DESCRIPTIONS OF FECAL PELLETS OF SOME COMMON INVERTEBRATES IN THE LOWER YORK RIVER AND LOWER CHESAPEAKE BAY, VIRGINIA

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ABSTRACT

Fecal material voided by 71 invertebrate species is described; 66 of these for the first time. Pellet measurements are given for species producing solidified feces. Pellet size is related to size of animals, and linear regressions were computed for two species. Pellet characteristics described are cross-sectional shape, sculpture, differentiation, composition, and shape. Pellet morphology may be used to identify many animals to specific level, but in most instances no single character is sufficient. Certain species void diffuse fecal material, others shed pelleted feces lacking consistent morphology or with no differentiating characteristics. In the latter instances specific identification is not possible.

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INTRODUCTION

Lister (Moore and Kruse, 1956) in 1678 was the first to observe differences in the morphology of pellets voided by various invertebrates. Later papers have expanded the knowledge of this subject (Moore, 1931a, 1931b, 1932a, 1932b, 1933a, 1933b, 1939; Moore and Kruse, 1956; Edge, 1934; Manning and Kumpf, 1959; Arakawa, 1962, 1963, 1965). Abbott (1954a) used pellet morphology and position in the intestine in conjunction with other features to revise the genus Echinius. Kornicker (1962) studied changes in shape of feces in conjunction with evolutionary development of molluscs.

Fecal pellets of marine organisms accumulate in marine sediments, where their occurrence has been noted by geologists and marine ecologists. Geologists have shown that fecal pellets in sediments may serve as precursors to glauconite formation or may be the central cores of oolites (Buchanan, 1890; Van Tuyl, 1916; Takahashi and Yagi, 1929; Galliher, 1932). Fecal materials may change sediment structure (Kornicker and Purdy, 1957). Verwey (1952), Lund (1953), Ito and Imai (1955), and Haven and Morales-Alamo (in press) have emphasized the importance of fecal material accumulation in sediments adjacent to oysters and other molluscs.

The objective of the present study was to describe fecal pellets of common invertebrates living in the York River near Gloucester Point, Virginia. Specific identification of pellets is a necessary preliminary to more exact studies on the role of pellets in marine ecology.

METHODS

Fecal pellets were obtained from freshly collected living invertebrates taken in the York River near Gloucester Point, Yorktown, Sandy Point, and Sarah Creek; others were obtained from Middle Ground in Hampton Roads (Fig. 1). Specimens from the littoral and sublittoral zones were collected from pilings, algae, Zostera, or by screening animals from the sediments with a 1.0 mm seive. A Petersen grab or a gravity corer was used to collect sediments in deeper water.

Immediately after collection individual animals were placed in separate glass containers containing sea water and held until pellets were voided. This procedure permitted relating pellet size to animal size. Containers were held in a water bath at ambient river water temperature for not over twelve hours as was suggested by Manning and Kumpf (1959). This method of collection and holding assured that pellet composition would be similar to pellets voided by animals in their natural habitat.

Visual observations during the holding period indicated that filter feeders continued to filter water. In certain instances, absence of suspended matter resulted in production of abnormally shaped pellets termed "starvation pellets". These were recognized by atypical size, shape, or composition when compared to pellets produced earlier in the holding period. Detritus and deposit feeders did not have access to particulate matter while being held in jars, and the few pellets voided near the end of twelve hours were generally deformed or much narrower or shorter than those shed initially. The descriptions are based on typical pellets unless otherwise stated, and atypical forms are described only under remarks.

Several filter feeders were placed in flowing water troughs designed to collect fecal pellets (Haven and Morales-Alamo, 1965). In this manner large numbers of pellets were obtained from oysters and similar species. However, this method was not always practical since many animals such as Mya arenaria produce only minimal quantities of abnormally shaped pellets when removed from their natural substrate.

Each specimen and its pellets were preserved in neutral 5% sea water formalin and stored until examined. Animals were measured to the nearest 1.0 mm. Greatest lengths of molluscs and polychaetes were measured, but lengths of many soft-bodied forms are of less value because of preservative contraction. Other measurements were: ophiuroids, diameter of the central disk; tunicates, width; crabs, carapace width; barnacles, basal diameter; and all other arthropods, median dorsal length.

All pellets from the specimens held in jars and subsamples of pellets obtained from animals in flowing water troughs were measured at their greatest length and width, to the nearest 0.01 mm, with an ocular micrometer on a compound microscope. Since most pellets were circular or broadly oval in cross-section, thickness measurements were not taken. Thickness of ribbon-like pellets was taken at the midridge, or the central part of the crescent if the midridge was absent; however, these measurements varied over wide limits along the length of a single pellet, and their value as an aid to fecal pellet identification seems questionable.

Pellets from many species are shed as continuous strings which break into rod- or ribbon-like sections with jagged ends and are defined as broken; lengths of these pellets may vary over wide limits. In contrast, pellets which are either ellipsoid or ovoid are shed with rounded ends, and have characteristic lengths or length to width ratios.

Pellets were classified in the manner outlined by Manning and Kumpf (1959). Exterior shape and internal differentiation are the major criteria for this classification. Any regularly appearing pattern on the pellet's exterior is termed sculpturing; it may be longitudinal, spiral, or transverse. A smooth exterior is one which appears smooth to the eye and is without cracks, pits, or protuberances. If the pellet is indented, but is lacking repetitions of grooves, undulations, or constrictions, its outline is termed irregular. Internal differentiation is defined as a constant localization of materials of different shape or consistency in definite parts of the pellet.

All drawings were made with the aid of a microprojector and a dissecting microscope. Internal morphology and exterior sculpture of pellets was studied by first imbedding them in five percent agar. Later, cubes of agar containing pellets were held in a specially designed holder and sections were sliced with a razor blade. Drawings of these cross-sections showed shape of the pellet, internal differentiation, and characteristics of the sculpture. Composition was determined by crushing pellets on a glass slide and examining the material under the high power of a compound microscope. The components were then classified into categories such as sand, diatoms, detritus, or unidentified.

RESULTS

Fecal pellets from six phyla and 55 families representing 71 species were studied; 66 are described for the first time. In general, no single morphological criterion is sufficient to place a pellet in the proper phyla; however, four definitive characteristics aid in identifying most pellets: shape, sculpture, differentiation, and cross-section. Secondary characteristics such as surface cracks, protuberances or pits, size ranges, and composition further define pellets. Gelatinous sheaths were found on pellets from species in each of the three major phyla studied: Annelida, Arthropoda, and Mollusca, and may be present or absent in any single species. Consequently this feature is of little value.

A detailed analysis relates length and width of pellets to size of animal. Under each species is listed size of the largest and smallest individual along with the range and mean size of their pellets. If pellets for any species were ovoid or ellipsoid the length to width ratios were calculated for all pellets. For these ratios to be valuable they should remain constant for a given individual and for the species; therefore, these data are summarized in two ways: the range in length to width ratios for all pellets and range in mean length to width ratio for pellets of individual animals.

Additional data are given in Tables 1, 2, and 3. The size of the largest and smallest animals of each species is reported; in addition total animals and pellets examined during this study are tabulated. Also tabulated are the ranges in length and width of all pellets and the range in mean sizes of pellets from individual species. If less than three individuals produced pellets or if no solidified material was shed the data were given in the text and omitted from the table.

The results are given in systematic order and the familial order within each phylum follows the classification by the listed authority. In the discussion differentiation refers only to internal structure. If the largest or smallest individual produced less than three fecal pellets it is stated, if not, values for mean pellet size are given. All measurements are in mm and the following abbreviations have been used: W for wide or width, L for long or length, $\bar{x}$ for mean, R for range, and L/W for length to width ratio.

Phylum Annelida

The classification of Hartman (1959) is used.

Class Polychaeta

Family Nereidae

Neanthes succinea (Frey and Leuckart 1847) Pl. 1, fig. a

Pellets broken, rod-like; cross-section circular; constricted at irregular intervals forming series of multi-form beads; sculpture lacking. Composition diatoms, detritus, some sand; material compacted. Differentiation lacking; color dark brown. Smallest individual 21 L; R W - 0.31 to 0.40, $\bar{x}$W - 0.38; R L - 0.79 to 1.51, $\bar{x}$L - 1.04. Largest individual 60 L; R W - 0.61 to 0.66, $\bar{x}$W - 0.63; R L - 1.08 to 1.13, $\bar{x}$L - 1.10.

Remarks: The illustration shows a "typical pellet", but shape and constrictions may vary over a wide range. The shape may appear ellipsoidal or rod-like and the constrictions may be definite or absent.

Family Nephtyidae

Nephtys incisa (Malmgren 1865) Pl. 1, fig. b

Pellet rod-like; cross-section circular. Exterior irregular, covered by gelatinous sheath; sculpture lacking. Composition unidentified material, detritus, some sand. Differentiation lacking; color dark brown. One pellet from individual 52 L; W - 0.53; L - 1.99.

Remarks: This pellet was the only one produced from 29 individuals. It was quite irregular, being helically coiled at one end and irregularly folded at the other. There was an additional 0.12 mm of sheath beyond the end of the pellet material. The extreme irregularity suggests this species may produce pellets of dissimilar shape.

Family Glyceridae

Glycera dibranchiata Ehlers 1868 Pl. 1, fig. c

Feces irregular, rod-like; cross-section roughly circular. Gelatinous sheath folded into longitudinal ridges or smooth, sometimes absent. Sculpture lacking; exterior of fine unidentified material; interior with the same material forming matrix around sand grains. Differentiation, if present, not clear. Color light yellowish tan to grayish green. Smallest individual 58 L; R W - 0.65 to 0.97, $\bar{x}$W - 0.81; R L - 0.66 to 1.97, $\bar{x}$L - 1.32. Largest individual 123 L; one pellet W - 2.00; L - 15.05.

Remarks: The cross-sectional shape may be masked by surface irregularities and raised ridges of the gelatinous sheath. The pellet is well compacted, but sand grains make sectioning difficult.

Family Chaetopteridae

Chaetopterus variopedatus (Renier 1804) Pl. 1, fig. i

Pellets ellipsoidal; cross-section circular. Exterior slightly irregular; sculpture lacking. Composition diatoms, some unidentified material, solidly packed; diatoms cause fuzzy exterior appearance under high magnification. Differentiation lacking; color tannish brown. One individual 84 L; R W - 0.35 to 0.85, $\bar{x}$W - 0.60; R L - 1.08 to 3.31, $\bar{x}$L - 2.42. R L/W - 3.09 to 4.77, $\bar{x}$L/W - 4.06.

Spiochaetopterus oculatus (Webster 1879) Pl. 1, fig. d

Pellets ellipsoidal; cross-section circular. Exterior smooth; sculpture lacking. Composition diatoms, some unidentified material. Differentiation lacking; color light tan. One individual 50 L; R W - 0.23 to 0.24, $\bar{x}$W - 0.24; R L - 1.07 to 1.20, $\bar{x}$L - 1.14. R L/W - 4.65 to 5.22, $\bar{x}$L/W - 4.86.

Remarks: The pellets were found inside the occupied tube surrounded by white, flocculent, unidentified material which fell apart when removed from the tube exposing the pellets. The pellets have a more regular outline and a slightly greater length to width ratio than those of Chaetopterus. Since the descriptions of pellets of this species and of Chaetopterus are based on single specimens the differences should be verified.

Family Cirratulidae

Cirriformia filigera (della Chiaje 1828) Pl. 1, fig. g

Pellet curved, broken, rod-like; cross-section circular. Surface typically pitted; sculpture lacking. Composition of solidly packed unidentified material. Differentiation lacking; color tan to grey brown. Smallest individual 33 L; R W - 0.33 to 0.37, $\bar{x}$W - 0.35; R L - 0.54 to 0.97, $\bar{x}$L - 0.72. Largest individual 55 L; R W - 0.43 to 0.46, $\bar{x}$W - 0.44; R L - 0.64 to 1.06, $\bar{x}$L - 0.91.

Remarks: The identification of this species is tentative. In correspondence between Dr. Marian Pettibone, United States National Museum, and Dr. Marvin Wass, Virginia Institute of Marine Science, Dr. Pettibone stated that positive identification must wait revision of the family.

Family Maldanidae

Clymenella torquata (Leidyi 1855)

No recognizable pellet was produced by eight isolated specimens, but several were observed emitting a cloud of fine material not sufficiently compacted to form a pellet. Rhoads and Stanley (1965) found that sand and silt are transported through the gut and shed as unconsolidated feces.

Family Sabellariidae

Sabellaria vulgaris Verrill 1873 Pl. 1, fig.e

Pellet rod-like; cross-section circular; sculpture lacking. Composition diatoms and detritus. Differentiation lacking; color light tan, speckled with brown. Two individuals 6 L; R W - 0.08 to 0.11, $\bar{x}$W - 0.10; R L - 0.35 to 0.66, $\bar{x}$L - 0.55.

Family Pectinariidae

Cistenides gouldii (Verrill 1873) Pl. 1, fig.j

Pellets ovoid; cross-section circular, sculpture lacking. Composition sand and diatoms, some detritus. Differentiation lacking; color light tan. Smallest individual 14 L; R W - 0.08 to 0.11, $\bar{x}$W - 0.09; R L - 0.15 to 0.26, $\bar{x}$L - 0.21. Largest individual 29 L; R W - 0.09 to 0.20, $\bar{x}$W - 0.16; R L - 0.19 to 0.81, $\bar{x}$L - 0.48. R L/W all pellets 1.9 to 5.0; R $\bar{x}$L/W for all specimens 2.22 to 3.86.

Remarks: Cistenides was observed to shed fecal material in aquaria in a cloud similar to that made by Clymenella but with more sand. Animals without their sand tubes did not produce pellets, and since pellets the size and shape described for Cistenides are numerous in the estuarine sediments, those described for this species may have been contamination from the tubes. This may also explain the considerable variation in size of pellets found with some individuals.

Family Terebellidae

Amphitrite ornata (Leidy 1855)

So much slime was associated with the nine specimens collected that no fecal material in a definite shape was discernible.

Family Serpulidae

Eupomatus uncinatus (Phillipi 1844) Pl. 1, fig. f

Pellets broken, rod-like; cross-section circular. Surface slightly irregular, lacking definite sculpture; gelatinous sheath present or absent. Composition diatoms and unidentified material. Differentiation lacking; color light tan. One individual 35 L; R W - 0.18 to 0.26, $\bar{x}$W - 0.22; R L - 0.66 to 1.94, $\bar{x}$L - 1.09.

Family Ampharetidae

Melinna maculata Webster 1879 Pl. 1, fig. h

Pellet broken, curved or straight, rod-like; cross-section circular to slightly ovoid. Sculpture lacking. Composition detritus and unidentified material. Differentiation lacking; color light tan to dark brown. Smallest individual 23 L; R W - 0.39 to 0.43, $\bar{x}$W - 0.41; R L - 0.55 to 1.15, $\bar{x}$L - 0.87. Largest individual 37 L; R W - 0.40 to 0.54, $\bar{x}$W - 0.52; R L - 0.60 to 1.35, $\bar{x}$L - 0.96.

Remarks: Complete pellets were not observed, but some broken pieces had a rounded end.

Phylum Mollusca

The classification of Abbott (1954b) is used.

Class Gastropoda

Family Littorinidae

Littorina irrorata (Say 1822) Pl. 1, fig.k

Pellet ovoid; outline irregular; cross-section circular. Sculpture lacking. Composition detritus and diatoms. Differentiation lacking; color light to dark brown, often speckled. Smallest individual 20 L; R W - 0.42 to 0.47, $\bar{x}$W - 0.45; R L - 1.08 to 1.16, $\bar{x}$L - 1.14. Largest individual 22 L; R W - 0.46 to 0.54, xW - 0.50; R L - 1.51 to 2.11, $\bar{x}$L - 1.83. R L/W for all pellets 1.72 to 5.16, R $\bar{x}$L/W for all specimens 1.72 to 3.87.

Remarks: These pellets are similar to those described by Moore (1931a), Manning and Kumpf (1959), and Arakawa (1963) for other littorinids, but those of L. irrorata have a more irregular outline and contain more detritus.

Family Cerithiidae

Bittium alternatum (Say 1822) Pl. 1, fig.m

Pellet ovoid; cross-section circular; sculpture lacking. Composition diatoms and detritus. Differentiation lacking; color light tan to brown. Smallest individual 3 L; R W - 0.05 to 0.07, $\bar{x}$W - 0.06; R L - 0.19 to 0.22; $\bar{x}$L - 0.22. Largest individual 4 L; R W - 0.08 to 0.11, $\bar{x}$W - 0.10; R L - 0.17 to 0.25, $\bar{x}$L - 0.24. R L/W all pellets 1.9 to 4.2, R $\bar{x}$L/W for all specimens 2.3 to 3.6.

Remarks: Pellets resemble those shed by members of the Cerithiidae described by Manning and Kumpf (1959), and exhibit variations in shape similar to those described by Arakawa (1965) for Australoba picta.

Family Epitoniidae

Epitonium rupicolum (Kurtz 1860) Pl. 1, fig. l

Pellets rod-like, but tapered; cross-section ellipsoidal. Sculpture lacking, but with numerous random surface cracks. Composition unidentified, well compacted, and fine. Differentiation lacking; color tan sometimes speckled with brown. Smallest individual 7 L; two pellets R W - 0.17 to 0.18; R L - 0.22 to 0.32. Largest individual 8 L; one pellet W - 0.31; L - 1.75.

Family Calyptraeidae

Crepidula convexa Say 1822 Pl. 1, fig. n

Pellets ovoid; cross-section circular; sculpture lacking. Composition diatoms and detritus; firmly packed. Differentiation lacking; color light tan to dark brown. Smallest individual 14 L; R W - 0.10 to 0.14, $\bar{x}$W - 0.11; R L - 0.23 to 0.38, $\bar{x}$L - 0.27. Largest individual 16 L; R W - 0.12 to 0.16, $\bar{x}$W - 0.14; R L - 0.24 to 0.39, $\bar{x}$L - 0.29. R L/W all pellets 1.8 to 2.8, R $\bar{x}$L/W for all specimens 2.1 to 2.4.

Crepidula fornicata (L. 1867)

One specimen held in flowing sea water produced only cloud-like masses of material. Manning and Kumpf (1959) found that consolidated fecal material was not produced by this species. The ecology of *C. fornicata* and *C. convexa* should be investigated to determine why one produces consolidated feces and the other emits feces in a particulate cloud.

Family Muricidae

Eupleura caudata (Say 1822)

None of the 12 specimens shed solidified fecal material.

Urosalpinx cinerea (Say 1822)

None of the 23 specimens shed solidified fecal material.

Family Columbellidae

Anachis avara (Say 1822)

Pellet rod-like, highly irregular; cross-section undetermined. Sculpture lacking; gelatinous matrix present. Composition unidentified, contents poorly consolidated. Differentiation undetermined; color light tan. One individual 13 L; one pellet W - 0.22; L - 1.00.

Remarks: The pellet was produced by one of 13 individuals, and its consistency agrees with the description of Euplica scripta by Arakawa (1965). Manning and Kumpf (1959) list Nitidella ocellata as producing no, or undiscernible, fecal material. The extremely weak structure of the present pellet, Arakawa's and Manning and Kumpf's descriptions suggest that pellets of this group may either be poorly consolidated, and therefore easily destroyed, or shed uncompacted.

Mitrella lunata (Say 1826)

None of the ten specimens shed fecal material in a recognizable form.

Family Nassariidae

Nassarius obsoletus (Say 1822)

None of the 16 specimens produced fecal material of a definite shape.

Nassarius vibex (Say 1822)

None of the 11 specimens shed fecal material of a definite shape. Manning and Kumpf (1959) also list N. vibex as a species that produces feces of undiscernible shape.

Family Retusidae

Retusa canaliculata (Say 1822) Pl. 1, fig. p

Pellet ovoid; cross-section circular; sculpture lacking. Composition unidentified; differentiation lacking; color light yellowish tan. All individuals 3 L; R W - 0.12 to 0.14, $\bar{x}$W - 0.13; R L - 0.24 to 0.44, $\bar{x}$L - 0.37. R L/W all pellets 1.8 to 3.3, R $\bar{x}$L/W for all specimens 2.4 to 2.8.

Family Pyramidellidae

Odostomia bisuturalis Say 1821

None of the 15 specimens voided solidified feces.

Turbonilla interrupta Totten 1835

None of the ten specimens shed solidified feces.

Turbonilla stricta Verrill 1874

None of the three specimens produced solidified feces.

Family Ellobiidae

Melampus bidentatus Say 1822 Pl. 1, fig. o

Pellet rod-like, cross-section circular, sculpture lacking; outline slightly irregular. Composition large detritus and diatoms, consistency loose. Differentiation lacking; color light tan. Smallest individual 5 L; R W - 0.16 to 0.23, $\bar{x}$W - 0.18; R L - 0.27 to 2.11, $\bar{x}$L - 0.87. Largest individual 7 L; one pellet W - 0.19; L - 4.43.

Remarks: This pellet seems to agree reasonably well with the description of the pellet of Melampus coffeus by Manning and Kumpf (1959). The large pieces of detritus found in M. bidentatus are not mentioned for M. coffeus and this compositional difference may be enough to separate the two.

Class Pelecypoda

Family Arcidae

Anadara transversa (Say 1822) Pl. 2, fig. a

Pellets thin fragile ribbons; cross-section crescentic; sculpture lacking. Composition diatoms, algal cells, and some unidentified material. Differentiation lacking; color yellowish tan. Smallest individual 9 L; R W - 0.22 to 0.26, $\bar{x}$W - 0.24; R L - 0.33 to 0.53, $\bar{x}$L - 0.42. Largest individual 51 L; one pellet W - 2.85; L - 3.90. Thickness at crescent midpoint 0.09.

Remarks: Starved animals produce slightly thinner ribbons with the free edges rolled to touch or overlap. Normal pellets of this species can be distinguished from those produced by Arca umbonata (Manning and Kumpf, 1959), and Anadara (Scapharca) subcrenata (Arakawa, 1965), by the almost semicircular crescent produced by the former species as opposed to the flattened crescents of the two latter forms.

Family Mytilidae

Brachidontes recurvus (Rafinesque 1820) Pl. 2, fig. b

Pellets thin ribbons; cross-section crescentic. Sculpture lacking; composition mostly diatoms and algal cells. Differentiation lacking; color tan. Smallest individual 22 L; R W - 0.53 to 0.56, $\bar{x}$W - 0.55; R L - 0.61 to 1.39, $\bar{x}$L - 1.03. Largest individual 35 L; R W - 1.12 to 1.17, $\bar{x}$W - 1.16; R L - 0.56 to 1.46, $\bar{x}$L - 1.01. Thickness at crescent midpoint 0.15.

Remarks: These ribbons may be distinguished from those of Anadara transversa by the flatter crescent formed, and the slightly more pointed tips of the crescent. The slightly pointed tips also distinguish this pellet from Arca umbonata and Anadara subcrenata discussed with Anadara transversa. This pellet is not at all similar to the bi-crescentic ribbons of Brachidontes citrinus or B. exustus figured by Manning and Kumpf (1959).

Mytilus edulis L. 1758

The bi-crescentic ribbons shed by this species have been described by Moore (1931a) from Conway, Port Erin, and Plymouth in the Eastern Atlantic, and the pellets produced by M. edulis here do not vary from his description. Smallest individual 35 L; R W - 0.84 to 0.87; $\bar{x}$W - 0.86; R L - 0.88 to 1.14, $\bar{x}$L - 1.01. Largest individual 57 L; R W - 1.24 to 1.31, $\bar{x}$W - 1.27; R L - 0.98 to 1.73, $\bar{x}$L - 1.42.

Volsella demissa (Dillwyn 1817) Pl. 2, fig. c

Pellet ribbon-like; cross-section flattened bi-crescentic. Sculpture of low midridge, midgroove present or nearly absent. Composition diatoms. Differentiation lacking; color light tan. Smallest individual 51 L; R W - 1.03 to 1.05, $\bar{x}$W - 1.04; R L - 0.72 to 1.73, $\bar{x}$L - 1.14. Thickness at midridge 0.12. Largest individual 110 L; R W - 1.63 to 1.67, $\bar{x}$W - 1.66; R L - 1.96 to 2.12, $\bar{x}$L - 2.06.

Remarks: The pellets of this species show little relation to the feces of Volsella americana described by Manning and Kumpf (1959), except that the ribbon is not strongly recurved as in some other Mytilidae. It is easily distinguished from pellets of M. edulis by the flatness of the ribbon.

Family Anomiidae

Anomia simplex Orbigny 1845

Pellet ribbon-like; cross-section crescentic; sculpture lacking. Composition diatoms, detritus, occasional sponge spicules. Differentiation lacking; color light tan. Smallest individual 7 L; one pellet W - 0.29; L - 1.65. Largest individual 38 L; R W - 0.56 to 0.90; $\bar{x}$W - 0.66; R L - 0.50 to 1.00, $\bar{x}$L - 0.71.

Remarks: These pellets have a much more irregular outline than those of the Mytilidae and when the ribbon is broken perpendicular to the longitudinal axis there appears to be a more jagged end. These pellets are similar to those of Anadara transversa in most other aspects.

Family Ostreidae

Crassostrea virginica (Gemlin 1792) Pl. 2, fig. d

Pellet ribbon-like; cross-section bi-crescentic. Sculpture of high longitudinal midridge, grooved longitudinally in center of midridge and deeply so ventrally. Composition predominantly diatoms. Differentiation lacking; color brown to tan. Smallest individual 52 L; R W - 0.57 to 0.75, $\bar{x}$W - 0.66; R L - 0.54 to 3.29, $\bar{x}$L - 1.12. Largest individual 77 L; R W - 1.76 to 1.84, $\bar{x}$W - 1.79; R L - 0.82 to 3.38, $\bar{x}$L - 1.79. Thickness of midridge 0.14.

Remarks: Pellets are fragile and will break in half along the midridge if handled roughly. Most specimens have the groove along the central part of the midridge, but in one pellet it was lacking. The amount of curvature of the pellet margin varies from almost flat to almost touching. The pellets of this species are similar in sculpture to those of *Brachidontes citrinus* (Manning and Kumpf, 1959), but those of *C. virginica* seem to have a deeper midventral groove. The pellets of the Ostreidae described by Arakawa (1965) resemble those of *C. virginica* only by their ribbon shape and longitudinal midridge.

Family Lucinidae

Lucina multilineata Tuomey and Holmes 1857

None of the seven specimens shed feces with a definite shape. Two other members of the family, *Lucina pennsylvanica* and *Codakia orbicularis*, (Manning and Kumpf, 1959) also produce pellets of undiscernable shape.

Family Leptonidae

Aligena elevata Stimpson 1851

None of the nine specimens produced feces of a definite shape.

Family Cardiidae

Laevicardium mortoni (Conrad 1830) Pl. 2, fig. g

Pellets rod-like; cross-section circular. Exterior smooth, but sculptured by deep transverse constrictions. Composition detritus, diatoms, and algal bits. Differentiation lacking; color tan to greenish tan.

Smallest individual 5 L; R W - 0.16 to 0.23, $\bar{x}$W - 0.18; R L - 0.27 to 0.86, $\bar{x}$L - 0.48. Largest individual 23 L; R W - 0.44 to 0.47, $\bar{x}$W - 0.45; R L - 0.46 to 1.00, $\bar{x}$L - 0.85.

Remarks: Large sections of feces may be slightly concave laterally rather than with parallel sides. The pellets are easily broken at the constrictions into ovoid pieces with sharply truncated ends. Arakawa (1965) has found pellets from Fulvia mutica similar to those of L. mortoni except that their larger segments have a convex outline rather than a concave one. Arakawa also noted the tendency to break into single pieces with a slight touch. Manning and Kumpf (1959) reported ovoid pieces from Trigoniocardium medium, and though they made no mention of sharply truncated ends it is possible that these pieces were sections of a larger pellet. Starvation pellets for an animal 23 L decreased from a mean width of 0.45 to 0.25.

Family Veneridae

Mercenaria mercenaria (L. 1758) Pl. 2, fig. j

Pellet rod-like; cross-section ellipsoid. Sculpture lacking, some surface cracks. Composition diatoms, detritus, and occasionally sponge spicules. Differentiation variable; external ring of fine material completely surrounding coarse internal material; central longitudinal hole; both hole and differentiation sometimes absent. Color variable; tan, greenish tan, brown, dark chocolate brown, or gray. Smallest individual 25 L; R W - 0.14 to 0.25, $\bar{x}$W - 0.20; R L - 0.43 to 0.80, $\bar{x}$L - 0.72. Largest individual 80 L; R W - 0.49 to 0.68, $\bar{x}$W - 0.61; R L - 1.18 to 4.75, $\bar{x}$L - 2.12.

Remarks: Most of the Veneridae studied have produced similar pellets. Arakawa (1963) reported that Tapes (Amygdala) semidecussata produced a rod-like pellet, and that *Dosinia* (*Phacosoma*) *japonica* shed a rod (1965), but he also noted that *Meretrix lusoria* may produce smooth rods or slightly grooved ones (1965). *M. mercenaria* is the only venerid species reported to have an ellipsoidal cross-section. A linear regression analysis of animal length to pellet width showed a correlation of .96; the equation for the line was $y = 0.08 + 0.068x$.

Family Tellinidae

Macoma balthica (L. 1758) Pl. 2, fig. f

Pellet rod-like; cross-section circular. Sculpture of deep constrictions 0.11 to 0.27 apart, longest sections at end of pellet; exterior otherwise smooth. Composition mostly unidentified, but with some diatoms and detritus; material well compacted. Differentiation lacking; color tan to dark brown. One individual 25 L; R W - 0.32 to 0.37, $\bar{x}$W - 0.36; R L - 0.27 to 0.78, $\bar{x}$L - 0.47.

Remarks: Individual sections may break off at the constrictions to form button-like pieces. The fecal strings are very similar to those of *M. tenta*.

Macoma tenta Say 1834 Pl. 2, fig. e

Pellet rod-like; cross-section circular. Sculpture of deep constrictions 0.06 to 0.14 apart; exterior otherwise smooth. Composition mostly unidentified, but with some diatoms and algal cells; material well compacted. Differentiation lacking; color tan with black speckles to dark tannish green. Smallest individual 6 L; R W - 0.12 to 0.13, $\bar{x}$W - 0.12; R L - 0.12 to 0.18, $\bar{x}$L - 0.15. Largest individual 16 L; R W - 0.27 to 0.28, $\bar{x}$W - 0.27; R L - 0.22 to 0.46, $\bar{x}$L - 0.33.

Remarks: A linear regression analysis of animal length to pellet width showed a correlation of .69; the equation for the line was

$y = 0.089 + 0.096x$. Moore (1931a) has shown that two other species of tellinids, Tellina crassa and T. donacina, produce pellets similar to those of M. tenta and M. balthica.

Family Sanguinolariidae

Tagelus plebeius (Solander 1786) Pl. 2, fig.h,i

Pellets rod-like; cross-section circular. Sculpture of deep constrictions 0.32 to 0.54 apart; exterior otherwise smooth. Composition unidentified; solidly packed material. Differentiation lacking; color light tan to greenish brown or brown. Smallest individual 43 L; R W - 0.37 to 0.51, $\bar{x}$W - 0.44; R L - 0.54 to 1.40, $\bar{x}$L - 0.84. Largest individual 71 L; R W - 0.63 to 0.76, $\bar{x}$W - 0.69; R L - 0.97 to 1.62, $\bar{x}$L - 1.42.

Remarks: Sharply truncated individual segments may break loose from these pellets. Similar sculpturing and segmentation was found in pellets produced by Macoma tenta, M. balthica, and Laevicardium mortoni. The segments of this species are more elongate than those produced by Macoma species, and are distinguished from the larger segments of Laevicardium pellets by being either parallel-sided or convex with respect to the longitudinal axis. Starvation pellets have less regular constrictions and may be helically coiled.

Family Solenidae

Ensis directus Conrad 1843 Pl. 2, fig.k

Pellets broken, slightly curved, rod-like; cross-section circular. Sculpture lacking; exterior smooth. Composition diatoms and detritus; material solidly packed. Differentiation lacking; color light tan to chocolate brown, banded or solid. One individual 93 L; R W - 0.35 to 0.42, $\bar{x}$W - 0.38; R L - 0.97 to 2.08, $\bar{x}$L - 1.33.

Remarks: Arakawa (1963) reported a similarly shaped pellet for *Solen gouldi*, but the pellets of *Ensis* are slightly curved, a characteristic not noted for *Solen*.

Family Mactridae

Mulinia lateralis (Say 1822) Pl. 2, fig.1

Pellets broken, often slightly curved, rod-like; cross-section circular. Sculpture lacking; surface cracks numerous. Composition mostly diatoms and detritus; small amount of fine sand. Differentiation lacking; color brown to greenish brown. Smallest individual 6 L; R W - 0.12 to 0.17, $\bar{x}$W - 0.16; R L - 0.27 to 0.81, $\bar{x}$L - 0.44. Largest individual 20 L; R W - 0.40 to 0.47, $\bar{x}$W - 0.44; R L - 0.50 to 1.83, $\bar{x}$L - 1.15.

Remarks: These pellets have extremely rough surfaces and show cracks or crevices throughout their length.

Family Myacidae

Mya arenaria (L. 1758)

One specimen of 16 produced a poorly consolidated yellowish tan ribbon, and a darker irregularly coiled rod-like pellet of the same texture, which may have been a tightly wound ribbon. These are both probably starvation pellets and are treated as such. The ribbon was a lopsided crescent lacking sculpture. There was no apparent localization of material within the rod or ribbon. The ribbon was 0.27 W and 4.85 L; the rod was 0.82 W and 2.05 L. Observations on *Mya* in aquaria indicate that they do not characteristically emit feces in a solidified form, but produce clouds of unconsolidated material.

Family Lyonsiidae

Lyonsia hyalina Conrad 1831

Pellet flocculent irregular ball or unconsolidated; material too loosely consolidated for cross-sectioning. Sculpture not apparent.

Composition unidentified. Differentiation not apparent; color light tan. Smallest individual 10 L; one pellet 0.29 in diameter. Largest individual 25 L; R diameter 0.34 to 0.46, $\bar{x}$ diameter 0.39.

Remarks: Pellets with a definite shape resembled a flocculent ball. There was little compaction of the fecal material, and the pellets could not be sectioned.

Phylum Arthropoda

The classification of Williams (1965) is used for the Decapods, while Waterman and Chace (1960) is used for all other forms.

Class Crustacea

Subclass Cirripedia

Order Thoracica

Family Balanidae

Balanus eburneus Gould 1841 Pl. 2, fig. m

Pellet broken, curved, rod-like; cross-section circular except where modified by external irregularities. Sculpture lacking; surface irregularly constricted or smooth. Composition diatoms, detritus, occasional sponge spicules, and arthropod appendages. Differentiation lacking; color yellowish tan to dark greenish brown. Smallest individual 10 W; R W - 0.43 to 0.54, $\bar{x}$W - 0.47; R L - 1.30 to 3.10, $\bar{x}$L - 2.08. Largest individual 15 W; R W - 0.23 to 0.44, $\bar{x}$W - 0.32; R L - 0.77 to 2.35, $\bar{x}$L - 1.24.

Remarks: The measurements indicate that size is not a good criteria for describing pellets of this species.

Balanus improvisus Darwin 1854 Pl. 2, fig. o

Pellets slightly curved or straight, rod-like; cross-section circular. Sculpture lacking, but small surface irregularities present;

gelatinous sheath present or absent. Ends of pellet usually broken, occasionally rounded. Composition diatoms, detritus, arthropod appendages, and unidentified granular material. Differentiation lacking; color light tan to dark chocolate brown. Smallest individual 3 W; R W - 0.11 to 0.14, $\bar{x}$W - 0.11; R L - 0.81 to 1.24, $\bar{x}$L - 0.92. Largest individual 6 W; R W - 0.21 to 0.46, $\bar{x}$W - 0.33; R L - 0.99 to 2.11, $\bar{x}$L - 1.46.

Remarks: Individuals of this species produce pellets more closely related to their size than those of *B. eburneus*. The pellets are straighter than those of *B. eburneus*, and though one end may be rounded it typically appears broken. It is rare to see even one end of a *B. eburneus* pellet rounded.

Subclass Malacostraca

Order Cumacea

Family Diastylidae

Oxyurostylus smithi Calman 1912 Pl. 2, fig. q

Pellets broken, rod-like; cross-section circular. One end sometimes rounded. Sculpture lacking; composition undetermined. Differentiation lacking; color dark brown. One individual 7 L; two pellets, W - 0.21; R L - 0.22 to 0.65.

Order Isopoda

Family Sphaeromidae

Sphaeroma quadridentatum Say 1818 Pl. 2, fig. n

Pellet broken, ribbon-like; cross-section "W" shaped. Midridge relatively high, wide; midgroove directly below midridge. Ends of pellet, though broken, slightly rounded. Composition unidentified. Differentiation in transverse bands of alternating dark brown and translucent tan or solid brown. Of seven specimens, one produced pellets. Individual

5 L; R W - 0.51 to 0.56, $\bar{x}$W - 0.53; R L - 0.54 to 0.61, $\bar{x}$L - 0.58. Thickness at midridge 0.19.

Remarks: This was the only ribbon-like pellet produced by any of the arthropods examined. Edge (1934) noted that the isopod *Ligyda occidentalis* produced pellets "which in cross-section appears to be a double rod"; these may have been similar to the pellets formed by *Sphaeroma*. The transverse banding seems to be due to two types of material, but it is not present in all pellets.

Family Idoteidae

Erichsonella attenuata (Harger 1873)

Pellets broken, rod-like; cross-section circular. Some narrower at one end; sculpture lacking. Composition detritus, diatoms, and algal cells. Differentiation lacking; color light tan to brown. Smallest individual 19 L; two pellets W - 0.34; R L - 0.71 to 1.13. Largest individual 21 L; R W - 0.32 to 0.38, $\bar{x}$W - 0.35; R L - 0.84 to 1.75, $\bar{x}$L - 1.08.

Idotea baltica (Pallas 1772) Pl. 2, figs

Pellets broken, rod-like; cross-section circular. Sculpture lacking. Composition mostly detritus. Differentiation lacking; color light tan, speckled with dark brown or solid dark brown. Smallest individual 12 L; R W - 0.32 to 0.40, $\bar{x}$W - 0.35; R L - 0.88 to 2.17, $\bar{x}$L - 1.27. Largest individual 17 L; two pellets, R W - 0.27 to 0.28; L - 0.48.

Remarks: it is difficult to separate pellets of this species from those of *E. attenuata*; however, those of *I. baltica* seem to be larger than those of *E. attenuata* when similar sized individuals are compared.

Order Amphipoda

Family Ampeliscidae

Ampelisca macrocephala Lilljeborg 1852 — Pl. 2, fig. r

Pellet broken, curved or straight, rod-like; cross-section circular. Sculpture lacking; faint longitudinal striae present or absent, but not visible in cross-section. Gelatinous sheath present or absent. Composition coarse in appearance; mostly diatoms and detritus, occasionally small sand grains. Differentiation lacking; color yellowish tan to dark brown, speckled with dark material at times. Smallest individual 7 L; R W - 0.15 to 0.16, $\bar{x}$W - 0.15; R L - 0.53 to 0.71, $\bar{x}$L - 0.64. Largest individual 11 L; R W - 0.23 to 0.24, $\bar{x}$W - 0.24; R L - 0.62 to 0.79, $\bar{x}$L - 0.70.

Family Gammaridae

Gammarus mucronatus (Say 1818) — Pl. 2, fig. t

Pellet broken, slightly curved; rod-like; cross-section circular. Sculpture lacking; gelatinous sheath present or absent. Composition diatoms and detritus. Differentiation lacking; color light tan speckled with dark brown detritus. Three individuals 12 L; R W - 0.20 to 0.25, $\bar{x}$W - 0.23; R L - 0.81 to 1.68, $\bar{x}$L - 1.19.

Melita fresneli (Audouin 1826) — Pl. 2, fig. u

Pellet curved, broken, rod-like; cross-section circular; sculpture lacking. Composition mostly unidentified, some algal cells. Differentiation lacking; color light tan speckled with darker brown. Smallest individual 7 L; R W - 0.16 to 0.19, $\bar{x}$W - 0.18; R L - 1.82 to 2.13, $\bar{x}$L - 2.04. Largest individual 10 L; two pellets, W - 0.25; R L - 0.89 to 0.97.

Family Ampithoidae

Ampithoe longimana Smith 1873 Pl. 3, fig. a

Pellets broken, slightly curved, rod-like; cross-section circular. Sculpture lacking; thin gelatinous sheath. Composition diatoms and unidentified material. Differentiation lacking; color light tan to dark brown, some light speckling. Two individuals. Smaller individual 9 L; two pellets, W - 0.18; R L - 0.93 to 2.92. Larger individual 10 L; R W - 0.18 to 0.21, $\bar{x}$W - 0.20; R L - 1.22 to 1.43, $\bar{x}$L - 1.34.

Family Caprellidae

Caprella equilibra Say 1818 Pl. 2, fig. p

Pellets straight, broken, rod-like; cross-section circular. Sculpture lacking; composition unidentified. Differentiation lacking; color light tan speckled with dark brown. Smallest individual 8 L; R W - 0.08 to 0.09, $\bar{x}$W - 0.08; R L - 0.27 to 0.65, $\bar{x}$L - 0.46. Largest individual 9 L; R W - 0.09 to 0.11, $\bar{x}$W - 0.10; R L - 0.59 to 0.84, $\bar{x}$L - 0.74.

Order Decapoda

Family Palaemonidae

Palaemonetes pugio Holthuis 1949 Pl. 3, fig. d

Pellets curved, broken, rod-like; cross-section circular. Sculpture lacking; gelatinous sheath present or absent. Composition mostly diatoms and algal cells. Differentiation lacking; color light to dark tan with darker brown speckles. Smallest individual 28 L; R W - 0.12 to 0.15, $\bar{x}$W - 0.13; R L - 0.83 to 1.98, $\bar{x}$L - 1.51. Largest individual 30 L; R W - 0.13 to 0.16, $\bar{x}$W - 0.14; R L - 0.65 to 1.24, $\bar{x}$L - 0.91.

Remarks: Johannes and Satomi (1966) have shown extreme variability in width and length of these pellets, but their material was obtained under laboratory conditions during a feeding experiment.

Palaemonetes vulgaris (Say 1818) Pl. 3, fig.e

The pellet of P. vulgaris seems identical to that of P. pugio in all respects; but individuals of P. vulgaris may produce pellets slightly wider than those of a similar sized P. pugio (Table 3). Smallest individual 25 L; R W - 0.20 to 0.24, $\bar{x}$W - 0.22; R L - 0.27 to 2.07, $\bar{x}$L - 1.22. Largest individual 32 L; R W - 0.23 to 0.27, $\bar{x}$W - 0.25; R L - 1.03 to 3.63, $\bar{x}$L - 2.14.

Family Ogyrididae

Ogyrides limicola Williams 1955 Pl. 3, fig.c

Pellets broken, rod-like; cross-section circular. Sculpture lacking; thin gelatinous sheath present or absent; pellet ends typically broken, but one end sometimes rounded. Composition unidentified. Differentiation lacking; color light tan to greenish brown. Smallest individual 14 L; R W - 0.11 to 0.17, $\bar{x}$W - 0.15; R L - 0.41 to 1.62, $\bar{x}$L - 0.86. Largest individual 16 L; two pellets, R W - 0.17 to 0.19; R L - 0.76 to 1.10.

Family Hippolytidae

Hippolyte pleuracantha (Stimpson 1874) Pl. 3, fig.b

Pellet broken, curved, rod-like; cross-section circular. Sculpture lacking; gelatinous sheath present or absent. Composition coarse, diatoms, detritus, some algal cells. Differentiation lacking; color tan to dark greenish tan. Smallest individual 17 L; R W - 0.12 to 0.15, $\bar{x}$W - 0.13; R L - 0.54 to 2.52, $\bar{x}$L - 1.58. Largest individual 18 L; R W - 0.14 to 0.16, $\bar{x}$W - 0.15; R L - 2.27 to 3.56, $\bar{x}$L - 2.86.

Family Callianassidae

Upogebia affinis (Say 1818) Pl. 3, fig.i

Pellet broken, rod-like; cross-section slightly ovoid, flattened on side opposite longitudinal groove. Sculpture longitudinal groove running length of pellet; slight undulations present or absent on rest of surface except for flattened area. Composition unidentified. Differentiated into outer ring of well compacted fine material, and internal matrix of fine, flocculent material with a series of circular canals running longitudinally throughout the pellet. "W" shaped area lacking canals separates them into groups, apex of W midridge facing away from surface groove. Color light tan to brown or gray brown. Smallest individual 12 L; R W - 0.39 to 0.43, $\bar{x}$W - 0.41; R L - 0.57 to 0.85, $\bar{x}$L - 0.72. Largest individual 54 L; one pellet, W - 1.13; L - 3.68.

Remarks: There is a total of 140 canals. Inside, and adjacent to, the outer layer of well compacted fine material is a ring of 30 circular canals; 15 on either side of the longitudinal groove. Between this ring of canals and the outer arms of the W are two more rings with 28 canals in each; 14 on either side of the longitudinal groove. Interior to the third ring of canals is the arm of the W, a space which lacks canals, but immediately inside this arm, and between it and the apex of the W, are three more rows with nine canals in each row. The end members of these nine are end members of the three outer rings.

This pellet is similar to the pellets of *Upogebia deltaura* and *U. stellata* described by Moore (1932b). The surface does not have the ridges he described for the ventral side; instead there is a single longitudinal groove. The slight undulations of the surface seem to be caused by the canal system below. Moore (1932b) does not mention the layer of fine material exterior to the system of canals. There are two more canals in the outer arcs of *U. affinis* than in the two species described by Moore. The inner rows of nine canals each in pellets of *U. affinis* are not present in those of the two other species, but are replaced by a group of five canals.

Family Paguridae

Pagurus longicarpus Say 1817 Pl. 3, fig. f

Pellet strongly curved, broken, rod-like; cross-section nearly circular. Sculpture, longitudinal groove running length of pellet which may separate coarse material from fine; gelatinous sheath present or absent. Composition unidentified. Differentiation formed by pellet divided into halves by coarse and fine material to either side of longitudinal groove. Color tan to gray tan. Pellets all individuals; R W - 0.31 to 0.42; R L - 0.78 to 4.86.

Remarks: One pellet had only a small portion of coarse material. This material was displaced to one side of the midgroove three-fifths of the way around one side and extended to a point opposite the midgroove. This coarse material did not extend all the way to the center of the pellet. All other pellets had coarse material occupying one-half the pellet. Since animals were in mollusc shells measurements were not made.

Family Portunidae

Callinectes sapidus Rathbun 1896

Pellet broken, rod-like; cross-section circular. Sculpture lacking; gelatinous sheath tough. Pellet extremely flexible. Composition mostly unidentified, some shell present. Differentiation lacking; color light tan to light grayish white. Two individuals. Smallest individual 29 W; one pellet W - 0.67; L - 1.91. Largest individual 33 W; one pellet, W - 0.73; L - 2.49.

Family Xanthidae

Neopanope texana sayi (Smith 1869) Pl. 3, fig. g

Pellets broken, rod-like; cross-section nearly circular. Sculpture of longitudinal canal along pellet length. Canal nearly straight; exterior of pellet entirely fine material or differentiated fine and coarse as in

Panopeus. Composition of coarse material on inside, and fine material extending below canal and around most of pellet. Color gray tan to dark brown. Smallest individual 12 W; two pellets, W - 0.54; R L - 1.40 to 2.46. Largest individual 24 W; R W - 0.86 to 1.06, $\bar{x}$W - 0.99; R L - 1.30 to 4.38, $\bar{x}$L - 2.87.

Remarks: The coarse material in pellets of this species is more granular, and does not contain large shell fragments as do pellets of Panopeus. The cross-section is more circular, and if a protrusion is formed below the longitudinal canal it is not as pronounced as those of Panopeus.

Panopeus herbstii H. Milne-Edwards 1834 Pl. 3, fig. h

Pellet broken, rod-like; cross-section ovoid. Sculpture of longitudinal canal running length of pellet complicated by coarse particles protruding from one side presenting toothed appearance. Composition sand and shell material externally on one side; unidentified material on other. Differentiation coarse material internally; fine material forming protrusion beneath canal surface and extending around exterior. Color light tan. One specimen 43 W; two pellets, W - 1.57; R L - 4.43 to 5.67.

Family Ocypodidae

Uca minax (Le Conte 1855) Pl. 3, fig. j

Pellets broken, rod-like; cross-section nearly circular. Sculpture lacking; gelatinous sheath when present, thin. Three-fourths of exterior material fine, one-fourth coarse. Composition coarse material, detritus, fine unidentified. Differentiation interior coarse material; exterior fine and thinnest on side opposite coarse surface band, thickest perpendicular to latter. Pellets sometimes breaking in area opposite coarse band forming false surface canals which are highly irregular. Color light brown to dark chocolate brown. Smallest individual 29 W; all pellets W - 2.80;

R L - 1.00 to 4.51, $\bar{x}$L - 3.17. Largest individual 38 W; R W - 2.11 to 2.67, $\bar{x}$W - 2.32; R L - 3.05 to 4.11, $\bar{x}$L - 3.52.

Remarks: It should be noted that the smallest individual produced pellets wider than those of the largest individual, indicating pellet size is highly variable.

Uca pugnax (Smith 1870) Pl. 3, fig. k

Pellets were morphologically identical to those of *U. minax*, but contained less detritus and more sand. One individual 17 W; R W - 1.13 to 1.80, $\bar{x}$W - 1.54; R L - 1.56 to 2.98, $\bar{x}$L - 2.13.

Family Majidae

Libinia dubia H. Milne-Edwards 1834

Pellet broken, rod-like; cross-section circular. Sculpture lacking; gelatinous sheath heavy. Composition detritus and sand. Differentiation lacking; color yellowish tan to dark brown. One individual 51 W; R W all 1.00, $\bar{x}$W - 1.00; R L - 1.21 to 1.40, $\bar{x}$L - 1.34.

Phylum Phoronida

The classification of Hyman (1959) is used.

Phoronis architecta Andrews (1890)

None of the 20 specimens shed fecal material in a recognizable form.

Phylum Echinodermata

The classification of Hyman (1955) is used.

Class Ophiuroidea

Family Amphiuridae

Amphiodia atra Stimpson Pl. 3, fig. l

Pellet irregular, ellipsoid; cross-section roughly circular; sculpture lacking. Composition fine material, compacted, unidentified. Differentiation lacking; color light tan. Two individuals; central disk diameter 5; two pellets, R W - 0.30 to 0.32; R L - 1.07 to 1.40.

Remarks: Since only two pellets were produced and both were slightly different in external structure the drawing should be used only as a general form.

Phylum Chordata

The classification of Van Name (1945) is used.

Class Ascidiacea

Order Phlebobranchia

Family Molgulidae

Molgula manhattensis (DeKay 1834) Pl. 3, fig. m

Pellet broken, rod-like; cross-section roughly circular, but hollow. Sculpture spiral; formed by rods produced in anterior of gut becoming coiled and pressed together in posterior part. Composition detritus and diatoms. Pellets fragile, sometimes breaking into concavo-convex sections of pellet, or into small sections of constituent rods which formed the spiral. Differentiation lacking; color dark chocolate brown, greenish tan or speckled tan. Smallest individual 14 W; R W - 1.10 to 1.19, $\bar{x}$W - 1.16; R L - 1.45 to 1.58, $\bar{x}$L - 1.51. Largest individual 25 W; R W - 1.78 to 2.09, $\bar{x}$W - 1.91; R L - 1.53 to 2.11, $\bar{x}$L - 1.68.

SUMMARY

Pellets with certain characteristics may be identified to species by referring to the following outline, and by comparing pellets to the descriptions, drawings and measurements given under results. As an aid to pellet identification, the outline treats animals and pellets of this study by phyla, and categorizes the pellets within the phyla.

Annelida

Polychaeta

Errantia

Rod-like to almost ellipsoid, outline irregular, no apparent consistent form.

Neanthes succinea
Nephtys incisa
Glycera dibranchiata

Sedentaria

Ovoid, not pointed at either end.

*Cistenides gouldii**

Ellipsoid

Chaetopterus variopedatus
Spiochaetopterus oculatus

Rod

Straight, plain, outline regular, undifferentiated, cross-section circular.

Sabellaria vulgaris
Eupomatus uncinatus

Curved, outline regular, differentiation lacking, surface smooth or pitted.

Cirriformia filigera
Melinna maculata

Feces not solidified or in a definite shape.

Amphitrite ornata
Clymenella torquata
*Cistenides gouldii**

*Pellet questionable

Mollusca

Gastropoda

Ovoid

Drawn into a point or nearly so at one end.

Littorina irrorata
Retusa canaliculata

Rounded at both ends.

Bittium alternatum
Crepidula convexa

Rod

Cross-section slightly ellipsoidal; surface cracks numerous, random.

Epitonium rupicolum

Cross-section round, outline slightly irregular, composition of large pieces of detritus.

Melampus bidentatus

Outline irregular, poorly consolidated.

Anachis avara

Feces not solidified into definite shape.

Crepidula fornicata
Eupleura caudata
Urosalpinx cinerea
Mitrella lunata
Nassarius obsoletus
N. vibex
Odostomia bisuturalis
Turbonilla interrupta
T. stricta

Pelecypoda

Flocculent ball.

Lyonsia hyalina

Rod

Transverse or spiral sculpture, sharply truncated segments or "button-like" sections, cross-section circular.

Laevicardium mortoni
Macoma balthica
M. tenta
Tagelus plebeius

Sculpture lacking, cross-section ellipsoid.

Mercenaria mercenaria

Plain, cross-section circular, surface irregular because of numerous surface cracks; curved or straight.

Mulinia lateralis

Plain, cross-section circular, surface smooth, curved, large.

Ensis directus

Pelecypoda (continued)

Ribbon

Plain.

Anadara transversa
Brachidontes recurvus
Anomia simplex

Sculptured with longitudinal midridge.

Mytilus edulis
Volsella demissa
Crassostrea virginica

Unconsolidated material

Lucina multilineata
Aligena elevata
*Mya arenaria**

Arthropoda

Ribbon

Sphaeroma quadridentatum

Rod

One end rounded or pellet surface slightly irregular or both.

Balanus eburneus
B. improvisus
Oxyurostylus smithi
Ogyrides limicola

Plain, composition with large pieces of sand or shell, pellets usually large.

Libinia dubia
Callinectes sapidus

Plain, no differentiation, circular cross-section, composition of very fine detrital material, sand or diatoms. Pellets from 0.08 to 0.34 mm wide, usually between 0.12 and 0.28 mm. Pellets indistinguishable.

Erichsonella attenuata
Idotea baltica
Ampelisca macrocephala
Gammarus mucronatus
Melita fresneli
Ampithoe longimana
Caprella equilibra
Palaemonetes pugio
P. vulgaris
Hippolyte pleuracantha

Exterior with longitudinal sculpture, internally differentiated.

Upogebia affinis
Pagurus longicarpus
Panopeus herbstii
Neopanope texana sayi

Externally differentiated.

Uca minax
U. pugnax

*Pellet questionable

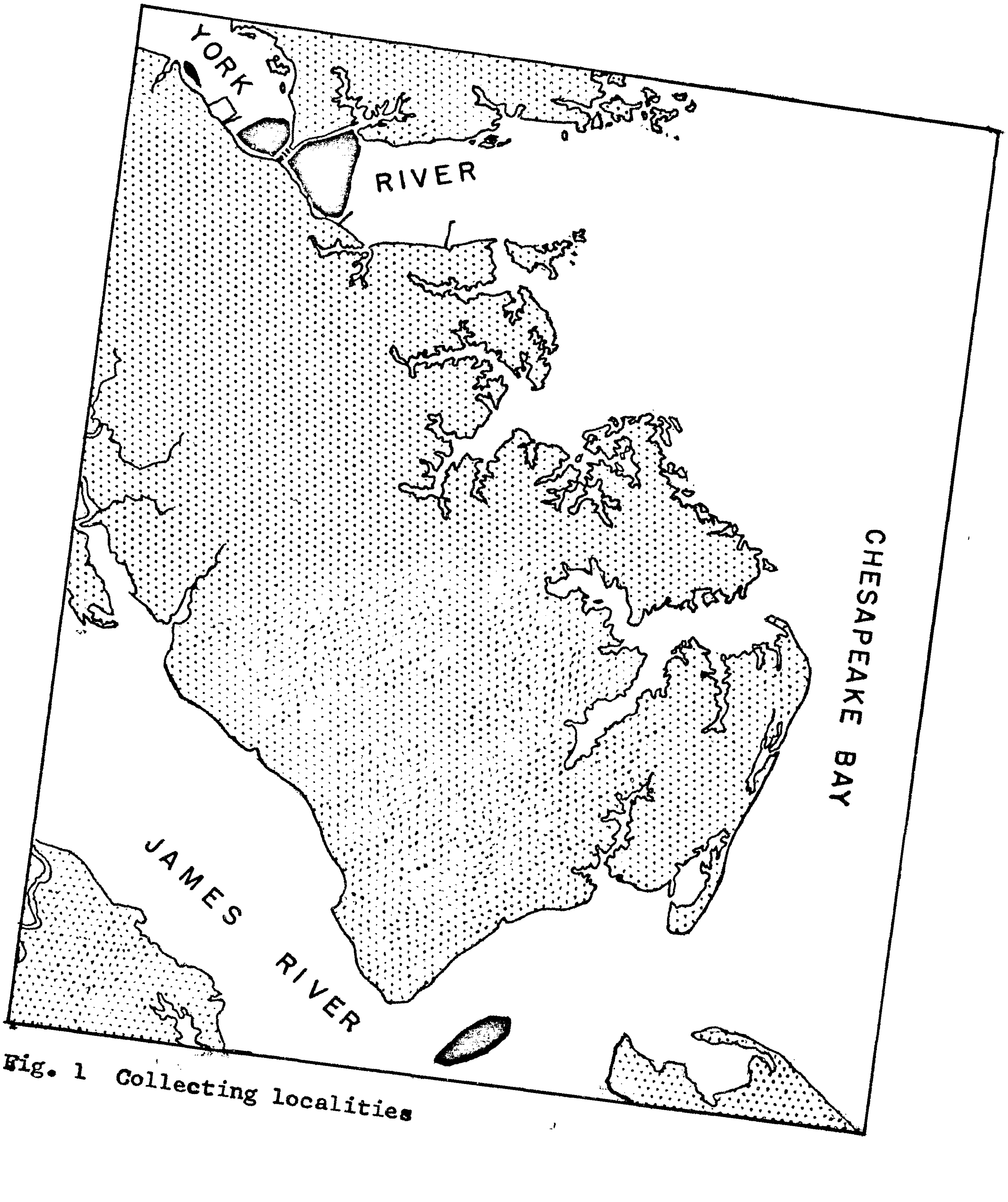

Fig. 1 Collecting localities

FIGURE 2

PLATE 1: Pellets of the Annelida (a. to j.) and the Mollusca (Gastropoda, k. to p.).

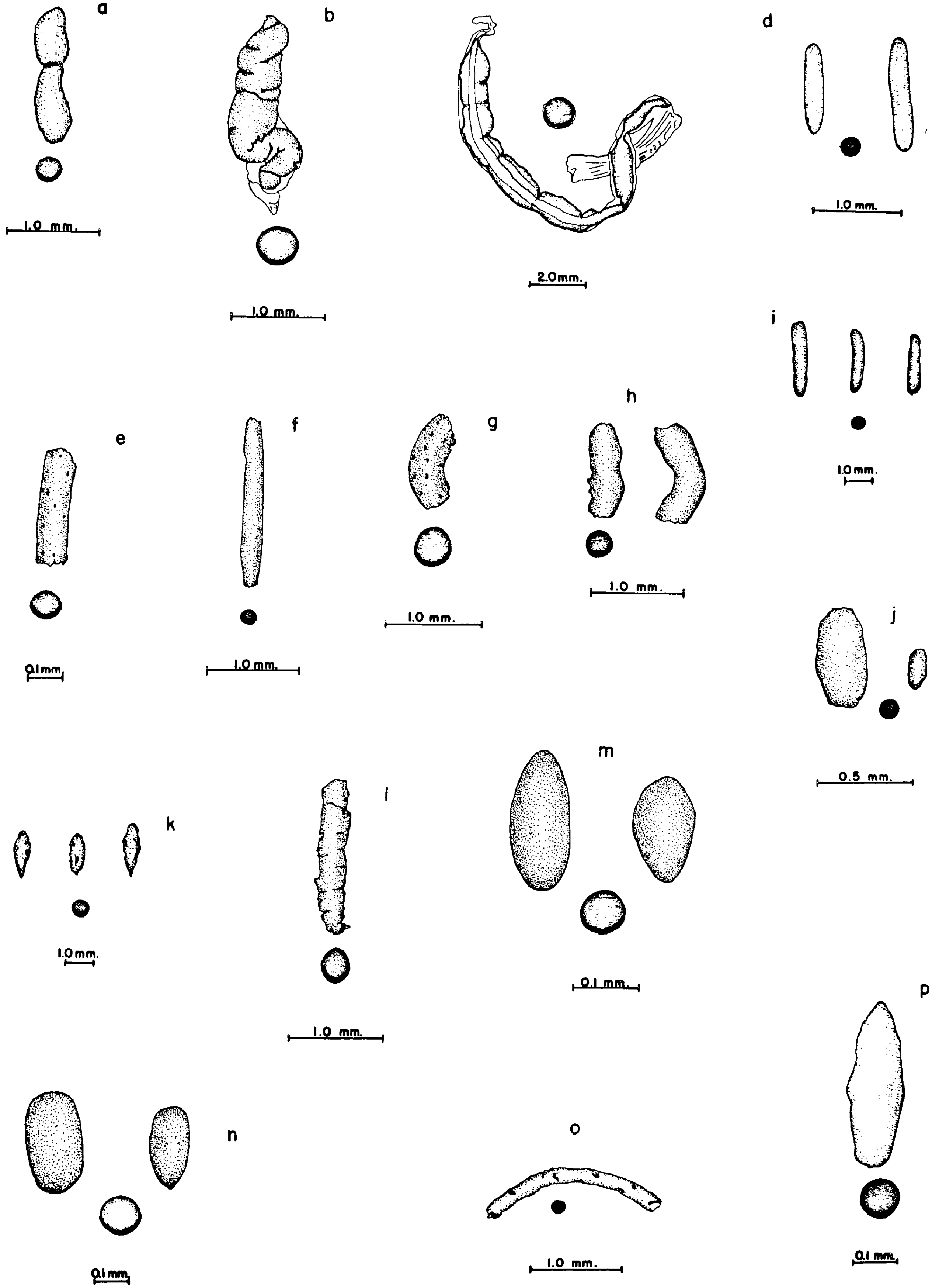
a
1.0 mm.
b
1.0 mm.
2.0mm.
d
1.0 mm.
i
1.0 mm.
e
0.1mm
f
1.0 mm.
g
1.0 mm.
h
1.0 mm.
j
0.5 mm.
k
1.0 mm.
l
1.0 mm.
m
0.1 mm.
n
0.1 mm
o
1.0 mm.
p
0.1 mm.

FIGURE 3

PLATE 2: Pellets of the Mollusca (Pelecypoda, a. to l.) and the Arthropoda (m. to u.).

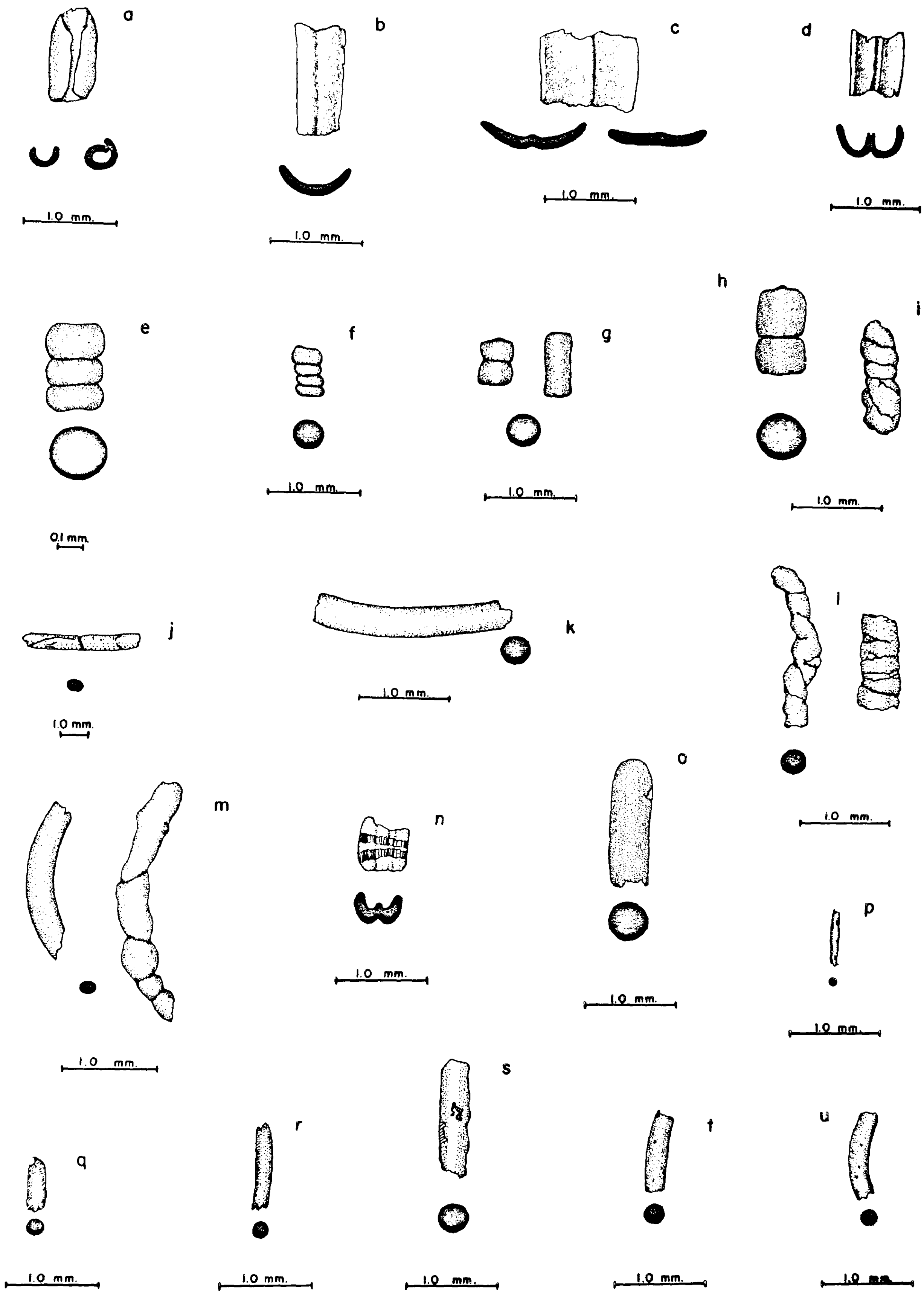
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t
u
1.0 mm.
0.1 mm.

FIGURE 4

PLATE 3: Pellets of the Arthropoda (a. to k.), the Echinodermata (Ophiuroidea, l.), and the Chordata (Ascidiacea, m.).

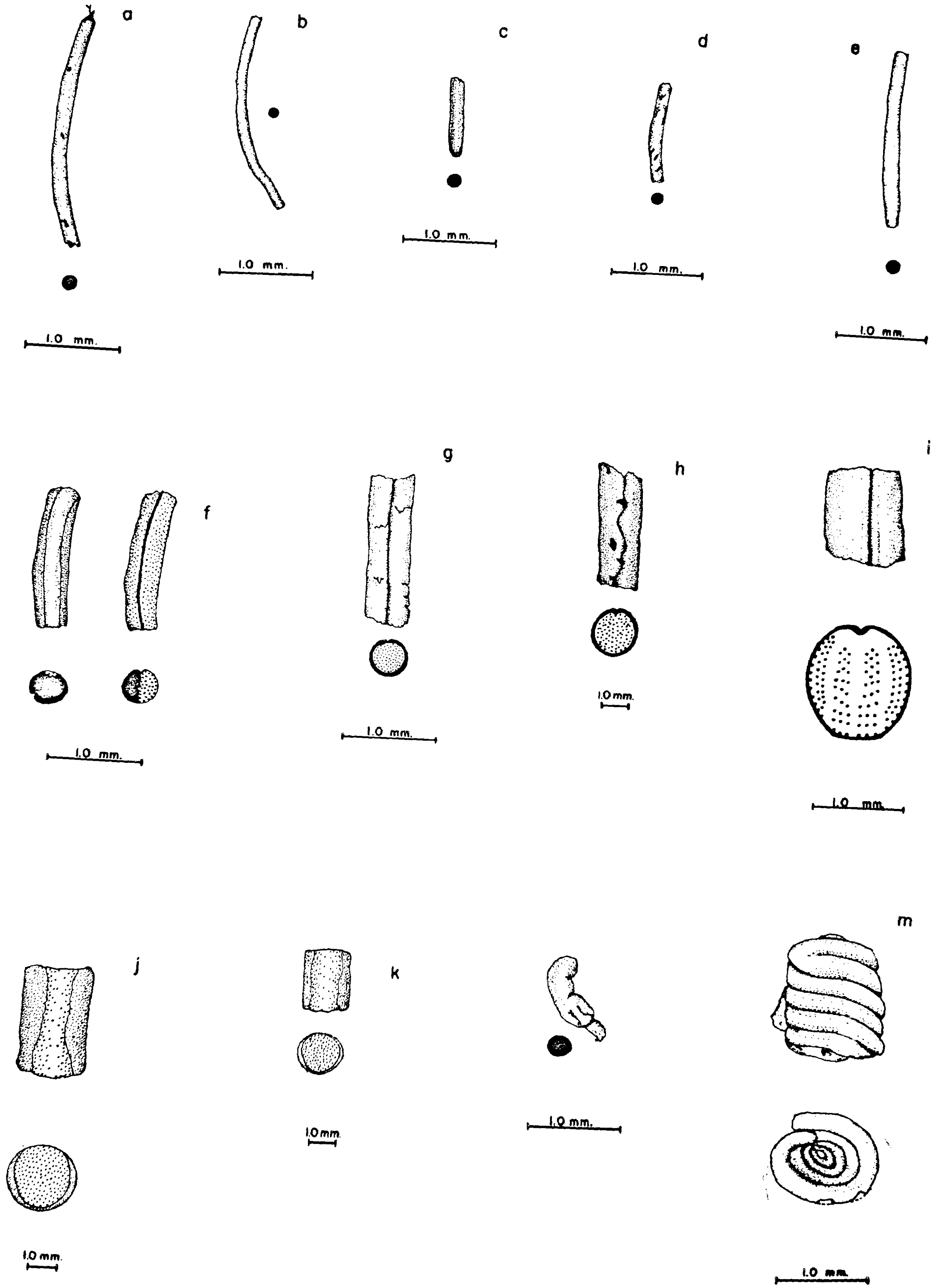
a
1.0 mm.
b
1.0 mm.
c
1.0 mm.
d
1.0 mm.
e
1.0 mm.
f
1.0 mm.
g
1.0 mm.
h
1.0 mm.
i
1.0 mm.
j
1.0 mm.
k
1.0 mm.
1.0 mm.
m
1.0 mm.

TABLE 1

NUMBER AND SIZES* OF PELLETS AND ANNELIDS

Species	Animals		Pellet	Size of Pellet			
	Number	Size Range	Number	Width Range	Mean Width	Length Range	Mean Length
Cirriformia filigera	5	33-55	19	0.33-0.46	0.35-0.44	0.54-1.06	0.72-0.91
Cistenides gouldii**	9	14-29	32	0.07-0.28	0.07-0.16	0.11-0.81	0.21-0.48
Glycera dibranchiata	3	58-123	4	0.65-2.00	0.81-2.00	0.66-7.00	1.32-7.00
Melinna maculata	4	23-37	29	0.39-0.54	0.41-0.52	0.55-1.35	0.87-0.96
Neanthes succinea	3	21-60	5	0.13-0.77	0.38-0.75	0.79-1.51	1.04-1.10

* All sizes in mm

**Pellets questionable

TABLE 2

NUMBER AND SIZES* OF PELLETS AND MOLLUSCS

Species	Animals		Pellet	Size of Pellet			
	Number	Size Range	Number	Width Range	Mean Width	Length Range	Mean Length
Anadara transversa	7	9-51	48	0.22-2.85	0.24-2.85	0.33-3.90	0.42-3.90
Anomia simplex	7	7-38	40	0.25-0.90	0.27-0.66	0.25-1.65	0.29-1.65
Bittium alternatum	9	3-4	34	0.05-0.11	0.06-0.10	0.17-0.25	0.22-0.24
Brachidontes recurvus	4	22-35	23	0.53-1.17	0.55-1.16	0.54-1.46	1.01-1.06
Crepidula convexa	5	14-16	45	0.10-0.16	0.11-0.14	0.23-0.39	0.27-0.29
Crassostrea virginica	7	52-77	40	0.57-1.85	0.69-1.79	0.42-3.38	1.12-1.79
Epitonium rupicolum	4	7-8	5	0.17-0.31	0.18-0.31	0.22-1.75	0.27-1.75
Laevicardium mortoni	7	5-23	29	0.16-0.47	0.18-0.45	0.27-1.00	0.48-0.85
Littorina irrorata	13	20-22	94	0.42-0.88	0.45-0.57	1.08-2.62	1.14-1.83
Lyonsia hyalina	6	10-25	12	0.29-0.46	0.30-0.39	These are ovals	
Macoma tenta	12	6-16	103	0.12-0.28	0.12-0.27	0.12-0.46	0.15-0.33

*All sizes in mm

continued

TABLE 2 (continued)

Species	Animals		Pellet	Size of Pellet			
	Number	Size Range	Number	Width Range	Mean Width	Length Range	Mean Length
Melampus bidentatus	6	5-7	21	0.16-0.23	0.18-0.21	0.27-4.43	0.67-4.43
Mercenaria mercenaria	7	25-80	79	0.14-0.78	0.20-0.61	0.56-4.75	0.72-2.12
Mulinia lateralis	5	6-20	14	0.12-0.47	0.16-0.44	0.27-1.83	0.44-1.15
Mytilus edulis	4	35-57	39	0.84-1.31	0.86-1.27	0.88-1.73	1.01-1.42
Retusa canaliculata	13	all 3	27	0.12-0.14	0.13	0.24-0.44	0.37
Tagelus plebeius	4	43-71	37	0.37-0.80	0.44-0.69	0.54-2.00	0.84-2.00
Volsella demissa	4	51-110	28	1.03-1.67	1.04-1.66	0.72-2.12	1.14-2.06

TABLE 3

NUMBER AND SIZES* OF PELLETS AND ARTHROPODS

Species	Animals		Pellet	Size of Pellet			
	Number	Size Range	Number	Width Range	Mean Width	Length Range	Mean Length
Ampelisca macrocephala	13	7-11	63	0.15-0.25	0.15-0.24	0.43-2.15	0.64-1.35
Balanus eburneus	5	10-15	21	0.23-0.54	0.32-0.47	0.63-3.10	1.20-2.08
Balanus improvisus	3	3-6	16	0.11-0.46	0.11-0.33	0.76-2.11	0.92-1.46
Caprella equilibra	3	8-9	13	0.08-0.11	0.08-0.10	0.27-0.84	0.46-0.74
Erichsonella attenuata	3	19-21	15	0.32-0.38	0.34-0.35	0.71-1.75	0.92-1.08
Hippolyte pleuracantha	3	17-18	24	0.12-0.16	0.13-0.15	0.30-3.56	0.68-2.86
Idotea baltica	4	12-17	11	0.28-0.42	0.28-0.37	0.48-2.17	0.48-1.27
Melita fresneli	3	7-10	6	0.16-0.25	0.18-0.25	0.89-2.13	0.93-2.13
Neopanope texana sayi	3	12-24	6	0.49-1.06	0.49-0.99	1.30-4.38	1.93-2.87
Ogyrides limicola	3	14-16	14	0.11-0.19	0.15-0.18	0.41-1.61	0.54-0.93

*All sizes in mm

continued

TABLE 3 (continued)

Species	Animals		Pellet	Size of Pellet			
	Number	Size Range	Number	Width Range	Mean Width	Length Range	Mean Length
Palaemonetes pugio	3	28-30	14	0.12-0.16	0.13-0.14	0.65-1.98	0.91-1.51
Palaemonetes vulgaris	5	25-32	34	0.15-0.27	0.16-0.25	0.27-3.63	1.22-2.14
Uca minax	4	29-38	10	2.10-2.80	2.21-2.80	1.05-4.54	3.21-4.22
Upogebia affinis	6	12-54	9	0.39-1.13	0.41-1.13	0.57-3.68	0.72-3.68

LITERATURE CITED

Abbott, T. R. 1954a. Review of the Atlantic periwinkles, Nodilittorina, Echinius, and Tectarius. Proc. U. S. Natl. Mus. 103 (3328): 449-464.

Abbott, T. R. 1954b. American seashells. D. Van Nostrand Co., Inc. New York. 541 pp.

Arakawa, K. Y. 1962. A coprological study on the molluscan feces. A preliminary note. Venus (Japanese Malacol.) 22: 151-172.

Arakawa, K. Y. 1963. Studies on the molluscan feces (I). Publ. Seto Mar. Biol. Lab. 11: 185-208.

Arakawa, K. Y. 1965. Studies on the molluscan feces (II). Publ. Seto Mar. Biol. Lab. 13: 1-21.

Buchanan, J. Y. 1890. On the occurrence of sulphur in marine muds and nodules, and its bearing on their mode of formation. Proc. Roy. Soc. Edinburgh 18: 17-39.

Edge, E. R. 1934. Faecal pellets of some marine invertebrates. Amer. Midl. Nat. 15: 78-84.

Galliher, E. W. 1932. Organic structures in sediments. J. Sed. Petrol. 2: 46-47.

Hartman, O. 1959. A catalog of the polychaetous annelids of the world. Part I and II. Allan Hancock Foundation Publ. Occas. Paper 23, 628 pp.

Haven, D. S. and R. Morales-Alamo. 1965. Apparatus for holding individual oysters under equal water flows. Limnol. Oceanog. 10: 605-606.

Haven, D. S. and R. Morales-Alamo. Aspects of biodeposition by oysters and other invertebrate filter feeders. In press.

Hyman, L. H. 1955. The Invertebrates. Vol. IV. Echinodermata. McGraw-Hill, New York, pp. 589-689.

Hyman, L. H. 1959. The Invertebrates. Vol. V. Smaller coelomate groups. McGraw-Hill, New York, pp. 228-274.

Ito, S. and T. Imai. 1955. Ecology of oyster bed I. On the decline of productivity due to repeated cultures. Tokoka J. Agri. Res. 5: 9-26.

Johannes, R. E. and M. Satomi. 1966. Composition and nutritive value of fecal pellets of a marine crustacean. Limnol. Oceanog. 11: 191-197.

Kornicker, L. A. 1962. Evolutionary trends among mollusk fecal pellets. J. Paleontol. 36: 829-832.

Kornicker, L. A. and E. G. Purdy. 1957. A Bahamian faecal-pellet sediment. J. Sed. Petrol. 27: 126-128.

Lund, E. J. 1953. Self silting by the oyster and its significance for sedimentary geology. Publ. Inst. Mar. Sci. Univ. Texas 4: 320-327.

Manning, R. B. and H. E. Kumpf. 1959. Preliminary investigation of the fecal pellets of certain invertebrates of South Florida area. Bull. Mar. Sci. Gulf Caribbean 9: 291-309.

Moore, H. B. 1931a. The systematic value of a study of molluscan feces. Proc. Malacol. Soc. London 19: 281-290.

Moore, H. B. 1931b. The specific identification of faecal pellets. J. Mar. Biol. Ass. U. K. 17: 359-365.

Moore, H. B. 1932a. The faecal pellets of the Trochidae. J. Mar. Biol. Ass. U. K. 18: 235-242.

Moore, H. B. 1932b. The faecal pellets of the Anomura. Proc. Roy. Soc. Edinburgh 52: 296-308.

Moore, H. B. 1933a. The faecal pellets of _Hippa asiatica_. Proc. Roy. Soc. Edinburgh 53: 252-254.

Moore, H. B. 1933b. The faecal pellets from marine deposits. Discovery Rept. 7: 17-26.

Moore, H. B. 1939. Faecal pellets in relation to marine deposits. p. 516-524. _In_ Recent marine sediments. Society of Economic Paleontology and Mineralology Special Publication 4. The American Association of Petroleum Geologists.

Moore, H. B. and P. Kruse. 1956. A review of present knowledge of faecal pellets. Univ. Miami Mar. Lab. ML 13860, 24 pp.

Rhoads, D. C. and D. J. Stanley. 1965. Biogenic graded bedding. J. Sed. Petrol. 35: 956-963.

Takahashi, J. and T. Yagi. 1929. Peculiar mud grains and their relation to the origin of glauconite. Econ. Geol. 24: 838-852.

Van Name, W. G. 1945. The North and South American ascidians. Bull. Amer. Mus. Nat. Hist. 84: 1-476.

Van Tuyl, F. M. 1916. A contribution to the oolite problem. J. Geol. 24: 792-797.

Verwey, J. 1952. On the ecology of distribution of cockle and mussel in the Dutch Waddensea, their role in sedimentation and the source of their food supply. Arch. Neeland. Zool. 10: 171-249.

Waterman, T. H. and F. A. Chace, Jr. 1960. General crustacean biology, p. 1-33. In Waterman's Physiology of Crustacea, Vol. I.

Williams, A. B. 1965. Marine decapod Crustacea of the Carolinas. U. S. F&WS. Fish. Bull. 65: 1-298.

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