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A Quantitative Study of Benthic Fauna in Lower Chesapeake Bay with Emphasis on Animal-Sediment Relationships

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A QUANTITATIVE STUDY OF BENTHIS FAUNA IN LOWER CHESAPEAKE BAY WITH EMPHASIS ON ANIMAL - SEDIMENT RELATIONSHIPS

by

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ABSTRACT

The dredging and dumping of spoil material by the United States Army Corps of Engineers during the winter of 1962 practically eliminated the existing fauna in the respective channel and disposal areas. Quantitative evidence from subsequent sampling indicated that repopulation by the more stable species was occurring in both areas.

Considerable seasonal variation was noted in the numbers of benthic organisms. The razor clam, *Ensis directus*, showed numerical reductions of 97 to 100 per cent in one month.

Animal-sediment relationships were defined for sand and mud communities. The *Nephtys incisa*-*Retusa canaliculata* community was characteristic of the silty sediments in the lower bay, while the suspension feeders, *Ampelisca spinipes* and *Lyonsia hyalina*, were associated with sandier sediments.

INTRODUCTION

History of Previous Work

Quantitative benthic studies received impetus from C. G. J. Petersen subsequent to a series of papers published in 1911 and later. Petersen presented methods and invented instruments such as the "Petersen grab" which gave quantitative sampling a firm basis (Hedgpeth, 1957).

Sparck (1935), summarized the importance of quantitative investigations under several major subjects. At first, benthic studies were undertaken to determine the amount of fish food available per square meter of sea-bottom. These studies were economically important to the fishing industry, since there seemed to be a close relation between the number of benthic animals and the population of bottom fishes. Secondly, there was a need for simplified methods of describing the benthic fauna. Petersen solved the latter by indicating the few quantitatively dominant species and referring to these as a community. The community concept enables the investigator to make certain broad statements concerning the faunal assemblage over fairly large areas which could not be thoroughly covered by sampling in any reasonable amount of time. This concept is emphasized in Sparck's discussion of marine ecology. Ecological importance includes the possibility of naming communities according to the type of sediment associated with the organism. It is with this last aspect that the present study is primarily concerned.

Previous research involving quantitative sampling and animal-sediment relationships on the east coast of the United States has been directed largely toward the study of pelecypods. Bader (1954) reported that the organic content of sediments and the state of decomposition were primary factors in controlling the distribution of infaunal pelecypods in the region of Mt. Desert Island, Maine. Stickney and Stringer (1957) conducted biological studies of the soft clam (Mya arenaria) and the hard clam (Mercenaria mercenaria) in Greenwich Bay, Rhode Island. They indicate the possibility that certain species might serve as indicators of localities favorable for commercially important species. Wells (1957) studied hard clam populations in the Chincoteague Bay area of Maryland and determined distribution correlated with bottom types. Clams were most abundant in areas of shell. Sand ranked second and the abundance decreased through sand-mud mixtures to a low in mud samples. Clams were more abundant in deeper water and areas of strong currents.

The most recent studies of animal-sediment relationships have been done by Sanders (1958) in Buzzards Bay, Massachusetts, and McNulty et al. (1962) in Biscayne Bay, Florida. Sanders (1958) separated two primary feeding types, the filter-feeders and the deposit-feeders. He found numerical dominance of these types in the sand and mud sediments, respectively. Results indicated that clay was the most valid sediment type for correlating distribution of deposit-feeding organisms, while the filter-feeding organisms were most abundant in fine, well sorted sand with median diameters of 0.18 mm.

McNulty et al.(1962) found dominant organisms occurring at different grain sizes from those found by Sanders. They separated the organisms into three feeding types: deposit, detritus, and filter feeders. Dominance was figured in terms of tissue dry weight instead of numbers of individuals. Detritus-feeders were predominant in the fine sediments, while deposit- and filter-feeders were most abundant in sediments with a median diameter about 0.4 mm.

Purpose of Present Investigation

The dredging operation for the U. S. Army Corps of Engineers removed sediment in the Rappahannock Shoals ship channel to a depth of approximately five feet below the surrounding bottom. Spoil material was pumped into hopper barges and towed to a disposal site where the material was dumped.

The present quantitative investigation of the benthic fauna in the lower Chesapeake Bay was undertaken under Contract DA-44-110-CIVENG-61-181 with the U. S. Army Corps of Engineers over the period July, 1961, through July, 1963. The purpose was twofold. First, to determine the effect of dredging and the dumping of the dredged material into the disposal area on the existing fauna and the length of time necessary for repopulation in these areas. Second, to compare the animal-sediment relationships in the lower Chesapeake Bay with similar studies in other areas.

Area of Investigation

Chesapeake Bay and its tributaries comprise one of the largest estuaries in the world. The bay is approximately one hundred and eighty miles long from the mouth of the Susquehanna River, the northernmost and largest tributary, to its oceanic mouth between Cape Henry and Cape Charles. (Fig. 1). The width varies from three to thirty miles. Ryan (1953) indicates that coarse sands of the western shore grade outward through finer sands to clayey-silts in the channel, while east of the main channel the sediments are sands regardless of depth. He further states that the lower bay has the lowest silt and clay percentages.

The majority of the samples taken during the present study were restricted to the silts in the deeper portions of the bay (Fig. 5). The northernmost sampling station was located in an area adjacent to the mouth of the Great Wicomico River, while the southernmost transect crossed the bay opposite the mouth of the Piankatank River (Fig. 1).

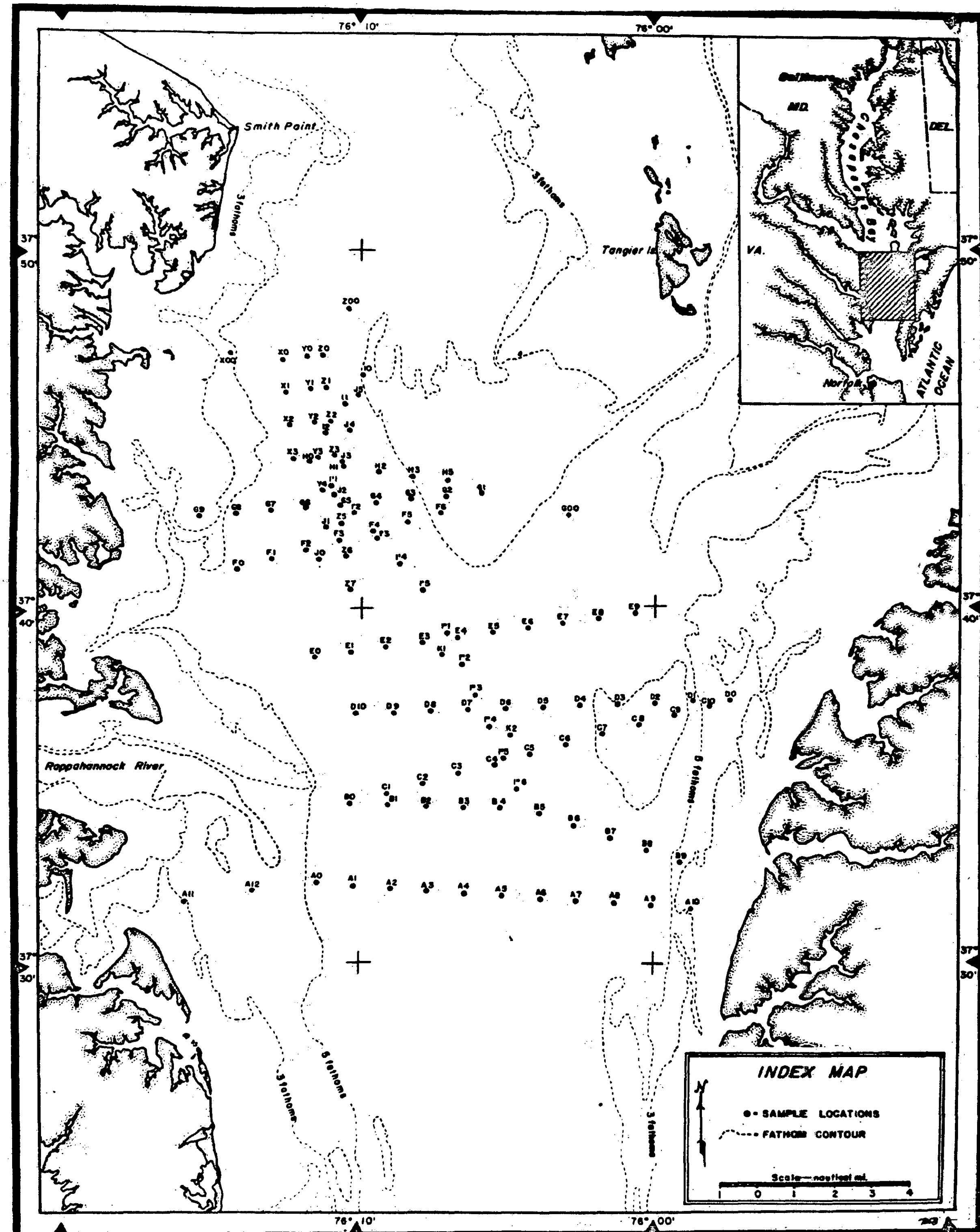

Fig. 1. Map of lower Chesapeake Bay showing sampling transects.

MATERIALS AND METHODS

Sampling stations were initially established at intervals of one mile along transects between principal buoys (Fig. 1). These were supplemented by additional stations, closely spaced, to give adequate coverage to the areal distribution of the benthos and sediment types in the dredged area and disposal site.

One hundred stations were sampled individually in July, 1961 (Table 1) and ninety samples were taken from 84 stations in January and February, 1962. June and July, 1962, transects included 119 samples taken from 108 stations. Only 13 stations were sampled in April, 1963, with replicate samples being taken at 11 of these.

Faunal samples were collected by using a Petersen grab with a capacity of .067 square meter. The grab was

TABLE 1

NUMBER OF SAMPLES AND STATIONS

Sampling Period	No. of Samples Taken	No. of Stations Sampled
July 1961	100	100
Jan. Feb. 1962	90	84
Jun. July 1962	119	108
April 1963	40	13

lowered from the deck of the research vessel upon assuming a stationary position in the sample area. Weights were added to the grab, bringing the total weight to twenty-five pounds, to facilitate sampling in deep water. When the grab was hauled to the deck, the sample was dumped into a set of two screens, the top screen having a 2 mm. mesh and the bottom screen 1 mm. The samples were immediately washed, and the animals removed and preserved in dilute formalin for later laboratory identification.

The results from two methods of sediment analysis were used in preparing animal-sediment interrelationships. Size analysis for the 100 samples obtained during July, 1961, were prepared by Batten (Annual Progress Report, 1962) using a modification of a standard sieving and pipetting method (Krumbein and Pettijohn, 1938, p. 135). Batten's samples were not dried and weighed before pipetting. This was the only difference from the standard method. Sediment analyses for the remainder of the samples were prepared by Harrison and Lynch (1963) of the Virginia Institute of Marine Science by a standard sieve analysis and hydrometer method (Dawson, 1959). The results reported by Harrison and Lynch (1963) yielded coarser sediment size values than the samples analyzed by Batten (Annual Progress Report, 1962).

To define community composition in relation to sediment type, the samples were considered as either sand or mud according to the textural class provided by Batten (Annual Progress Report, 1962) and Harrison and Lynch (1963). The separation between mud and sand can be seen in Figure 2. Muds, as used in this study, are marked off by dashed lines. Samples which occurred in the remaining area of the sediment triangle were considered to be sands (Fig. 2).

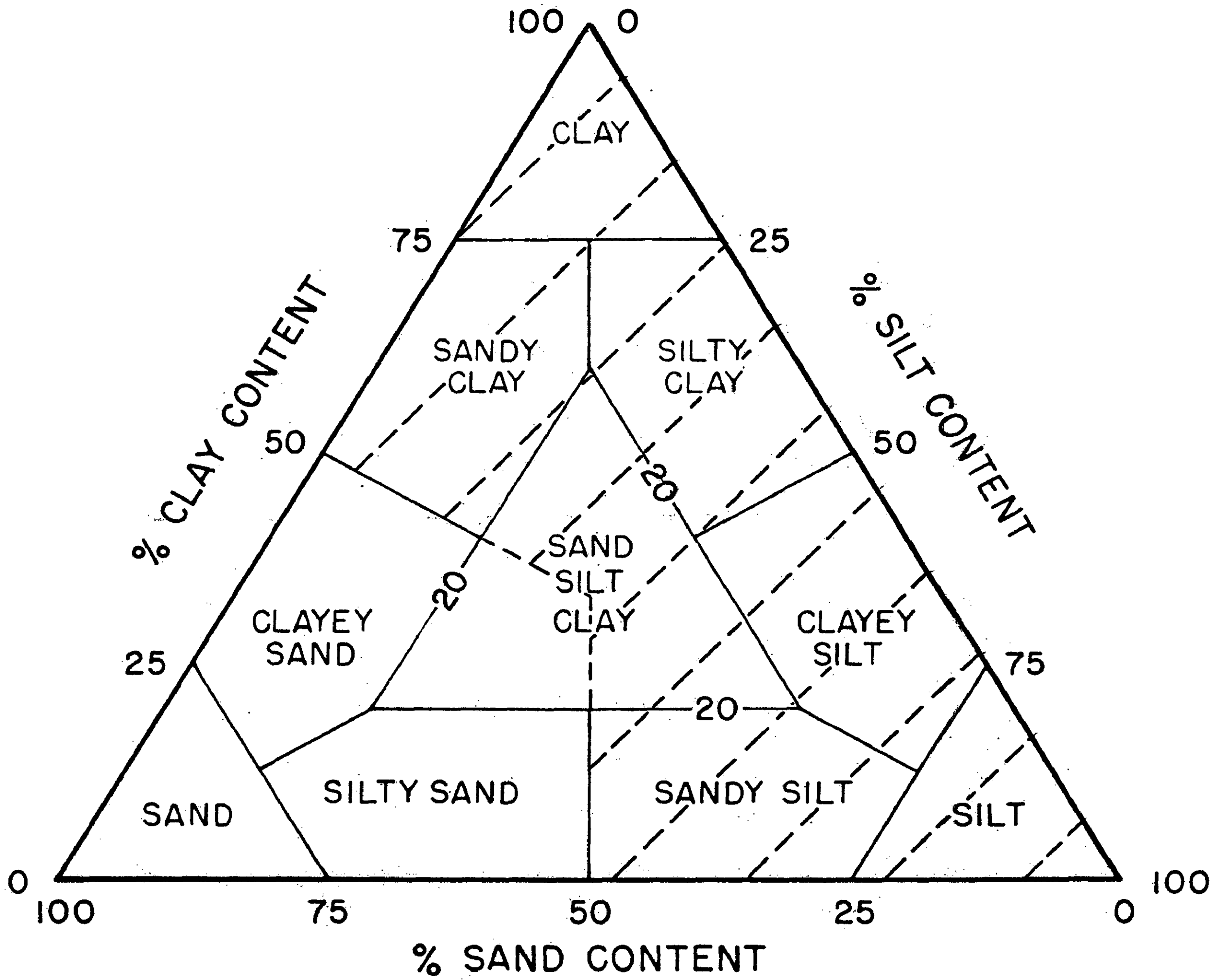

Fig. 2. Nomenclature of sediment types. (After Shepard, 1954, p. 157)

RESULTS

The July, 1961, samples were taken prior to the dumping of the spoil material in the disposal site to give an indication of what might be expected under relatively "normal" conditions. Samples taken during January and February, 1962, followed the conclusion of the Corps of Engineers project by approximately one month. It was evident from the thick, lumpy texture of the sediment and the absence of most organisms that the two samples had come from the disposal site. G-5 and J-2 were the only two stations where the mass properties found by Harrison and Lynch (1963, p.35) were not representative of typical, normally consolidated sediments of the area. Subsequent sampling at stations G-5 and J-2 indicated that repopulation in the disposal area was occurring slowly. Numerical composition of the fauna at stations G-5

TABLE 2

QUANTITATIVE ANALYSIS OF BENTHOS AT STATION G-5

Date	No. of Species	No. of Individuals
July, 1961	10	76
Jan. Feb., 1962	3	3
June, 1962	27	294
April, 1963*	5	23

*Mean of three samples.

and J-2 was indicative of the rate of repopulation in the disposal area, as pointed out by the respective 89 and 80 per cent increases in the number of individuals at these two stations from winter, 1962, to April, 1963, if the results for June, 1962, are discounted (Table 2). In the June, 1962, spoil samples, there was evidence in the form of abundant juveniles that the mass mortality probable from setting on unfavorable bottom types had not yet occurred.

TABLE 3

QUANTITATIVE ANALYSIS OF BENTHOS AT STATION J-2

Date	No. of Species	No. of Individuals
July, 1961	5	34
Jan. Feb., 1962	2	6
June, 1962	13	1007
April, 1963*	5	24

*Mean of seven samples.

The only station located in the actual dredged area, I"-3, similarly reflected the sparsity of species and individuals following the completion of the project (Table 4). The June, 1962, sample, likewise, showed an abundance of organisms at this station. Station I"-3 was not sampled in April, 1963, but the most recent survey in the dredged area consisted of a series of three transects across the channel during July, 1963. Each transect contained ten stations, five in the dredged channel and five outside the channel. Statistically, there was a significant difference between the average number of individuals per sample found in the channel and outside (Fig. 3). Interval estimates at the 95% confidence level for the average number of individuals per .067 square meter sample in the dredged channel were 17.4 to 30.3, while corresponding figures for outside the channel were 122.0 to 179.4.

Combined tables of animal-sediment relationships are presented in the appendix. They include sediment types, total numbers of species per sample, total numbers of organisms per sample, and the five most abundant organisms found during the sampling period. The first three sampling dates were the only ones used in the tables, since the April, 1963, samples were limited to a small area of finer grain size material in and surrounding the disposal site.

The total number of organisms was greatest in June,

TABLE 4

QUANTITATIVE ANALYSIS OF BENTHOS AT STATION I"-3

Date	No. of Species	No. of Individuals
July, 1961	10	57
Jan. Feb., 1962	2	8
June, 1962	19	643

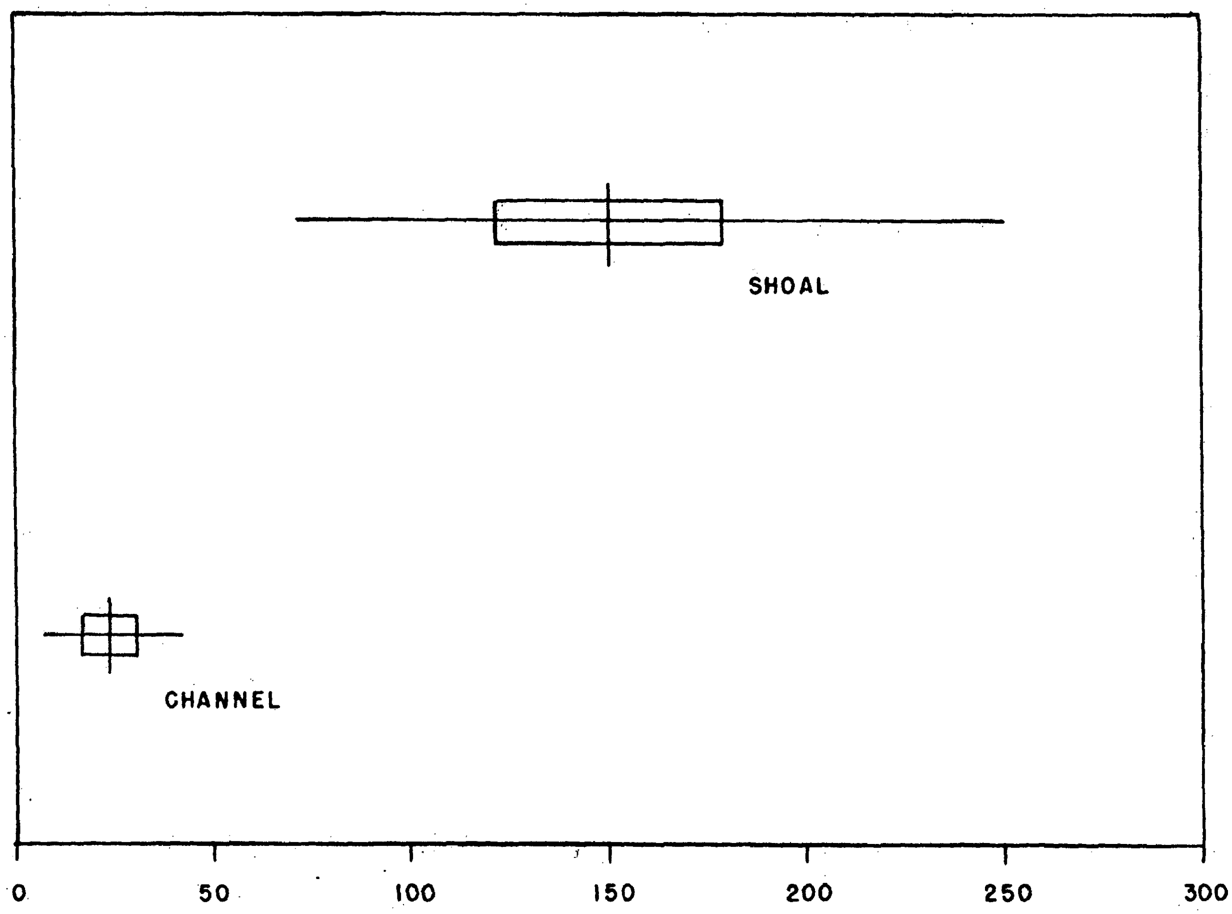

FIG. 3 THE MEANS, STANDARD ERRORS AND THE RANGES OF THE NUMBER OF INDIVIDUALS FOUND IN CHANNEL AND SHOAL SAMPLES. CENTRAL VERTICAL LINE, MEAN; HOLLOW BAR, $T_{0.05}\, S\bar{X}$ ON EITHER SIDE OF THE MEAN; HORIZONTAL LINE, RANGE.

1962, with the occurrence of 52,304 individuals in 93 samples. The other two major sampling dates produced considerably fewer, with 9739 individuals from 100 samples in the summer of 1961 and 4700 in 90 samples during January and February, 1962.

The five most abundant organisms for each sampling date are listed in Table 5, where mean numbers of individuals per sample are related to mean grain size in phi (Ø) units, where the phi (Ø) unit is $-\log_2$ of the diameter in millimeters (King, 1961, p. 3). Phi (Ø) units for the July, 1961, samples were furnished by Batten (Annual Progress Report, 1962), while phi (Ø) units for the remaining samples were computed by Harrison and Lynch (1963). The majority of the samples were taken in silty sediments. More emphasis should be put on the mean values found in the > 5Ø division because a large number of samples gives a good estimation of the mean. This is especially true for the July, 1961, samples, where the 3-4 and 4-5 Ø divisions contained only two samples each, while the > 5Ø division included thirty-five samples. If the < 3Ø and 3-4 Ø divisions for <u>Mulinia</u> are lumped together as sand samples, the mean number of individuals per sample would be 19.4, while a similar lumping of the mud samples yields 55.9 individuals per sample. The apparent trend noticed for <u>Mulinia</u> in the July, 1961, samples was slightly reversed in the June, 1962, results. The reason for this can be found in the variation between the grain-size values given by Batten (Annual Progress Report, 1962) and those found by Harrison and Lynch (1963). Although both methods of grain size analysis are internally consistent, the grain sizes found by Harrison and Lynch (1963) were coarser as shown in the appendices. This would cause some of the samples which had been considered silt in the July, 1961, series, to be placed in the sand division in June, 1962. Trends would then shift toward the sandy sediments. A column listing the feeding type was also included in Table 5, to emphasize the relationship between sediment size and feeding type. Generally, 4 Ø is considered to be the separation between sand and silt (Shepard, 1954). The polychaete, Nephtys incisa, is considered carnivorous by many investigators (Clark, 1962), but Sanders (1960) found it to be a non-selective deposit feeder. Personal observation of the gut contents of this polychaete indicated it was a selective detritus feeder in this area. There was no evidence that this species indiscriminately ingested the sediments. The digestive tract contained a green material completely void of sediment.

TABLE 5

LIST OF THE NUMERICALLY DOMINANT SPECIES, FEEDING TYPES[a], AND MEAN NUMBERS OF INDIVIDUALS PER SAMPLE[b] RELATED TO THE GRAIN SIZE DIVISION IN WHICH THEY OCCUR

July, 1961	Feed. Type	<3Ø (8)	3-4Ø (2)	4-5Ø (2)	>5Ø (35)
Mulinia lateralis	SF	11.0	53.0	1.0	62.4
Molgula manhattensis	SF	9.9	4.0	1.5	4.7
Nephtys incisa	SDF	4.0	18.0	11.5	12.7
Lyonsia hyalina	SF	9.6	24.0	3.5	4.0
Retusa canaliculata	C	3.6	3.0	10.0	5.4
Jan. Feb., 1962		(5)	(6)	(10)	(17)
Retusa canaliculata	C	8.5	4.8	12.3	12.2
Ampelisca spinipes	SF	4.8	13.6	4.7	4.0
Nephtys incisa	SDF	3.8	7.4	8.6	7.4
Molgula manhattensis	SF	3.5	20.0	7.3	5.2
Amphiodia atra	SDF	1.2	2.6	1.6	1.2
June, 1962		(8)	(7)	(14)	(21)
Ensis directus	SF	950.7	263.7	115.7	169.8
Cistenides gouldi	NSDF	23.7	50.3	22.2	28.1
Mulinia lateralis	SF	14.1	12.3	12.0	12.1
Ampelisca spinipes	SF	26.6	9.7	5.1	3.0
Nephtys incisa	SDF	7.4	13.0	16.2	19.9

[a] SF = Suspension feeder
SDF = Selective detritus feeder
NSDF = Non-selective deposit feeder
C = Carnivore

[b] Number of samples per grain size division indicated in parentheses.

DISCUSSION

Disposal Area

Samples from the disposal area contained a thick, lumpy sediment with large mud balls being the outstanding feature. The mud balls are evidently artificial, probably produced during the dredging operation and transported to the disposal site in hoppers. Kornicker et al. (1958) observed a dredge in action in the Laguna Madre and inspected the sediment ejected from the pipe end. They found the sediment being dredged to be nearly homogenous, but the dredged material issuing from the pipe at the disposal area contained abundant mud balls. The rotary action of the steel screw on the dredge breaks the sediment into chunks which become rounded by abrasion.

At the Corps of Engineers disposal site, the dredged material was dumped from hoppers, releasing a large quantity of material in a short period of time. Further compaction of the dredged material may occur in the hopper as the heavier materialsettles to the bottom. If numerous mud balls were formed from the silt-clay mixture being pumped into the hopper, these compacted chunks of material probably would resist dispersion in the water column when released. Therefore, if some of the material did reach bottom relatively intact, additional compaction of both spoil and natural sediment would occur. It follows that bottom samples from this area would be likely to contain these agglutinated sediments. Samples G-5 and J-2 were characterized by this thick, lumpy sediment and an insignificant number of organisms. This visual evidence plus the significant mass property data found by Harrison and Lynch (1963) delineated the disposal site.

A prodigious increase in the benthic fauna was observed at all stations during the 1962 summer sampling period. The mean number of individuals per sample obtained in the sand sediments increased from 56.9 in January and February, 1962, to 783.9 in June, 1962(Fig. 3). The occurrence of abundant populations at this time of year is not in itself evidence of repopulation. The large number of juveniles merely indicated that spawning had recently occurred. However, a few larger individuals were also found in the samples from stations G-5 and J-2. The mean number of individuals found at Station G-5 in April, 1963, was 23, while a mean of 24 was present at J-2. This is a 93 and 98 per cent decrease respectively from the summer value. However, the April, 1963, samples were 89 and 80 per cent larger than the winter, 1962, samples, indicating that repopulation was occurring. Nephtys incisa, a selective detritus-feeding polychaete worm, and Retusa canaliculata, a carnivorous gastropod, comprised 82% of the samples taken at G-5 and J-2 in April. These seem to be relatively stable animals (i.e., organisms capable of withstanding adverse fluctuations in the environment and consequently not exhibiting extreme numerical variations), occurring more often in finer sands, silt, and clay. Notable was the almost complete absence of lamellibranchs. Many species of this group have unstable populations and are more dependent on relatively stable habitats than Nephtys or Retusa (Thorson, 1957).

Dredged Area

The removal of five feet of sediment in the channel was more than sufficient to eliminate the existing benthic fauna. The total of eight individuals found at station I"-3 shortly after the dredging was significantly lower than the mean of 43.0 individuals per sample in the other mud stations. The eight individuals, consisting of two species of errant polychaetes, could have easily migrated to the area from nearby sediments. The June, 1962, sample at station I"-3 reflected the recent spawning. Conclusive evidence on the rate of repopulation was obtained from a number of stations in July, 1963, inside and outside the channel. There was a distinct difference in the number of species and individuals in each area (Fig. 2). A comparison of numbers of individuals between this date and the winter of 1962 revealed that slow repopulation by the more stable species was also occurring here. Again, the lamellibranchs were notably absent.

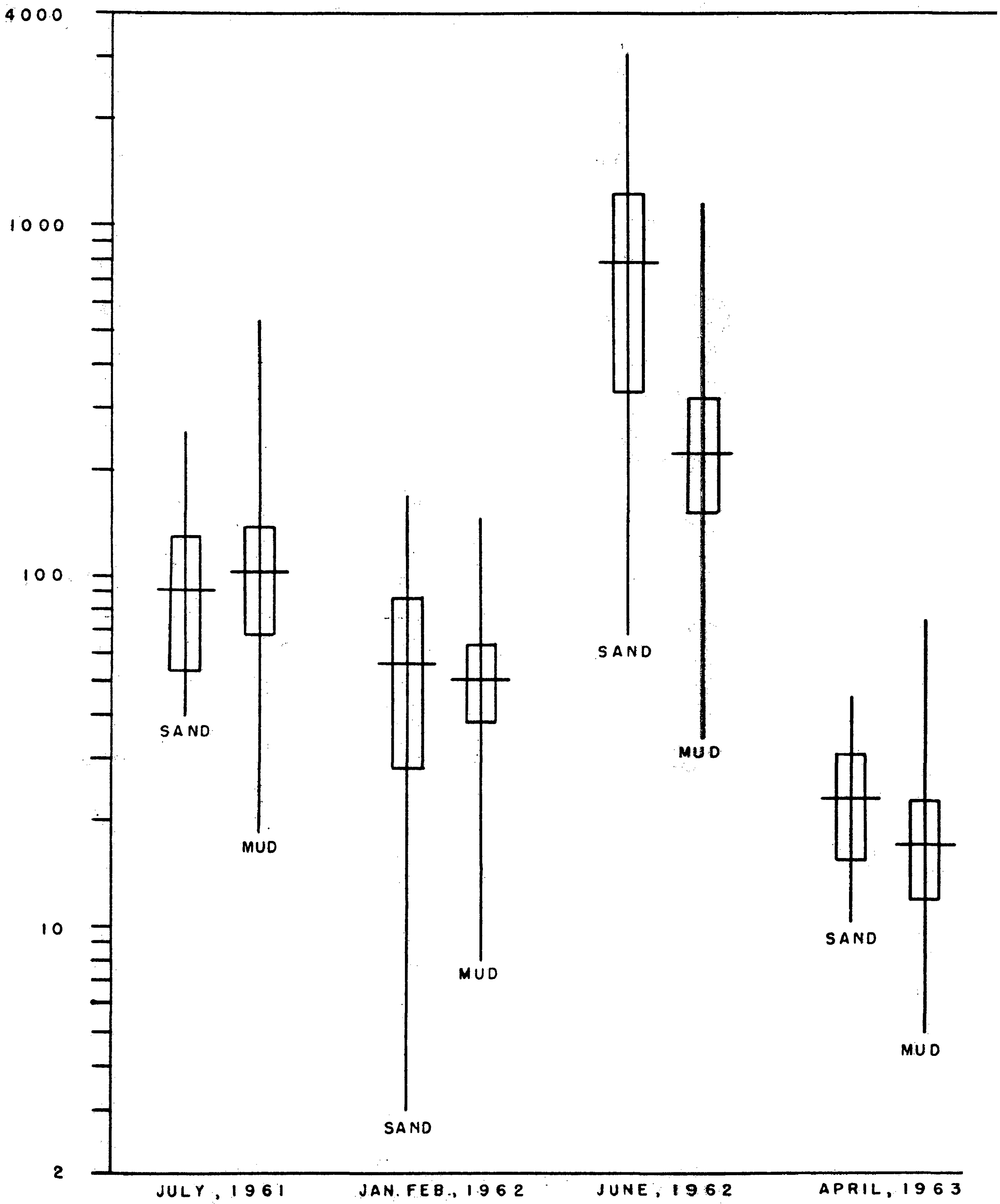

FIG. 4 SEASONAL VARIATION SHOWN BY THE MEANS, STANDARD ERRORS AND RANGES FOR THE NUMBER OF INDIVIDUALS PER SAMPLE DURING THE FOUR MAJOR SAMPLING DATES.

Seasonal Variation

There is considerable seasonal variation in the number of benthic organisms (Fig. 3). As an example of this, one sample taken in June, 1962, approximately six to eight weeks after spawning of the razor clam, *Ensis directus*, contained 2,243 individuals, which gives an estimated population of 33,478 individuals per square meter. *Ensis* numbered 2,063 of the total 2,243 individuals contained in the sample. The following month a sample taken at the same station contained only 294 individuals, of which only 48 were *Ensis*. The July duplicate stations showed reductions of 97 to 100 per cent in the number of *Ensis* per sample (Table 6). The number of individuals in the winter samples decreased considerably from the summer samples, but this is apparently a seasonal phenomenon related to natural mortality from setting on unfavorable bottom types, predation, disease, interspecific and intraspecific competition.

TABLE 6

COMPARISON OF JUNE AND JULY, 1962, DUPLICATE STATIONS GIVING NUMBER OF *ENSIS DIRECTUS* PER SAMPLE

Station	June	July
A-0	117	0
A-1	142	0
A-2	176	2
A-3	825	0
A-4	643	0
A-5	920	0
A-6	275	0
A-7	176	3
A-8	1339	14
A-9	2063	48
B-0	102	0

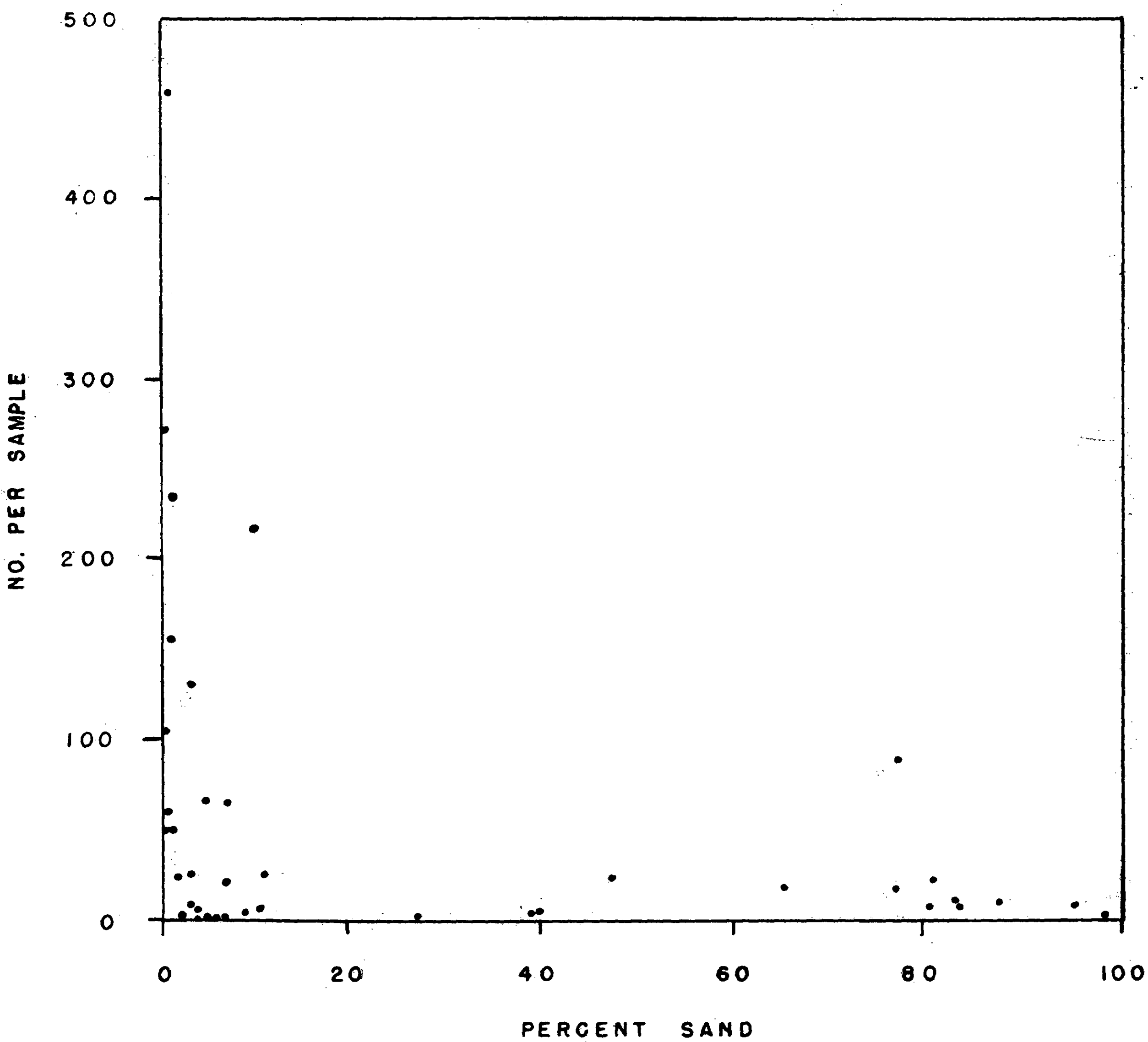

FIG. 5 NUMERICAL ABUNDANCE OF *MULINIA LATERALIS* RELATED TO PERCENT SAND FOR JULY, 1961.

Animal-Sediment Relationships

Animal-sediment relationships corresponding to similar relationships found in Buzzards Bay by Sanders (1958) and Biscayne Bay by McNulty *et al.* (1962) were discernible in the present area of investigation. Two of the most abundant species, the amphipod, *Ampelisca spinipes*, a suspension feeder, and the active polychaete, *Nephtys incisa*, a selective detritus feeder, were found predominantly in sand and silty sediments, respectively (Table 5). Relationships for most of the species, however, were not as apparent. The suspension feeding lamellibranch, *Mulinia lateralis*, normally associated with sandy sediments, was also abundant in the silty sediments (Fig. 4). Sanders (1958) found the areas with silty sediments in Buzzards Bay contained insufficient suspended matter for survival by large numbers of suspension feeders.

The Chesapeake Bay estuary differs considerably from the areas investigated by Sanders (1958) and McNulty *et al.* (1962); not in sediment type, but in the amount of detritus and sediment continually being brought into the middle and lower bay by the complex of large tributary rivers. Biscayne Bay and Buzzards Bay are both shallow, relatively well protected areas with no major rivers entering them. The influx of organic material from the tributaries of the Chesapeake Bay enables suspension feeders, such as *Mulinia*, to establish communities successfully in silty sediments which in the aforementioned areas may not contain enough suspended material for successful communities of filter feeders. This phenomenon dampens any distinct over-all animal-sediment interrelationship, but does not mask trends which indicate preference for, though not dependency on, certain sediment fractions.

Faunal Assemblage

To achieve a more accurate picture of the actual benthic community structure from season to season, it is necessary to rank the organisms according to the number of times they appear as one of the most abundant species. This was done by using a faunal index value (Sanders, 1960), for the frequency that a given species appears as one of the three most abundant (Tables 7, 8, and 9). A rank of one has a value of three points, two a value of two points, and three equals one point. If there are 100 samples and one species appears as the most abundant every time, it receives a maximum value of 300.

Three species are outstanding in their numerical occurrence in the mud sediments. These are Nephtys incisa, Retusa canaliculata, and Mulinia lateralis. Infaunal communities are usually associated with two numerically dominant species with relatively stable populations (Thorson, 1957). This qualification would necessitate the exclusion of Mulinia, since this lamellibranch is subject to large areal and seasonal fluctuations, as has been shown from the April, 1963, and July, 1963, samples. Forty samples taken in April, 1963, did not produce a single Mulinia. In July, 1963, fifteen samples taken outside the channel contained 279 Mulinia, while fourteen samples in the channel produced only three. The Nephtys incisa-Retusa canaliculata community is similar to the Nephtys incisa-Nucula proxima community defined by Sanders (1958) in Buzzards Bay in that many of the animals are detritus or deposit feeders. A notable exception to this was Mulinia. As mentioned previously, the characteristic large tributaries entering into Chesapeake Bay, heavy-laden with suspended matter and nutrients, allow the suspension-feeders to survive in the mud communities.

The sandy sediments are characterized by the Ampelisca spinipes-Lyonsia hyalina community. Both of these animals and most of the others in the community are suspension-feeders. A similar sand community in Buzzards Bay is the Ampelisca spp. community (Sanders, 1958).

Epifaunal species, such as Molgula, often rank high numerically, but are not considered in the infaunal communities mentioned above.

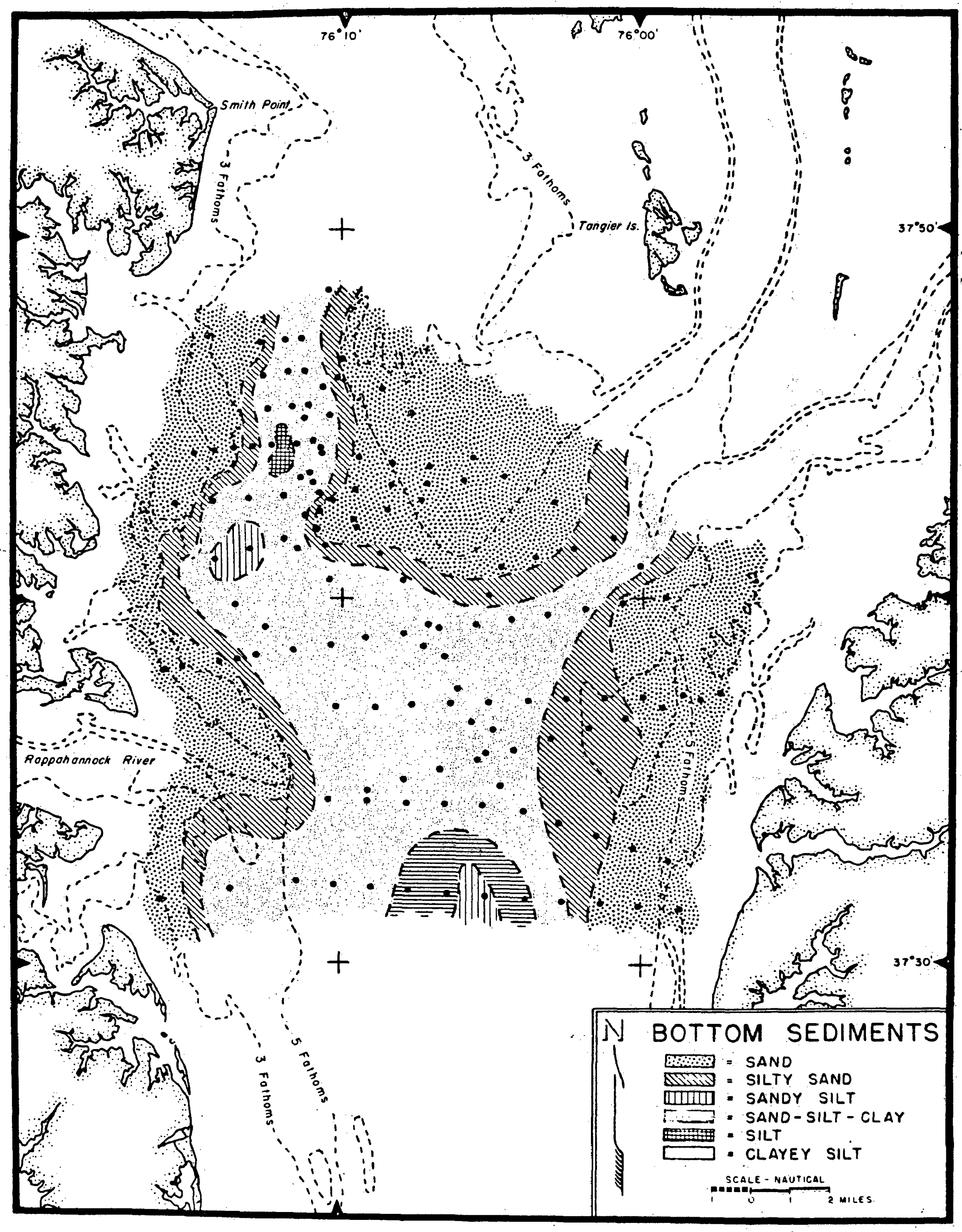

Fig. 6. Bottom sediment distribution in sampling area.

TABLE 7

INDEX VALUES AND FREQUENCY OF 15 SPECIES COMPRISING 90% OF FAUNA IN LOWER CHESAPEAKE BAY SURVEY SUMMER, 1961

Species	1st	2d	3d	Value	Freq.	Total
Nephtys incisa	21	32	20	147	91	1062
Mulinia lateralis	35	14	4	137	86	3750
Ampelisca sp.	13	16	11	98	81	1254
Molgula manhattensis	11	14	11	69	66	1043
Retusa canaliculata	5	9	13	46	74	397
Lyonsia hyalina	5	6	16	43	76	597
Macoma tenta	2	8	12	34	60	271
Cistenides gouldi		4	10	18	50	287
Cirriformia filigera	2	2	3	13	27	137
Amphiodia atra	1	1	2	7	40	114
Gemma gemma	2	1	1	7	6	119
Lucina multilineata		2	2	6	21	73
Nucula proxima	2			6	9	22
Pseydeurythoe paucibranchiata			4	4	43	61
Ensis directus			3	3	21	63

TABLE 8

INDEX VALUES AND FREQUENCY OF 15 SPECIES COMPRISING 76% OF FAUNA IN LOWER CHESAPEAKE BAY SURVEY WINTER, 1962

Species	1st	2d	3d	Value	Freq.	Total
Retusa canaliculata	32	19	6	140	77	811
Nephtys incisa	20	25	4	114	65	561
Ampelisca spinipes	10	8	14	60	59	594
Molgula manhattensis	9	7	3	44	36	453
Cyathura polita	6	1		20	14	66
Ampelisca macrocephala	2	5	3	19	30	150
Amphiodia atra	1	3	10	19	43	155
Melinna maculata	1	4	4	15	30	106
Cirriformia filigera	2	2	3	13	18	97
Mulinia lateralis	3		3	12	22	107
Macoma tenta		2	4	8	45	134
Cistenides gouldi		1	6	8	37	107
Anadara transversa	1	2		7	19	111
Turbonilla interrupta		1	5	7	43	86
Oxyurostylus smithi	1		2	5	12	25

TABLE 9

INDEX VALUES AND FREQUENCY OF 15 SPECIES COMPRISING 95% OF FAUNA IN LOWER CHESAPEAKE BAY SURVEY SUMMER, 1962

Species	1st	2d	3d	Value	Freq.	Total
Ensis directus	69	10	9	236	92	42178
Nephtys incisa	16	32	18	130	94	1602
Cistenides gouldi	11	20	13	86	83	1738
Mulinia lateralis	6	11	19	59	91	1123
Ampelisca spinipes	2	13	15	47	81	1154
Molgula manhattensis	4	7	4	30	40	465
Lyonsia hyalina	1	7	9	26	84	1066
Retusa canaliculata	3	6	4	25	96	518
Asabellides oculata		6	8	20	64	582
Cirriformia filigera	1	2	7	14	42	290
Ampelisca macrocephala	3	1	1	12	39	303
Pseudeurythoe paucibranchiata	1	3	3	12	70	214
Ericthonius brasiliensis	1	1	3	8	39	200
Polycirrus eximius		2	1	5	19	404
Mya arenaria			5	5	72	364

SUMMARY

Numerical composition of the fauna at the disposal and dredged stations for the different sampling dates was indicative of the habitat prior to and after dredging. The fauna existing in the channel and disposal areas was almost completely eliminated by dredging and the dumping of spoil. Repopulation by the more stable species preceded the June, 1962, sampling in both the dredged and disposal areas.

Significant differences were found between the number of organisms in samples from the shoal next to the channel and samples from within the channel. The channel fauna consisted largely of errant organisms.

Mass property data from studies by Harrison and Lynch (1963), mud balls, and the absence of all but a few errant organisms delineated the disposal site.

There is considerable seasonal variation in benthic populations. The razor clam, *Ensis directus*, showed numerical reductions of 97 to 100 per cent in one month.

Relationships between feeding types and sediment size were discernible for some species. *Nephtys incisa* was found predominantly in silty sediments, while *Ampelisca spinipes* was most abundant in sandy sediments. Suspended material brought into the bay by large tributaries apparently influenced the occurrence of filter-feeders.

The *Nephtys incisa*-*Retusa canaliculata* community was

defined for the mud sediments. Sand sediments were characterized by the filter-feeders, *Ampelisca spinipes*-*Lyonsia hyalina*. Faunal indices were used to obtain a more accurate picture of community structure.

LITERATURE CITED

Annual Progress Report on the effects of dredging and dredge spoil disposal on the marine environment. June, 1962. Va. Inst. of Mar. Science. Mimeo. report.

BADER, R. G. 1954. The role of organic matter in determining the distribution of pelecypods in marine sediments. Jour. Mar. Res., 13: 32-47.

CLARK, R. B. 1962. Observations on the food of Nephtys. Limnol. Oceano., 7: 380-385.

DAWSON, R. F. 1959. Laboratory manual in soil mechanics. Pitman, New York. 177 p.

HARRISON, W., and M. P. LYNCH. 1963. Mass properties of sediments of lower Chesapeake Bay. In Annual progress report on the effects of dredging and dredge spoil disposal on the marine environment. Va. Inst. of Mar. Science. Mimeo. report.

HEDGPETH, J. W. 1957. Introduction. In Treatise on marine ecology and paleoecology (J. W. Hedgpeth, ed.). Geol. Soc. America Memoir 67, 1: 1-16.

KING, C. A. M. 1961. Beaches and coasts. Arnold, London. 403 p.

KORNICKER, L. S., C. H. OPPENHEIMER and J. T. CONOVER. 1958. Artificially formed mud balls. Publications of the Inst. Mar. Science, Univ. of Texas, 5: 148-150.

KRUMBEIN, W. C. and F. J. PETTIJOHN. 1938. Manual of sedimentary petrography. Appleton, New York. 549 p.

McNULTY, J. K., R. C. WORK and H. B. MOORE. 1962. Some relationships between the infauna of the level bottom and the sediments in South Florida. Bull. Mar. Science Gulf and Caribbean, 12: 322-332.

RYAN, C. J. 1953. The sediments of Chesapeake Bay. Maryland Dept. Geol., Mines and Water Res. Bull., 12. 120 p.

SANDERS, H. L. 1958. Benthic studies in Buzzards Bay. I. Animal-sediment relationships. Limnol. Oceanogr., 3: 245-258.

--------. 1960. Benthic studies in Buzzards Bay. III. The structure of the soft-bottom community. Limnol. Oceanogr., 5: 138-153.

SHEPARD, F. P. 1954. Nomenclature based on sand-silt-clay ratios. Jour. of Sed. Petrol., 24:151-158.

SPARCK, R. 1935. On the importance of quantitative investigation of the bottom fauna in marine biology. Jour. Du Conseil, X: 3-19.

STICKNEY, A. P. and L. D. STRINGER. 1957. A study of the invertebrate bottom fauna of Greenwich Bay, Rhode Island. Ecology, 38: 111-122.

THORSON, G. 1957. Bottom communities (sublittoral or shallow shelf). <u>In</u> Treatise on marine ecology and paleoecology (J. W. Hedgpeth, ed.). Geol. Soc. America Memoir 67, 1: 461-534.

WELLS, H. W. 1957. Abundance of the hard clam *Mercenaria mercenaria* in relation to environmental factors. Ecology, 38: 123-128.

APPENDIX 1

LIST OF JULY, 1961, STATIONS AT WHICH BOTH GEOLOGICAL AND BIOLOGICAL DATA WERE AVAILABLE. SEDIMENT TYPES AND MEAN GRAIN SIZES IN Ø UNITS ARE FOLLOWED BY TOTAL SPECIES AND INDIVIDUALS PER SAMPLE, PLUS THE NUMBERS OF THE FIVE MOST ABUNDANT ORGANISMS PRESENT IN THE JULY SAMPLES.

Station	% Sand	% Silt	% Clay	Mean Size (Ø)	Total No. Species	Total No. Individuals	Mulinia lateralis	Molgula manhattensis	Nephtys incisa	Lyonsia hyalina	Retusa canaliculata
A-0	6.0	64.0	30.0	6.8	10	66	1	3	15	2	3
A-5	39.3	43.6	17.1	5.6	24	141	3	15	19	0	5
A-6	27.2	49.6	23.2	5.8	22	135	1	17	14	2	7
A-7	54.7	28.5	16.8	4.3	16	62	0	1	10	0	7
B-0	2.2	59.4	38.4	7.2	6	30	3	21	3	1	0
C-5	9.3	62.7	28.0	6.0	20	73	4	20	2	0	1
C-6	10.3	61.6	28.1	6.6	15	53	5	4	8	11	10
C-9	80.3	11.1	8.6	2.4	21	139	8	33	6	10	2
D-5	3.8	61.1	35.1	7.4	10	75	26	8	11	11	11
D-6	5.9	60.4	33.7	7.1	6	18	1	0	9	0	2
D-7	4.3	62.7	33.0	6.9	7	34	0	0	5	1	24
D-8	31.7	43.6	24.7	5.6	7	36	0	5	6	0	17
D-9	3.9	68.1	28.0	7.[illegible]	8	33	7	0	11	5	5
E-1	4.6	57.9	37.5	7.4	5	23	4	0	9	0	0
E-2	4.2	65.3	30.5	7.0	10	37	5	8	11	0	4
E-3	6.5			6.0	9	105	0	72	11	1	0
E-4	5.3	62.9	31.8	6.6	12	47	2	0	25	2	6
E-5	4.5	65.1	30.3	6.8	11	54	1	6	15	3	13
E-6	11.2	66.1	22.7	6.0	12	56	26	2	8	1	3
E-8	80.9	11.6	8.4	2.2	12	55	23	8	1	0	0
E-9	77.2	10.2	12.5	2.5	10	76	17	10	4	23	0
F-3	83.7	12.0	3.0	2.5	17	130	9	16	8	13	2
G-1	95.8	3.3	0.9	2.2	18	52	8	0	0	4	7
G-3	87.9	7.7	4.4	2.0	10	51	10	0	0	17	2
G-5	5.3			5.9	10	76	67	1	0	1	0
G-6	0.7	59.4	35.7	7.6	2	54	50	0	0	4	0
G-7	10.0	53.2	33.1	7.1	8	244	217	0	0	14	4
H-0	0.8	86.9	12.3	6.4	5	269	236	0	14	3	13
H-3	98.9	1.1	0.0	2.1	21	96	2	1	0	1	6
I'-1	1.7	59.4	38.8	7.6	11	182	157	0	9	2	6
I"-1	47.2	33.6	19.2	4.9	16	55	2	2	13	7	13

APPENDIX 1 (CONT.)

Station	% Sand	% Silt	% Clay	Mean Size (Ø)	Total No. Species	Total No. Individuals	Mulinia lateralis	Molgula manhattensis	Nephtys incisa	Lyonsia hyalina	Retusa canaliculata
I-2	3.5	58.8	37.7	7.3	9	155	130	1	6	0	9
I'-2	83.7	11.4	4.8	2.4	19	142	11	11	13	9	10
I"-3	7.1	63.5	29.4	7.0	10	57	0	10	9	2	4
I'-4	39.8	38.4	21.8	5.4	12	35	4	0	6	7	0
I"-5	7.0	60.9	32.1	7.1	14	105	20	7	37	7	5
J-1	65.7	24.1	8.6	3.4	10	39	17	8	0	0	3
J-2	2.2	66.7	30.0	6.9	5	34	23	1	5	0	4
X-0	77.2	15.0	7.8	3.3	17	259	89	0	36	52	3
X-1	46.9	30.9	21.6	5.9	9	73	23	0	30	6	0
X-2	6.8	49.6	43.6	7.3	10	105	65	0	22	7	4
X-3	0.0	57.4	42.6	7.9	11	173	106	30	11	6	2
Y-2	0.0	62.1	37.8	7.5	11	325	273	0	26	12	1
Y-3	0.9	57.1	42.0	7.7	8	526	460	13	28	16	4
Z-0	0.0	61.1	38.9	7.8	6	60	38	0	10	0	3
Z-1	0.5	53.3	46.2	7.9	5	67	50	0	8	3	5
Z-3	0.9	61.2	37.9	7.4	5	82	60	0	16	3	0

APPENDIX 2.

LIST OF JANUARY AND FEBRUARY, 1962, STATIONS AT WHICH BOTH GEOLOGICAL AND BIOLOGICAL DATA WERE AVAILABLE. SEDIMENT TYPES AND MEAN GRAIN SIZES IN Ø UNITS ARE FOLLOWED BY TOTAL SPECIES AND INDIVIDUALS PER SAMPLE, PLUS THE NUMBERS OF THE FIVE MOST ABUNDANT ORGANISMS PRESENT IN THE JANUARY AND FEBRUARY SAMPLES.

Station	% Sand	% Silt	% Clay	Mean Size (Ø)	Total No. Species	Total No. Individuals	Retusa canaliculata	Ampelisca spinipes	Nephtys incisa	Molgula manhattensis	Amphiodia atra
A-0	28.5	63.7	7.8	5.0	15	54	7	3	23	1	0
A-6	47.8	52.0	0.2	4.1	15	53	6	3	8	2	2
B-0	20.5	63.3	16.2	5.6	5	54	31	0	14	0	2
C-5	35.0	64.5	0.5	4.3	14	75	11	9	7	3	0
C-9	90.4	9.6	0.0	2.4	6	20	0	0	1	0	2
D-6	25.2	64.8	10.0	5.0	5	22	11	0	4	0	0
D-7	28.0	60.2	11.8	5.2	6	26	16	0	5	0	2
D-9	25.2	64.4	10.4	5.2	16	45	11	5	8	0	7
E-1	28.6	64.0	7.4	5.0	13	121	1	19	1	57	0
E-2	26.1	61.0	12.5	5.1	14	81	0	20	0	10	0
E-3	84.5	15.5	0.0	2.4	14	48	2	0	8	3	1
E-4	46.0	33.8	20.2	5.3	7	26	10	0	6	0	6
E-5	24.0	61.4	14.6	5.4	7	36	19	1	7	0	2
E-7	31.5	55.9	12.6	5.1	15	62	3	8	14	0	3
E-9	89.6	10.4	0.0	2.3	8	41	23	0	11	0	2
F-3	68.2	21.6	10.2	3.7	17	53	15	1	3	0	0
G-3	46.0	46.9	7.1	4.3	15	65	20	10	12	0	7
G-5	66.0	28.5	5.5	3.7	3	3	0	0	0	0	0
G-6	18.5	70.5	11.0	5.5	6	33	23	0	6	0	1
G-7	17.4	57.1	25.5	6.0	8	47	14	0	12	0	0
G-8	21.0	65.1	13.9	5.6	25	145	20	21	8	30	1
H-0	15.5	60.5	24.0	5.9	8	52	5	0	12	3	0
H-3	99.9	0.1	0.0	2.5	17	41	6	7	1	2	1
I'-2	81.5	12.0	6.5	2.9	15	49	5	12	2	12	0
I"-3	24.0	58.2	17.8	5.6	2	8	0	0	6	0	0
I'-4	69.5	22.3	8.2	3.7	30	170	5	50	0	18	8
I"-5	35.0	53.6	11.4	4.9	6	45	27	0	8	0	2

APPENDIX 2 (CONT.)

Station	% Sand	% Silt	% Clay	Mean Size (Ø)	Total No. Species	Total No. Individuals	Retusa canaliculata	Ampelisca spinipes	Nephtys incisa	Molgula manhattensis	Amphiodia atra
J-1	80.0	14.2	5.8	3.1	14	115	0	5	11	56	4
J-2	61.8	28.2	10.0	3.9	2	6	0	0	5	0	0
X-0	76.2	19.4	4.4	3.6	24	100	4	12	18	26	1
X-1	38.5	53.5	8.0	4.8	17	66	8	5	15	2	0
X-2	21.5	60.4	18.1	5.5	8	33	14	2	5	0	0
X-3	18.9	48.6	32.5	6.0	3	38	32	0	5	0	0
Y-2	27.0	55.8	17.2	5.9	7	20	10	1	5	0	0
Y-3	19.0	59.8	21.2	5.8	5	24	4	0	2	0	0
Z-0	45.0	55.0	0.0	4.2	5	20	12	0	5	0	0
Z-1	21.0	58.0	21.0	5.7	7	51	12	0	6	3	0
Z-3	63.0	22.3	14.7	4.1	9	68	1	6	5	44	0

APPENDIX 3.

LIST OF JUNE, 1962, STATIONS AT WHICH BOTH GEOLOGICAL AND BIOLOGICAL DATA WERE AVAILABLE. SEDIMENT TYPES AND MEAN GRAIN SIZES IN Ø UNITS ARE FOLLOWED BY TOTAL SPECIES AND INDIVIDUALS PER SAMPLE, PLUS THE NUMBERS OF THE FIVE MOST ABUNDANT ORGANISMS PRESENT IN THE JUNE SAMPLES.

Station	% Sand	% Silt	% Clay	Mean Size (Ø)	Total No. Species	Total No. Individuals	Ensis directus	Cistenides gouldi	Mulinia lateralis	Ampelisca spinipes	Nephtys incisa
A-0	28.5	63.7	7.8	5.0	15	178	117	3	4	1	18
A-5	45.0	53.4	1.6	5.5	21	1148	920	5	1	48	90
A-6	47.8	52.0	0.2	4.1	22	385	275	3	2	20	18
A-7	69.0	31.0	0.0	3.2	22	297	176	23	10	2	18
B-0	20.5	63.3	16.2	5.6	9	138	102	0	5	0	10
C-5	35.0	64.5	0.5	4.3	15	224	159	2	11	5	15
C-6	84.8	11.0	4.2	2.6	38	2055	1861	6	11	23	11
C-9	90.4	9.6	0.0	2.4	34	1409	1239	1	19	21	0
D-5	31.8	53.7	14.5	5.2	21	244	173	2	1	0	21
D-6	25.2	64.8	10.0	5.0	20	322	242	3	11	2	24
D-7	28.0	60.2	11.8	5.2	13	85	44	0	5	2	12
D-8	23.0	58.2	18.8	5.9	26	372	282	1	1	1	19
E-1	28.6	64.0	7.4	5.0	16	272	217	4	0	1	21
E-2	26.1	61.4	12.5	5.1	31	1057	814	100	9	7	22
E-3	84.5	15.5	0.0	2.4	35	2554	2264	34	21	15	22
E-4	46.0	33.8	20.2	5.3	13	133	48	18	15	0	16
E-5	24.0	61.4	14.6	5.4	19	103	26	10	12	3	26
E-6	48.0	40.5	11.5	4.5	22	511	367	42	11	9	21
E-7	31.5	55.9	12.6	5.1	12	401	233	92	31	3	22
E-8	33.9	37.7	29.4	5.5	11	144	64	31	9	0	23
E-9	89.6	10.4	0.0	2.3	14	159	54	46	11	7	22
F-3	68.2	21.6	10.2	3.7	21	154	76	2	2	4	14
G-1	97.5	2.4	0.1	2.3	33	278	106	74	10	8	0
G-3	46.0	46.9	7.1	4.3	17	227	121	23	13	2	26
G-5	66.0	28.5	5.5	3.7	27	294	122	36	3	29	9
G-6	18.5	70.5	11.0	5.5	11	158	41	61	5	0	17
G-7	17.4	57.1	25.5	6.0	10	61	2	15	4	0	14
G-8	21.0	65.1	13.9	5.6	11	34	0	1	2	0	11
H-0	15.5	60.5	24.0	5.9	12	170	24	82	32	0	8
H-3	99.9	0.1	0.0	2.5	43	941	582	5	15	42	0
I'-1	37.5	62.5	0.0	4.3	9	71	0	0	3	0	8
I"-1	40.0	59.0	1.0	4.6	18	463	192	153	46	1	29

APPENDIX 3 (CONT.)

Station	% Sand	% Silt	% Clay	Mean Size (Ø)	Total No. Species	Total No. Individuals	Ensis directus	Cistenides gouldi	Mulinia lateralis	Ampelisca spinipes	Nephtys incisa
I-2	29.0	63.4	7.6	5.2	10	140	19	74	21	0	16
I'-2	81.5	12.0	6.5	2.9	52	3089	2630	6	24	80	2
I"-3	24.0	58.2	17.8	5.6	19	643	549	2	9	4	9
I'-4	69.5	22.3	8.2	3.7	32	751	560	24	19	18	19
I"-5	35.0	53.6	11.4	4.9	22	212	111	3	2	2	24
J-1	80.0	14.2	5.8	3.1	26	184	100	3	3	5	11
J-2	61.8	28.2	10.0	3.9	13	1007	670	243	13	14	0
X-0	76.2	19.4	4.4	3.6	16	122	0	7	27	15	16
X-1	38.5	53.5	8.0	4.8	9	39	13	2	5	5	4
X-2	21.5	60.4	18.1	5.5	7	43	14	2	6	0	16
X-3	18.9	48.6	32.5	6.0	12	65	14	15	10	1	13
Y-2	27.0	55.8	17.2	5.9	10	89	12	33	15	0	16
Y-3	19.0	59.8	21.2	5.8	10	302	115	117	38	0	19
Y-4	30.0	69.9	0.1	4.6	11	55	11	0	9	1	12
Z-0	45.0	55.0	0.0	4.2	7	41	8	0	10	0	12
Z-1	21.0	58.0	21.0	5.7	7	77	4	3	46	0	14
Z-3	63.0	22.3	14.7	4.1	7	67	16	16	20	1	9
Z-5	93.9	6.1	0.0	2.3	19	173	78	28	9	5	17