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Distribution and Structure of Benthic Communities in the Hampton Roads Area, Virginia: A Technical Ecological Report to the Hampton Roads Sanitation District Commission

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DISTRIBUTION AND STRUCTURE OF BENTHIC COMMUNITIES IN THE HAMPTON ROADS AREA, VIRGINIA

A Technical Ecological Report

to the

Hampton Roads Sanitation District Commission

BY

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I. INTRODUCTION

Research on estuarine ecosystems has intensified greatly in recent years, at least partially as a direct result of man's increasing encroachment on these systems and the resulting conflict among opposing interests. Many larger estuaries have multiple uses, accommodating commerce, navies, fisheries, recreation, and waste disposal. Because of the complexity of these ecosystems, detailed knowledge of their structure and function is essential.

Benthic organisms perform important recycling roles in the functioning of shallow water systems and provide the basis of estuarine fishery productivity. In addition, benthic invertebrates have proved to be effective biological indicators of water quality because of their non-motility and consequent lack of ability to avoid pollutants and because of their relatively long lives. Carriker's (1967) comprehensive discussion of the ecology of estuarine benthic invertebrates will mislead the reader who relates the impressive volume of the paper with the extent of our knowledge of estuarine benthos until he realizes that it was intended not solely as a review but as a perspective. Actually, the ecology of estuarine benthos, especially its synecology, is very poorly known. The most recent significant contributions to estuarine benthic synecology are those of Muus (1967) on Danish estuaries and Sanders et al. (1965) on a small fluctuating estuary in Massachusetts.

The structure of marine benthic macrofaunal communities has recently received increasing attention (Sanders, 1968, 1969; Lie, 1968, 1969; Macdonald, 1969; McCloskey, 1970), yet little information is available on community structure in man-influenced ecosystems, especially estuaries. Investigations by Reish (1956, 1959), Reish and Winter (1954), Dean and Haskin (1964), Filice (1959), and McNulty (1970) were concerned with macrobenthos in polluted marine environments but did not include discussions of community structure *per se*. On the other hand, investigations of freshwater benthos (Wilhm and Dorris, 1968) and some marine investigations (Warinner and Brehmer, 1966; Pearson, Storrs and Selleck, 1967) have found community structure valuable as a sensitive biological measure of water quality.

The study reported herein is of benthic macrofaunal communities, their distribution and structure in a multi-use estuarine system, the Hampton Roads port area. Hampton Roads has historically been among the largest and militarily most important ports in the United States. It is a moderately large commercial shipping center and home port for the U. S. Navy's Atlantic Fleet. Nearly one million people inhabit the immediate area and considerable commercial and sport fisheries exist in the lower Chesapeake Bay-James River area. The system is influenced by activities related to shipping and to municipal and industrial waste disposal.

Hampton Roads proper covers approximately 65 km^2 (Calder and Brehmer, 1967) at the confluence of Chesapeake Bay and the James River estuary. The Nansemond, Elizabeth and Hampton rivers are tidal tributaries of Hampton Roads but none contribute significantly to the freshwater discharge of the James River which accounts for approximately 14% of the total discharge of the Chesapeake Bay system. The Roads is characterized by extensive shoals (less than 6 m deep) and a deep central channel (7-22 m). Navigation channels of 12-14 m are maintained through Hampton Roads and into the Elizabeth River.

The James River estuary is a horizontal boundary estuary with salinities slightly higher on the right side of the river looking upstream. The level of no net motion varies from horizontal to nearly vertical in cross section, depending on the freshwater discharge rate (M. M. Nichols, personal communication). The tidal range is about 0.8 m and resulting current velocities usually do not exceed 2 m/sec.

Although salinity fluctuates slightly during a tidal cycle, the greatest salinity and temperature variations are seasonal. Salinity and temperature data, gathered by the Environmental

Chemistry Section of the Virginia Institute of Marine Science at a location below Newport News Point during the year 1969 (which includes all benthic sampling dates), are presented in Figure 1. Whereas the seasonal temperature range is great, in excess of 25 C, the seasonal bottom salinity range is restricted to 3-4‰.

Also presented in Figure 1 are surface salinity-temperature data for two other years of record in the Hampton Roads area (from Calder and Brehmer, 1967). The form of these latter two t-s polygons is typical, the fall salinities exceeding those in spring. The 1969 t-s polygon is characterized by crossing over by the fall portion of the figure, reflecting the lower than normal salinities in the months of September, October, and November due to floods caused by Hurricane Camille in the upper watershed of the James in late August and heavy rainfall in the following months.

Temperature and salinity ranges may be slightly greater in shallow areas adjacent to the shore but, for the most part, the environment experienced at the benthic sampling locations is validly described by Figure 1. Reduced and more variable salinities might be expected in those sampled portions of the Elizabeth River, yet fragmentary data indicate that salinity only infrequently drops below 15‰ at any of the Elizabeth River stations.

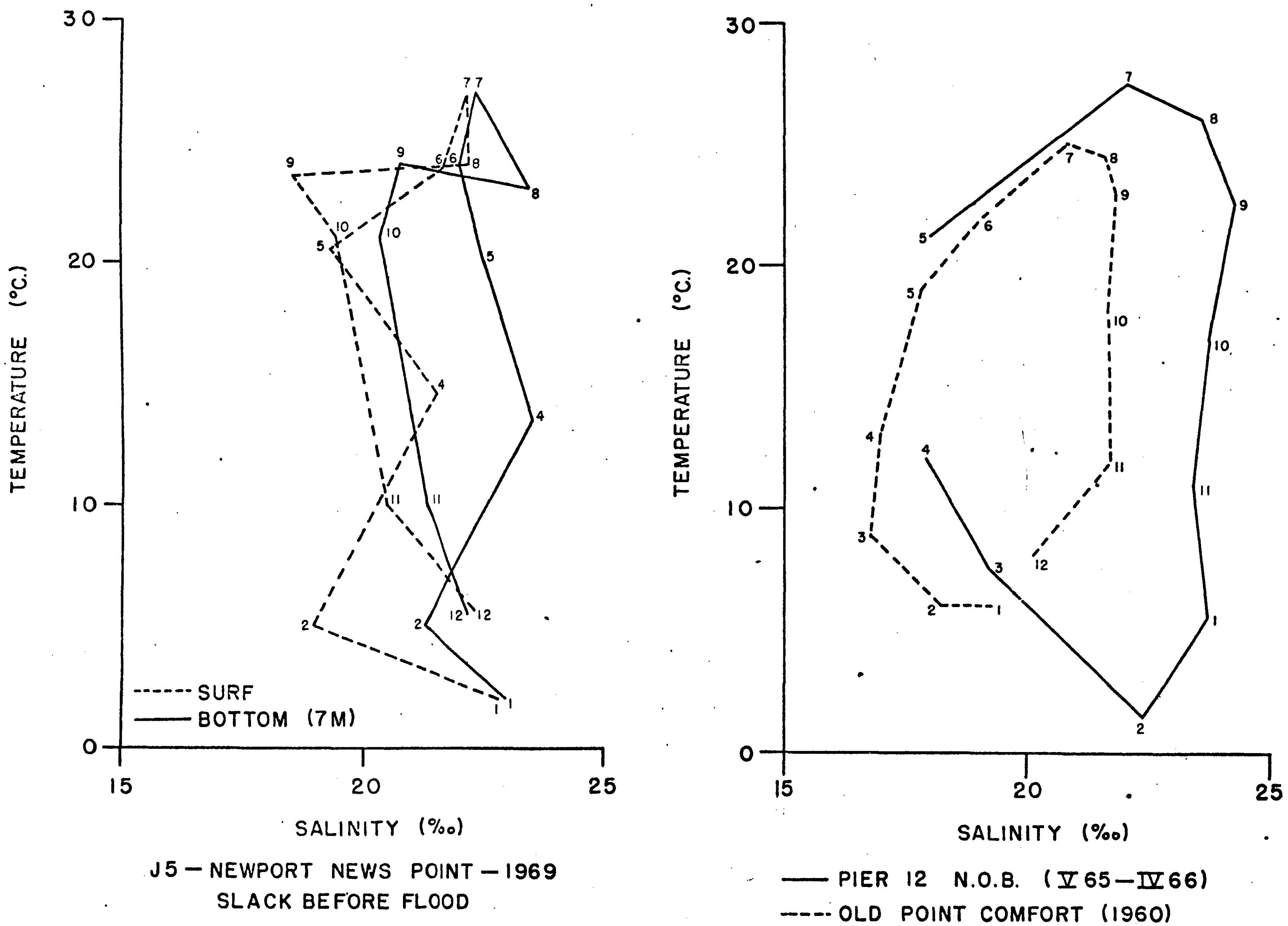


Figure 1. Salinity-temperature polygons for Hampton Roads in 1969 and two other years.

II. METHODS

Sixteen stations in the Hampton Roads area (Fig. 2) were sampled in early February, early May, and early August 1969 with the exception of station E8 which was not sampled in February. Three replicates at each station were obtained with an 0.06 m^2 Foerst-Petersen grab in February and an 0.07 m^2 modified Van Veen grab in May and August. The contents of the grab were sieved through a 1.0 mm mesh screen, and that fraction retained was preserved in 10% formalin in seawater. All animals were removed from the preserved debris by examination under a dissecting microscope and were identified and counted.

Both grabs functioned well in muddy sediments and usually filled to capacity. The heavier Van Veen grab proved superior in sandy sediments, and repeated attempts were often necessary to secure adequate samples in sand with the Foerst-Petersen grab. In all cases, however, only swift or deep-burrowing animals, which were numerically unimportant could escape being sampled.

In the February sampling (May for station E8), a fourth grab sample was taken and a sediment sample was removed from the relatively undisturbed sediment-water interface. Sediment particle size distribution was determined by sieving and pipette analyses following the procedures of Folk (1961). Sediments were disaggregated by immersion in 50 ml of 4% sodium hexametaphosphate

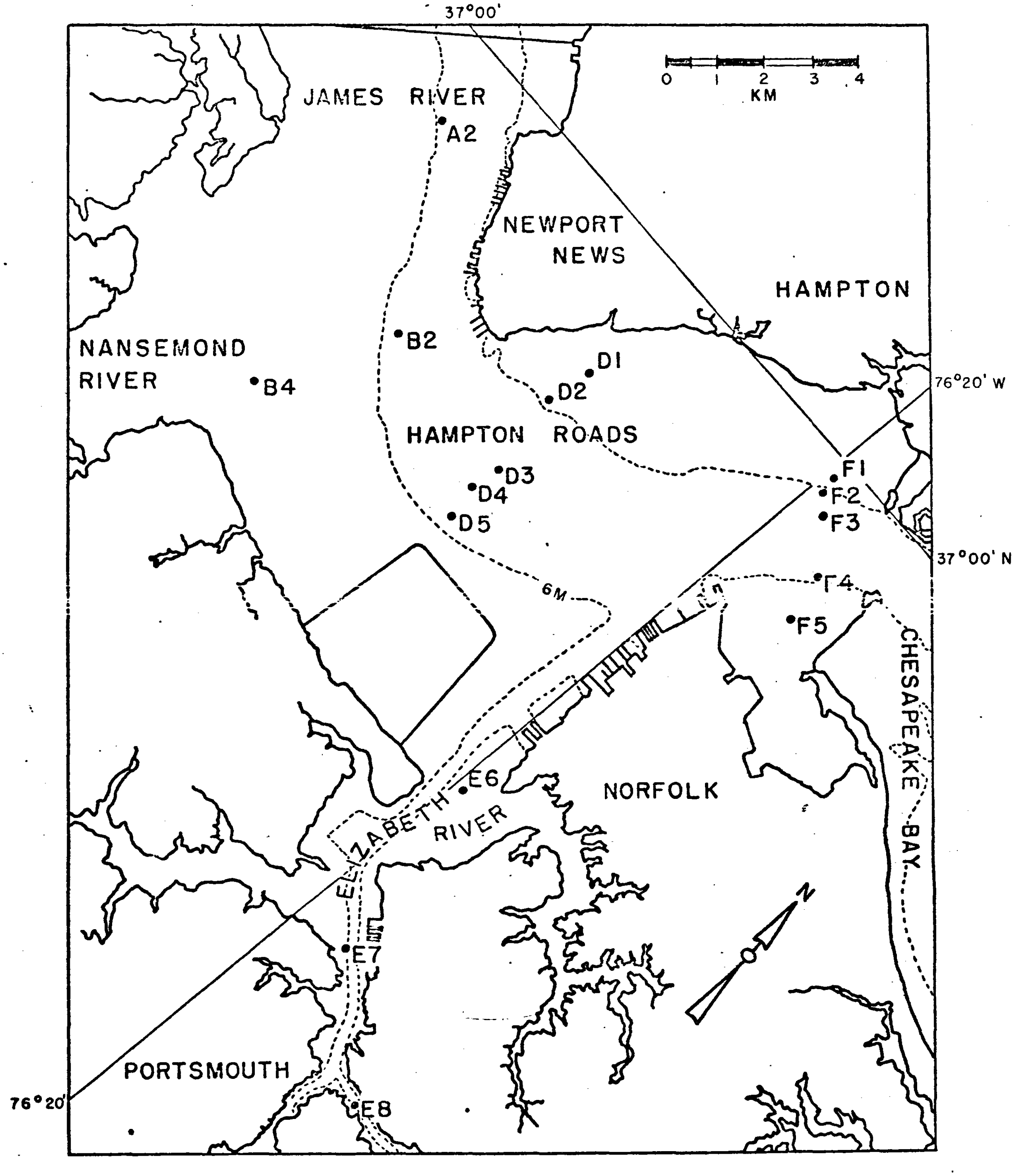


Figure 2. Map of Hampton Roads area showing location of the benthic sampling stations.

(Calgon) solution for 24 hours.

III. RESULTS

a. Sediments

Percent of total sediment mass was computed for each phi size class (1.0 through 8.0 ϕ). These were plotted as cumulative percent curves on probability paper and the median diameter (Mdϕ) and standard deviation ($\sigma\phi$) were computed from interpolated values by using equations given by Inman (1952). Percentages of sand, silt and clay were calculated and sediments classified according to Shepard's (1954) sand-silt-clay terminology. These descriptive sediment statistics together with the water depth at the time of collection are given in Table 1. In addition, percentages of sand, silt and clay of the total sand-silt-clay fraction (i.e., excluding fraction larger than sand size) are graphically presented on a triangular coordinate diagram (Fig. 3).

The sediments ranged from silty clay (Md 8.0 ϕ) for station B2 at the mouth of the Nansemond River to fine sand (Md 2.5 ϕ) at station F4 located on a shallow bar, Sewell's Point Spit. Coarse sediments predominated on the shoals at the northern side of the harbor and at its eastern end where medium to fine sands comprised most of the sediment. Finer sediments predominated on the shoals to the south, in the lower James River, and in the Elizabeth River.

TABLE 1. Depth; sediment shell-gravel, sand, silt and clay percentages; particle median diameter in phi units and millimeters and standard deviation in phi units; and sediment classification for each station (samples taken in February except for E8 which was taken in May).

Station	Depth (m)	% Shell-Gravel	% Sand	% Silt	% Clay	Md_{ϕ}	Md_{mm}	σ_{ϕ}	Classification
A2	7.6	3.02	37.83	24.74	34.41	4.7	0.039		sand-silt-clay
B2	7.6	3.55	25.25	39.91	31.29	5.5	0.022		sand-silt-clay
B4	5.5	0.65	4.57	35.43	59.35	8.0	0.004		silty clay
D1	3.3	0.43	90.47	3.88	5.22	2.5	0.177	0.8	sand
D2	7.6	2.03	70.00	13.55	15.51	3.2	0.108	1.9	clayey sand
D3	4.5	1.94	82.29	7.46	8.31	2.7	0.154	1.0	sand
D4	7.4	0.06	63.41	17.10	19.43	3.6	0.082	3.1	clayey sand
D5	4.5	0.94	56.40	15.16	27.50	3.5	0.088	3.8	clayey sand
E6	4.8	2.85	60.27	12.54	24.34	3.8	0.072	3.7	clayey sand
E7	3.6	0.87	40.63	28.77	29.73	4.6	0.041	4.1	sand-silt-clay
E8	5.0	1.92	39.24	21.56	37.28	4.8	0.036		sand-silt-clay
F1	3.0	0.29	87.90	5.72	6.09	3.0	0.125	0.6	sand
F2	7.0	0.59	80.35	8.43	10.63	3.1	0.117	1.0	sand
F3	12.3	2.53	75.96	10.87	10.64	3.3	0.102	1.2	sand
F4	3.1	0.55	89.64	6.48	3.33	2.5	0.177	0.8	sand
F5	3.6	0.30	80.64	8.42	10.64	3.1	0.117	0.9	sand

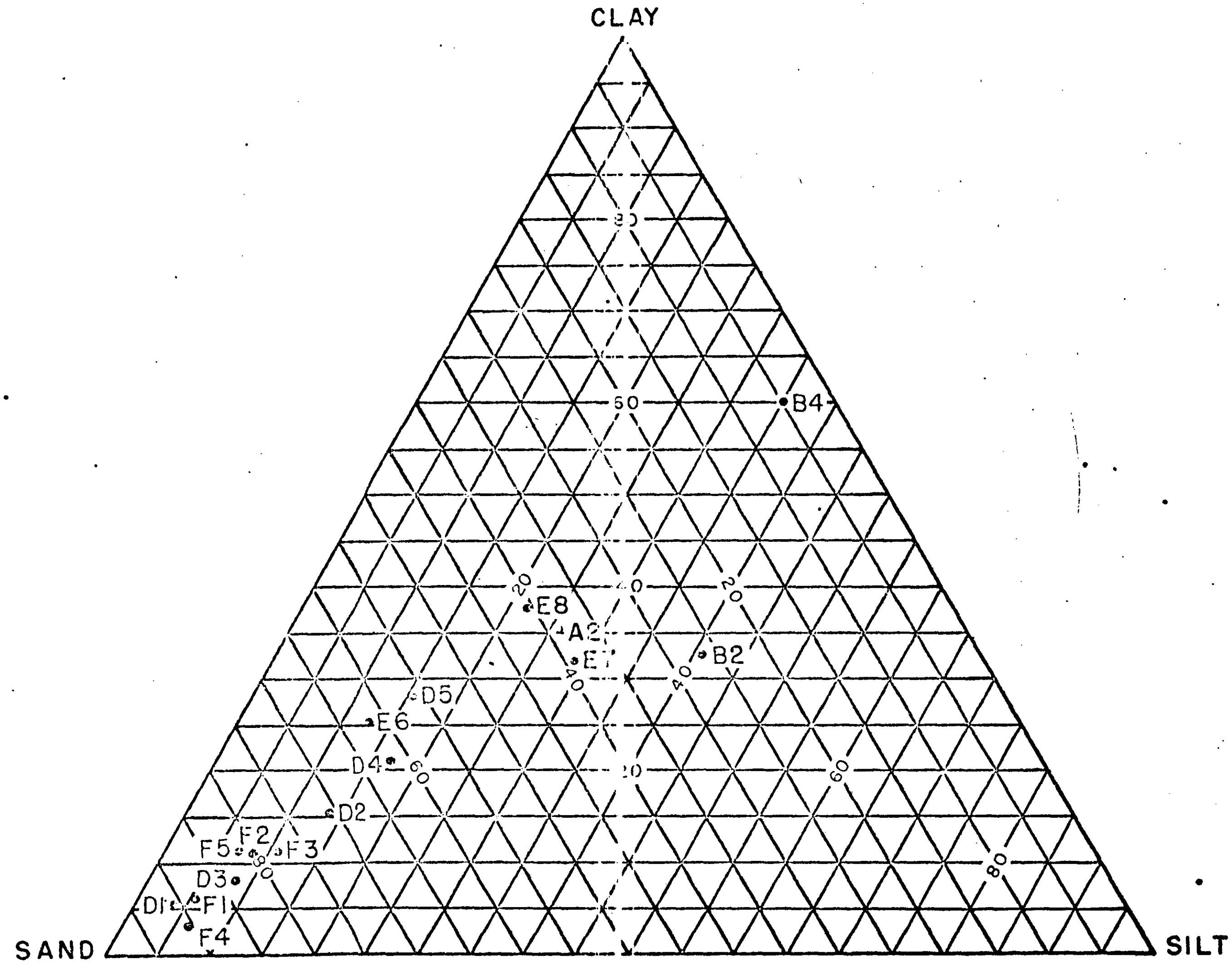


Figure 3. Triangular coordinate diagram showing sand, silt, and clay percentages of sediment samples from the benthic sampling stations.

At these locations sediments were comprised of clays, silts and very fine sands.

As shown by standard deviation values, sediments were well sorted at shallow stations e.g., at F1, F4 and D1, which were located in depths of 3.3 m or less. Wave action obviously plays an important role in determining the composition of sediment in the shoal areas. Sediments at stations located in deeper water generally had higher standard deviations and were, therefore, more poorly sorted.

b. Macrofauna

The samples yielded 175 recognizable taxa of animals; 164 of these were identified to species (Appendix I). The most speciose taxa were Polychaeta (54 identified to species) Gastropoda (23), Amphipoda (22), and Bivalvia (18). A complete list of species taken at each station is given in Appendix II together with their abundances expressed as total numbers taken in each of the three sampling periods (two periods for E8) and grand totals. Species abundance for each sampling period is the combined total of three replicate samples, covering a total area of 0.2 m^2. Frequency of occurrence at each station in the three replicates for three sampling periods, or a total of 9 replicates (6 for E8), is also given in Appendix II.

c. Associations

A rank analysis modified from a method of Fager (1957) was used to assess the numerically dominant species at each station. A score, or biological index, was assigned to the five species which were highest-ranked numerically in each replicate sample. The most numerous species received 5 points, the next 4 points, etc. These scores were summed for the 9 replicate samples at each station (6 replicates at E8) and these sums are included in Appendix II.

The biological indices for each species were summed for all stations and divided by the total number of replicate samples (141) to yield a mean biological index per sample for all stations. These values for the 15 top ranked species are given in Table 2 together with their frequency in these 141 samples and their median numerical density per 0.2 m^2. Those species ranked highest in this analysis, *Spiochaetopterus oculatus*, *Paraprionospio pinnata*, *Retusa canaliculata* and *Heteromastus filiformis*, were found in more than half of the samples and had moderately high median densities. These are ubiquitous species found over a wide variety of local habitats and generally widely distributed geographically.

In order to distinguish faunal "associations" the numerically dominant species of all pairs of stations were compared. The biological index summed for all samples at a station was used as a measure of the species dominance at each station. Pairs of stations

TABLE 2. Rank analysis dominant species for all stations.

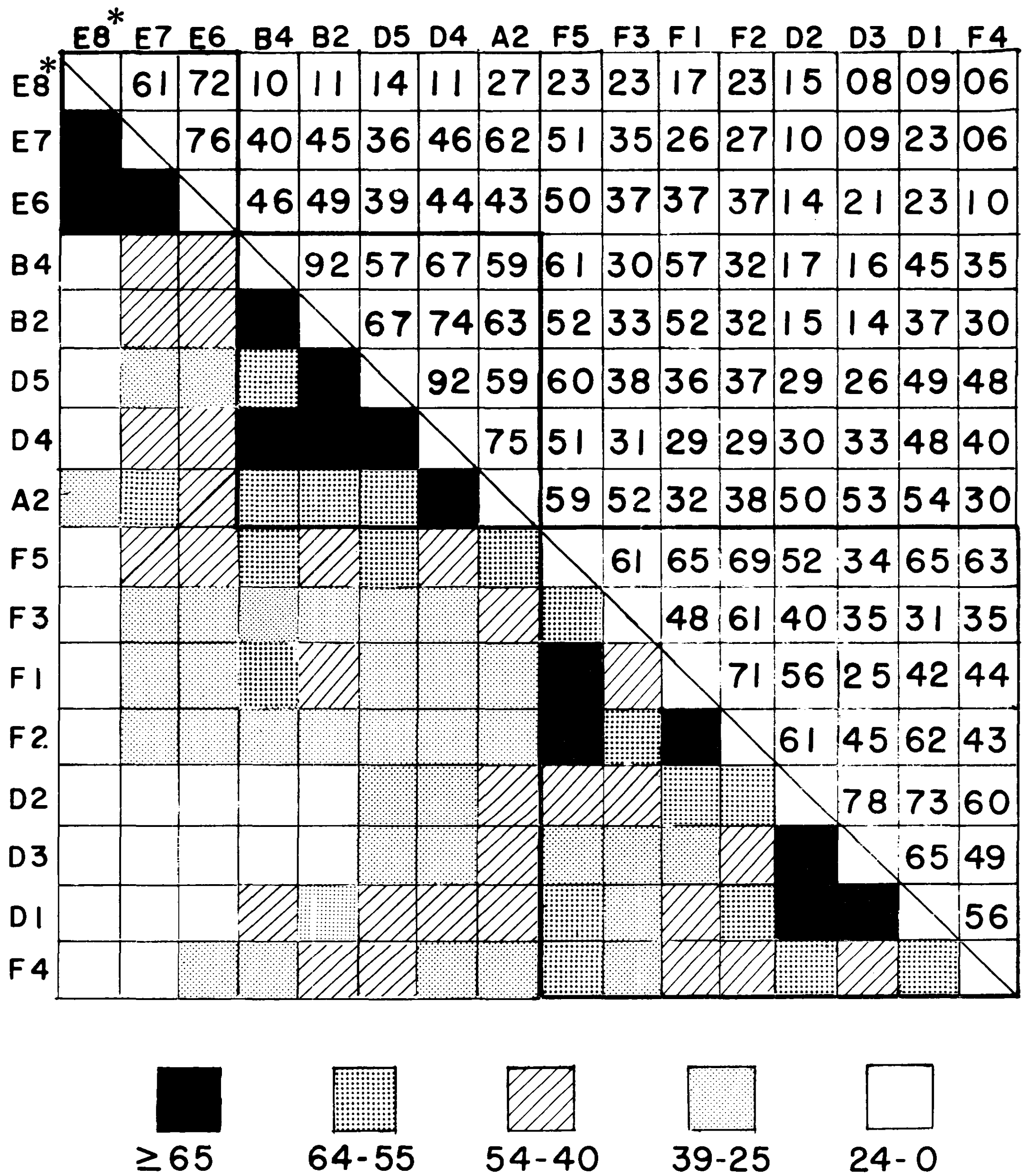
Species	Mean Biological Index per sample (5 point system)	Frequency (in 141 samples)	Median Density (0.2 m^2)
1. *Spiochaetopterus oculatus* (P)	1.50	116	17
2. *Paraprionospio pinnata* (P)	1.41	102	12
3. *Retusa canaliculata* (G)	1.39	106	14
4. *Heteromastus filiformis* (P)	1.13	101	9
5. *Phoronis architecta* (Ph)	1.06	70	4
6. *Spiophanes bombyx* (P)	0.70	51	0
7. *Polydora ligni* (P)	0.66	61	1
8. *Unciola irrorata* (A)	0.65	61	1
9. *Ampelisca vadorum* (A)	0.60	75	5
10. *Mulinia lateralis* (B)	0.58	72	1
11. *Nereis succinea* (P)	0.55	93	4
12. *Ensis directus* (B)	0.38	46	1
13. *Mya arenaria* (B)	0.37	14	0
14. *Nephtys magellanica* (P)	0.31	63	2
15. *Pseudeurythoe paucibranchiata* (P)	0.29	69	2
Streblospio benedicti (P)	0.29	45	0

(P = Polychaete, G = Gastropod, Ph = Phoronid, A = Amphipod, B = Bivalve) were compared and the minimum biological indices of species common to both stations were summed, yielding similarity index, a "shared biological index value" (SBV). This method is similar to the "index of affinity" of Sanders (1960) except that minimum index values rather than minimum percentages are summed. This has the effect of limiting the influence on the similarity index of species which were extremely abundant at a station only infrequently, while emphasizing the importance of the consistently dominant species.

The symmetrical (16 x 16) matrix of SBV's for all pairs of stations were then arranged by eye so that each station is approximate to those other stations with which it is most highly associated (Fig. 4). Three station groups or "associations" are evident in which there are high degrees of internal association but little association between stations of different groups. One group includes stations E6, E7, and E8, the Elizabeth River stations. The second group includes stations A2, B2, B4, D4 and D5, i.e., those stations at which the sediment was approximately 40% or more silts and clays. This group of stations was termed "mud stations". The remaining group, "sand stations", includes stations D1, D2, D3, F1, F2, F3, F4 and F5, i.e., those stations in sediments of at least 70% sand.

The affinities between stations within the latter group were generally lower than those within the other two groups, but this

Figure 4. Matrix of "shared biological index values" for all pairs of stations. Biological indices for station E8 were multiplied by 1.5 to compensate for the lower number of replicate samples.


E8* E7 E6 B4 B2 D5 D4 A2 F5 F3 F1 F2 D2 D3 D1 F4
E8* 61 72 10 11 14 11 27 23 23 17 23 15 08 09 06
E7 76 40 45 36 46 62 51 35 26 27 10 09 23 06
E6 46 49 39 44 43 50 37 37 37 14 21 23 10
B4 92 57 67 59 61 30 57 32 17 16 45 35
B2 67 74 63 52 33 52 32 15 14 37 30
D5 92 59 60 38 36 37 29 26 49 48
D4 75 51 31 29 29 30 33 48 40
A2 59 52 32 38 50 53 54 30
F5 61 65 69 52 34 65 63
F3 48 61 40 35 31 35
F1 71 56 25 42 44
F2 61 45 62 43
D2 78 73 60
D3 65 49
D1 56
F4
≥65
64-55
54-40
39-25
24-0

was largely the result of low affinities between the somewhat aberrant stations F3 and D3 and the other sand stations. Of all 16 stations, however, only station F5 showed appreciable affinities for stations outside the station group in which it is included.

The difference between the assemblages can be further quantified if the rank order analysis is applied to the three station groups separately. Tables 3, 4, and 5 list mean biological index, frequency, and median density for the dominant species from sand, mud, and Elizabeth River stations, respectively.

For the sand stations, the five top-ranked species are, with the exception of *Spiophanes*, ubiquitous. *Retusa canaliculata* was equally common at mud and sand stations although it reached its highest population densities in sand (196/0.2 m^2 at F3 in February). *Heteromastus filiformis* occurred in all three habitat types but was more abundant at sand and Elizabeth River stations. *Unciola irrorata* and *Polydora ligni* are epifaunal organisms which occur on hydroids, shells, etc. They were common on both sand and mud but only during the February and May sampling. *Spiophanes* was found at all sand stations and, with the exception of one specimen at D4, was not found elsewhere. Other dominant species limited to the sand stations were *Ampelisca verrilli* and *Glycera dibranchiata*. *Ampelisca vadorum*, *Spiochaetopterus oculatus* and *Glycera dibranchiata* were taken very frequently but seldom in great numbers; instead, they maintained relatively small but consistent populations.

TABLE 3. Rank analysis dominant species for sand stations (D1,D2,D3,F1,F2,F3,F4,F5).

Species	Mean Biological Index per sample (5 point system)	Frequency (in 72 samples)	Median Density (0.2 m^2)
1. *Retusa canaliculata* (G)	1.57	60	16.5
2. *Heteromastus filiformis* (P)	1.40	58	16
3. *Spiophanes bombyx* (P)	1.38	50	10
4. *Unciola irrorata* (A)	1.06	41	5.5
5. *Polydora ligni* (P)	1.04	40	6.5
6. *Ampelisca vadorum* (A)	0.90	59	16
7. *Phoronis architecta* (Ph)	0.78	39	5
8. *Ensis directus* (B)	0.69	31	2
9. *Spiochaetopterus oculatus* (P)	0.61	54	10
10. *Nephtys magellanica* (P)	0.60	49	3
11. *Ampelisca verrilli* (A)	0.54	44	9
12. *Paraprionospio pinnata* (P)	0.47	43	3
13. *Glycera dibranchiata* (P)	0.40	60	9
14. *Sabellaria vulgaris* (P)	0.36	20	0
15. *Mulinia lateralis* (B)	0.24	37	2

(G = Gastropod, P = Polychaete, A = Amphipod, Ph = Phoronid, B = Bivalve)

TABLE 4. Rank analysis dominant species for mud stations (A2,B2,B4,D4,D5).

Species	Mean Biological Index per sample (5 point system)	Frequency (in 45 samples)	Median Density (0.2 m^2)
1. *Paraprionospio pinnata* (P)	3.00	44	47
2. *Spiochaetopterus oculatus* (P)	2.93	43	33
3. *Phoronis architecta* (Ph)	1.93	25	8
4. *Retusa canaliculata* (G)	1.82	41	17
5. *Mulinia lateralis* (B)	1.11	21	1
6. *Ampelisca vadorum* (A)	0.44	15	0
7. *Pseudeurythoe paucibranchiata* (P)	0.42	23	3
8. *Unciola irrorata* (A)	0.36	18	1
9. *Polydora ligni* (P)	0.33	10	0
10. *Nereis succinea* (P)	0.31	24	3
11. *Ogyrides limicola* (D)	0.27	24	2
12. *Nassarius vibex* (G)	0.24	23	2
13. *Heteromastus filiformis* (P)	0.22	23	3
14. *Pectinaria gouldii* (P)	0.20	24	3

(P = Polychaete, Ph = Phoronid, G = Gastropod, B = Bivalve, A = Amphipod, D = Decapod)

TABLE 5. Rank analysis dominant species for Elizabeth River stations (E6,E7,E8).

Species	Mean Biological Index per sample (5 point system)	Frequency (in 24 samples)	Median Density (0.2 m^2)
1. *Mya arenaria* (B)	2.08	12	54
2. *Nereis succinea* (P)	2.04	22	21.5
3. *Heteromastus filiformis* (P)	2.00	20	23.5
4. *Spiochaetopterus oculatus* (P)	1.50	19	5.5
5. *Streblospio benedicti* (P)	1.46	12	13.5
6. *Paraprionospio pinnata* (P)	1.25	15	7
7. *Mulinia lateralis* (B)	0.63	14	5
8. *Sabella micropthalma* (P)	0.63	10	2
9. *Corophium acherusicum* (A)	0.42	6	0
10. *Molgula manhattensis* (U)	0.42	7	1

(B = Bivalve, P = Polychaete, A = Amphipod, U = Urochordate)

All mud station dominants are ubiquitous with the exception of Ogyrides limicola, ranked eleventh, which was absent at the sand stations except for one juvenile taken at F4. The first and second ranked species, Paraprionospio pinnata and Spiochaetopterus oculatus, were found in almost all replicate samples from the mud stations and at consistently high densities. Although also common in sand, these two species developed much larger population densities in mud. Retusa canaliculata was very frequent but its population densities in mud never approached those found at some sand stations. Phoronis architecta ranked high but had a low frequency of occurrence because of its great numerical importance at D4 and D5 coupled with its rarity at most other mud stations. Phoronis constructs long tubes of sand grains and perhaps the higher sand content of the sediment at D4 and D5 enhanced the development of large populations there. Mulinia lateralis similarly ranked high with a low frequency of occurrence because of its abundance at B2 and B4. At B2 especially, this clam developed a huge population of approximately 7,000/m^2 by February. The population was considerably reduced by May and decimated by August. Species ranked lower than fifth for the mud stations were relatively unimportant, as shown by an abrupt drop in the mean biological index between species 5 and 6.

The most notable difference in the fauna at the Elizabeth River stations was the abundance of Mya arenaria in February and May samples. This clam was not found outside the Elizabeth River except for two isolated occurrences of very small specimens. The ubiquitous Nereis succinea was abundant in most of the samples taken at the three stations. It was commonly found elsewhere but never in numbers like those found in the Elizabeth River. Heteromastus filiformis, the second ranked species for sand stations, was likewise frequent and abundant at the Elizabeth River stations. Streblospio benedicti was only abundant in May, thus its high index and low frequency. Noticeably rare at the Elizabeth River stations were Retusa canaliculata and Ampelisca vadorum, two important species at the mud stations.

Because the sediments and salinity at the three Elizabeth River stations were not unlike those at some of the "mud stations" it is suggested that the environmental factors causing the observed faunal differences are those relating to the pollution stress existing in the Elizabeth River. Abundant non-biological evidence chronicles the polluted conditions of these waters and additional evidence from the benthic fauna is presented later in this report to substantiate this contention.

d. Periodicity

An assemblage of organisms tends to change through time in species numerical composition, due to recruitment and mortality related to biotic and abiotic factors. The results reported to this point have integrated seasonal effects by considering differences among the stations in terms of combined faunal composition for all three sampling periods. Therefore, rank orders were broken down by sampling period within station groups and the six most important species in each category appear in Table 6.

Retusa was numerically the most important species at the sand stations in February but steadily declined in importance as other species developed larger populations. The epifaunal *Polydora ligni* and *Unciola irrorata* and infaunal juvenile *Ensis directus* were abundant in February and May but virtually absent in August. *Heteromastus* and *Ampelisca vadorum* remained consistent in importance, *Heteromastus* reaching a peak in importance and abundance in May. *Spiophanes*, *Phoronis* and *Ampelisca verrilli* were rare in February, more common in May, and very abundant in August.

In contrast to the sand stations, the dominant fauna of the mud stations did not change much seasonally. The one exception to this rule was *Mulinia lateralis* which, as mentioned above, was tremendously abundant at certain stations in February and May but virtually absent in August. The two most important species, *Paraprionospio* and *Spiochaetopterus*, did not relinquish their positions and were ranked first and second, or vice versa, in each sampling period.

TABLE 6. The six most important species (by rank analysis) for sand, mud, and polluted stations during each sampling period.

	February	May	August
SAND STATIONS	*Retusa*	*Heteromastus*	*Spiophanes*
	Polydora	*Polydora*	*Phoronis*
	Heteromastus	*Unciola*	*Ampelisca verrilli*
	Unciola	*Ensis*	*Heteromastus*
	Ampelisca vadorum	*Retusa*	*Spiochaetopterus*
	Ensis	*Ampelisca vadorum*	*Ampelisca vadorum*
MUD STATIONS	*Paraprionospio*	*Paraprionospio*	*Spiochaetopterus*
	Spiochaetopterus	*Spiochaetopterus*	*Paraprionospio*
	Retusa	*Mulinia*	*Phoronis*
	Ogyrides	*Pseudeurythoe*	*Retusa*
	Nereis	*Retusa*	*Pseudeurythoe*
	Phoronis	*Phoronis*	*Nereis*
Elizabeth River Stations	*Mya*	*Mya*	*Spiochaetopterus*
	Nereis	*Streblospio*	*Nereis*
	Mulinia	*Heteromastus*	*Heteromastus*
	Heteromastus	*Nereis*	*Paraprionospio*
	Spiochaetopterus	*Spiochaetopterus*	*Sabella*
	Sabella	*Sabella*	*Molgula*

The periodicity of Mya particularly characterized the Elizabeth River stations. Abundant both in February and May, these clams did not survive the summer, for in August none were taken. The size of these clams in May, roughly 20-27 mm, indicates that most of these individuals had been recruited in the fall of 1968. Rising temperatures or phytoplankton blooms during the summer months could have led to the demise of these large populations (Jon Lucy, personal communication). Mulinia was important in February but less so in May, and only two specimens were taken in August in the Elizabeth River. Streblospio had developed large populations by May but was much rarer during the other sampling periods.

e. Community Structure

Among the simplest statistics descriptive of community structure is the abundance of species and individuals. Table 7 lists the number of species and number of individuals taken in three replicate grabs at each station during each sampling period.

Densities of macrobenthic organisms ranged from 30 to 1,773 individuals/0.2 m^2 (extrapolated densities of 150 to 8,865 individuals/m^2). Geometric means for sand, mud and Elizabeth River stations were 532.5, 276.4 and 209.4 individuals/0.2 m^2, respectively, and although these values appear quite separated, the log-transformed means were not significantly different at the 0.05 level.

TABLE 7. Number of individuals (N) and species (S) per 0.2 m^2 (3 lumped replicates) for all stations.

Station	February N	February S	May N	May S	August N	August S	Total N	Total S
SAND STATIONS								
D1	374	42	526	55	1011	39	1911	74
D2	496	49	292	43	548	55	1336	83
D3	860	51	845	65	556	51	2261	93
F1	422	41	582	43	733	36	1737	66
F2	301	43	524	52	559	49	1384	75
F3	381	36	1178	82	1773	64	3332	105
F4	146	33	254	44	554	55	954	85
F5	452	39	790	57	457	46	1699	82
MUD STATIONS								
A2	148	34	572	46	214	35	984	65
B2	1556	22	563	37	166	27	2285	51
B4	104	9	356	23	165	20	625	34
D4	250	34	432	55	147	38	829	72
D5	247	31	264	41	252	46	763	68
Elizabeth River Stations								
E6	518	24	575	29	152	20	1245	43
E7	314	21	131	12	30	9	475	28
E8			636	26	104	20	740	33

Within the sand stations, geometric mean density increased from February to May to August, but the differences were non-significant. For the mud stations, mean density was highest in May and lowest in August, and the means of these two periods were significantly different from each other but not from that for February. Mean densities progressively declined from February to August for the Elizabeth River stations, that for August being significantly different from all others.

In contrast, the number of species taken in three replicate samples was characterized by more marked differences between the station groups. The arithmetic means were 48.75, 33.20 and 20.13 species for sand, mud and Elizabeth River stations, respectively. The mean number of species at sand stations was significantly different from the means for mud ($p < 0.02$) and Elizabeth River ($p < 0.01$) stations. The difference between the mean number of species at mud and Elizabeth River stations approached significance ($0.05 < p < 0.10$). Within station groups, however, no significant differences existed between means for different sampling periods. In general though, at most stations the largest number of species was taken in May and the smallest in February.

These data indicate intrinsic differences in the structure of the respective communities and suggest further analyses. Species diversity indices are mathematical expressions which permit summarization of a great amount of information about the numbers and kinds of organisms in a collection. Diversity indices developed from information theory are probably the most useful, theoretically meaningful, and accurate, and definitely the most popular of the many published measures of diversity. These indices are expressions of the degree of uncertainty involved in predicting the species of a randomly selected individual. The more diverse an assemblage, the more uncertain the prediction and, conversely, the less diverse, the more certain the prediction. The index used most often is computed by Shannon's formula (Shannon and Weaver, 1963):

$$H' = -\sum p_i \log p_i$$

where p_i is the proportion of individuals belonging to the i-th species. This index was applied in this study using base 2 logarithms, with the units of the index being "bits per individual."

As Lloyd and Ghelardi (1964) have pointed out, this expression of species diversity has two components. One is the "species richness" component and is related to the number of species in the collection. The other is the "equitability" or "evenness" component, or the relative distribution of individuals among the species. An increase in the number of species or more equitable relative abundance will be reflected in a higher value of H'.

Species richness was described by using Sanders' (1968) "rarefaction method," a graphical method allowing comparison of samples of unequal size. This procedure involves computing the number of species in increasingly smaller samples while keeping the percentage composition of the component species constant, that is, rarefying the samples. The curve generated may be visually compared with those for other samples. Figures 5, 6 and 7 are rarefaction curves for all stations of the February, May and August sampling periods, respectively. Grassle (1967) used the number of species predicted by the rarefaction method for a standard sample size as a numerical index of the species richness component. He used number of species in a 180-individual sample and his precedent was followed in this study.

The index of equitability used here is that of Lloyd and Ghelardi (1964):

$$\varepsilon = S'/S$$

in which S is the number of species in the sample and S' the number of species predicted by MacArthur's broken-stick model, assuming the observed diversity H'. Lloyd and Ghelardi presented tables of S' which facilitates the computation of E.

Table 8 lists H', ε and the number of species in a rarefied sample of 180 individuals (abbreviated spp/180) for all stations for each sampling period. Diversity (H') was highest at D3 in May with a value of 4.93 and lowest at B2 in February with a value of 0.83. The median diversity for sand stations was 3.95,

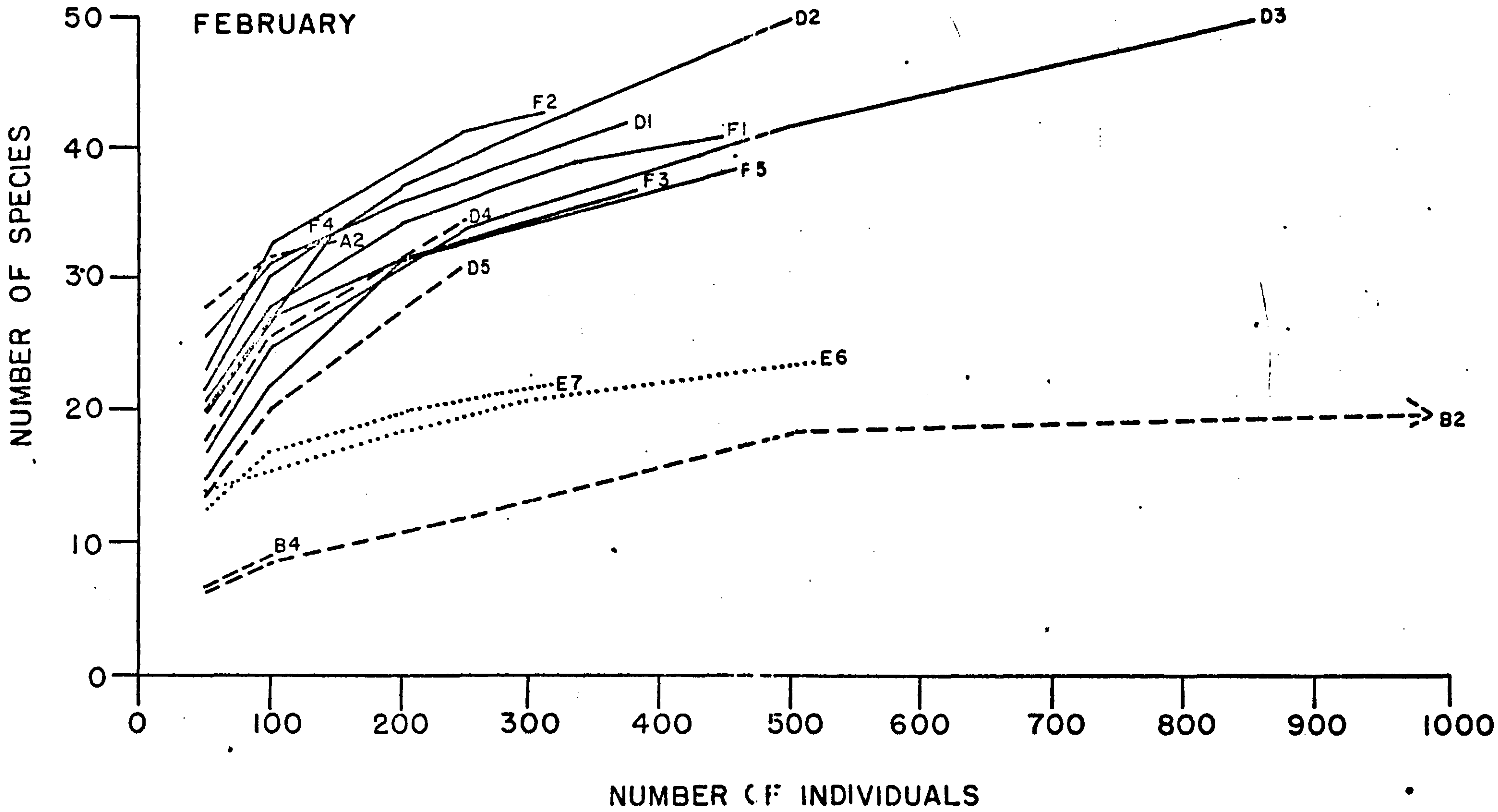


Figure 5. Rarefaction curves for macrobenthos in February samples (solid lines--sand stations; broken lines--mud stations; dotted lines--Elizabeth River stations).

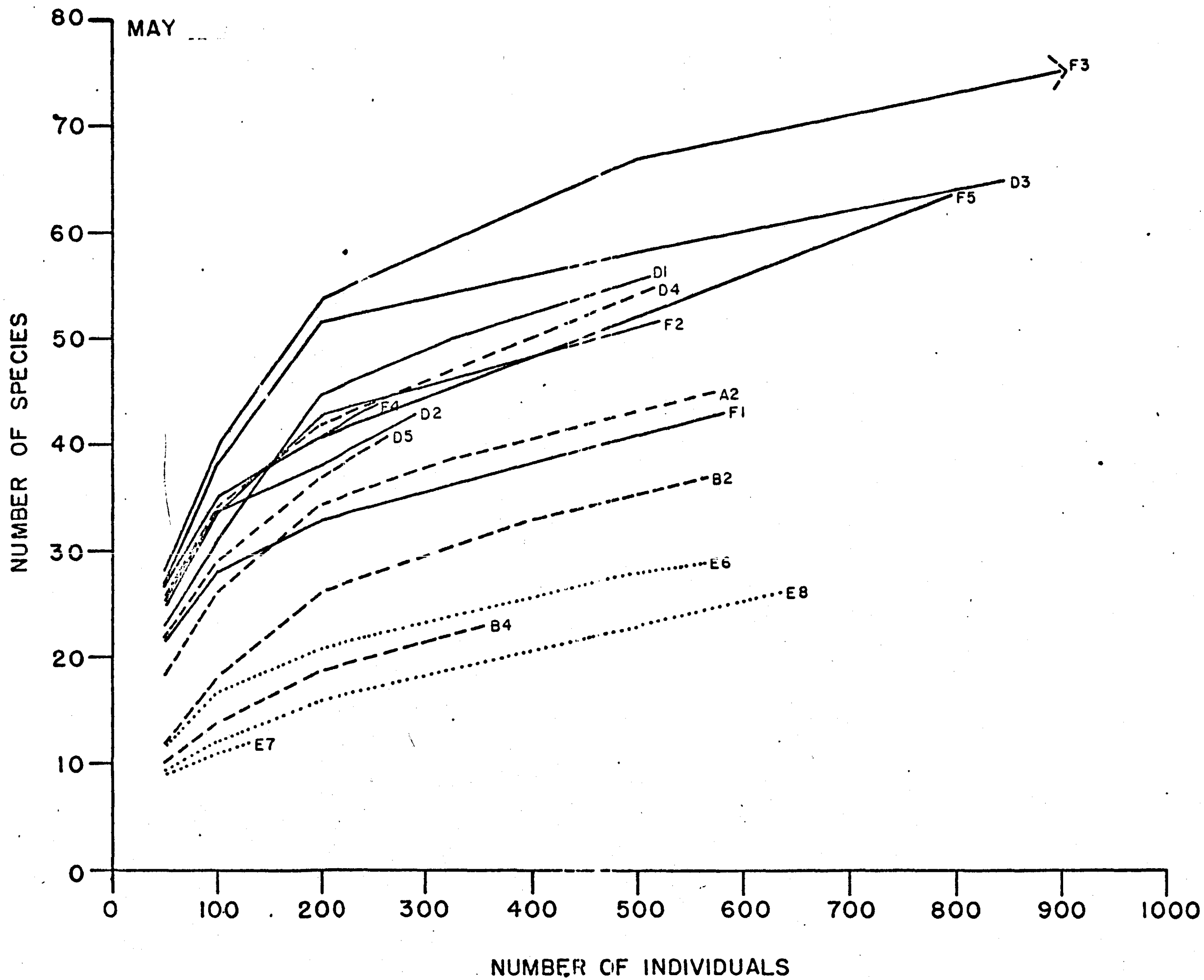


Figure 6. Rarefaction curves for May samples (symbols as in Fig. 5).

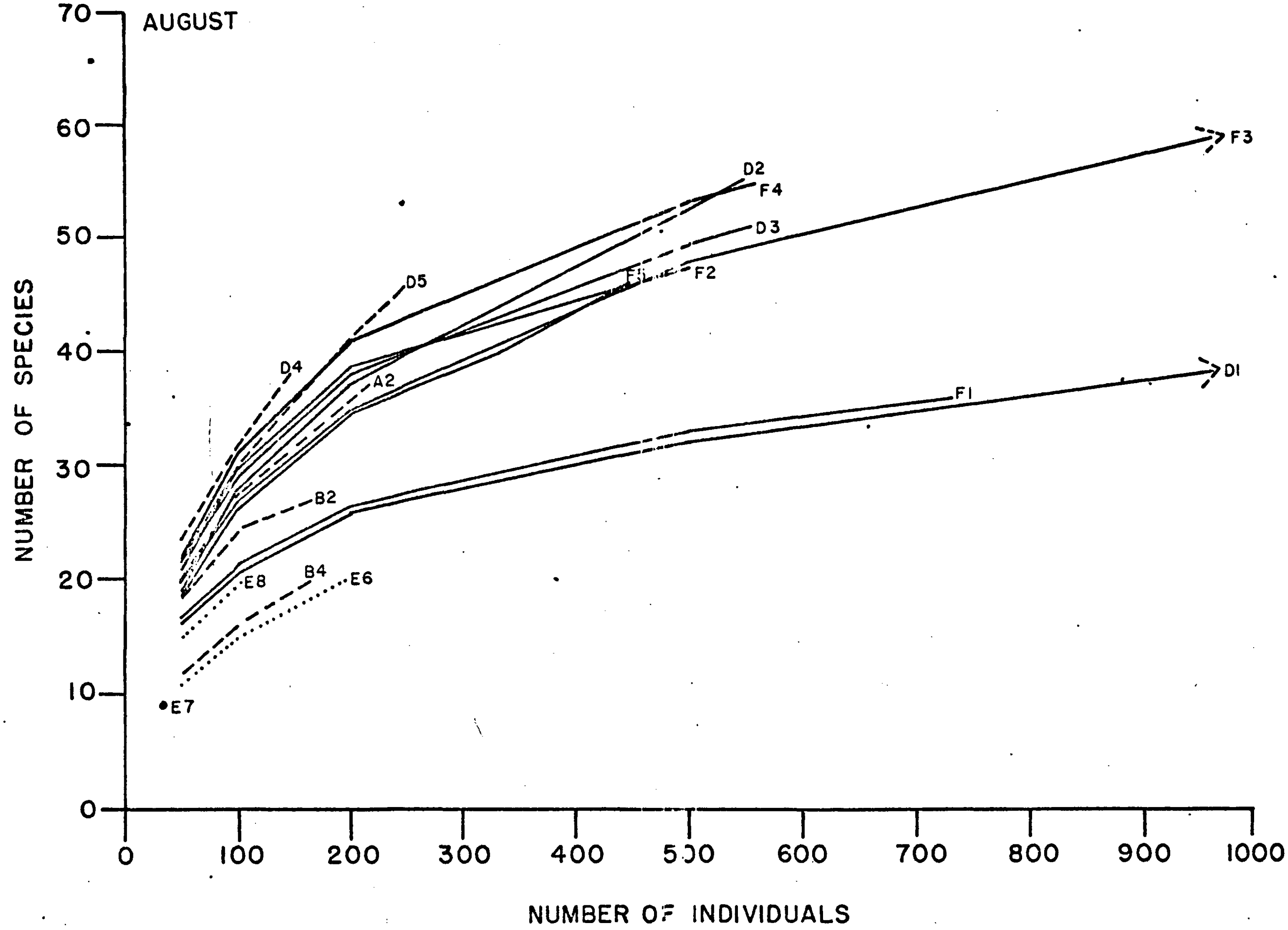


Figure 7. Rarefaction curves for August samples (symbols as in Fig. 5).

TABLE 8. Shannon's formula diversity (H'), equitability (ε) and number of species in rarefied samples of 180 individuals for all stations (3 lumped replicates). Asterisk indicates sample of less than 180 individuals, in which value was obtained by extrapolation.

	FEBRUARY			MAY			AUGUST		
	H'	ε	spp/180	H'	ε	spp/180	H'	ε	spp/180
SAND STATIONS									
D1	4.38	0.74	35.5	4.27	0.50	42.5	3.61	0.46	25.0
D2	3.87	0.42	36.0	4.58	0.82	37.0	3.88	0.38	35.5
D3	3.48	0.32	29.5	4.93	0.69	49.0	4.04	0.47	36.5
F1	3.97	0.56	33.0	4.29	0.67	32.0	3.15	0.36	25.5
F2	4.40	0.72	38.0	4.61	0.69	41.0	3.97	0.47	37.0
F3	2.95	0.30	29.0	4.77	0.50	51.0	3.94	0.34	33.5
F4	3.46	0.48	34.0*	4.49	0.75	40.0	3.89	0.40	39.0
F5	3.75	0.51	30.5	4.58	0.59	40.0	3.77	0.43	33.0
MUD STATIONS									
A2	4.69	1.12	33.0*	3.34	0.31	33.0	4.07	0.68	34.5
B2	0.83	0.09	10.5	2.51	0.22	24.5	3.40	0.56	37.5*
B4	1.63	0.44	11.5*	2.45	0.30	28.0	2.96	0.55	21.0*
D4	3.70	0.56	30.5	4.80	0.76	40.1	4.45	0.84	41.0
D5	3.16	0.42	26.0	4.07	0.61	35.5	3.67	0.39	39.0
Elizabeth R. Stations									
E6	3.19	0.54	18.0	2.97	0.38	20.0	2.97	0.55	19.0
E7	3.01	0.50	19.5	2.06	0.50	13.0*	2.45	0.77	16.0*
E8				1.82	0.19	15.0	3.03	0.60	23.5*

for mud stations 3.40, and for Hampton Roads stations 2.97. Median H' of sand stations was highest in May (4.53) and lowest in August (3.88), whereas in mud it was highest in August (3.67) and lowest in February (3.16); in the Elizabeth River it was highest in February (3.10) and lowest in May (2.06).

The equitability component (ε) ranged from 1.12 at A2 in February to 0.09 at B2 in February. Median values were 0.49, 0.55, and 0.52 for sand, mud and Elizabeth River stations, respectively. As with H', no seasonal patterns of ε consistent among the station groups were evident. Median equitability was highest in May (0.68) and lowest in August (0.43) for sand stations, highest in August (0.56) and lowest in May (0.31) for mud stations, and highest in August (0.60) and lowest in May (0.38) for Elizabeth River stations.

Species richness as expressed by spp/180 was greatest at F3 in May (51.0) and least at B2 in February (10.5). Median values were 35.7, 33.0 and 18.5 for sand, mud and Elizabeth River stations, respectively. Median spp/180 values were highest in May (40.5) and lowest in February (34.7) in sand, highest in August (37.5) and lowest in February (26.0) in mud, and highest in August (19.0) and lowest in May (15.0) in the Elizabeth River.

4. DISCUSSION

a. Association Relationships

Published descriptions of benthic communities on the Atlantic coast of the United States have been amazingly few. Foremost among these and of considerable historical importance are those of Sanders (1956, 1958, 1960) of benthos in Long Island Sound and Buzzards Bay. Sanders described a Nephtys incisa-Yoldia limatula association in Long Island Sound and a Nephtys incisa-Nucula proxima association in Buzzards Bay fine sediments. These same species were found in Hampton Roads but never in great numbers. Sanders (1960) analyzed dominance at station R in Buzzards Bay by a biological index technique similar to the one used in this study and only one of the ten top-ranked species, Retusa canaliculata (9th), was among the dominants in Hampton Roads. The overall Hampton Roads dominants (Table 2) were either relatively rare or absent at Sanders' station R. Among these important species in the sandier sediments in Buzzards Bay, however, were Ampelisca vadorum (= spinipes) and Ampelisca verrilli (= macrocephala) (Sanders, 1958), ranked 6th and 11th in Hampton Roads.

M. L. Wass and others at the Virginia Institute of Marine Science have surveyed some of the benthos of the lower Chesapeake Bay and its sub-estuary rivers, although most of the results are unpublished (Wass, 1965; Wass, McCain and Kerwin, 1967; Harrison and Wass, 1965; Stone, 1963; Haven et al., 1967). In an intensively sampled area in Chesapeake Bay off the mouth of the Rappahannock River, the ten top-ranked dominants by biological index were Nephtys incisa, Retusa canaliculata, Ensis directus, Mulinia lateralis, Molgula manhattensis, Pectinaria gouldii, Ampelisca vadorum, Macoma tenta, Lyonsia hyalina, and Cirratulus grandis (Wass et al., 1967). At a mud bottom station in the lower York River, Virginia, which was sampled periodically over a 6-year period, the biological index dominants were Nephtys incisa, Retusa canaliculata, Ogyrides limicola, Mulinia lateralis, Edwardsia elegans, Pectinaria gouldii, Ampelisca spp., Amphiodia atra, and Phoronis architecta (M. L. Wass, personal communication).

The most notable difference between the Hampton Roads area benthic fauna and that of other nearby areas was the remarkable rarity of Nephtys incisa in the former. This species, which is common and abundant elsewhere, was only taken in 4 of the 141 samples in this study. Its congener, N. magellanica, which prefers sandier sediments than does N. incisa, was much more common, but as it was found less abundant at mud stations, it was not replaced by N. incisa, as is the usual case. Other species abundant in mud in the York River, for instance, were not as abundant in mud in Hampton Roads. These include Ogyrides limicola and Edwardsia elegans.

Four of the six top-ranked species in Hampton Roads were not among the dominants either off the Rappahannock or in the York River: Spiochaetopterus oculatus, Paraprionospio pinnata, Heteromastus filiformis, and Spiophanes bombyx. Spiochaetopterus is abundant in the York River only at very shallow depths in the lower part of the river and in somewhat deeper water in the mesohaline portion of that estuary. Paraprionospio and Heteromastus are common but usually not very abundant in the York. Spiophanes can be found in small numbers in shallow water in the York River but it was a community dominant subtidally in sandy sediments at the mouth of Chesapeake Bay and on the shallow continental shelf off Virginia (Boesch, unpublished data).

The dominant members of the macrobenthic fauna of the Hampton Roads system are, therefore, considerably different from those of nearby areas with generally similar environmental characteristics. However, no explanations for these differences seem evident.

b. Density of Individuals

The density of macrobenthic animals reported from various investigations reflects the type and efficiency of sampler used and the mesh size used in sieving the sample, as well as real differences in animal density. Screen size is an especially important criterion since the numbers of individuals retained by an only slightly smaller mesh size may be drastically increased (Reish, 1959b).

Some density data are available in the literature for 1 mm screened samples. Wigley and McIntyre (1964) found means of 4,740 indiv./m^2 for the inner continental shelf, 1,496 indiv./m^2 for the outer shelf, and 1,214 indiv./m^2 for the slope in a transect south of Cape Cod. Lowry (1969) found mean densities of 7,629 and 6,285 indiv./m^2 for two stations in mud at Arthur Harbour, Antarctica. Lowry calculated mean densities (1 mm screen) of 928 indiv./m^2 for two mud stations and 5,548 indiv./m^2 for two sand stations studied by Haven et al. (1967) in the York River.

Numbers per square meter as extrapolated from geometric mean numbers of individuals per 0.2 m^2 for this study were 2,663 for sand stations, 1,382 for mud stations, and 1,047 for Elizabeth River stations. Values extrapolated from arithmetic means would be 3,045, 1,839, and 1,538, respectively. The mud and Elizabeth River stations generally had higher densities than Haven's data would indicate for comparable sediments in the York River. Sand stations showed densities considerably below those found by Haven in York River sand and below Wigley and McIntyre's inner shelf and Lowry's Antarctic densities. Both Wigley and McIntyre's and Lowry's stations were in areas of unusually rich planktonic productivity and Lowry believed this rich food source was responsible for the high densities.

c. Species Diversity

As Pielou (1966a), Sanders (1968) and Wilhm and Dorris (1968) have noted, the species diversity measure H' is dependent on sample size. For a given population, H' will increase asymptotically with sample size. Therefore, it seems necessary to decide what minimum sample size is necessary to adequately define H' for the real population. An attempt was made to estimate this minimum adequate sample size by computing H' for successively pooled series of 10 replicate grab samples from three locations in Hampton Roads sampled previously by M. L. Wass and J. B. Feeley. Figure 8 shows the characteristic curves describing the increase of H' with sample size (numbers of individuals) for these three locations (B3, HB, MG) and for three pooled replicates from four stations sampled during this study (D2M, D5M, F5A, E7F). All curves had nearly leveled off before the first 150 to 200 individuals were considered. In all cases, H' at these sample sizes had reached 90% of its asymptotic value. The conclusion is, then, that for these assemblages a sample size of 150 individuals yields an adequate estimate of H'. Only 5 of the 47 samples (3 replicates each) taken in this study included less than 150 individuals and only one of these less than 100 individuals. It is evident that H' values presented here are good estimates of the asymptotic H' or the "population H'" (Pielou, 1966b) of the macrofaunal community.

Although, as Pianka (1966) pointed out, there has been little discussion of the application of statistical procedures to measures such as H', various parametric statistical tests have been used to compare H' values (Wilhm, 1967; Tramer, 1969; Dahlberg and Odum, 1970). There is no evidence to show that the

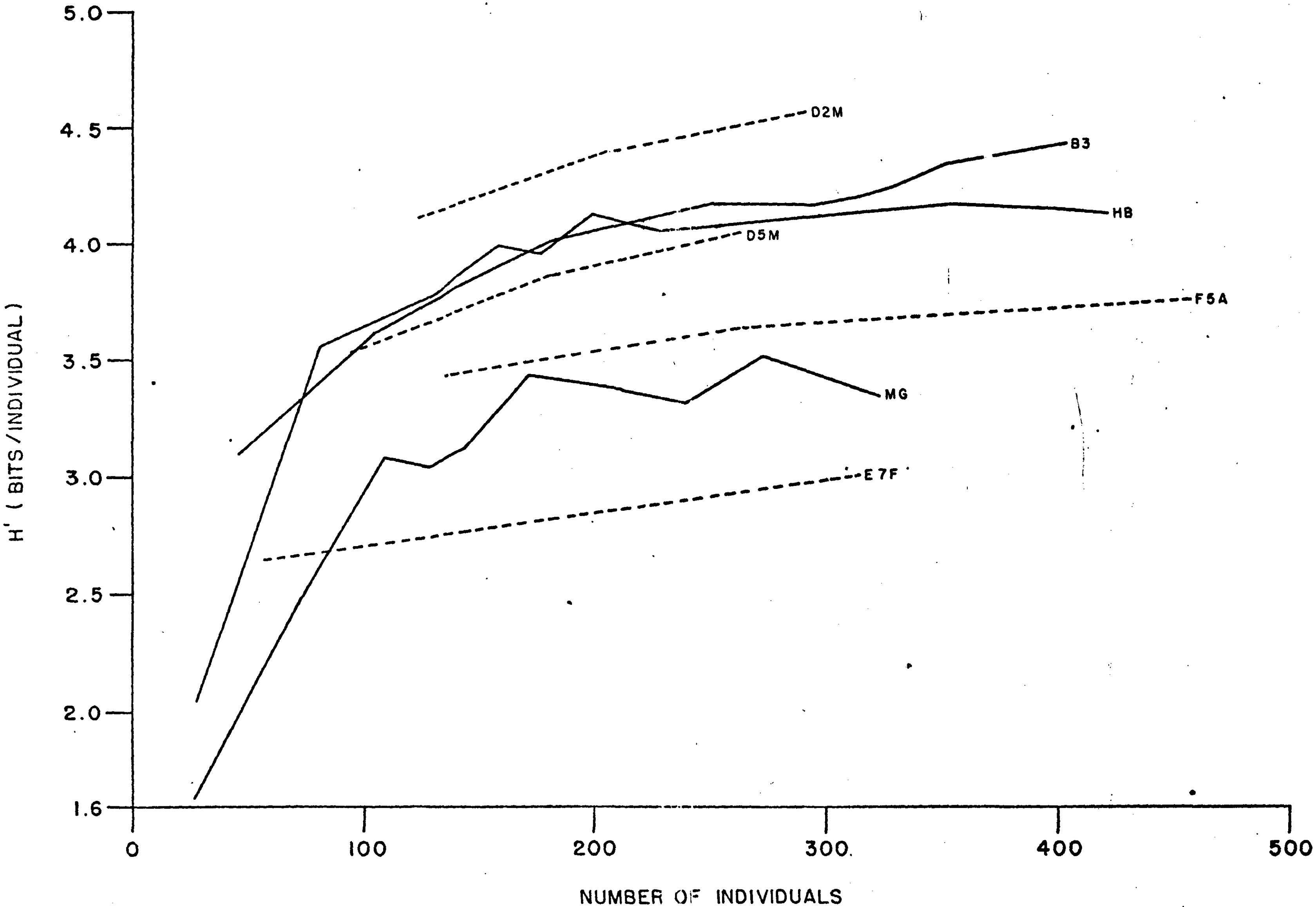


Figure 8. The effect of sample size on H'. Solid lines relate H' in 10 consecutively pooled replicates for three Hampton Roads stations sampled by Wass and Feeley. Broken lines represent H' in three consecutively pooled replicates for four stations sampled during this study.

variance criteria which must be assumed to employ these parametric tests are satisfied, that is, that the distribution of H' is normal. On the contrary, the dependence of H' on sample size (for small samples) tends to indicate otherwise and makes the employment of these tests unsound. Therefore, I have avoided the use of parametric statistical tests in analyses performed on these data.

Ranges within station groups of H', ε and spp/180 may be compared and the central tendencies of their distributions may be demonstrated by median plus or minus one quartile ranges (Fig. 9). In this way, the degree of overlap of the total ranges and the ranges of the central most half of the values indicate the strength of the dissimilarities between station groups for the three measures.

Values of the diversity measure H' for sand stations are dissimilar from those for mud stations and strongly dissimilar from those for Elizabeth River stations, which are, in turn, also dissimilar from those for mud stations. On the other hand, no noticeable dissimilarities exist for values of ε between the various station groups. Values of spp/180 show the same pattern as those of H' except that the strength of the dissimilarity between mud and Elizabeth River stations is greater for spp/180.

The indication is, then, that the species richness component was primarily responsible for differences in the H' diversity of

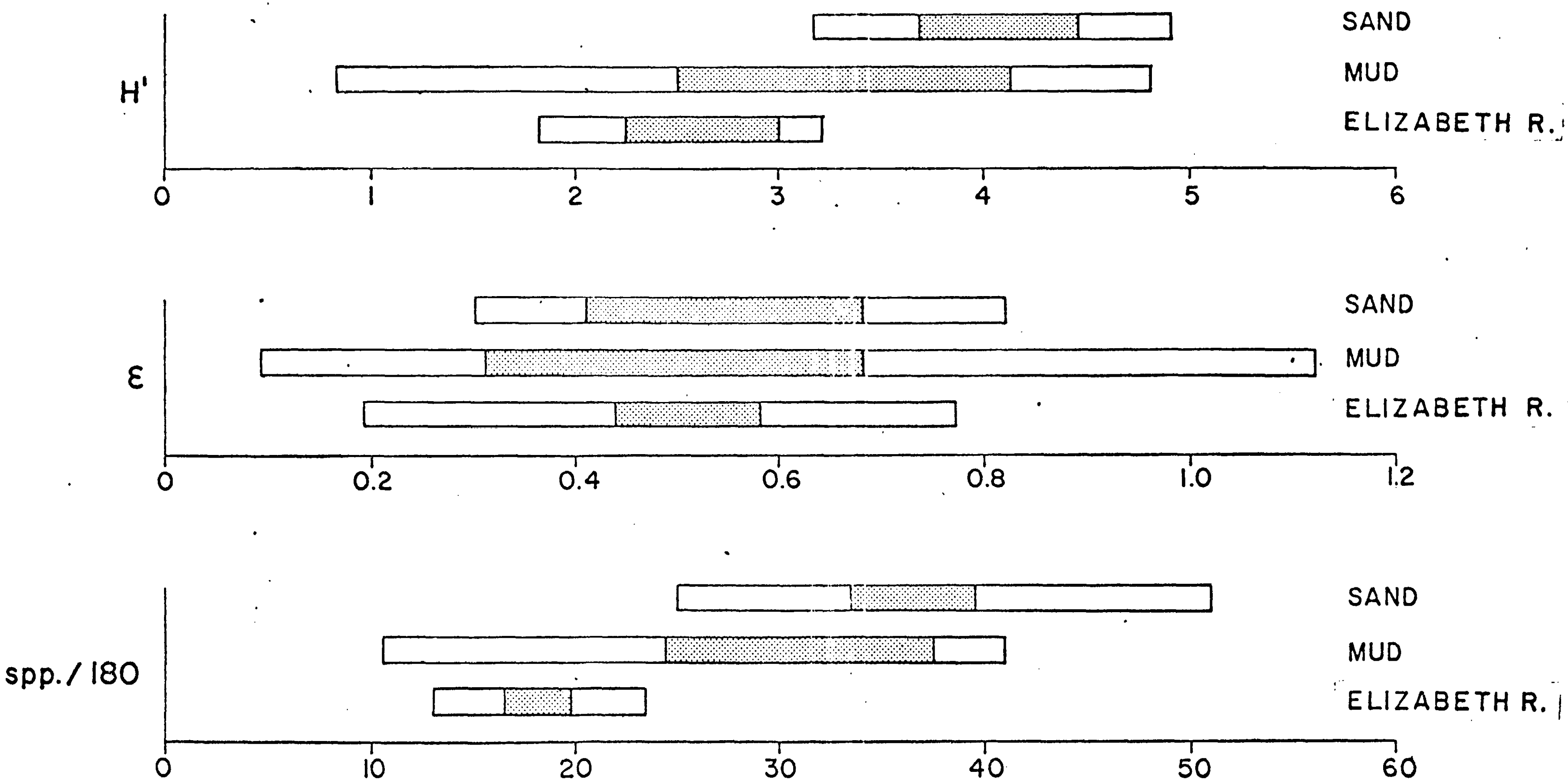


Figure 9. Total ranges (bars) and ranges of central half of values (shaded portions) of H', ε, and spp/180 for the three station groups.

the three habitats. The equitability component was of little or no significance in this respect. This is in general agreement with the findings of Tramer (1969) that, for 267 breeding bird censuses, differences in diversity were closely correlated with species richness while the relative abundance or equitability component remained stable. This is in disagreement with the findings of Sager and Hasler (1969) who, for phytoplankton communities in Wisconsin lakes, attributed variability of H' to the equitability component as expressed in the 10 to 15 most abundant species. To explain these differences, Tramer explained that plankton are "opportunistic," i.e., species can reproduce quickly and become extremely abundant under favorable conditions, whereas birds are mostly "equilibrium" species whose physical environment and resources are relatively stable and who are predominantly biotically controlled. Certainly estuarine benthic invertebrates cannot be considered "equilibrium" species in the same sense as birds, but because their generation times are much longer than those of phytoplankters and the spatial integrity of benthic populations is to some degree maintained by biotic controls (Thorson, 1966), they are certainly much less "opportunistic" than lacustrine phytoplankton.

As shown by Sanders (1968), within a given area the sand bottom fauna is generally more diverse than the mud bottom fauna. Data presented here indicate that this difference is basically attributable to the species richness component. Sanders suggested that the fauna of stable sand bottoms is inherently more diverse because of the "greater variety of microhabitats." Thus, the explanation for this difference may be generally included in that class of arguments termed the "theory of spatial heterogeneity," according to Pianka's (1966) classification. The differences in diversity between mud and Elizabeth River stations cannot be explained by differences in spatial heterogeneity, however. The environmental factors characteristically different in the Elizabeth River are those related to pollution stress. It is my contention that pollution stress, as evidenced by various physical, chemical and additional biological parameters, affected community structure and lowered species diversity.

H' and its components were also compared by sampling period within station groups. Values for the three measures were ranked by season (= sampling period) and the ranks within station groups tested for concordance using Kendall's coefficient (Siegel, 1956, p. 229). The predominant rankings, coefficient values, and their associated probabilities are presented in Table 9. An insufficient number of rankings disallowed application of the test to the Elizabeth River station group.

For sand stations, the spring values generally ranked highest in all measures, and the winter values ranked higher than spring values for H' and ε but were lower than these values for spp/180.

TABLE 9. Seasonal patterns in diversity components as tested by Kendall coefficient of concordance *W*.

			W	p
SAND STATIONS	H'	SPRING $\gg$ WINTER $>$ SUMMER	0.578	<0.01
	ε	SPRING $\gg$ WINTER $>$ SUMMER	0.672	<0.01
	spp/180 indiv.	SPRING $>$ SUMMER $>$ WINTER	0.609	<0.01
MUD STATIONS	H'	SUMMER $>$ SPRING $>$ WINTER	0.480	>0.05
	ε	SUMMER $\gg$ WINTER $>$ SPRING	0.360	>0.05
	spp/180 indiv.	SUMMER $\gg$ SPRING $\gg$ WINTER	0.840	<0.01
Elizabeth River Stations	H'	WINTER $>$ SUMMER $>$ SPRING		
	ε	SUMMER $>$ WINTER $>$ SPRING		
	spp/180 indiv.	WINTER $>$ SUMMER $>$ SPRING		

All ranks were significantly concordant at the 0.01 level. Seasonally then, H' was obviously affected by changes in both components, equitability and species richness, and although the influence of ε seemed slightly stronger, neither component was predominantly influential. Ranks for ε and spp/180 were in relative agreement and in both spring values ranked highest. What took place, then, was the recruitment of many new species in spring, followed by a gradual reduction in the number of species, coupled with increased dominance of a few species (e.g., Spiophanes) during the summer. Marsh (1970) found that spring brought low equitabilities together with high numbers of species of eelgrass epifauna in the York River. The net effect was rather seasonally stable H' values as the change in the two components, in effect, "canceled" each other. Dahlberg and Odum (1970) found significant seasonal fluctuations of the equitability component in Georgia estuarine fish populations due to the influx of juveniles into the estuary in the fall which caused low ε values.

For mud stations only the ranks for spp/180 proved significantly concordant, and then very strongly so. Although the richness component had a marked effect on H', the seasonal trends of H' were not concordant among the stations. Even though the test was not applied for the Elizabeth River stations, subjective appraisal showed that seasonal trends for all three measures were very weak.

In general though, spring values ranked lowest for all three measures. Although clear seasonal patterns existed for all measures at the sand stations and for spp/180 at the mud stations, no patterns were common to more than one habitat type.

d. Relationships of the Diversity Components

As an additional attempt at discerning the relationships of the components of species diversity, Spearman's rank correlation test (Siegel, 1956, p. 202) was applied to all combinations of pairs of values of the number of species (S), the number of individuals (N), H', ε and spp/180. Correlation coefficients and their associated probability values (one-tailed) for all possible combinations are listed in Table 10 in order of their coefficient value.

As would be expected, S was very highly correlated with spp/180; that is, the number of species in a sample with the species richness component as measured by the rarefaction index. Very high correlations existed between H' and both spp/180 and S, demonstrating the general dependence of H' on the richness component and the specific importance of the richness component in this study. The correlation between H' and ε was almost as high, however, and the influence of the equitability component on H' was also evident in this study. The significant correlation between N and S and N and spp/180 is perhaps somehow related to

TABLE 10. Spearman's rank correlation of components of species diversity.

	r_s	p	
S - spp/180 indiv.	0.856	< 0.001	
H' - spp/180 indiv.	0.850	< 0.001	
S - H'	0.714	< 0.001	
H' - ε	0.647	< 0.001	
N - S	0.609	< 0.001	
N - spp/180 indiv.	0.421	< 0.005	
ε - spp/180 indiv.	0.363	< 0.01	significant
N - H'	0.161	< 0.20	not significant at 0.01 level
S - ε	0.036	< 0.40	
N - ε	-0.322	< 0.05	

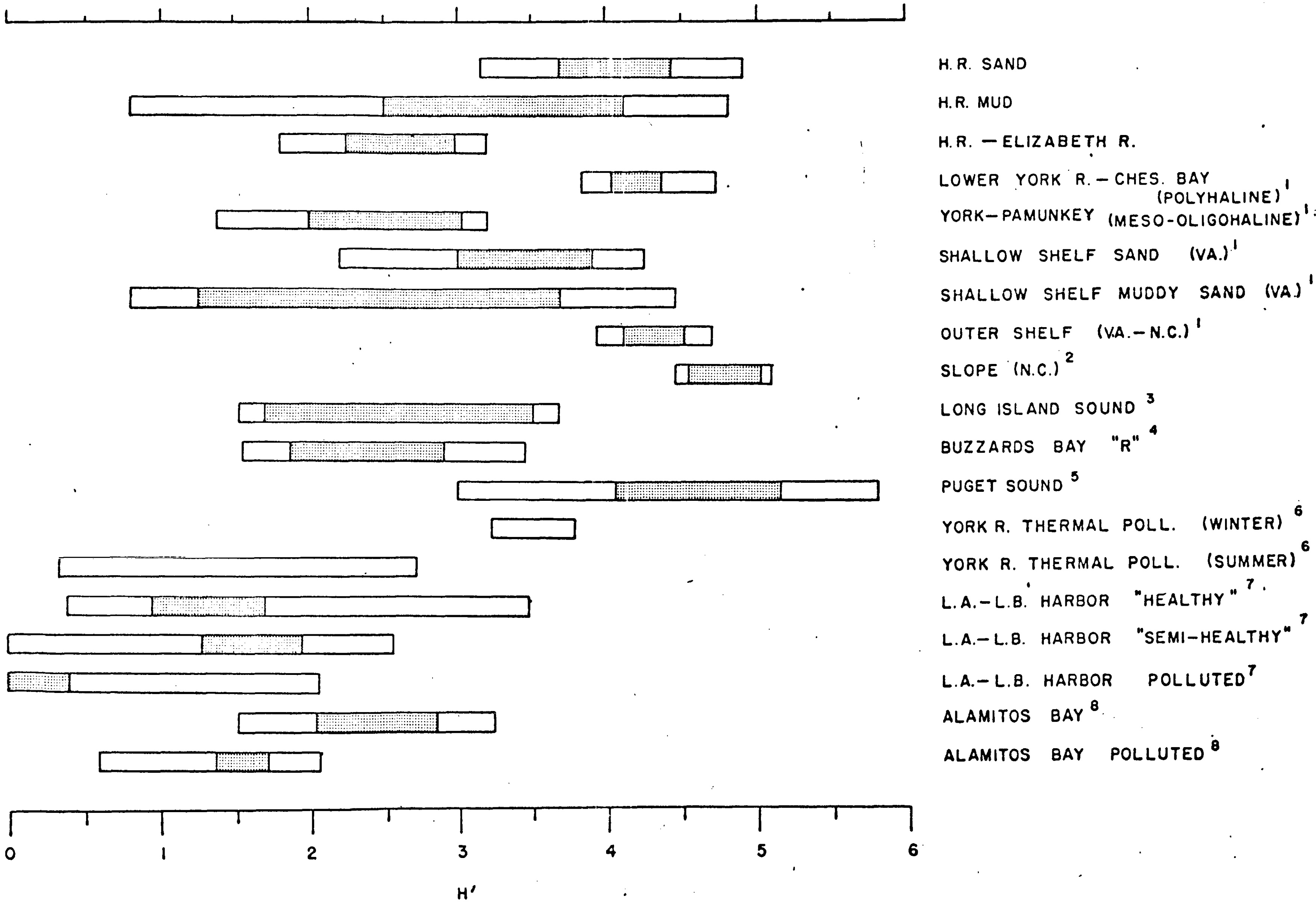
the commonly observed phenomenon of an increase in the number of species taken by successively larger sample sizes, if one considers number of individuals as a measure of sample size.

A significant correlation between ε and spp/180 existed because overwhelming dominance by one or a few species affects both measures. The effect of this on the relative abundance component is obvious, and, because overwhelming dominance is often accompanied by rather large total population levels, the number of species predicted in this rather small proportion (i.e., 180 individuals) of a large N sample is also reduced. The lack of significant correlation between N and both H' and ε is an indication that these measures are independent of sample size, at least at the sample sizes considered here. The lack of correlation between S and ε indicates independence of the species richness and equitability components, even though there existed significant correlation between ε and spp/180. As suggested above, this latter correlation is probably related to the nature of the particular richness index, spp/180.

e. Species Diversity Comparisons

H' values measured in this study are compared to those for macrobenthos of other locations in Figure 10. H' at mud and sandy-mud bottoms in the lower York River and adjacent Chesapeake Bay was similar to that found at Hampton Roads sand stations and slightly greater than that found at Hampton Roads mud stations.

Figure 10. Total ranges and ranges of the central half of values of H' for macrobenthos of Hampton Roads station groups, various habitats in the Virginia area, and other locations reported in the literature. [1) Boesch, unpublished data; 2) Grassle, 1967 (values are of H, not H' and consequently slightly lower than equivalent H' values); 3) Sanders, 1958 (calculated by author); 4) Sanders, 1960 (calculated by Grassle, 1967, values are of H); 5) Lie, 1968 (total fauna samples only); 6) Warinner and Brehmer, 1966; 7) Reish 1959a (calculated by author); 8) Reish and Winter, 1954 (calculated by author)]


H.R. SAND
H.R. MUD
H.R. — ELIZABETH R.
LOWER YORK R. — CHES. BAY (POLYHALINE) 1
YORK—PAMUNKEY (MESO-OLIGOHALINE) 1
SHALLOW SHELF SAND (VA.) 1
SHALLOW SHELF MUDDY SAND (VA.) 1
OUTER SHELF (VA.—N.C.) 1
SLOPE (N.C.) 2
LONG ISLAND SOUND 3
BUZZARDS BAY "R" 4
PUGET SOUND 5
YORK R. THERMAL POLL. (WINTER) 6
YORK R. THERMAL POLL. (SUMMER) 6
L.A.—L.B. HARBOR "HEALTHY" 7
L.A.—L.B. HARBOR "SEMI-HEALTHY" 7
L.A.—L.B. HARBOR POLLUTED 7
ALAMITOS BAY 8
ALAMITOS BAY POLLUTED 8
0
1
2
3
4
5
6
H'

The salinity regime in this area is like that of Hampton Roads and may be classified as polyhaline (Carriker, 1967). Farther up the York River estuary and into the Pamunkey River, in the long mesohaline and oligohaline zones, H' values were considerably lower, mostly below 3.0, and were similar to those found for the Elizabeth River stations in this study.

Diversities of macrobenthos on the shallow continental shelf off Virginia's Eastern Shore were lower than those in Hampton Roads sand and similar to those in mud. Some very low diversities were recorded from muddy sand depressions on the shelf, which were related to low equitability caused by the presence of tremendous concentrations (up to 12,000 indiv./m^2) of the polychaete Pherusa affinis--a phenomenon not unlike that of the Mulinia population "explosion" observed in Hampton Roads. H' was generally higher on the outer continental shelf and slope off Virginia and North Carolina than in Hampton Roads. All the values recorded by Grassle (1967) for the continental shelf and slope off Cape Lookout surpassed all but a few of the Hampton Roads values.

The general increase in H' with depth agrees with the direct relationship between environmental stability, which increases with depth in the ocean, and species diversity, which has been well documented by Sanders (1968) and Grassle (1967). That the shallow shelf fauna was less diverse than the fauna of Hampton Roads sand bottoms may be explained by the fact that the bottom in this shelf area is unstable, the fauna being dominated by haustoriid amphipods and other animals indicative of shifting sand, and thus rather rigorous conditions. A very cogent discussion of the relationship of environmental stability and benthic species diversity can be found in Grassle (1967).

H' diversity values computed for benthic collections reported in Sanders' (1958, 1960) studies in Long Island Sound and Buzzards Bay are considerably lower than most of those recorded from Hampton Roads. Most of the Hampton Roads fauna is also found in New England and the physical environment of Hampton Roads is actually less stable. The temperature and salinity ranges experienced are certainly greater than in either of the areas studied by Sanders. Possible causes of the diversity disparity include sampling techniques, i.e., Sanders used a 0.2 mm mesh screen in the Buzzards Bay study, and differences in the nature of the sediments.

H' values reported by Lie (1968) for Puget Sound benthos are considerably higher than those observed in this study, and some exceed Grassle's Atlantic continental slope values. This agrees well with Sanders' (1969) observations that benthic species diversity is greater in "maritime climate boreal communities", such as found on west coasts of continents in the Northern Hemisphere, than in "continental climate boreal communities", such as found on east coasts. He attributes this to the greater environmental stability in the former.

Some examples of benthic species diversity in polluted marine systems are also given in Figure 10. Warinner and Brehmer (1966) investigated the macrobenthos of a shallow sandy area in the York River, Virginia, which was adjacent to an outfall from a steam-electric power plant. H' was roughly equivalent to that found at Hampton Roads mud stations in the winter, but in summer, when heated water became a limiting factor, H' values were generally lower than those observed in the Elizabeth River.

Reish (1959) studied the macrobenthos of Los Angeles and Long Beach, California, harbors, which were being polluted by numerous domestic and industrial sources. He categorized the harbor bottom into five zones, reflecting degree of pollution, on the basis of indicator organisms. "Healthy" bottoms were characterized by Tharyx parvus, Cossura candida, and Nereis procera; "semi-healthy I" stations by Polydora paucibranchiata and Dorvillea articulata; "semi-healthy II" bottoms by Cirriformia luxuriosa; "polluted" bottoms by Capitella capitata; and "very polluted" bottoms by the absence of macrofauna. The H' values calculated for Reish's data for the "healthy" and "semi-healthy I and II' zones range much lower (Fig. 10) than would be expected for macrobenthos not affected by pollution. Thus, probably because he was confronted with such gross pollution in some areas, Reish seemingly underestimated the more subtle effects of pollution in the less grossly polluted zones.

Similarly, Reish and Winter (1954), in studying Alamitos Bay, California, concluded that the benthos was basically unaffected by pollution. Other authors (Wass, 1967; Wilhm and Dorris, 1968) have re-examined Reish and Winter's data and have demonstrated alteration presumably by pollution stress. I have separated those stations in Alamitos Bay near sources of pollution (oil fields and sewer outfalls) and calculated H' for these "polluted" stations and for those not adjacent to such sources (Fig. 10). H' is strongly dissimilar between these stations.

Pearson et al. (1967) have also found H' of macrobenthos a good indicator of severity of estuarine pollution. Working in San Francisco Bay, they observed H' values of 4.5 to 1.7 (mean 3.3) in the vicinity of Golden Gate. This dropped to a mean of 1.6 ten miles south in the vicinity of San Francisco but increased south of there only to decrease again to values below 1.0 40 miles south of the mouth of the bay where pollution was severe.

Values of the equitability index (ε) are more difficult to compare because its meaning is perhaps more obscure and because of the paucity of authors who have used this particular measure. Fine (1970) observed a mean equitability of 0.64 for the non-colonial macrofauna of <u>Sargassum</u>. Marsh's (1970) mean ε for epifauna on <u>Zostera</u> was 0.40. Deevey (1969) reported equitability values for Foraminifera in deep sea cores, the means of which were roughly

0.6 and 0.8 for pelagic and benthic species, respectively. The Hampton Roads median ε values were 0.49 for sand, 0.55 for mud, and 0.52 for Elizabeth River stations. In the case of Sargassum fauna and forams, the numbers of species (richness component) were small compared to the numbers in Hampton Roads benthos or Zostera epifauna. The two former groups also inhabit environments more stable than the two latter ones. Perhaps one or both of these facts may account for their more equitable distribution of individuals among species.

The species richness component as measured by the rarefaction method (spp/180) is likewise difficult to compare. Sanders (1968, 1969), the author of this method, used only the polychaete-bivalve fraction of the fauna in his analyses. Grassle (1967) did use the method for total benthic macrofauna and computed spp/180 for his North Carolina shelf and slope samples. Grassle's mean values of 50.2 for shelf samples and 61.0 for slope samples are well above the Hampton Roads medians of 35.7, 33.0, and 18.5 for sand, mud and Elizabeth River stations, respectively. However, ample comparative data are available if numbers of species per sample are considered as a measure of species richness. The mean number of species for Hampton Roads sand stations (48.8) is considerably higher than that for Haven et al.'s (1967) two York River sand stations (38.4). Likewise, the mean number for Hampton Roads mud stations (33.2) is higher than that for Sanders' (1960) Buzzards Bay station R (27.7) and Haven's two mud stations (18.0). The means for all habitats in Hampton Roads are, however, quite lower than those reported by Grassle for the shelf (81.2) and slope (78.2). Of course, the number of species per sample depends on the size of the sample and sieve size, and these studies have varied with regard to these criteria.

To summarize then, the benthic communities of Hampton Roads were characterized by what might be termed "higher than expected" H' diversity, considering the amount of environmental variability. The distribution of individuals among species was only moderately equitable and the richness component was primarily responsible for this high diversity. H' was noticeably affected by pollution stress at the Elizabeth River stations, yet the effect was much less than that observed in more severely polluted areas elsewhere.

f. Effects of Pollution

That environmental stress accompanying pollution can alter the composition of benthic communities has long been known (Kolkwitz and Marsson, 1909) and has proved useful in assessing the biological effects of pollution. The theory underlying this phenomenon is that pollution stress excludes or deters some species while allowing other more tolerant species to flourish because of relaxed biotic pressures, such as competition and predation. Historically, presence and abundance of those species known to be favored by pollution stress have been used as biological indication of pollution. Thus, the use of "indicator species," such as tubificid oligochaetes and tendipedid insect larvae in freshwaters and certain polychaetes, such as Capitella capitata, in marine waters, has become common.

In the Elizabeth River, pollution stress has disfavored some species, notably Retusa canaliculata, and, through relaxed competition or predation, has favored others. Notably favored are Mya arenaria and Nereis succinea, which are extremely uncommon, in the case of Mya, and common but not abundant, in the case of Nereis, elsewhere in the Hampton Roads area. The blue crab, Callinectes sapidus, is a main predator of young Mya in the Chesapeake Bay area and usually succeeds in decimating populations of the clams before they reach a very large size (Jon Lucy, personal communication). Perhaps pollution stress hinders the effectiveness of this or other predators and allows substantial populations of Mya to develop.

Reliance solely on indicator species has some drawbacks, however. It is important to remember that these species also occur in natural, unperturbed situations and, at times, because of their tolerance and usually great reproductive potential, may be found in great numbers in such systems. Therefore, the presence or even the abundance of these "indicator species" does not necessarily indicate pollution. In addition, where in freshwater it might be sufficient to observe that tubificids and tendipedids are abundant and therefore pollution is indicated, it is not sufficient to assume that the abundance of say, capitellids, likewise indicates marine pollution. That is, the taxa used as marine indicators must be identified at the specific or at least generic level; thus the taxonomic problems are more difficult in marine and estuarine situations.

Gaufin and Tarzwell (1956) recognized indicator communities of macroinvertebrates in addition to the traditional indicator species. Since that time the trend among pollution ecologists has been toward using the community and its structure as the principal biological indicator (Patrick and Strawbridge, 1963; Wilhm and Dorris, 1968).

Community structure, as reflected by diversity indices, has been shown to be altered due to pollution stress in the Elizabeth River. However, the degree of alteration is certainly not as extreme as that observed elsewhere, e.g., in certain California bays and harbors. Species diversity as measured by H' has, however, proved to be a sensitive and useful index of the effects of pollution on the macrobenthos.

I must caution against the adoption of H' or any similar index as a water quality "standard" or "criterion" as suggested by Wilhm and Dorris (1968). Any numerical value of this type does not have meaning in and of itself but is only useful when subjected to ecological interpretation. Establishing a numerical criterion does not take into account discrepancies in sampling procedures and disregards natural variations in species diversities. Unperturbed communities undergoing internal instability, such as the population "explosions" of <u>Mulinia</u> and <u>Pherusa</u> mentioned earlier, and those in naturally rigorous environments which exhibit low diversity must be taken into consideration. There remains no substitute for final subjective appraisal of objectively derived information.

5. SUMMARY

1. The macrobenthos of the Hampton Roads area was surveyed in an attempt to analyze the structure of this important component of a multi-use estuarine ecosystem. Sixteen stations were established in Hampton Roads, the lower James River, and the Elizabeth River, and three replicate grab samples were taken at each station in February, May and August 1969. Sediment samples were collected at each station and analyzed for particle size distribution.

2. One hundred seventy-five macrofaunal taxa were recognized in the samples, 164 of which were identified to the species level, including 54 polychaete, 23 gastropod, 22 amphipod, and 18 bivalve species.

3. On the basis of dominant species, the stations were divided into three station groups which corresponded to differences

in sediment type and degree of pollution. "Sand stations" were characterized by the presence of Spiophanes bombyx, Ampelisca verrilli and Glycera dibranchiata and a few less abundant "sand-specific" species. "Elizabeth River stations" were characterized by the presence of Mya arenaria and the great abundance of certain ubiquitous species such as Nereis succinea and Streblospio benedicti. "Mud stations" were characterized by the absence of both Spiophanes and Mya and the abundance of the ubiquitous species Paraprionospio pinnata and Spiochaetopterus oculatus.

4. A rank analysis yielded biological index values for each species within each station group. The three top-ranked dominants were, for sand stations, Retusa canaliculata, Heteromastus filiformis and Spiophanes; for mud stations, Paraprionospio, Spiochaetopterus and Phoronis architecta; and for Elizabeth River stations, Mya, Nereis and Heteromastus. Seasonal periodicity of dominant species was noticeable among sand stations, where Spiophanes increased in abundance from low population levels in February and May to very high levels in August, and among Elizabeth River stations, where large February and May Mya populations were entirely eliminated by August. There was very little change in relative population levels among mud station dominants.

5. The Hampton Roads fauna is widely distributed elsewhere in the Chesapeake Bay system and along the U. S. Atlantic coast. The dominants in the Hampton Roads area are for the most part not

among the dominant species known from these other areas. For example, Nephtys incisa, which is a community dominant in much of the Chesapeake Bay system was rather rare in Hampton Roads.

6. The structure of the communities was investigated by measuring species diversity by Shannon's formula (H') and its components, species richness and equitability. H' was much greater among the sand stations than among the mud stations and greater among the mud stations than among Elizabeth River stations. The differences in species diversity among the three station groups was primarily attributable to differences in the species richness component, as differences in the equitability component were slight. However, both richness and equitability components can account for seasonal differences in H' within station groups.

7. As an index of species diversity, H' was shown to be independent of sample size and sensitive to both species richness and equitability components.

8. H' values were compared with those for macrobenthos from other locations in the Virginia area and from other locations as reported in the literature. The values for Hampton Roads, especially those for the sand stations, were quite high, exceeded only by those from the outer continental shelf and slope and Pacific coastal waters. H' values for mildly polluted areas in the Elizabeth River were generally lower than those for unperturbed systems but higher than those for other perhaps more grossly polluted systems.

9. The continued use of benthic organisms as biological indicators of pollution was recommended, but the acceptance of certain "indicator species" or of community structure indices as water quality "criteria" without subjective ecological interpretation was cautioned against.

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APPENDIX I

Species Collected in the Hampton Roads Area, February 1969-August 1969, and Stations at Which They Were Found

CNIDARIA	
Ceriantheopsis americanus (Verrill)	B2;D1,3,4,5;F1,2,3,4,5
Diadumene leucolena (Verrill)	A2;B4;D1,3;E6,8;F3,4
Edwardsia elegans Verrill	A2;B2,4;D1,2,3,4;F1,2,3,4,5
TURBELLARIA	
Stylochus ellipticus (Girard)	F1,3
Turbellaria (unid)	D3
PHORONIDA	
Phoronis architecta Andrews	A2;B2,4;D1,2,3,4,5;E6,7;F1,2,4,5
RHYNCHOCOELA	
Amphiporus bioculatus (McIntosh)	D1,2,3;F3
Carinomella lactea Coe	B2;D3,4;E6;F1,2,3
Cerebratulus lacteus (Leidy)	B2;D2,3,4,5;E6,7,8;F1,2,3
Cerebratulus luridus Verrill	F3,5
Micrura leidyi (Verrill)	D1,2,3;F2,3
Tubulanus pellucidus (Coe)	D2,3,4;E8;F3,5
Nemerteans (unid)	all stations
POLYCHAETA	
Aglaophamus verrilli (McIntosh)	F1,2
Ancistrosyllis hartmannae Pettibone	D2
Arabella irricolor (Montagu)	F3
Aricidea jeffreysi (McIntosh)	D2,3
Asabellides oculata (Webster)	A2;B2;D3,4,5;F2,3,4
Capitella capitata (Fabricius)	E6
Clymenella torquata (Leidy)	A2;B2;D1,2,3,4,5;F1,2,3,4
Clymenella zonalis (Verrill)	D1;F1,2,3,5
Diopatra cuprea (Bosc)	A2;B2,4;D1,4,5;F3,5
Drilonereis filum (Claparede)	D2,3,5;F1,2,3
Eteone heteropoda Hartman	A2;B4;D1,2,3,4;E6,7,8;F3,4,5
Eteone lactea Claparede	F1,2
Eumida sanguinea (Oersted)	D2,3;F3,5
Glycera americana Leidy	A2;B2,4;D2,4,5;E6,7,8;F1,2,3,4,5
Glycera dibranchiata Ehlers	D1,2,3;F1,2,3,4,5
Glycinde solitaria (Webster)	A2;B2,4;D1,2,3,4,5;E6;F1,2,3,4,5

Gyptis vittata (Webster & Benedict)	E8
Harmothoe extenuata (Grube)	D1,2,3,4,5;F3,4,5
Heteromastus filiformis (Claparede)	all stations
Hydroides hexagona (Bosc)	A2;E8;F3,5
Lepidonotus sublevis Verrill	A2;D1,2,3;E6,8;F2,3,4,5
Loimia medusa (Savigny)	D2,3,4,5;F1,2,3,4,5
Lumbrineris tenuis (Verrill)	D4;F3,4,5
Marphysa sanguinea (Montagu)	F3
Melinna maculata Webster	D4;F1,2
Nephtys incisa (Malmgren)	D4,5;F3
Nephtys magellanica (Augener)	A2;B2;D1,2,3,4,5;E6,7; F1,2,3,4,5
Nephtys picta (Ehlers)	F4
Nereis succinea (Frey & Leuckart)	A2;B2,4;D1,2,3,4,5;E6,7,8; F2,3,4,5
Notocirrus spiniferus (Moore)	D2;F3
Notomastus latericius Sars	F3
Odontosyllis fulgurans Claparede	D1,4
Paleanotus heteroseta Hartman	A2;B2;D1,2,3,4,5;F3,5
Paranaitis speciosa (Webster)	A2;D1,2,3;F2,3
Paraprionospio pinnata (Ehlers)	all stations
Pectinaria gouldii (Verrill)	A2;B2,4;D1,2,3,4,5;E6,7; F1,2,3,4,5
Phyllodoce arenae Webster	A2;B2;D1,2,3,4,5;E6;F1,2,3,4,5
Phyllodoce mucosa Oersted	D2;F4
Podarke obscura Verrill	D2,3,4;E8;F3,4,5
Polycirrus eximius (Leidy)	D1,2,3;F3,4,5
Polydora ligni Webster	A2;B2;D1,2,3,4,5;E6,7,8; F1,2,3,4,5
Polydora sp.	D5;F4
Prionospio cirrifera Viren	D5
Prionospio heterobranchiata Moore	D1,2
Prionospio sp.	F3
Pseudeurythoe paucibranchiata Fauvel	A2;B2,4;D1,2,3,4,5;E6,7; F1,2,3,4,5
Sabella microphthalma Verrill	A2;D1,2,3,4,5;E6,7,8;F2,3,4,5
Sabellaria vulgaris Verrill	A2;D1,2,3,4;F3,4,5
Scolelepsis bousfieldi Pettibone	D3;F1
Scoloplos fragilis Verrill	A2;B4;E6,7,8;F1
Scoloplos robustus Verrill	D1,2,3;F1,3,4,5
Spio setosa (Verrill)	D2,3;F1,2,3,4,5
Spiochaetopterus oculatus Webster	all stations
Spiophanes bombyx Claparede	D1,2,3,4;F1,2,3,4,5
Streblospio benedicti Webster	all stations
Tharyx setigera Hartman	B2;D1,2,4;E6,7;F1,2,3,4,5
Polychaetes (unid)	D1,3,5;F3

OLIGOCHAETA

Oligochaetes (unid)	A2;B2;D2,3,4;E6;F1,2,3,4,5

BIVALVIA	
Amygdalum papyria (Conrad)	D3,4;F2,3,5
Anadara ovalis (Bruguiere)	A2;D3,4;F2
Anadara transversa (Say)	A2;B4;D1,2,3,4,5;F1,2,3,4,5
Anomia simplex Orbigny	F3
Barnea truncata (Say)	D5
Ensis directus Conrad	A2;B2,4;D1,2,3,4,5;E6,8; F1,2,3,4,5
Gemma gemma (Totten)	F4
Lucina multilineata Tuomey & Holmes	D1,2,3;F1,4,5
Lyonsia hyalina Conrad	A2;B4;D1,2,3,4,5;F1,2,3,4,5
Macoma balthica (Linnaeus)	E6
Macoma tenta Say	A2;B2,4;D1,2,3,4,5;F1,2,3,5
Mercenaria mercenaria (Linnaeus)	A2;D3,5;E6;F2,3,4
Mulinia lateralis (Say)	all stations
Mya arenaria (Linnaeus)	A2;D5;E6,7,8
Mysella bidentata (Montagu)	B2;D3
Nucula proxima Say	A2;D1,2,3,4;F1,2,3,4,5
Tellina agilis Stimpson	D1,2;F1,2,3,4,5
Yoldia limulata (Say)	D4;F2
GASTROPODA	
Acteon punctostriatus Adams	D1
Anachis translirata Ravenel	D2,3,4;F3
Cerithiopsis greeni Adams	D2,3;F3,4
Crepidula convexa Say	D2;E6;F2,3,4,5
Crepidula fornicata (Linnaeus)	F3
Doridella obscura Verrill	F1
Doris verrucosa Linnaeus	D3;F3
Epitonium rupicolum (Kurtz)	A2;D1,2,3,4,5;F1,2,3,4,5
Eupleura caudata (Say)	A2;D1,2,3,4,5;F1,2,3,4
Haminoea solitaria (Say)	D1;F1,4,5
Mangelia cerina Kurtz & Stimpson	D3
Mangelia plicosa Adams	A2;D1,2,3,4,5;F1,3,4,5
Marginella denticulata Conrad	D3
Melanella intermedia Contraine	D1,2;F3
Mitrella lunata (Say)	A2;B2,4;D1,2,3,4,5;F1,2,3,4,5
Nassarius obsoletus (Say)	E7
Nassarius vibex (Say)	A2;B2,4;D1,2,3,4,5;E6,7; F1,2,3,4,5
Odostomia impressa Say	B2;D1;F2,3,4,5
Pyramidella fusca Adams	D1,2,5;F1,2,3,4,5
Pyramidella sp.	D1
Retusa canaliculata (Say)	A2;B2,4;D1,2,3,4,5;E6,7; F1,2,3,4,5
Turbonilla interrupta Trotten	A2;B2;D1,2,3,4,5;F1,2,3,5
Turbonilla stricta Verrill	D3
Urosalpinx cinerea (Say)	A2;F1,2
Nudibranchs (unid)	D5;F3,4

PYCNOGONIDA	
Anoplodactylus parvus Giltay	F1
Callipallene brevirostris (Johnston)	F5
Tanystylum obiculare Wilson	D3
OSTRACODA	
Sarsiella zostericola Cushman	D5;F1,2,3,4
CIRRIPEDIA	
Balanus improvisus Darwin	B2;E7
MYSIDACEA	
Heteromysis formosa (Smith)	F3
Neomysis americana (Smith)	A2;B2;D1,2,3,4,5;E6;F1,2,4,5
CUMACEA	
Cyclaspis sp.	F4
Leucon americanus Zimmer	B2,4;D4;E8
Oxyurostylis smithi Calman	A2;D1,2,3,4,5;F1,2,3,4,5
ISOPODA	
Cyathura burbancki Frankenberg	D2,3
Cyathura polita (Stimpson)	E8
Edotea triloba (Say)	A2;B2,4;D3,4,5;E6,7,8; F1,2,3,4,5
Erichsonella filiformis (Say)	F4,5
AMPHIPODA	
Acanthohaustorius intermedius Bousfield	F4
Ampelisca abdita Mills	A2;B2,4;D5
Ampelisca vadorum Mills	A2;D1,2,3,4,5;E6;F1,2,3,4,5
Ampelisca verrilli Mills	D1,2,3;F1,2,4,5
Batea catharinensis Muller	A2;D1,2,3;F2,3,4,5
Bathyporiea sp.	F3
Caprella equilibra Say	D4;F2,3,5
Caprella geometrica Say	B2;D1;E8;F3,4,5
Cerapus tubularis Say	A2;D1,4,5;F1,2,4,5
Corophium acherusicum Costa	all stations
Corophium tuberculatum Shoemaker	D3;F3,4
Elasmopus laevis (Smith)	A2;B2;D1,2,3,4,5;E8;F3,4
Erichthonius brasiliensis Dana	A2;B2;D1,2,3,4,5;F2,3,4
Gammarus mucronatus Say	A2;B2,4;D1,2,3,4,5;E6,8; F3,4,5
Jassa falcata (Montagu)	D3;F2
Listriella clymenellae Mills	A2;D1,2,3;F1,2
Melita appendiculata (Say)	E8
Monoculodes edwardsi Holmes	B2,4;D2;F5
Paracaprella tenuis Mayer	A2;D1,2,3,4,5;F1,2,3,4,5
Paraphoxus epistomus Shoemaker	D2;F1,3,4,5

Stenothoe minuta (Holmes)	D3;F4
Sympleustes glaber (Boeck)	A2;D5
Unciola irrorata Say	A2;B2;D1,2,3,4,5;E6,7;F1,2,3,4,5
Amphipods (unid)	
DECAPODA	
Alpheus heterochaelis Say	E8
Callinectes sapidus Rathbun	D1;E7;F5
Crangon septemspinosa (Say)	B2;D4;E6;F2,3
Euceramus praelongus Stimpson	D3;F3,4,5
Eurypanopeus depressus (Smith)	E8
Libinia dubia H. Milne-Edwards	F3
Neopanope texana (Smith)	A2;B2,4;D1,2,3,4,5;E6;F1,2,3,4,5
Ogyrides limicola Williams	A2;B2,4;D4,5;E6;F4
Pagurus longicarpus Say	D1,3;F5
Panopeus herbsti H. Milne-Edwards	F3
Pinnixa sayana Stimpson	B2,4;D5;E6;F1,2
Upogebia affinis (Say)	B2;D3,5F3,4
ECHINODERMATA	
Amphiodia atra Stimpson	A2;D3,4,5;F2,4,5
Cucumaria pulcherrima (Ayres)	D2
Thyone briareus (LaSueur)	A2;D4,5
HEMICHORDATA	
Saccoglossus kowalewskii (A. Agassiz)	B4;D4,5
UROCHORDATA	
Molgula manhattensis (Dekay)	A2;B2;Dc,5;E6,7,8:F2,3,4,5
PISCES	
Gobiesox strumosus Cope	A2
Gobiosoma bosci (Lacepede)	F5
Microgobius thalassinus (Jordan & Gilbert)	A2;F5
Trinectes maculatus (Lacepede)	A2

APPENDIX II

Species Abundance, Frequency and Biological Index Value for Each Station,
Hampton Roads Area, February, May and August 1969

STATION A2

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Unciola irrorata	11	265	5	281	7	12
Spiochaetopterus oculatus	21	20	56	97	8	25
Paraprionospio pinnata	22	51	9	82	9	24
Nereis succinea	10	19	28	57	7	11
Polydora ligni		57		57	3	10
Ampelisca vadorum		4	33	37	6	10
Anadara transversa	6	11	8	25	7	6
Retusa canaliculata	6	10	9	25	8	9
Heteromastus filiformis	7	8	3	18	7	4
Sabellaria vulgaris	2	1	14	17	4	4
Corophium acherusicum		16		16	3	3
Streblospio benedicti		13		13	3	1
Ensis directus		12		12	3	1
Glycera americana	4	5	2	11	7	1
Nassarius vibex	6	2	3	11	7	1
Pseudeurythoe paucibranchiata	1	7	2	10	4	
Neopanope texana	4	4	1	9	4	2
Clymenella torquata	2	6		8	5	1
Pectinaria gouldii	1	6	1	8	5	1
Diadumene leucolena		2	5	7	2	1
Oligochaeta		7		7	3	1
Ampelisca abdita	6			6	3	2
Elasmopus laevis	5		1	6	2	4
Erichthonius brasiliensis		4	2	6	3	
Mitrella lunata	2	2	2	6	3	

STATION A2 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Phoronis architecta			6	6	2	
Epitonium rupicolum		2	3	5	2	
Ogyrides limicola	2		3	5	4	1
Eteone heteropoda		4		4	1	
Eupleura caudata	2	1	1	4	3	
Glycinde solitaria		3	1	4	3	
Hydroides hexagona	2	1	1	4	3	
Lepidonotus sublevis	2	1	1	4	4	
Mulinia lateralis		4		4	3	
Mya arenaria	4			4	2	2
Anadara ovalis	3			3	2	
Cerapus tubularis			3	3	2	1
Edotea triloba	1	1	1	3	3	
Macoma tenta	3			3	2	
Mercenaria mercenaria	1	1	1	3	3	
Palaeonotus heteroseta		3		3	1	
Paracaprella tenuis		3		3	1	
Phyllodoce arenae			3	3	1	1
Sabella microphthalma	2		1	3	3	
Sympleustes glaber		3		3	1	
Thyone briareus	3			3	2	
Neomysis americana	1	1		2	2	
Nephtys magellanica		2		2	1	
Nucula proxima	1	1		2	2	
Nemerteans (unid)		1	1	2	2	
Oxyurostylis smithi		2		2	2	
Urosalpinx cinerea	2			2	1	
Amphiodia atra	1			1	1	
Asabellides oculata	1			1	1	
Batea catharinensis			1	1	1	
Diopatra cuprea			1	1	1	
Edwardsia elegans	1			1	1	
Gobiesox strumosus		1		1	1	
Listriella clymenellae		1		1	1	
Lyonsia hyalina			1	1	1	

STATION A2 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Mangelia plicosa		1		1	1	
Paranaitis speciosa		1		1	1	
Scoloplos fragilis			1	1	1	
Trinectes maculatus		1		1	1	
Turbonilla interrupta		1		1	1	
Total individuals	148	572	214	984		
Total species	34	46	35	65		

STATION B2

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Mulinia lateralis	1393	313		1706	6	30
Paraprionospio pinnata	65	82	56	203	9	36
Spiochaetopterus oculatus	16	67	33	116	9	29
Retusa canaliculata	26	6	19	51	9	17
Balanus improvisus	17	10		27	6	10
Ensis directus		13		13	3	3
Pseudeurythoe paucibranchiata		8	2	10	4	4
Molgula manhattensis	6	3		9	6	
Ogyrides limicola	3	2	4	9	6	
Phoronis architecta		1	8	9	3	5
Streblospio benedicti		9		9	3	3
Ampelisca abdita	3	1	4	8	6	
Nereis succinea	4	1	3	8	6	
Pectinaria gouldii	3	5		8	4	
Nemerteans (unid)	1	3	4	8	6	1
Glycera americana	3	2	2	7	6	1
Cerebratulus lacteus	2	4		6	4	
Glycinde solitaria		3	3	6	4	1
Edotea triloba	2	3		5	3	
Nassarius vibex	2		3	5	4	1
Neomysis americana	2	3		5	4	
Clymenella torquata	1	2	1	4	3	
Heteromastus filiformis		2	2	4	3	
Macoma tenta			4	4	3	2
Corophium acherusicum		2	1	3	3	
Diopatra cuprea	2		1	3	2	
Unciola irrorata		3		3	2	
Edwardsia elegans	1		1	2	2	
Elasmopus laevis			2	2	1	1
Erichthonius brasiliensis			2	2	1	1
Gammarus mucronatus		2		2	1	
Mitrella lunata			2	2	1	2

STATION B2 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Monoculodes edwardsi		2		2	1	
Mysella bidentata			2	2	2	
Palaeonotus heteroseta			2	2	1	1
Pinnixa sayana			2	2	1	1
Tharyx setigera	1		1	2	2	
Turbonilla interrupta	2			2	1	
Oligochaeta		1	1	2	2	
Asabellides oculata		1		1	1	
Caprella geometrica		1		1	1	
Carinomella lactea		1		1	1	
Ceriantheopsis americanus		1		1	1	
Crangon septemspinosa		1		1	1	
Leucon americana		1		1	1	
Neopanope texana		1		1	1	
Odostomia impressa		1		1	1	
Phyllodoce arenae			1	1	1	
Polydora ligni		1		1	1	
Upogebia affinis	1			1	1	
Total individuals	1556	563	166	2285		
Total species	22	37	27	51		

STATION B4

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Paraprionospio pinnata	66	78	31	175	9	38
Mulinia lateralis		170	1	171	4	15
Retusa canaliculata	19	43	51	113	9	34
Spiochaetopterus oculatus	13	2	16	31	8	15
Phoronis architecta			30	30	3	11
Leucon americanus		21		21	3	4
Ogyrides limicola	1	1	14	16	5	6
Pseudeurythoe paucibranchiata		6	3	9	5	1
Glycinde solitaria		4	3	7	4	2
Ampelisca abdita		5	1	6	3	1
Corophium acherusicum		6		6	3	2
Heteromastus filiformis		5		5	3	1
Scoloplos fragilis		1	4	5	4	
Glycera americana	1	1	2	4	4	2
Ensis directus		2	1	3	3	
Nemerteans (unid)		2	1	3	3	
Diadumene leucolena		2		2	2	
Edotea triloba		1	1	2	2	
Anadara transversa			1	1	1	
Diopatra cuprea	1			1	1	1
Edwardsia elegans		1		1	1	
Eteone heteropoda	1			1	1	1
Gammarus mucronatus		1		1	1	
Lyonsia hyalina		1		1	1	
Macoma tenta			1	1	1	
Mitrella lunata			1	1	1	
Monoculodes edwardsi		1		1	1	
Nassarius vibex		1		1	1	
Neopanope texana	1			1	1	1
Nereis succinea	1			1	1	1

STATION B4 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
<u>Pectinaria gouldii</u>			1	1	1	
<u>Pinnixa sayana</u>			1	1	1	
<u>Saccoglossus kowalewskii</u>			1	1	1	
<u>Streblospio benedicti</u>		1		1	1	
Total individuals	104	356	165	625		
Total species	9	23	20	34		

STATION D1

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Spiophanes bombyx	12	11	273	296	9	16
Phoronis architecta	1	2	168	171	5	11
Spiochaetopterus oculatus	1	48	116	165	7	15
Retusa canaliculata	79	13	47	139	9	14
Polydora ligni	45	84		130	6	24
Ampelisca vadorum	5	18	101	124	9	6
Ampelisca verrilli	10	40	65	115	8	8
Heteromastus filiformis	10	76	5	91	8	14
Unciola irrorata	8	52		60	6	9
Glycera dibranchiata	5	8	42	55	8	
Glycinde solitaria	10	15	27	52	9	2
Corophium acherusicum	1	3	34	38	6	3
Haminoea solitaria	35	1		36	4	7
Nereis succinea	8	18	1	27	7	3
Oxyurostylis smithi	12	3	9	24	7	
Mitrella lunata	19	4		23	5	5
Pyramidella fusca	6		15	21	3	
Phyllodoce arenae	1	6	13	20	5	
Nassarius vibex	9	4	5	18	7	
Paracaprella tenuis	1	4	13	18	5	
Nucula proxima	9	7		16	5	
Mangelia plicosa	7	9		16	5	
Turbonilla interrupta	16			16	2	2
Cerapus tubularis			15	15	3	
Erichthonius brasiliensis			15	15	2	
Mulinia lateralis	8	6	1	15	7	
Clymenella torquata	1	12	1	14	5	
Ensis directus	2	12		14	4	
Odostomia impressa	11		1	12	4	
Anadara transversa	7	4		11	5	
Paraprionospio pinnata	3	3	5	11	6	
Pseudeurythoe paucibranchiata		2	8	10	5	
Caprella geometrica		3	6	9	2	
Listriella clymenellae		8	1	9	4	

STATION D1 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Clymenella zonalis	4	3		7	3	
Elasmopus laevis		2	5	7	3	
Macoma tenta	6	1		7	3	
Neopanope texana	4	2		6	4	
Lyonsia hyalina		3	2	5	3	
Nemerteans (unid)		1	4	5	4	
Nephtys magellanica	5			5	3	
Polycirrus eximius		5		5	2	
Sabella micropthalma		5		5	2	
Epitonium rupicolum	1	1	2	4	4	
Gammarus mucronatus		4		4	2	
Tellina agilis	1	3		4	3	
Edwardsia elegans	1	1	1	3	3	
Eupleura caudata	3			3	2	
Pectinaria gouldii	2	1		3	3	
Polychaetes (unid)		2		2	1	
Streblospio benedicti		3		3	2	
Diadumene leucolena		2		2	1	
Harmothoe extenuata		2		2	1	
Neomysis americana			2	2	1	
Sabellaria vulgaris	1	1		2	2	
Tharyx setigera	2			2	2	
Acteon punctostriatus		1		1	1	
Amphiporus bioculatus			1	1	1	
Batea catharinensis			1	1	1	
Ceriantheopsis americanus			1	1	1	
Crangon septemspinosum	1			1	1	
Diopatra cuprea		1		1	1	
Eteone heteropoda		1		1	1	
Lepidonotus sublevis			1	1	1	
Lucina multilineata			1	1	1	
Melanella intermedia		1		1	1	
Micrura leidyi	1			1	1	
Odontosyllis fulgurans		1		1	1	

STATION D1 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Pagurus longicarpus			1	1	1	
Palaeonotus heteroseta			1	1	1	
Paranaitis speciosa		1		1	1	
Prionospio heterobranchiata		1		1	1	
Pyramidella sp.			1	1	1	
Scoloplos robustus		1		1	1	
Total individuals	374	526	1011	1911		
Total species	42	55	39	74		

STATION D2

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Unciola irrorata	183	5	1	189	6	15
Spiophanes bombyx	2	9	141	152	6	15
Ampelisca verrilli	8		107	115	5	13
Ampelisca vadorum	13	19	55	87	9	12
Polydora ligni	72	12		84	6	13
Glycera dibranchiata	5	9	44	58	9	6
Ensis directus	1	54		55	4	14
Phoronis architecta		5	31	36	4	7
Heteromastus filiformis	3	15	17	34	7	5
Retusa canaliculata	18	8	1	27	7	5
Spiochaetopterus oculatus	4	6	17	27	7	
Mitrella lunata	11	4	11	26	7	
Nereis succinea	22	1	3	26	6	3
Spio setosa		24	1	25	4	8
Nucula proxima	19	4	1	24	6	4
Oxyurostylis smithi	15	3	5	23	7	1
Paracaprella tenuis		7	16	23	3	2
Cyathura burbancki	6	12	1	21	6	1
Glycinde solitaria	4	12	3	19	8	3
Anadara transversa	16			16	3	1
Nassarius vibex	4	4	8	16	7	
Neopanope texana	14	1	1	16	4	2
Gammarus mucronatus		14		14	3	3
Mangelia plicosa	7	1	5	13	6	
Oligochaeta	13			13	3	3
Mulinia lateralis	2	9		11	4	
Turbonilla interrupta	6		5	11	4	
Clymenella torquata	1	3	6	10	5	
Scoloplos robustus		9		9	3	3
Elasmopus laevis	1		7	8	2	
Eupleura caudata	4		4	8	5	
Lyonsia hyalina	1	7		8	4	
Tellina agilis	4	2	2	8	4	

STATION D2 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Polycirrus eximius	2	4	1	7	4	
Sabella microphthalma			7	7	1	
Aricidea jeffreysii	2	4		6	3	
Nephtys magellanica	1	1	4	6	5	
Pectinaria gouldii	2		4	6	3	
Pyramidella fusca	6			6	2	
Pseudeurythoe paucibranchiata		4	1	5	3	
Sabellaria vulgaris			5	5	2	
Cerebratulus lacteus		2	2	4	2	
Erichthonius brasiliensis		2	2	4	2	
Eumida sanguinea	4			4	1	
Neomysis americana	3	1		4	3	
Paraprionospio pinnata	1		3	4	3	
Streblospio benedicti		4		4	2	
Batea catharinensis			3	3	1	
Cucumaria pulcherrima	1	2		3	2	
Paraphoxus epistomus	3			3	2	
Amphiporus bioculatus			2	2	2	
Crepidula convexa		1	1	2	2	
Edwardsia elegans	1		1	2	2	
Epitonium rupicolum	2			2	2	
Listriella clymenellae		2		2	1	
Micrura leidyi			2	2	1	
Monoculodes edwardsi		2		2	1	
Nemerteans (unid)			2	2	1	
Phyllodoce arenae		1	1	2	2	
Podarke obscura	1		1	2	2	
Tharyx setigera	1		1	2	2	
Amphipod (unid)	1			1	1	
Anachis translirata	1			1	1	
Ancistrosyllis hartmannae			1	1	1	
Cerithiopsis greeni			1	1	1	
Corophium acherusicum	1			1	1	
Drilonereis filum			1	1	1	
Eteone heteropoda	1			1	1	

STATION D2 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Glycera americana			1	1	1	
Harmothoe extenuata	1			1	1	
Lepidonotus sublevis	1			1	1	
Loimia medusa			1	1	1	
Lucina multilineata			1	1	1	
Macoma tenta			1	1	1	
Melanella intermedia		1		1	1	
Molgula manhattensis			1	1	1	
Notocirrus spiniferus		1		1	1	
Palaeonotus heteroseta		1		1	1	
Paranaitis speciosa			1	1	1	
Phyllodoce mucosa			1	1	1	
Prionospio heterobranchiata	1			1	1	
Tubulanus pellucidus			1	1	1	
Unidentified animal			1	1	1	
Total individuals	496	292	548	1336		
Total species	49	43	56	83		

STATION D3

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Unciola irrorata	176	117	8	301	7	28
Polydora ligni	256	43		299	6	19
Ampelisca vadorum	134	51	32	217	9	16
Spiophanes bombyx		2	141	143	5	12
Pseudeurythoe paucibranchiata	3	125		128	5	13
Elasmopus laevis	1		99	100	3	6
Anadara transversa	41	43	6	90	8	10
Clymenella torquata	37	37	4	78	8	2
Nereis succinea	15	37	13	65	9	2
Spiochaetopterus oculatus	23	29	4	56	8	3
Ampelisca verrilli	6	12	36	54	8	8
Glycera dibranchiata	7	12	28	47	9	6
Cyathura burbancki	6	19	17	42	7	1
Heteromastus filiformis		30	11	41	6	2
Paracaprella tenuis	4	4	33	41	5	4
Sabellaria vulgaris	1	40		41	4	3
Mitrella lunata	15	19	6	40	8	2
Phoronis architecta	9	8	23	40	7	4
Sabella microphthalma	14	26		40	6	1
Neopanope texana	11	24	2	37	7	
Retusa canaliculata	14	14	1	29	6	
Nucula proxima	8	9	3	20	7	
Oligochaeta		19		19	3	
Palaenotus heteroseta	3	13		16	4	
Oxyurostylis smithi	8	5	2	15	8	
Mangelia plicosa	11	1	2	14	6	
Batea catharinensis			13	13	2	1
Erichthonius brasiliensis		2	11	13	3	
Phyllodoce arenae	5		8	13	5	
Cerithiopsis greeni	2	8	1	11	4	
Ensis directus		10	1	11	4	
Glycinde solitaria		7	3	10	5	
Eupleura caudata	4	1	3	8	6	

STATION D3 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Lyonsia hyalina	2	5	1	8	5	
Nephtys magellanica	3	5		8	6	
Streblospio benedicti		8		8	3	
Jassa falcata	7			7	3	
Nemerteans (unid)		1	6	7	4	
Paraprionospio pinnata	2	4	1	7	4	
Turbonilla interrupta	5	2		7	5	
Mulinia lateralis		2	4	6	3	
Carinomella lactea		5		5	3	
Edwardsia elegans	1	2	2	5	5	
Eteone heteropoda	3	2		5	4	
Molgula manhattensis			5	5	1	
Nassarius vibex	1	3	1	5	3	
Asabellides oculata		4		4	3	
Paranaitis speciosa		3	1	4	2	
Pectinaria gouldii	4			4	2	
Polychaete (unid)	2	2		4	3	
Polycirrus eximius		2	2	4	4	
Aricidea jeffreysi	1		2	3	2	
Cerebratulus lacteus		3		3	2	
Diadumene leucolena			3	3	2	
Epitonium rupicolum	1	2		3	2	
Macoma tenta	1		2	3	2	
Anachis translirata	1	1		2	2	
Corophium acherusicum	2			2	1	
Drilonereis filum		2		2	2	
Eumida sanguinea	1	1		2	2	
Gammarus mucronatus	1	1		2	2	
Harmothoe extenuata		2		2	2	
Lepidonotus sublevis			2	2	1	
Listriella clymenellae		2		2	2	
Mercenaria mercenaria		2		2	1	
Neomysis americana	1	1		2	2	
Pagurus longicarpus			2	2	2	
Podarke obscura	1	1		2	2	
Spio setosa		2		2	1	

STATION D3 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Unidentified animal			2	2	1	
Amygdalum papyria		1		1	1	
Amphiporus bioculatus			1	1	1	
Amphiodia atra			1	1	1	
Anadara ovalis	1			1	1	
Ceriantheopsis americanus	1			1	1	
Corophium tuberculatum	1			1	1	
Doris verrucosa		1		1	1	
Edotea triloba			1	1	1	
Euceramus praelongus	1			1	1	
Loimia medusa			1	1	1	
Lucina multilineata			1	1	1	
Mangelia cerina			1	1	1	
Marginella denticulata	1			1	1	
Micrura leidyi		1		1	1	
Mysella bidentata		1		1	1	
Scolelepis bousfieldi			1	1	1	
Scoloplos robustus		1		1	1	
Stenothoe minuta		1		1	1	
Tanstylum orbiculare			1	1	1	
Tubulanus pellucidus		1		1	1	
Turbellaria			1	1	1	
Turbonilla stricta	1			1	1	
Upogebia affinis		1		1	1	
Total individuals	860	845	556	2261		
Total species	51	65	51	93		

STATION D4

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Paraprionospio pinnata	47	65	19	131	9	29
Phoronis architecta	50	54	17	121	8	31
Spiochaetopterus oculatus	35	59	11	105	9	26
Pseudeurythoe paucibranchiata	1	49	10	60	6	10
Retusa canaliculata	30	17	2	49	8	7
Unciola irrorata	2	28	1	31	5	4
Polydora ligni	13	9		22	4	5
Nassarius vibex	8	5	8	21	7	4
Pectinaria gouldii	2	4	15	21	6	7
Mulinia lateralis		18	1	19	4	2
Ampelisca vadorum		5	11	16	4	4
Clymenella torquata	6	5	5	16	8	
Nephtys magellanica	6	4	4	14	7	1
Ogyrides limicola	11	1	1	13	4	3
Nereis succinea	4	7	1	12	5	1
Turbonilla interrupta	4	3	2	9	5	1
Glycinde solitaria		5	3	8	4	
Heteromastus filiformis	6	1	1	8	4	2
Streblospio benedicti		8		8	2	
Anadara transversa		6	1	7	3	
Cerebratulus lacteus	1	6		7	4	1
Ensis directus		6	1	7	4	
Glycera americana	2	4	1	7	5	
Paracaprella tenuis		6	1	7	3	
Macoma tenta	1		5	6	3	
Mangelia plicosa	3	3		6	4	
Nemerteans (unid)		2	4	6	5	1
Gammarus mucronatus		5		5	3	
Erichthonius brasiliensis		4	1	5	4	
Cerapus tubularis		3	1	4	2	
Ceriantheopsis americanus		2	2	4	4	
Corophium acherusicum	2	2		4	3	
Neomysis americana		4		4	2	

STATION D4 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Palaenotus heteroseta	1	3		4	3	
Edotea triloba	1	1	1	3	3	
Epitonium rupicolum	1	1	1	3	3	
Leucon americanus		3		3	2	
Loimia medusa			3	3	1	
Nephtys incisa		1	2	3	2	
Thyone briareus	1		2	3	2	
Amygdalum papyria		2		2	1	
Asabellides oculata		2		2	1	
Edwardsia elegans	2			2	1	
Eupleura caudata			2	2	1	
Lyonsia hyalina	1	1		2	2	
Melinna maculata		2		2	2	
Mitrella lunata		1	1	2	2	
Neopanope texana	1	1		2	2	
Nucula proxima	2			2	2	
Phyllodoce arenae		2		2	1	
Sabella microphthalma			2	2	2	
Yoldia limatula		2		2	1	
Amphiodia atra	1			1	1	
Anachis translirata		1		1	1	
Anadara transversa	1			1	1	
Caprella equilibra		1		1	1	
Carinomella lactea			1	1	1	
Crangon septemspinosa		1		1	1	
Diopatra cuprea		1		1	1	
Elasmopus laevis	1			1	1	
Eteone heteropoda		1		1	1	
Harmothoe extenuata		1		1	1	
Lumbrineris tenuis		1		1	1	
Odontosyllis fulgurans		1		1	1	
Oligochaeta		1		1	1	
Oxyurostylis smithi	1			1	1	
Podarke obscura		1		1	1	
Sabellaria vulgaris			1	1	1	
Saccoglossus kowalewskii			1	1	1	

STATION D4 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Spiophanes bombyx			1	1	1	
Tharyx setigera	1			1	1	
Tubulanus pellucidus	1			1	1	
Total individuals	250	432	147	829		
Total species	34	55	38	72		

STATION D5

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Phoronis architecta	51	66	73	190	9	40
Spiochaetopterus oculatus	71	38	69	178	9	37
Retusa canaliculata	53	15	2	70	7	15
Paraprionospio pinnata	17	14	2	33	8	8
Ampelisca vadorum		5	19	24	5	6
Paracaprella tenuis	1	20		21	3	7
Pectinaria gouldii	8	8	4	20	9	1
Mulinia lateralis	1	17		18	4	3
Anadara transversa	7	4	4	15	7	1
Ensis directus		13		13	3	2
Nassarius vibex	4	2	7	13	4	5
Pseudeurythoe paucibranchiata		9	4	13	4	4
Heteromastus filiformis	1	3	8	12	6	3
Glycera americana	2	4	4	10	8	
Nereis succinea	3	6	1	10	5	1
Ogyrides limicola	6	1	1	8	5	2
Clymenella torquata	1	3	3	7	5	
Corophium acherusicum	1		6	7	3	2
Ceriantheopsis americanus		2	3	5	3	
Asabellides oculata		3	1	4	2	
Edotea triloba		1	3	4	3	
Epitonium rupicolum	1		3	4	3	
Mitrella lunata	2	2		4	2	
Neopanope texana	1	3		4	2	
Phyllodoce arenae	1	2	1	4	4	
Unciola irrorata	1	2	1	4	4	
Ampelisca abdita	3			3	2	
Cerapus tubularis		2	1	3	2	
Diopatra cuprea		1	2	3	2	
Elasmopus laevis	1	1	1	3	3	
Loimia medusa			3	3	1	
Molgula manhattensis	1		2	3	2	2
Nephtys magellanica	1	1	1	3	3	
Sabella microphthalma			3	3	1	
Nemerteans (unid)		2	1	3	2	
Barnea truncata	2			2	2	

STATION D5 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Neomysis americana		1	1	2	2	
Oxyurostylis smithi			2	2	2	
Polydora ligni	1	1		2	2	
Saccoglossus kowalewskii			2	2	2	
Streblospio benedicti		2		2	1	
Upogebia affinis		1	1	2	2	
Amphiodia atra			1	1	1	
Cerebratulus lacteus	1			1	1	
Drilonereis filum		1		1	1	
Erichthonius brasiliensis			1	1	1	
Eupleura caudata			1	1	1	
Gammarus mucronatus		1		1	1	
Glycinde solitaria			1	1	1	
Harmothoe extenuata			1	1	1	
Lyonsia hyalina		1		1	1	
Macoma tenta			1	1	1	
Mangelia plicosa		1		1	1	
Mercenaria mercenaria			1	1	1	
Mya arenaria		1		1	1	
Nephtys incisa	1			1	1	
Nudibranch (unid)			1	1	1	
Palaenotus heteroseta	1			1	1	
Pinnixa sayana			1	1	1	
Polychaete (unid)	1			1	1	
Polydora sp.			1	1	1	
Prionospio cirrifera			1	1	1	
Pyramidella fusca		1		1	1	
Sarsiella zostericola			1	1	1	
Sympleustes glaber		1		1	1	
Thyone briareus			1	1	1	
Turbonilla interrupta	1			1	1	
Total individuals	247	264	252	763		
Total species	31	41	46	68		

STATION E6

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Mya arenaria	119	174		293	6	23
Sabella microphthalma	99	53	2	154	5	9
Heteromastus filiformis	51	66	15	132	9	21
Streblospio benedicti	8	117		125	6	14
Mulinia lateralis	108	11		119	6	12
Nereis succinea	30	58	7	95	9	12
Spiochaetopterus oculatus	28	6	52	86	9	14
Paraprionospio pinnata	11	36	3	50	8	10
Pseudeurythoe paucibranchiata	1	6	27	34	5	9
Scoloplos fragilis	2	5	25	32	7	9
Pectinaria gouldii	13	3	2	18	6	
Polydora ligni	9	9		18	5	
Nassarius vibex	11	2	1	14	6	
Retusa canaliculata	14			14	3	1
Phoronis architecta	1	1	7	9	5	5
Eteone heteropoda	1	7		8	3	2
Lepidonotus sublevis	2	3		5	3	
Diadumene leucolena		4		4	1	
Glycera americana	1	1	1	3	3	
Neopanope texana	2	1		3	2	
Cerebratulus lacteus	1	1		2	2	
Crangon septemspinosa		2		2	1	
Crepidula convexa	2			2	2	
Edotea triloba		2		2	2	
Glycinde solitaria			2	2	2	
Molgula manhattensis	1	1		2	2	
Tharyx setigera	2			2	1	
Ampelisca vadorum			1	1	1	
Capitella capitata		1		1	1	
Carinomella lactea			1	1	1	
Corophium acherusicum	1			1	1	
Ensis directus		1		1	1	
Macoma balthica		1		1	1	

STATION E6 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Mercenaria mercenaria		1		1	1	
Nemertean (unid)			1	1	1	
Neomysis americana		1		1	1	
Nephtys magellanica			1	1	1	
Ogyrides limicola			1	1	1	
Oligochaeta			1	1	1	
Phyllodoce arenae			1	1	1	
Pinnixa sayana		1		1	1	
Unciola irrorata			1	1	1	
Total individuals	518	575	152	1245		
Total species	24	29	20	43		

STATION E7

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Mya arenaria	106	2		108	3	12
Streblospio benedicti		77		77	3	15
Paraprionospio pinnata	48	1	12	61	6	20
Heteromastus filiformis	35	21	2	58	7	19
Nereis succinea	40	12	1	53	7	18
Spiochaetopterus oculatus	39	5	3	45	7	21
Mulinia lateralis	7		1	8	4	
Scoloplos fragilis			8	8	1	4
Corophium acherusicum		6		6	3	6
Molgula manhattensis	6			6	2	
Edotea triloba	4			4	2	
Glycera americana	3	1		4	4	
Pseudeurythoe paucibranchiata	4			4	2	
Retusa canaliculata	4			4	2	
Nassarius vibex	2		1	3	2	
Nephtys magellanica	3			3	2	
Pectinaria gouldii	2		1	3	3	
Callinectes sapidus	2			2	1	
Eteone heteropoda		2		2	2	
Nemerteans (unid)	1		1	2	2	
Phoronis architecta	2			2	1	1
Polydora ligni		2		2	2	1
Sabella microphthalma	2			2	2	
Balanus improvisus	1			1	1	
Cerebratulus lacteus	1			1	1	
Gammarus mucronatus		1		1	1	
Nassarius obsoletus	1			1	1	
Tharyx setigera		1		1	1	
Unciola irrorata	1			1	1	
Total individuals	314	131	30	475		
Total species	21	12	9	28		

STATION E8

Species	May	Aug	Total	Frequency (in 6 samples)	Biological Index (5 point system)
Mya arenaria	454		454	3	15
Nereis succinea	39	13	52	6	19
Molgula manhattensis	2	45	47	3	10
Corophium acherusicum	38		38	2	4
Heteromastus filiformis	26	1	27	4	8
Streblospio benedicti	19		19	3	6
Gammarus mucronatus	13		13	1	2
Mulinia lateralis	12	1	13	4	3
Sabella microphthalma	2	10	12	3	6
Diadumene leucolena	2	7	9	4	5
Polydora ligni	5	3	8	4	2
Eteone heteropoda	5	1	6	3	
Hydroides hexagona		6	6	1	4
Alpheus heterochaelis	2	3	5	4	1
Edotea triloba	3	1	4	2	1
Elasmopus laevis	1	2	3	3	
Gyptis vittata		3	3	2	1
Spiochaetopterus oculatus	1	2	3	3	1
Ensis directus	2		2	1	1
Melita appendiculata	2		2	1	
Scoloplos fragilis	1	1	2	2	1
Caprella geometrica	1		1	1	
Amphipods (unid)	1		1	1	
Cerebratulus lacteus		1	1	1	1
Cyathura polita	1		1	1	
Eurypanopeus depressus		1	1	1	
Glycera americana	1		1	1	
Lepidonotus sublevis		1	1	1	
Leucon americanus	1		1	1	
Nemertean (unid)	1		1	1	
Paraprionospio pinnata		1	1	1	
Podarke obscura	1		1	1	
Tubulanus pellucidus		1	1	1	
Total individuals	636	104	740		
Total species	26	20	33		

STATION F1

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Spiophanes bombyx	6	21	334	361	8	15
Retusa canaliculata	81	15	85	181	9	22
Ensis directus	97	62		159	6	18
Mulinia lateralis	4	93	3	100	6	13
Heteromastus filiformis	6	64	21	91	9	9
Paraprionospio pinnata	17	36	34	87	9	12
Glycera dibranchiata	5	8	58	71	9	10
Nephtys magellanica	24	41	3	68	8	10
Spiochaetopterus oculatus	3	29	23	55	7	5
Ampelisca verrilli	5	15	30	50	8	2
Oxyurostylis smithi	37	5	8	50	8	10
Oligochaeta	11	34		45	4	6
Glycinde solitaria	6	20	14	40	9	1
Ampelisca vadorum	7	9	16	32	9	
Polydora ligni	9	23		32	6	
Haminoea solitaria	30	1		31	4	5
Phoronis architecta	2	1	27	30	5	
Spio setosa		29		29	3	
Macoma tenta	15	2	6	23	7	1
Pseudeurythoe paucibranchiata		4	14	18	6	
Tellina agilis	5	12		17	5	
Edotea triloba	1	10	3	14	4	
Nassarius vibex	7	2	5	14	7	
Phyllodoce arenae	1	1	12	14	5	
Turbonilla interrupta	12	1	1	14	5	
Nemerteans (unid)	2	1	7	10	5	
Tharyx setigera		4	6	10	6	
Cerebratulus lacteus		6		6	3	
Scoloplos robustus		4	2	6	4	
Streblospio benedicti		6		6	3	
Pyramidella fusca	5		1	6	4	
Anadara transversa	2	3		5	5	
Eteone heteropoda		5		5	3	

STATION F1 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Clymenella torquata		2	2	4	3	
Loimia medusa			4	4	2	
Paracaprella tenuis	3	1		4	2	
Epitonium rupicolum	2	1		3	2	
Neopanope texana	3			3	2	
Urosalpinx cinerea	1	2		3	3	
Aglaophamus verrilli	2			2	2	
Carinomella lactea		1	1	2	2	
Ceriantheopsis americanus		2		2	2	
Drilonereis filum		2		2	2	
Listriella clymenellae			2	2	2	
Melinna maculata			2	2	2	
Neomysis americana	1	1		2	2	
Pectinaria gouldii			2	2	2	
Scoloplos robustus	2			2	2	
Anoplodactylus parvus			1	1	1	
Cerapus tubularis			1	1	1	
Clymenella zonalis	1			1	1	
Corophium acherusicum		1		1	1	
Doridella obscura	1			1	1	
Edwardsia elegans	1			1	1	
Eupleura caudata			1	1	1	
Glycera americana	1			1	1	
Lucina multilineata			1	1	1	
Lyonsia hyalina		1		1	1	
Mangelia plicosa	1			1	1	
Mitrella lunata	1			1	1	
Paraphoxus epistomus			1	1	1	
Pinnixa sayana			1	1	1	
Sarsiella zostericola			1	1	1	
Scolelepsis bousfieldi	1			1	1	
Stylochus ellipticus		1		1	1	
Unciola irrorata	1			1	1	
Total individuals	422	582	733	1737		
Total species	41	43	36	66		

STATION F2

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Spiophanes bombyx	15	29	175	219	9	20
Heteromastus filiformis		66	75	141	6	25
Nephtys magellanica	43	63	29	135	9	27
Retusa canaliculata	47	35	25	107	9	18
Polydora ligni	43	37		80	6	17
Paraprionospio pinnata	4	24	33	61	8	5
Ensis directus	14	37		51	6	4
Ampelisca vadorum	21	2	25	47	7	7
Ampelisca verrilli	8	10	29	47	9	4
Mulinia lateralis		39	1	40	4	5
Phoronis architecta	1	3	26	30	5	2
Turbonilla interrupta	19	5	5	29	9	3
Paracaprella tenuis		18	4	22	4	1
Macoma tenta	6	12	2	20	6	
Nucula proxima	11	5	2	18	8	1
Streblospio benedicti	1	17		18	4	
Tellina agilis	3	11	4	18	7	
Clymenella torquata	2	7	6	15	7	
Corophium acherusicum	1	1	12	14	4	1
Spiochaetopterus oculatus	1	7	6	14	6	
Oxyurostylis smithi	6	3	4	13	7	
Caprella equilibra		12		12	2	1
Glycera dibranchiata	2		10	12	4	
Nassarius vibex	3	2	6	11	7	
Oligochaeta	11			11	1	3
Phyllodoce arenae	1	1	9	11	4	
Glycinde solitaria	1	2	7	10	6	
Cerebratulus lacteus		8		8	3	
Nemerteans (unid)	1	2	5	8	6	
Nereis succinea	4	3	1	8	5	
Unciola irrorata	2	6		8	3	
Amygdalum papyria		7		7	1	

STATION F2 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Anadara transversa	3	1	3	7	4	
Edwardsia elegans	1	2	4	7	4	
Erichthonius brasiliensis		2	5	7	4	
Loimia medusa			7	7	2	
Neopanope texana	3	4		7	4	
Listriella clymenellae		3	3	6	4	
Pectinaria gouldii		2	4	6	5	
Pseudeurythoe paucibranchiata	1	5		6	4	
Spio setosa		6		6	3	
Amphiodia atra	1		4	5	3	
Edotea triloba	2	2	1	5	4	
Mitrella lunata	5			5	2	
Asabellides oculata		4		4	3	
Carinomella lactea	1		3	4	2	
Ceriantheopsis americanus			4	4	2	
Aglaophamus verrilli		2	1	3	3	
Clymenella zonalis	3			3	3	
Epitonium rupicolum	1		2	3	3	
Eteone lactea		3		3	2	
Lepidonotus sublevis		3		3	2	
Sarsiella zostericola			3	3	1	
Yoldia limulata	1	1	1	3	3	
Cerapus tubularis	2			2	2	
Crangon septemspinosa		2		2	2	
Drilonereis filum			2	2	2	
Lyonsia hyalina		1	1	2	2	
Micrura leidyi			2	2	1	
Neomysis americana		1	1	2	2	
Odostomia impressa	2			2	2	
Pyramidella fusca	1		1	2	2	
Tharyx setigera		2		2	1	
Anadara ovalis	1			1	1	
Batea catharinensis		1		1	1	
Crepidula convexa			1	1	1	
Eupleura caudata		1		1	1	
Glycera americana			1	1	1	

STATION F2 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Jassa falcata	1			1	1	
Melinna maculata			1	1	1	
Mercenaria mercenaria		1		1	1	
Molgula manhattensis			1	1	1	
Paranaitis speciosa		1		1	1	
Pinnixa sayana			1	1	1	
Sabella microphthalma	1			1	1	
Urosalpinx cinerea			1	1	1	
Total individuals	301	524	559	1384		
Total species	43	52	49	75		

STATION F3

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Sabellaria vulgaris		26	465	491	5	15
Heteromastus filiformis	30	265	107	402	8	22
Ampelisca vadorum		94	298	392	6	22
Retusa canaliculata	196	11	2	209	7	15
Unciola irrorata		121	39	160	6	8
Nereis succinea		20	123	143	5	4
Erichthonius brasiliensis		9	106	115	6	3
Batea catharinensis	1	8	96	105	5	4
Hydroides hexagona			95	95	3	3
Anadara transversa	3	25	62	90	8	
Paracaprella tenuis	1	52	11	64	6	3
Polycirrus eximius		58	2	60	5	5
Neopanope texana	1	30	27	58	7	
Corophium acherusicum	2	5	42	49	5	
Nucula proxima	2	39	4	45	7	
Harmothoe extenuata		44		44	3	2
Paraprionospio pinnata	43		1	44	3	12
Oligochaeta	21	18	2	41	6	2
Glycera dibranchiata	4	17	12	33	9	
Tharyx setigera	1	28	4	33	5	1
Nephtys magellanica	20	9	3	32	9	6
Sabella micropthalma		5	26	31	5	
Elasmopus laevis		4	26	30	6	
Ensis directus		27		27	3	3
Diadumene leucolena		6	20	26	4	
Pseudeurythoe paucibranchiata	2	13	7	23	7	
Pectinaria gouldii	2		20	22	4	
Lepidonotus sublevis	1		20	21	4	
Polydora ligni		21		21	3	
Podarke obscura		1	18	19	4	
Caprella geometrica		18		18	3	
Eteone heteropoda		17	1	18	3	1
Glycinde solitaria	7	6	3	16	7	
Mitrella lunata	2	3	11	16	6	

STATION F3 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Eumida sanguinea		3	12	15	4	
Mangelia plicosa		5	9	14	5	
Paranaitis speciosa		7	7	14	4	
Nemerteans (unid)	1	1	11	13	5	
Paraphoxus epistomus	1	12		13	2	
Spio setosa		13		13	2	
Spiochaetopterus oculatus	3	8	2	13	6	
Eupleura caudata		5	7	12	4	
Macoma tenta	11	1		12	4	5
Palaeonotus heteroseta		11		11	2	
Amygdalum papyria		10		10	3	
Clymenella torquata	1	7	1	9	5	
Streblospio benedicti	2	7		9	4	
Edwardsia elegans	1	1	6	8	5	
Lumbrineris tenuis		4	4	8	5	
Asabellides oculata		7		7	3	
Epitonium rupicolum	3	2	2	7	5	
Heteromysis formosa			7	7	2	
Micrura leidyi		5	2	7	3	
Nassarius vibex	1	1	5	7	5	
Arabella iricolor		6		6	3	
Oxyurostylis smithi		6		6	3	
Spiophanes bombyx			6	6	3	
Tellina agilis		6		6	1	
Edotea triloba	2	3		5	4	
Notomastus latericius		5		5	2	
Amphiodia atra	2		2	4	3	
Crepidula convexa		1	3	4	3	
Loimia medusa			4	4	2	
Mulinia lateralis		4		4	2	
Nephtys incisa	4			4	3	
Phyllodoce arenae	1	1	2	4	3	
Amphiporus bioculatus			3	3	1	
Anomia simplex			3	3	3	
Crangon septemspinosa		3		3	2	
Drilonereis filum		3		3	3	

STATION F3 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Euceramus praelongus		1	2	3	3	
Melanella intermedia		3		3	2	
Molgula manhattensis			3	3	2	
Odostomia impressa	2	1		3	2	
Polychaetes (unid)	3			3	2	
Upogebia affinis			3	3	2	
Anachis translirata		1	1	2	2	
Bathyporiea sp.	2			2	2	
Caprella equilibra		2		2	2	
Carinomella lactea		1	1	2	2	
Ceriantheopsis americanus		1	1	2	2	
Cerithiopsis greeni	1	1		2	2	
Clymenella zonalis		2		2	2	
Crepidula fornicata		2		2	1	
Glycera americana			2	2	2	
Marphysa sanguinea			2	2	1	
Mercenaria mercenaria		2		2	2	
Nudibranch (unid)		2		2	1	
Scoloplos robustus			2	2	2	
Turbonilla interrupta	1	1		2	2	
Cerebratulus lacteus		1		1	1	
Cerebratulus luridus		1		1	1	
Corophium tuberculatum		1		1	1	
Diopatra cuprea		1		1	1	
Doris verrucosa			1	1	1	
Gammarus mucronatus		1		1	1	
Libinia dubia			1	1	1	
Lyonsia hyalina		1		1	1	
Panopeus herbsti		1		1	1	
Prionospio sp.			1	1	1	
Pyramidella fusca		1		1	1	
Notocirrus spiniferus		1		1	1	
Sarsiella zostericola			1	1	1	
Stylochus ellipticus			1	1	1	

STATION F3 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
<u>Tubulanus pellucidus</u>		1		1	1	
Total individuals	381	1178	1773	3332		
Total species	36	82	64	105		

STATION F4

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Phoronis architecta	6		171	177	6	19
Spiophanes bombyx	2		120	122	4	13
Retusa canaliculata	66	2	5	73	6	16
Caprella geometrica	1	64	2	67	4	5
Glycera dibranchiata	1	3	29	33	6	5
Paracaprella tenuis		15	10	25	6	4
Spiochaetopterus oculatus	1		22	23	4	2
Unciola irrorata	1	17	4	22	5	6
Nemerteans (unid)	1		20	21	4	1
Pyramidella fusca	2		18	20	4	3
Tellina agilis	13	5	2	20	6	15
Nassarius vibex	5	1	10	16	7	4
Tharyx setigera		14	1	15	3	4
Ampelisca verrilli	1		13	14	4	3
Mitrella lunata	5	6	3	14	7	4
Harmothoe extenuata		12		12	2	2
Heteromastus filiformis		6	6	12	5	1
Nereis succinea	1	7	4	12	6	1
Nucula proxima	4	7	1	12	6	2
Elasmopus laevis		10	1	11	2	4
Ensis directus	7	4		11	3	5
Paraphoxus epistomus	3	8		11	5	2
Ampelisca vadorum		1	9	10	4	
Ericthonius brasiliensis			10	10	3	1
Oxyurostylis smithi	1	1	8	10	5	
Edotea triloba	2		6	8	5	
Sabella microphthalma			8	8	3	
Sabellaria vulgaris		8		8	2	3
Cerapus tubularis			7	7	3	
Phyllodoce arenae			7	7	2	
Podarke obscura		6	1	7	2	1
Spio setosa		7		7	3	5
Epitonium rupicolum			6	6	3	

STATION F4 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Glycinde solitaria		1	5	6	4	
Neopanope texana	1	5		6	3	
Polycirrus eximius	1	5		6	4	
Nudibranch (unid)		2	3	5	4	
Pseudeurythoe paucibranchiata		3	2	5	4	
Anadara transversa	1	3		4	2	
Eupleura caudata			4	4	3	
Gammarus mucronatus		4		4	2	
Mulinia lateralis	1	2	1	4	4	
Nephtys picta	4			4	2	3
Polydora ligni	4			4	3	2
Sarsiella zostericola			4	4	3	
Corophium acherusicum			3	3	3	
Edwardsia elegans			3	3	2	
Eteone heteropoda		3		3	3	
Lepidonotus sublevis			3	3	2	
Mangelia plicosa	1		2	3	3	
Odostomia impressa	3			3	1	2
Paraprionospio pinnata	2		1	3	3	
Scoloplos robustus		3		3	2	1
Streblospio benedicti		3		3	1	
Asabellides oculata		2		2	1	1
Batea catharinensis		2		2	2	
Clymenella torquata	1		1	2	2	
Diadumene leucolena			2	2	2	
Euceramus praelongus			2	2	2	
Lumbrineris tenuis		2		2	2	
Lyonsia hyalina		1	1	2	2	
Nephtys magellanica		2		2	2	
Pectinaria gouldii			2	2	1	
Acanthohaustorius intermedius	1			1	1	
Callipallene brevirostris			1	1	1	
Ceriantheopsis americanus			1	1	1	
Cerithiopsis greeni		1		1	1	
Corophium tuberculatum		1		1	1	
Crepidula convexa		1		1	1	

STATION F4 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Cyclaspis sp.	1			1	1	
Erichsonella filiformis			1	1	1	
Gemma gemma		1		1	1	
Glycera americana			1	1	1	
Haminoea solitaria	1			1	1	
Loimia medusa			1	1	1	
Lucina multilineata			1	1	1	
Mercenaria mercenaria			1	1	1	
Molgula manhattensis			1	1	1	
Neomysis americana	1			1	1	
Ogyrides limicola			1	1	1	
Oligochaeta		1		1	1	
Phyllodoce mucosa			1	1	1	
Polydora sp.		1		1	1	
Stenothoe minuta		1		1	1	
Upogebia affinis			1	1	1	
Total individuals	146	254	554	954		
Total species	33	44	55	85		

STATION F5

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Retusa canaliculata	171	84	1	266	7	23
Heteromastus filiformis	22	107	47	176	9	23
Spiochaetopterus oculatus	17	13	137	167	9	19
Unciola irrorata	31	74	1	106	7	10
Nucula proxima	6	66		72	6	6
Phoronis architecta	19	4	47	70	7	13
Corophium acherusicum	1	63	2	66	5	4
Ensis directus	23	43		66	6	5
Streblospio benedicti	1	52		53	4	2
Paraprionospio pinnata	29	1	19	49	7	5
Sabellaria vulgaris	20	21	8	49	5	5
Spiophanes bombyx		9	39	48	6	8
Nereis succinea	7	23	15	45	9	1
Oligochaeta	21	21		42	6	4
Glycinde solitaria	14	9	8	31	8	2
Caprella geometrica		30		30	3	4
Glycera dibranchiata	4	9	12	25	6	2
Ampelisca vadorum	5	1	17	23	6	2
Nassarius vibex	5	11	2	18	7	
Sabella microphthalma		1	16	17	3	1
Mitrella lunata	4	12		16	6	
Mulinia lateralis	3	12		15	5	
Nephtys magellanica	5	2	8	15	7	
Phyllodoce arenae	5	3	7	15	8	
Nemertean			14	14	3	
Paracaprella tenuis	2	9	2	13	6	
Pseudeurythoe paucibranchiata		2	11	13	5	
Tellina agilis		12		12	3	
Neopanope texana	4	7		11	3	
Polydora ligni	1	10		11	4	
Mangelia plicosa		9	1	10	3	
Macoma tenta	8		1	9	4	
Oxyurostylis smithi	6	2	1	9	5	

STATION F5 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Spio setosa		8		8	2	
Tharyx setigera	2	6		8	5	
Diopatra cuprea	1	4	2	7	6	
Hydroides hexagona		5	1	6	2	
Lumbrineris tenuis		3	3	6	4	
Pectinaria gouldii		1	5	6	4	
Anadara transversa	1	3	1	5	3	
Cerapus tubularis		3	2	5	4	
Edotea triloba	2	3		5	3	
Edwardsia elegans	2		3	5	3	
Polycirrus eximius		5		5	3	
Eteone heteropoda		4		4	3	
Neomysis americana			4	4	1	
Pyramidella fusca	3	1		4	3	
Corophium tuberculatum		3		3	1	
Euceramus praelongus			3	3	1	
Ampelisca verrilli			2	2	1	
Amygdalum papyria		2		2	2	
Batea catharinensis	1	1		2	2	
Cerebratulus luridus		2		2	1	
Epitonium rupicolum	1		1	2	2	
Eumida sanguinea		1	1	2	2	
Lucina multilineata			2	2	1	
Scoloplos robustus		2		2	1	
Tubulanus pellucidus			2	2	2	
Turbonilla interrupta		1		1	2	
Amphiodia atra	1			1	1	
Callinectes sapidus	1			1	1	
Caprella equilibra		1		1	1	
Ceriantheopsis americanus			1	1	1	
Clymenella zonalis			1	1	1	
Crepidula convexa		1		1	1	
Erichsonella filiformis	1			1	1	
Gammarus mucronatus		1		1	1	
Glycera americana			1	1	1	
Gobiosoma bosci			1	1	1	

STATION F5 continued

Species	Feb	May	Aug	Total	Frequency (in 9 samples)	Biological Index (5 point system)
Haminoea solitaria	1			1	1	
Harmothoe extenuata		1		1	1	
Lepidonotus sublevis			1	1	1	
Loimia medusa			1	1	1	
Lyonsia hyalina		1		1	1	
Microgobius thalassinus			1	1	1	
Molgula manhattensis			1	1	1	
Monoculodes edwardsi	1			1	1	
Odostomia impressa		1		1	1	
Pagurus longicarpus		1		1	1	
Palaenotus heteroseta			1	1	1	
Paraphoxus epistomus		1		1	1	
Podarke obscura		1		1	1	
Total individuals	452	790	457	1699		
Total species	39	57	46	82		