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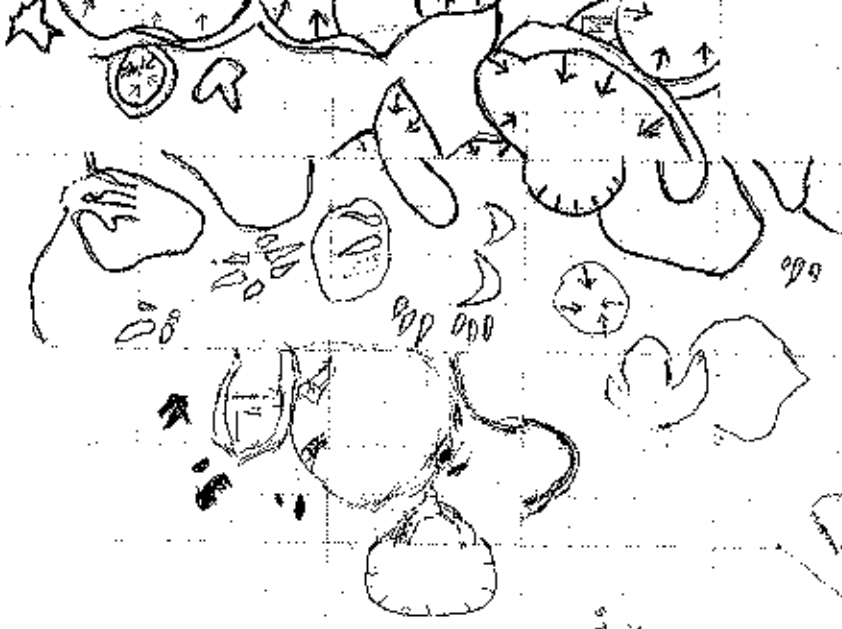
2.5 cm = 1 meter

by Jane Bayne

2.5 cm = 1 m



WATER



CHLOROPLAST



1.1 INTRODUCTION

No organism has been preserved unchanged in its original life position. Instead, each fossil has been altered to some degree, ranging from desiccation or freezing but with the majority of soft tissues still present to degradation of hard parts so that all that remains is a partial imprint or a residual grain too small to assign to any phylum. In addition, the majority of fossils are not entombed in life position or even in their position of death, but have generally at least rotated over so that their longest axis lies on the substratum. Many have been moved by currents, waves or mobile organisms for some unknown distance from the place at which they died.

The study of this history of individual fossils and of fossil assemblages, from death to observation or collection by a paleontologist or field geologist is known as taphonomy. Taphonomy has yielded a distinct body of knowledge and new understanding of the process of preservation. Many exciting new insights into carnivory and scavenging activity, utilization of skeletal remains by subsequent organisms, hydrodynamic processes that affect skeletal remains, sedimentary geochemistry, and other topics are currently developing in taphonomic studies. For many paleontologists, however, the changes that have afflicted fossils constitute a set of filters that diminish the amount of information available about the once-living organisms.

The purposes of this exercise are:

- 1 to consider as much as possible the history of changes that fossils in various states of preservation have experienced; and
- 2 to examine the probable effects of some taphonomic processes on the potential for preservation of a living marine community.

1.2 TAPHONOMIC CHANGES

The taphonomic history of most fossils may be divided into three intergrading stages: pre-burial, burial, and post-burial. (Fossils of burrowing organisms that were never exhumed from their enclosing sediment before they were collected have only a post-burial history.) Generally, burial is the briefest part of the history and post-burial is the most extended. Potential events in a fossil's taphonomic history are summarized below. Possible pre-burial alterations include the following:

1 Transportation. This redistributes the remains of organisms within the original habitat or mixed into other environments. Often breakage or abrasion reduces the size of transported skeletal fragments so that their identification becomes progressively more difficult. However, if the original skeletal microstructure is preserved, particularly if that is supplemented by retention of some original surface morphology, even rather small grains in thin sections can be identified for many marine invertebrates as indicated in Fig. 1.1. Over a century ago, Charles Darwin (1881, p. 251) used microstructure to recognize sand-sized fragments of "land mollusc" shells in castings made by earthworms.

(a) **Currents.** Currents cause sorting by size, shape, and density. Abrasion begins to erode surface morphology and causes rounding if there is extended current transportation. In addition, a preferential orientation of non-spherical skeletons is likely to develop, which gives an indication of the final direction of current movement before burial occurred.

(b) **Shoreface waves.** These waves, which stir up the sediment in the intertidal zone and just offshore along beaches, generate some fragmentation, but abrasion and sorting are especially characteristic. The effects of shoreface waves on fossil remains are difficult to distinguish from the effects of currents except through study of geometry, sedimentary structures, and lithologic associations of the enclosing sediments.

(c) **Storm waves.** These relatively brief but vigorous waves often result in more fragmentation than abrasion and sorting. They extend deeper into the water and so affect organic remains on parts of the sea or lake floor that are not touched by normal waves.

(d) **Rafting and transportation by animals.** Either of these may be hypothesized for exotic occurrences, but is difficult or impossible to demonstrate. Possible modes of transportation include ice, pumice, floating vegetation, and mobile organisms (such as sea gulls that break mollusks open by dropping them onto pavement). If unaffected by other types of transportation, abrasion and fragmentation are commonly slight.

2 Biological.

(a) **Preservation by bioimmuration.** Bioimmuration is the covering over of an organism by some other encrusting organism such that the shape and perhaps surface texture of the underlying organism is preserved on the underside of the encruster after the two become detached.

(b) **Destruction.** (i) **Exogenous:** these are external destructive forces, including fragmentation by such organisms as crabs and grazing fish. (ii) **Endogenous:** endogenous destruction occurs from within the organism or its remains, e.g. excavation of skeleton by boring organisms such as endolithic algae, sponges, barnacles, and drill holes made by carnivorous gastropods, or bacterial decomposition of organic portions of skeletons.

3 Chemical.

(a) **Preservation.** Skeletal cavities may be filled by minerals during early diagenesis (Fig. 1.2), which is the sequence of changes that occur as sediment is transformed to rock. This includes permineralization, which fills mineral material into tiny pore spaces within organisms or their skeletons.

(b) **Destruction.** Changes in acidity (pH) or oxidation potential (Eh) so that a critical value termed a chemical fence is crossed, results in the original material being dissolved or replaced by a different material (Fig. 1.3).

Figure 1.4 summarizes the common potential pre-burial taphonomic alterations that corals distributed across a reef may experience. Clearly, the types and severity of taphonomic alterations, even for this one group of organisms distributed

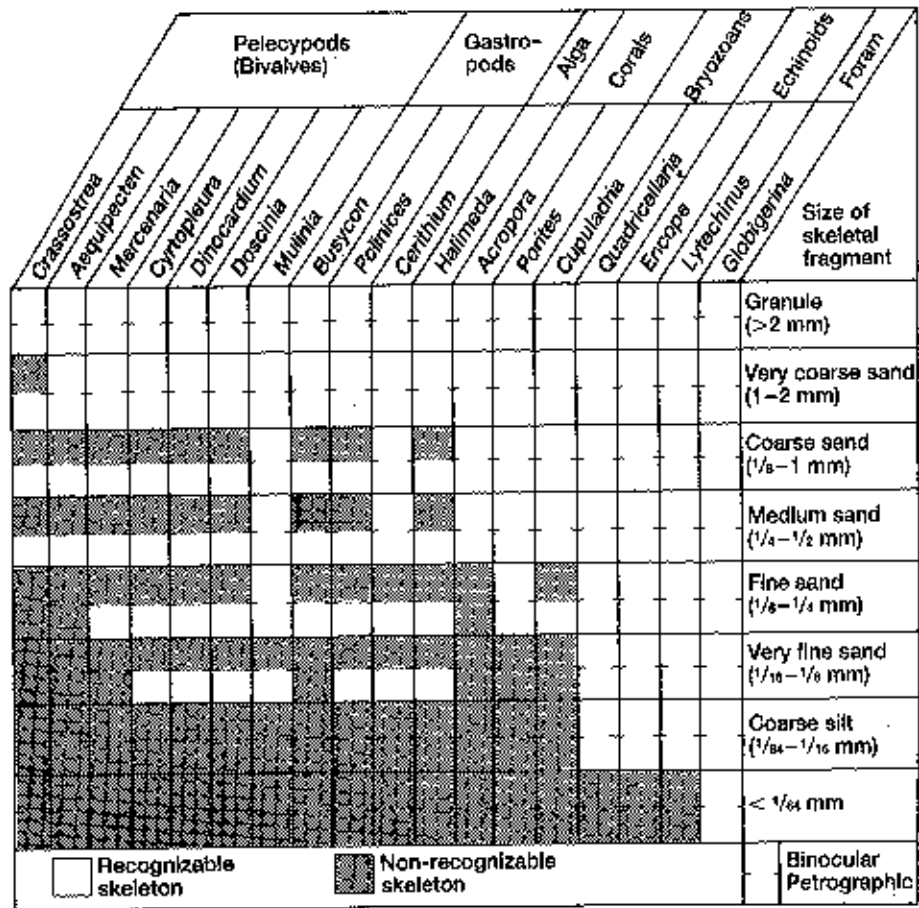


Fig. 1.1 Sizes at which fragments derived from skeletons of various marine organisms are recognizable when studied with a binocular microscope and when studied in thin sections with a petrographic microscope. From Feray *et al.* (1962) with permission from the American Association of Petroleum Geologists.

Fig. 1.2 Drawings from photomicrographs of: (a) a thin-section of skeleton cut from a living coral that has been diagenetically altered only by minute boring algae along the surface of the skeleton (producing the dark margin known as a micritic envelope); and (b) a coral, collected about 30 cm below the surface of a reef, in which aragonite cement has grown profusely into the interstices of the skeleton. From Friedman & Amiel (1974).



across subzones of a single environment, are basically different and characteristic for each specific type of occurrence. (Questions 1 and 2)

Burial situations include the following:

1 Rate.

(a) Catastrophic. This includes sudden influxes of sediment that cover over the fossil in its original habitat or move the fossil some distance as a sedimentary particle that ends up

on the bottom or is buried within an accumulation of sediments.

(b) Slow. This is gradual burial of the fossil because of grain-by-grain or layer-by-layer accumulation.

2 Locale.

(a) *In situ*. Organisms may be buried at the place where they died. This is most common for benthic organisms that lived on fine-grained sediments. (i) In life position: preservation in life position generally is most common for

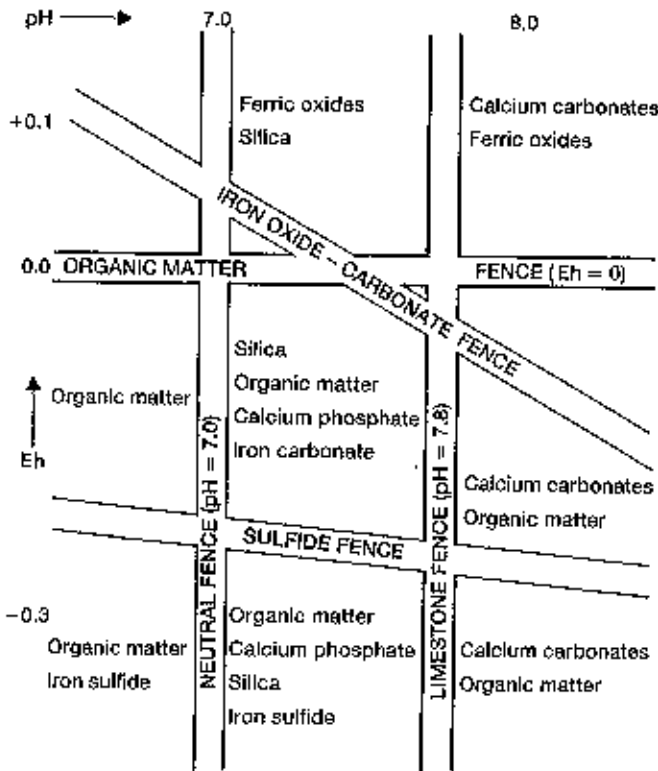


Fig. 1.3 Diagram of the common chemical fences that are pertinent in diagenesis of sedimentary rocks and in taphonomic alteration of fossils. Each fence separates two chemical fields characterized by contrasting occurrences of specific materials. For example, organic matter can exist below the organic matter fence ($Eh=0$), in conditions of negative Eh, but it does not exist above the organic matter fence, in conditions of positive Eh. From Towe in Boardman *et al.* (1987) after Krumbain & Garrels (1952).

burrowers or stationary organisms that live partially buried, less common for epifaunal sedentary organisms, and least common for mobile animals. (ii) Prone: most organisms topple over or collapse into a stable orientation on the substratum before they are buried.

(b) Transported. Transportation is indicated by abrasion and rounding and is suggested by preservation in coarse-grained sediment. It should be considered as a possibility where fossils in fine-grained sediments appear to rest on one another, forming the structural framework of the rock.

(Question 3)

Possible post-burial alterations include the following:

1 Pre-lithification (before consolidation of sediment into rock).

(a) Compaction. Especially severe in dewatering of clays. It results in plastic-style flattening of flexible fossils and in flattening of rigid fossils by cracking into fragments that generally are contiguous.

(b) Chemical. (i) Preservation: this continues the filling of cavities during early diagenesis and includes permineralization. (ii) Destruction: fossils may be destroyed when they cross certain chemical fences as illustrated in Fig. 1.3.

(c) Biological. (i) Exogenous: this almost always consists of fragmentation by excavating or burrowing deposit feeders, but it includes shallowly buried shells trampled by heavy vertebrates such as dinosaurs. (ii) Endogenous: bacteria may decompose organic material after burial.

2 Post-lithification (after consolidation of sediment into rock).

(a) Physical. (i) Structural deformation. (ii) Physical weathering.

(b) Chemical. (i) Recrystallization. (ii) Permineralization. (iii) Replacement. (iv) Distillation: selective removal of oxygen and hydrogen from organic material results in the concentration of carbon. (v) Dissolution:

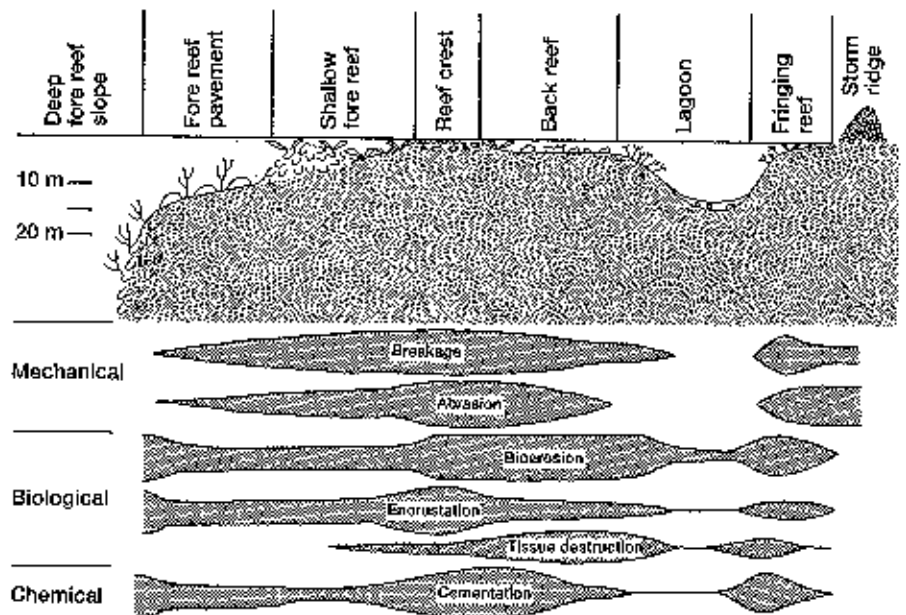


Fig. 1.4 Relative intensity of pre-burial taphonomic effects on corals across shore-parallel zones from offshore (left) to onshore (right). From MacIntyre (1984).

where skeletal material is dissolved from rock, *molds* of the exterior → and in some cases interior — surfaces are produced where the rock retains the impression of the fossil. (vi) *Casts*: casts are infillings (including plastics) of natural molds and replicate the original shape of the fossil material.

(Question 4)

1.3 LOSS OF INFORMATION FROM PRESERVED ASSEMBLAGES

Fossil assemblages, even those that are preserved *in situ*, lack large numbers of the original components of the living community. Certain size classes of the preserved species may be absent or under-represented, and many species have left no record at all. The similarity of the fossil assemblage to the original community depends on the original chemical composition of the species in the community and on the vicissitudes of preservation that have been summarized in Section 1.2.

Artificial or hypothetical degradation of modern communities can give useful insights into the types of organisms that may be lacking in fossil assemblages, particularly Cenozoic assemblages of fossils that have close living representatives.

The final question in this exercise will be a comparison of Oligocene oyster reefs from the Atlantic Coastal Plain of North Carolina with living oyster reefs in the estuaries and lagoons along the coast of North Carolina, based on work by Lawrence (1968). The Oligocene assemblage is dominated by densely packed, upright specimens of the oyster *Crassostrea gigantissima* which are associated with skeletons of several bryozoan species, one pelecypod (bivalve), one annelid, and one barnacle species. In addition, the oyster skeletons contain excavations made by sponges, bryozoans, an annelid, and a pelecypod; skeletal blisters that formed in response to a different annelid; and the imprint of a low-spired gastropod. In all, between 16 and 18 species are represented.

A total of 303 species has been identified in the *Crassostrea virginica* reefs in the vicinity of Beaufort, North Carolina (Wells, 1961), excluding monerans, copepods, ostracodes, nematodes, herring gulls, *Homo sapiens* and most protists. Of the 303 species, 81 occur in 40% or more of the sites examined and will be the basis for comparison with the Oligocene reefs in the question below. The purpose of this part of the exercise is to see how comparison of a geologically

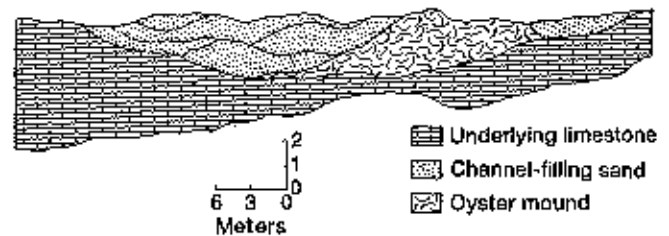


Fig. 1.5 A cross-section through an Oligocene oyster build-up and the channel deposits in which it is situated at Belgrade, North Carolina. From Lawrence (1968).

“degraded” recent community with a fossil analogue can be used to address such questions as probable similarity of communities and possible increase through time in species richness.

(Question 5)

The Belgrade oyster reef assemblage was preserved in porous terrigenous sediments deposited in a channel that was cut into underlying calcareous strata (Fig. 1.5). Movement of groundwater has strongly leached the deposit, allowing only calcitic fossils to be preserved as body fossils. Therefore, the hypothetical preservation state of the Beaufort oyster reefs in the column entitled “Calcitic skeletons preserved, with species marked by r restored” should be most comparable to that of the Oligocene oyster reef assemblage at Belgrade.

(Question 6)

FURTHER READING

- Allison, P. A., 1988. Konservat-Lagerstätten: cause and classification. *Paleobiology* 14:331–344.
- Behrensmeier, A. K. & Kidwell, S. M., 1985. Taphonomy's contributions to paleobiology. *Paleobiology* 11:105–119.
- Durham, J. W., 1967. The incompleteness of our knowledge of the fossil record. *Journal of Paleontology* 41:559–569.
- Krumbein, W. C. & Garrels, R. M., 1952. Origin and classification of chemical sediments in terms of pH and oxidation-reduction potential. *Journal of Geology* 60:1–33.
- Thomas, R. D. K. (ed.), 1986. Taphonomy: ecology's loss is sedimentology's gain. *Palaio* 1(3). (An issue of the journal *Palaio* that consists of 10 papers on various aspects of taphonomy, written by various authors.)

QUESTION 1

Destruction due to transportation. Examine the specimens provided, which have been affected predominantly by one of the four categories of transportation as listed in the text of this exercise. Carefully note the range of effects that the specimens exhibit. In the spaces below, briefly (1) describe the effects, (2) determine the probable cause, and (3) explain why you answered (2) as you did.

1 Effects seen in specimens: _____

2 Probable type of transportation: _____

3 Explanation: _____

QUESTION 2

Endogenous biological destruction. Examine the specimens provided, which have been affected to varying degrees by boring organisms that are identified to phylum on the specimen label. (1) Describe the shape(s) of the cavities generated, (2) estimate the percent of original skeletal material that has been removed by the boring organisms in the most severely affected example, and (3) state how the specimen's ability to resist physical damage is affected by the presence of the borings.

1 Shape(s) of cavities: _____

2 Estimated % skeleton lost: _____

3 Effect on resistance to physical damage: _____

QUESTION 3

Examine the slabs provided. For each assess the probable burial situation and give the bases for your conclusions.

Burial situation for fossils in slab 1: _____

Bases for assessment: _____

Burial situation for fossils in slab 2: _____

Bases for assessment: _____

QUESTION 4

Labeled examples of several types of preservation are provided. For each give as complete a taphonomic history as possible, which consists of the taphonomic evidence exhibited and the implications or interpretation of each bit of evidence. Organize your answers in the following sequence: (1) chemical fences crossed and the direction they were crossed, (2) pre-burial events, (3) burial situation, (4) post-burial events. Each of the categories may not be pertinent for all specimens. Burial situation is impossible to determine for specimens that have been entirely removed from their original rock, unless they are conspicuously abraded. If a specimen provides no information for one of the parts (1)–(4), write NA on that line.

Specimen:

Type preservation:

<i>Observation</i>	<i>Interpretation</i>
1 _____	_____
2 _____	_____
3 _____	_____
4 _____	_____

Specimen:

Type preservation:

<i>Observation</i>	<i>Interpretation</i>
1 _____	_____
2 _____	_____
3 _____	_____
4 _____	_____

Specimen:

Type preservation:

<i>Observation</i>	<i>Interpretation</i>
1 _____	_____
2 _____	_____
3 _____	_____
4 _____	_____

Specimen:

Type preservation:

<i>Observation</i>	<i>Interpretation</i>
1 _____	_____
2 _____	_____
3 _____	_____
4 _____	_____

Specimen:

Type preservation:

<i>Observation</i>	<i>Interpretation</i>
1 _____	_____
2 _____	_____
3 _____	_____
4 _____	_____

Specimen:

Type preservation:

<i>Observation</i>	<i>Interpretation</i>
1 _____	_____
2 _____	_____
3 _____	_____
4 _____	_____

Specimen:

Type preservation:

Observation

Interpretation

1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____

Specimen:

Type preservation:

Observation

Interpretation

1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____

Specimen:

Type preservation:

Observation

Interpretation

1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____

Specimen:

Type preservation:

<i>Observation</i>	<i>Interpretation</i>
1 _____	_____
2 _____	_____
3 _____	_____
4 _____	_____

Specimen:

Type preservation:

<i>Observation</i>	<i>Interpretation</i>
1 _____	_____
2 _____	_____
3 _____	_____
4 _____	_____

QUESTION 5

In the following list of 81 species that are widespread in North Carolina oyster reefs, skeletal composition of each is recorded as A = aragonite or mixed aragonite and calcite, B = calcium phosphate (bone), C = calcite or predominantly calcite, O = largely or entirely organic, and Si = silica. In addition, organisms likely to generate preservable borings, imprints, or to stimulate identifiable responses in calcareous skeletons are indicated by an "r".

Complete the chart by filling an X in the boxes in each column if remains of the species should have survived to be represented at that stage of preservation. In column 1, score an X for all organisms that would still be represented if all well-mineralized skeletons are preserved and all organisms with organic skeletons have decayed and left no trace. In column 2, score only those organisms that would still be represented if only calcite or predominantly calcite skeletons — but *not* aragonite or mixed skeletons — are preserved. In column 3, *repeat* the scores from column 2 and *also* score those organisms that are likely to leave some identifiable boring, imprint, or response in a host. (Column 3 will have more species scored than are scored in column 2.)

Species	Skeleton	Column		
		1	2	3
Phylum Protozoa				
Folliculinid species	O			
Phylum Porifera				
<i>Cliona cellata</i>	Si, r			
<i>Cliona spirilla</i>	Si, r			
<i>Cliona truitti</i>	Si, r			
<i>Haliclona permollis</i>	Si			
<i>Hymeniacidon heliophila</i>	Si			
<i>Streblospio benedicta</i>	Si			
Phylum Coelenterata				
<i>Aiptasia pallida</i>	O			
<i>Aiptasia eruplaurantia</i>	O			
<i>Diadumene leucoleuca</i>	O			
<i>Diadumene luciae</i>	O			
<i>Leptogorgia virgulata</i>	O			
<i>Obelia</i> sp.	O			
Phylum Platyhelmintha				
<i>Stylochus ellipticus</i>	O			
Phylum Nemertea				
<i>Amphiporus ochraceus</i>	O			
<i>Tubulanus pellucidus</i>	O			
Phylum Mollusca: Class Gastropoda				
<i>Bittium varium</i>	A			
<i>Cantharus inctus</i>	A			
<i>Crepidula fornicata</i>	A			
<i>Diodora cayenensis</i>	A			
<i>Fasciolaria hunteria</i>	A			
<i>Mitrella lunata</i>	A			
<i>Odostomia dianthophila</i>	A			
<i>Odostomia impressa</i>	A			
<i>Urosalpinx cinerea</i>	A, r			
Phylum Mollusca: Class Bivalvia				
<i>Anomia simplex</i>	C			
<i>Arca umbonata</i>	A			
<i>Brachidontes exustus</i>	A			
<i>Brachidontes recurvus</i>	A			
<i>Chione grus</i>	A			
<i>Crassostrea virginica</i>	C			
<i>Lithophaga bisulcata</i>	A, r			
<i>Martesia smithi</i>	A			
<i>Modiolus americanus</i>	A			
<i>Modiolus demissus</i>	A			
<i>Musculus lateralis</i>	A			
<i>Ostrea equestris</i>	C			
<i>Petricola pholadiformis</i>	A, r			
Phylum Annelida				
<i>Amphitrite ornata</i>	O, r			
<i>Capitella capitata</i>	O			

Species	Skeleton	Column		
		1	2	3
<i>Eteone heteropoda</i>	O			
<i>Eupomatus dianthus</i>	O			
<i>Haplosyllis spongicola</i>	O			
<i>Marphysa sanguinea</i>	O			
<i>Neanthes succinea</i>	O			
<i>Nereiphylla fragilis</i>	O			
<i>Nereis occidentalis</i>	O			
<i>Polydora websteri</i>	O, r			
<i>Sabella microphthalmia</i>	O			
<i>Sabellaria vulgaris</i>	O, r			
Phylum Arthropoda				
<i>Balanus amphitrite</i>	C			
<i>Balanus eburneus</i>	C			
<i>Balanus improvisus</i>	C			
<i>Caprella acutifrons</i>	O			
<i>Caprella linearis</i>	O			
<i>Cassidiscus lunifrons</i>	O			
<i>Chthamalus fragilis</i>	C			
<i>Clibanarius vittatus</i>	O			
<i>Corophium cylindricum</i>	O			
Dipteran larva	O			
<i>Dyaneme perforata</i>	O			
<i>Eurypanopeus depressus</i>	O			
<i>Gammarus locusta</i>	O			
<i>Leptochelia savignyi</i>	O			
<i>Melita appendicula</i>	O			
<i>Melita dentata</i>	O			
<i>Neopanops texana sayi</i>	O			
<i>Panopeus herbatii</i>	O			
<i>Pinnotheres ostreum</i>	O			
<i>Sphaeroma quadridentatum</i>	O			
Phylum Bryozoa				
<i>Alcyonidium polyoum</i>	O			
<i>Anguinella palmata</i>	O			
<i>Bugula neritina</i>	O			
<i>Electra crustulenta</i>	C			
<i>Membranipora tenuis</i>	C			
<i>Schizoporella errata</i>	C			
<i>Victorella pavida</i>	O			
Phylum Pycnogonida				
<i>Nymphon rubrum</i>	O			
Phylum Chordata				
<i>Bobiosoma bosci</i>	B			
<i>Molgula manhattensis</i>	O			
<i>Styela plicata</i>	O			
Total for each column				

