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SITING CONTAINMENT ISLANDS IN NEW YORK HARBOR

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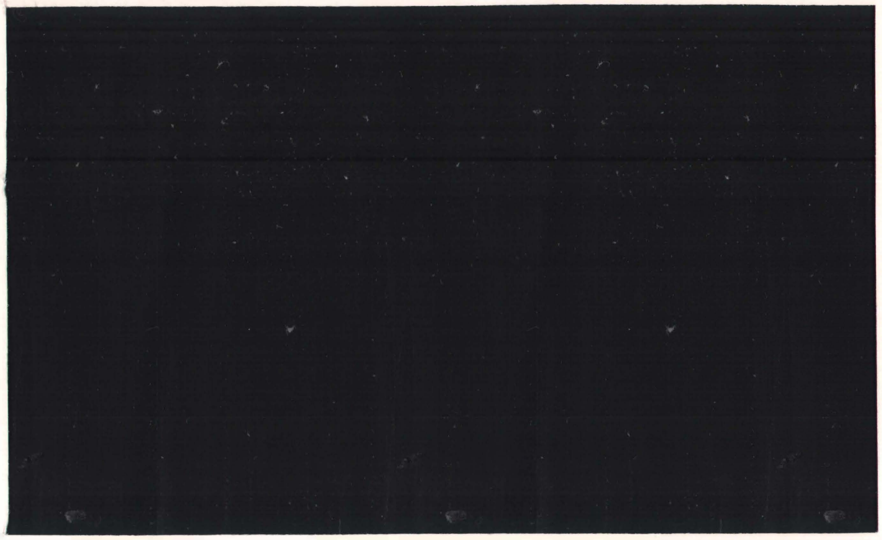

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ABSTRACT

The construction and use of containment islands is a technically feasible option for the disposal of dredged sediment. The ecological impacts due to the loss of sea floor under the island might be minimized by chosing a site with relatively low population densities. For the Lower Bay of New York Harbor sets of information on the fisheries, on the occurrence of commercially important shellfish and on the abundance and diversity of benthic populations were used to search for sites of low biological utilization. Under a variety of criteria, one "deep-water" site persistently emerged north of the Raritan Bay Channel about midway between the Chapel Hill Channel and Old Orchard Shoal (Figure 13). The northern, shoal section of the East Bank also is classified as a low use area.

INTRODUCTION

The authors of the Mitre Report (Conner et al., 1979) concluded that the disposal of dredged sediment in containment facilities is a disposal alternative that is possible in special cases. The construction of large or medium-sized containment islands in the Lower Bay of New York Harbor is within the present technical ability, containment can be achieved, and environmental problems, such as effects on water quality, tidal flushing, and shore erosion, can be anticipated and ameliorated by proper design (Bokuniewicz and Cerrato, 1985). The cost of such containment facilities is estimated to be between 2 and 3.5 times the cost of open-water disposal. The specific cost and unavoidable environmental impacts, however, cannot be determined until the facility has been designed and the facility cannot be designed until a site is chosen. At the present time, one obstacle to the selection of a site appears to be the presumed adverse ecological impact of the loss of bay floor.

Most of the studies of biological resources of the Lower Bay have covered only limited areas and relatively short time periods. The general state of knowledge concerning the biology of Lower Bay up to 1980 have been compiled from these local studies by Brinkhuis (1980) and more recently reviewed in brief by the Fish and Wildlife Service (Hamilton, 1982). Although 179 invertebrate taxa have been identified the density and diversity of macrobenthic invertebrates were found to be significantly lower when compared to other estuarine environments (Hamilton, 1982; Gandarillas and Brinkhuis, 1981). In addition, there are detailed long-term benthic data for a few sites in the Lower Bay associated with borrow pits on the West Bank (Cerrato and Scheier, 1984). Some regional benthic surveys have also been done in Raritan and Sandy Hook Bays. The New Jersey Division of Fish, Game, and Wildlife collected shellfish data at 107 stations in New Jersey waters (T. McCoy, per. com., 1984 as reported in Bokuniewicz and Cerrato, 1985) to show the presence or absence of mussels, oysters, soft clams, and surf clams and also to show areas where hard clams are present and where hard clam abundances are high or moderate. Stainken (1984) and colleagues (Stainken et al., 1984) examined the macrobenthos at stations in Raritan Bay and the Lower Bay. Several studies have been done of the fishes in selected areas of the Lower Bay. Brinkhuis (1980) reviewed the earlier work and since that review was done, five other studies have been completed (Pacheco, 1983; Conover et al., 1983; National Marine Fisheries Service, 1984; Figley, 1984; Woodhead et al., 1987). Lower Bay, including Raritan Bay and Sandy Hook Bay, is utilized extensively by nearly 70 species of fishes (Hamilton, 1982). When searching for potential sites for large containment islands in Lower Bay, shoal areas that are considered to be productive sportfishing grounds and the designated shellfish harvest area along the Staten Island coast might be eliminated from consideration for this reason.

We know of no widely accepted method to quantify the effects of the loss of bay bottom on the ecosystem in general (Lunz and Kendall, 1982; Hansen et al., 1980; Klose, 1980). Applied ecologists have investigated the problem of quantifying ecological changes but many problems remain before generally applicable procedures are available (Gosselink et al., 1974; Shabman and Batie, 1980; Schamberger and Kumpf, 1980; Lunz and Kendall, 1982). Until such a methodology is established opinions concerning the value of the bay floor will be largely subjective, although any loss can be minimized by siting the island in an area of low productivity and arguing that the area covered is small compared to the bay as a whole. An island covering 500 acres will only remove about 0.8% of the floor of Lower Bay (including Raritan Bay and Sandy Hook Bay). Effects on the tidal currents due to the presence of such an island are negligibly small and confined to the local vicinity of the island (Vieira, 1986). So the impact would be principally confined to the actual area covered by the island, and should have negligible influence on migratory fishes. The fraction of the benthic community lost by the construction of an island lacks any obvious importance to man unless it can be linked to other biological resources with human importance, such as fishes (Lunz and Kendall, 1982).

It is not possible, however, to confidently forecast changes in the fish population to specific changes in their habitat (Livingston, 1980; Lunz and Kendall, 1982). In large part the difficulties are due to the extreme variability of feeding habits and to inadequacies in sampling. Diets not only vary among different species of fishes, for example, but the same species may change its diet as it grows in size (Hodson et al., 1981) or as it changes location (Overstreet and Heard, 1978, as reported in Lunz and Kendall, 1982) or even as the availability and abundance of food change (Powell and Schwartz, 1979; Miller and Dunn, 1980). Furthermore, studies are expensive and time consuming and the disadvantages are such that success cannot be guaranteed; the disadvantages include the selective and inefficient nature of the sampling (Lunz and Kendall, 1982), the mobility of fish populations, and their variability on both daily and seasonal time periods (Karr, 1981).

Direct measurements of productivity and changes in productivity are virtually impossible to determine especially where migratory species are involved. Some indirect measurements must be used as surrogates to productivity values. It seems reasonable to assume that some areas of the bay floor should be less important to the ecosystem than others. One way to attempt to identify those areas would be to search for areas with lower biological populations. If the information used is representative of a wide range of trophic levels, then at least one component should show the influence of any exceptionally productive group. In 1985, this was done using the data then available (Bokuniewicz and Cerrato, 1985). Since that time new, extensive sets of biological data have been collected and analyzed. It is the purpose of this article to re-examine the issue of siting large or medium-sized containment islands in the Lower Bay of New York Harbor in light of our new information.

PREVIOUS WORK

To compare areas of the Lower Bay, the biological information used in the analysis should be "mappable". That is, the data sets which would be most useful at this stage of the site selection process should cover a large portion of the Lower Bay, and that the coverage should be adequate enough to see gradients in the data. Of the data sets available for the Lower Bay, very few meet this criterion. In 1985, Bokuniewicz and Cerrato used data taken from three sources.

a. McGrath (1974) sampled 65 stations in the Lower Bay complex. Sampling was done in the winter with a 0.1 square meter Smith-McIntyre grab. The data as originally reported by McGrath was used. Recently, however, Steimle and Caracciolo-Ward (in preparation) re-examined McGrath's samples and revised his preliminary estimates upward.

b. The New Jersey Department of Environmental Protection, Division of Fish, Game, and Wildlife conducted a survey of local fishermen concerning the locations of both commercial and recreational fishing grounds (Figley, 1984). The limitations of the study were discussed by Figley:

"It should be noted that these charts show the fishing grounds and not the distribution of each species. Fishing grounds represent only a portion of the geographic range of a species. Their extent is often limited by factors such as the density of fish, the suitability of an area for fishing, depth, regulations, pollution and distance from port. Furthermore, the charts depict only primary and secondary fishing grounds, areas where the majority of recreational and commercial fishing occurs; they do not include areas where rare or infrequent catches are made or where a species is taken as a bycatch of another species. In addition, fishing ground boundaries are not permanent. Fishing effort adapts to changes in fish distribution and the location of grounds can vary from year to year. The information contained on these charts must therefore be considered in the context of time. It must also be recognized that although the survey included a large and diverse sample of New Jersey's recreational and commercial fishermen, not all fishermen were interviewed. Therefore, some actively fished areas may have been omitted.

"The charts of Raritan/Sandy Hook Bay indicate the fishing ground of New Jersey fishermen only."

Despite these limitations, the study is both thorough and recent. Nine maps were used; these were:

1) the recreational fishing areas for sea bass, tautog, porgy, and spot

2) the commercial netting areas

3) the commercial eel pot and horseshoe crab dredge areas

4) the commercial blue crab dredging areas

5) the primary and secondary recreational fishing areas for bluefish

6) the primary and secondary recreational fishing areas for weakfish

7) the primary and secondary recreational fishing areas for summer flounder

8) the primary and secondary recreational fishing areas for winter flounder

9) the primary and secondary recreational fishing areas for striped bass.

c. The New Jersey Division of Fish, Game, and Wildlife also collected shellfish data at 107 stations in New Jersey waters (T. McCoy, per. comm. 1984 as reported in Bokuniewicz and Cerrato, 1985).

Based on a synthesis of such data, a relative comparison of different areas of the sea floor was done. Three areas were identified that have relatively low population densities (Figure 1).

Between September, 1984 and March, 1986 an extensive series of ground trawls were done in the area to assess the fin fish community with particular attention to the three sites identified in Figure 1 (Woodhead et al., 1987). Of these three sites, the northeasternmost site had a relatively diverse, high density community and it was considered to be a poor choice for a containment island site. The other two sites had relatively low population densities and these were considered to be suitable choices.

In the spring of 1986 an extensive survey of benthic organisms was begun. One hundred and fourteen stations were sampled seasonally on a grid throughout the Lower Bay includng a concentration of sampling stations at the three sites identified in Figure 1. For the present study, this benthic data was used to replace the data sets by McGrath (1974) and the shellfish survey of New Jersey waters (McCoy, 1984, as reported in Bokuniewicz and Cerrato, 1985). Benthic samples were taken using a 0.1 square meter Smith-McIntyre grab. Data on average abundance and average number of species per 0.1 m^2 were plotted, and contour maps were generated for each data set. Contour intervals were chosen based on the cumulative frequency distributions. A map of benthic abundance and a map of species richness was generated for each season; eight maps were generated, therefore, to represent the benthic population. A relatively high number of species was taken to be indicative of an area favorable to the bay's overall ecology.

These benthic data were also used to construct four additional maps showing the presence or absence of commercial bivalve species (mussels, oysters, soft clams and surf clams).

PROCEDURE

The procedure used to compare different areas of the bay floor was the same as that used by Bokuniewicz and Cerrato (1985). Twenty-two mappable data sets were used (Table 1). The Lower Bay was divided into 280 boxes, or quadrates, of about 250 acres each. For each data map, quadrates were rated as an area of primary use, secondary use or tertiary (low) use based on the criteria listed in Table 1 and assigned a score from 1 to 3 respectively. As shown in this table, quadrates designated as

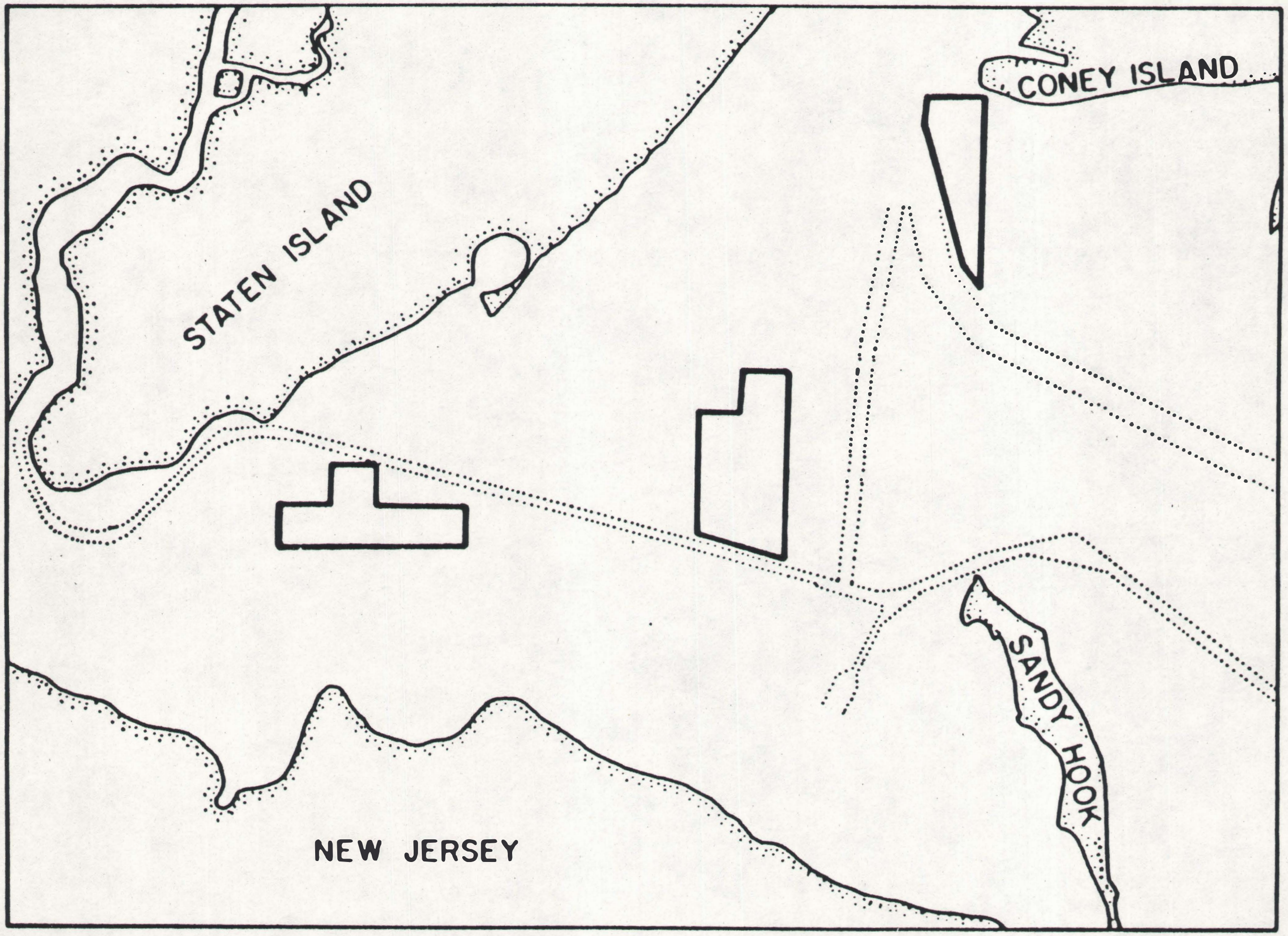


Figure 1. Potential containment area sites based on data available in 1985 on biological resources and population (Bokuniewicz and Cerrato, 1985)

Table 1. Data sets and score assignments for the site-selection process.

DATA MAPS

1. Fishing areas for striped bass
2. Fishing areas for sea bass, spot, tautog, or porgy
3. Commercial netting areas
4. Commercial eel pot and horseshoe crab dredge areas
5. Commercial blue crab dredging areas
6. Fishing areas for bluefish
7. Fishing areas for weakfish
8. Fishing areas for summer flounder
9. Fishing areas for winter flounder
10. Occurrence of hard clams
11. Occurrence of mussels
12. Occurrence of oysters
13. Occurrence of soft clams
14. Occurrence of surf clams
15. Benthic abundance - Spring
16. Species richness - Spring
17. Benthic abundance - Summer
18. Species richness - Summer
19. Benthic abundance - Fall
20. Species richness - Fall
21. Benthic abundance - Winter
22. Species richness - Winter

SCORE ASSIGNMENTS:

Usage:	primary use area	secondary use area	tertiary use area
Score:	1	2	3
Fishing data:	Primary fishing area	Secondary fishing area	Non-fishing
Occurrence of commercially important shellfish:	present in 3 or 4 seasons	present in 2 seasons	present in 1 season or not present
Benthic data:			
Abundance	>3000	1000-3000	<1000
Species	>18	10-18	<10

tertiary-use areas are less populated than those designated as primary-use areas.

For any particular quadrate, a sum of its scores on each map can be found. These sums can be displayed for the entire set of maps or for any particular subset of them.

At this point, two non-biological constraints were included in the site selection process. In order to accommodate barges, water depths of 18 feet or more are needed on at least one side of a containment island. In addition, quadrates which include a portion of a channel should be ignored. Those locations excluded by these constraints are displayed as hatched areas in Figure 2. Unhatched areas in this figure represent the remaining acceptable localities. It should be noted that while hatched areas were not considered further as the location for a containment island, information from these areas was always utilized in the analysis of the biological data.

To identify potential sites, individual data maps were combined and we proceeded to identify those quadrates with the lower combined utilization when compared to other localities. This process was done sequentially, beginning with the areas of lowest utilization, then including areas of slightly greater utilization, and so on. In general, what we saw as we sequentially searched for the low use areas is illustrated in the following specific example. In this example, the fisheries data derived from Figley (1984) and discussed earlier (Table 1) will be used. In summing these nine data maps, the quadrates designated as tertiary-use areas on at least eight of the nine maps are shown by a pair of asterisks (**). These comprise 10% of the total area of the Lower Bay Complex (Figure 3). Note that only isolated quadrates appear within the unhatched area of this figure. Since quadrates represent areas approximately 250 acres in size, these single, isolated quadrates are too small for a medium-sized containment island. An intermediate case, generated by adding slightly more utilized areas is shown in Figure 4. The ornamented quadrates on this map were designated as tertiary-use areas on at least six of the nine maps; these comprise 36% of the Bay floor. In this figure, small patches have appeared within the unhatched area. Since these patches consist of two or more quadrates, they are large enough to accommodate a 500-acre containment island. Finally, as the level of utilization is raised, the patches tend to grow and coalesce. The ornamented quadrates in Figure 5 had been designated as tertiary use areas on at least four of the nine maps; these comprise 61% of the Bay floor. Note that rather sizable areas have appeared within the unhatched region.

In our analysis of the biological data, we decided to stop the selection process at a level comparable to that found in Figure 4, that is only until areas just large enough to accommodate a 500-acre containment island appeared in the unhatched region of the map. This process produces a fairly conservative selection of sites since we determined after many

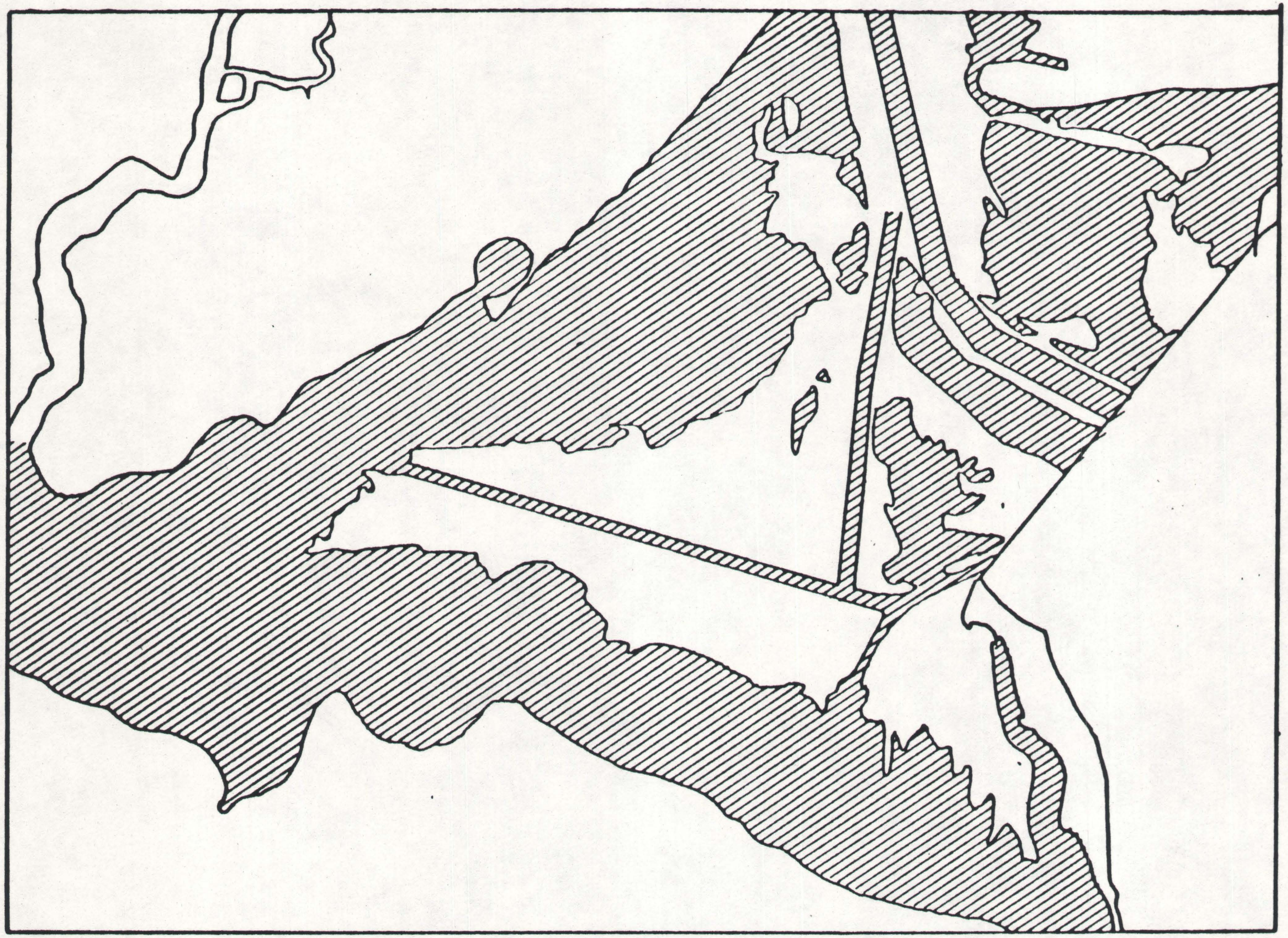
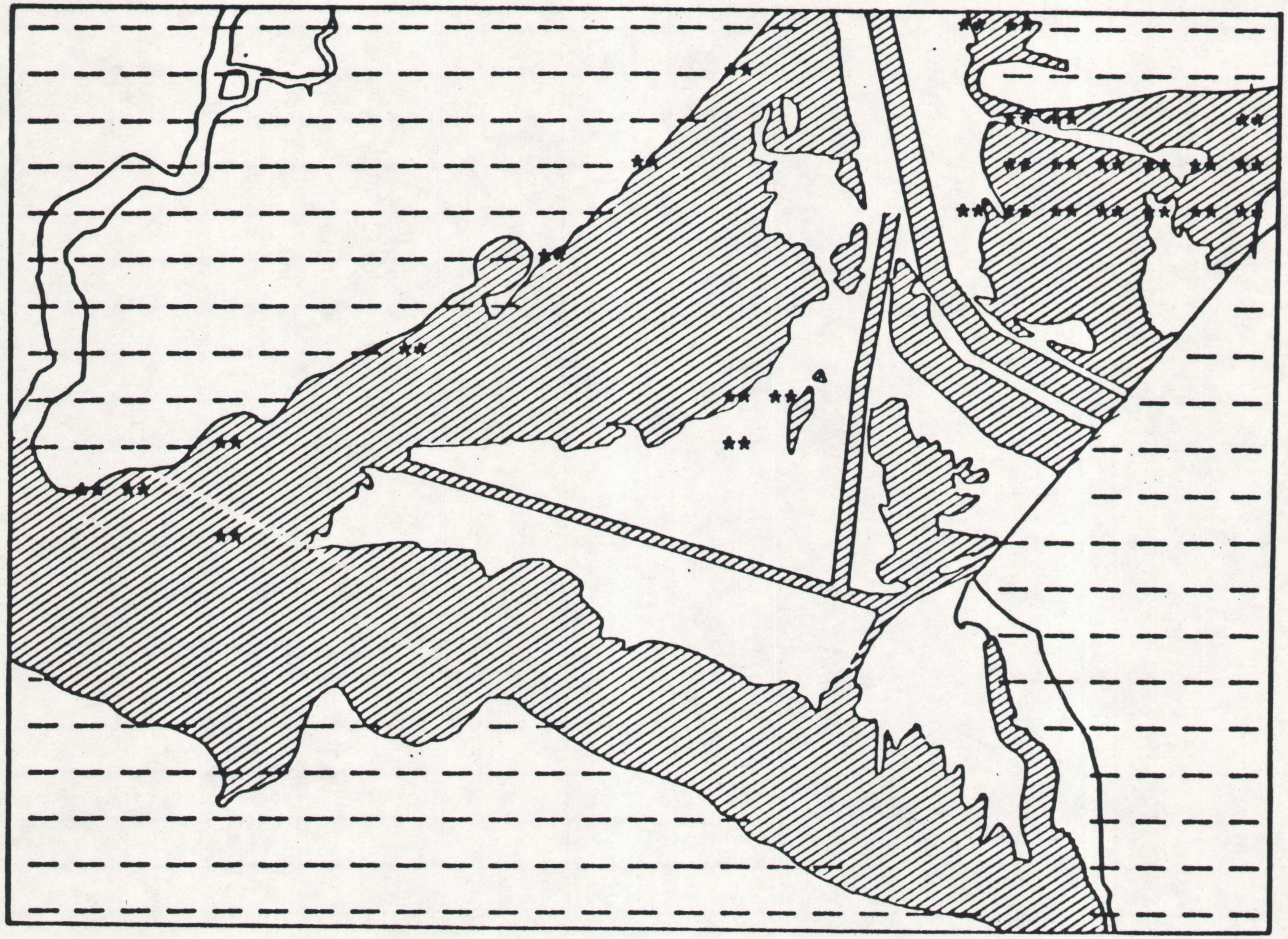
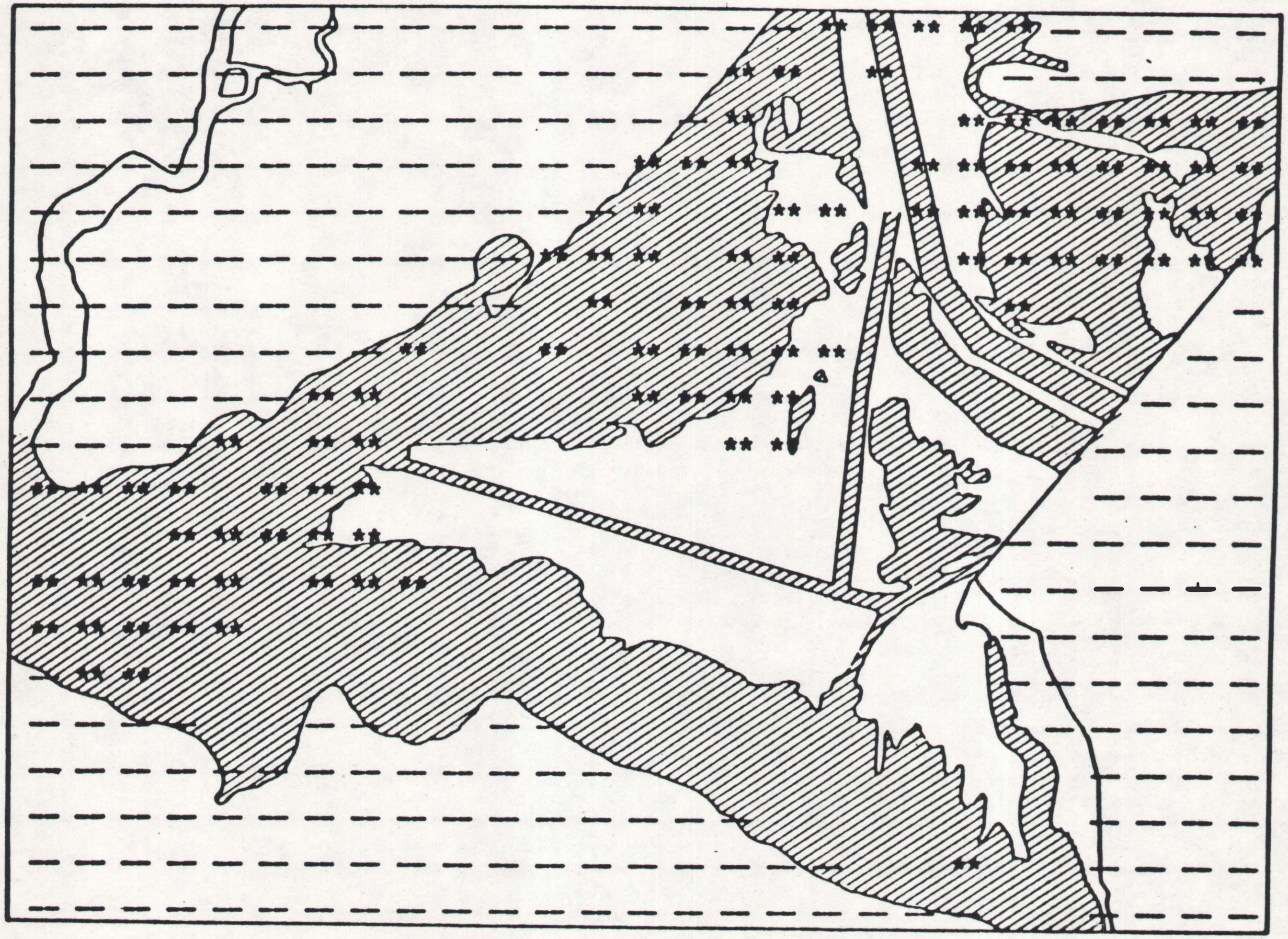


Figure 2. A Lower Bay map showing the locations of shallow areas (<18 ft.) and ship channels.



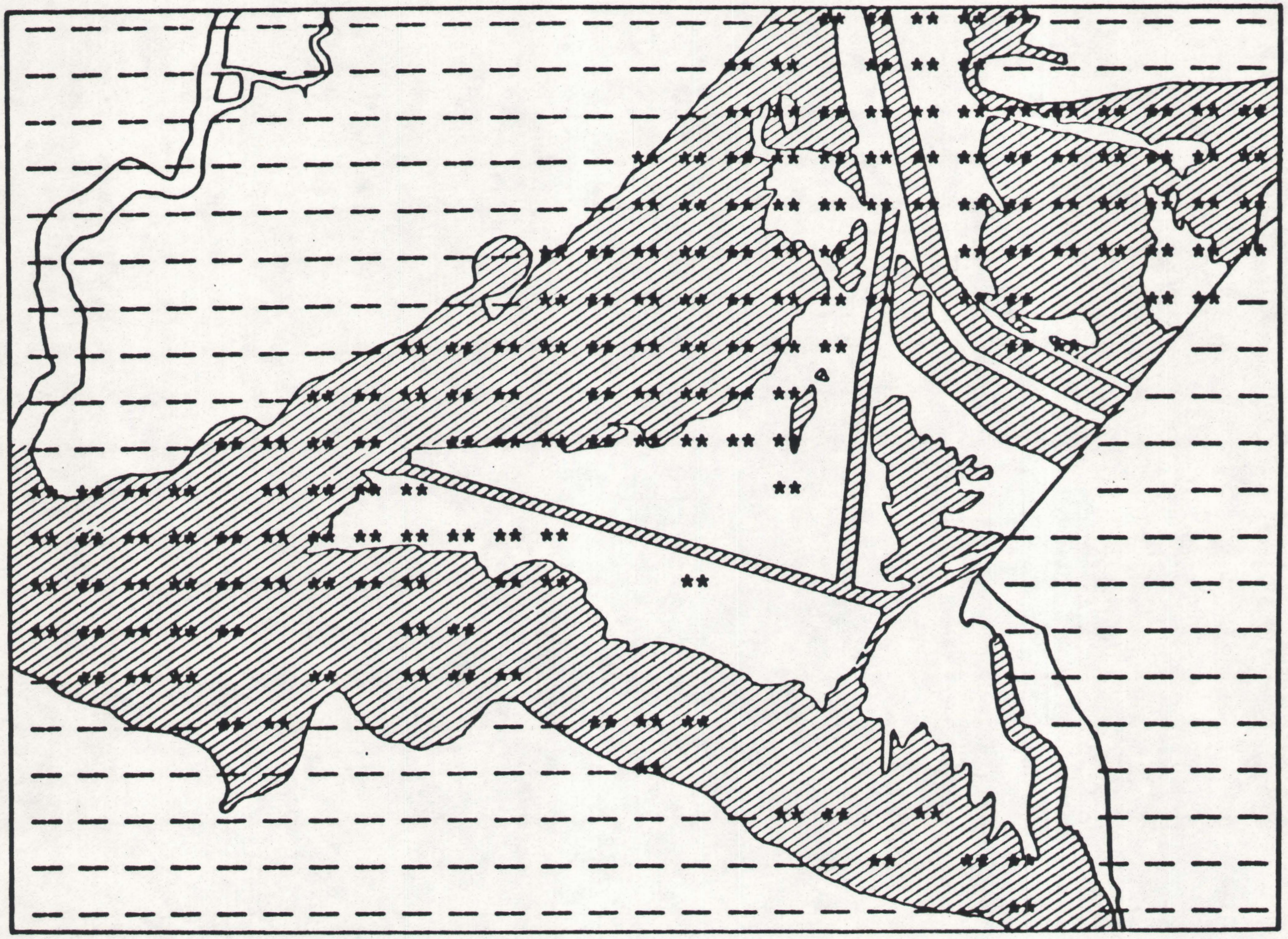
FISH DATA

Figure 3. Fisheries data as designated by maps 1 through 9 (Table 1) The symbol "**" indicates those quadrates in the lower 10% of utilized area.



FISH DATA

Figure 4. Fisheries data as designated by maps 1 through 9 (Table 1) The symbol "**" identifies those quadrates in the lower 36% of the utilized area.



FISH DATA

Figure 5. Fisheries data as designated by maps 1 through 9 (Table 1). The symbol "**" identifies those quadrates in the lower 61% of the utilized areas.

trials using different combinations of the data maps that the values included were always within about the lowest third of the combined use.

One of our concerns in this analysis was whether certain data sets should be given more weight than others in the site selection process. For example, if we simply combined the data maps listed in Table 1, then the fisheries data, which includes maps of fishing areas as well as maps of the occurrence of commercially important shellfish, would be counted most heavily since fourteen of the twenty-two data maps were used to define the fisheries resource. Weighting effects were examined by dividing the available data maps into two groups. The first group consisted of the fisheries data maps including the commercially important shellfish; the second group combined the benthic data maps derived from the 1986-1987 surveys (Table 1). Details of the method of calculation are given in Appendix 1.

RESULTS

Different weightings were explored ranging from assigning 100% of the weight to the group consisting of the benthic data maps to assigning 100% of the weight to the fisheries group. Intermediate weightings of the fisheries and benthic data groups of 75% to 25%, 67% to 33%, 50% to 50%, 33% to 67%, and 25% to 75% were also analyzed. These trials are presented in Figures 6 to 12.

As a result of these trials, two areas of the bay persistently emerge as regions of low utilization (Figure 13) and no species was unique to either site. The boundaries of these areas were drawn on the basis of an equal weighting between the fisheries maps and the benthic maps. For different weightings, the same general areas appear; they are always areas of lower utilization than the original sites in the East Bank borrow pit or in the Raritan Bay. The results are insensitive to the weightings, and both areas appear in every trial. In other words, the results are independent of the way the maps are combined. As various weights are used, the shape of the areas change somewhat. These shape changes can be seen in Figures 6 through 12 which show the low-use areas based upon different weighting. At this level of utilization a few other smaller areas also appear that are not shown on Figure 13. Some are near the southernmost borrow pit on the West Bank and the eastern tip of Romer Shoal (Figure 9). However, unlike the two areas shown in Figure 13, these smaller areas did not appear in every trial.

DISCUSSION

One of the low-use areas shown in Figure 13 is north of the Raritan Bay Channel about midway between the Chapel Hill Channel and Old Orchard Shoal. This is the northern part of one of the sites identified in the earlier study (Figure 1; Bokuniewicz and

Cerrato, 1985). It was also identified as a site of low fin fish diversity and population density in the most recent surveys (Woodhead, et al., 1988).The other is designated by a dotted line because it is almost entirely in water less than 18 feet deep whereas we had required a water depth of 18 feet or more to accommodate the barges. The southern part of the area on the East Bank is also the northern part of the "low-use area" designated independently by fishing surveys shown on figure fifty-four of the report by Woodhead and McCafferty (1986; Appendix II). This area has been proposed by Woodhead, et al (1988) as an alternate site. In terms of the fishery resources, the study by Woodhead, et al. (1988) independently confirms the results here.

Concerning the benthic population, both low-use areas identified in this report are regions with very high sand content (>95%) and very low organic content in the bottom sediments (<1.5%). Substrate type is known to exert a strong influence on the benthic community structure in the bay (Diaz and Boesch, 1984). The environmental factors responsible for the observed distributions in the bay are complicated, but sediment type may be an important indicator here.

Several prior benthic surveys have been conducted within or near the two sites identified in this report. For the site near Old Orchard Shoal, there are benthic data from McGrath's (1974) study in 1973 and from two other studies (Gandarillas and Brinkhuis, 1981; Cerrato and Scheier, 1984) covering the period between 1979-83. Benthic abundances measured in all of these surveys were comparable to that found during the 1986-87 study at this site. Species richness and faunal composition was also comparable with the exception of a notable rareness of amphipods and several other arthropod groups in the earlier studies. For the East Bank site, the abundances, species richness, and faunal composition found during the 1986/7 benthic study was quite similar to a 1979/80 survey of this area by Gandarillas and Brinkhuis (1981). Overall, these preliminary comparisons do not suggest that the benthos at these two sites has changed considerably over time.

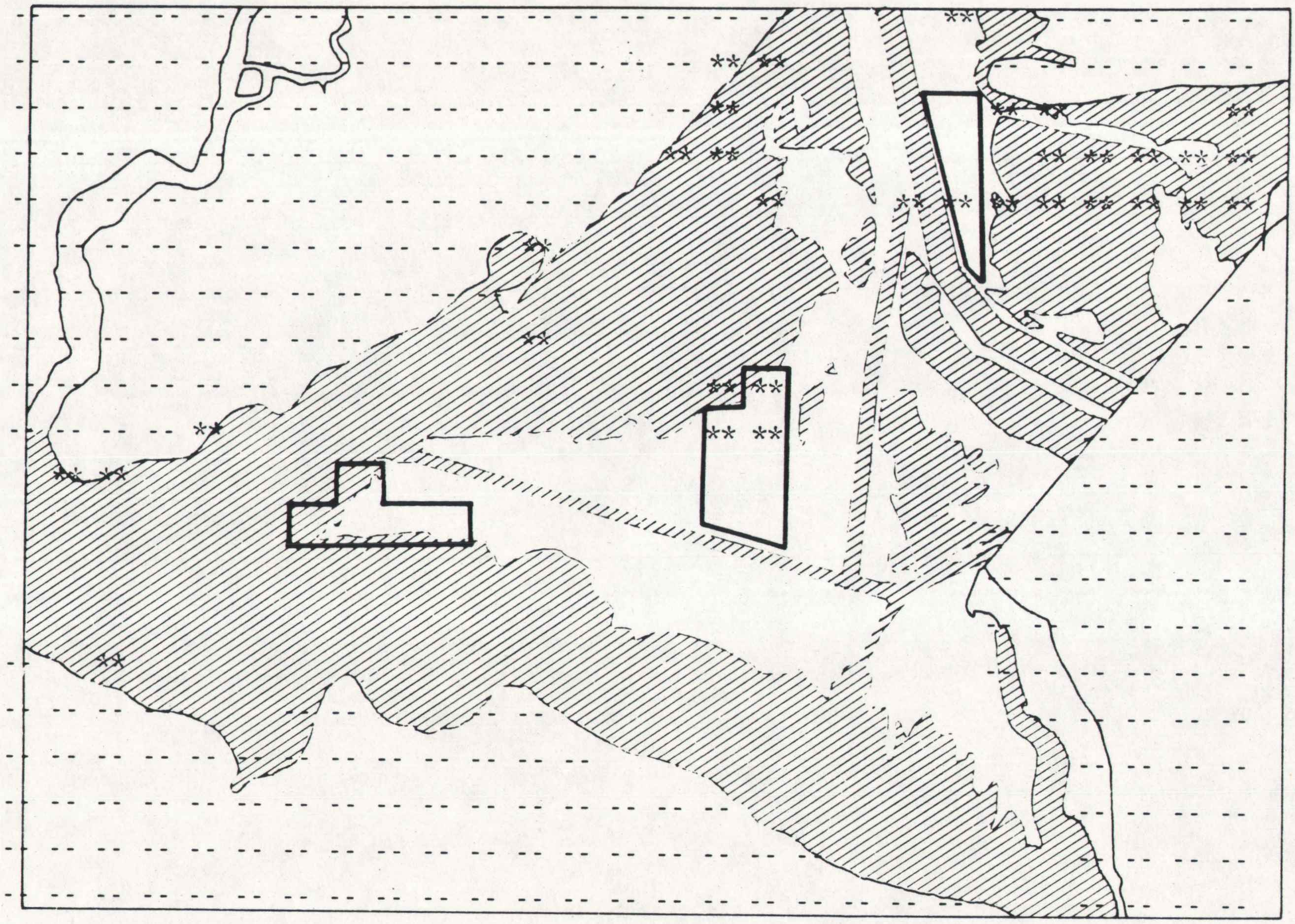


Figure 6. Site identification (as described in the text) using only fisheries data.

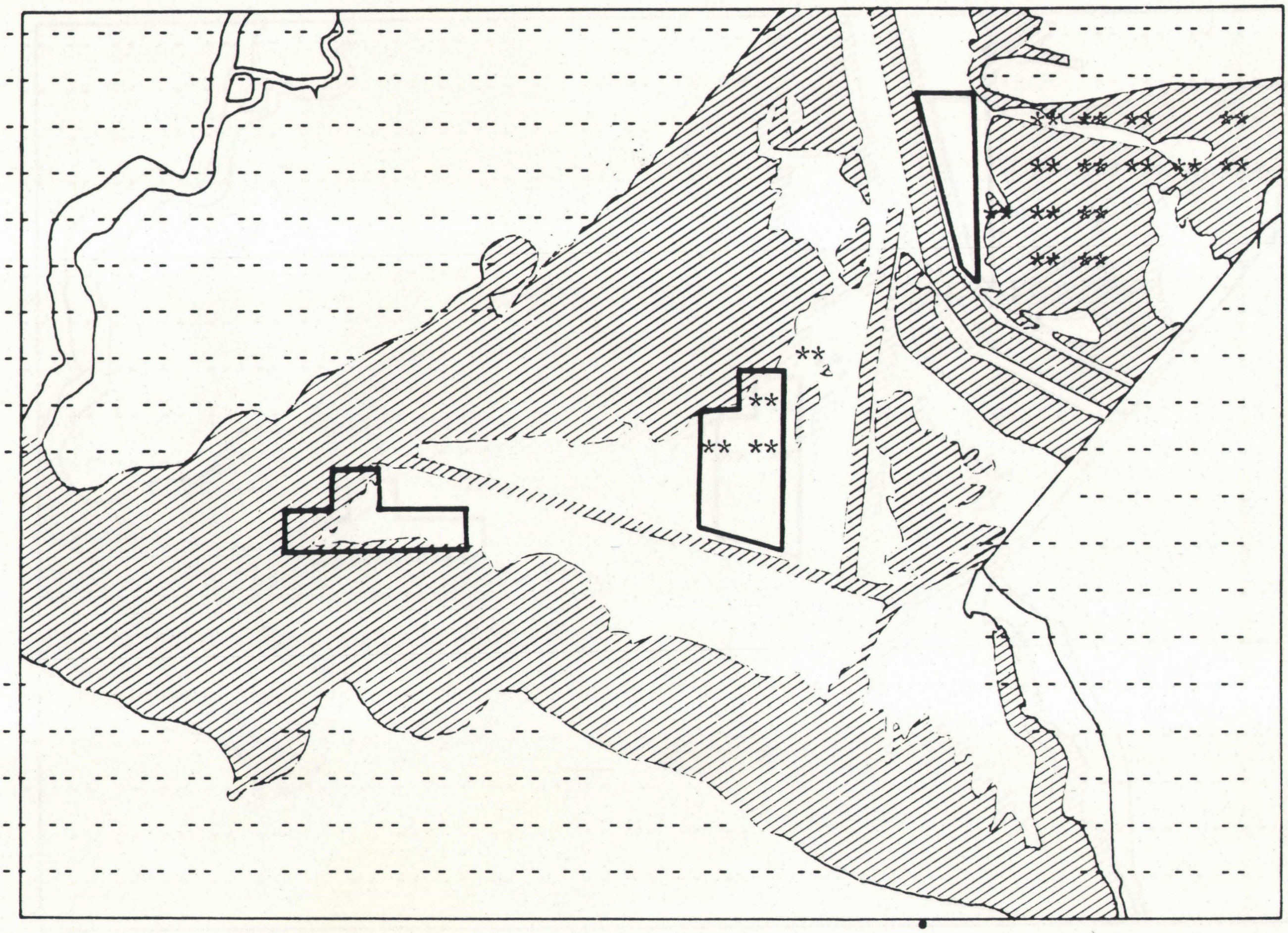


Figure 7. Site identification (as described in the text) based on an unequal weighting of the fish and benthic data. This map assigns 75% of the scores' weight from the fisheries data and 25% from the benthic data.

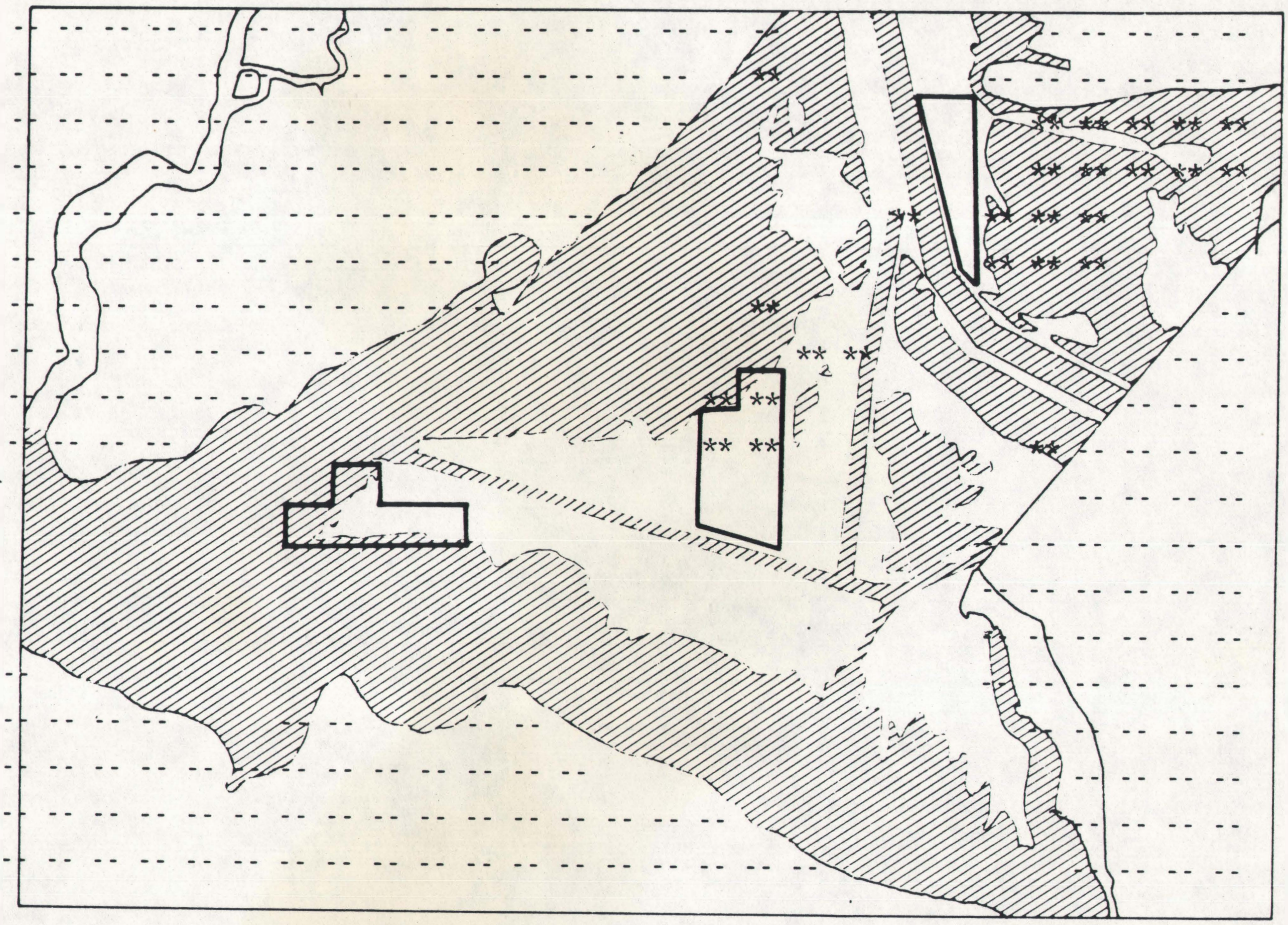


Figure 9. Site identification (as described in the text) based on an equal weighting of the fish and benthic data. This map assigns 50% of the scores' weight from the fisheries data and 50% from the benthic data.

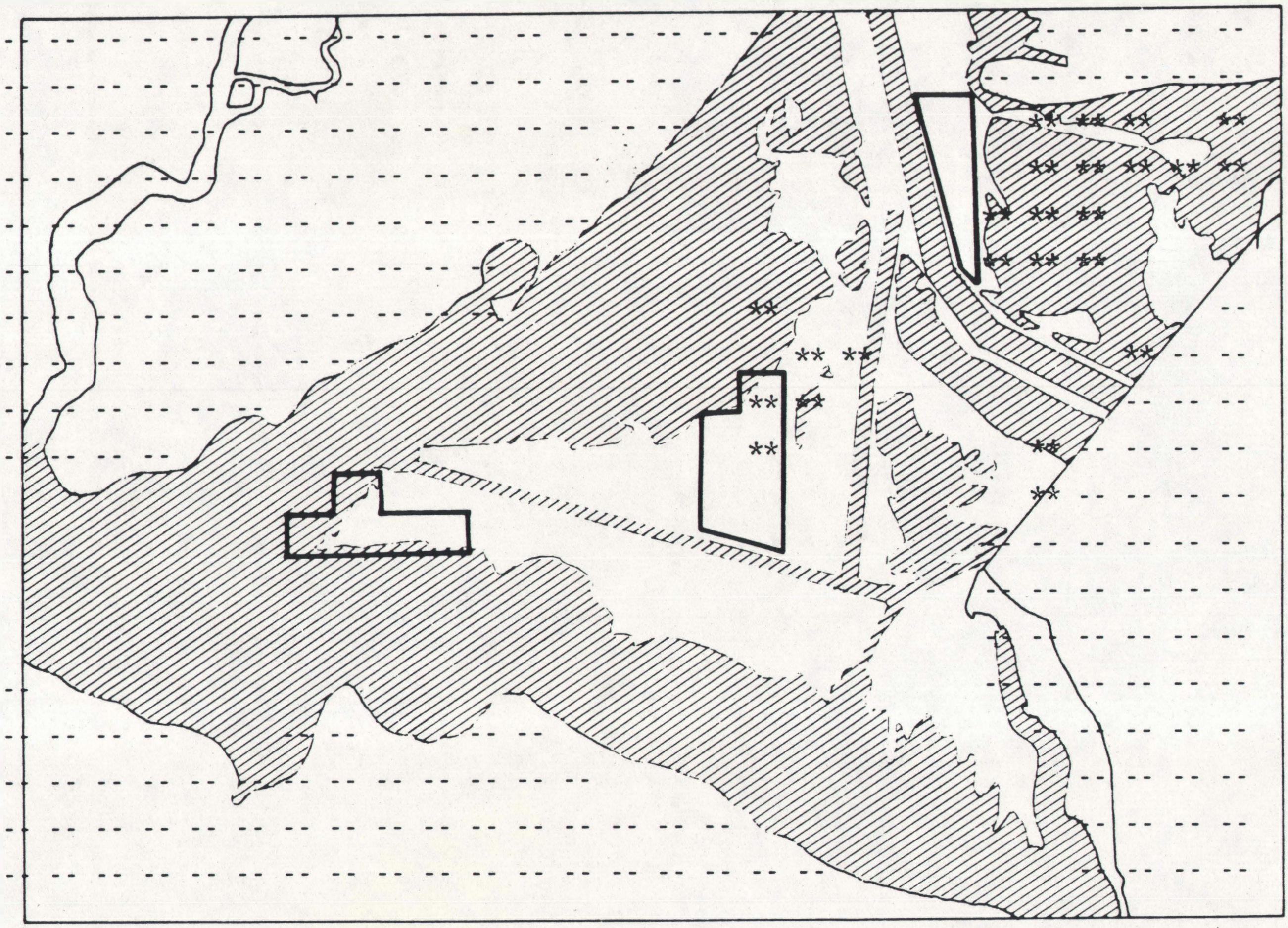


Figure 10. Site identification (as described in the text) based on an unequal weighting of the fish and benthic data. This map assigns 33% of the scores' weight from the fisheries data and 67% from the benthic data.

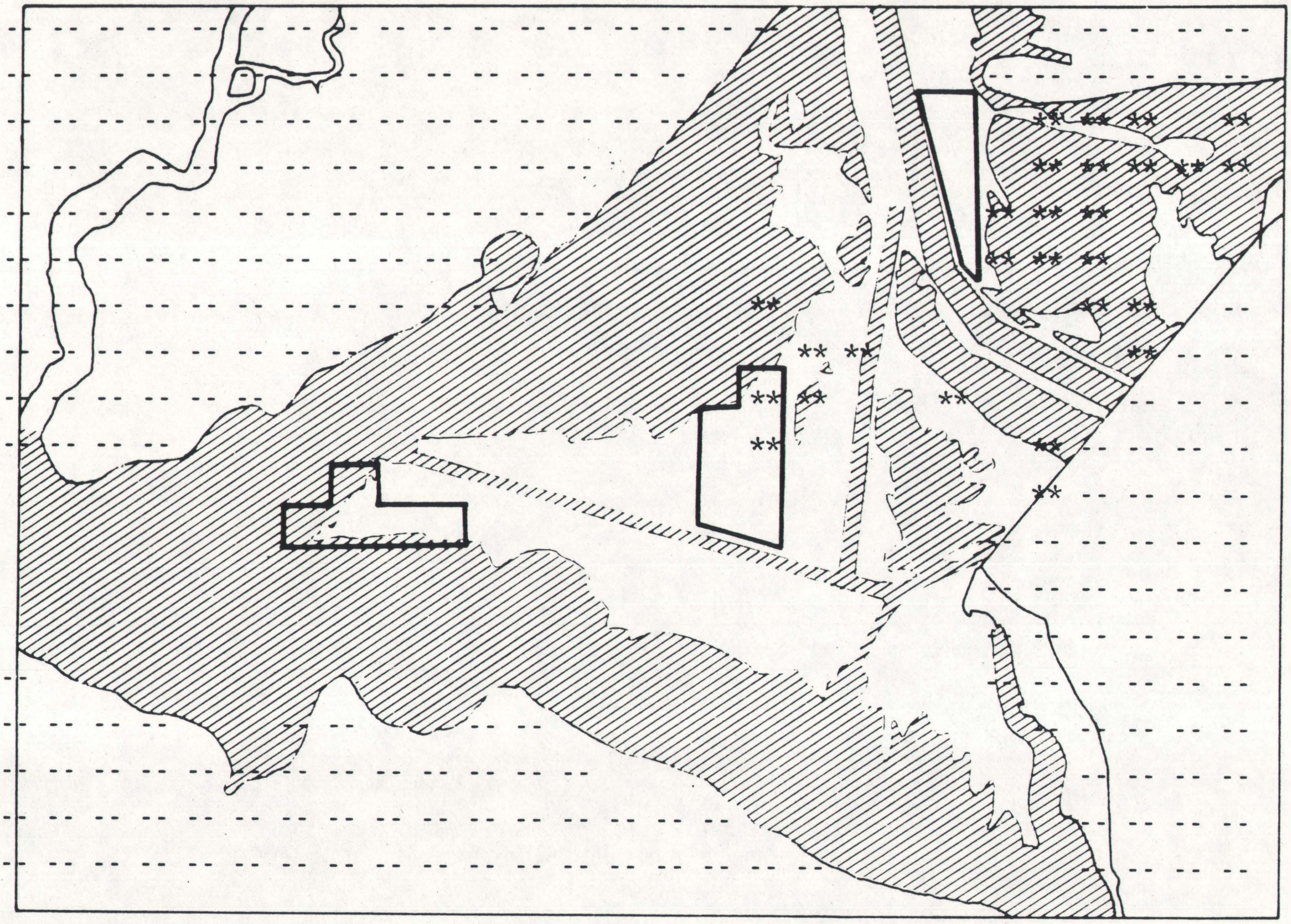


Figure 11. Site identification (as described in the text) based on an unequal weighting of the fish and benthic data. This map assigns 25% of the scores' weight from the fisheries data and 75% from the benthic data.

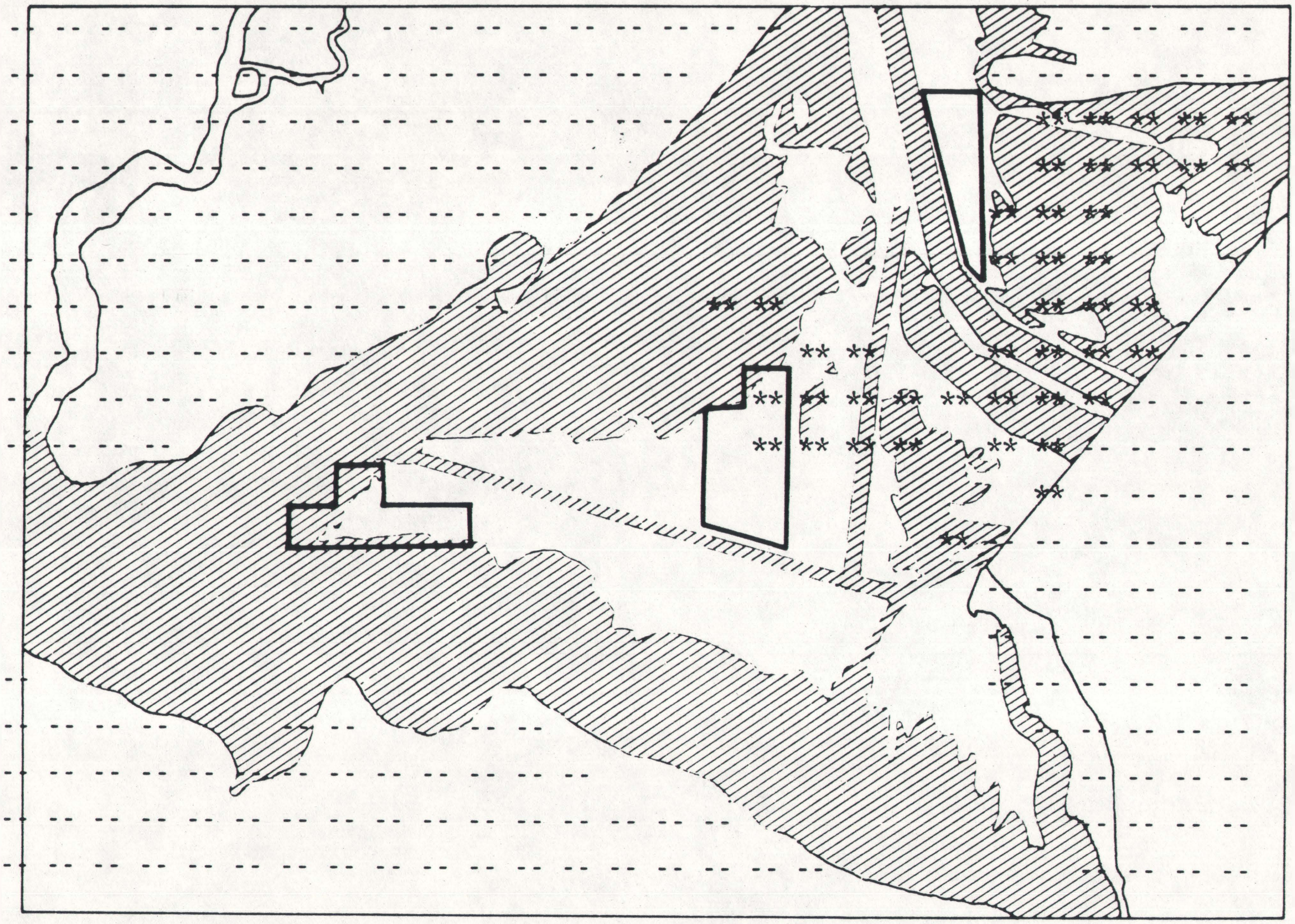


Figure 12. Site identification (as described in the text) using only the benthic data.

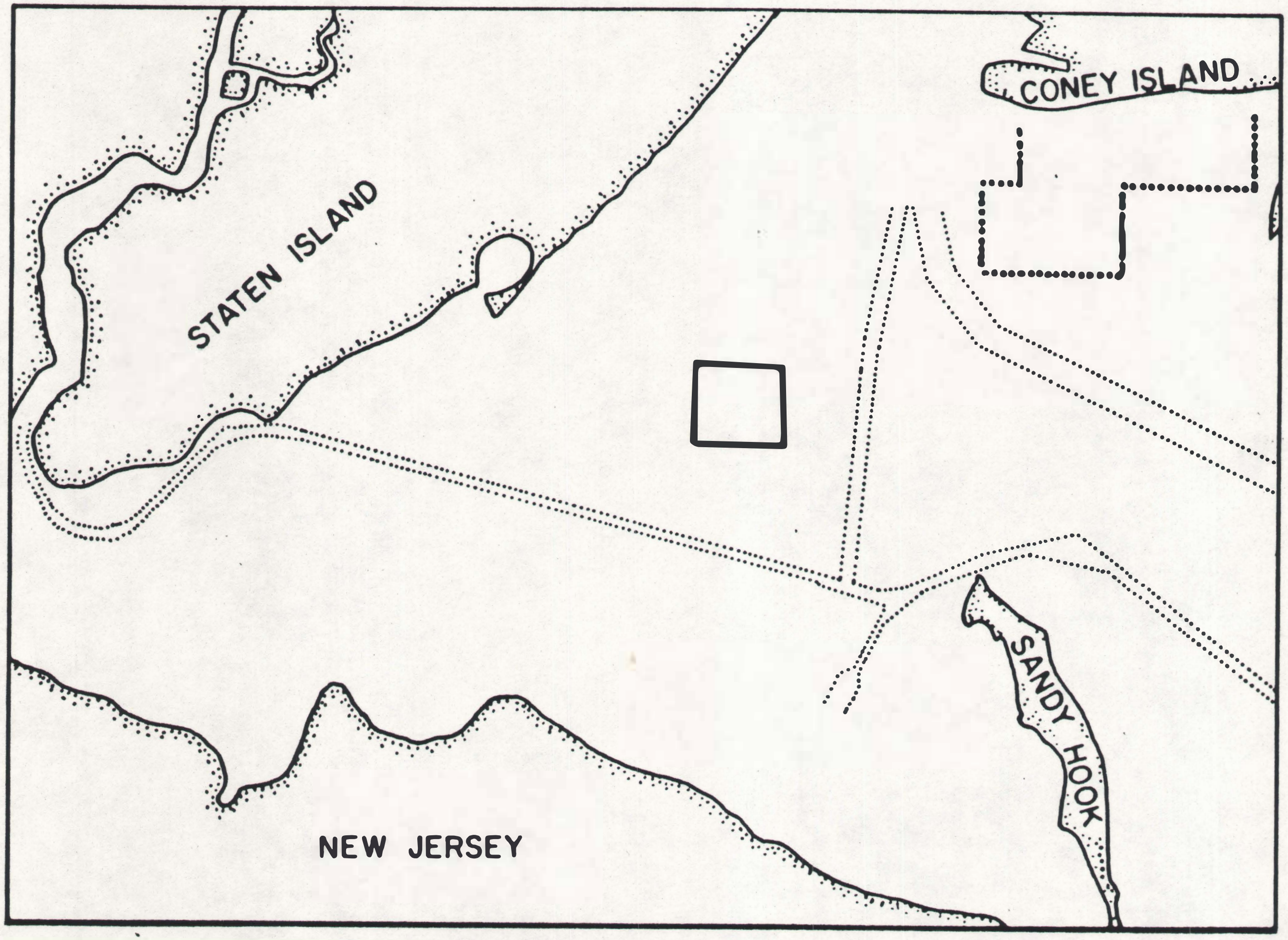


Figure 13. Potential containment area site (solid line) based on available data on biological resources and population. The area bordered by the dotted line is another low use area but one in shallower water.

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Appendix I

The specific method used for examining weighted sets of data maps is based on the following. Let N be the total number of data maps used, and let S_i be a quadrate score for data map i, i=1,2,...,N. We can associate with the data maps certain weighting factors $W_1, W_2, \ldots, W_N$ depending on the importance assigned to each data map. If this is the case, then a weighted total quadrate score, S_T, is given by

$$(1) \qquad S_T = W_1S_1 + W_2S_2 + \ldots + W_NS_N = \sum_{i=1}^{N} W_iS_i \ .$$

For example, if we wish to weight each data map equally, then we could assign $W_i=1$, i=1,2,...,N, and we would have

$$(2) \qquad S_T = \sum_{i=1}^{N} 1S_i = \sum_{i=1}^{N} S_i$$

where

$$(3) \qquad W_1 + W_2 + \ldots + W_N = \sum_{i=1}^{N} W_i = \sum_{i=1}^{N} 1 = N \ .$$

Now suppose that we partition the data maps into two groups. Let

B = the set of benthic survey data maps, and

F = the set of fisheries data maps.

Within each group, we will assign equal weights, i.e.

$$(4) \qquad W_i = W_B \quad \text{for } i \in B$$

$$(5) \qquad W_i = W_F \quad \text{for } i \in F$$

where W_B is the weighting factor assigned to each benthic data map, and W_F is the weighting factor assigned to each fisheries data map. Maintaining the constraint that the sum of the weights equal the total number of data maps used (Equation 3), we have that

$$(3) \qquad W_1 + W_2 + \ldots + W_N = N$$

implies

(6)
$$n_B W_B + n_F W_F = N$$

where n_B is the number of benthic survey data maps, and n_F is the number of fisheries data maps.

Finally, if p is the proportion of the total weight assigned to the benthic survey data, and therefore, (1 - p) is the proportion of the total weight assigned to the fisheries data, then the above analysis suggests that an appropriate weighting is assigned to the two groups when

(7)
$$n_B W_B = pN$$

(8)
$$n_F W_F = (1 - p)N \ .$$

Equations (7) and (8) when solved for W_B and W_F yield

(9)
$$W_B = pN/n_B$$

(10)
$$W_F = (1 - p)N/n_F \ .$$

Appendix II

This appendix is a map from a report by Woodhead and McCafferty (1986) showing an area of low usage by the fin fish community on the East Bank utilizing data from a recent extension of ground trawl survey between September 1984 and March 1986.

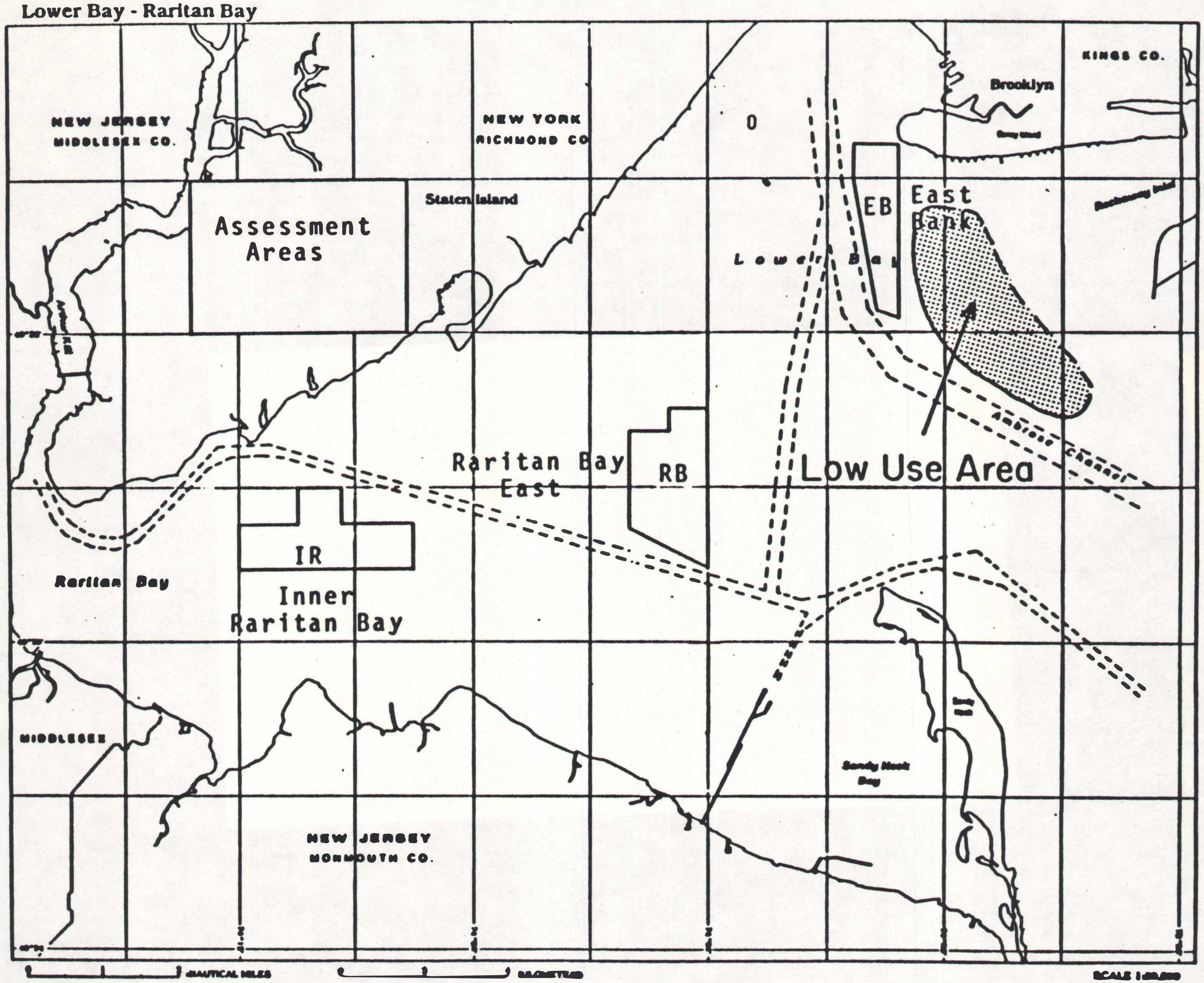

Figure 54. Alternative area of low usage by the fish community on the East Bank (shown speckled, from Woodhead & McCafferty, 1986), in relation to the EB site.