Benthic Faunal Assemblages in the Lower Bay of New York Harbor

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J.R. Schubel

J.R. Schubel, Director

Abstract

Benthic macrofauna was sampled by Shipek grab at 74 stations in the Lower Bay of New York Harbor, U.S.A. Samples were taken in May, July, and October 1979 and in March and May 1980. Lower Bay stations were found to have significantly reduced densities and diversities of macrobenthic invertebrates compared to similar estuarine environments. Abundances were found to vary seasonally, with highest densities appearing in the spring and fall and lower densities in the winter and summer. Abundances were consistently higher on Old Orchard Shoal and Romer Shoal than on the East Bank. Average abundances ranged from approximately 400 individuals$\cdot m^{-2}$ on Old Orchard and Romer Shoals to 250 individuals$\cdot m^{-2}$ on the East Bank. Numerical classification using the Bray-Curtis dissimilarity measure and flexible clustering helped define three faunal assemblages. Old Orchard Shoal was characterized by deposit-feeding polychaetes, such as *Aricidea jeffreysii;* Romer Shoal by an amalgam of deposit/suspension feeding and carnivorous polychaetes (e.g., *Sabellaria vulgaris*), amphipods, and a Tanaid isopod (*Cyathura polita*); and the East Bank by Haustorid amphipods such as *Acanthohaustorius millsi*. These distributions are attributed to various physical factors such as sediment grain size, tidal current and wave energy, and relative levels of pollution. One hundred and seventy-nine invertebrate taxa were identified, fifty-seven of which had not been previously reported. Notable among these are *Aricidea jeffreysii* and three species of Caprellid amphipods.

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Acknowledgements

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INTRODUCTION

Background

Sand deposits in the Lower Bay of New York Harbor are potentially a rich source of commercial sand. They have been a large source for fill and aggregate material in construction projects within the New York metropolitan area since 1963 (Schlee, 1975; Kastens et al., 1978). According to the New York State Office of General Services (OGS), in excess of 95 million cubic yards of sand have been mined from the Lower Bay between 1950 and 1975 (Marotta, personal comment). Recently (1975), sand from the Lower Bay has been used for the New Jersey Sports Complex and Battery Park City construction projects.

The demand for sand obtained from the Lower Bay will likely increase in the near future (Courtney et al., 1979). Commercial and public demand for sand and aggregate in the metropolitan area will probably exceed 8.5 million cubic yards per year (Marotta, personal communication) based on current and pending construction proposals. The potential removal of sand from the Lower Bay by proposed sand mining projects has been estimated at 43 million cubic yards. Demand for Lower Bay sand will increase as this resource becomes economically more attractive than sources on land. Due to urbanization and suburban spreading, sand resources located on land have dwindled and overland transportation costs have risen. Overland transport from sources greater than 50-60 miles is becoming prohibitively expensive (Carlisle and Wallace, 1978), now making Lower Bay sand economically attractive.

Since 1973, the mining of sand from the Lower Bay has been restricted due to environmental concerns raised by a variety of agencies and citizen groups. During this period of restricted mining, a number of studies were sponsored by OGS and the New York Sea Grant Institute (NYSGI). These are:

1) effects on shore erosion due to altered bathymetry (Kinsman et al., 1979)
2) effects on circulation patterns due to altered bathymetry (Wong and Wilson, 1979)
3) environmental descriptions (Kastens et al., 1978)
4) effects of deep holes on circulation, water quality, and sediments (Swartz and Brinkhuis, 1978)
5) surficial sediment distribution and resource availability (Kastens et al., 1978; Carlisle and Wallace, 1978; Jones et al., 1979)
6) distribution and depth of surficial sediment deposits (Bokuniewicz and Fray, 1979)
7) assessment of the biological effects of sand mining on fauna as determined from the literature (Brinkhuis, 1980).

On 16 May 1979 a meeting with representatives from the Department of Environmental Conservation (DEC), OGS, NYSGI, and the Marine Sciences Research Center (MSRC) was held to delineate a study to ascertain the composition and nature of the infauna and epifauna at two proposed mining sites and one control area in the Lower Bay. The present study was designed to generate seasonal information on benthic fauna of the Lower Bay and to provide adequate data on the benthic community at the proposed mining sites on the East Bank and Old Orchard Shoal.

Previous Studies

Few studies have been conducted in the Lower Bay Complex (Lower Bay, Raritan Bay, and Sandy Hook Bay) concerning the spatial and temporal distribution and abundance of the benthic macrofauna (> 1 mm). Only seven studies have addressed this question in some way. Dean and Haskin (1964) sampled 20 stations in the lower 20 km of the Raritan River estuary during the summers of 1957 to 1960. A total of 17 marine taxa were recorded. Walford (1971) reported the results from a study of eight stations on the west side of Ambrose Channel (Lower Bay). He found a total of 31 taxa and concluded that the area was very impoverished with regard to standing crop and species diversity relative to comparable estuarine environments. No attempt was made to monitor seasonal or long term changes. Steimle and Stone (1973) sampled a total of 39 stations along the south shore of Long Island at monthly intervals between 1966 and 1967. Only one station along one transect lies within the Lower Bay. A total of 70 taxa were found along this transect. McGrath (1974) surveyed 78 stations west of Ambrose Channel in the Lower Bay Complex in January and February, 1973. He reported an average of 4 species per sample and an average of 110 individuals·m^2. McGrath concluded that the area he surveyed was an impoverished one. Dean (1975) reported a total of 127 taxa identified from 193 stations in the Lower Bay Complex. Samples were taken during the summers of 1957 to 1960. Only 4 stations east of Ambrose Channel were sampled. Woodward and Clyde (1975) sampled 8 stations on the East Bank of Lower Bay using a Shipek grab and sieving the material through a 0.5 mm mesh. Densities ranged from 67 to 55,011 individuals·m^2, with a mean of 5406 individuals·m^{-2}. A total of 51 invertebrate taxa were identified. They concluded that the East Bank was not impoverished. Between 1977 and 1978 Brinkhuis (1980) obtained Shipek grab samples at 40 stations on the East and West Banks of Ambrose Channel in and around holes that remained after mining operations. The average number of species per station on the East and West Banks were 2 and 1, respectively. The East Bank averaged 21 individuals·m^{-2}, while the West Bank averaged 8 individuals·m^{-2}. A total of 12 taxa were identified to genus or species.

Description of Study Area

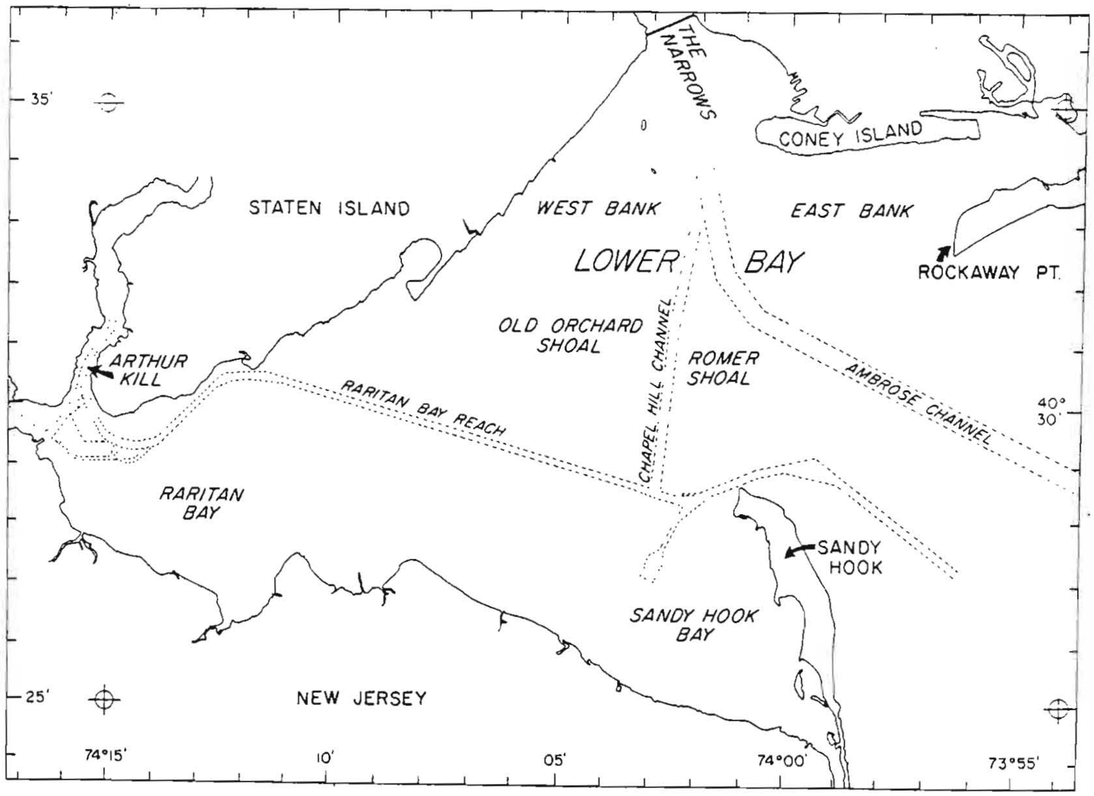
The Lower Bay of New York Harbor is located at the western end of Long Island and bordered to the northwest, southwest, and southeast by Staten Island, New Jersey, and the Atlantic Ocean, respectively (see Fig. 1). The Bay is connected to the Hudson

River via the Narrows between Brooklyn and Staten Island and the Upper Bay of New York Harbor. The Arthur Kill and Raritan River enter the Bay via Raritan Bay to the west and water from Jamaica Bay enters through Rockaway Inlet to the east. The Lower Bay communicates with the Atlantic Ocean through the transect from Rockaway Point to Sandy Hook.

The Lower Bay lies at the mouth of the Hudson River and is described as a laterally stratified estuary with a counter-clockwise, net non-tidal circulation. Water of higher salinity enters the Bay from the Atlantic along the bottom, and at all depths on the eastern side while fresher water from the Hudson and Raritan Rivers leaves at the surface and at depth on the western side (Doyle and Wilson, 1978). The physical characteristics and oceanography of the Lower Bay have been described in detail by Duedall et al. (1974).

The Lower Bay lies entirely on the Outwash Plain which was laid down during the retreat of the last (Wisconsin) glacial period. It is therefore underlain by unconsolidated glacial till and sand which has been subsequently modified by marine forces, and in some places covered by marine sediments (Kastens et al. 1978). The Bay is shallow with an average depth of about 6 meters (20 ft.), the bottom topography is broken by dredged navigation channels 14 meters (45 ft.) deep and shallow shoals which rise above the general level of the bottom to within 2-3 meters

Figure 1. Location map showing Lower Bay Complex.


THE NARROWS
CONEY ISLAND
STATEN ISLAND
WEST BANK
EAST BANK
LOWER BAY
ROCKAWAY PT.
OLD ORCHARD SHOAL
CHAPEL HILL CHANNEL
ROMER SHOAL
ARTHUR KILL
RARITAN BAY REACH
AMBROSE CHANNEL
RARITAN BAY
SANDY HOOK
SANDY HOOK BAY
NEW JERSEY
35'
25'
40° 30'
74°15'
10'
05'
74°00'
73°55'

(6-10 ft.) of the surface.

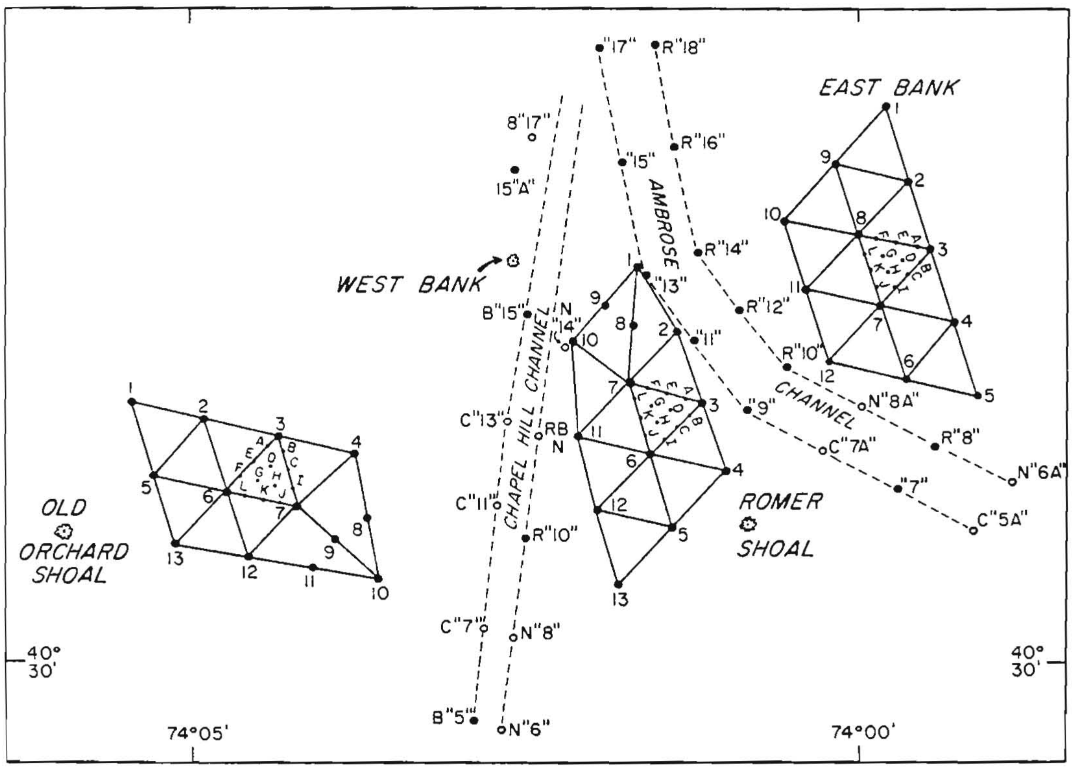
The Lower Bay is surrounded by the nation's largest metropolitan region, the home of some 8 million people and is invariably impacted by man's activities.

MATERIALS AND METHODS

Sampling

Three areas in the Lower Bay of New York Harbor, Old Orchard Shoal, Romer Shoal, and the East Bank, were sampled in May, July, and October 1979 and in March and May 1980. A grid composed of triangles was sampled at each area (Fig. 2). These grids correspond to those used in a computer simulation study on the possible effects of bathymetric changes on the circulation in the Lower Bay Complex (Wong and Wilson, 1979). Two schemes of sampling were employed; one involved sampling at widely spaced stations (800 m apart - designated by numbers) and the other involved more intense sampling over a smaller area with closely spaced stations (200 m apart - designated by letters). The widely spaced stations correspond to the nodes of the triangles forming the grid. Where grid nodes were more than 800 m apart, stations were sampled along the line between adjacent nodes. The closely spaced stations were located within one triangle of the grid at each area (see Fig. 2). Thirteen widely spaced stations and twelve closely spaced stations were sampled at Old Orchard and Romer Shoals. On the East Bank, twelve widely spaced and twelve closely spaced stations were sampled. A total of 74 stations were sampled during each cruise. Only Old Orchard Shoal and the East Bank were sampled during the March 1980 cruise because of poor weather conditions. Longitude and latitude of stations sampled is given

Figure 2. Map showing location of sampling grids.


"17"
R"18"
EAST BANK
8"17"
R"16"
15"A"
"15"
AMBROSE
R"14"
WEST BANK
"13"
R"12"
B"15"
CHAPEL HILL CHANNEL
"14"
"11"
R"10"
N"8A"
C"13"
RB
N
"9"
CHANNEL
R"8"
C"7A"
N"6A"
"7"
OLD ORCHARD SHOAL
ROMER SHOAL
C"11"
R"10"
C"5A"
C"7"
N"8"
40° 30'
B"5"
N"6"
74°05'
74°00'

in Appendix 1.

Samples were collected using a .04 m^2 Shipek grab sampler. This device was chosen because of its ease of handling and its reliability as an all-sediment sampler (Flannagan, 1970). Three grabs were taken at each station, pooled and the contents sieved aboard ship through a 1.0 mm mesh screen. Samples were first placed in a refrigerator to relax the specimens and then preserved with 10% buffered Formalin. Rose Bengal was added to stain the organisms. In the laboratory, all organisms were sorted and identified to species where possible. Identifications and nomenclature were based on Pettibone (1963), Gosner (1971), and Bousfield (1973). A subsample of the unsieved material was taken at each station in May 1979 for subsequent grain size analysis. The sediment subsamples were analyzed for particle-size distribution by dry sieving following the procedures of Folk (1964).

Demersal fish were also sampled using a 30' foot-rope, one-inch mesh, otter trawl net. Duplicate trawls of twenty minutes duration (approximately 2 km) were made over each area in opposite directions, with and against the tide. The fish were brought aboard and kept alive in a 200-liter container. All specimens were identified to species. Identifications and nomenclature were based on Thomson et al., (1971). Total wet weight and number was obtained for each species encountered.

Large species were measured for length, small species were not.

Statistical Analysis

Classification by Cluster Analysis

The use of multivariate statistical methods in the analysis of ecological data has grown rapidly with the availability of computer facilities. The application of these methods becomes increasingly important as the size and complexity of the data set expands. As complexity increases, the ability to "see" clear patterns or trends diminishes to the point where important relationships may become lost. Multivariate analysis may often lend itself to the perception of meaningful ecological relationships, however, caution must be exercised. Computers will generate output without regard to it being ecologically meaningful and are no substitute for the trained ecologist with an in depth knowledge of the study area.

Cluster Analysis was used in this study to investigate relationships between stations and species sampled in the Lower Bay Complex. This method of analysis involves several steps but may be summarized as a technique by which stations with similar patterns of species occurrence are grouped together to form "clusters." This process is called "normal analysis" because it has become the most traditional application of this technique. The relationship among species may also be investigated using "inverse analysis" (Boesch, 1977). In this approach species with similar patterns of occurrence at stations are grouped together. Figure 3 outlines the steps necessary to perform cluster analysis.

The first step was, of course, data acquisition, followed by careful inspection to acquire some "feel" or intuition for the data. Upon completion of this first step interesting regularities regarding geographical and species groupings were observed, prompting the use of cluster analysis to investigate them more closely. The original data matrix was arranged with stations as columns and species as rows with individual abundance values filling in the body. Prior to clustering, a resemblance matrix must be calculated from the original data matrix using some resemblance measure. The Bray-Curtis dissimilarity coefficient (Clifford and Stephenson, 1975) was selected for this purpose and can be expressed as follows:

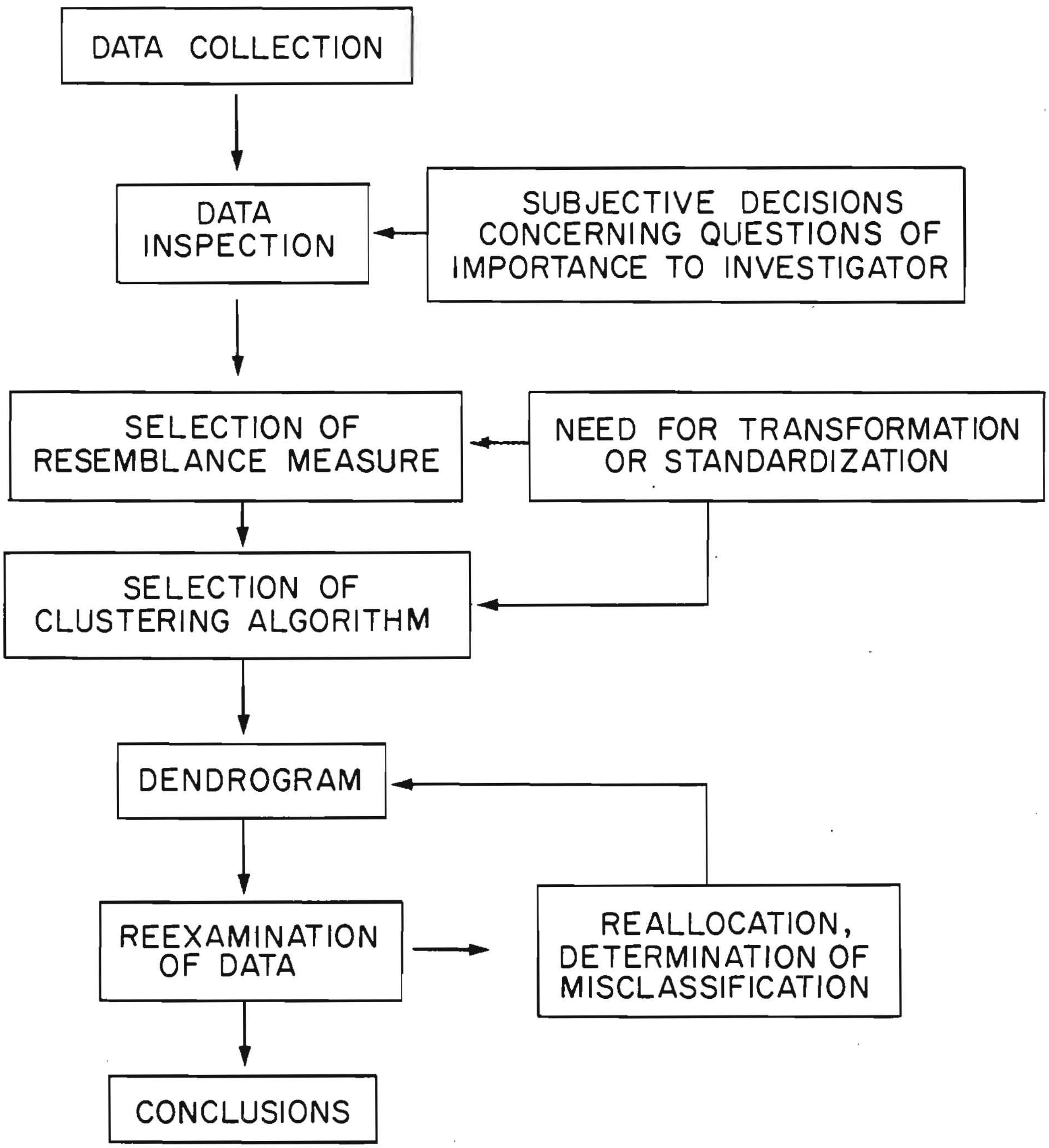
$$D_{jk} = \frac{\sum_i (X_{ij} - X_{ik})}{\sum_i (X_{ij} + X_{ik})}$$

where X_{ij} and X_{ik} are the abundances of species i at stations j and k respectively. In the Bray-Curtis coefficient, attributes with high scores largely determine the value of the measure whereas attributes with low scores are relatively unimportant (Boesch, 1977). This was not believed to be a major problem for this study because of the relatively low range of abundance values.

However a $\sqrt{X}$ transformation was applied to lessen the sensitivity of this measure to high scores and to normalize the data (Clifford and Stephenson, 1975).

The next choice to be made involved the selection of a clustering algorithm. Agglomerative hierarchical clustering strategies are the most widely used in ecology (Boesch, 1977). A flexible clustering strategy proposed by Lance and Williams (1971) was used. This clustering method proceeds from the resemblance matrix by progressive fusion of stations or species. Stated simply, it scans the resemblance matrix for similar values of the dissimilarity coefficient. When a similar pair is found the two values are fused and the next most similar value is sought until the entire matrix has been scanned. The flexible strategy allows one to purposefully adjust the clustering intensity (i.e., the tendency to form new clusters rather than add entities to already existing ones). This is achieved by varying β, the clustering intensity coefficient. A value of $\beta = -0.25$ was used as it has produced satisfactory results in a wide range of studies (Boesch, 1977). At this level of β, flexible clustering is an intensely clustering, moderately space-dilating strategy. This means that as agglomerations are made, there is a bias against a station (or species) or group joining an already large group and a bias favoring stations (or species) or small groups joining to form separate branches of the hierarchy. In other words, as a group

Figure 3. Flow diagram for steps used in classification strategy.


DATA COLLECTION
DATA INSPECTION
SUBJECTIVE DECISIONS CONCERNING QUESTIONS OF IMPORTANCE TO INVESTIGATOR
SELECTION OF RESEMBLANCE MEASURE
NEED FOR TRANSFORMATION OR STANDARDIZATION
SELECTION OF CLUSTERING ALGORITHM
DENDROGRAM
REEXAMINATION OF DATA
REALLOCATION, DETERMINATION OF MISCLASSIFICATION
CONCLUSIONS

gets larger there is a disinclination for new stations (or species) to join it and a tendency to form new small groups.

With the above choices made, the cluster analysis was run using the NT-SYS programs of Rohlf et al. (1972) on a Univac 1110 Computer.

Diversity and Evenness

Diversity was calculated at each station for every sampling period using the Shannon-Wiener function:

$$H = -\sum_{i=1}^{s} (pi)(\log_2 pi)$$

where pi is the proportion of individuals belonging to the i th species.

Two components of diversity are combined in this function, the number of species present in the sample and the evenness of allotment of individuals among the species (Lloyd and Ghelardi, 1964). The evenness component was determined by calculating the following:

$$H_{max} = S(\frac{1}{s} \log_2 \frac{1}{s}) = \log_2 S$$

where H_{max} = species diversity under conditions of maximal evenness, S = number of species in the sample. Evenness is defined as the ratio:

$$E = \frac{H}{H_{max}}$$

The incorporation of two components, number of species present, and the evenness of allotment of individuals among species in the Shannon-Wiener function allows the species diversity (H) as measured by this function to be affected by two different aspects of the abundance data. Species diversity may be increased or decreased by changing the number of species present or by changing the allotment of individuals among species. The calculation of the E allows us to inspect the relative contribution of the evenness component to diversity.

RESULTS

Taxa

One hundred and seventy-nine invertebrate taxa were identified from the Lower Bay during the five sampling periods beginning in May 1979 and ending May 1980 (Table 1). These taxa included 92 species of polychaetes, 18 species of molluscs, 14 haustorid amphipods, 13 corophids, 8 gammarid amphipods, 7 decapods, 5 isopods, and 3 species of echinoderms. Several other genera were identified, such as, 2 holothurians and 4 caprellids. The number of nematode and oligochaete species is unknown, as these were not identified. The hierarchy presented in Table 1 is based on the nomenclature from Gosner (1971), Bousfield (1973), and Pettibone (1963). A total of 57 species, predominantely amphipods, have not been previously reported in the Lower Bay Complex. The majority of these new species are from Romer Shoal and a few, for example *Cerebratulus lacteus* and *Aricidea jeffreysii* were common at all three sites throughout the year. Ampeliscid amphipods, and the bivalves *Gemma gemma* and *Mulinia lateralis* were not found during the sampling although these have been previously reported at common.

Table 1. Taxa found in samples taken between May 1979 and May 1980 at stations on Old Orchard Shoal (OOS), Romer Shoal (RS), and East Bank (EB). A total of 179 species were recorded during the survey. IDENT refers to codes used in classification analysis in Fig. 15-18.

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	P. Cnidaria (Coelenterates)					
	C. Anthozoa					
	O. Actinaria					
	F. Metridiidae					
MET10	*Metridium senile*		RS	EB		
	P. Rhynchocoela (nemertean worms)					
	C. Anopla					
	O. Heteronemertea					
	F. Lineidae					
	Unidentif. spp.	RS,EB,OOS	RS,EB,OOS	RS,EB,OOS	EB,OOS	RS,EB,OOS
CER30	*Cerebratulus lacteus*	RS,EB,OOS	RS,EB,OOS	RS,EB,OOS	EB,OOS	RS,EB,OOS
	P. Aschelminthes					
	C. Nematoda					
NE40	Unidentif. spp.	RS,EB	RS,EB,OOS	RS,EB,OOS	EB,OOS	RS,EB
	P. Mollusca					
	C. Gastropoda					
	O. Mesogastropoda					

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	F. Calyptraeidae					
CRE50	*Crepidula fornicata*	RS		OOS		
CRE60	*Crepidula plana*	RS,OOS	RS	OOS	OOS	RS
	O. Neogastropoda					
	F. Muricidae					
URO70	*Urosalpinx* spp.			RS		
	F. Nassariidae					
NAS80	*Nassarius trivittatus*	RS,OOS	RS,OOS	RS,EB,OOS	OOS	RS
	O. Nudibranchia					
	F. Corambidae					
COR90	*Corambella depressa*					RS
	C. Bivalvia					
	O. Protobranchia					
	F. Nuculanidae					
NUC100	*Nuculana messanensis*		EB,OOS			
	O. Pteroconchida					
	F. Mytilidae					
MYT110	*Mytilus edulis*	RS,EB			EB	RS,EB
	O. Heterodontida					

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	F. Cardiidae					
LAE120	*Laevicardium mortoni*	RS				
CER130	*Cerastoderma pinnulatum*					
	F. Veneridae					
MER140	*Mercenaria mercenaria*	RS				EB
	F. Mactridae					
SPS150	*Spisula solidissima*	RS,EB,OOS	RS,EB	RS,EB,OOS	EB,OOS	RS,EB,OOS
	F. Tellinidae					
TEL160	*Tellina agilis*	RS,EB,OOS	RS,EB,OOS	RS,EB,OOS	EB,OOS	RS,EB,OOS
MAC170	*Macoma calcarea*					EB
	F. Solenidae					
ENS180	*Ensis directus*			EB		
SOL185	*Solen viridis*	EB		EB		EB,OOS
SIL190	*Siliqua costata*					RS
	F. Myidae					
MYA200	*Mya arenaria*	EB,OOS		RS,OOS		RS,OOS
	F. Hiatellidae					
HIA210	*Hiatella arctica*		RS			
	O. Teuthidida					
	F. Loliginidae					
	Loligo pealei	EB	EB			EB

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	P. Annelida					
	C. Polychaete					
	O. Phyllodocida					
	F. Phyllodocidae					
PHY220	Phyllodocid			00S		
PHY230	*Phyllodoce* spp.			00S		
PHY240	*Phyllodoce groenlandica*	RS				RS
PHY250	*Phyllodoce arenae*					RS
PHY260	*Phyllodoce mucosa*			RS		
PAR270	*Paranaitis speciosa*		RS,EB			
ETE280	*Eteone* spp.			00S		00S
ETE290	*Etone lactea*	RS				
ETE300	*Eteone trilineata*		RS	00S		
ETE310	*Eteone heteropoda*	EB	RS			00S
ETE320	*Eteone flava*	RS	RS,00S			
EUM330	*Eumida sanguinea*	RS		RS		RS,00S
EUL340	*Eulalia viridis*	00S	RS,EB	RS		
EUL350	*Eulalia bilineate*		RS,00S	00S		
NOT360	*Notophyllum*		EB			
	F. Polynoidae					
EUC370	*Eucranta villosa*	RS		RS		RS
LEP380	*Lepidametria commensalis*		EB			
LEP390	*Lepidametria* spp.					RS
LEP400	*Lepidonotus squamatus*	RS		RS		RS
HAR410	*Harmothoe imbricata*					RS
HAR420	*Harmothoe extenuata*	RS,00S	EB			

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	F. Sigalionidae					
SIG430	*Sigalione arenicola*	EB		EB		EB
	F. Glyceridae					
GLY440	*Glycera* spp.	RS	RS,OOS	OOS		
GLY450	*Glycera capitata*	RS,OOS	RS,EB,OOS	RS	OOS	RS,EB
GLY460	*Glycera americana*	RS,OOS	OOS	RS		RS
GLY470	*Glycera dibranchiata*	RS,OOS	RS,OOS	RS,OOS		RS,OOS
	F. Goniadidae					
GON480	*Goniadia maculata*	EB	OOS			
OPG490	*Ophioglycera gigantea*		RS			
	F. Chrysopetalidae					
DYS500	*Dysponetus pygmaeus*			EB		
	F. Nephtyidae					
NEP510	*Nephtys* spp.		RS		EB	RS,EB
NEP520	*Nephtys bucera*	RS,EB,OOS	RS,EB,OOS	RS,EB,OOS	EB,OOS	RS,EB,OOS
NEP530	*Nephtys incisa*					OOS
NEP540	*Nephtys picta*	RS	RS,EB,OOS			RS,EB
	F. Syllidae					
SYL550	Syllid					RS
AUT560	*Autolytus* spp.	RS	RS			
AUT570	*Autolytus fasciatus*	RS				
SYL580	*Syllides setosa*			RS		RS,EB

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	F. Hesionidae					
POD590	*Podarke obscura*	RS				
	F. Nereidae					
NER600	*Nereis* spp.		EB	RS		RS
NER610	*Nereis arenaceodonta*	RS,EB,OOS	RS	RS,OOS		RS
NER620	*Nereis succinea*		RS	RS,EB		RS
NER630	*Nereis diversicolor*		RS			
NER640	*Nereis pelagica*	OOS				
	O. Capitellida					
	F. Capitellidae					
CAP650	*Capitella capitata*	EB	RS	RS	EB,OOS	
CAP660	*Capitella* spp.		RS,EB,OOS			
	F. Maldanidae					
MAL670	Maldanid A	RS,EB,OOS	OOS	RS,EB,OOS	OOS	RS,OOS
MAL680	Maldanid B		OOS	OOS		EB
MAL690	Maldanid C	RS				
CLY700	*Clymenella* spp.		OOS		OOS	
	F. Opheliidae					
TRA710	*Travisia carnea*		RS			
OPH715	*Ophelia* spp.		OOS			
AMM720	*Ammotrypane aulogaster*	RS	OOS			
	O. Spionida					

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	F. Spionidae					
SPI730	Spionid	RS,EB	EB,00S			
SPI740	*Spio filicornis*		RS,EB,00S			
SCO750	*Scolecolepides viridis*	RS,EB,00S	RS,EB,00S	RS,EB,00S	00S	EB,00S
STR760	*Streblospio benedicti*	RS,EB,00S	00S	RS,00S	00S	RS,00S
SCL770	*Scolelepis squamata*	EB,00S	EB,00S	EB,00S	EB,00S	RS,EB,00S
PRI780	*Prionospio* spp.		EB,00S			
POL790	*Polydora* spp.					
POL800	*Polydora ligni*	EB,00S	EB,00S	RS		RS,EB,00S
SPI810	*Spiophanes bombyx*	RS,EB,00S	RS,EB,00S	RS,EB,00S	EB,00S	RS,EB,00S
DIS820	*Dispio uncinata*	00S				RS
SPI735	*Spio* spp.		RS			
	F. Paraonidae					
PAR830	*Paraonis* spp.	RS	RS,EB,00S	RS		
PAR840	*Paraonis gracilis*			RS,EB	EB	EB
ARI850	*Aricidea jeffreysii*	RS,EB,00S	RS,EB,00S	RS,EB,00S	00S	RS,EB,00S
ARI860	*Aricidea wassi*				EB	RS
	F. Sabellariidae					
SAB870	*Sabellaria vulgaris*	RS,EB,00S	RS,EB	RS,EB,00S		RS,EB
	O. Eunicida					
	F. Onuphidae					
ONU880	Onuphid			RS		
	F. Lumbrinereidae					
LUM890	Lumbrinerid	RS			EB,00S	

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
LUM900	*Lumbrineris acuta*			RS		
LUM910	*Lumbrineris brevipes*			RS		EB
LUM920	*Lumbrineris fragilis*				EB	
LUM930	*Lumbrineris tenuis*		OOS			
LUM940	*Lumbrineris impatiens*		RS			
	F. Arabellidae					
DRI950	*Drilonereis*				EB	RS
DRI950	*Drilonereis longa*	RS,OOS	RS,OOS	RS,OOS		RS,EB,OOS
	F. Dorvilleidae					
STA960	*Stauronereis caecus*		EB			
	O. Magelonida					
	F. Magelonidae					
MAG970	*Magelona rosea*	RS,EB	RS,EB	RS,EB,OOS	EB,OOS	RS,EB,OOS
	O. Ariciida					
	F. Orbiniidae					
OR3980	*Orbinia ornata*		EB	RS,EB		
SCP990	*Scoloplos robustus*			EB,OOS		
	O. Cirratulida					
	F. Cirratulidae					
CIR1000	Cirratulid					
CHA1010	*Chaetozone setosa*			EB		
THA1020	*Tharyx acutus*	RS,EB,OOS	RS,EB,OOS	RS,EB,OOS	EB,OOS	RS,EB,OOS
DOD1030	*Dodecaceria coralli*		RS			

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	O. Oweniida					
	F. Oweniidae					
OWE1040	Owenid			EB		
	O. Terebellida					
	F. Pectinariidae					
PEC1050	*Pectinaria gouldii*	EB,OOS	EB,OOS	OOS	OOS	RS
	F. Ampharetidae					
AMP1060	Ampharetid					
AMP1070	*Ampharete* spp.	RS				
ASA1080	*Asabellides oculata*	RS,EB,OOS	RS,EB,OOS	RS,OOS	OOS	RS,OOS
ANO1090	*Anobothrus gracilis*		OOS			
HYP1100	*Hypaniola grayi*	OOS	RS,OOS			
	O. Flabelligerida					
	F. Flabelligeridae					
BRA1110	*Brada* spp.	EB				
	O. Sabellida					
	F. Serpulidae					
HYD1120	*Hydroides dianthus*	RS	RS	RS		RS
MAR1130	C. Oligochaete		RS			
	P. Arthropoda					
	C. Merostomata					

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	O. Xiphosurida					
	F. Limulidae					
	Limulus polyphemus	OOS	OOS	OOS		RS
	C. Crustacea					
	O. Calanoida					
CEN1140	*Centropages hamatus*				EB	
	O. Thoracica					
	F. Balanidae					
BAL1150	*Balanus balanoides*	RS,OOS		OOS		
	O. Cumacea					
	F. Nannastacidea					
ALM1160	*Almyracuma* spp.					RS
	F. Diastylidae					
DIA1170	*Diastylis quadrispinosa*	EB				RS,OOS
DIA1180	*Diastylis polita*		EB			
COXY1190	*Oxyurostylis smithi*			RS		
	O. Tanaidacea					
	F. Tanaidae					
TAN1200	*Tanais* spp.		EB			
TAN1210	*Tanais cavolini*			EB		
	F. Paratanaidae					
LET1220	*Leptognatha* spp.	RS				

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	O. Isopoda					
IS01230	Isopod	OOS				
FLS1240	Flabelliferid		OOS			
	F. Anthuridae					
	Cyathura polita	RS	RS	RS		RS
	F. Aegidae					
AEG1260	*Aega psora*			RS		
	F. Idoteidae					
ED01270	*Edotea montosa*	RS				
ED01280	*Edotea triloba*			RS		
	O. Amphipods					
	F. Corophiidae					
COR1290	*Corophium* spp.		RS	RS		OOS
COR1295	*Corophium tuberculatum*				OOS	
COR1300	*Corophium acutum*			RS		
COR1310	*Corophium acherusicum*	RS				
COR1320	*Corophium bonelli*			RS	EB	RS
COR1330	*Corophium insidiosum*	RS	RS			
COR1340	*Corophium lacustre*			RS		RS
COR1360	*Corophium similis*	RS				
ERI1360	*Erichthonius brasiliensis*			RS		
UNI1370	*Unicola* spp.		RS,EB,OOS			
UNI1380	*Unicola irrorata*					RS
UNI1390	*Unicola serrata*	RS	EB			EB
UNI1400	*Unicola dissimilis*	RS		RS		RS

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	F. Haustoriidae					
BAT1490	*Bathyporeia quoddyensis*					EB
BAT1500	*Bathyporeia parkeri*	EB				
PRH1505	*Protohaustorius* spp.			RS		
PRH1510	*Protohaustorius deichmannae*	RS,EB	EB			
PRH1520	*Protohaustorius wigleyi*	RS,EB	RS,EB	RS,EB	EB	RS,EB
PAH1530	*Parahaustorius longimerus*	EB	RS,EB	EB	EB	EB
PAH1540	*Parahaustorius holmesi*	RS,EB	RS,EB	RS,EB		EB
PAH1550	*Parahuastorius attenuatus*	EB	EB	EB		EB
ACH1560	*Acanthohaustorius millsi*	RS,EB	RS,EB	RS,EB	EB	RS,EB
ACH1570	*Acanthohaustorius shoemakeri*		RS	RS		
ACH1580	*Acanthohaustorius intermedius*	RS,EB				
HAU1590	*Haustorius canadensis*		RS,EB			
NEH1600	*Neohaustorius biarticulatus*		EB			
HAU1595	Haustorid		RS,EB			
	F. Lysianassidae					
ORC1610	*Orchomonella pinquis*	EB				
	F. Phoxocephalidae					
PHO1620	*Phoxocephalus holbolli*	RS	RS	RS		RS
PAR1630	*Paraphoxus spinosus*	RS	RS,EB	RS		RS,EB
TRI1640	*Trichophoxus epistomus*	RS,EB	RS,EB	RS,EB		RS,EB
HAR1650	*Harpinia propinqua*		RS,EB			
	F. Gammaridea					
GAM1440	Gammaridian Amphipod	EB	RS,EB,OOS			RS,EB,OOS
GAM1410	*Gammarus oceanicus*			RS	EB	RS
GAM1420	*Gammarus lawrencianus*	RS,EB,OOS	RS,EB,OOS	RS,EB	EB,OOS	RS,EB
GAM1430	*Gammarus annulatus*	RS	RS,EB			
GAM1450	*Gammarus fasciatus*	RS				
ELA1460	*Elasmopus levis*	RS		RS		RS
	O. Caprellidea					

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	F. Caprellidae					
CAP1660	*Caprella* spp.		EB	RS		RS
CAP1670	*Caprella andreae*			RS		
CAP1680	*Caprella penantis*			RS		
CAP1690	*Caprella unica*			RS		
CAP1700	*Caprellid*	RS				EB
	O. Mysidacea					
	F. Mysidae					
NMY1710	*Neomysis americana*	OOS				OOS
HMY1720	*Heteromysis formosa*	RS		RS		OOS
	O. Decapoda					
	F. Crangonidae					
CRG1730	*Crangon septemspinosa*	EB,OOS	OOS	RS,EB,OOS	EB,OOS	EB,OOS
	F. Nephropsidae					
	Homarus americanus	OOS	RS,OOS	OOS	OOS	OOS
	F. Paguridae					
PAG1740	*Pagurus acadianus*	RS	RS,OOS			RS
PAG1750	*Pagurus longicarpus*	RS,OOS	EB,OOS			RS
PAG1760	*Pagurus pollicarus*	RS				EB
	O. Brachyuara					
	F. Majidae					
	Libinia emarginata			EB		EB

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	F. Cancridae					
CAN1780	*Cancer irroratus*	RS,OOS	RS,EB,OOS	RS,EB,OOS	EB,OOS	RS,EB
	F. Portunidae					
OVA1790	*Ovalipes ocellatus*	RS	RS,EB,OOS	RS,EB,OOS	EB	RS,EB,OOS
	Callinectes sapidus			EB		
	F. Xanthiadae					
EUR1800	*Eurypanopeus depressus*	RS	OOS			RS
	P. Echinodermata					
	C. Holothuroidea					
HOL1810	Holothurian		RS			
	F. Psolidae					
PSO1820	*Psolus* spp.		RS			
	C. Stelleroidae					
	O. Forcipulatida					
	F. Asteriidae					
AST1860	*Asterias forbesi*		RS,EB,OOS	RS,EB,OOS		RS,EB
	P. Chordata					
	C. Osteichthyes					
	O. Perciformes					
	F. Ammodytidae					
AMM1830	*Ammodytes americanus*	EB	EB	RS,EB	EB,OOS	

Table 1. (continued)

IDENT	Taxon	1979 May	July	Oct	1980 March	May
	O. Scorpanenidormes					
	F. Triglidae					
PN01840	*Prionotus evolans*		RS			
	F. Cottidae					
MY01850	*Myoxocephalus scorpius*			RS		

Abundance

One of the most basic pieces of information generated by a benthic survey is the abundance of organisms, usually expressed in terms of some unit of area (i.e, number of individuals$\cdot m^2$). Inspection of this type of data may reveal patterns of variation which can be related to factors affecting benthic organisms (e.g., geography, season, sediment type, etc.).

The abundance data collected as a result of this study were inspected in an effort to elucidate the spatial and temporal variation inherent in the macrobenthos of the Lower Bay. Figure 4 is a histogram depicting the Grand Mean Abundance (average number of individuals$\cdot m^2$ = GMA) for each of the samoling periods. The abundances at all 74 stations per cruise were used in calculating the GMA (49 in March 1980). These means were compared using a t-test and all data were $\sqrt{X + \frac{1}{2}}$ transformed. As can be seen from the histogram, the lowest GMA (212) occurred in July 1979 and the highest (491) occurred in May 1980. This initial comparison reveals the gross seasonal variation in abundance of the macrobenthos. Higher abundances were found in the spring and fall months than in the summer or winter sampling periods. The GMA for July was significantly lower than all other abundances except for March 1980 ($p < 0.05$). The highest GMA (May 1980) was significantly greater than the values for July and March

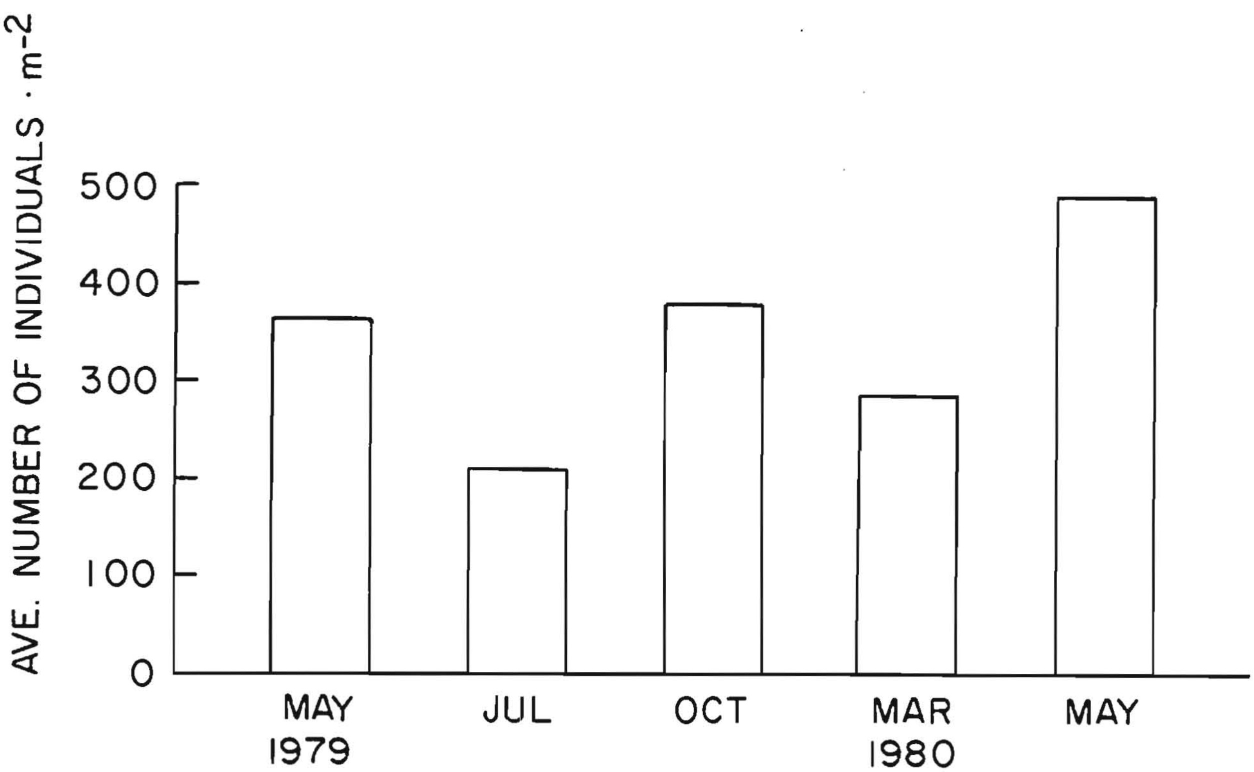
($p < 0.05$). No significant differences were observed between the GMA's for May 1980, October 1979, or May 1979. May 1979's abundance was not significantly greater than that of March.

A comparison of abundance was also made within sampling periods between sampling areas (see Fig. 2). Figure 5 presents the average number of individuals$\cdot m^2$ for each area during the sampling period. The values ranged from a low of $138 \cdot m^{-2}$ at the East Bank in March to a high of $713 \cdot m^{-2}$ at Old Orchard Shoal in May 1980. As can be seen, the values are lower for the East Bank at all times of the year except July, when no statistical difference was found for any area. The average number of individuals at Old Orchard and Romer Shoals did not differ at any time of the year.

Seasonal variation in abundance within each area was also examined by multiple comparisons using t-tests for each area over the year. Means were calculated from 25 stations for each sampling area (24 for the East Bank). Figure 6a shows that the highest number of individuals$\cdot m^{-2}$ at Old Orchard Shoal occurred in May 1980 (713) and the lowest in July 1979 (152). The abundances in May and October 1979, and March 1980 were not significantly different ($P < .05$). This pattern closely reflects the trends observed for the Grand Mean Abundance described earlier.

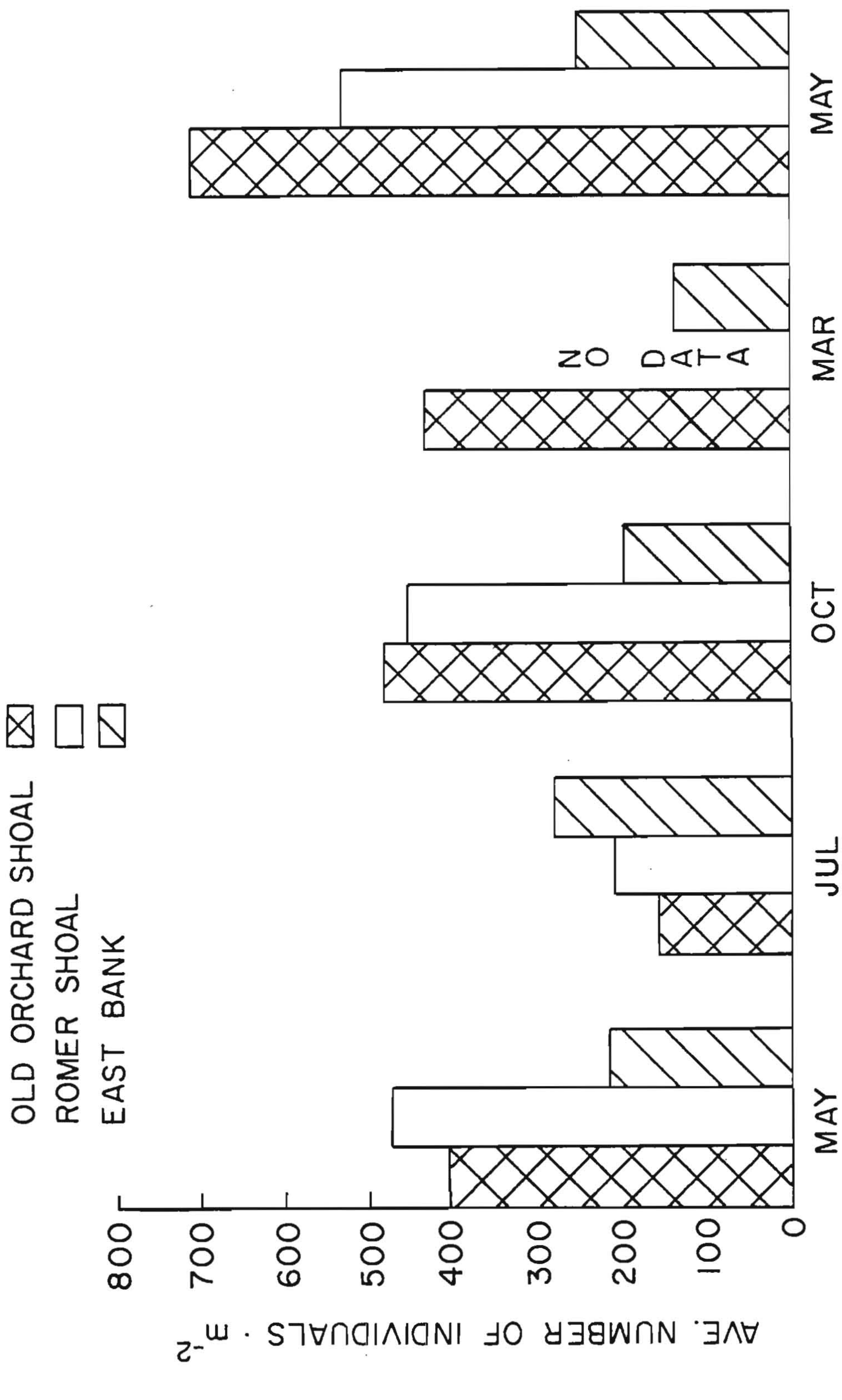
Mean abundance at Romer Shoal (Fig. 6b) fluctuated less over the year than it did at Old Orchard Shoal. Abundances in May

Figure 4. Grand Mean Abundance (GMA) for each sampling period. Means calculated from abundance data at 74 stations for each month on East Bank, Romer, and Old Orchard Shoals. Romer Shoal was not sampled in March 1980 (49 station total).



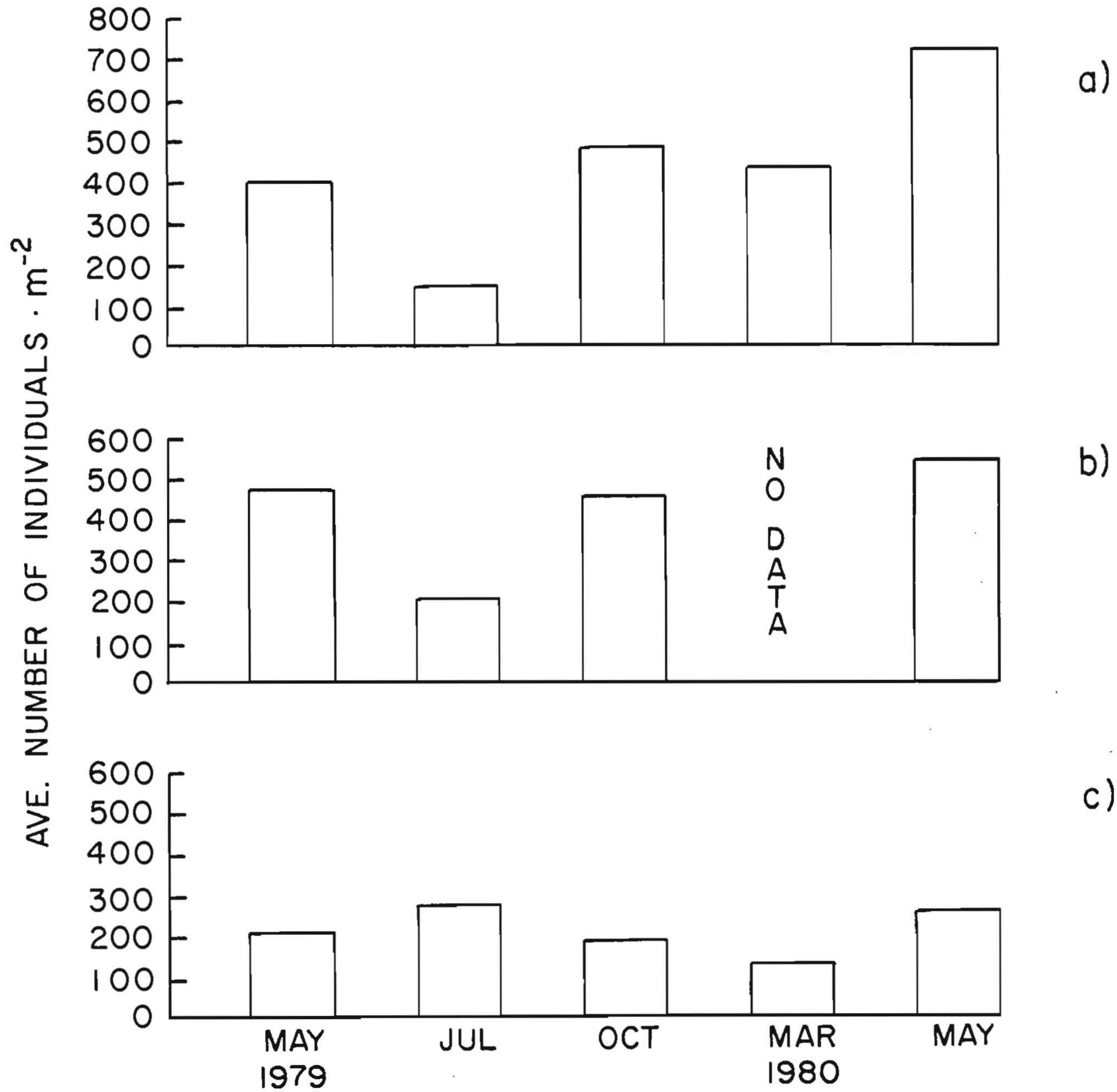
AVE. NUMBER OF INDIVIDUALS · m-2
500
400
300
200
100
0
MAY
1979
JUL
OCT
MAR
1980
MAY

Figure 5. Mean abundance of individuals at the 3 sampling sites during May 1979 to May 1980. Means calculated from 25 stations on Old Orchard Shoal and Romer Shoal and 24 stations at the East Bank.



AVE. NUMBER OF INDIVIDUALS · m-2
800
700
600
500
400
300
200
100
0
OLD ORCHARD SHOAL
ROMER SHOAL
EAST BANK
MAY
1979
JUL
OCT
MAR
1980
NO DATA
MAY

Figure 6. Mean number of individuals for each sampling site. Means calculated from 25 stations for Old Orchard Shoal (a) and Romer Shoal (b) and 24 stations at the East Bank (c).



800
700
600
500
400
300
200
100
0
a)
600
500
400
300
200
100
0
NO DATA
b)
600
500
400
300
200
100
0
c)
AVE. NUMBER OF INDIVIDUALS · m-2
MAY
1979
JUL
OCT
MAR
1980
MAY

and October 1979 and May 1980 were not significantly different, but the mean abundance was significantly lower in July ($P < .05$).

Fig. 6c shows the mean abundance values for the East Bank for each sampling period. It can be seen that the average abundance changed even less over the year than at Romer Shoal. No significant differences were determined between May, July, and October 1979 and May 1980. March 1980 abundance was significantly lower than that in October 1979 and May 1980, but was not different from May 1979 or July 1979.

Diversity

Diversity was tested for significant variation by ANOVA (Sokal and Rohlf, 1969). A transformation (Y^2) of mean diversity (average diversity of 24 or 25 stations in each area sampled) was found to normalize the data by the Kolmogorov-Smirnov test for goodness of fit to a normal distribution (Sokal and Rohlf, 1969). Therefore, all data were thus transformed prior to analysis by ANOVA. No significant added variation was found for the months of May 1979 or July 1979 (see Figure 7). Although the diversity for these three areas was not statistically different for these months, a trend is suggested: Old Orchard Shoal, having higher values, followed by Romer Shoal and the East Bank, with the latter having the lowest diversity. There was significant ($P < 0.05$) added variance for the months of October, March, and May 1980. The diversity data for these months were analyzed using the Student-Newman-Keuls test (Sokal and Rohlf, 1969). The results of these tests showed that diversity was significantly higher ($P < 0.01$) on Romer Shoal in October 1979 and May 1980 than on either Old Orchard Shoal or the East Bank, neither of which were statistically different during these two months. In March it was found that diversity was significantly higher ($P < 0.05$) on Old Orchard Shoal than on the East Bank.

Fluctuations in diversity within a given area over time were also tested. Using Y^2 transformed data, t-tests of means were carried out and the results are summarized in Figure 8. Figure 8a illustrates the fluctuation in diversity at Old Orchard Shoal. No significant difference was found between the mean diversities at this area during the sampling period. Figure 8b shows the same data for the Romer Shoal study area. Diversity was statistically similar in May and July 1979; October 1979 and May 1980 also had statistically similar diversities. However, the latter two months had significantly higher diversity values than the former pair ($P < 0.05$). This pattern reflects the variation in abundance, with higher abundances being observed in the fall and spring months. The average diversities for the East Bank are shown in Figure 8c. Diversity was higher in May 1980 than at any other time of the year and significantly greater ($P < 0.05$) than diversity in July and October 1979 and March 1980. It was not significantly different from the diversity in May 1979.

Figure 7. Mean diversity ($\overline{H}'$) at each sampling site for all sampling periods. Means calculated from 25 stations for Old Orchard Shoal and Romer Shoal and 24 for the East Bank.

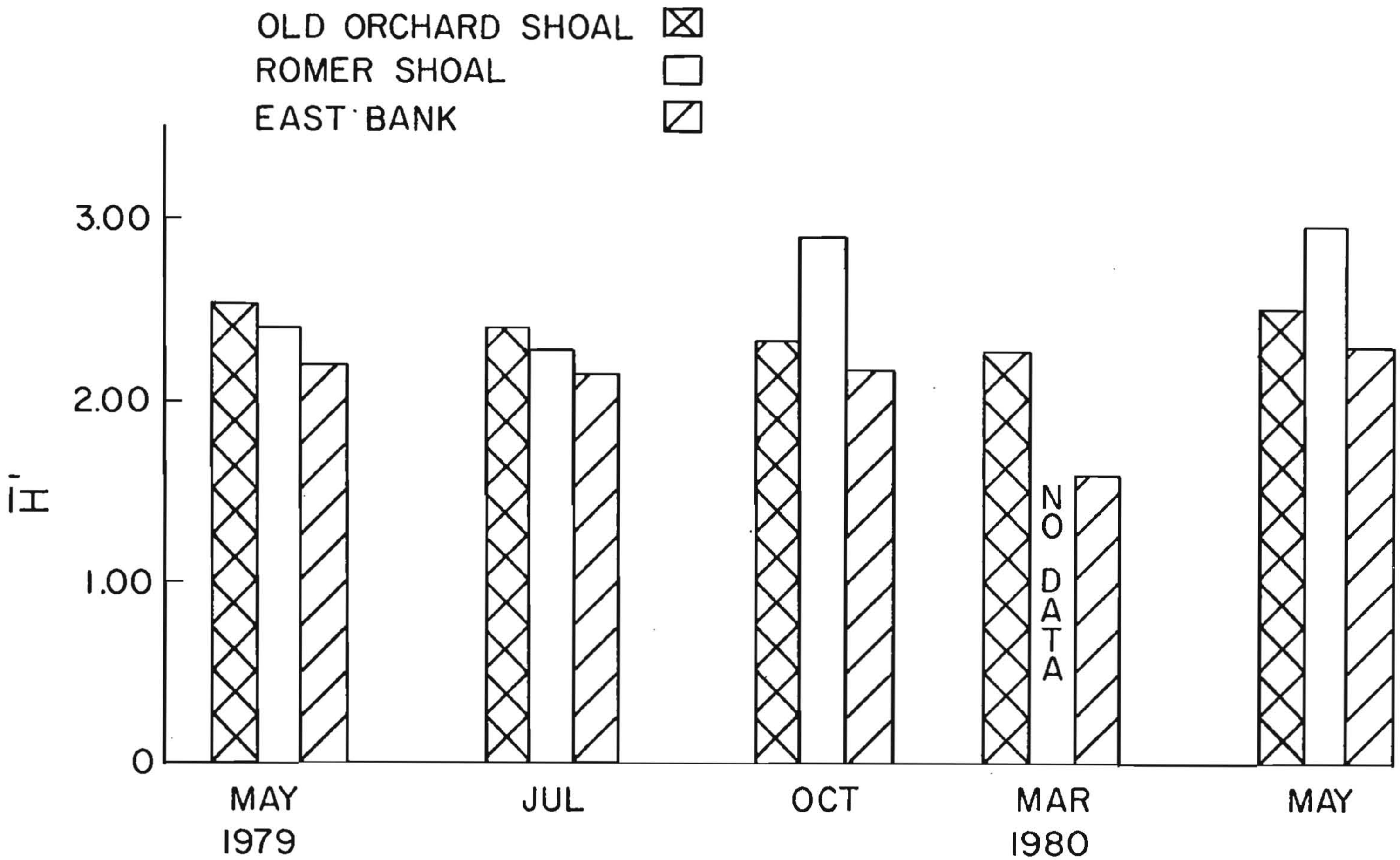

OLD ORCHARD SHOAL
ROMER SHOAL
EAST BANK
3.00
2.00
1.00
0
H'
NO DATA
MAY 1979
JUL
OCT
MAR 1980
MAY

Figure 8. Histrograms of mean diversity (H') for each area over the entire sampling period. Means based on 25 stations for Old Orchard Shoal (a) and Romer Shoal (b) and 24 stations for the East Bank (c).

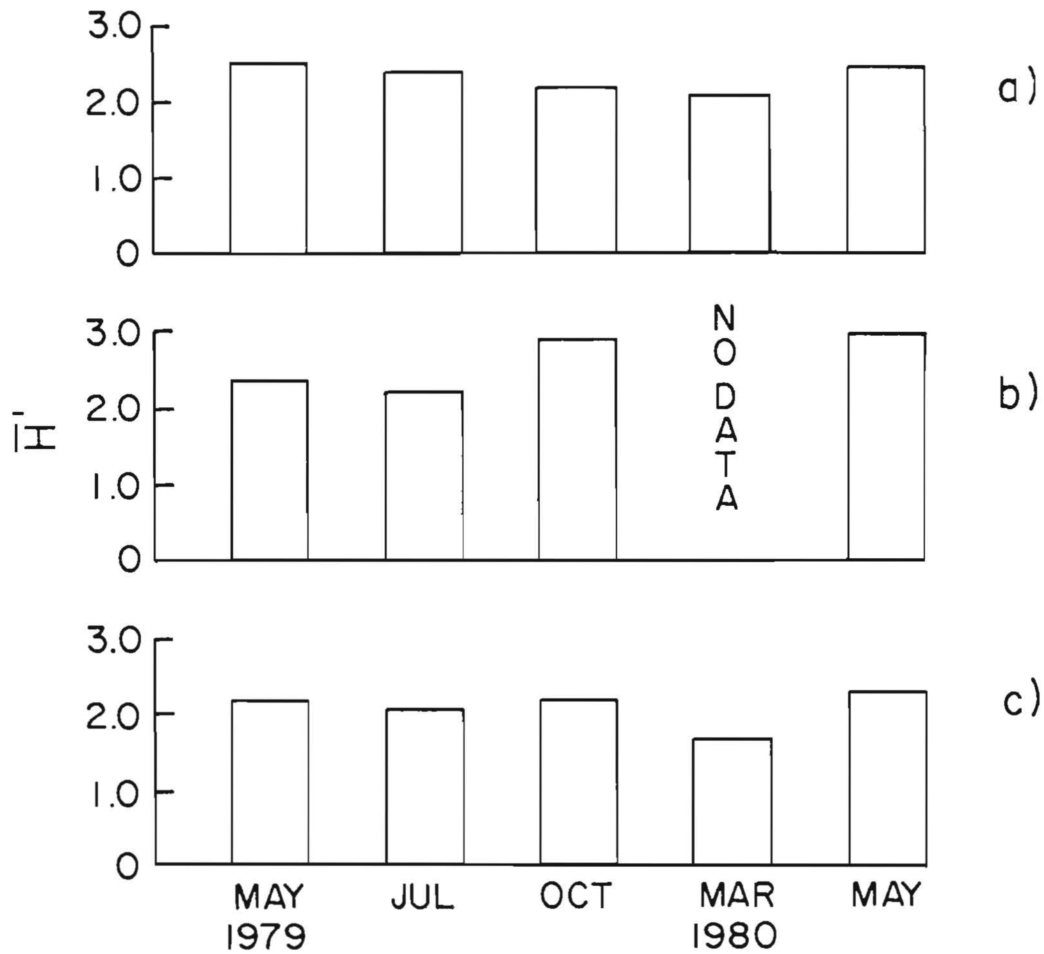

3.0
2.0
1.0
0
a)
NO DATA
b)
$\bar{H}$
c)
MAY
1979
JUL
OCT
MAR
1980
MAY

Table 2 summarizes the mean diversity for each area by month.

Evenness

Evenness was calculated for each station and the mean value for each area was computed (Table 2). The data were found to conform to the assumptions for ANOVA (Sokal and Rohlf, 1969), therefore no transformations were applied. The mean evenness values are illustrated graphically in Figure 9. The analysis of variance revealed that there was significant added variance in May 1979 and March 1980. Subsequent analysis using the SNK-test (Sokal and Rohlf, 1969) found that in May evenness was significantly greater on the East Bank than at Romer Shoal or Old Orchard Shoal ($P < 0.05$). In March 1980 the evenness was higher on the East Bank as compared to Old Orchard Shoal ($P < 0.05$). For all other times of the year evenness was not found to vary among areas.

Fluctuation of evenness within an area over time was analyzed by multiple comparison t-tests. Figure 10a depicts the mean evenness for Old Orchard Shoal. Analysis revealed that evenness was significantly greater ($P < 0.05$) in July than at any other time of the year. On Romer Shoal (Fig. 10b) evenness was higher in October 1979 and May 1980 than in May 1979 ($P < 0.05$). May 1979 was not statistically different from July 1979, and July was not significantly different from October 1979 or May 1980. Mean evenness on the East Bank (Fig. 10c) was not found to be

Table 2. Average Diversity ($\overline{H}'$) and Evenness ($\overline{E}$) at the three sampling sites during May 1979 to May 1980. Based on 25 stations at Old Orchard Shoal and Romer Shoal, and 24 stations at the East Bank. An asterisk (*) indicates significant statistical difference at $P < 0.05$ in comparisons between stations within a given month.

	AREA	$\overline{H}'$	$\overline{E}$
May 1979:	Old Orchard Shoal	2.504	0.7752
	Romer Shoal	2.420	0.7388
	East Bank	2.292	0.8521 *
July 1979:	Old Orchard Shoal	2.431	0.8704
	Romer Shoal	2.286	0.7924
	East Bank	2.148	0.8258
October 1979:	Old Orchard Shoal	2.332	0.7468
	Romer Shoal	2.862 *	0.8232
	East Bank	2.159	0.8054
March 1980:	Old Orchard Shoal	2.279 *	0.7504
	Romer Shoal	No Data	No Data
	East Bank	1.605	0.8912 *
May 1980:	Old Orchard Shoal	2.488	0.7484
	Romer Shoal	2.947 *	0.8320
	East Bank	2.310	0.8095

Figure 9. Mean Evenness ($\bar{E}$) for each area during each sampling period. Calculated on 25 stations for Old Orchard Shoal and Romer Shoal and 24 stations on the East Bank.

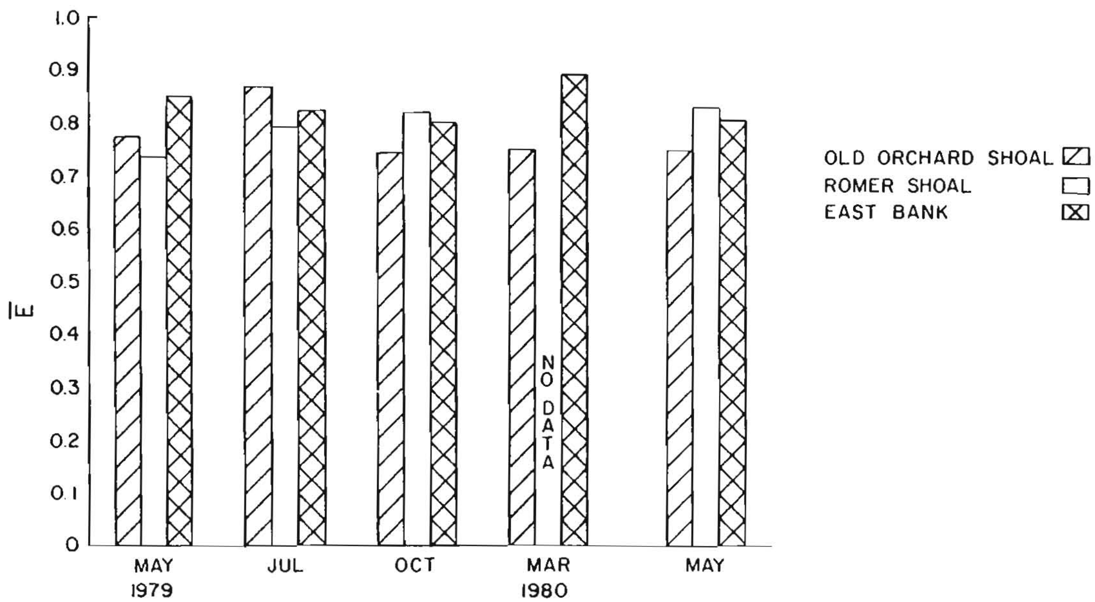
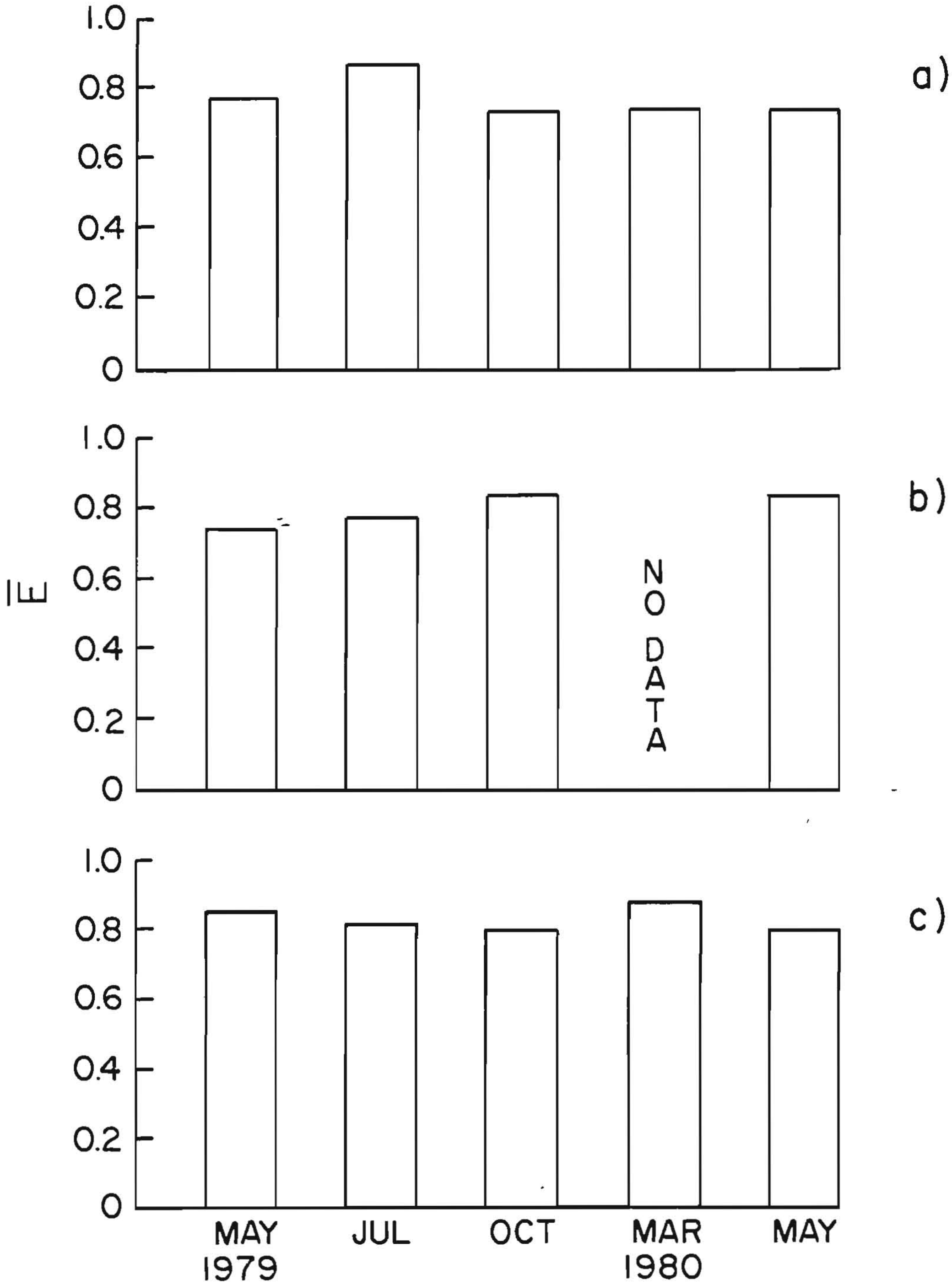

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$\overline{E}$
NO DATA
MAY
1979
JUL
OCT
MAR
1980
MAY
OLD ORCHARD SHOAL
ROMER SHOAL
EAST BANK

Figure 10. Mean Evenness ($\overline{E}$) for entire sampling period for each area. Calculated from 25 stations on Old Orchard Shoal (a) and Romer Shoal (b) and 24 stations on the East Bank (c).



a)
b)
c)
$\bar{E}$
1.0
0.8
0.6
0.4
0.2
0
NO DATA
MAY 1979
JUL
OCT
MAR 1980
MAY

statistically different at any time of the year with the exception that it was higher in March 1980 than in October 1979 ($P < 0.05$).

Dominant Species

Historically, the study of marine bottom communities has been based on dominant or "characterizing species" (Thorson, 1957), whereby communities are defined by the most numerically abundant species. A list of the numerically dominant species for each area in the present study is shown in Table 3, along with their percent frequency. Designations indicating some pertinent ecological information for each species (i.e., infauna, epifauna, deposit feeder, sediment preference, etc.) as gleaned from the literature are also presented in the table.

May 1979

In May, Old Orchard Shoal was dominated by the deposit-feeding, tube-dwelling polychaetes *Aricidea jeffreysii*, *Streblospio benedicti*, Maldanid A, and *Scolecolepides viridis*. These four polychaetes accounted for 61% of the total number of individuals encountered at this site. With the inclusion of the deposit feeding bivalve *Tellina agilis*, 72% of all individuals identified is accounted for. *A. jeffreysii* was particularly important, being found in large numbers at 23 of the 25 stations sampled. This species alone contributed 35% of all the individuals observed.

Table 3. Dominant species occurring at Old Orchard Shoal (OOS), Romer Shoal (RS), and East Bank (EB) during the sampling interval May 1979 to May 1980. Data are percent of total individuals of all species found at 25 stations each on OOS and RS and 24 stations on EB. Percent of stations these species were found at is also shown. The comments column includes life habit, feeding type, and sediment preference. See explanation of codes at end of table.

May 1979

Area	Species	% Total Individuals	% Stations Occurring	Comments*** Habit	Feeding	Sediment
OOS	*Aricidea jeffreysii*	35	92	IF	D	S-M
	Streblospio benedicti	12	72	IF	D	S-M
	Tellina agilis	11	92	IF	D	MS
	Maldanid A	9	76	IF	D	S-M
	Scolecolepides viridis	5	64	IF	D	M
RS	*Sabellaria vulgaris*	26	48	EF	S	H
	Hydroides dianthus	8	36	EF	S	H
	Acanthohaustorius millsi	8	36	IF	S	MFS
	Cyathura polita	6	28	IF	G,C	S
	Paraphoxus spinosus	5	24	IF	S	F
EB	**Scolecolepides viridis*	14	4	IF	D	M
	***Tellina agilis*	13	54	IF	D	MS
	Spisula solidissima	10	62	IF	S	S

* All individuals found at station EB6, ** 11% found at EB6

Table 3. (continued)

May 1979 (continued)

Area	Species	% Total Individuals	% Stations Occurring	Comments: Habit	Comments: Feeding	Comments: Sediment
EB	*Acanthohaustorius millsi*	10	71	IF	S	S
	Parahaustorius longimerus	9	58	IF	S	S
	Protohaustorius wigleyi	5	62	IF	S	S
	**Asabellides oculata*	3	4	IF	D	F
	Ammodytes americanus	2	38	IF	P	S
July 1979						
OOS	*Scolecolepides viridis*	21	72	IF	D	M
	Aricidea jeffreysii	18	64	IF	D	S-M
	Tellina agilis	8	72	IF	D	MS
	Streblospio benedicti	8	52	IF	D	S-M
	Maldanid A	5	44	IF	D	S-M
RS	*Acanthohaustorius millsi*	18	48	IF	S	S
	Tharyx acutus	11	28	IF	D	M
	Sabellaria vulgaris	11	16	EF	S	H
	Trichophoxus epistomus	7	68	EF	C	F
	Gammarus lawrencianus	3	16	IF	D	S

* All individuals found at station EB6

Table 3. (continued)

July 1979 (continued)

Area	Species	% Total Individuals	% Stations Occurring	Comments		
				Habit	Feeding	Sediment
EB	**Tellina agilis*	30	58	IF	D	MS
	Spisula solidissima	19	54	IF	S	S
	Parahaustorius longimerus	7	50	IF	S	S
	Acanthohaustorius millsi	5	71	IF	S	S
	***Scolecolepides viridis*	5	4	IF	D	M
	Protohaustorius wigleyi	5	46	IF	S	S
October 1979						
OOS	*Aricidea jeffreysii*	38	92	IF	D	S-M
	Tharyx acutus	12	64	IF	D	M
	Tellina agilis	10	96	IF	D	MS
	Streblospio benedicti	9	60	IF	D	M
	Nephtys bucera	9	88	IF	C	S
RS	*Eulalia viridis*	11	24	EF	C	S-M
	Elasmopus levis	9	20			
	Paraphoxus spinosus	9	40	IF	S	F
	Acanthohaustorius millsi	8	52	IF	S	MFS
	Trichophoxus epistomus	6	72	EF	C	F

* (16% at EB11, 9% at EB10), ** (all at one station, EB 11)

Table 3. (continued)
October 1979 (continued)

Area	Species	% Total Individuals	% Stations Occurring	Habit	Comments Feeding	Comments Sediment
EB	*Paraonis gracilis*	30	54	IF	D	S
	Spisula solidissima	20	96	IF	S	S
	Acanthohaustorius millsi	10	46	IF	S	S
	Magelona rosea	8	71	IF	D	
	Protohaustorius wigleyi	3	42	IF	S	S
March 1980						
OOS	*Aricidea jeffreysii*	47	92	IF	D	S-M
	Tharyx acutus	13	68	IF	D	M
	Nephtys bucera	12	96	IF	C	S
	Tellina agilis	8	88	IF	D	MS
	Maldanid A	5	80	IF	D	S-M
EB	*Spisula solidissima*	35	79	IF	S	S
	Paraonis gracilis	14	29	IF	D	S
	Gammarus lawrencianus	16	46	IF	D	S
	Acanthohaustorius millsi	6	33	IF	S	S
	Protohaustorius wigleyi	4	29	IF	S	S

Table 3. (continued)

May 1980

Area	Species	% Total Individuals	% Stations Occurring	Habit	Feeding	Sediment
					Comments	
OOS	*Aricidea jeffreysii*	33	96	IF	D	S-M
	Polydora ligni	21	84	IF	D	M
	Scolecolepides viridis	15	64	IF	D	M
	Nephtys bucera	8	92	IF	C	S
	Tellina agilis	7	92	IF	D	MS
RS	**Mytilus edulis*	9	16	EF	S	H
	Tellina agilis	8	80	IF	D	MS
	Acanthohaustorius millsi	8	58	IF	S	S
	Cyathura polita	7	20	IF	G,C	F
	Spisula solidissima	7	68	IF	S	S
EB	*Tellina agilis*	26	79	IF	D	MS
	Spisula solidissima	16	88	IF	S	S
	Acanthohaustorius millsi	8	58	IF	S	S
	Protohaustorius wigleyi	5	54	IF	S	S
	Scolelepis squamata	4	58	IF	D,S	S

* (6% at Station RS2, 3% at RS1)

Table 3. (continued)

Table of Dominant Species

Legend

IF	=	infaunal	S-M	=	sand to mud
EF	=	epifaunal	M	=	mud
D	=	deposit feeder	S	=	sand
S	=	suspension or filter feeder	MS	=	muddy sand
C	=	carnivore	F	=	fine sand
G	=	grazer	H	=	hard substrate
			MFS	=	mud to fine sand

*** Information obtained from:

Bousfield (1973)
Burbanck (1972)
Gosner (1971)
Hartman (1945)
Pearson and Rosenberg (1978)
Pettibone (1963)
Rhoads (1974)

Romer Shoal was characterized by a different group of dominant species. This group was composed of the infaunal and epifaunal suspension feeders *Sabellaria vulgaris, Hydroides dianthus, Acanthohaustorius millsi*, and *Paraphoxus spinosus*. These, together with the infaunal grazer/carnivore *Cyathura polita,* contributed 53% of the total number of individuals. S. vulgaris, the numerically dominant species, was encountered at 12 stations and accounted for 26% of all the individuals identified.

The preponderant number of individuals on the East Bank belonged to the species *Scolecolepides viridis, Tellina agilis, Spisula solidissima, Acanthohaustorius millsi,* and *Parahaustorius longimerus.* This group exhibits a mixture of both deposit and suspension filter feeding organisms. However, all of the individuals of *S. viridis* and 83% of the *T. agilis* were found at one station, EB 6. If this station were excluded the list of dominants would read: *S. solidissima, A. millsi, P. longimerus, Protohaustorius wigleyi,* and the Sand Lance (*Ammodytes americanus*). This latter group of species would then account for 53% of all individuals. This new grouping includes five suspension feeding infaunal species and one infaunal predator. It is also worth noting that three of the dominants are Haustorid amphipods, species well adapted for rapid burrowing in high energy sand environments.

July 1979

The same five species dominated Old Orchard Shoal in July as in May. The order was slightly different, however, with *Scolecolepides viridis* replacing *Aricidea jeffreysii* as the most numerous species. The hierarchy now reads: *S. viridis*, *A. jeffreysii*, *Tellina agilis*, *Streblospio benedicti*, and Maldanid A. These species contributed 60% of the total number of individuals. *S. viridis* and *A. jeffreysii* accounted for 39% of all individuals. As in May, this group is exclusively composed of infaunal deposit feeding organisms, four of them polychaetes and one a bivalve.

The dominant species on Romer Shoal included *Acanthohaustorius millsi*, *Tharyx acutus*, *Sabellaria vulgaris*, *Trichophoxus epistomus*, and *Gammarus lawrencianus*. This group contributed 50% of the individuals to the total collection. As in May this group is a collection of infaunal and epifaunal species exhibiting suspension, deposit, and carnivorous feeding strategies. This group included three amphipods and only two polychaetes, as opposed to the group that dominated Old Orchard Shoal.

The East Bank was dominated by *Tellina agilis*, *Spisula solidissima*, *Parahaustorius longimerus*, *Acanthohaustorius millsi*, and *Scolecolepides viridis*. All of the individuals of S. viridis were found at one station, EB 11. If this station is omitted the list would read, *S. solidissima*, *T. agilis*, *P. longimerus*, *A. millsi*, and *Protohaustorius wigleyi*, with these species contributing 63% of all individuals. This grouping is composed of infaunal species, four of which are suspension/filter feeders and one a deposit feeder. As in May, three of the five dominants are Haustorid amphipods.

October 1979

In October the list of dominant species on Old Orchard Shoal changed with the addition of two new polychaete species, *Tharyx acutus* and *Nephtys bucera*. Once again *Aricidea jeffreysii* was the dominant species, accounting for 38% of all the individuals collected. As in the previous sampling periods, the group of dominants is preponderantly infaunal deposit feeding polychaetes along with the deposit feeding clam *Tellina agilis*. The five species accounted for 78% of all individuals collected.

The dominant species on Romer Shoal were again a mixture of epifaunal and infaunal organisms. Only one polychaete (*Eulalia virdis*) is among the five dominants; the four other species are amphipods. Two of these important species are suspension feeders, while *E. viridis* and *Trichophoxus epistomus* are carnivores. Together, these five species contributed 43% of the total number of individuals.

The East Bank was dominated by a mixed group of infaunal deposit and suspension/filter feeding species, including the polychaete *Paraonis gracilis*, the bivalve *Spisula solidissima*, the amphipod *Acanthohaustorius millsi*, the polychaete *Magelona* *rosea*, and the Haustorid amphipod *Protohaustorius wigleyi*. As before on the East Bank, Haustorid amphipods are among the important species. The five species in this group accounted for 71% of all the individuals.

March 1980

Due to weather conditions, only Old Orchard Shoal and the East Bank were sampled in March. The dominant species on Old Orchard Shoal were *Aricidea jeffreysii*, *Tharyx acutus*, *Nephtys bucera*, *Tellina agilis*, and Maldanid A. These five species comprised 85% of all individuals collected. The group was composed of infaunal deposit feeders, with the exception of the carnivorous polychaete *N. bucrea*. *A. jeffreysii* was again the dominant organism, contributing 47% of the individuals collected.

The East Bank was once again dominated by a combination of infaunal suspension/filter feeders and deposit feeders. One bivalve, one polychaete, and three amphipod species comprised the group. The Haustorid amphipods *Acanthohaustorius millsi* and *Protohaustorius wigleyi* were again important.

May 1980

The final month sampled in this study yielded similar geographically distinct feeding type groups. On Old Orchard Shoal, the Paraonid polychaete *Aricidea jeffreysii* once again dominated the area, occurring in large numbers at 24 of the 25 stations. A new species became important in May -- *Polydora ligni*, a Spionid polychaete. This species was found in very low numbers in May 1979. Other dominants were: *Scolecolepides viridis*, *Nephtys bucera*, and *Tellina agilis*. With the exception of *N. bucera*, all of these species are infaunal deposit feeders and were also dominant in May 1979. In May 1980, 84% of all the individuals collected belonged to one of these five species.

The dominant group on Romer Shoal was a combination of one epifaunal and four infaunal species. *Mytilus edulis*, the single most numerous species, was encountered at only two station, RS 1 and RS 2. *Cyathura polita* was among the dominant species, repeating the pattern observed in May 1979. The feeding strategy of the dominants was a mixture of primarily deposit and suspension feeders, with the notable exception of *Cyathura polita*, a grazer/carnivore.

Tellina agilis, *Spisula solidissima*, *Acanthohaustorius millsi*, *Protohaustorius wigleyi* and *Scolelepis squamata* were the numerically important species on the East Bank. With the exception of *S. squamata*, these species were also important in May 1979. This group is composed predominantly of infaunal suspension/filter feeders, with the exception of *Tellina agilis*. The Haustorid amphipods are among the dominant species at the East Bank stations as they were during all the previous sampling periods.

Summary

A consistent pattern may be seen by inspection of the annual fluctuation of the dominant species at the three areas. In general, Old Orchard Shoal is consistently dominated by infaunal deposit feeding polychaetes, in particular *Aricidea jeffreysii*. The dominant group on Romer Shoal tended to be composed of a combination of infauna and epifauna which were either deposit feeders or suspension/filter feeders. *Acanthohaustorius millsi* is a consistent member of this group. The East Bank stations were characterized by the predominance of infaunal suspension/filter feeders, such as the Haustorid amphipods *Acanthohaustorius millsi* and *Protohaustorius wigleyi*. However, the deposit feeders *Tellina agilis* and *Paraonis gracilis* were also important at various times of the year.

Normal Classification

The interesting faunal groups resulting from the inspection of the dominant species led to the application of cluster analysis in an attempt to objectively test the notion that the three areas did indeed differ based on the species present. The analysis was performed only on the data for May 1979, July 1979, October 1979, and March 1980. The results are presented as dendrograms.

For May (Figure 11) three main groups were found at the 0.266 resemblance level. Group I contained thirteen of the twenty-five Romer Shoal stations. Group II incorporated twenty-four of the Old Orchard Shoal stations, with only one station from this area not clustering with the others. Group III included twenty-three of the twenty-four East Bank stations, plus twelve stations from Romer Shoal and one from Old Orchard Shoal. Upon reexamination of the original data, the lone Old Orchard Shoal station, OOS A, was reallocated to Group II. This station exhibited the typical dominance features of other stations in Group II. *A. jeffreysii* contributed 72% of the total individuals, deposit feeding polychaetes were present and no amphipods or epifaunal species were encountered. The inclusion of so many Romer Shoal stations in Group III was not surprising due to the large overlap of similar species between it and the East Bank. Six of the Romer Shoal stations and one East Bank station join Group III as a small cluster at the 0.183 level and could quite reasonably be considered a separate subgroup. Station EB 6 did not join any cluster until the 0.344 level where it fused with Group II, the predominantly Old Orchard Shoal cluster. Reference back to the original data supports this grouping - EB 6 had an anomalously high abundance ($1833 \cdot m^{-2}$) and had large numbers of *Tellina agilis* and *Scoleco-lepides viridis*, both of which are typically found at Old Orchard Shoal stations. To summarize briefly, Group I was composed primarily of Romer Shoal stations, Group II of Old Orchard Shoal stations, and Group III had a preponderance of East Bank stations.

Figure 12 presents the results from clustering the stations from July by species. The clustering is broken into five major

Figure 11. Dendrogram of normal classification for May 1979 stations.

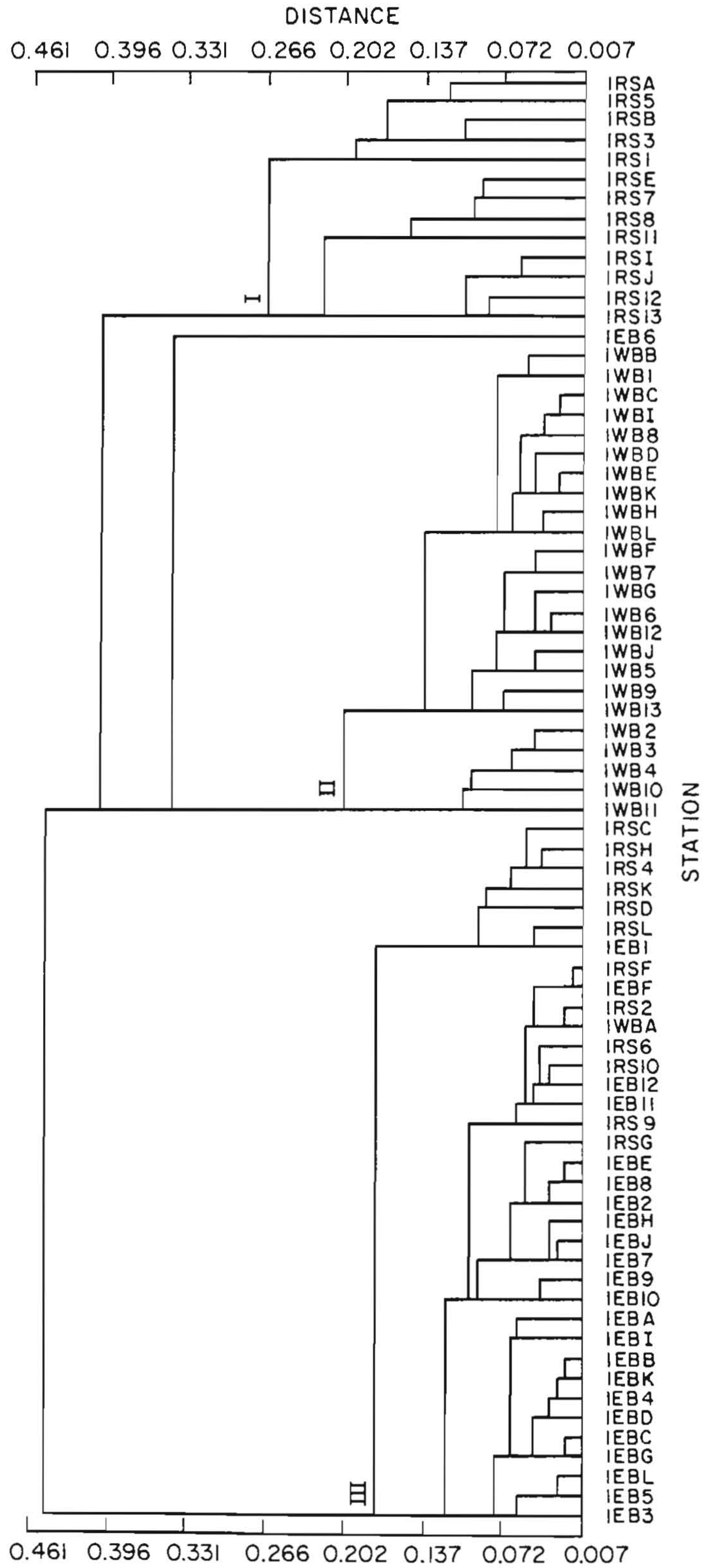
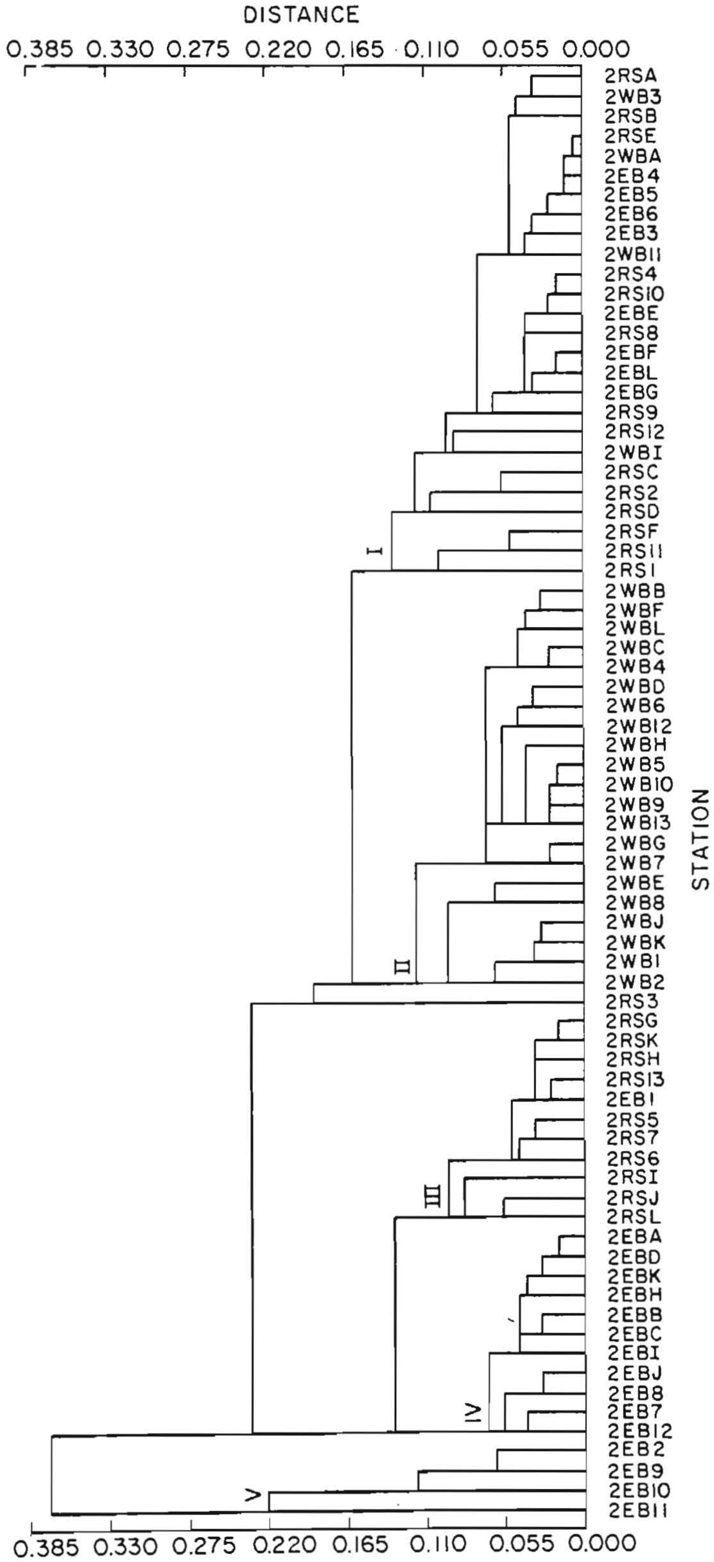

DISTANCE
0.461 0.396 0.331 0.266 0.202 0.137 0.072 0.007
IRSA
IRS5
IRSB
IRS3
IRS1
IRSE
IRS7
IRS8
IRS11
IRSI
IRSJ
IRS12
IRS13
IEB6
IWBB
IWB1
IWBC
IWBI
IWB8
IWBD
IWBE
IWBK
IWBH
IWBL
IWBF
IWB7
IWBG
IWB6
IWB12
IWBJ
IWB5
IWB9
IWB13
IWB2
IWB3
IWB4
IWB10
IWB11
IRSC
IRSH
IRS4
IRSK
IRSD
IRSL
IEB1
IRSF
IEBF
IRS2
IWBA
IRS6
IRS10
IEB12
IEB11
IRS9
IRSG
IEBE
IEB8
IEB2
IEBH
IEBJ
IEB7
IEB9
IEB10
IEBA
IEBI
IEBB
IEBK
IEB4
IEBD
IEBC
IEBG
IEBL
IEB5
IEB3
I
II
III
STATION
0.461 0.396 0.331 0.266 0.202 0.137 0.072 0.007

Figure 12. Dendrogram of normal classification for July 1979 stations.


DISTANCE
0.385 0.330 0.275 0.220 0.165 0.110 0.055 0.000
2RSA
2WB3
2RSB
2RSE
2WBA
2EB4
2EB5
2EB6
2EB3
2WB11
2RS4
2RS10
2EBE
2RS8
2EBF
2EBL
2EBG
2RS9
2RS12
2WBI
2RSC
2RS2
2RSD
2RSF
2RS11
2RS1
2WBB
2WBF
2WBL
2WBC
2WB4
2WBD
2WB6
2WB12
2WBH
2WB5
2WB10
2WB9
2WB13
2WBG
2WB7
2WBE
2WB8
2WBJ
2WBK
2WB1
2WB2
2RS3
2RSG
2RSK
2RSH
2RS13
2EB1
2RS5
2RS7
2RS6
2RSI
2RSJ
2RSL
2EBA
2EBD
2EBK
2EBH
2EBB
2EBC
2EBI
2EBJ
2EB8
2EB7
2EB12
2EB2
2EB9
2EB10
2EB11
I
II
III
IV
V
STATION
0.385 0.330 0.275 0.220 0.165 0.110 0.055 0.000

groups, all forming below the 0.220 level. Group I contains fourteen Romer Shoal stations, eight East Bank stations, and four stations from Old Orchard Shoal. Inspection of the original data would suggest that all four Old Orchard Shoal stations are misallocated to this Group and could be justifiably reallocated to Group II. All four of these stations were dominated by deposit feeding polychaetes, typical of Old Orchard Shoal. The frequency of East Bank stations in Group I is again not surprising, considering the frequent occurrence of similar species at both Romer Shoal and the East Bank. Group II is formed at the 0.126 resemblance level and is composed exclusively of Old Orchard Shoal stations. Twenty-one of a possible twenty-five stations clustered in this Group. Group III forms at the 0.099 level and contains ten Romer Shoal stations and one East Bank station. Group IV congeals at the 0.066 level and is composed of eleven East Bank stations. The last cluster, Group V, does not form until the 0.220 level and is composed of only four East Bank stations.

To summarize, Group I is composed predominantly of Romer Shoal stations and after reallocation of the Old Orchard Shoal stations, it overlaps only with stations from the East Bank. Group II contains Old Orchard Shoal stations exclusively. Group III contains ten Romer Shoal stations which cluster more closely with the East Bank stations of Group IV than with the other Romer Shoal stations in Group I. Group V is composed of East Bank stations.

The results of the normal analysis for the October 1979 sampling period are presented in Figure 13. The dendrogram can be divided into three main clusters. Group I congeals at the 0.391 level and is composed entirely of Romer Shoal stations. Group II is a composite group incorporating twenty-three of the twenty-four East Bank stations and thirteen Romer Shoal stations plus one Old Orchard Shoal station (OOS A). Group III consolidated at the 0.241 level and is composed of twenty-four of the twenty-five Old Orchard Shoal stations plus one station from the East Bank (EB 12). Station EB 12 is a somewhat atypical East Bank station. *Tellina agilis* and *Nephtys bucera* accounted for 66% of the individuals. Both these species are more common at Old Orchard Shoal than on the East Bank. Once again we see that the three geographical areas cluster separately, with some overlap between Romer Shoal and East Bank station.

In March 1980 only Old Orchard Shoal and the East Bank were sampled. The dendrogram in Figure 14 presents the results of clustering. The separation of geographically distinct stations was almost perfect. Only two main groups can be identified both forming at or below the 0.364 level. Group I contained all of the East Bank stations and one Old Orchard Shoal station. (Station OOS A, clustered with East Bank stations, as in May. Inspection of the original data indicates that this station should be reallocated to Group II.) Group II consisted of all

Figure 13. Dendrogram of normal classification for October 1979 stations.

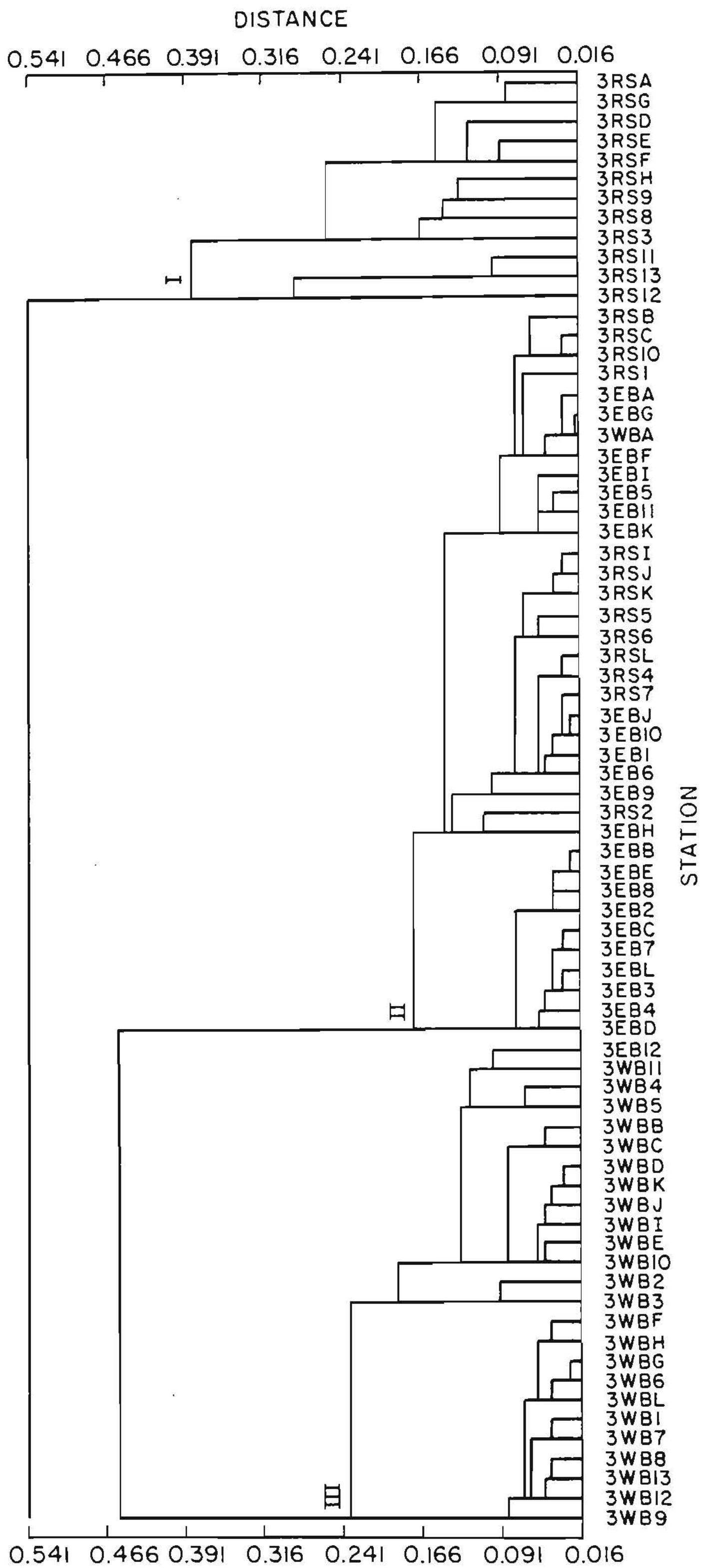
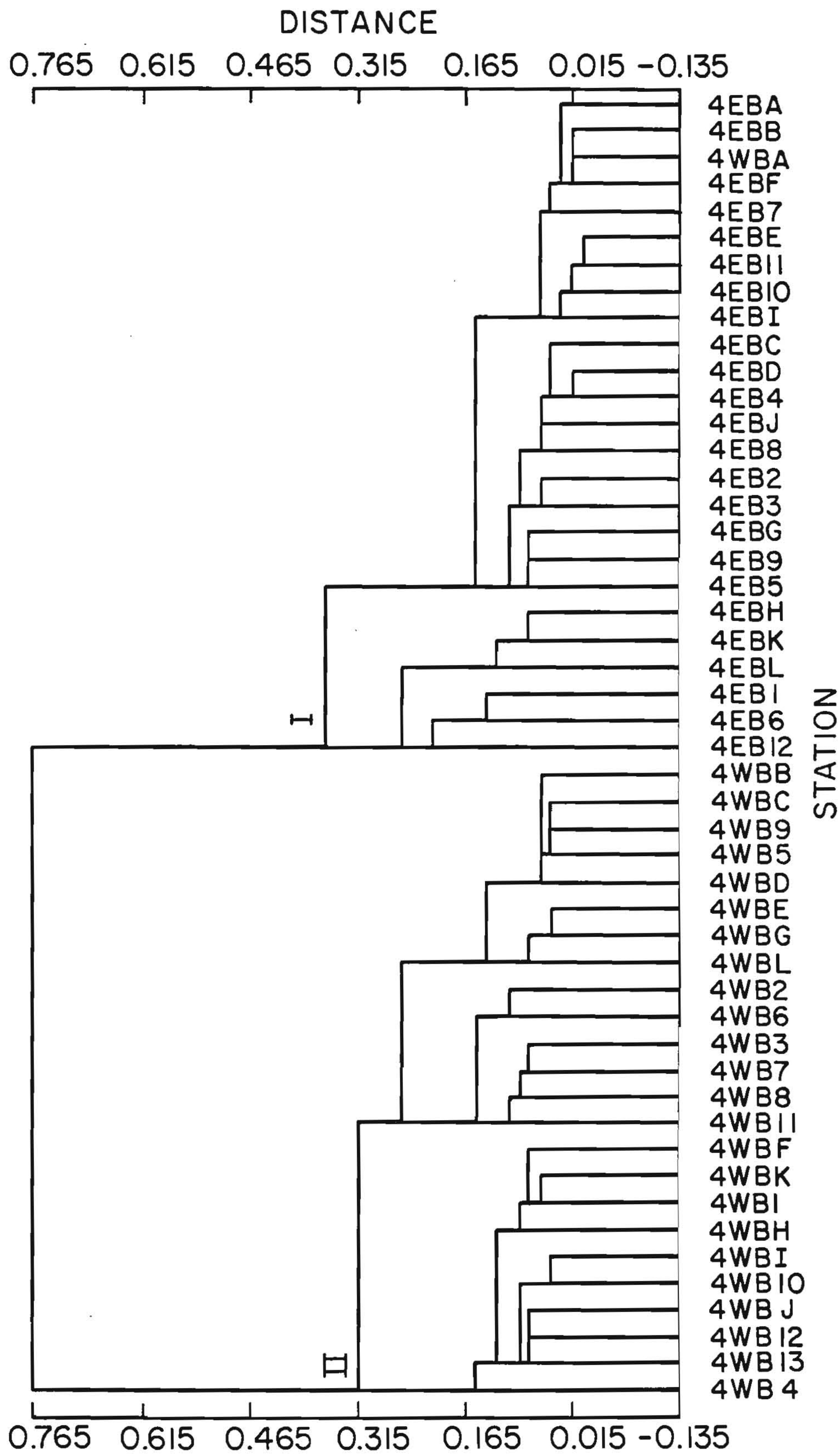

DISTANCE
0.541 0.466 0.391 0.316 0.241 0.166 0.091 0.016
3RSA
3RSG
3RSD
3RSE
3RSF
3RSH
3RS9
3RS8
3RS3
3RS11
3RS13
3RS12
3RSB
3RSC
3RS10
3RS1
3EBA
3EBG
3WBA
3EBF
3EBI
3EB5
3EB11
3EBK
3RSI
3RSJ
3RSK
3RS5
3RS6
3RSL
3RS4
3RS7
3EBJ
3EB10
3EB1
3EB6
3EB9
3RS2
3EBH
3EBB
3EBE
3EB8
3EB2
3EBC
3EB7
3EBL
3EB3
3EB4
3EBD
3EB12
3WB11
3WB4
3WB5
3WBB
3WBC
3WBD
3WBK
3WBJ
3WBI
3WBE
3WB10
3WB2
3WB3
3WBF
3WBH
3WBG
3WB6
3WBL
3WB1
3WB7
3WB8
3WB13
3WB12
3WB9
I
II
III
STATION
0.541 0.466 0.391 0.316 0.241 0.166 0.091 0.016

Figure 14. Dendrogram of normal classification for March 1980 stations.


DISTANCE
0.765 0.615 0.465 0.315 0.165 0.015 -0.135
4EBA
4EBB
4WBA
4EBF
4EB7
4EBE
4EB11
4EB10
4EBI
4EBC
4EBD
4EB4
4EBJ
4EB8
4EB2
4EB3
4EBG
4EB9
4EB5
4EBH
4EBK
4EBL
4EB1
4EB6
4EB12
4WBB
4WBC
4WB9
4WB5
4WBD
4WBE
4WBG
4WBL
4WB2
4WB6
4WB3
4WB7
4WB8
4WB11
4WBF
4WBK
4WB1
4WBH
4WBI
4WB10
4WBJ
4WB12
4WB13
4WB4
I
II
STATION
0.765 0.615 0.465 0.315 0.165 0.015 -0.135

the remaining Old Orchard Shoal station, clearly indicating the dissimilar nature of the species abundances at these two areas.

Inverse Classification

Efficacious clustering of species was more difficult and the results less clear than those from normal analysis. The problem of chaining (Clifford and Stephenson, 1975) was common, leading to large clusters with little ecological insight. However, some interesting groups were identified using this method.

Figure 15 shows the results as a dendrogram for the May 1979 sampling period. Five groups were identified. Group I consolidated at the 0.260 level and consists of infaunal species including deposit feeders, suspension/filter feeders and carnivores. With the exception of the Sand Lance (*Ammodytes americanus*) and the Haustorid amphipod, *Parahaustoius holmesi*, the group is composed of species which were quite common to all of the sampling areas. *A. americanus* and *P. holmesi* were less common and, when encountered, were usually found on Romer Shoal or on the East Bank.

Group II congealed at the 0.240 level and consists largely of epifaunal species, including *Hydroides diathanus, Balanus balanoides, Crepidula plana* and *Cancer irroratus*. Several of the group members appeared as dominants on Romer Shoal at various times of the year (e.g. *Hydroides dianthus, Cyathura polita, Paraphoxus spinosus* and *Elasmopus levis*).

Group III is a large group resulting from excessive chaining and contains many of the rarer species e.g., Maldanid C, *Autolytus fasciatus*, *Podarke obscura*, and *Mya arenaria*. It is quite possible that this clustering represents species which were similar due to non-occurrence. In other words, they were grouped because they didn't appear at the majority of stations.

Group IV contains four amphipods which frequently co-occurred at Romer Shoal and the East Bank. *Acanthohaustorius millsi*, *Protohaustorius wigleyi*, and *Parahaustorius longimerus* are infaunal suspension/filter feeders and were dominant species on the East Bank at most times of the year. *Trichophoxus epistomus* is a carnivorous amphipod which was frequently encountered on Romer Shoal. The deposit-feeding infaunal polychaete, *Magelona rosea* was also important at times on the East Bank.

Group V is composed of deposit feeding polychaetes and the deposit feeding bivalve *Tellina agilis*. The polychaetes, *Aricidea jeffreysii*, *Streblospio benedicti*, Maldanid A, and *Scolecolepides viridis* frequently co-occurred and were often dominant species on Old Orchard Shoal.

Excessive chaining makes the interpretation of the dendrogram for July (Figure 16) difficult. Five groups are identified. Group I is a large group of chained species which were probably clustered due to coincident non-occurrence. Group II is a composite group containing a carnivore (*Glycera dibranchiata*),

Figure 15. Dendrogram of inverse classification of species collected in May 1979.

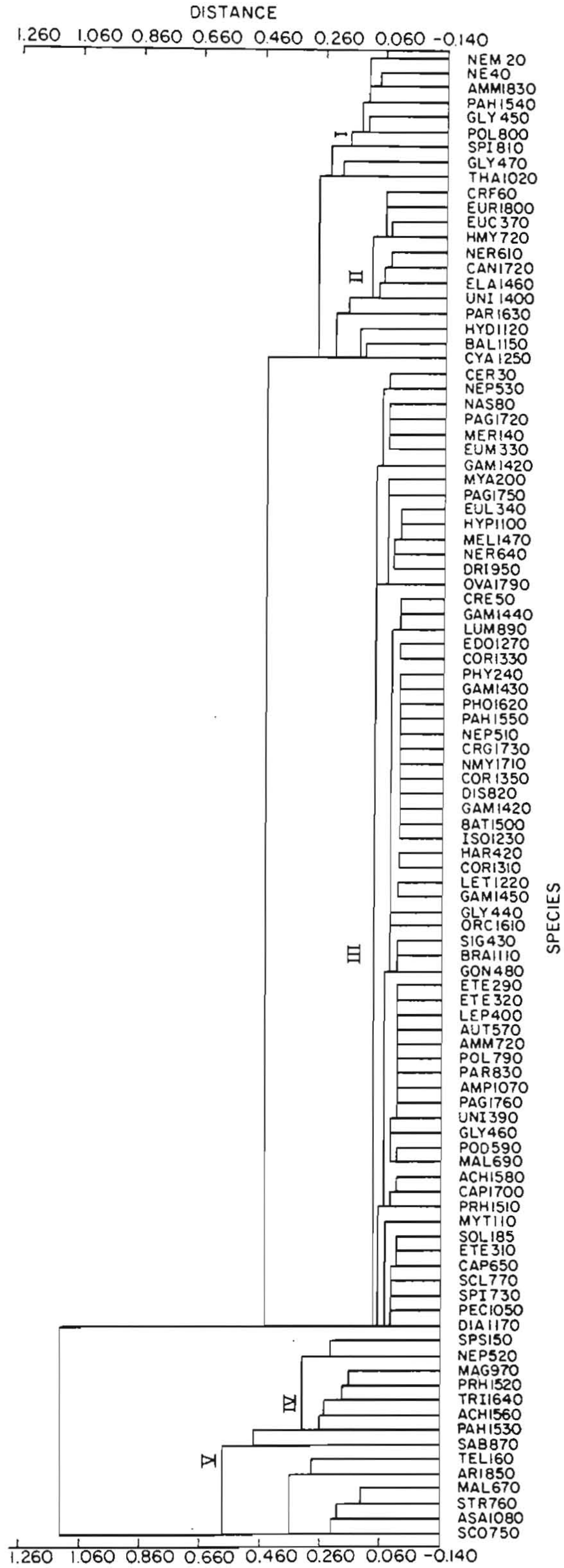
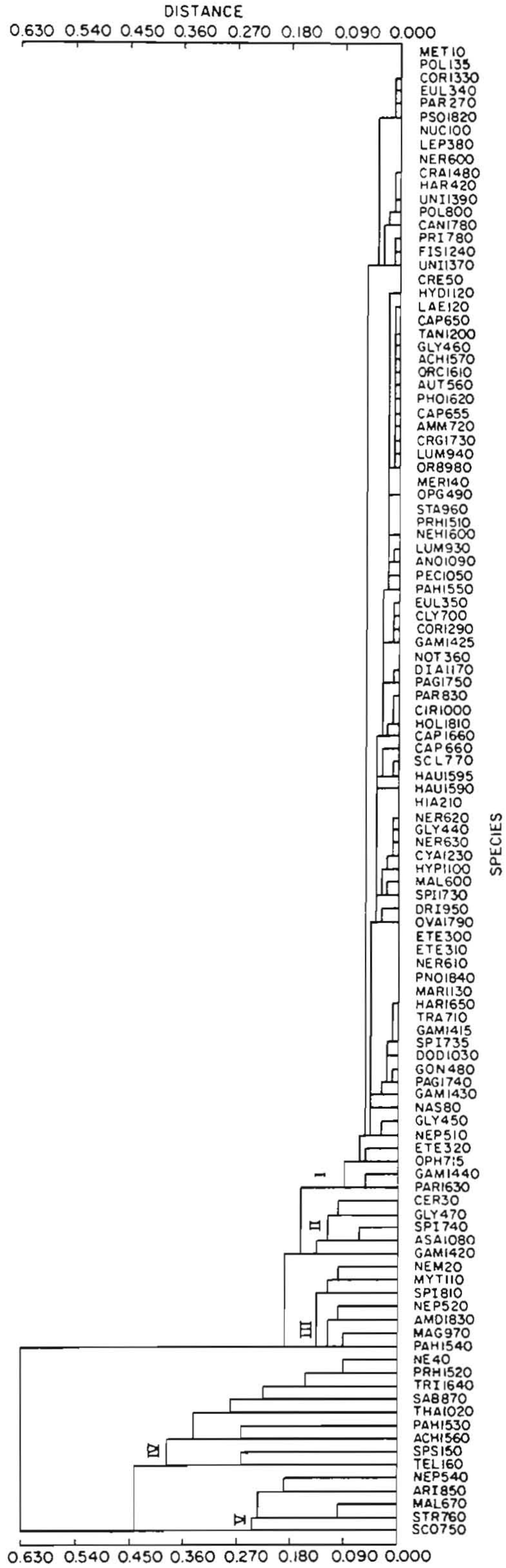

DISTANCE
1.260 1.060 0.860 0.660 0.460 0.260 0.060 -0.140
SPECIES
I
II
III
IV
V
NEM 20
NE40
AMM1830
PAH1540
GLY 450
POL800
SPI810
GLY470
THA1020
CRF60
EUR1800
EUC370
HMY720
NER610
CAN1720
ELA1460
UNI 1400
PAR1630
HYD1120
BAL1150
CYA1250
CER30
NEP530
NAS80
PAG1720
MER140
EUM330
GAM1420
MYA200
PAG1750
EUL340
HYP1100
MEL1470
NER640
DRI950
OVA1790
CRE50
GAM1440
LUM890
EDO1270
COR1330
PHY240
GAM1430
PHO1620
PAH1550
NEP510
CRG1730
NMY1710
COR1350
DIS820
GAM1420
BAT1500
ISO1230
HAR420
COR1310
LET1220
GAM1450
GLY440
ORC1610
SIG430
BRA1110
GON480
ETE290
ETE320
LEP400
AUT570
AMM720
POL790
PAR830
AMP1070
PAG1760
UNI390
GLY460
POD590
MAL690
ACH1580
CAP1700
PRH1510
MYT110
SOL185
ETE310
CAP650
SCL770
SPI730
PEC1050
DIA1170
SPS150
NEP520
MAG970
PRH1520
TRI1640
ACH1560
PAH1530
SAB870
TEL160
ARI850
MAL670
STR760
ASA1080
SCO750
1.260 1.060 0.860 0.660 0.460 0.260 0.060 -0.140

Figure 16. Dendrogram of inverse classification of species collected in July 1979.


DISTANCE
0.630 0.540 0.450 0.360 0.270 0.180 0.090 0.000
SPECIES
I
II
III
IV
V

two deposit feeders (*Spio filicornis,* and *Asabellides oculata*) and a scavenger/grazer (*Gammarus lawrencianus*). Group III is also composed of a mixture of species of different feeding types: deposit feeders, suspension feeders, and carnivores. There is more commonality among the species of this group than those in Group II. *Mytilus edulis, Magelona rosea, Parahaustorius holmesi,* and *Ammodytes americanus* were more frequently encountered on the East Bank and Romer Shoal than on Old Orchard Shoal.

Group IV does not congeal until the 0.396 level but at least eight of the nine species it contains are important on Romer Shoal and the East Bank. Most are suspension/filter feeding infaunal species. *Protohaustorius wigleyi, Parahaustorius longimerus,* and *Acanthohaustorius millsi* are all Haustorid amphipods and suspension/filter feeders often dominant on the East Bank. *Tellina agilis, Spisula solidissima* and *Trichophoxus epistomus* are frequently encountered species on Romer Shoal, as is *Tharyx acutus.* It would therefore seem reasonable to assume that this cluster resulted from the co-occurrence of these species on the East Bank and Romer Shoal.

Group V formed at the 0.250 level and is composed of infaunal deposit feeding polychaetes typical of Old Orchard Shoal, with the exception of *Nephtys bucera,* a predacious polychaete. All of these species, *N. bucera, Scolecolepides viridis, Streblospio benedicti,* Maldanid A and *Aricidea jeffreysii* are

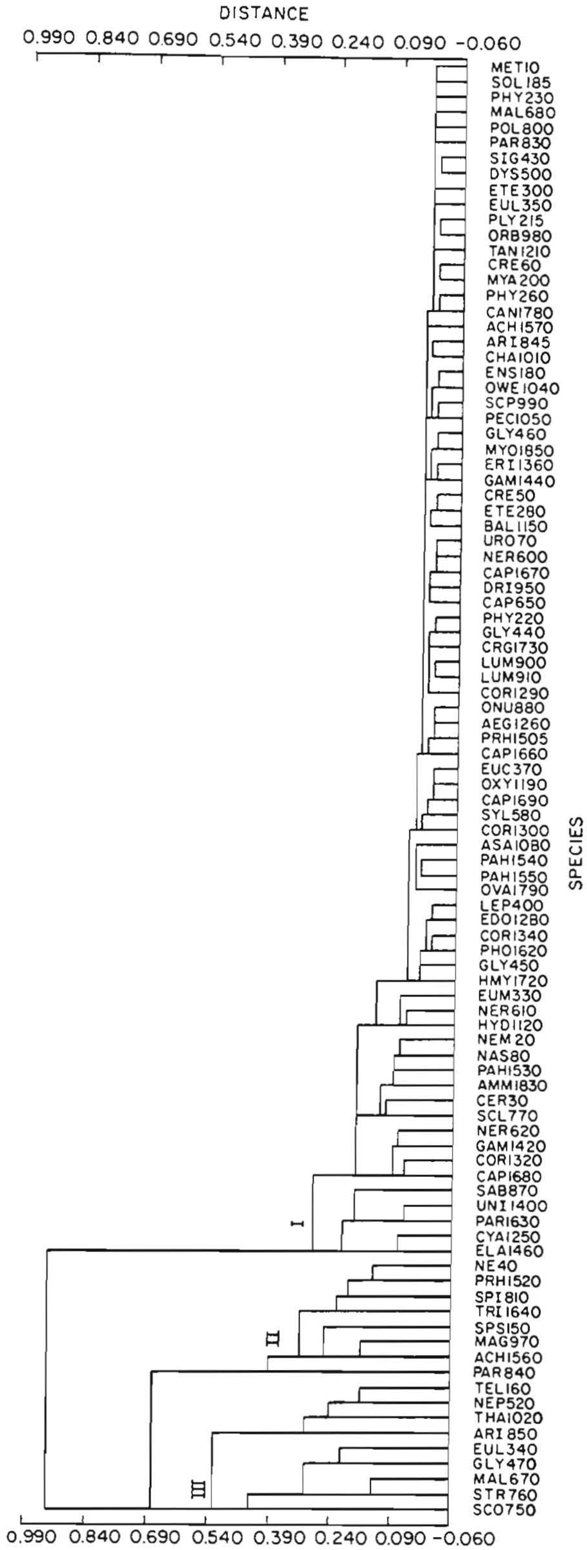
are important on Old Orchard Shoal at most times of the year.

The inverse analysis of the October data is severely hampered by extensive chaining (Figure 17). Three main clusters can be recognized, two of which lend some insight to the data. Group I was produced by extensive chaining of rare species. Group II consolidates at the 0.390 level and is composed of infaunal species which were very common to both Romer Shoal and the East Bank, namely *Trichophoxus epistomus*, *Spisula solidissima*, *Acanthohaustorius millsi*, and *Protohaustorius wigleyi*. It is interesting that three of the four are amphipods and three are suspension/filter feeders. The deposit feeders *Magelona rosea* and *Paraonis gracilis* were also dominant members of Group II and the East Bank at this time of the year.

Tellina agilis, *Nephtys bucera*, *Tharyx acutus*, *Aricidea jeffreysii*, and *Streblospio benedicti* were the five dominants on Old Orchard Shoal in October, and are all members of Group III. Maldanid A and *Scolecolepides viridis* are also in this cluster and have been important at this area at other times of the year. *Glycera dibranchiata* was present in marked numbers at Old Orchard Shoal in October. *Eulalia viridis* was apparently misclassified as it did not appear at any Old Orchard Shoal stations or East Bank stations but was the dominant species on Romer Shoal.

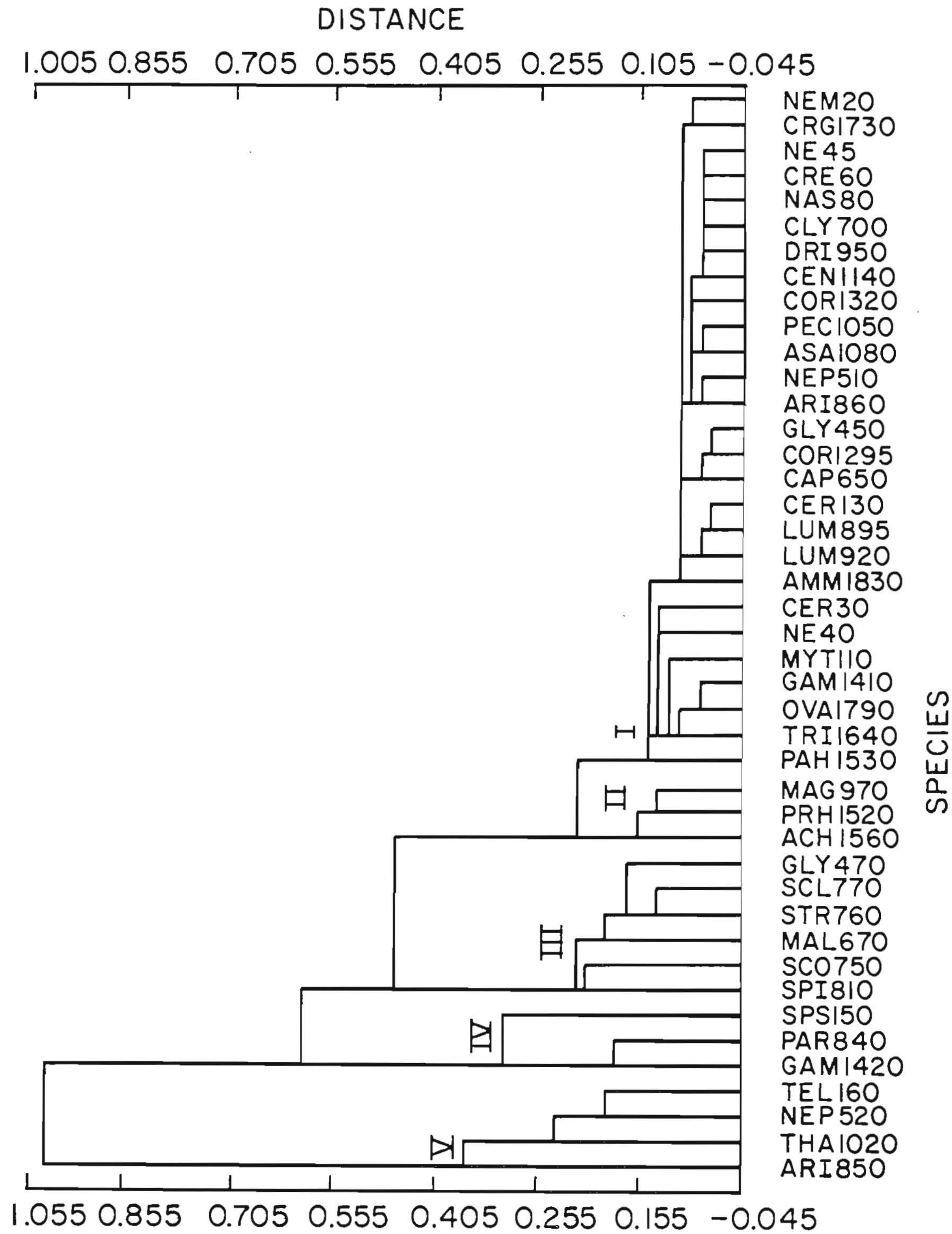
Five clusters were identified from the dendrogram (Figure 18) resulting from the analysis of the March 1980 data. Group I

Figure 17. Dendrogram of inverse classification of species collected in October 1979.



DISTANCE
0.990 0.840 0.690 0.540 0.390 0.240 0.090 -0.060
SPECIES
METIO
SOL185
PHY230
MAL680
POL800
PAR830
SIG430
DYS500
ETE300
EUL350
PLY215
ORB980
TAN1210
CRE60
MYA200
PHY260
CAN1780
ACH1570
ARI845
CHA1010
ENS180
OWE1040
SCP990
PEC1050
GLY460
MYO1850
ERI1360
GAM1440
CRE50
ETE280
BAL1150
URO70
NER600
CAP1670
DRI950
CAP650
PHY220
GLY440
CRG1730
LUM900
LUM910
COR1290
ONU880
AEG1260
PRH1505
CAP1660
EUC370
OXY1190
CAP1690
SYL580
COR1300
ASA1080
PAH1540
PAH1550
OVA1790
LEP400
EDO1280
COR1340
PHO1620
GLY450
HMY1720
EUM330
NER610
HYD1120
NEM20
NAS80
PAH1530
AMM1830
CER30
SCL770
NER620
GAM1420
COR1320
CAP1680
SAB870
UNI1400
PAR1630
CYA1250
ELA1460
NE40
PRH1520
SPI810
TRI1640
SPS150
MAG970
ACH1560
PAR840
TEL160
NEP520
THA1020
ARI850
EUL340
GLY470
MAL670
STR760
SCO750
I
II
III
0.990 0.840 0.690 0.540 0.390 0.240 0.090 -0.060

Figure 18. Dendrogram of inverse classification of species collected in March 1980.


DISTANCE
1.005 0.855 0.705 0.555 0.405 0.255 0.105 -0.045
NEM20
CRG1730
NE45
CRE60
NAS80
CLY700
DRI950
CEN1140
COR1320
PEC1050
ASA1080
NEP510
ARI860
GLY450
COR1295
CAP650
CER130
LUM895
LUM920
AMM1830
CER30
NE40
MYT110
GAM1410
OVA1790
TRI1640
PAH1530
MAG970
PRH1520
ACH1560
GLY470
SCL770
STR760
MAL670
SCO750
SPI810
SPS150
PAR840
GAM1420
TEL160
NEP520
THA1020
ARI850
I
II
III
IV
V
SPECIES
1.055 0.855 0.705 0.555 0.405 0.255 0.155 -0.045

is the product of extensive chaining of the rare species. Group II consists of two Haustorid amphipods, *Protohaustorius wigleyi* and *Acanthohaustorius millsi*, which were dominant members of the fauna at the East Bank in March, and the polychaete *Magelona rosea* which was important at this area at other times of the year. Group III is composed entirely of deposit feeding polychaetes (*Glycera dibranchiata, Scolelepis squamata, Streblospio benedicti,* Maldanid A). Many of these species were important at Old Orchard Shoal at various times of the year and Maldanid A was a member of the dominant species in March. Group IV contains three species, all of which were dominants on the East Bank in March. *Spisula solidissima, Paraonis gracilis,* and *Gammarus laurencianus* accounted for 65% of the total number of individuals at the East Bank stations. Group V is similarly composed of dominant species but from Old Orchard Shoal rather than from the East Bank. *Tellina agilis, Nephtys bucera, Aricidea jeffreysii,* and *Tharyx acutus* together accounted for 80% of all individuals found at the Old Orchard Shoal stations in March.

Fish

Fish species were surveyed at Old Orchard Shoal, Romer Shoal, and the East Bank during each of the benthic sampling cruises. The results of this survey are presented in Table 4. A total of 26 fish species were found. Three of these were previously unreported for the Lower Bay Complex, *Microgadus*

Table 4. Fish species found at each sampling area for each month. Sampled with a 30' foot rope otter trawl fish net. Number found, wet weight, and average length are also indicated.

May 1979

Old Orchard Shoal

Species	Number Found	Wet Weight (kg)	Average Length (cm)
Acipenser oxyrhyncus	1	2.1	67
Alosa aestivalis	2	0.04	
Anchoa mitchilli	33	0.125	
Stenotomus chrysops	18	0.4	
Tautoga anitis	12	15.3	32.6
Tautogolabrus adspersus	1		12
Prionotus carolinus	1		15
Peprilus triacanthus	1		
Scophthalmus aquosus	53	7.0	
Pseudopleuronectes americanus	43	1.3	
Others			
Limulus polyphemus	3		
Ovalipes ocellatus	10		
Homarus americanus	3		
Metridium senile	1		

East Bank

Species	Number Found	Wet Weight (kg)	Average Length (cm)
Anchoa mitchilli	8		
Stenotomus chrysops	52	1.2	
Ammodytes americanus	3		
Peprilus triachanthus	1		
Scophthalmus aquosus	10	1.9	
Pseudopleuronectes americanus	5	0.6	

Table 4. (continued)

Species	Number Found	Wet Weight (kg)	Average Length (cm)
Others			
Ovalipes ocellatus	12		
Crangon septemspinosa	1		
Loligo pealei	2		
Romer Shoal			
Anchoa mitchilli	26		
July 1979			
Old Orchard Shoal			
Mustelus canis	5	3.0	55.2
Anchoa mitchilli	155	0.5	
Stenotomus chrysops	52	1.5	
Tautoga onitis	24	12.5	
Tautogolabrus adspersus	4	0.1	
Peprilus triacanthus	47		
Priontus carolinus	4		
Paralichthys dentatus	9	7.8	44.7
Scophthalmus aquosus	17	3.6	
Pseudopleuronectes americanus	151	5.9	
Limanda ferruginea	1	0.1	
Others			
Ovalipes ocellatus	22		
Cancer irroratus	2		
Eurypanopeus depressus	2		
Homarus americanus	2	1.2	
Crangon septemspinosa	8		
Limulus polyphemus	1		

Table 4. (continued)

Species	Number Found	Wet Weight (kg)	Average Length (cm)
East Bank			
Alosa aestivalis	3		
Anchoa mitchilli	3		
Ammodytes americanus	5		
Scophthalmus aquosus	7	0.6	
Others			
Ovalipes ocellatus	4		
Loligo pealei	9		
Asterias forbesi	2		
Romer Shoal			
Tautoga onitis	1		
Scophthalmus aquosus	7	0.5	
Pseudopleuronectes americanus	1		
Other			
Ovalipes ocellatus	1		
October 1979			
Old Orchard Shoal			
Alosa aestivalis	1		
Alosa mediocris	9		
Brevoortia tyrannus	48		
Clupea harengus	16		
Anchoa mitchilli	795		
Merluccius bilinearis	1		
Stenotomus chrysops	1		
Tautoga onitis	2		
Ammodytes americanus	2		

Table 4. (continued)

Species	Number Found	Wet Weight (kg)	Average Length (cm)
Peprilus triacanthus	18		
Prionotus carolinus	2		
Myoxocephalus octodecemspinosus	2		
Paralichthys dentatus	1		
Scophthalmus aquosus	17	2.6	
Paralichthys dentatus	71	9.5	
Others			
Cancer irroratus	56	2.5	
Ovalipes ocellatus	408		
Homarus americanus	9		5
Crangon septemspinosa	80		
Limulus polyphemus	1		
Asterias forbesi	1		
Metridium senile	1		
East Bank			
Anchoa hepsetus	2		
Anchoa mitchilli	8		
Microgadus tomcod	7		
Peprilus triacanthus	6		
Ammodytes americanus	6		
Sphoeroides maculatus	6	1.0	
Paralichthys oblongus	10		
Scophthalmus aquosus	224	46.5	
Pseudopleuronectes americanus	123	11.5	
Others			
Cancer irroratus	104		
Ovalipes ocellatus	28		
Callinectes sapidus	6		

Table 4. (continued)

Species	Number Found	Wet Weight (kg)	Average Length (cm)
Libinia emarginata	1		
Crangon septemspinosa	10		
Asterias forbesi	8		
Romer Shoal			
Alosa aestivalis	1		
Anchoa mitchilli	252	1.6	
Stenotomus chrysops	4	0.9	
Sphoeroides maculatus	1		
Peprilus triacanthus	9		
Prionotus carolinus	1		
Limanda ferruginea	2		
Others			
Cancer irroratus	1		
Ovalipes ocellatus	3		
Asterias forbesi	7		
March 1980			
Old Orchard Shoal			
Clupea harengus	3		
Scophthalmus aquosus	3		
Pseudopleuronectes americanus	21	1.55	
Others			
Cancer irroratus	3		
Crangon septemspinosa	18		
East Bank			
Alosa pseudoharengus	1		
Clupea harengus	9	4.0	

Table 4. (continued)

Species	Number Found	Wet Weight (kg)	Average Length (cm)
Ammodytes americanus	3		
Scophthalmus aquosus	16	3.1	
Pseudopleuronectes americanus	1	0.5	
Others			
Cancer irroratus	4		
Romer Shoal			
Clupea harengus	7		
Merluccius bilinearis	5	0.25	
Peprilus triacanthus	1		
Myoxocephalus octodecemspinosus	18	5.25	
Scophthalmus aquosus	63	14.0	
Pseudopleuronectes americanus	28	4.28	
Others			
Cancer irroratus	2		
Ovalipes ocellatus	1		
Asterias forbesi	30		
May 1980			
Old Orchard Shoal			
Alosa aestivalis	3		
Engraulis eurystole	53		
Merluccius bilinearis	1		
Peprilus triacanthus	6		
Paralichthys dentatus	3	1.8	
Scophthalmus aquosus	6	1.6	
Pseudopleuronectes americanus	6	0.5	

Table 4. (continued)

Species	Number Found	Wet Weight (kg)	Average Length (cm)
Others			
Ovalipes ocellatus	3		
Homarus americanus	2		6.4
Crangon septemspinosa	11		
East Bank			
Anchoa mitchilli	2		
Urophycis chuss	9		
Ammodytes americanus	5		
Prionotus carolinus	1		
Centropristis striata	1		
Stenotomus chrysops	5		
Paralichthys dentatus	10	4.4	
Scopthalmus aquosus	38	6.0	
Pseudopleuronectes americanus	23	1.8	
Others			
Cancer irroratus	15		
Ovalipes ocellatus	56		
Libinia emarginata	1		
Loligo pealei	13		
Romer Shoal			
Urophycis chuss	4		
Stenotomus chrysops	70		
Tautogolabrus adspersus	18	11.9	
Prionotus carolinus	4		
Paralichthys dentatus	3	1.0	
Scophthalmus aquosus	53	9.4	
Pseudopleuronectes americanus	7	1.3	

Table 4. (continued)

Species	Number Found	Wet Weight (kg)	Average Length (cm)
Others			
Cancer irroratus	2		
Ovalipes ocellatus	7		
Limulus polyphemus	1		
Asterias forbesi	6		

tomcod and *Paralichthys oblongus* were found only in October on the East Bank. *Limanda ferruginea* was found on Romer Shoal in October and on Old Orchard Shoal in July. Table 4 also shows the macrobenthic invertebrates collected by the Otter Trawl during the fish survey. Two species of potential economic importance were found, *Homarus americanus* (lobster) and *Callinectes sapidus* (blue claw crab). Lobster were found in May 1979, July, October, and May 1980 on Old Orchard Shoal. *Callinectes sapidus* was found in October on the East Bank.

Sediment

The results of sediment grain size analysis are presented in Table 5. Values are % dry weight for each size class. In all, 37 stations were analyzed, 16 from Old Orchard Shoal, 13 from Romer Shoal and 8 from the East Bank. The three areas were predominantly medium to fine sand, however a trend is indicated with Romer Shoal and the East Bank having somewhat larger grain sizes than Old Orchard Shoal. On Romer Shoal and the East Bank, the fractions from medium sand, coarse and very coarse sand, and shell/gravel together accounted for 60.79% and 62.75% (respectively) of the sediment, and 54% on Old Orchard Shoal. Romer Shoal had the highest shell/gravel fraction, comprising an average 6.53% of the sediment. This fraction was less than 1% in both the East Bank and Old Orchard Shoal stations. The silt/clay fraction was low at the three sampling areas, Old

Table 5. Sediment grain size analysis of 37 stations from the East Bank, Old Orchard Shoal, and Romer Shoal in the Lower Bay. Values are % dry weight. Means of the grain size fraction are also shown for each sampling area. See note for class sizes.

Old Orchard Shoal (OOS)	Station	% Shell/ Gravel	% Very Coarse Sand	% Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	Silt/Clay
OOS	1	3.32	0.52	0.79	15.37	76.11	3.76	0.13
OOS	3	0.22	0.80	12.71	65.13	17.84	3.06	0.22
OOS	5	0.69	0.04	4.78	41.55	43.08	9.85	0.00
OOS	6	0.47	0.98	8.84	72.65	15.56	1.36	0.12
OOS	7	0.13	1.21	8.30	26.24	11.98	1.07	0.00
OOS	11	0.27	0.60	2.46	21.50	71.38	3.67	0.06
OOS	12	0.32	0.69	8.09	56.50	32.53	1.76	0.09
OOS	13	0.00	0.25	7.30	54.20	35.46	2.73	0.00
OOS	B	0.18	1.96	12.37	42.51	40.18	6.92	0.00
OOS	C	3.22	4.86	15.80	35.89	37.95	2.11	0.15
OOS	E	0.72	1.35	8.87	74.49	13.22	1.27	0.07
OOS	F	0.35	0.19	15.53	65.74	16.69	1.49	0.00
OOS	G	0.07	0.58	16.35	70.85	11.55	0.58	0.00
OOS	J	1.70	0.99	3.08	11.59	74.59	7.88	0.15
OOS	K	0.16	1.29	4.94	35.07	56.19	2.29	0.07
OOS	L	3.14	0.72	3.19	10.85	74.25	7.84	0.00
	Mean %	0.935	1.064	8.34	43.76	39.28	3.59	0.06

Table 5. (continued) Sediment grain-size analysis.

East Bank (EB)	Station	% Shell/ Gravel	% Very Coarse Sand	% Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	Silt/Clay
EB	1	0.00	0.05	8.82	66.12	23.11	1.87	0.00
EB	4	0.00	0.00	0.14	31.78	67.45	0.63	0.00
EB	8	0.00	0.00	2.35	73.79	23.71	0.14	0.00
EB	9	1.81	0.07	2.61	63.67	31.23	0.60	0.00
EB	10	0.00	0.05	8.82	66.12	23.11	1.87	0.00
EB	F	0.09	0.00	2.39	82.80	14.68	0.03	0.00
EB	K	0.00	0.00	0.11	46.64	53.04	0.20	0.00
EB	L	0.51	0.00	4.55	72.02	17.89	0.04	0.00
	Mean %	0.30	0.015	2.78	59.65	36.47	0.76	0.00
Romer Shoal (RS)								
RS	2	3.80	0.40	1.75	16.13	72.04	5.76	0.09
RS	3	19.68	1.49	3.65	9.91	62.35	2.92	0.00
RS	4	5.35	3.17	4.67	8.77	46.23	31.49	0.30
RS	5	0.19	0.30	1.52	72.87	20.00	0.01	0.00
RS	7	0.62	0.98	8.14	57.98	43.48	0.53	0.00
RS	11	2.73	6.52	17.31	55.54	17.71	0.17	0.00

Table 5. (continued) Sediment grain size analysis.

Romer Shoal (RS)	Station	% Shell/ Gravel	% Very Coarse Sand	% Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	Silt/Clay
RS	12	9.73	2.48	9.32	46.03	31.45	0.97	0.00
RS	13	2.74	2.30	10.55	60.45	23.73	0.22	0.00
RS	D	6.01	0.89	2.88	44.46	44.53	1.22	0.00
RS	G	0.00	0.16	6.85	68.73	28.33	0.12	0.00
RS	H	0.03	0.09	3.44	63.55	32.46	0.41	0.00
RS	I	33.10	12.22	13.02	11.68	27.18	2.78	0.00
RS	K	0.86	0.20	5.03	70.09	23.70	0.07	0.00
	Mean %	6.53	2.40	6.78	45.09	36.39	3.59	0.03

Note:

% Shell/Gravel > 2.00 mm

% Very Coarse Sand < 2.00 > 1.00

% Coarse Sand < 1.00 > 0.50

% Medium Sand < 0.50 > 0.25

% Fine Sand < 0.25 > 0.125

% Very Fine Sand < 0.125 > 0.065

% Silt/Clay < 0.065

Orchard Shoal had the highest values followed by Romer Shoal and the East Bank.

DISCUSSION

Faunal Assemblages

Three benthic assemblages were identified from the dominant species data and supported by inverse and normal cluster analysis. Paraonid and Spionid polychaetes were the dominant organisms on Old Orchard Shoal at all times of the year. The prevalent species were *Aricidea jeffreysii, Streblospio benedicti, Scolecolepides viridis, Tharyx acutus,* and *Tellina agilis.* All of these species are either mobile burrowing or sedentary tubiculous deposit feeders that have similar habitat requirements. The Romer Shoal assemblage is composed of a mixture of suspension feeders, deposit feeders, and carnivores, such as *Sabellaria vulgaris, Tharyx acutus,* and *Eulalia viridis.* Gammaridean amphipods such as *Gammarus lawrencianus, Acanthohaustorius millsi,* and *Trichophoxus epistomus* are also important in this assemblage. The East Bank assemblage is characterized by suspension/filter feeding, rapidly burrowing, Haustorid amphipods. *Acanthohaustorius millsi* and *Protohaustorius wigleyi* were consistent members of the dominant species groups. Deposit feeders such as *Paraonis gracilis, Magelona rosea,* and *Tellina agilis* were also important.

Several studies on the physical oceanography and geology of the Lower Bay Complex have been conducted previously. From these, a picture of conditions existing at the three sampling areas can be drawn and related to the observed faunal assemblages.

Old Orchard Shoal lies on the western side of the Lower Bay; it is protected from ocean waves by Flynn's Knoll and Romer Shoal (Kinsman et al., 1979). Tidal current velocities are low over much of the shoal, ranging from 15 to 46 $cm \cdot s^{-1}$ (Duedall et al., 1974). Tidal energy dissipation over the Shoal was found to be low (< 0.5 $W \cdot m^{-2}$) in a computer simulation study (Mellor, personal communication). This relatively low energy environment has produced a sediment regime ranging from medium sand to mud (Jones et al., 1979). Swartz and Brinkhuis (1978) found that fine organic matter tended to settle on the West Bank, an area north of the Shoal but with similar hydrography. This input of organic matter, the fine sediments and the low energy of the environment may account for the predominance of deposit-feeders at this area. Craig and Jones (1966) found that the majority of infaunal species are deposit-feeders and are often associated with fine-grained sediments.

Romer Shoal, situated in the central portion of the bay, is exposed to ocean waves entering from the Atlantic via the Sandy Hook-Rockaway Point transect. Kinsman et al. (1979), in a computer simulation model, found that ocean waves crossing Romer Shoal were strongly refracted, indicating that they "felt" bottom and, therefore, are capable of disturbing the bottom sediments. Tidal current velocities are higher than on Old Orchard Shoal, ranging from 30 to 108 $cm \cdot s^{-1}$ (Duedall et al., 1974); tidal energy dissipation is also higher (0.5 - $3W \cdot m^{-2}$) (Mellor, personal communication). The sediments on Romer Shoal tend to be medium to coarse sand (Kastens et al., 1978) with a large amound of dead mussel shells (personal observation). The dominance of epifaunal and infaunal suspension feeders on Romer Shoal correlates well with the physical environment. Coarser sediments are frequently associated with lower organic content and would tend to favor the development of a suspension feeding community (Craig and Jones, 1966; Rhoads and Young, 1970).

The East Bank lies just east of Romer Shoal, on the other side of the Ambrose Channel. Kinsman et al. (1979) also found that ocean waves here were refracted while passing over the shallow water. Tidal currents over the East Bank run between 30 and $108 \cdot cm \cdot s^{-1}$ (Duedall et al., 1974), and tidal energy dissipation is similar to that on Romer Shoal (Mellor, personal communication). Sediments on the East Bank tend to be medium to fine sand (Kastens et al., 1978) with a lower shell fraction than on Romer Shoal (personal observation). While no direct information is available on organic input, Swartz and Brinkhuis (1979) observed that holes (depressions) in the East Bank did not seem to be accreting much fine organic matter. Haustorid amphipods are adapted to high energy environments and are equipped to draw nourishment from suspended particles (Bousfield, 1970). The presence of a suspension/filter feeding community, composed of these rapid burrowers, is consistent with an environment of medium to fine sand with a low sediment accretion rate.

Segregation of organisms by feeding type has been noted by Rhoads and Young (1970). They found that the distribution of feeding types changed across a gradient of substrate stability. The proportion of deposit-feeders, in Buzzards Bay, was greatest on the unstable mud bottom. Suspension-feeders were largely restricted to muddy sands (Sanders, 1958). The spatial segregation of these two feeding types has been noted on muddy bottoms on a world-wide scale (Rhoads,1974). The three assemblages identified by this study seem to segregate in a similar way. The Old Orchard Shoal assemblage, dominated by deposit feeding polychaetes, is located in an area of the bay which receives sediment loads from the Hudson River (Duedall et al., 1974) and is a lower energy environment than Romer Shoal or the East Bank. While deposit-feeders are also found on the East Bank and Romer Shoal, their proportion of the fauna is significantly less and dominance is assumed by epifaunal and infaunal suspension/filter feeders and carnivores. Both of these areas have sediments with larger median grain sizes than Old Orchard Shoal (Jones et al., 1979; Kastens et al., 1978). The large shell fraction of Romer Shoal sediments helps explain the abundance of epibenthic species, as most of these species require a hard substrate on which to afix themselves.

Other factors undoubtedly influence the observed species distributions in the Lower Bay Complex. Boesch (1977) concluded that the macrobenthos of the Hudson-Raritan estuarine system has apparently been grossly altered from its natural state due to both the discharge of toxic and oxygen demanding wastes and physical modifications of the habitat (e.g., dredging). Grieg and McGrath (1977) found that the arithmetic mean metals value (Ag, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Sc, Se, Zn) ranged from 30 to 53 ppm (on a dry weight basis) in sediments near Old Orchard Shoal and was only 6-7 ppm in the sediment at Romer Shoal. Searl et al. (1977) measured the amounts of hydrocarbons in the sediments of the Lower Bay. They found the sediment concentration of C_{15+} hydrocarbons at two stations near Old Orchard Shoal to be 136 and 629 ppm on a dry weight basis. Three stations measured on or near Romer Shoal and the East Bank had concentrations of 32, 26, and 97 ppm. Swartz and Brinkhuis (1978) found lower oxygen concentrations in the bottom water at the West Bank (an area similar to Old Orchard Shoal) than at the East Bank.

The tolerance of stress varies from species to species. These differences have been used to identify "indicator species", species with lower tolerances whose presence was used to "indicate" the general health of the environment, or species with high tolerances whose presence may "indicate" pollution. Blumer et al. (1970), in his study of the West Falmouth oil spill, found

Ampeliscid amphipods to be sensitive to hydrocarbons in the environment. In a study of physiologic tolerance to stress, McErlean et al. (1972) found Arthopods to be least tolerant, followed by Molluscs, with Annelids showing the most tolerance. Garlo et al. (1979) studied the effects of hypoxia ($[O_2] < 2$ ppm) on the macrobenthos in the vicinity of Little Egg Inlet, New Jersey. She found that Echinoderms suffered the greatest mortalities, followed by crustaceans and bivalves. Polychaetes apparently had very low mortalities, while Haustorid amphipods were quite sensitive. With these facts in mind, it would seem reasonable to speculate that the observed distribution of species found in this study may also reflect a gradient of pollution and/or organic enrichment, with greater stress due to pollution on Old Orchard Shoal than on Romer Shoal or the East Bank. This interpretation is supported by the total lack of any Haustorid amphipods, a stress sensitive group (Garlo et al., 1979), at the Old Orchard Shoal site and their abundance on both Romer Shoal and the East Bank. Furthermore, *Cyathura polita*, a frequently cited low tolerance "indicator" species (Ristich, 1977; Burbanck, 1962), was regularly encountered in significant numbers on Romer Shoal. Dean and Haskin (1964) suggest that the dominance of organisms such as *Cyathura polita* indicates the general health of the estuary. Deposit-feeding polychaetes, such as *Streblospio benedicti*, *Tharyx acutus*, and Capitellids have been identified as "organic enrichment species" (Pearson and Rosenberg, 1978). Their dominance on Old Orchard Shoal and the dominance of sensitive amphipod species on the East Bank and Romer Shoal supports previously reported pollution gradients.

Previous Studies

Densities of organisms ranged from a low of $25 \cdot m^{-2}$ on the East Bank in July (1979) to a high of $2282 \cdot m^{-2}$ on Romer Shoal in May 1980. The average density (GMA) for all sites showed the same pattern, with the lowest GMA in July ($212 \cdot m^{-2}$) and the highest in May 1980 ($490 \cdot m^{-2}$). The abundances are quite low when compared with values for similar estuarine environments. Table 6 shows the minimum, maximum, and mean density values found by studies conducted in Port Jefferson Harbor (PJH), Buzzards Bay, Mass., Long Island Sound (LIS), and Moriches Bay, Long Island. These values range from a low of $750 \cdot m^{-2}$ (PJH) to a high of $46{,}398 \cdot m^{2}$ (LIS), with mean values between 3413 and $16{,}443 \cdot m^{2}$. These densities are much greater than those encountered by this study, and it may be concluded that the abundances of fauna at all three study sites are markedly reduced.

Species diversity (H') was also low, with the average diversity for any one area ranging from a low of 1.605 on the East Bank in March 1980 to a high of 2.947 at Romer Shoal in May 1980. Diversity over all stations ranged from 0 on the East Bank in March to 3.80 on Romer Shoal in October 1979. The overall average

Table 6. Abundances of benthic invertebrates for some typical east coast environments compared to the present study. Minimum and maximum density and mean density expressed as individuals per square meter.

	Port Jefferson Harbor[1]	Buzzards Bay[2]	Long Island Sound[2]	Moriches Bay	Lower Bay[4]
Maximum Density	9,500	12,576	46,398	------	2,282
Minimum Density	750	1,064	5,563	------	25
Mean Density	3,413	4,430	16,443	5,402	340

1 - Klein (1976)

2 - Sanders (1958)

3 - O'Connor (1972)

4 - This Study

diversity was 2.36. These values are lower than values obtained by Boesch (1973) in a study conducted at Hampton Roads, Virginia. He found an average diversity (H') of 3.57 and a range from 0.83 to 4.93. McGrath (1974) observed an average diversity of $\overline{H}' = 1.45$ for 21 stations near the present sampling locations. It would appear that diversity has increased since McGrath's study.

Seven previous studies have enumerated the macrobenthos of the Lower Bay Complex. Dean and Haskin (1964) reported a total of 17 taxa, Walford (1971) reported 31 taxa, Stiemle and Stone (1973) found 70 taxa along the one transect line near the Lower Bay. McGrath (1974) reported an average of 4 species per sample and an average abundance of $110 \cdot m^{-2}$. Dean (1975) reported a total of 127 taxa from 193 stations sampled during the summers of 1957 to 1960. A study by Woodward and Clyde (1975) concluded that the East Bank was not impoverished. They reported a mean of $5406 \cdot m^{-2}$ and 51 invertebrate taxa. However, their mean is heavily skewed by one station, at which they found $13{,}285 \cdot m^{2}$ *Mytilus edulis*. Brinkhuis (1980) reported only 12 taxa from stations sampled from the East and West Banks in 1977 and 1978. All of the above studies, except Woodward and Clyde (1975) reported reduced abundances and numbers of species for the Lower Bay Complex. Walford (1971) and McGrath (1974) both concluded that the macrobenthos in the areas they studied were impoverished. In the present study abundances and diversity were somewhat higher, but generally consistent with, those previously reported.

An interesting comparison can be made with the results of McGrath's 1974 study. In looking at community structure, he concluded that two principal communities may be found in the Lower Bay Complex. One community (A), in the central portion of the Lower Bay, was dominated by the deposit-feeding bivalve *Tellina agilis* and two polychaete worms, *Streblospio benedicti* and *Nephtys bucera*. This community is very similar to the assemblage identified on Old Orchard Shoal by this study. McGrath's second community (B) was found in western Raritan Bay and Sandy Hook Bay muds, areas quite dissimilar to the sites sampled in this study. It is noteworthy, however, that the dominant bivalve (*Mulinia lateralis*), an opportunistic species found frequently by McGrath in his second community, was never encountered during the present investigation.

New Species

This study constitutes the first intensive sampling of the macrobenthos in the Lower Bay to be conducted on a seasonal basis. One hundred and seventy-nine invertebrate taxa were identified. Of these, fifty-seven were species not previously reported for this area. Table 7 presents seventeen of the more common, yet previously unreported species. Most of the new species were amphipods, a group poorly represented in previous studies. Three species of Caprellids were also identified, and

Table 7. Common species in the Lower Bay, but not previously reported for this area.

Cerebratulus lacteus	*Corophium bonelli*
Eulalia bilineate	*Corophium insidiosum*
Syllides setosa	*Corophium lacustre*
Dispio unicinata	*Acanthohaustorius shoemakeri*
Aricidea wassi	*Haustorius canadensis*
Aricidea jeffreysii	*Harpinea propinqua*
Paraonis gracilis	*Caprella andreae*
Hypaniola dianthus	*Caprella penantis*
Tanais cavolini	*Caprella unica*

they were found mostly on Romer Shoal. The single most surprising report of a new species is *Aricidea jeffreysii*. This species was found at all the sampled areas and dominated Old Orchard Shoal at several times of the year. It could not have existed so ubiquitously in prior years, and have been missed. Its population must have experienced growth, both in numbers and vagility. *Paraonis gracilis* was also an important species found abundantly on the East Bank and Romer Shoal which had not been previously reported.

Several previously reported species were not found by this study. Table 8 lists 13 such species. Of special interest is *Mulinia lateralis*, the dominant bivalve in McGrath's community B (McGrath, 1974).

Fish

The waters of the Lower Bay Complex are a habitat for permanent resident species, as well as a seasonal haven for species migrating to the Hudson River for spawning. Seventy-one species have been previously reported in the Lower Bay Complex. Only two recent reports deal with the distribution and abundance of fishes in the area. Wilk and Silverman (1976) conducted a summer study of fish distributions in Sandy Hook Bay and Wilk et al. (1977) surveyed the fishes in the whole Lower Bay Complex.

Four species -- *Pseudopleuronectes americanus*, *Prionotus evolans*, *Scophthalmus aquosus*, and *Prionotus carolinus* accounted

Table 8. Species previously reported in the Lower Bay, but not found in this study. Species name, followed by reference of studies which reported it.

Mulinia lateralis	Dean (1975), McGrath (1974)
Ampelisca sp.	Dean (1975), Steimle and Stone (1973)
Jassa falcata	Dean (1975), McGrath (1974), Steimle and Stone (1973)
Neopanope texana sayi	Brinkhuis (1980), Dean (1975), Steimle and Stone (1973)
Lunatia heros	Woodward-Clyde (1975), Dean (1975), McGrath (1974), Steimle and Stone (1973)
Nucula proxima	Woodward-Clyde (1975), Dean (1975)
Gemma gemma	Brinkhuis (1980), Dean (1975)
Autolytus cornutus	Woodward-Clyde (1975), Dean (1975), Steimle and Stone (1973)
Diopatra cupria	Woodward-Clyde (1975), Dean (1975)
Cirratulis grandis	McGrath (1974), Steimle and Stone (1973)
Polycirrus phosphoreus	Dean (1975), Steimle and Stone (1973)
Balanus improvisus	Dean (1975), McGrath (1974), Walford (1971), Dean and Haskin (1964)
Leptocuma minor	Woodward-Clyde (1975), Steimle and Stone (1973)

for 68% by number of the total catch in the survey by Wilk and Silverman (1976). With the exception of *Prionotus evolans*, these species were also important in the present study. Wilk et al. (1977) reported that Lower Bay stations exhibited a greater number of species and number of individuals per species during the fall months. This was also true in the present study where 20 species were found in October 1979, with fewer being found during the other sampling months. March 1980 yielded the fewest number of species and number of individuals per species of any month sampled. It appears that fish catch by otter trawl was very low when compared to that in adjacent New York Bight waters using similar equipment (Wilk et al., 1977).

Summary

The Lower Bay was found to have significantly reduced densities and diversities of macrobenthic invertebrates when compared with other, similar estuarine environments. Abundances were found to vary seasonally, with highest densities appearing in the spring and fall and lower densities in the winter and summer. Abundances were consistently higher on Old Orchard Shoal and Romer Shoal than on the East Bank. Three species assemblages were identified: Old Orchard Shoal was characterized by deposit-feeding polychaetes; Romer Shoal by an amalgam of deposit/suspension feeding and carnivorous polychaetes and amphipods; and the East Bank by Haustorid amphipods and deposit-feeding polychaetes. These distributions are attributed to various physical factors such as sediment grain size, tidal current and wave energy and relative levels of pollution. One hundred and seventy-nine invertebrate taxa were identified, fifty-seven of which had not been previously identified.

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Appendix 1. Station longitude, latitude, and depth.

Old Orchard Shoal Station No.	Latitude	Longitude	Depth (Feet)
OOS1	40° 31' 28"	74° 05' 26"	15
OOS2	40° 31' 23"	74° 04' 56"	15
OOS3	40° 31' 16"	74° 04' 24"	15
OOS4	40° 31' 11"	74° 03' 48"	19
OOS5	40° 31' 03"	74° 05' 16"	17
OOS6	40° 30' 59"	74° 04' 45"	17
OOS7	40° 30' 52"	74° 04' 14"	19
OOS8	40° 30' 47"	74° 03' 43"	18
OOS9	40° 30' 41"	74° 03' 56"	20
OOS10	40° 30' 26"	74° 03' 36"	19
OOS11	40° 30' 30"	74° 04' 05"	21
OOS12	40° 30' 34"	74° 04' 35"	20
OOS13	40° 30' 38"	74° 05' 06"	18
OOSA	40° 31' 12"	74° 04' 27"	17
OOSB	40° 31' 10"	74° 04' 19"	17
OOSC	40° 31' 05"	74° 04' 15"	18
OOSD	40° 31' 06"	74° 04' 20"	18
OOSE	40° 31' 08"	74° 04' 33"	18
OOSF	40° 31' 03"	74° 04' 40"	18
OOSG	40° 31' 00"	74° 04' 30"	18
OOSH	40° 30' 59"	74° 04' 21"	18
OOSI	40° 30' 58"	74° 04' 14"	19
OOSJ	40° 30' 54"	74° 04' 20"	18
OOSK	40° 30' 55"	74° 04' 29"	18
OOSL	40° 30' 56"	74° 04' 35"	18

Romer Shoal Station No.	Latitude	Longitude	Depth (Feet)
RS1	40° 32' 15"	74° 01' 40"	40
RS2	40° 31' 51"	74° 01' 22"	28
RS3	40° 31' 28"	74° 01' 12"	20
RS4	40° 31' 04"	74° 00' 59"	15
RS5	40° 30' 45"	74° 01' 25"	20
RS6	40° 31' 10"	74° 01' 35"	18
RS7	40° 31' 35"	74° 01' 46"	17
RS8	40° 31' 55"	74° 01' 45"	17
RS9	40° 32' 03"	74° 01' 55"	17
RS10	40° 31' 49"	74° 02' 09"	18
RS11	40° 31' 16"	74° 02' 10"	25
RS12	40° 30' 50"	74° 01' 59"	20
RS13	40° 30' 25"	74° 01' 46"	20
RSA	40° 31' 29"	74° 01' 18"	19
RSB	40° 31' 24"	74° 01' 17"	18
RSC	40° 31' 17"	74° 01' 24"	18
RSD	40° 31' 25"	74° 01' 30"	18
RSE	40° 31' 32"	74° 01' 28"	18
RSF	40° 31' 35"	74° 01' 40"	17
RSG	40° 31' 26"	74° 01' 32"	15
RSH	40° 31' 21"	74° 01' 30"	17
RSI	40° 31' 15"	74° 01' 29"	15
RSJ	40° 31' 17"	74° 01' 45"	15
RSK	40° 31' 23"	74° 01' 43"	15
RSL	40° 31' 27"	74° 01' 45"	15

East Bank Station No.	Latitude	Longitude	Depth (Feet)
EB1	40° 33' 10"	73° 59' 50"	15
EB2	40° 32' 44"	73° 59' 43"	15
EB3	40° 32' 20"	73° 59' 30"	13
EB4	40° 31' 54"	73° 59' 23"	12
EB5	40° 31' 30"	73° 59' 10"	18
EB6	40° 31' 36"	73° 59' 45"	20
EB7	40° 32' 00"	73° 59' 55"	15
EB8	40° 32' 25"	74° 00' 03"	12
EB9	40° 32' 50"	74° 00' 15"	18
EB10	40° 32' 30"	74° 00' 38"	25
EB11	40° 32' 05"	74° 00' 25"	15
EB12	40° 31' 41"	74° 00' 15"	60
EBA	40° 32' 21"	73° 59' 40"	12
EBB	40° 32' 14"	73° 59' 35"	10
EBC	40° 32' 10"	73° 59' 42"	13
EBD	40° 32' 16"	73° 59' 44"	12
EBE	40° 32' 22"	73° 59' 47"	12
EBF	40° 32' 25"	73° 59' 55"	12
EBG	40° 32' 18"	73° 59' 50"	12
EBH	40° 32' 11"	73° 59' 48"	12
EBI	40° 32' 05"	73° 59' 46"	12
EBJ	40° 32' 07"	73" 59' 56"	12
EBK	40° 32' 12"	73° 59' 58"	15
EBL	40° 32' 18"	74° 00' 00"	15