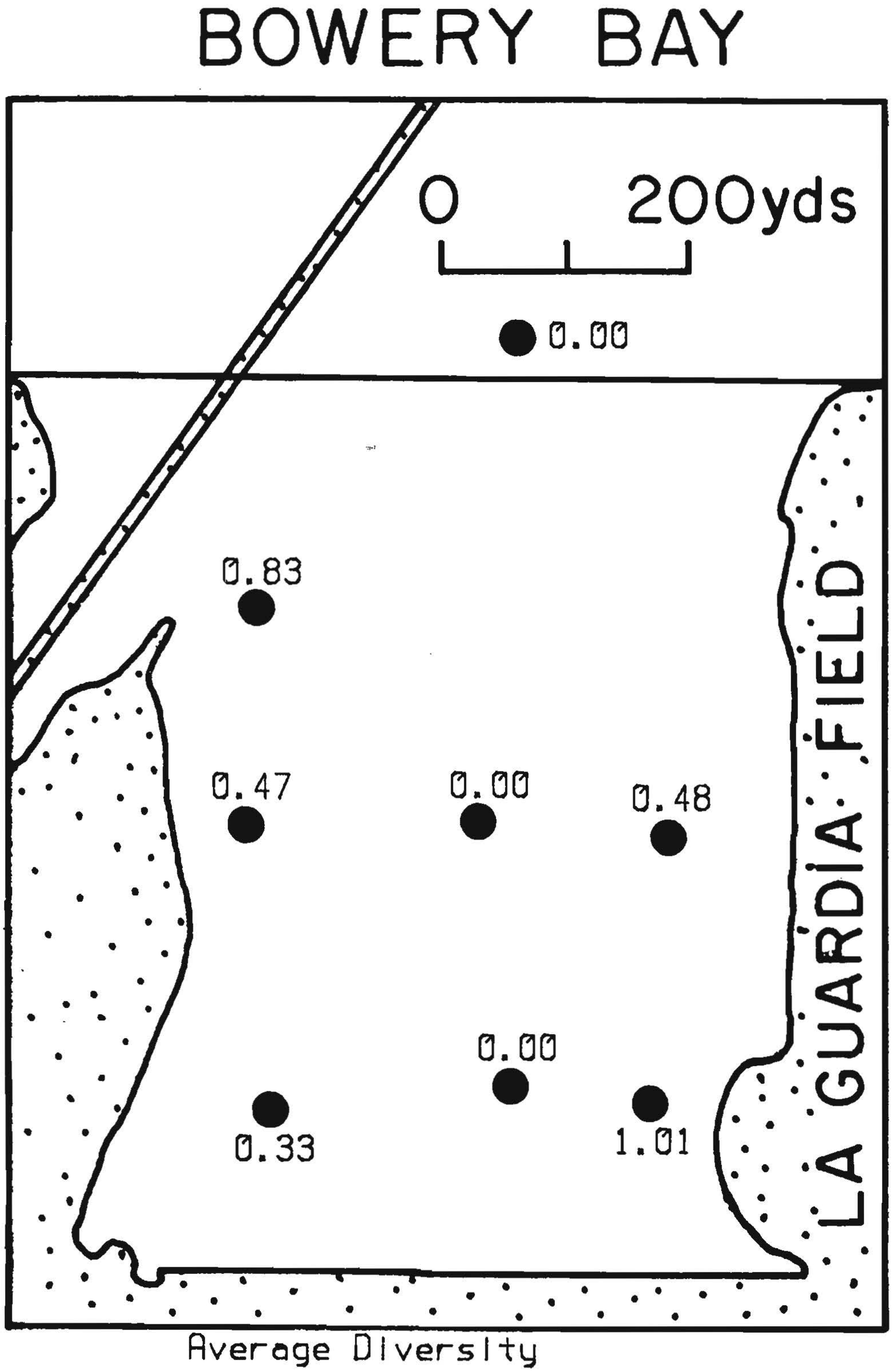

BOWERY BAY
0
200yds
0.00
0.83
0.47
0.00
0.48
0.00
0.33
1.01
LA GUARDIA FIELD
Average Diversity

Figure 58

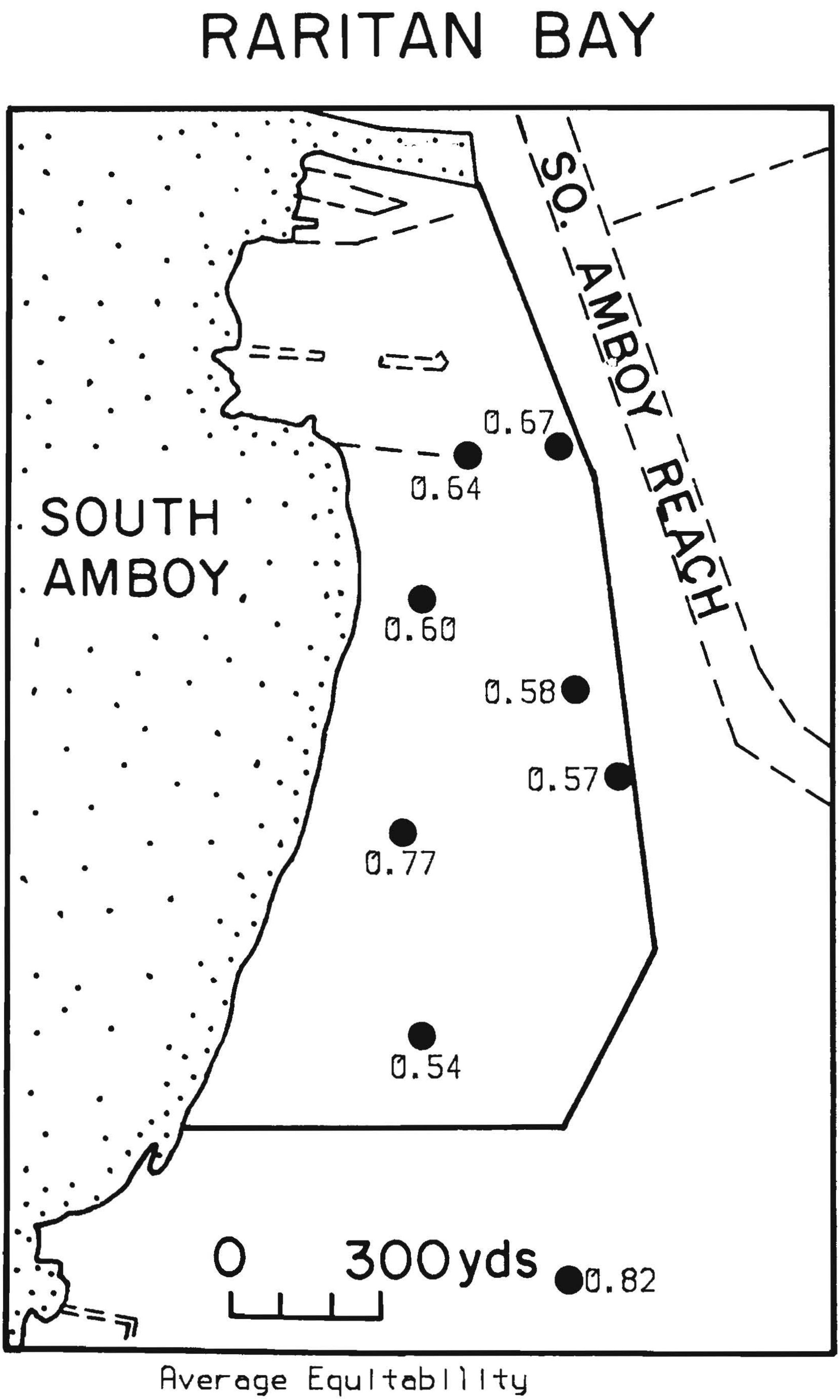

RARITAN BAY
SO. AMBOY REACH
SOUTH AMBOY
0.67
0.64
0.60
0.58
0.57
0.77
0.54
0 300yds
0.82
Average Equitability

Figure 59

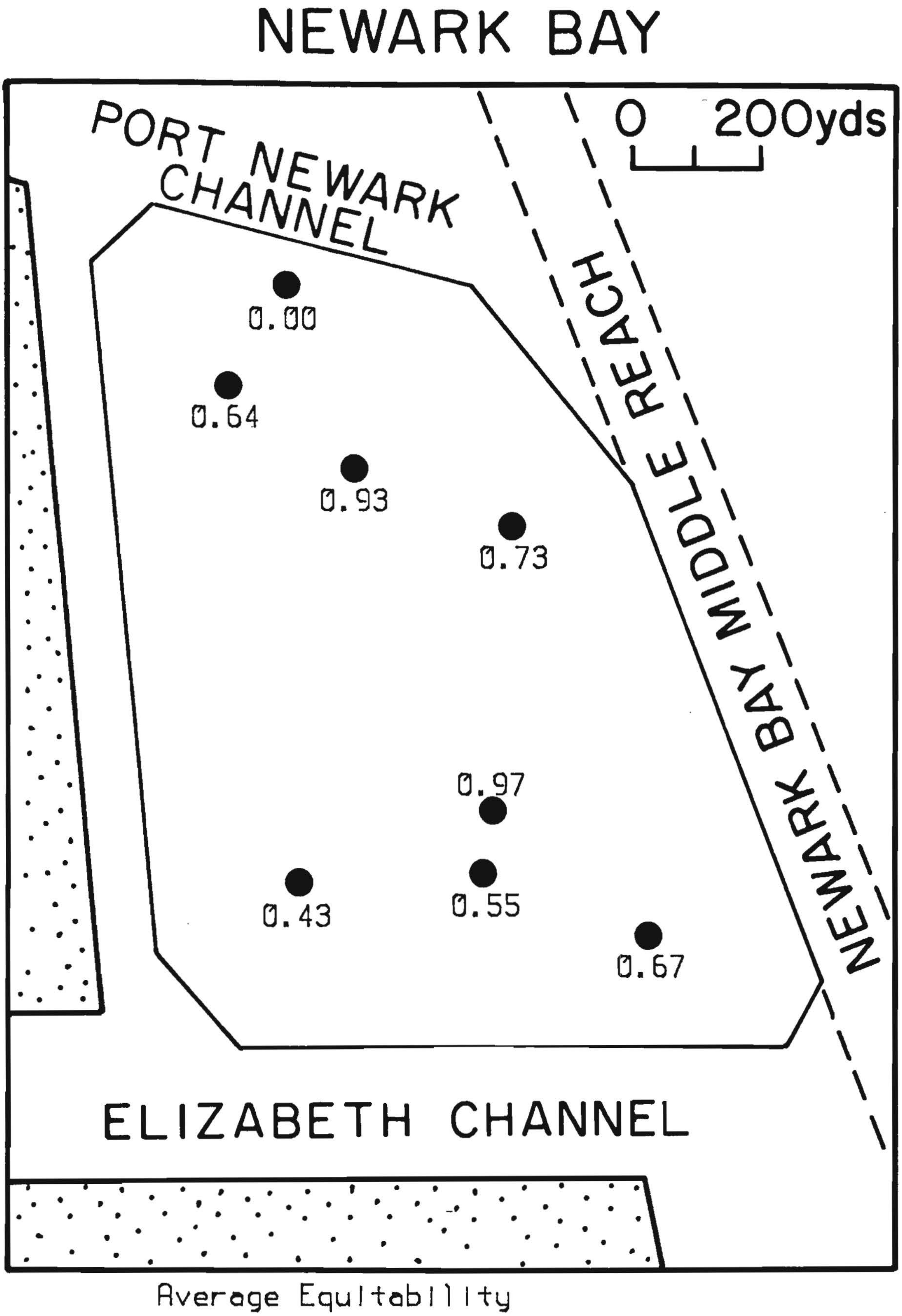

NEWARK BAY
PORT NEWARK CHANNEL
0 200yds
NEWARK BAY MIDDLE REACH
0.00
0.64
0.93
0.73
0.97
0.43
0.55
0.67
ELIZABETH CHANNEL
Average Equitability

Figure 60

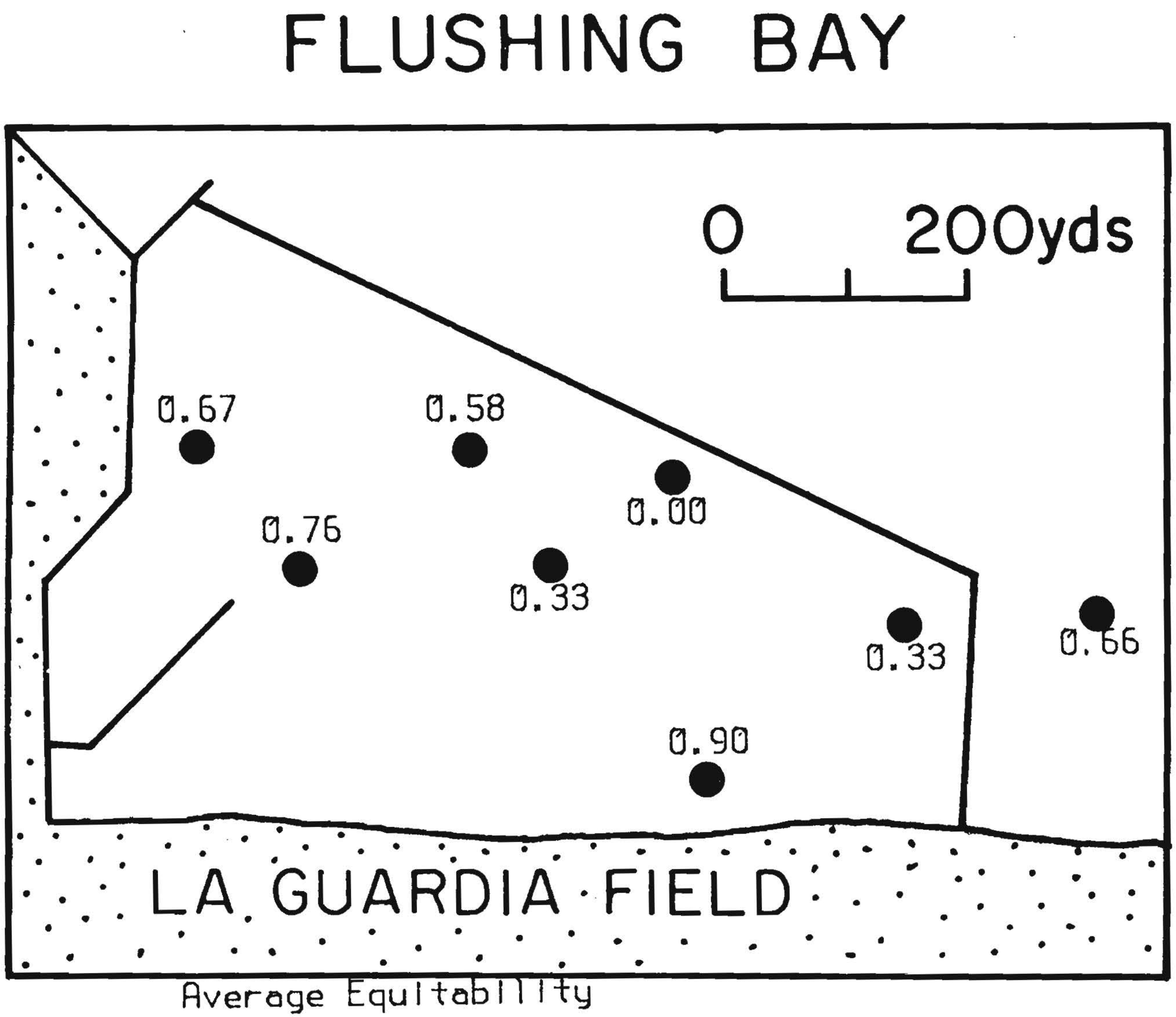

FLUSHING BAY
0 200yds
0.67
0.58
0.00
0.76
0.33
0.33
0.66
0.90
LA GUARDIA FIELD
Average Equitability

Figure 61

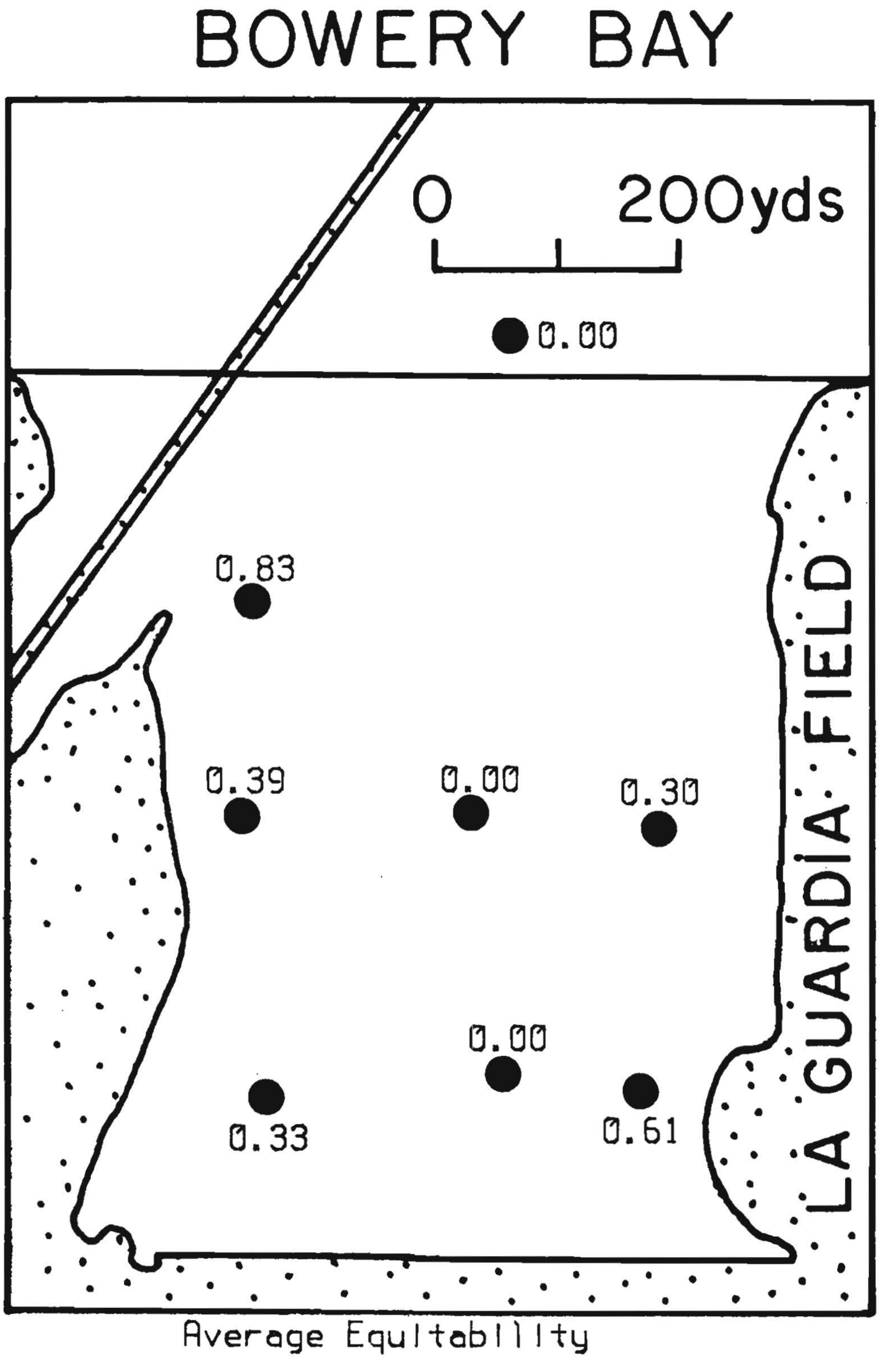

BOWERY BAY
0 200yds
0.00
0.83
0.39
0.00
0.30
0.00
0.33
0.61
LA GUARDIA FIELD
Average Equitability

Figure 62

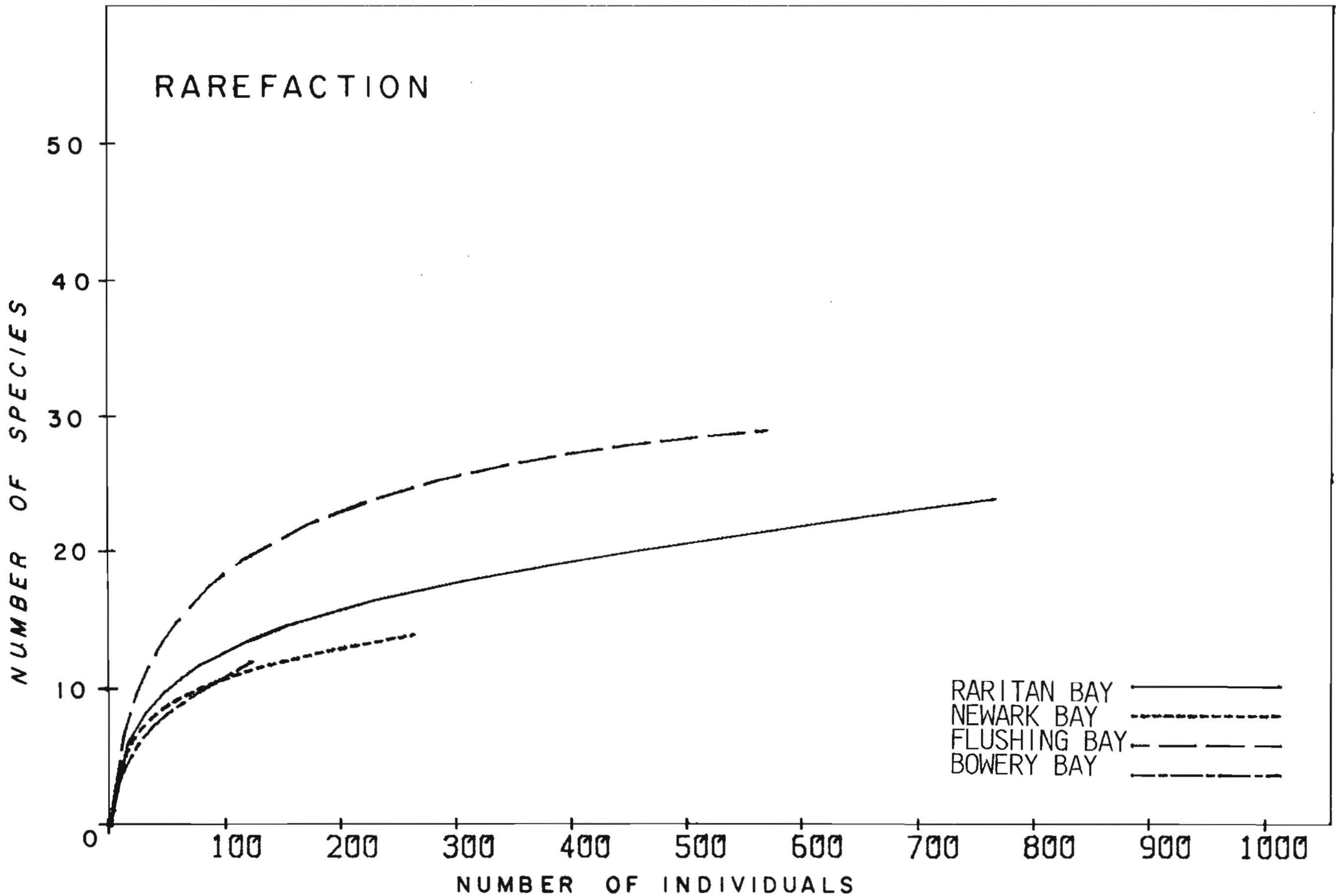

RAREFACTION
NUMBER OF SPECIES
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
NUMBER OF INDIVIDUALS
RARITAN BAY
NEWARK BAY
FLUSHING BAY
BOWERY BAY

Figure 63

APPENDIX A

Shipek Grab Data

Note: * Indicates presence of a nonenumerable species.

	1A	1B	1C	2A	2B	2C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
Nemertea sp.					1	
SIPUNCULA						
Sipuncula sp.		1				
POLYCHAETA						
Capitellidae sp. A	2		4	1	1	1
Glycera capitata				4	2	5
Glycera dibranchiata		1	1			
Nereis succinea			1			
Haploscoloplos fragilis	5	4	14	2	1	2
Pectinaria gouldii	8		11			
Eteone heteropoda			4			
Eteone sp.		2				
Scolelepis squamata				2	2	1
Streblospio benedicti			5	20	64	20
Syllidae sp.	1					
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
Rhithropanopeus harrisii		1				
MYSIDACEA						
Neomysis americana	1		1			
GASTROPODA						
Ilyanassa obsoleta			1	3	2	2
BIVALVIA						
Mya arenaria	8	9	10			
Ensis directus		1				
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	6	7	10	6	7	6
NUMBER OF INDIVIDUALS	25	19	52	32	73	31

	3A	3B	3C	4A	4B	4C
PORIFERA						
CNIDARIA						
Hydrozoa sp.						*
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Glycera dibranchiata	1		1			
Nereis succinea			2		1	2
Haploscoloplos fragilis	8	2			1	1
Pectinaria gouldii		3	4	2	2	2
Polydora ligni	5	2	2	4	7	1
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
MYSIDACEA						
Neomysis americana				1		
GASTROPODA						
Nassarius trivittata	1					
Ilyanassa obsoleta	1		6	1		
BIVALVIA						
Mya arenaria	36	21	63	13	19	25
ECTOPROCTA						
CHORDATA						
Molgula manhattensis	9		3	1	3	6
NUMBER OF SPECIES	7	4	7	6	6	7
NUMBER OF INDIVIDUALS	61	28	81	22	33	37

	5A	5B	5C	6A	6B	6C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A					1	
Glycera americana	1					
Glycera capitata				1		
Nereis succinea		1	2			
Haploscoloplos fragilis	1			6	8	8
Pectinaria gouldii	9	1	10	1		1
Polydora ligni		3	3			
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
MYSIDACEA						
GASTROPODA						
Ilyanassa obsoleta			2			
BIVALVIA						
Mya arenaria	20	10	38	1		1
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	4	4	5	4	2	3
NUMBER OF INDIVIDUALS	31	15	55	9	9	10

	7A	7B	7C	8A	8B	8C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
Turbellaria sp.			1			
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A		1	2			
Glycera dibranchiata		1	2			
Haploscoloplos fragilis		8	4		1	1
Pectinaria gouldii			6	1	1	
Eteone heteropoda		1				
Eteone sp.			1			
Polydora ligni	1				5	2
Streblospio benedicti	2	5	32			
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
MYSIDACEA						
GASTROPODA						
BIVALVIA						
Mulinia lateralis			1			
Mya arenaria	1		1	17	20	14
ECTOPROCTA						
CHORDATA						
Molgula manhattensis				3	4	1
NUMBER OF SPECIES	3	5	9	3	5	4
NUMBER OF INDIVIDUALS	4	16	50	21	31	18

	9A	9B	9C	10A	10B	10C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
Nemertea sp.				1		
SIPUNCULA						
POLYCHAETA						
Nereis succinea				2		1
Streblospio benedicti				2		2
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
Rhithropanopeus harrisii				1		1
MYSIDACEA						
Neomysis americana			1			
GASTROPODA						
BIVALVIA						
Macoma balthica				1	2	1
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	0	0	1	5	1	4
NUMBER OF INDIVIDUALS	0	0	1	7	2	5

	11A	11B	11C	12A	12B	12C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
Nemertea sp.		1		1		2
SIPUNCULA						
POLYCHAETA						
Nereis virens				2	11	9
Nereis sp.	3	1	4			
Paraonidae sp.			1			
Eteone heteropoda					2	
Streblospio benedicti				10	11	24
AMPHIPODA						
CAPRELLIDEA						
Caprellidea sp.					1	
CIRRIPEDIA						
ISOPODA						
DECAPODA						
Rhithropanopeus harrisii	3	1	1	2		
MYSIDACEA						
GASTROPODA						
BIVALVIA						
Mulinia lateralis			1			
Macoma balthica	1		1		2	
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	3	3	5	4	5	3
NUMBER OF INDIVIDUALS	7	3	8	15	27	35

	13A	13B	13C	14A	14B	14C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
Nemertea sp.		1		2		
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A		1				1
Nereis virens						1
Nereis sp.		1				
Streblospio benedicti		64	1			16
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
Thoracica sp.			*			
ISOPODA						
DECAPODA						
Rhithropanopeus harrisii	2	4	1	2	2	8
MYSIDACEA						
GASTROPODA						
BIVALVIA						
Mya arenaria			1			
Macoma balthica		1		1		2
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	1	6	4	3	1	5
NUMBER OF INDIVIDUALS	2	72	3	5	2	28

	15A	15B	15C	16A	16B	16C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
Nemertea sp.					3	1
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A		1				2
Nereis virens				2		1
Streblospio benedicti				1	3	1
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
Rhithropanopeus harrisii	3			4	4	
MYSIDACEA						
GASTROPODA						
BIVALVIA						
Mya arenaria	3	1		3		
Macoma balthica				2	3	2
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	2	2	0	5	4	5
NUMBER OF INDIVIDUALS	6	2	0	12	13	7

	17A	17B	17C	18A	18B	18C
PORIFERA						
Cliona sp.				*	*	*
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A	3	2		3	2	1
Tharyx acutus				2	2	1
Glycera sp.						1
Nereis succinea	7	1	3	7	8	5
Pectinaria gouldii	1			1		
Eteone sp.					3	
Eumida sanguinea					3	
Phyllodoce sp.				2		
Lepidonotus squamatus				1		
Polynoidae sp.						2
Polydora ligni	12		1		2	
Scolecolepides viridis			2			
Streblospio benedicti	8	2		31	35	34
AMPHIPODA						
Lembos websteri				3	6	3
Corophiidae sp.					10	
Melita nitida	2			7		
CAPRELLIDEA						
Caprellidea sp.					1	
CIRRIPEDIA						
Thoracica sp.				*	*	*
ISOPODA						
Edotea montosa				3	5	
DECAPODA						
Neopanope texana sayi						1
Rhithropanopeus harrisii	1			1	1	1
MYSIDACEA						
GASTROPODA						
Crepidula plana					1	
BIVALVIA						
Crassostrea virginica	2				1	1
Tellina agilis	1					
ECTOPROCTA						
Ectoprocta sp.				*	*	*
CHORDATA						
NUMBER OF SPECIES	9	3	3	14	17	13
NUMBER OF INDIVIDUALS	37	5	6	61	80	50

	19A	19B	19C	20A	20B	20C
PORIFERA						
Cliona sp.			*			
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A	3	13	11			
Tharyx acutus	1	1			1	
Glycera americana	1	3	5			
Nereis succinea	10	14	31		3	6
Pectinaria gouldii	1	6	1	1	1	
Eteone sp.	1					
Phyllodoce sp.	4		1			
Lepidonotus squamatus	3					
Sabellaria vulgaris	10	2	5			
Polydora ligni	4	14			5	2
Streblospio benedicti	48	21	3		2	3
AMPHIPODA						
Lembos websteri	4					
Melita nitida	28	1	11			1
CAPRELLIDEA						
CIRRIPEDIA						
Thoracica sp.	*	*	*			*
ISOPODA						
Edotea montosa	5	1	3			
DECAPODA						
Neopanope texana sayi			2			1
Rhithropanopeus harrisii	1					
MYSIDACEA						
GASTROPODA						
Crepidula sp.						1
BIVALVIA						
Tellina agilis		1				
ECTOPROCTA						
Ectoprocta sp.	*	*	*			*
CHORDATA						
NUMBER OF SPECIES	17	13	13	1	5	8
NUMBER OF INDIVIDUALS	124	77	73	1	12	14

	21A	21B	21C	22A	22B	22C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Nereis succinea				1		
Streblospio benedicti	1					
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
MYSIDACEA						
GASTROPODA						
BIVALVIA						
Mulinia lateralis					1	
Mya arenaria			3			2
Ensis directus	1	1				
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	2	1	1	1	1	1
NUMBER OF INDIVIDUALS	2	1	3	1	1	2

	23A	23B	23C	24A	24B	24C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Tharyx acutus					2	
Glycera sp.			1			
Polydora ligni						1
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
MYSIDACEA						
GASTROPODA						
BIVALVIA						
Mya arenaria	4	1	1	2	3	1
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	1	1	2	1	2	2
NUMBER OF INDIVIDUALS	4	1	2	2	5	2

	25A	25B	25C	26A	26B	26C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A						1
AMPHIPODA						
Ampelisca sp.	1					
Gammarus mucronatus		1				
Melita nitida	1					
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
MYSIDACEA						
GASTROPODA						
BIVALVIA						
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	2	1	0	0	0	1
NUMBER OF INDIVIDUALS	2	1	0	0	0	1

	27A	27B	27C	28A	28B	28C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A		2	3	1		
Nereis succinea			1	3		
Eteone sp.			1			
Streblospio benedicti			4			
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
MYSIDACEA						
Neomysis americana		1	2			
GASTROPODA						
Ilyanassa obsoleta				3	1	1
BIVALVIA						
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	0	2	5	3	1	1
NUMBER OF INDIVIDUALS	0	3	11	7	1	1

	29A	29B	29C	30A	30B	30C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A				26	21	19
Eteone sp.					2	1
Streblospio benedicti				3		
AMPHIPODA						
Lembos websteri					1	
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
Edotea montosa			1			
DECAPODA						
MYSIDACEA						
Neomysis americana		1				
GASTROPODA						
BIVALVIA						
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	0	1	1	2	3	2
NUMBER OF INDIVIDUALS	0	1	1	29	24	20

	31A	31B	31C	32A	32B	32C
PORIFERA						
CNIDARIA						
PLATYHELMINTHES						
RHYNCHOCOELA						
SIPUNCULA						
POLYCHAETA						
Capitellidae sp. A	1	8	2			
Eteone heteropoda	1					
Eteone sp.		1	2			
AMPHIPODA						
CAPRELLIDEA						
CIRRIPEDIA						
ISOPODA						
DECAPODA						
MYSIDACEA						
GASTROPODA						
Ilyanassa obsoleta				3	1	1
BIVALVIA						
ECTOPROCTA						
CHORDATA						
NUMBER OF SPECIES	2	2	2	1	1	1
NUMBER OF INDIVIDUALS	2	9	4	3	1	1

APPENDIX B

Biological Parameters for Each Sample

SAMPLE	ABUNDANCE (per sq m)	NUMBER OF SPECIES	DIVERSITY	EQUITABILITY
1A	625	6	2.179	0.843
1B	475	7	2.220	0.791
1C	1300	10	2.774	0.835
2A	800	6	1.775	0.687
2B	1825	7	0.847	0.302
2C	775	6	1.662	0.643
3A	1525	7	1.828	0.651
3B	700	4	1.200	0.600
3C	2025	7	1.293	0.460
4A	550	6	1.818	0.703
4B	825	6	1.798	0.696
4C	925	6	1.544	0.597
5A	775	4	1.246	0.623
5B	375	4	1.375	0.688
5C	1375	5	1.392	0.600
6A	225	4	1.447	0.723
6B	225	2	0.503	0.503
6C	250	3	0.922	0.582
7A	100	3	1.500	0.946
7B	400	5	1.774	0.764
7C	1250	9	1.894	0.597
8A	525	3	0.857	0.541
8B	775	5	1.533	0.660
8C	450	4	1.098	0.549
9A	0	0	0.000	0.000
9B	0	0	0.000	0.000
9C	25	1	0.000	0.000
10A	175	5	2.236	0.963
10B	50	1	0.000	0.000
10C	125	4	1.922	0.961
11A	175	3	1.449	0.914
11B	75	3	1.585	1.000
11C	200	5	2.000	0.861
12A	375	4	1.426	0.713
12B	675	5	1.788	0.770
12C	875	3	1.113	0.702
13A	50	1	0.000	0.000
13B	1800	6	0.725	0.281
13C	75	3	1.585	1.000
14A	125	3	1.522	0.960
14B	50	1	0.000	0.000
14C	700	5	1.593	0.686
15A	150	2	1.000	1.000
15B	50	2	1.000	1.000
15C	0	0	0.000	0.000
16A	300	5	2.189	0.943
16B	325	4	1.988	0.994
16C	175	5	2.236	0.963
17A	925	9	2.630	0.830
17B	125	3	1.522	0.960

SAMPLE	ABUNDANCE (per sq m)	NUMBER OF SPECIES	DIVERSITY	EQUITABILITY
17C	150	3	1.459	0.921
18A	1525	11	2.469	0.714
18B	2000	14	2.830	0.743
18C	1250	10	1.817	0.547
19A	3100	15	2.807	0.718
19B	1925	11	2.770	0.801
19C	1825	10	2.568	0.773
20A	25	1	0.000	0.000
20B	300	5	2.055	0.885
20C	350	6	2.217	0.858
21A	50	2	1.000	1.000
21B	25	1	0.000	0.000
21C	75	1	0.000	0.000
22A	25	1	0.000	0.000
22B	25	1	0.000	0.000
22C	50	1	0.000	0.000
23A	100	1	0.000	0.000
23B	25	1	0.000	0.000
23C	50	2	1.000	1.000
24A	50	1	0.000	0.000
24B	125	2	0.971	0.971
24C	50	2	1.000	1.000
25A	50	2	1.000	1.000
25B	25	1	0.000	0.000
25C	0	0	0.000	0.000
26A	0	0	0.000	0.000
26B	0	0	0.000	0.000
26C	25	1	0.000	0.000
27A	0	0	0.000	0.000
27B	75	2	0.918	0.918
27C	275	5	2.118	0.912
28A	175	3	1.449	0.914
28B	25	1	0.000	0.000
28C	25	1	0.000	0.000
29A	0	0	0.000	0.000
29B	25	1	0.000	0.000
29C	25	1	0.000	0.000
30A	725	2	0.480	0.480
30B	600	3	0.658	0.415
30C	500	2	0.286	0.286
31A	50	2	1.000	1.000
31B	225	2	0.503	0.503
31C	100	2	1.000	1.000
32A	75	1	0.000	0.000
32B	25	1	0.000	0.000
32C	25	1	0.000	0.000

DUE DATE