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ANIMAL-SEDIMENT RELATIONSHIPS AND EARLY SEDIMENT DIAGENESIS IN LONG ISLAND SOUND

by

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INTRODUCTION

Research in invertebrate paleontology and sedimentology is becoming increasingly environmental in scope. Problems of environmental reconstruction, early sediment diagenesis, adaptive morphology of fossil organisms, and paleosynecology lean heavily upon the knowledge of Recent marine organisms and geochemical processes. Studies of Long Island Sound provide an insight into biological and sedimentological processes in a boreal terrigenous marine environment. Buzzards Bay, Massachusetts has received more detailed study than Long Island Sound. For this reason, frequent reference will be made to Buzzards Bay data when discussing field observations of L.I. Sound animals and sediments. The purpose of this trip will be to: (1) sample and observe sedimentologic features that are important limiting factors in the distribution of bottom dwelling organisms, (2) present a new hypothesis for explaining the spatial separation of filter feeding and deposit feeding communities, (3) describe how animal-sediment relationships observed in Long Island Sound would be preserved in the fossil record, (4) characterize the chemical environment within the sediments and some of the changes taking place as a result of early diagenesis.

PHYSICAL OCEANOGRAPHY OF L.I. SOUND

The following summary is from Riley's work on the physical oceanography of the Sound (Riley, 1956).

Temperature and Salinity

Long Island Sound is approximately 90 miles long and 15 miles wide, with an area of 930 square miles. Most of the Sound is less than 30 meters in depth. A maximum depth of 100 meters is located near the eastern end of the embayment. Unrestricted passage of water through Block Island Sound permits free exchange of Sound and open shelf water. Seventy-five percent of the fresh water runoff enters the eastern end of the Sound where it is mixed with water of open ocean salinity. More restricted exchange of open ocean and L.I. Sound water at the western end results in water being about 5 ‰ (dissolved solids in parts per thousand) fresher than water at the eastern end. A summary of the temperature-salinity relations for spring and fall conditions 1952-1953 is given in figure 1. Maximum temperature and salinity are recorded in late summer and early fall when fresh water runoff is minimal and solar heating is greatest. The annual temperature range is 23°C (2°-25°C) and seasonal salinity flux about 4 ‰ (25-29 ‰). A small thermocline is present from February-March until August. Vertical salinity gradients exist throughout the year with

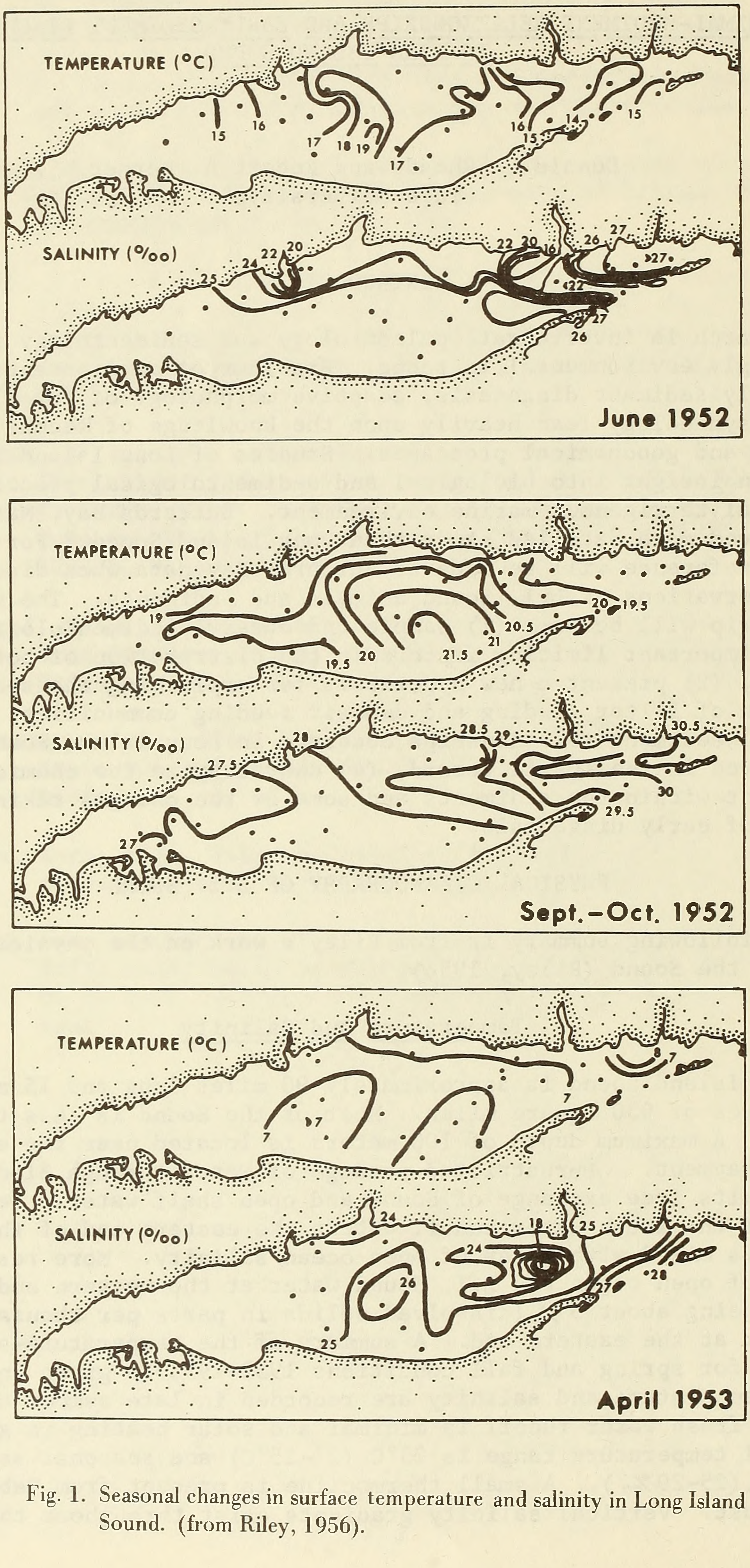


Fig. 1. Seasonal changes in surface temperature and salinity in Long Island Sound. (from Riley, 1956).

surface water being about 1‰ lower than bottom water. Although the salinity regime of L.I. Sound is more brackish than that of Buzzards (35‰), the major macrofaunal benthic associations are the same. It appears that these faunal associations are euryhaline within the range 35‰ -25‰.

Currents

Mean tidal range in the eastern end of the Sound is 0.75 meters increasing to 2.2 meters at the western end. Strong tidal currents flow between narrow passes scouring the bottom, producing sand, shell, and gravel deposits. Non-tidal currents fit the two layer transport system of other estuaries, i.e. relatively fresh surface water moves eastward from river mouths and is replaced by water of open ocean salinity moving westward along the bottom. Riley (1956) suggests a flushing rate of 30% of the volume of the Sound per month. Figure 2 gives the non-tidal current direction and surface velocity in the area of New Haven Harbor. Current velocities at the sediment-water interface are much lower, especially in the deeper central part of the basin.

Turbidity

Many compounds in the sea contribute to the turbidity of sea water (dissolved solids, colloids, plankton, planktonic detritus, and mineral detritus). Riley (1956) measured the turbidity of L.I. Sound water over a two year period. Much of the periodicity in turbidity was correlated with phytoplankton productivity, but over two thirds of the light extinction was related to the presence of suspended particulate non-living detritus. Riley suggests that resuspension of bottom sediments is important in contributing to decreased water transparency. Patten, Young, and Roberts (1966) found turbidity increasing with depth in the York River due mainly to an increase in inorganic detritus. Morton (1967) also found resuspension of bottom sediments to be locally important in Narragansett Bay and Rhode Island Sound. Recent unpublished work of Dr. David Young, M.B.L., Woods Hole, indicates that mud and small invertebrates are resuspended several meters off the bottom in 20 meters of water in Buzzards Bay.

Lithofacies

The sediment distribution map (fig. 3) is from Buzas (1965). A more detailed look at the major textural types reveals a gradual increase in the silt-clay fraction from the shoreline to the center of the Sound. Depths below 20 meters are especially high (> 50%) in silt-clay. Sands predominate nearshore, on topographic highs like Stratford Shoal, and in the current scoured bottoms in approaches to Block Island Sound. The general textural distribution pattern is also characteristic of Buzzards Bay, Massachusetts. A generalized cross-section of the basin showing the relationship of texture to bathymetry is given in figure 6. Major mineralogic components of the sediments are: quartz, muscovite, biotite, albite, microcline, kyanite, augite, hornblende, chlorite, aragonite, calcite, and dolomite (McCrone, Ellis, and Charmutz, 1961). Moore (1963) described the high percentage silt-clay basinal facies of Buzzards Bay as a protogreywacke and the marginal sand facies as consisting of arkosic sands, feldspathic sands, and quartzose sands (Pettijohn's classification). These compositional terms may also be applied to the major sediment facies found in Long Island Sound. Near-

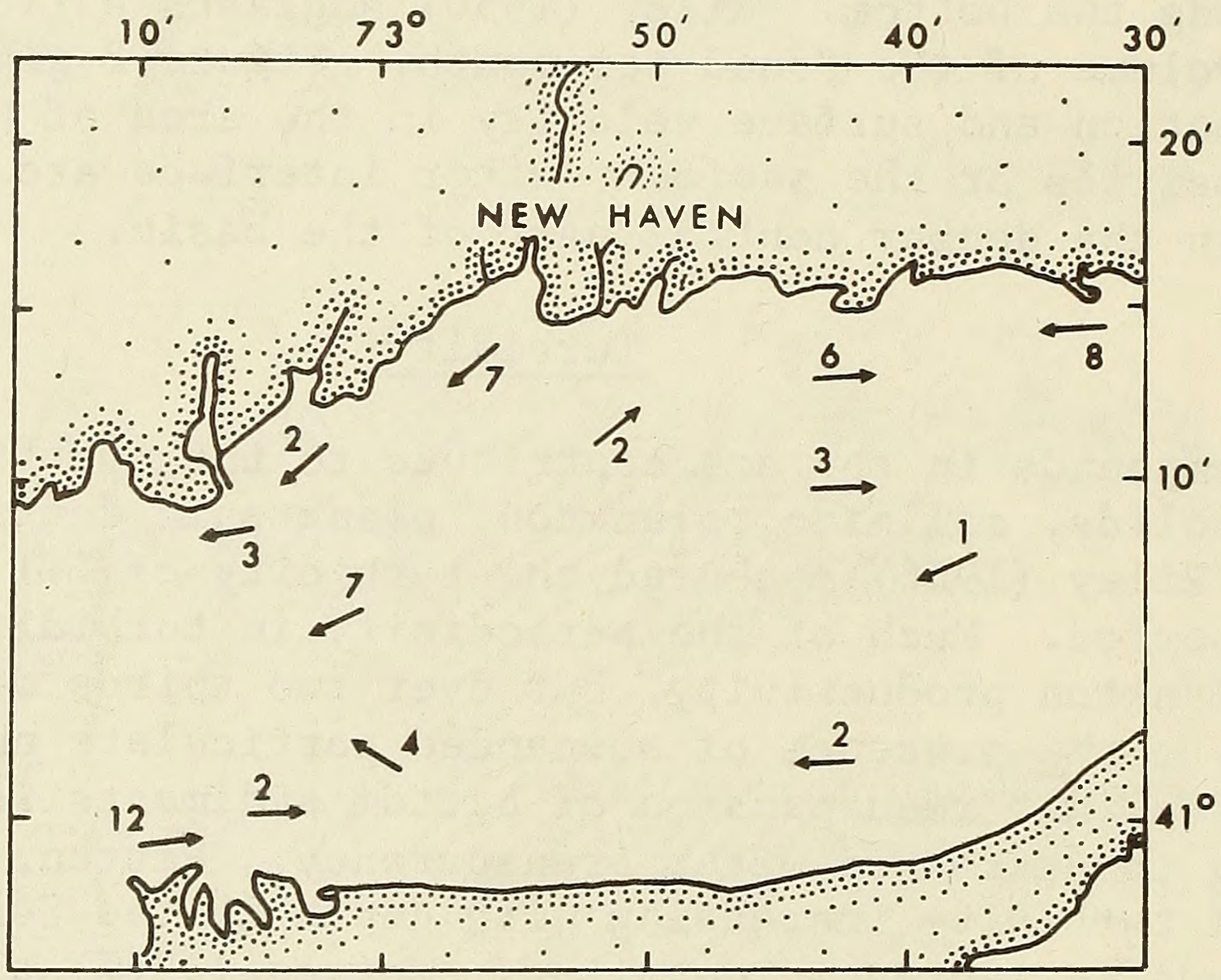


Fig. 2. Current speed and direction of nontidal drift (cm/sec.) in central L. I. Sound (from Riley, 1956).

Fig. 3. Sediment distribution map of Long Island Sound (Data from Buzas, 1965).

TABLE 1. Composition of Primary Feeding Types at Each Station. Stations Arranged in Order of Increasing Silt-Clay Percentage. (data from Sanders, 1956)

Station	*Suspension feeder*	*Deposit-Feeder*		*% silt-clay*
		Selective	*Nonselective*	
4	95.56%	4.30	0.14	5.4
1	82.94	16.63	0.43	4.7
Charles Is.	76.91	20.19	2.90	11.0
5	43.03	18.93	38.04	18.5
8	10.16	43.52	46.32	28.0
7	5.82	55.82	38.88	31.5
2	6.15	59.84	34.01	56.0
3	5.78	41.68	52.39	65.0

shore sands are crossbedded and contain shell layers. These grade laterally into deeper water muddy sands and silts showing alternating crossbedding and bioturbate structures. The basinal protogreywacke lacks current structures and appears completely reworked by organisms (fig. 6).

BIOFACIES AND ANIMAL-SEDIMENT RELATIONSHIPS

The variables of salinity, temperature, and sedimentary regime are the most important limiting factors controlling the distribution of Recent, and presumably, ancient marine benthos. Within L.I. Sound and Buzzards Bay, sediment type appears to be the major factor controlling benthic distribution patterns (Sanders, 1956, 1958, 1960). It is fortunate for the paleontologist that organisms are so closely tied to preservable aspects of the environment such as grain size and relative organic content.

Feeding Types

Heterotrophic benthic organisms make a living in four ways: (1) by filtering food from the water, (2) by feeding on organic matter in the substratum, (3) by predation, (4) by eating benthic plants. Some organisms feed exclusively by one or another of these four ways while others are facultative. Organisms feeding exclusively by deposit feeding would be expected to reach maximum diversity and biomass on substrata rich in organic matter, i.e. fine grained muds. Filter feeding organisms, in contrast, feed on suspended food. This suggests a greater independence of this trophic group from substratum composition. The distribution of predators and herbivores is controlled by the distribution of prey or plants rather than directly on sediment type. For this reason, we will not consider these trophic groups further. Sanders's work on bottom communities at nine stations in L.I. Sound (Sanders, 1956) and in Buzzards Bay (Sanders, 1958, 1960) are two excellent examples of the separation of trophic groups into different sediment types. Sanders's L.I. Sound stations cut across sediments ranging from coarse sands to silty muds (fig. 3, table 1). Organisms feeding by filtering (suspension or seston feeders) are found in greatest biomass at stations where the bottom is sandy and largely free from silt-clay (fig. 4). These same types of bottoms support the greatest biomass of epifaunal forms (fig. 5). Sanders has named this biofacies the Ampelisca community for the dominance of epifaunal tube dwelling amphipod crustaceans. Deposit feeding benthos, in contrast, attain a high standing crop at stations with a silt-clay content of >50% (fig. 4). Few epifaunal forms are found on these muddy bottoms. Sanders has named this biofacies the Nepthys incisa (polychaete)-Nucula proxima (protobranch bivalve) community. These two major communities are common to L.I. Sound and Buzzard Bay. We will occupy sampling stations off New Haven Harbor similar to Sanders's stations in sediment type and faunal composition. Grab samples will be taken for identification of organisms, feeding types, and sediment texture.

The Filter Feeding Paradox

The absence of deposit feeders from nearshore sands may be attributed to the absence of food in current washed sands. The relative absence of filter feeders from the high silt-clay bottoms presents a problem,

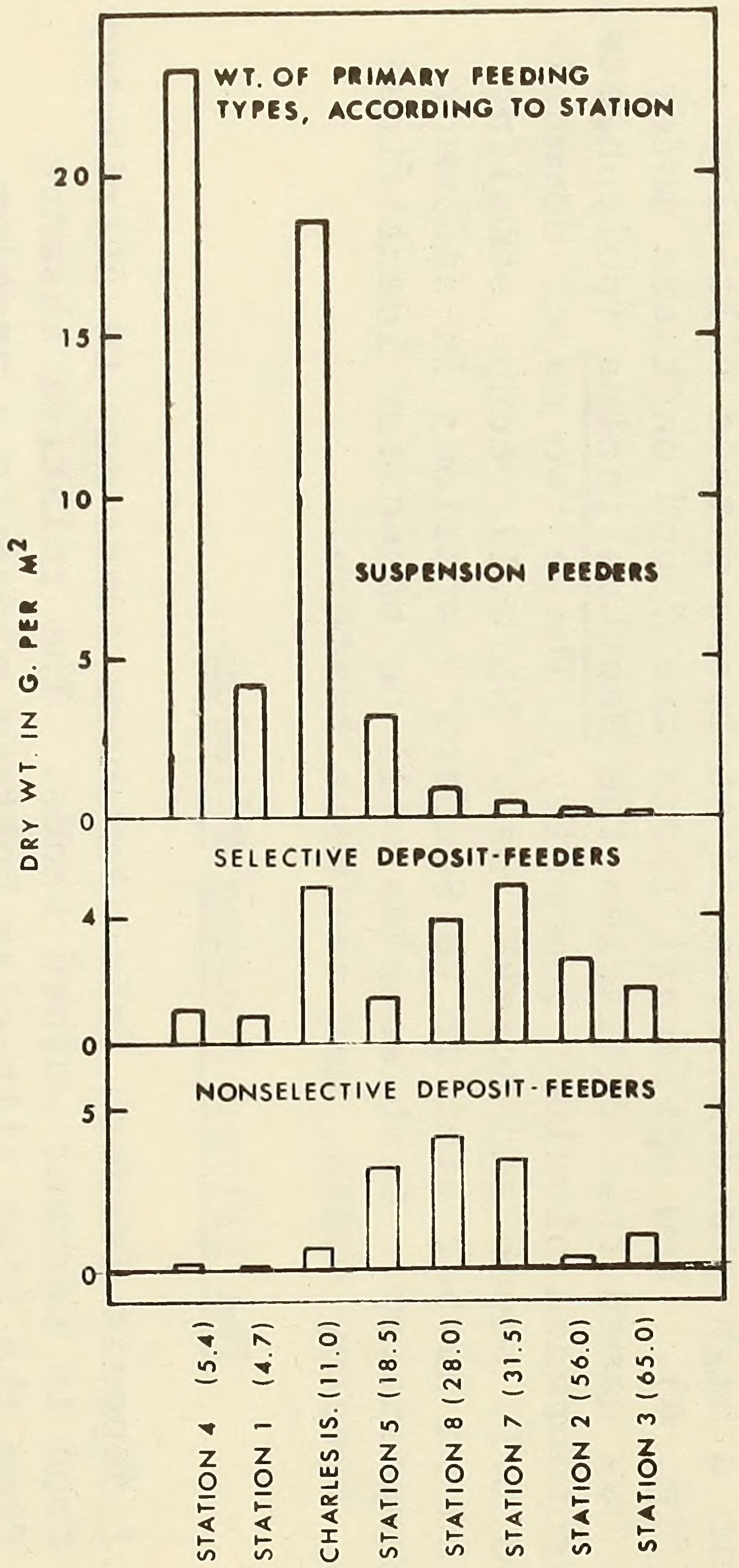


Fig. 4. Wt. of primary feeding types by station. Values following station numbers are percent silt-clay composition. (After Sanders, 1956).

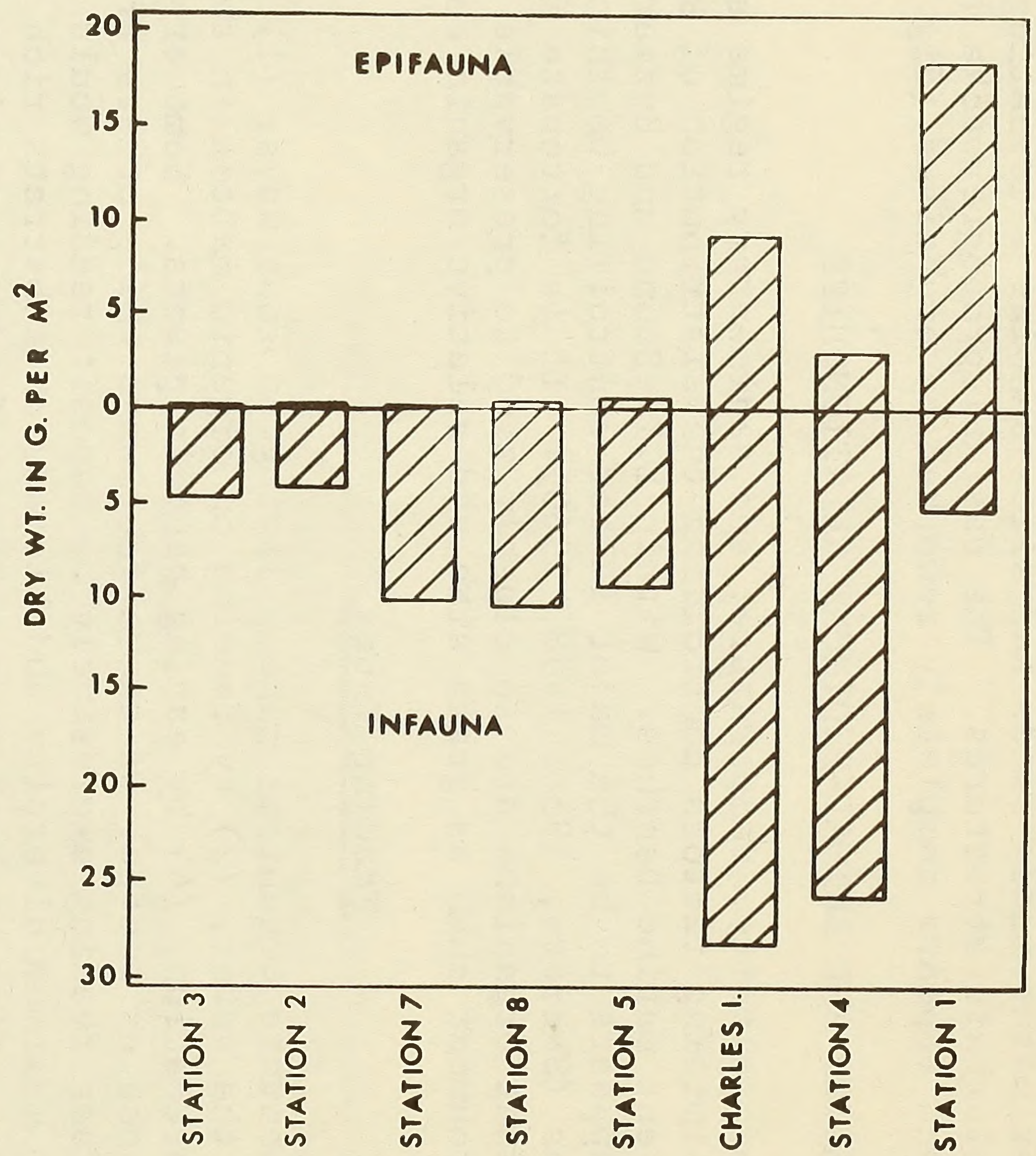
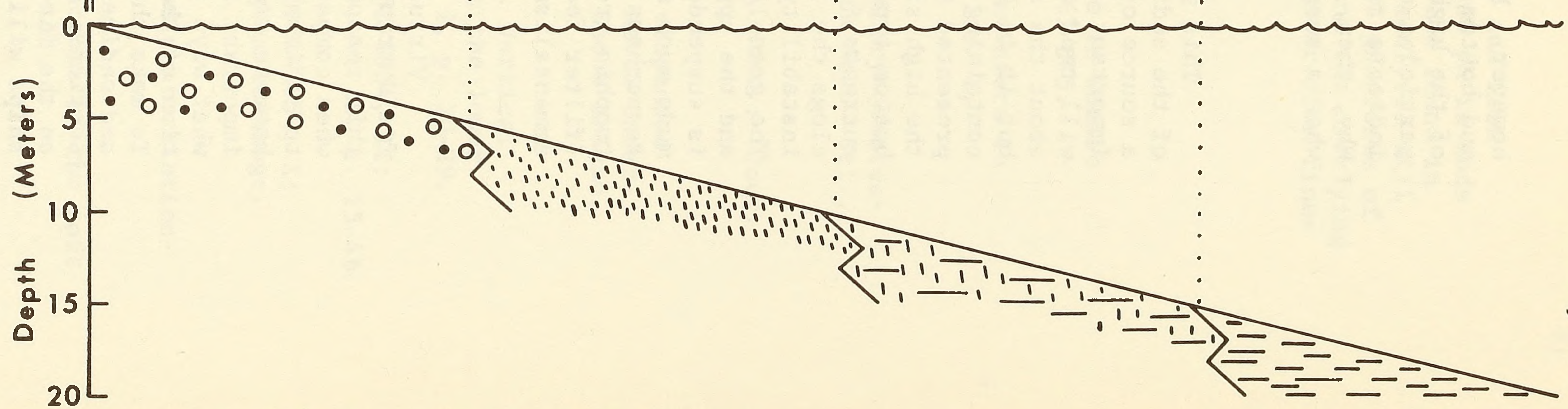


Fig. 5. Mean dry wt. of small infauna and epifauna at each station (after Sanders, 1956).

Fig. 6 Generalized Bathymetric Profile Relating Benthic Community Structure to Sedimentary Parameters.

Sediment Type	Crs. Sand, pebbles	Silty Sand	Muddy Sand and Silt	Muddy Silt-Clay
Organic Content	← < 1% →		← 1-2% →	> 2%
Interface Water Content	← < 30% →		← 30-60% →	> 60%
Interface Stability	Low; reworked freq. by shoaling waves	← Stable except during major storms →		Low, bottom easily suspended by weak bottom currents (1 cm./sec.)
Trophic Group Dominance	← Filter Feeders →		Mixed Filter and Deposit Feeding	Deposit feeders
Epifauna/Infauna	Epifauna and Infauna present but low diversity	Epifauna dominant	Mixed Epifauna and Infauna	Infauna
Sander's Community Name	. . .	*Ampelisca* Community →		*Nepthys incisa - Nucula proxima* Community
Sedimentary Structures	Low Angle Cross-Bedding	Cross-bedding, ripple lamination, and some bioturbate structures	Bioturbation alternating with storm produced cross-bedding.	Bioturbation Structures Dominate



however. Does this absence reflect a lack of suspended food over the mud bottom or are other limiting factors operating? Visual observation of the high silt-clay facies by diving indicates an abundance of suspended particles over the bottom. We have already cited several studies that indicate resuspension of bottom mud is an important factor in water turbidity. Why, then, are filter feeders rare in the >20 meter silt-clay bottoms when a suspended food source is available?

Interface Stability

This paradox may be resolved by considering the relative stability of the sediment-water interface. Filtering organisms must not only have a source of suspended food but the concentration of particles is also important. Dense concentrations of seston immediately above the bottom will tend to clog ciliary or mucus feeding structures. Little is known about the silting tolerance of early metamorphosed filtering organisms but it is known that adult bivalves feed most efficiently in suspensions containing only a few milligrams of detritus per liter. An hypothesis is presented to suggest that the intensive reworking of the interface of the high silt-clay facies by deposit feeders makes the surface of this bottom type extremely unstable. Resuspension of these bottom muds by weak currents (~1 cm/sec.) creates high turbidity which buries or otherwise clogs the filtering mechanisms of juvenile filter feeders. This interface instability may also explain the absence of epifauna on these bottoms. The granular appearance of the mud surface is largely faecal in origin and the upper 5 mm of mud contains 60-70% water. This upper 5mm zone is suspended by the slightest current action, making the deposit feeder muds much more unstable than bottoms lacking this trophic group. This is perhaps the first evidence that the feeding activities of one type of trophic grouping so change the environment that a second trophic group (filter feeders) is excluded. This kind of biotic relationship is called ammensalism.

PALEOECOLOGIC IMPLICATIONS

Virtually all of the animal-sediment relationships observed on this field trip are capable of being preserved in the fossil record. For this reason our observations may be directly applied to the fossil record when comparing Recent and ancient trophic groupings and their relationships to sediment parameters. If there is an ammensalistic relationship between trophic groupings, then this relationship has perhaps played an important role in shaping the distributions of fossil communities. In what ways did the Paleozoic 'protobranch' facies influence the distribution of the brachiopod-crinoid epifaunal filter feeding associations? To make this type of paleoecologic analysis requires integration of organism and sedimentologic data like that of figure 6. Photomicrographs of thin-sections, radiographs of cores, and bottom photographs will be available on the field trip to show in more detail how the animal-sediment relationships will be preserved.

Early Diagenesis

The effect of bacterial decomposition of organic matter on the chemical composition of sediment pore waters is considerable. Emphasis will be placed during the trip on evidence for anaerobicity in interstitial waters as evidenced by Eh and the presence of H_2S and iron sulfides. Direct electrometric measurement of H_2S, Eh, and pH in muds will be demonstrated. A discussion of the techniques can be found in Berner (1963). Results of pore water and other chemical analyses will be presented to illustrate diagenetic changes and chemical gradients of dissolved species (phosphate, sufate) between sediments and the overlying water. If time permits, techniques for extracting pore water from fine-grained sediments will also be demonstrated.

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