



The Echinoids of
Carrie Bow Cay, Belize

PORTER M. KIER

SMITHSONIAN CONTRIBUTIONS TO ZOOLOGY • NUMBER 206

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Carrie Bow Cay, Belize

Porter M. Kier



SMITHSONIAN INSTITUTION PRESS

City of Washington

1975

ABSTRACT

Kier, Porter M. The Echinoids of Carrie Bow Cay, Belize. *Smithsonian Contributions to Zoology*, number 206, 45 pages, 8 figures, 12 plates, 1975.—Twenty species were found living off Carrie Bow Cay. *Echinometra lucunter* (Linnaeus), *E. viridis* Agassiz, and *Diadema antillarum* Philippi are the most common species on the reef. In the lagoon, the most common in the *Thalassia* beds are *Lytechinus variegatus* (Lamarck), *Eucidaris tribuloides* (Lamarck), and *Clypeaster rosaceus* (Linnaeus). The deeper mud fields have large numbers of the spatangoids *Paraster doederleini* Chesher, fewer *Moira atropos* (Lamarck), and *Brissopsis elongata* Mortensen. *Meoma ventricosa* (Lamarck) occurs in sand fields both in the lagoon and on the reef. *Cassidulus cariboeorum* Lamarck lives in the lagoon's coarse sand in water one meter deep. This species has never been seen alive in situ before. Immature specimens were found of *Plagiobrissus grandis* (Gmelin) and *Meoma ventricosa* (Lamarck). These are the smallest specimens ever described of these species. Their growth changes are described. Rod-like structures are reported in *P. grandis*, which probably serve to strengthen its very thin test.

OFFICIAL PUBLICATION DATE is handstamped in a limited number of initial copies and is recorded in the Institution's annual report, *Smithsonian Year*. SI PRESS NUMBER 5261. SERIES COVER DESIGN: The coral *Montastrea cavernosa* (Linnaeus).

Library of Congress Cataloging in Publication Data

Kier, Porter M.

The echinoids of Carrie Bow Cay, Belize.

(Smithsonian contributions to zoology, no. 206)

Supt. of Docs. no.: SI 1.27:206

1. Sea-urchins—British Honduras—Carrie Bow Cay. I. Title. II. Series: Smithsonian Institution, Smithsonian contributions to zoology, no. 206.

QL1.554 no. 206 [QL384.E2] 591'.08s [563'.95] 74-23845

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402—Price \$0.00 (paper cover)

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The Echinoids of Carrie Bow Cay, Belize

Porter M. Kier

Introduction

Scientists from the Smithsonian Institution are making an ecosystem study of Carrie Bow Cay, a small island located on the barrier reef that extends along the coast of Belize (formerly British Honduras). This study will be an integrated program emphasizing the biological and geological interactions of the system. Initially the diversity and distribution of the benthic organisms will be studied, as well as their role in the construction and destruction of the reef. Specialists in each animal and plant group will first describe the fauna and flora. They will then try to formulate the interaction between the individual groups and in turn their involvement in the development of the reef itself.

This report on the echinoids follows one month of diving and collecting in 1973 and 1974. Most of the dives were made from the reef directly east of Carrie Bow Cay and, in particular, from a transect that will be studied by all participants in the program (Figure 1). The transect extends 600 meters from the Cay to a point over the reef drop-off. Many dives were also made in the lagoon west of Carrie Bow. Twenty species of echinoids were found. None of them are new, but several of them have never been seen alive before in their natural habitat. Of particular interest was the discovery of extremely small specimens of two spatangoids, *Plagiobrissus grandis* (Gmelin) and *Meoma ventri-*

cosa (Lamarck). They reveal new information about the development of these echinoids, such as the presence of rod-like structures in *P. grandis*, which probably serve to reinforce the very thin test.

The distribution of the echinoids is similar to that described for other sites in the Caribbean. *Echinometra lucunter* (Linnaeus), *E. viridis* Agassiz, and *Diadema antillarum* Philippi are the most common species occurring on the reef, although *D. antillarum* is not as numerous as elsewhere in the Caribbean. In the lagoon's *Thalassia* beds, *Lytechinus variegatus* (Lamarck), *Eucidaris tribuloides* (Lamarck), and *Clypeaster rosaceus* (Linnaeus) are the most common species occurring together with herds of *Diadema antillarum*. Spatangoids occur in great numbers in the mud fields of the lagoon, including many *Paraster doederleini* Cheshier, fewer *Moira atropos* (Lamarck), and *Brissopsis elongata* Mortensen.

An interesting feature of the echinoid fauna is the presence of only a few individuals of a large number of species. Only one dead specimen was found of *Clypeaster subdepressus* (Gray), one live specimen of *Leodia sexiesperforata* (Leske), no adults of *Plagiobrissus grandis*, no living specimens of *Agassizia excentrica* Agassiz, two specimens of *Paraster* cf. *P. floridiensis* (Kier and Grant), a few *Cassidulus cariboeorum* Lamarck, and two specimens of *Arbacia punctulata* (Lamarck). Although only one specimen of *Lytechinus williamsi* Cheshier was found, it may be common. I simply was not looking for it.

ACKNOWLEDGMENTS.—I thank William M. Kier, who served as my diving partner and did all the

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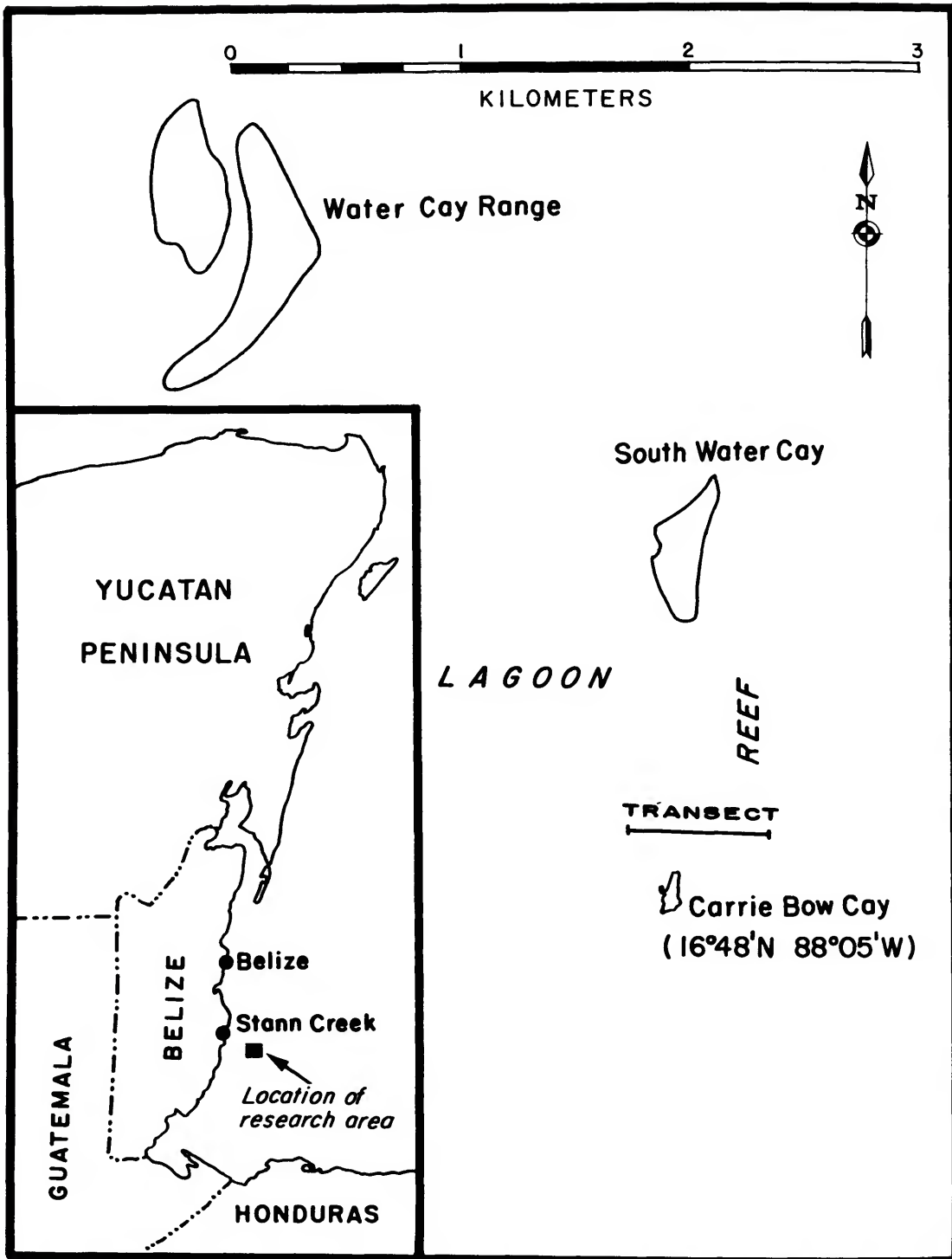


FIGURE 1.—Map showing location of Carrie Bow Cay and location of transect.

underwater photography. Many of the specimens described in this paper were collected by him. Thomas R. Waller, Frederick Hotchkiss, and Douglas Putman also collected some of the echinoids. Mary H. Lawson did the laboratory preparations and photography. The SEM photography was done by Walter R. Brown, and the map and graphs were drawn by Lawrence B. Isham. David L. Pawson and Richard H. Chesher critically read the manuscript and made many useful suggestions for its improvement.

This paper is contribution number 15 of the Smithsonian Institution Investigations of Marine Shallow-Water Ecosystems Project.

Plagiobrissus grandis (Gmelin)

FIGURES 2-5; PLATES 1-3; PLATE 4: FIGURES 1, 2

Echinus grandis Gmelin, 1791:3200. [For synonymy, see Mortensen, 1951:496.]

Immature specimens of *Plagiobrissus grandis* (Gmelin) and *Meoma ventricosa* (Lamarck) were found living buried in the sand at a depth of 50 to 100 mm, in sand fields in the grooves of the Spur and Groove Zone on the transect off Carrie Bow Cay at a depth of 10 m.

The immature of the two species resemble each other in general appearance (compare Plate 1: figure 1 with Plate 6: figure 1); but the young of *Plagiobrissus grandis* can be distinguished by their whiter spines and lack of large, black pedicellariae on their dorsal surface. If all specimens found had been less than 6 mm, it would have been difficult to identify these species; but specimens nearly 20 mm long are enough like the adults to make identification possible. These identifications were confirmed by the comparison of specific features in the tests of both immature and adult that are not affected by growth. Chesher (1968a) has shown that the fascioles remain on the same plates throughout the growth of the echinoid, that the number of plates beyond the petals are constant, and that the periproct remains enclosed by the same plates. These features were compared between the immature specimens and specimens of adults believed to be the same species and no differences were found.

No adult specimens of either species were living with these immature. Considering the great differ-

ences between the immature and the adult, it is not surprising that they live in different environments.

Three immature specimens were found of *P. grandis* varying in length from 5.8 to 20 mm. The smallest specimen is far smaller than any of this species previously described (Kier and Grant, 1965: 36, described a specimen 35 mm long) and shows features never seen before. These features and changes that occur in the larger specimens are described in detail below.

SHAPE.—The smaller specimens have a higher,

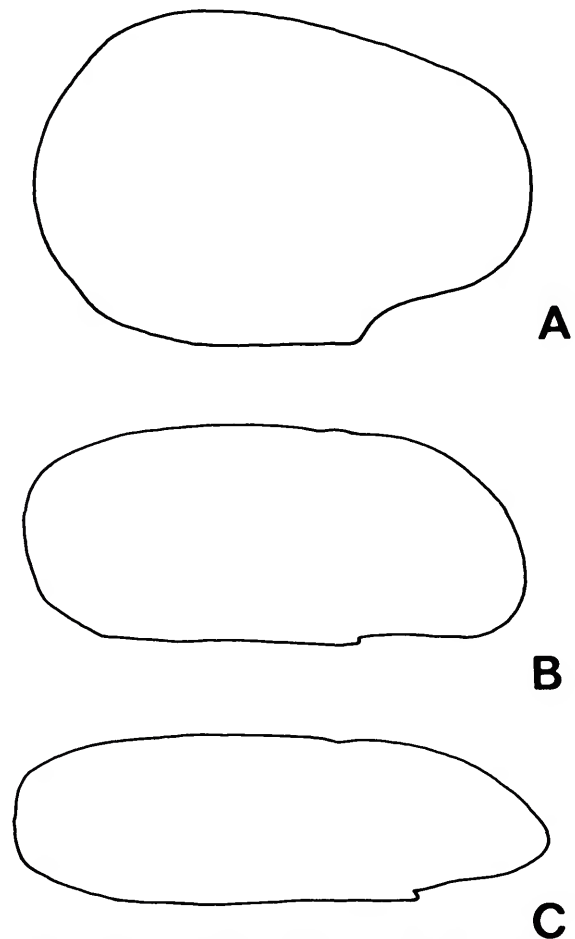
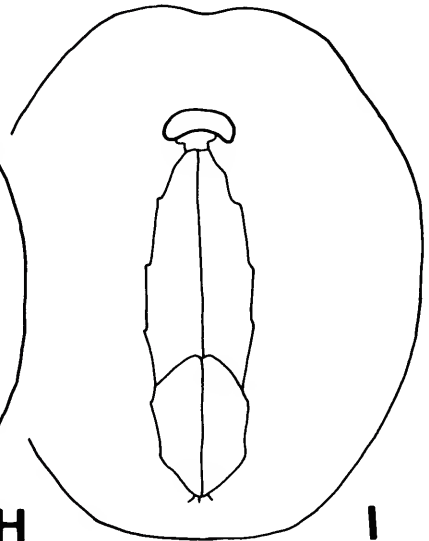
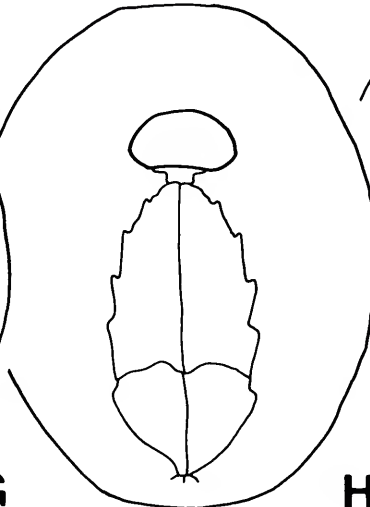
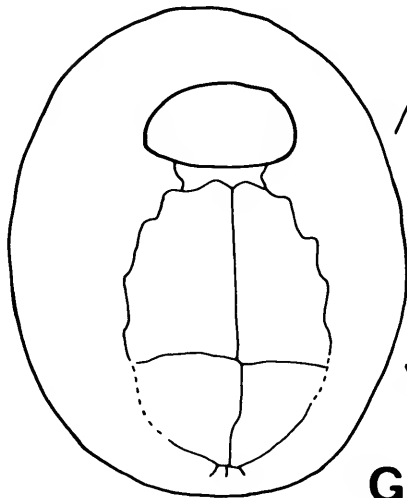
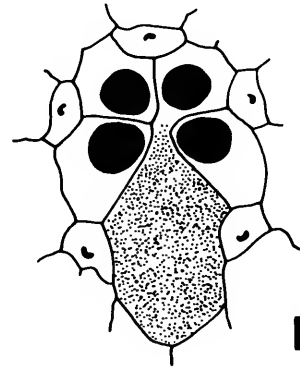
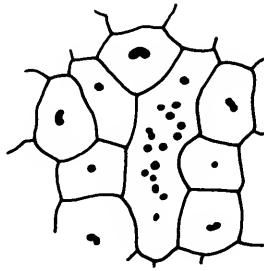
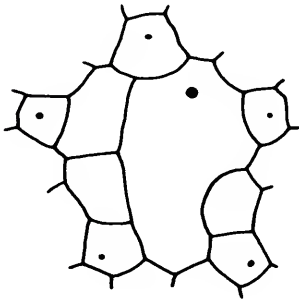
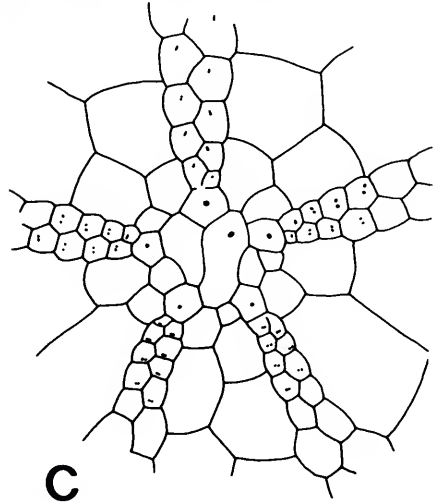
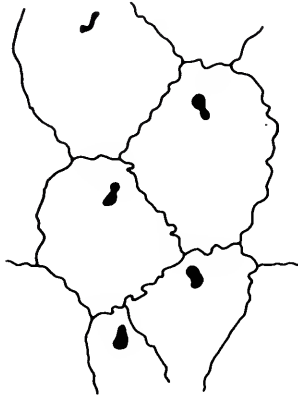
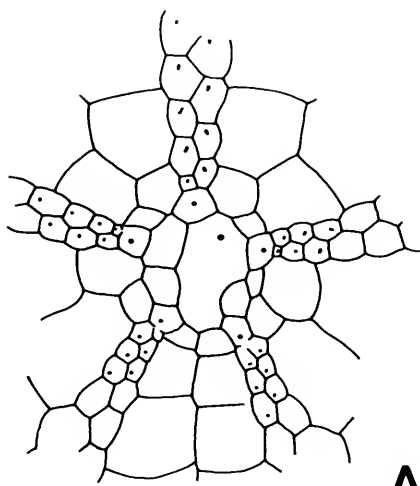


FIGURE 2.—*Plagiobrissus grandis* (Gmelin). Side views showing the decrease in relative height of the test in the larger specimens; A, specimen USNM E13730, 6.9 mm long, $\times 10$; B, specimen USNM E10304, 35 mm long, $\times 2$; C, specimen USNM E13737, 150 mm long, $\times \frac{1}{2}$. The two larger specimens (B and C) are from the Florida Keys.



more smoothly rounded test with a far larger periproct and peristome relative to the test's total length. The specimen 5.8 mm long has a very high test—a height equal to 67 percent of the length. In a specimen 35 mm long, the height is 45 percent of the length; and in an adult 150 mm long, only 33 percent (Figure 2). The test is smoothly rounded in the smallest specimen; but in an adult the margin is sharp, the adoral surface is more flattened, and the dorsal interambulacra are slightly ridged.

The periproct in the smallest specimen is very large, with its height equal to 38 percent of the length of the test and its width equal to 24 percent. In contrast, the periproct of a specimen 35 mm long has a height of only 18 percent and a width of only 10 percent. Finally, in an adult 150 mm long, the height of the periproct is only 10 percent; and the width is only 7 percent of the length of the test.

The periproct remains surrounded by the same interambulacral plates throughout its growth. The surrounding plates just become fewer in the adult. The smallest specimen's periproct occurs within interambulacral plates 5 through 10. An adult's falls within plates 5 through 8. The anus is situated so far dorsally in the smaller specimens (Figure 4A; Plate 1: figure 1) that it is almost entirely visible when viewed from the top. In an adult (Plate 1: figure 2) it has shifted down to a posterior truncation where most of it is now visible from a ventral view.

FIGURE 3.—*Plagiobrissus grandis* (Gmelin): A, petaloid area of specimen 5.8 mm long showing single pores in the paired petals, and medially constricted pores in ambulacrum III, USNM E13731, $\times 22$; B, ambulacrum III of same specimen under greater magnification showing nature of constricted pores suggesting that petaloid pores are originally single and then are divided in two, $\times 100$; C, petaloid area of specimen 6.9 mm long, USNM E13730, showing presence of pore-pairs in all petals, $\times 22$; D, apical system in smallest specimen 5.8 mm long, USNM E13731, has no genital pores and only a single madreporic pore, $\times 40$; E, specimen 20 mm long, USNM E13732, has small genital pores, and 16 madreporic pores, $\times 25$; F, specimen 150 mm long, USNM E13737 (from the Florida Keys) has greatly enlarged genital pores, hundreds of madreporic pores, and genital 2 extends posteriorly, $\times 6$; G-I, the peristome in the smaller specimens is much larger, and the plastron wider (G, specimen 6.9 mm long, USNM E13730, $\times 10$; H, specimen 20 mm long, USNM E13732, $\times 3.5$; I, specimen 150 mm long (from Florida Keys), USNM E13737, $\times 1/2$).

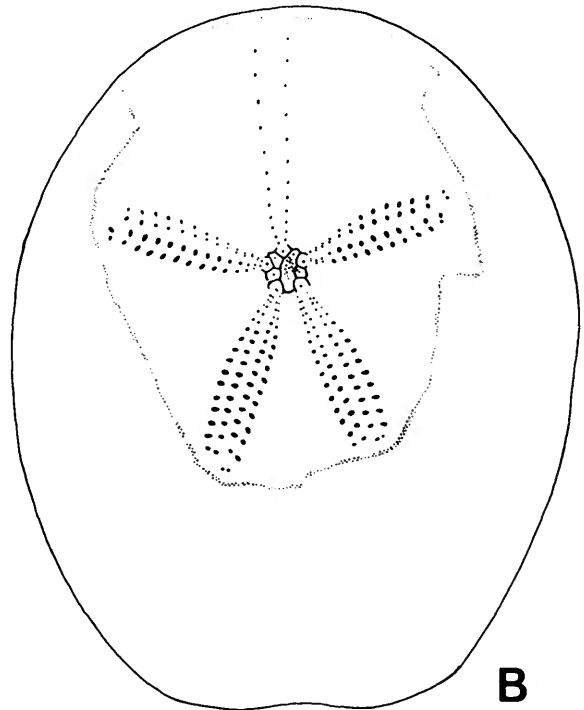
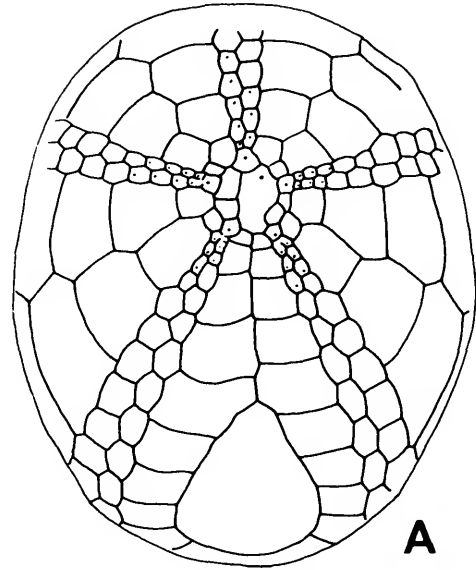


FIGURE 4.—*Plagiobrissus grandis* (Gmelin). A specimen 5.8 mm long (A) differs from one 20 mm long (B) in lacking pore-pairs in the petals and in having its periproct on an adapical surface: A, USNM E13731, $\times 14$; B, USNM E13732, $\times 5$.

The peristome, too, is much larger (Figure 3*G-I*; Plate 1: figures 3, 4) relative to the length of the test in the very young. The width of the peristome in the smallest specimen is 34 percent of the length of the test; in a specimen 20 mm long, only 13 percent. A decrease also occurs in the height of the peristome. The smallest specimen, 5.8 mm long, has a height equal to 22 percent of the length of the test; whereas, the peristome in a specimen 20 mm long is only 11 percent of the total length, and is only 4 percent in an adult 150 mm long. Part of this reduction in the height of the peristome is due to the development of a protruding labrum in the adult.

PLASTRON.—The plastron on the smaller specimens is far wider than that in the adult. A specimen 6.9 mm long has a plastron with a width equal to 43 percent of the length of the test (Figure 3*c*); whereas, a specimen 20 mm long has a plastron width of only 30 percent (Figure 3*h*). In an adult the width is only 20 percent (Figure 3*i*).

The plastron in the immature specimens bears many large tubercles, but in the adult the tubercles are smaller than those on the broad interambulacral areas. Presumably, the spines attached to the plastron in the immature (Plate 3: figure 2) are the primary means of locomotion and burrowing. During growth a change takes place, and these locomotive spines in the adult are attached to the interambulacra.

APICAL SYSTEM.—The apical system of an immature specimen differs from an adult in being much larger relative to the size of the test, lacking genital pores, having only one madreporic pore, and lacking an extension of the madreporite (genital 2) into the posterior interambulacrum.

The apical system in the smallest specimen (5.8 mm long) is 0.99 mm wide (measured at its greatest width across oculars *ii* and *iv*). This is 17 percent of the length of the test. The next largest specimen (6.9 mm long) has an apical system 0.98 mm wide or 14 percent of its length. A specimen 20 mm long has a system 1.2 mm wide or 6 percent of its length. An adult 150 mm long has a system 4.7 mm wide, which is only 3.1 percent of its length. Although the apical system does increase in size during the growth of the animal, its rate of growth is much less than the growth of the test.

No genital pores are present in the two smallest specimens, 5.8 and 6.9 mm long (Figure 3*c,d*); but

small pores occur in a specimen 20 mm long (Figure 3*e*). They are quite large in a specimen 35 mm long; in an adult 150 mm long, they are extremely large, occupying most of the genital plates excluding the madreporite (Figure 3*f*).

Only one madreporic pore is present in each of the two smaller specimens (Figure 3*c,d*), and this occurs in the right anterior portion of genital 2. Sixteen pores are present in a specimen 20 mm long (Figure 3*e*); 35 in a specimen 35 mm long, and hundreds in an adult 150 mm long (Figure 3*f*). Although the single pore in the two smaller specimens is large relative to the size of the test, the madreporic pores in all the specimens are approximately the same size, 0.03 to 0.04 mm in diameter.

The madreporite (genital 2) extends very far into the posterior interambulacrum in the adult specimen (Figure 3*f*), but in the smaller specimens (Figure 3*d,e*) this posterior extension does not occur.

PETALS.—The ambulacral plates of the petals are just beginning to be developed in the smallest specimen 5.8 mm long. These petaloid plates can be distinguished from the ambulacral plates beyond the petals by their smaller size and by their slightly larger pores (Plate 1: figure 1). The pores in the ambulacral plates beyond the petals are so small that they cannot be distinguished from the holes in the meshwork of the calcite plates. Each of the petaloid ambulacra have six to eight plates. The pore in each plate is single, not double as in an adult. Each of these pores was studied under high magnification (Plate 4: figures 1, 2) with a scanning electron microscope, and in none of them is there any indication of a partition developing to divide the pore in two. However, in the non-petaloid ambulacrum *iii*, each pore is constricted medially (Figure 3*b*; Plate 4: figure 1), suggesting that the ambulacral pores are originally single and then are divided in two by this constriction.

In the next larger specimen, 6.9 mm long, most of the petaloid pores are double (Figure 3*c*). The pores, though, are still very close together; and the ambulacra are not petal-like in appearance. Only eight plates are present in each petaloid ambulacra. A specimen 20 mm long has well-developed petals with the pores elongated transversely.

The petals are slightly depressed, not flush to the general surface of the test as in the smaller speci-

mens. Each anterior petal has 26 plates, and each posterior has 32. The petals in an adult 150 mm long (Plate 1: figure 2) are flexuous, not straight as in the smaller specimens. There are 70 plates in each anterior paired petal and 90 in each posterior.

FASCIOLAS.—The peripetalous fasciole is only slightly developed in the immature specimens, but the subanal fasciole is distinct and clearly functional. The fascioles increase in size, not by an increase in the size of the fasciole tubercles but by an increase in the number of these tubercles.

The peripetalous fasciole on a specimen 5.8 mm long is composed of a single row of tubercles. A second row of tubercles is present for part of the length of this fasciole in a specimen 6.9 mm long (Plate 1: figure 1). Most of this fasciole has 2 rows of tubercles in a specimen 20 mm long; 5 rows in a specimen 35 mm long; and 17 rows in an adult 150 mm long.

The subanal fasciole is very distinct in the smallest specimen (5.8 mm long) and consists of 2 to 3 rows of tubercles. There are 3 to 5 rows in a specimen 20 mm long; 9 to 13 in a specimen 35 mm long; and 30 to 35 in an adult 150 mm long.

The tubercles in both fascioles do not increase in size during the growth of the echinoid. They are between 0.05 and 0.06 mm in diameter in all the specimens regardless of the size of the echinoid.

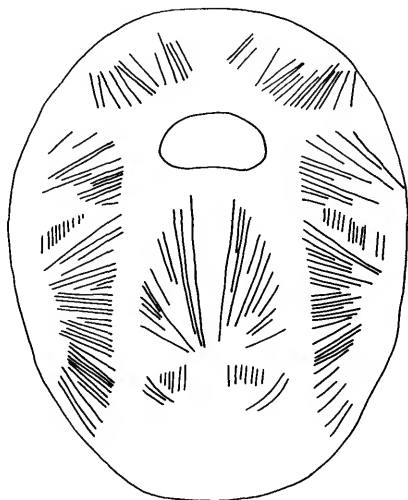


FIGURE 5.—*Plagiobrissus grandis* (Gmelin). Adoral view of specimen USNM E13732, 20 mm long, showing the rod-like structures that are herein considered to be for reinforcement, $\times 3.5$.

DORSAL TUBERCLES.—The large dorsal tubercles that typically occur within the peripetalous fasciole of an adult are absent or just forming in the smallest specimen. The plates that bear them in the adult are just beginning to be developed in the smaller specimens. A specimen 20 mm long has approximately 20 of these larger tubercles. A specimen 35 mm long has less than 50, and an adult has nearly 200.

VENTRAL RODS.—Rod-like structures (Figure 5) are very apparent on the ventral side of the smaller specimens, particularly when the specimens are wetted with xylene (Plate 2: figure 2). Under high magnification it can be seen that the rods are formed of the calcite matrix of the test and are produced by thickening of the calcite with a corresponding reduction in the size of the holes in the calcite meshwork (Plate 2: figures 3, 6). Where a rod meets the suture of an adjacent plate, it is overlapped by a rod extending from that plate (Plate 2: figures 4, 5). The rods are very conspicuous on the smaller specimens because of their thin tests, but much less apparent on an adult.

I suspect that these rods serve to strengthen the test, which is very thin in this species, especially in the immature. The rods are most developed where large tubercles occur, suggesting that they are especially needed here because of the strain exerted on the test by the strenuous movement of the ventral spines. The rods are not present in the immature of *Meoma ventricosa* (described below), but the test in that species is considerably thicker and perhaps needs no such reinforcement.

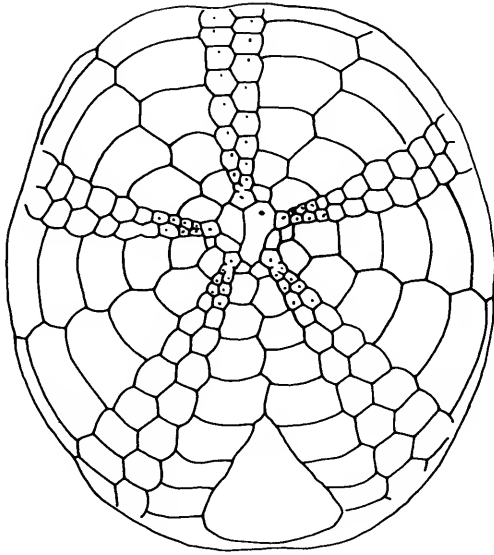
ADULTS.—Although I found no adults in the region, Richard Chesher (pers. comm., 1974) points out that, in his experience, they are one of the most difficult echinoids to find because they bury very deep, have no surface burrow, and do not come up at night.

Meoma ventricosa (Lamarck)

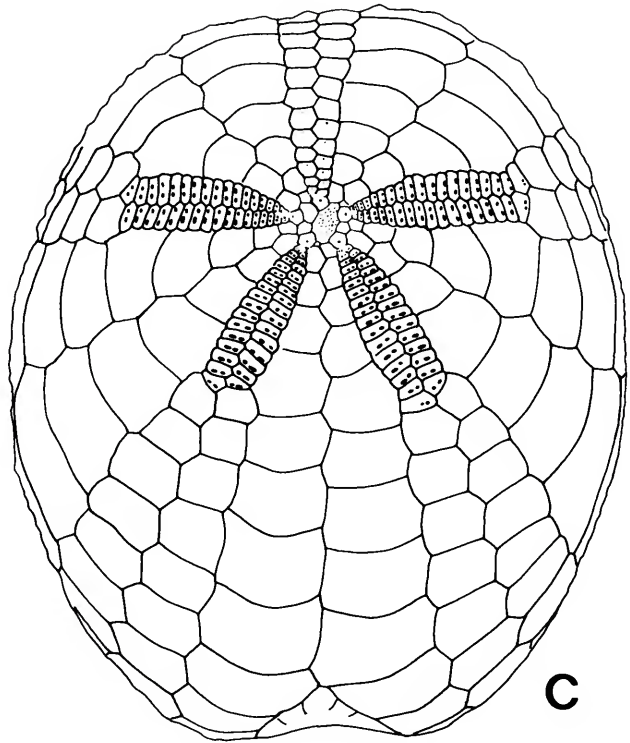
FIGURE 6; PLATE 4: FIGURES 3, 4; PLATE 5; PLATE 6:
FIGURES 1-3

Spatangus ventricosus Lamarck, 1816:323. [For synonymy, see Mortensen, 1951:529, and Chesher, 1970:737. The biology and living habits have been described by Kier and Grant, 1965:38, and Chesher, 1969, 1970.]

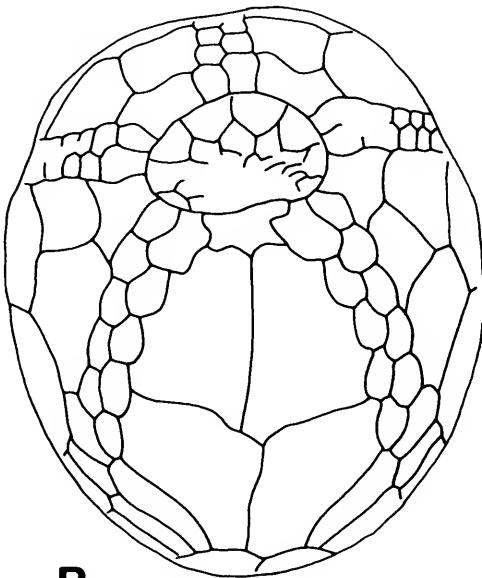
This species occurs off Carrie Bow Cay in sand grooves in the reef and in the lagoon west of the



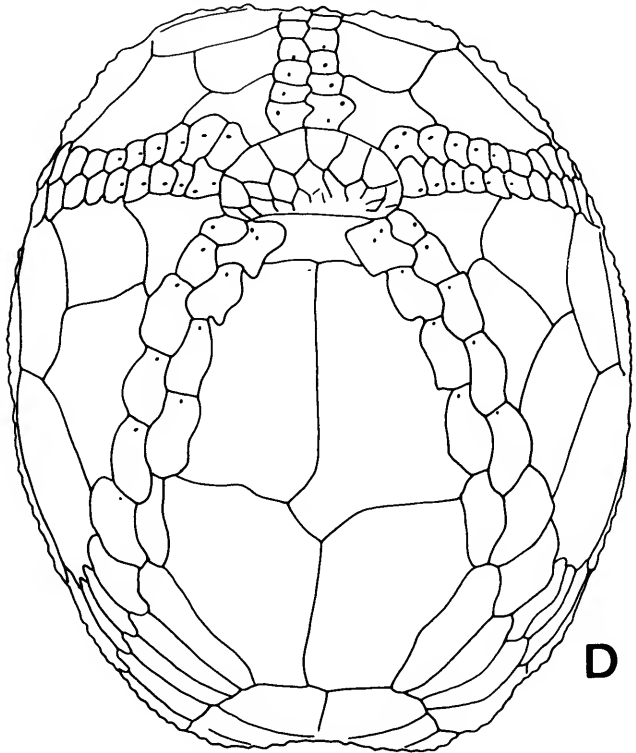
A



C



B



D

island. Its distribution is sparse in the reef where only three specimens were found alive. It is quite common in the deeper water (over 7 m) in the sand fields of the lagoon where specimens reach their greatest size. Here the specimens live completely buried in the sediment. Although it occurs in *Thalassia* beds where the water is over 5 m deep, specimens are less common and smaller. Individuals are not completely buried in the sediment, presumably because the network of *Thalassia* roots prevents burial. Here the echinoid lives much like *Glypeaster rosaceus*.

Immature specimens were found along the transect in the Spur and Groove Zone in sand fields at a depth of 10 meters. The echinoids were buried in the sand, and were only 5.8 to 17.5 mm long. They occur with the young of *Plagiobrissus grandis* and can be distinguished from them by their black pedicellariae, darker color due to yellow tips on their spines, and red tubefeet in the anterior ambulacrum. No adults were found in this zone.

The changes from the growth of a specimen 7 mm long to adult dimensions have been described by Kier and Grant (1965) and Chesher (1969, 1970). Only the changes from the smallest specimen 5.8 mm long to one 17.5 mm long are described here.

APICAL SYSTEM.—The apical system is very large relative to the size of the test in the immature. The specimen 5.8 mm long has an apical system (Figure 6A; Plate 6: figure 1) with a width equal to 16 percent of the length of the test. In the specimen 17.5 mm long, the width of the apical system is only 9 percent of the length of the test. No genital pores are present in either of these specimens. Kier and Grant (1965:44) report small genital pores in a specimen of this species 44 mm long. Only a single madreporic pore is present in the specimen 5.8 mm long, but 27 occur in the specimen 17.5 mm long.

PETALS.—The petals are just beginning to be developed in the specimen 5.8 mm long (Figure

6A; Plate 6: figure 1). Each petal has only six to eight pores. All appear to be single, although some of them are constricted medially. This indicates that their bifurcation into pore-pairs would have occurred soon. The specimen 17.5 mm long (Figure 6c; Plate 6: figure 2) has well-developed petals with 35 to 36 pore-pairs in the anterior petals II or IV. Thirty-one to 33 pore-pairs compose posterior petals V or I.

PLASTRON.—Although the plastron is relatively wider in the immature than in the adult, this difference is not nearly as great as in *Plagiobrissus grandis*. The smallest specimen, 5.8 mm long, has a plastron (Figure 6B) whose width is equal to 45 percent of the length of the test. The width of the plastron in the specimen 17.5 mm long (Figure 6D) is 40 percent of the length, and in an adult it is 35 percent.

FASCIOLES.—The peripetalous fasciole is very slightly developed in the smallest specimen (5.8 mm long) and is composed of a discontinuous single row of small tubercles (Plate 6: figure 1). This fasciole is well developed in the specimen 17.5 mm long and is composed of one to three rows of tubercles (Plate 6: figure 2).

The subanal fasciole is distinct in the smallest specimen and is composed of two rows of tubercles. The specimen 17.5 mm long has up to nine rows in this fasciole.

PEDICELLARIAE.—Approximately 10 globiferous pedicellariae (Plate 5) were present on the dorsal side of the specimens 5.8 mm and 17.5 mm long. They are very conspicuous on the smallest specimen because of their black color and easily distinguish the young of this species from the young of *Plagiobrissus grandis*. Although Mortensen (1951:531) reports no globiferous pedicellariae in an adult of *Meoma ventricosa*, Chesher (1969:99) has found them in an adult specimen from Bermuda.

Paraster doederleini Chesher

FIGURES 7, 8; PLATE 7; PLATE 8: FIGURES 1-5

Paraster doederleini Chesher, 1972a:10-25, figs. 1-9.

The Carrie Bow specimens are indistinguishable from the Floridian holotype of this species that previously was reported only from Florida and Colombia. Chesher (1972a:21) noted that the Co-

FIGURE 6.—*Meoma ventricosa* (Lamarck): A, B, adapical and adoral views of the smallest specimen (5.8 mm long) showing features of the immature test such as the lack of pore-pairs in the petal, the absence of genital pores, the presence of a single madreporic pore, adapical position of the periproct and relatively large peristome, USNM E13733, $\times 13$; C, D, adapical and adoral views of larger specimen 17.5 mm long, USNM E13734, $\times 6$.

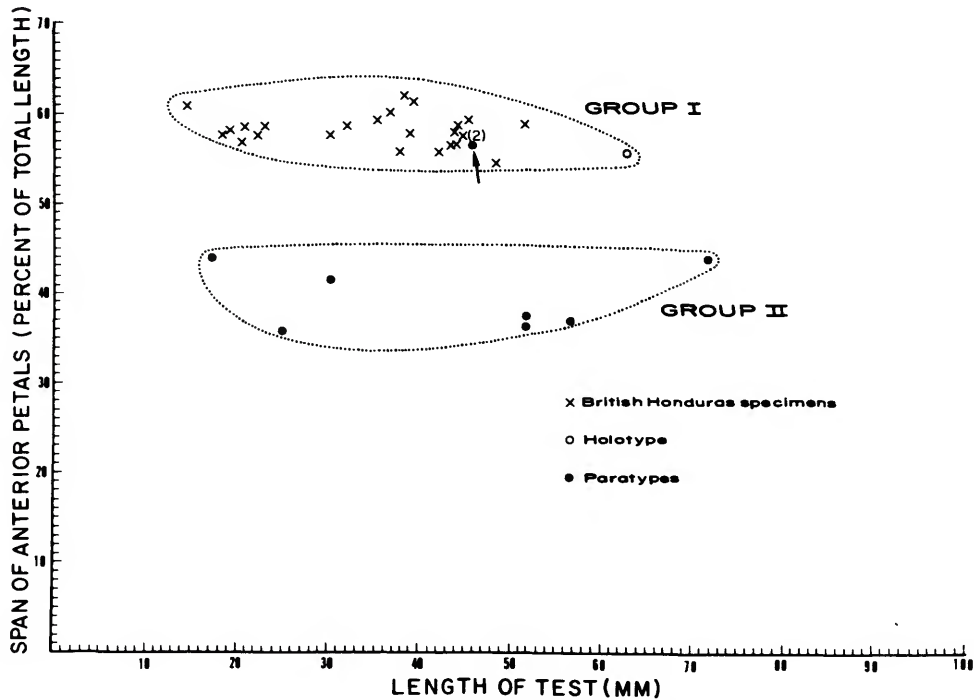
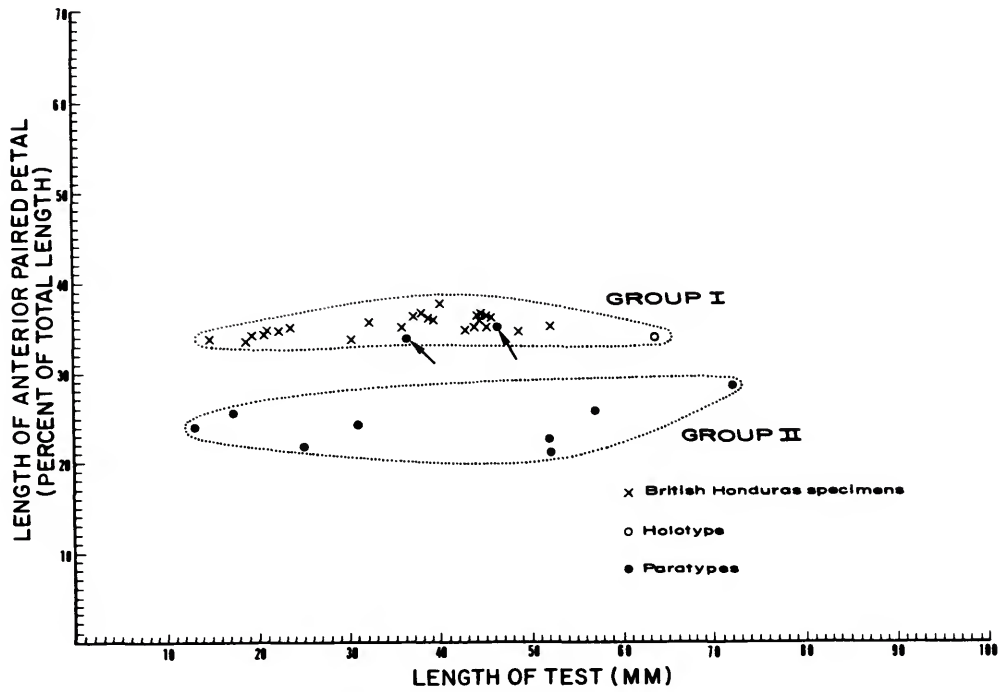


FIGURE 7.—The type-specimens of *Paraster doederleini* Chesher can be divided into two groups: one having curved posterior petals (group II) and the other having straight posterior petals (group I). As shown in the above scattergrams the group I specimens, including the specimens of Carrie Bow Cay, have longer anterior petals than the specimens of group II.

TABLE 1.—A comparison of the dimensions of the two "groups" of specimens of *Paraster doederleini* Chesher

CHARACTER	MEAN PERCENT OF LENGTH		T-TEST OF SIGNIFICANCE OF DIFFERENCE
	Group I (Min-Max)	Group II (Min-Max)	
AH (height periproct)	14.9 (11.3-18.6)	12.3 (10.5-13.8)	03.5-.010
AP (length anterior petal)	35.2 (33.6-37.8)	24.8 (21.2-28.5)	09.7-.001*
APE (span anterior petal)	58.2 (54.8-62.2)	39.8 (35.7-44.1)	10.5-.001*
APW (width anterior petal)	11.8 (09.5-14.0)	9.1 (07.8-11.1)	04.3-.001
FF (apical to fasciole along ambulacra III)	52.7 (48.0-55.9)	44.2 (41.6-46.0)	08.1-.001
AW (width periproct)	9.7 (07.5-11.8)	8.2 (07.1-09.2)	03.2-.010
LF (apical to fasciole along interambulacra 4)	16.7 (14.1-18.5)	11.5 (10.7-13.1)	12.0-.001
LP (labrum to posterior test)	76.3 (71.4-82.0)	81.3 (79.1-83.3)	03.2-.010
ND (depth anterior notch)	4.6 (03.4-15.6)	2.7 (01.8-03.7)	02.8-.010*
NW (width anterior notch)	20.32 (15.2-25.1)	18.2 (17.0-18.1)	03.9-.001*
PA (péristome to anterior test)	19.9 (15.2-25.1)	17.5 (16.8-18.1)	05.1-.001*
PP (length posterior petal)	16.5 (13.7-19.5)	13.6 (12.1-15.0)	05.3-.001
PPE (span posterior petal)	26.1 (22.8-28.1)	17.9 (16.1-21.1)	09.6-.001
PPFL (length periproct fasciole)	203.4 (186.0-215.1)	159.5 (140.9-177.4)	07.0-.001*
PPW (width posterior petal)	9.0 (06.9-10.6)	6.95 (06.0-07.7)	05.5-.001
TW (width test)	96.3 (92.5-99.0)	94.1 (92.2-95.8)	02.3-.050
WIII (width ambulacra III)	15.6 (11.2-22.3)	9.4 (07.4-12.8)	06.1-.001

Group I -- Carrie Bow Cay specimens (25) plus Chesher's E11376, 8397C, and 8397D. All these specimens have straight posterior petals.

Group II -- Chesher's E11378, E11377, 8398, 8396B+, 8396B, and 8396A. All these specimens have curved posterior petals.

*Because of few specimens in Group II, variance so high as to indicate in f-test that t-test may not be valid. However, there is no overlap between means in Group I and II (min-max) and differences appear to be very significant — see scattergrams for AP and APE.

Colombian specimens were slightly different from the Floridian specimens and postulated that the "differences between the two populations are not significant and will probably prove to be part of a morphological cline when more specimens are found." However, two of Chesher's Floridian paratypes are similar to the Colombian specimens. This suggests that a morphological cline based on geographic separation probably does not occur between the Floridian and Colombian populations. The Carrie Bow Cay specimens are indistinguishable from the holotype and two of the paratypes but readily differentiated both statistically and by visual inspection from the Colombian specimens and two of the Floridian paratypes. The fact that no in-

termediates between these two groups are present either among Chesher's types or among the Carrie Bow Cay specimens and that the two have never been found living together suggests that these groups should probably be differentiated taxonomically. However, until we know more of the geographic distribution of the two groups and the variation within the "Colombian population" it seems best to postpone any taxonomic decision.

The two groups are easily distinguished visually by the straight posterior petals and longer anterior petals found in the Carrie Bow Cay specimens, the holotype, and paratypes USNM E11376, MCZ 8397c, and MCZ 8397d (these specimens henceforth are referred to as group 1). The specimens in group

TABLE 2.—*The dimensions of specimens of Paraster floridiensis (Kier and Grant), P. cf. P. floridiensis, and P. doederleini Chesher (all statistics except the total length are the percent of the total length)*

CHARACTER	<u>Paraster cf. P. floridiensis</u>		<u>P. floridiensis</u>	<u>Paraster floridiensis</u>		<u>P. doederleini</u>
	USNM E13741	USNM E13742	Chesher (1972)	MCZ 8494	MCZ 8495	(holotype)
TL (length)	16.8 mm	12.8 mm	11.60 mean	15.87 mean	16.03 mean	63.43
TW (width)	86.90	88.52	92.66	95.59	91.08	96.58
H (height)	75.00	71.88	75.24	77.95	73.61	70.73
WIII (width amb. III)	14.88	16.64	12.35	14.68	12.66	11.19
AP (length ant. petal)	39.88	34.61	38.52	40.14	39.74	33.84
APE (span ant. petals)	62.50	57.27	66.19	65.34	67.19	55.75
APW (width ant. petal)	13.09	11.41	—	12.60	13.10	9.83
PP (length post. petal)	20.83	17.42	17–24	19.09	19.78	17.08
PPE (span post. petals)	29.16	27.81	30.19	28.36	31.19	26.54
PPW (width post. petal)	10.11	8.83	—	9.45	10.42	7.88
AX (apical syst. to ant. end)	58.33	55.94	53.61	56.27	57.39	49.92
PG (post genital pores)	—	6.25	—	2.52(?)	1.56	3.63
ND (notch depth)	1.78	—	—	—	—	4.05
NW (notch width)	14.88	21.33	—	—	—	20.34
PPFL (length fasciole)	250.00	228.91	253.72	266.54	238.93	198.63
FF (apical syst. to fasc. along amb. III)	64.88	54.14	55.41	59.42	59.45	48.24
LF (apical syst. to fasc. along inter. 4)	20.23	16.41	19.21	17.64	18.72	17.34
PF (apical syst. to fasc. along inter. 5)	22.02	18.98	19.35	19.72	21.21	18.29
LAF (latero-anal fasc.)	136.90	145.31	152.46	165.72	128.95	179.19
AH (anus height)	20.83	19.22	20–28	21.87	22.46	13.24
AW (anus width)	16.66	15.31	—	15.75	18.72	7.51
PL (plastron length)	57.14	57.81	56.61	56.52	59.45	50.18
B (plastron width)	30.95	34.06	25.00	—	—	25.85
C (plastron width)	36.90	42.66	35.00	—	—	35.47
D (plastron width)	39.88	42.19	41.27	—	—	38.41
L (labrum length)	9.52	7.81	6.48	—	6.05	9.25
LP (ant. labrum to post. test)	74.44	72.89	64–75	labrum missing	72.55	82.03
PW (peristome width)	—	25.00	—	24.13	26.64	17.75
PH (peristome height)	—	9.61	—	—	9.36	4.26
PA (ant. peristome to ant. test)	21.42	18.44	21.00	24.58	23.52	15.24
APW/AP	32.82	32.90	35.82	31.39	32.96	29.05
PPW/PP	48.57	50.60	48.75	49.50	52.68	46.14
PP/AP	52.23	50.33	50.59	47.56	49.77	50.47
AW/AH	79.98	79.66	79.07	72.02	83.35	56.72
D/PL	69.79	72.98	72.88	—	—	76.54

11 (the Colombian paratypes and the Floridian paratypes, USNM E11378 and MCZ 8398) have flexuous posterior petals and much shorter anterior petals. These differences are readily apparent when one compares the photographs of specimens equivalent in size in both groups on Plate 7: figures 3 (group I) and 6 (group II).

Statistically, specimens in group I differ from group 11 in having longer and wider anterior and posterior paired petals with a greater span and more pore-pairs. They have a wider ambulacrum III, larger periproct, and a greater distance between the apical system and the peripetalous fasciole as measured along the center of ambulacrum III and interambulacrum 4. The peristome is more posterior; the anterior notch, deeper and wider; the peripetalous fasciole, longer; and the test, slightly wider. The statistics of these characters for the two groups together with the results of t-tests of the significance of the differences are presented on Table 1. The difference between the two groups in the span and length of the anterior petals is shown graphically in Figure 7.

Although the groups are easily differentiated, the taxonomic separation is probably not as great as might seem. Specimens of both groups have their fascioles crossing the same plates in each ambulacrum and interambulacrum, a feature which Chesher has proved to be of great significance.

Because Chesher's description and statistics are based on specimens of both groups, I am including a description and statistics of 25 specimens from a single population from Carrie Bow Cay and the measurements (Table 2) of the holotype.

MATERIAL.—Statistics from 25 specimens collected at same locality.

SIZE AND SHAPE.—Specimens 14.7–51.9 mm long, mean 35.49 mm, width 96.47 percent TL (SD 1.72, CV 1.8), height 73.78 percent TL (SD 3.10, CV 4.2); posterior truncated obliquely, dorsally overhanging so that periproct visible adorally; greatest width of test anterior at anterior series of interambulacra 1 and 4; greatest height posterior at interambulacrum 5 between posterior petals.

APICAL SYSTEM.—Posterior of center, distance from anterior margin 52.86 percent of TL (SD 2.39, CV 4.5); ethmolytic, tetrabasal (Figure 8B) with four genital pores, anterior pair about one-third diameter of posterior pair; posterior pair present on all specimens including smallest 14.7

mm long, anterior pair absent on smaller specimens 14.7 and 17.7 mm long, present on next larger specimen 20.2 mm long and all other specimens; 14 specimens with plate sutures of apical system visible, 13 tetrabasal, one specimen tribasal with genital 1 missing (Figure 8B), 10 specimens with genital 2 extending posteriorly joining ocular v and separating genital 4 from genital 2 (Figure 8B), one specimen with genital 3 extending posteriorly into interambulacrum 5 instead of genital 2.

AMBULACRA.—Anterior ambulacrum III in sunken furrow extending from apical system to peristome

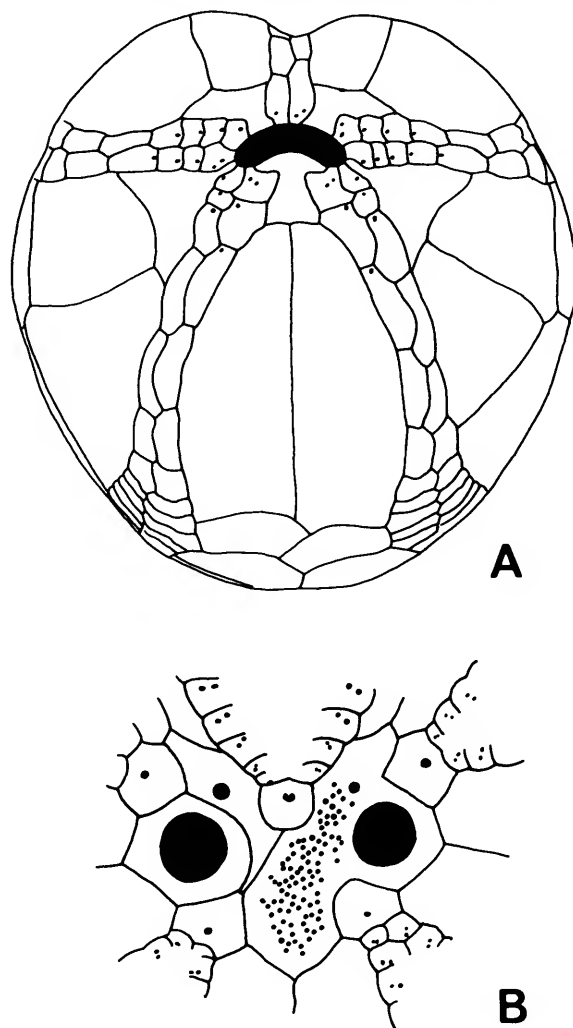


FIGURE 8.—*Paraster doederleini* Chesher: A, adorally view showing plate arrangement of USNM E113735, from Carrie Bow Cay, $\times 5$; B, apical system of same specimen, $\times 14$.

forming pronounced notch in front of test with depth 4.61 percent TL (SD 2.36, CV 51.1), width 20.23 TL (SD 2.15, CV 10.6), slightly sunken at edge of peristome; pore-pairs in single series, not conjugate, pronounced node separating pores of pair; pores situated parallel to plates but due to curvature of plates outer pore of pair slightly posterior to inner; greatest width of ambulacrum III 14.92 percent TL (SD 2.22, CV 13.9); peripetalous fasciole crosses ambulacrum III at distance from center of apical system equal to 52.96 percent TL (SD 1.64, CV 3.1); ambulacral plates beyond peripetalous fasciole with single pore in each plate.

Anterior petals (II and IV) slightly flexuous, length 35.36 percent TL (SD 1.03, CV 2.9), greatest width 12.01 percent TL (SD 0.98, CV 8.1), ends of anterior petals separated apart distance equal to 58.34 percent TL (SD 1.74, CV 3.0). Posterior petals (V, L) straight, short, length 16.60 percent TL (SD 1.58, CV 9.5), greatest width 9.19 percent TL (SD 0.61, CV 6.6), ends of petals separated by a distance equal to 26.30 percent TL (SD 1.11, CV 4.2).

INTERAMBULACRA.—In smaller specimen, 17.7 mm long, 10 plates in interambulacrum 3a, 8 in 4a, 13 in 5a; few plates added during growth with only 12 plates in interambulacrum 3a in specimen 30.5 mm long, 9 in interambulacrum 4a, 13 in 5a. Interambulacrum 2b and 3a separated from ocular III in specimen only 19.6 mm long indicating that production of new plates had ceased in these interambulacra (Kier, 1956).

PERISTOME.—Anterior, distance from anterior edge of peristome to anterior margin of test 19.87 percent TL (SD 1.39, CV 7.0); not sunken; width 16.66 percent TL (SD 1.74, CV 10.4), height 4.26 percent TL (SD 0.94, CV 15.2). Labrum well developed, short, length 11.26 percent TL (SD 1.22, CV 10.8), extending back to posterior portion of first adjoining ambulacral plate or anterior portion of second (Figure 8A); distance from anterior tip of labrum to posterior of test 76.05 percent TL (SD 2.13, CV 2.8); 33 or 34 oral tubefeet arising from single pores, on some larger specimen large ridge rising alongside pore or crossing pore dividing pore in two.

PLASTRON.—Length 47.58 percent TL (SD 1.98, CV 4.2), width at junction of second and third adjacent ambulacral plates 25.29 percent TL (SD 1.99, CV 7.9), width at junction of third and fourth adjacent ambulacral plates 36.09 percent TL (SD

1.70, CV 4.7), width at junction of fourth and fifth adjacent ambulacral plates 38.23 percent TL (SD 1.60, CV 4.2).

PERIPROCT.—Small, ovoid, height 14.91 percent TL (SD 1.78, CV 11.9), width 9.81 percent TL (SD 1.23, CV 12.5), situated near middle or slightly above midpoint on posterior.

FASCIOLAE.—Peripetalous fasciole curving slightly towards apical system in interambulacra 2, 3, more deeply in interambulacra 4 and 1; straight across interambulacrum 5; greatest width where passing around petals II and IV; distance from apical system to posterior portion 18.28 percent TL (SD 0.91, CV 5.0), to lateral portion (along center of interambulacrum 4) 16.87 percent TL (SD 0.86, CV 5.1); length of fasciole 203.42 percent TL (SD 6.17, CV 3.0); Lateroanal fasciole passes below anus, at distance from lower portion of anus slightly greater than height of anus; length of fasciole 170.45 percent TL (SD 4.31, CV 2.5).

See Chesher (1972:20) for plates on which fascioles occur.

PEDICELLARIAE.—Tridentate common, largest occurring near peristome with stalks 2 mm long, valves 1.2 mm long (Plate 7: figures 10, 11); rostrate (Plate 7: figures 12–14) less common with stalk 1.3 mm long, valves 0.75 mm long, seen on periproctal plates, in apical region near edge of petals; globiferous (Plate 7: figures 7–9) rare, with a circle of small spines surrounding the terminal opening.

ECOLOGY.—This species occurs in large numbers buried in mud fields west and south of Water Cay Range. The water depth is between 12 and 18 meters. These mud fields can be identified from the surface on a clear day by the azure-blue color of the water. The mud fields are white, with worm mounds and the algae *Penicillus* and *Udotea conglutinata* (Ellis and Solander). The echinoids live buried 20–100 mm below the surface. I could see no evidence of their presence at the surface. Their density varied from locality to locality but was greatest in the finer sediments, decreasing where the sediment contained some silt or sand. Maximum density was approximately one to two specimens every square meter. The echinoids are light yellowish tan with bright red tubefeet in the anterior ambulacrum (III) and orange tubefeet in the phylloides. They bury beneath the surface in approximately 15 minutes (Plate 8: figures 1–3). Three other spatangoids are present with them: *Brissoopsis*

elongata Mortensen, *Moira atropos* (Lamarck) and *Paraster* cf. *Paraster floridiensis* (Kier and Grant). *Paraster doederleini* occurs in far greater numbers than any of these species. In 20 minutes of collecting, 30 specimens were found of *P. doederleini*, six of *M. atropos*, one of *B. elongata*, and none of *P. cf. P. floridiensis*.

***Paraster* cf. *Paraster floridiensis* (Kier and Grant)**

PLATE 10: FIGURES 1-5, 8-11

Schizaster (Paraster) floridiensis Kier and Grant, 1965:50-54, fig. 15, pl. 13: figs. 4-6; pl. 14: figs. 1-9.—Kier, 1966:9.

Paraster floridiensis.—Chesher, 1966:1-19, figs. 1-6, tables 1-2; 1972a, tables 1, 2.

In 1973 we collected in the same mud field with *Paraster doederleini*, *Moira atropos*, and *Brissoopsis elongata*, one specimen of a small spatangoid very similar to *Paraster floridiensis*. When we returned to the same site in 1974, we were determined to find more specimens. After 11 dives and approximately 7 hours of searching, we located only one more. Because of the scarcity of the specimens, we thought that perhaps we were on the fringe of a larger population present in adjacent areas. Extensive searching within two to three miles of the site revealed no more specimens.

These specimens may be conspecific with *Paraster floridiensis*; but until more specimens are found, their reference to this species must be tentative. They may represent a new subspecies. They are similar in most of their dimensions (Table 2) to specimens from Florida referred to *P. floridiensis* by Kier and Grant, and Chesher. Their peripetalous fascioles and lateroanal fascioles also cross the same plates as in the Floridian specimens. They differ in that their tests are narrower, 86.90-88.52 percent of their total length as opposed to 91.08-95.59 percent of the total length in two Floridian specimens of approximately the same length (Chesher, 1972a:19, reports a mean of 92.66 for all the specimens he measured). The anterior paired petals in the Carrie Bow Cay specimens are straighter than in *P. floridiensis*. This difference is readily seen in a comparison of photographs (Plate 10) of the Carrie Bow Cay specimens and a specimen referred to *P. floridiensis* by Chesher (1966) of approximately the same size. The anterior petals in the Carrie Bow Cay specimens curve more an-

teriorly; whereas they curve more posteriorly in Chesher's specimen. Finally, the tridentate pedicellariae in the Carrie Bow Cay specimens (Plate 10: figures 10, 11) differ in having longer, better defined serrated heads than those figured by Chesher for *P. floridiensis*.

The Carrie Bow Cay specimens strongly resemble *P. rotundatus* Döderlein from the Galapagos. Their anterior petals are similar, not flexuous, as in *P. floridiensis*; but their tests are narrower and their anus larger. The tridentate pedicellariae in the Carrie Bow Cay specimens are intermediate in shape between those found in *P. floridiensis* and *P. rotundatus*, having their heads longer with better defined serrated heads than in *P. floridiensis* but shorter than in *P. rotundatus*.

Until more specimens have been found from Carrie Bow Cay, and of *P. rotundatus* from the Galapagos, it is impossible to know the significance of the differences between the Carrie Bow Cay specimens, *P. floridiensis* and *P. rotundatus*. At first glance I thought that the differences between the Carrie Bow Cay specimens and the Floridian specimens of *P. floridiensis* and the similarity shared by the Carrie Bow specimens and the Galapagos species suggested that the Carrie Bow Cay specimens were more similar to the Pacific species because of their nearer geographic location. However, a specimen of *P. floridiensis* recently collected by Dr. David Meyer from the San Blas Islands off the Republic of Panama (USNM E13753) is indistinguishable in the width of its test and flexuous petals from the Florida specimens, even though it occurs nearer to the Galapagos Islands than the Carrie Bow Cay specimens. Perhaps, as suggested by Chesher (1972b:149) the Pacific counterparts of the Atlantic species exist but remain to be found.

LOCALITY.—The two specimens were buried 10-15 mm beneath and surface at a depth of 15 m in mud fields west and south of Water Cay Range. Chesher (pers. comm., 1974) points out that his Floridian specimens were all found in coarse sand.

***Moira atropos* (Lamarck)**

PLATE 8: FIGURES 6-10

Spatangus atropos Lamarck, 1816:32. [For a synonymy, see Mortensen, 1951:329. Chesher, 1963, described the feeding mechanism; and Moore and Lopez, 1966, the ecology and productivity.]

This species lives in the same mud fields with *Paraster doederleini* Chesher, *P. cf. P. floridiensis* (Kier and Grant), and *Brissopsis elongata* Mortensen. They live buried 40–100 mm in the mud, and they can bury themselves (Plate 8: figures 8–10) beneath the surface in 12 minutes. They may bury deeper than 100 mm but, because of the mud's great density, we were not able to dig deeper with our hands in search of them.

This species has previously been reported from the coast of North Carolina south to the coast of Brazil from littoral depths to 145 meters.

Brissopsis elongata Mortensen

PLATE 9: FIGURES 1–6

Brissopsis elongata Mortensen, 1907:163, pl. 3: figs. 4, 14, 15, 19; pl. 4: figs. 1, 4, 13, 18; pl. 18: figs. 2, 15–17, 21, 28; pl. 19: figs. 12, 17. [See Chesher, 1968a:63, for synonymy, detailed description, and illustrations.]

This species occurs in mud fields with *Paraster doederleini* Chesher, *Paraster cf. P. floridiensis*, and *Moira atropos* (Lamarck). It is not common. We collected nine specimens, and it took approximately 20 minutes to find each one. They live buried 40–100 mm in the mud. Burrowing beneath the surface takes 10 minutes, faster than any of the other spatangoid species occurring with them. Observations of live *B. elongata*, in situ have never been published before, and photographs of it burying itself in its natural environment are on Plate 9: figures 4–6.

Brissopsis elongata has been previously reported from the South American coasts of Venezuela to Panama and from Puerto Rico at depths of 13–72 m (Chesher, 1968a:76).

Agassizia excentrica Agassiz

PLATE 9: FIGURES 8, 9

Agassizia excentrica Agassiz, 1869:276. [See Mortensen, 1951:345, for synonymy.]

One dead and denuded specimen was collected by Miss Annie Bowman in February 1974, on a beach on Carrie Bow Cay. This species is previously known from the West Indies (Cuba and the Florida Reef to Barbados) from depths of 45–900 meters (Mortensen, 1951:346).

Cassidulus cariboeorum Lamarck

PLATE 6: FIGURES 6–9

Cassidulus cariboeorum Lamarck, 1801:549. [For a synonymy see Mortensen, 1948a:205.]

Frederick Hotchkiss found six live specimens of this species while screening the coarse sand that lies in one meter of water 5–10 meters from the shore on the northeast side of Carrie Bow Cay. This discovery is particularly important because this species has never been seen before alive in situ. Nothing was known for certain of its living habits. The species was known to range from a depth of 46 cm (Kier, 1962:21) to 197 m (Agassiz, 1872:343). Although Mortensen (1948a:193, 209) reports that observations are lacking on living specimens, he predicted that it would be found living buried in coarse sand. As is so often the case with Mortensen's predictions, he was correct. After Hotchkiss discovered the specimens, he placed them in a glass vial with some of the coarse sand; and within 3–4 minutes they had buried out of sight. The specimens reached a maximum depth of 3.4 cm suggesting that this may be their normal depth of burial. Hotchkiss found only six specimens after hours of digging through square meters of sand; therefore, the species does not occur in large numbers. Two dead tests that were washed up on the beach on Carrie Bow Cay were found in April 1974 by Miss Annie Bowman; but I found no specimens in four weeks of diving in 1973 and 1974.

Hotchkiss reports that the specimens were white when alive but turned green when placed in formaldehyde.

Eucidaris tribuloides (Lamarck)

PLATE 11: FIGURES 4, 5

Cidarites tribuloides Lamarck, 1816:56. [For a synonymy, see Mortensen, 1928:400. The biology of this species has been described by McPherson, 1968.]

This echinoid lives both on the reef and in the lagoon. It lives in crevices in the coral in the following zones: reef crest, sand and rubble, patch reef, rubble and pavement, buttress, and spur and groove. It is not common in any of these environments. It occurs in great numbers in the lagoon, particularly east of Water Cay Range in *Thalassia* beds where the grass is especially luxurious and

the water depth is between 5 and 7 meters. Here the echinoid feeds on sponges and *Thalassia* and has a density of approximately one specimen per square meter. This distribution is not regular—commonly several specimens occur close together eating the same sponge.

Diadema antillarum Philippi

Cidaris antillarum Philippi, 1845:355. [For a synonymy, see Mortensen, 1940:269. For the biology of this species see Lewis, 1964, and Randall, Schroeder, and Starck, 1964. For illustrations, see Kier and Grant, 1965, pl. 2: figs. 4–7.]

This urchin occurs both on the reef and in the lagoon. It lives throughout the length of the transect in cavities in the coral or rock. It is most common in the Patch Reef Zone with a density of 6–7 per square meter. Rare at greater depths, no specimens were observed deeper than 40 meters. However, it has been reported elsewhere at far greater depths. Large herds of 20–40 specimens occur in profusion in the lagoon's *Thalassia* beds.

Arbacia punctulata (Lamarck)

PLATE 11: FIGURE 1

Echinus punctulatus Lamarck, 1816:47. [For synonymy, see Mortensen, 1935:573. For the biology of this species, see Harvey, 1956; Sharp and Gray, 1962; Kier and Grant, 1965:17; and Booloottian and Cantor, 1965.]

Only two specimens were found of this species. They both were living in the *Thalassia* beds east of Water Cay Range. Because this species does not cover itself, it is readily visible. In spite of this, a careful search for many days revealed no more specimens.

Echinometra viridis Agassiz

PLATE 11: FIGURE 3

Echinometra viridis Agassiz, 1863:22. [For synonymy, see Mortensen, 1943b:368. Kier and Grant, 1965, and McPherson, 1969, describe aspects of the biology of this species.]

This species is readily distinguished from *E. lucunter* by its blue-tipped spines. It is much more common, living in great numbers in niches in the coral, particularly in beds of *Agaricia* (leaf coral) in the Buttress Zone where approximately 10 speci-

mens are present per square meter. No specimens were found below a depth of 9 meters.

Echinometra lucunter (Linnaeus)

Echinus lucunter Linnaeus, 1758:665. [For a synonymy and illustrations, see Mortensen, 1943b:357. Kier and Grant, 1965, and McPherson, 1969, describe aspects of the biology of this species.]

This species is restricted to shallow water less than 3 meters deep, where it lives in crevices in the coral. It is more prevalent in a high energy environment and is absent from the lagoon.

Lytechinus variegatus (Lamarck)

PLATE 11: FIGURES 1, 2

Echinus variegatus Lamarck, 1816:48. [For a synonymy, see Mortensen, 1943a:437. Subsequent papers describing the biology and distribution are Moore, Jutare, Bauer, and Jones, 1963; Moore, 1965; Kier and Grant, 1965; Chesher, 1968b; and Serafy, 1973.]

This species is common to the lagoon in *Thalassia* beds where the water is more than 4 meters deep. It covers its test with blades of *Thalassia*. It is most common off Water Cay Range, where it occurs with *Clypeaster rosaceus* (Linnaeus), *Eucidaris tribuloides* (Lamarck), herds of *Diadema antillarum* Philippi, few *Tripneustes ventricosus* (Lamarck) and rare *Arbacia punctulata* (Lamarck). No specimens were found on the reef.

The vast majority of the specimens belong to the subspecies *L. variegatus variegatus*, but one specimen was collected of *L. variegatus carolinus* Agassiz. It is distinguished by its pink test and more numerous ambulacral and interambulacral plates. The subspecies has never been found this far south (see Serafy, 1973, fig. 1, for map of distribution of subspecies).

Lytechinus williamsi Chesher

Lytechinus williamsi Chesher, 1968b, figs. 1–4.

Frederick Hotchkiss collected one specimen of this species (subsequently identified by David L. Pawson) living in a crevice in coral on the outer fore-reef on the edge of the outer trough on the transect approximately 510 meters from its western end.

***Tripneustes ventricosus* (Lamarck)**

PLATE 12: FIGURE 3

Echinus ventricosus Lamarck, 1816:44. [For synonymy, see Mortensen, 1943a:490. Lewis, 1958; Moore, Jutare, Jones, McPherson, and Roper, 1963; Kier and Grant, 1965; and McPherson, 1965, describe aspects of the biology of this species.]

This echinoid was found both on the reef and in the lagoon, but it is rare in both environments. One large specimen was seen eating algae on the boulders in the Patch Reef Zone on the transect. One specimen was under the pier on the lagoon side of Carrie Bow Cay. Several other specimens were in the *Thalassia* beds east of Water Cay Range, where they were eating the *Thalassia*.

***Clypeaster rosaceus* (Linnaeus)**

PLATE 12: FIGURES 1, 2

Echinus rosaceus Linnaeus, 1758:665. [For a synonymy, see Mortensen, 1948b:40. See Kier and Grant, 1965:26, for description of living habits.]

This species was never found on the reef, but it is very common in the lagoon in *Thalassia* beds in water over 5 meters deep. It occurs with *Lytechinus variegatus*, *Meoma ventricosa*, *Eucidaris tribuloides*, *Tripneustes ventricosus*, and *Diadema antillarum*. It lives on top of the sediment or very slightly buried, but never with most of the thickness of its test under the surface of the seabottom. It holds blades of turtle grass or large shell fragments over its test. The echinoid grazes on *Thalassia* (many specimens were seen with blades of *Thalassia* between their teeth).

***Clypeaster subdepressus* (Gray)**

PLATE 6: FIGURE 4

Echinanthus subdepressus Gray, 1825:427. [For a synonymy,

see Mortensen, 1948b:112, and for a description of living habits, see Kier and Grant, 1965:28.]

Only one specimen (dead) was found of this species. It was located in water 30 meters deep in a sand trough on the reef just west of the dropoff on the transect. A thorough search was made in similar sand fields but no more specimens were found.

***Leodia sexiesperforata* (Leske)**

PLATE 9: FIGURE 7

Echinodiscus sexiesperforatus Leske, 1778:199. [For a synonymy, see Mortensen, 1948b:429. Goodbody, 1960, describes the feeding mechanism in this species and Kier and Grant, 1965:31, the living habits.]

This is the only sand dollar found off Carrie Bow Cay (many specimens of *Encope emarginata* (Leske) were found living off the mainland of Belize along the pier of the Pelican Beach Motel at Stann Creek). Only one specimen and many dead were found in sand fields at the western end of the transect in 2 to 3 meters of water. A careful search was made in sand fields throughout the Carrie Bow Cay region, but no more specimens were found. Local people report that a sand dollar used to be very common in the sand off the south end of South Water Cay, but none occur there now.

***Echinoneus cyclostomus* Leske**

PLATE 6: FIGURE 5

Echinoneus cyclostomus Leske, 1778:173. [For a synonymy, see Mortensen, 1948a:75.]

This species was found only on the reef, where it lives in coarse sand under coral rock.

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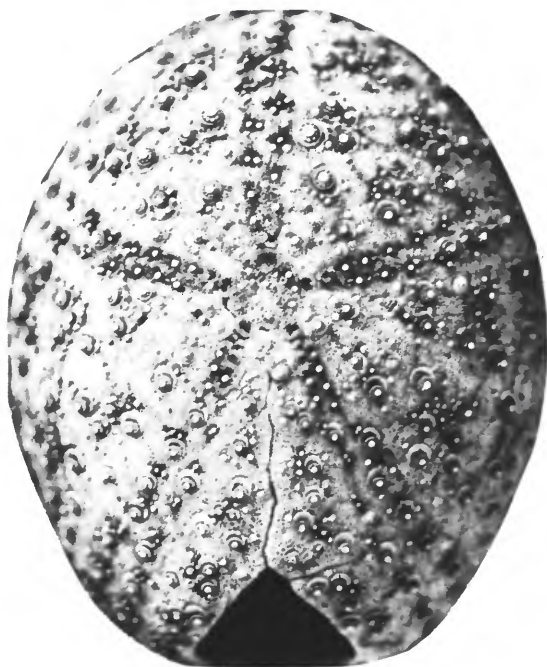
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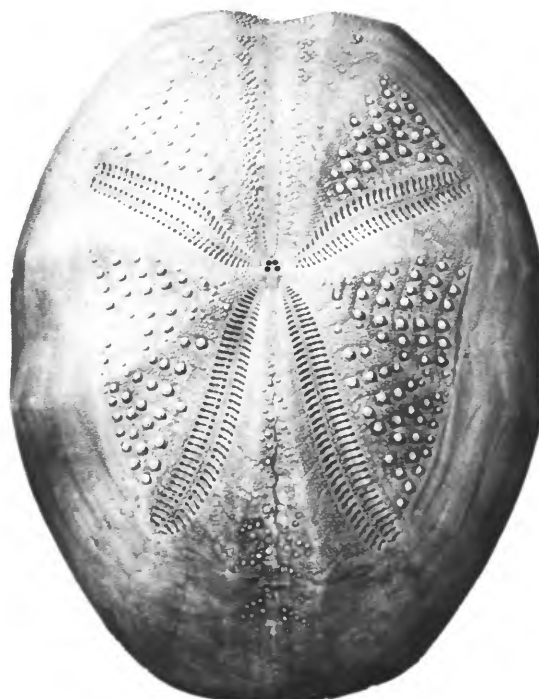
PLATES 1-12

PLATE 1*Plagiobrissus grandis* (Gmelin)

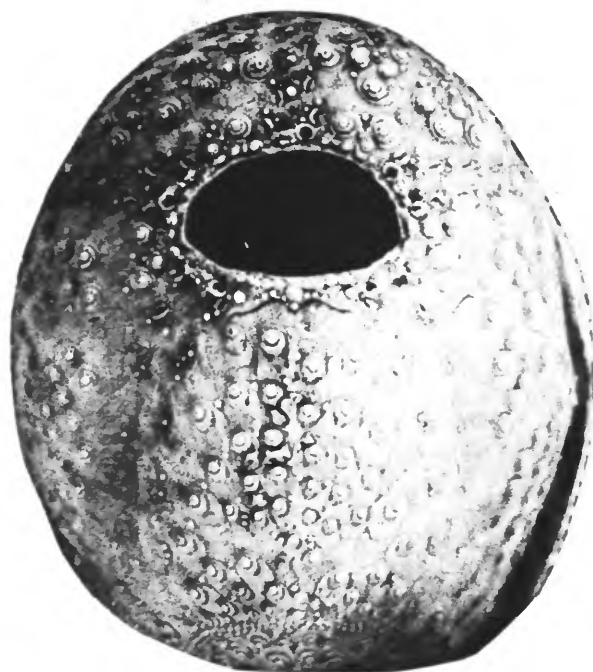
- 1, 3. Adapical, adoral view of specimen 6.9 mm long. Note immature features such as lack of petals, large apical system, large tubercles, slight development of peripetalous fasciole, adapical position of periproct, and large peristome. USNM E13730, $\times 13$.
- 2, 4. Adapical, adoral views of adult 150 mm long for comparison with immature specimen. USNM E13737, from sand field east of Molasses Reef, Florida Keys, depth of 30 meters, $\times \frac{2}{3}$.



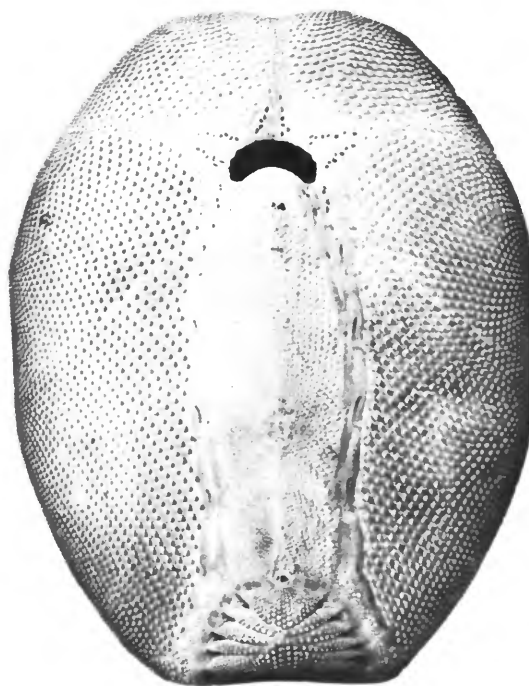
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PLATE 2*Plagiobrissus grandis* (Gmelin)

- 1, 2. Adoral view of specimen 20 mm long (USNM E13732), \times 5. Figure 2 shows the specimen photographed under xylene with the rod-like structures visible. Carrie Bow Cay.
3. More highly enlarged view of same specimen showing nature of rod-like structures, \times 16.
- 4, 5. Views of edge of plate showing extension of rods over suture. USNM E13736, \times 20. West of Molasses Reef, 10 meters depth, Florida Keys.
6. SEM photograph of ventral portion of interambulacrum 1 showing that rods are produced by thickening of the calcite with a corresponding reduction in size of the holes in calcite meshwork. USNM E13730, specimen 6.9 mm long, Carrie Bow Cay, \times 100.

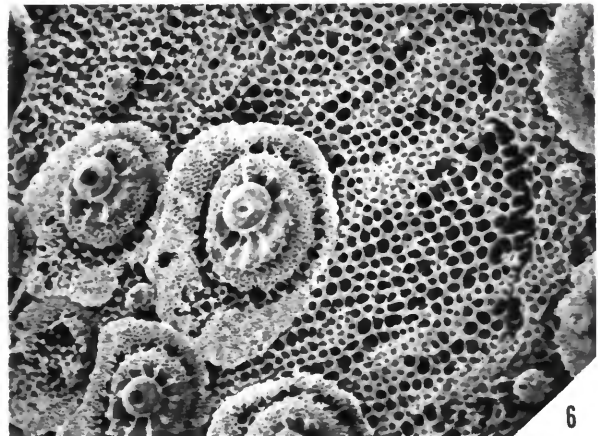
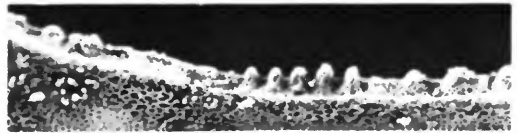
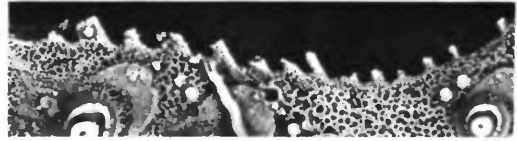
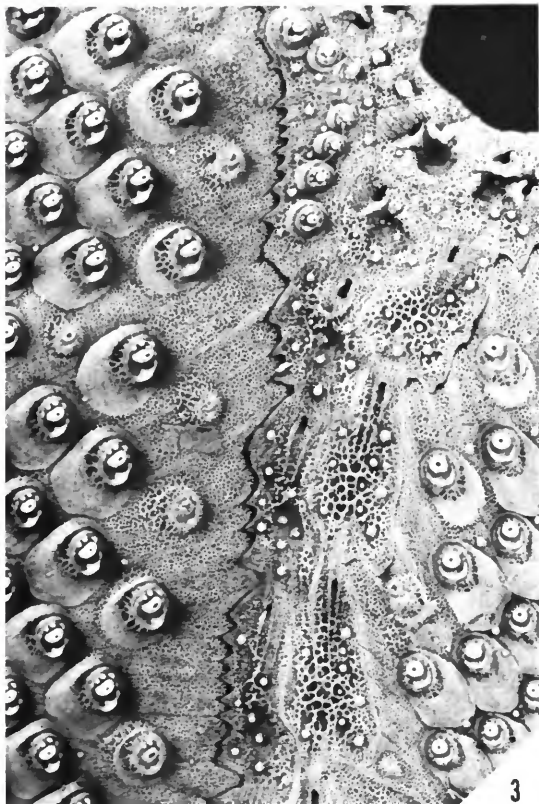
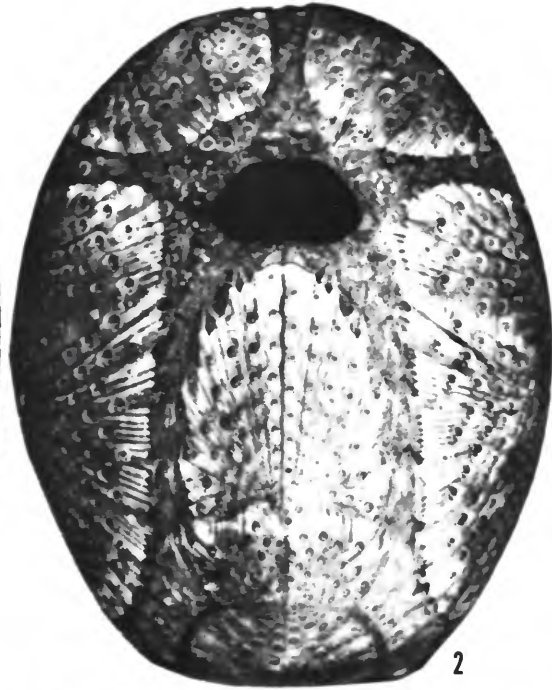
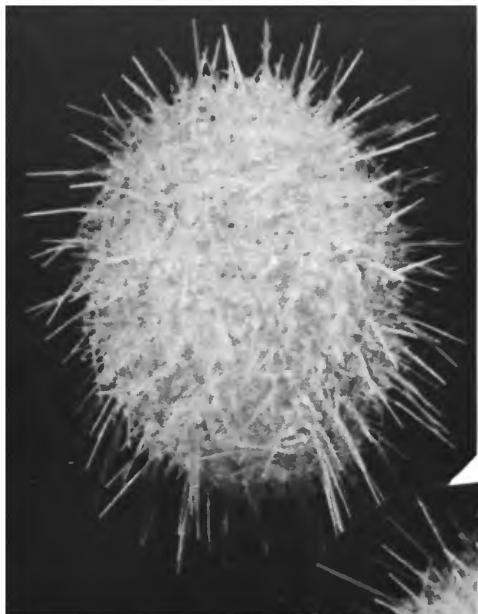
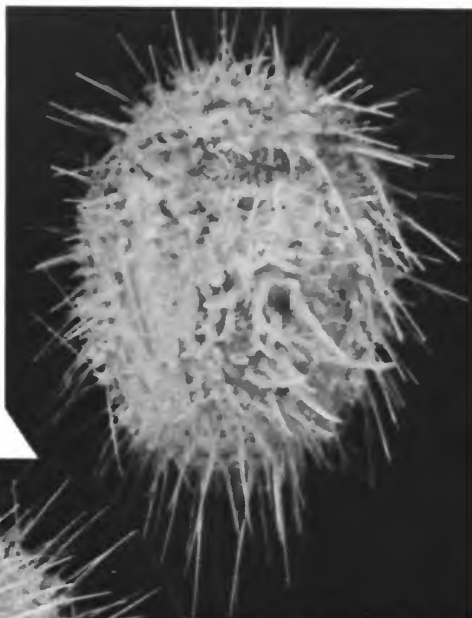


PLATE 3*Plagiobrissus grandis* (Gmelin)

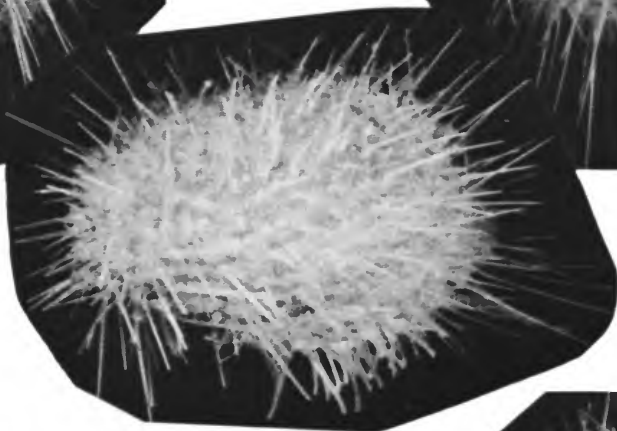
- 1, 2, 3. Adapical, adoral, left side of specimen 5.8 mm long, USNM E13731, $\times 10$.
4, 5. Adapical, adoral views of specimen 20 mm long, USNM E13732, $\times 4$.



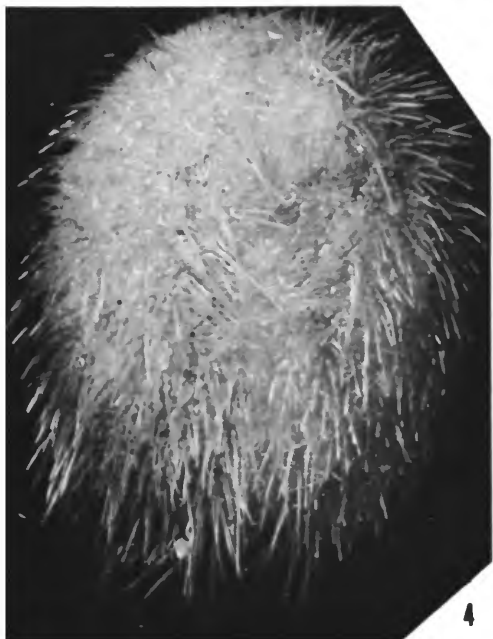
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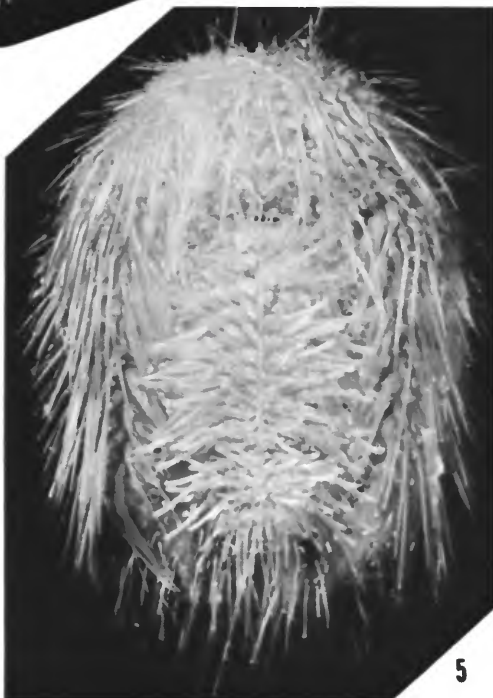
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PLATE 4*Plagiobrissus grandis* (Gmelin)

1. Ambulacrum III of immature specimen showing that the pores have begun to divide into two to form pore-pairs. The edge of the ocular plate is at the upper part of the photograph. USNM E13731, $\times 200$.
2. Petal II of same specimen showing that the pores have not yet begun to divide, $\times 200$.

Meoma ventricosa (Lamarck)

- 3, 4. Adapical, adoral views of specimen 17.5 mm long, USNM E13734, $\times 4.5$. A side view of this specimen is on Plate 6: figure 3.

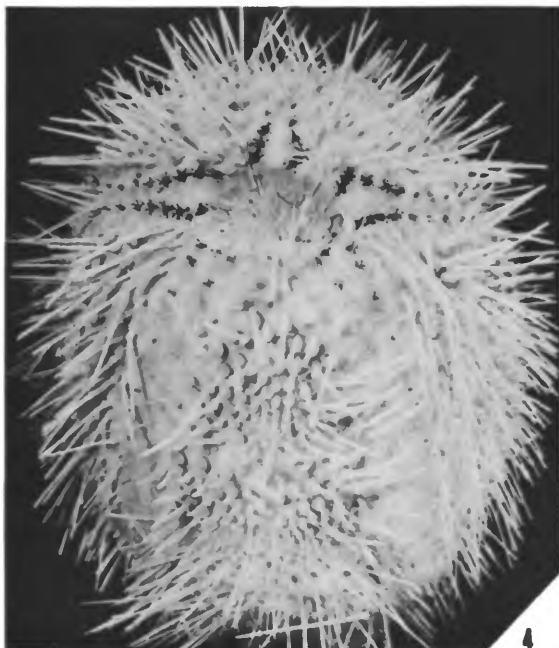
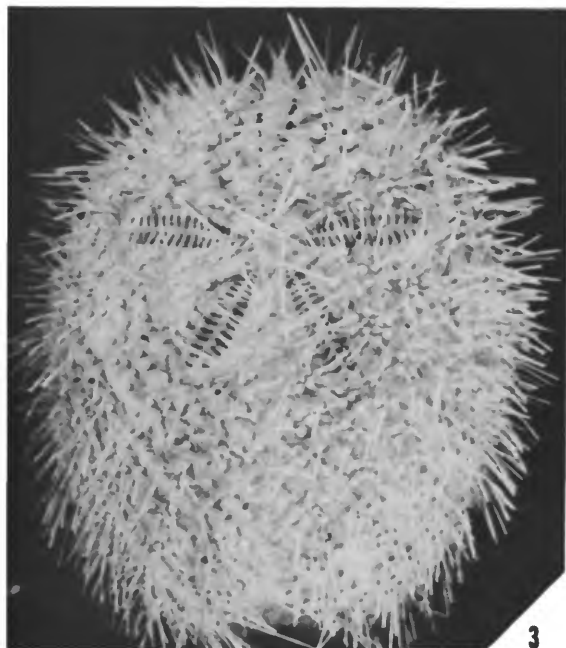
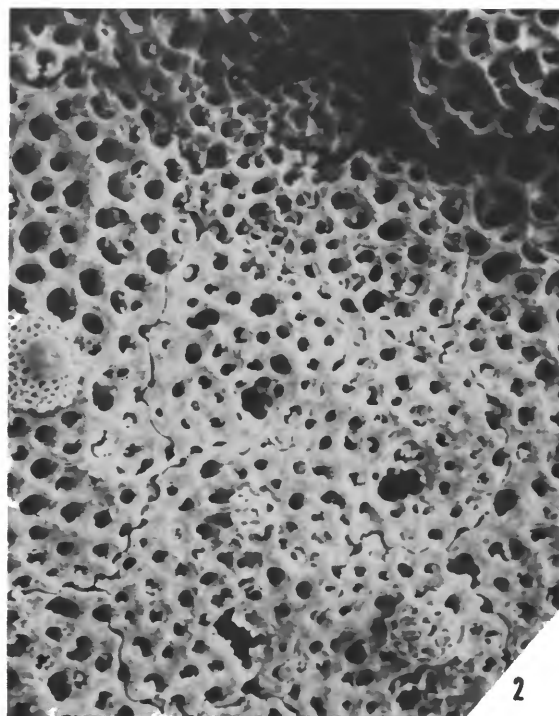
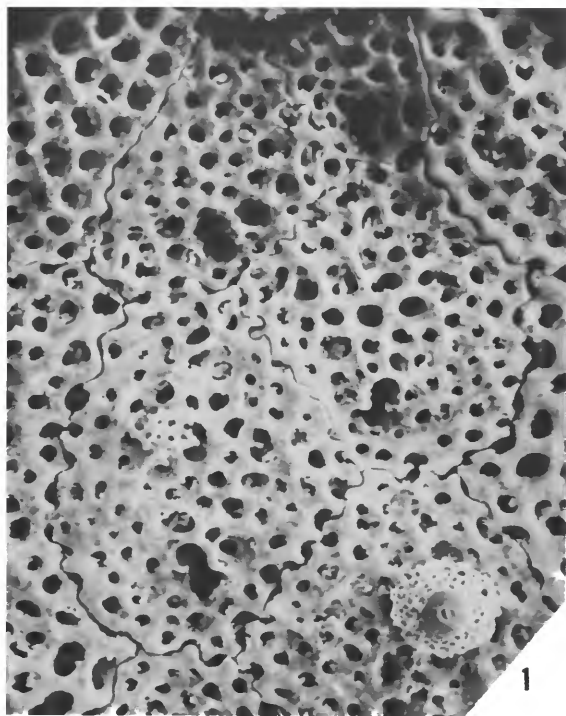


PLATE 5*Meoma ventricosa* (Lamarck)

- 1, 2, 3. Adapical, adoral, left side of specimen 5.8 mm long showing the relatively long spines and large black pedicellariae characteristic of an immature specimen. USNM E13733, $\times 15$.
4. Valve of globiferous pedicellaria from this specimen, $\times 400$.



PLATE 6*Meoma ventricosa* (Lamarck)

1. Adapical view of specimen 5.8 mm long showing the beginning of the development of the petals, the large apical system, and dorsal position of the periproct. USNM E13733, $\times 17$.
2. Adapical view of specimen 17.5 mm long. USNM E13734, $\times 5$.
3. Left side of same specimen before removal of spines, $\times 4.5$. Adapical and adoral views of this specimen with spines are on Plate 4: figures 3, 4.

Clypeaster subdepressus (Gray)

4. Adapical view of specimen USNM E13752, $\times 1/2$.

Echinoneus cyclostomus Leske

5. Adapical view of specimen USNM E13756, $\times 2$.

Cassidulus cariboeorum Lamarck

- 6, 7. Adapical and adoral views of USNM E13755, $\times 3$.
- 8, 9. Adapical and adoral views of specimen before removal of spines, $\times 3$.

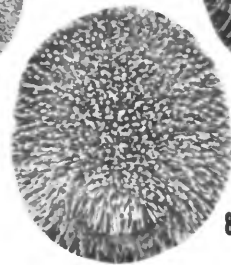
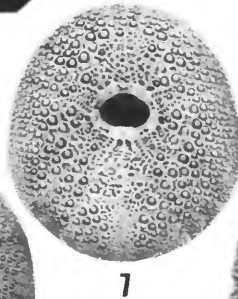
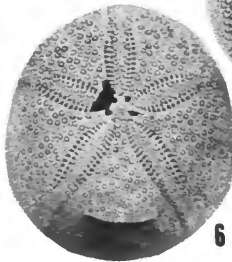
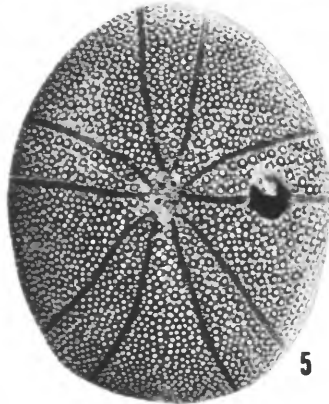
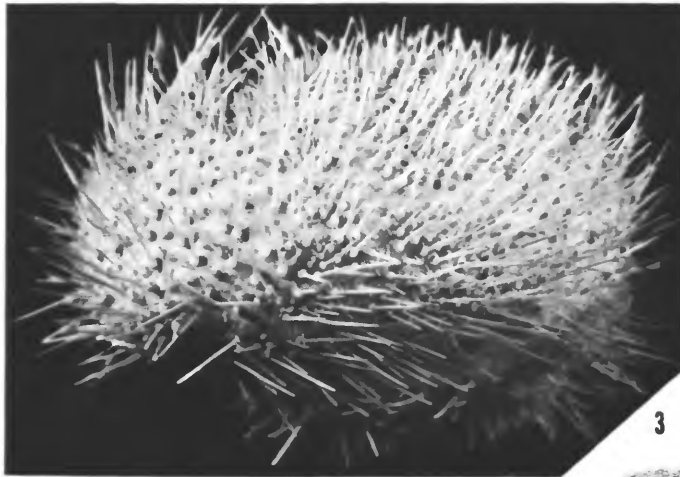
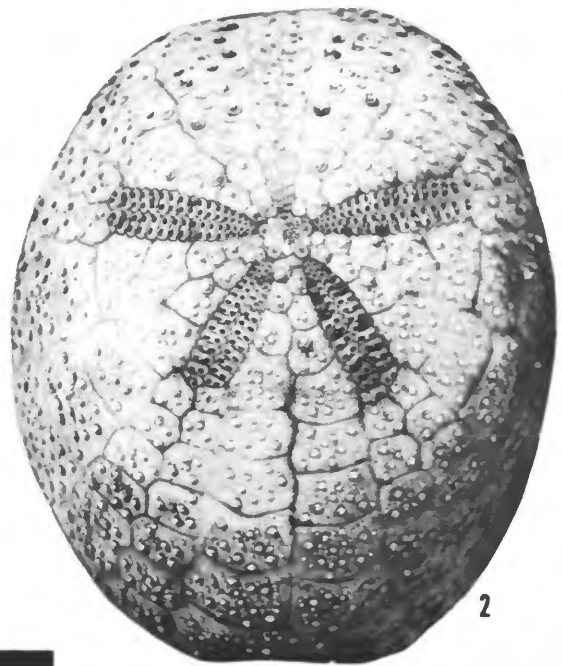
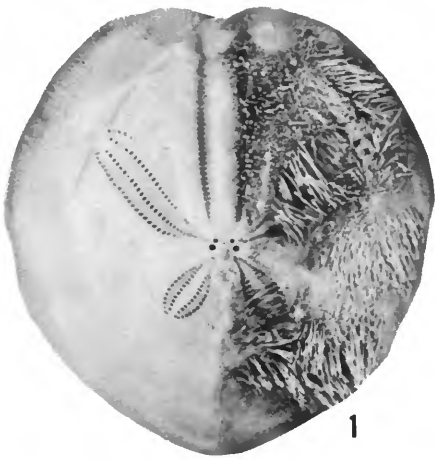
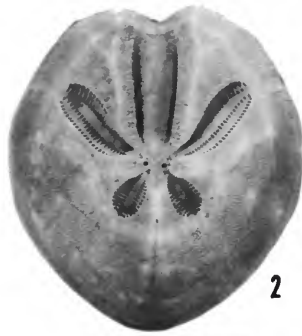


PLATE 7*Paraster doederleini* Chesher

1. Adapical view of the holotype USNM E11376 from White Shoals, Dry Tortugas, Florida, $\times 1$.
2. Adapical view of USNM E13743 from Carrie Bow Cay, $\times 1$.
3. Adapical view of USNM E13744 from Carrie Bow Cay, $\times 2$. Compare this specimen with a specimen from Colombia of similar size in figure 6, below. Note the larger petaloid area, more divergent posterior petals, and wider ambulacrum III in the Carrie Bow Cay specimen.
4. Adapical view of paratype USNM E11378 from Northwest Providence Channel, Bahama Islands, $\times 1$.
5. Adapical view of paratype USNM E11377 from off northern Colombia, $\times 1$.
6. Adapical view of paratype MCZ 8396 from off northern Colombia, $\times 2$.
7. Globiferous pedicellaria from Carrie Bow Cay specimen. USNM E13745, $\times 100$.
8. Valve of globiferous pedicellaria from Carrie Bow Cay specimen. USNM E13746, $\times 75$.
9. Enlarged view of teeth of same valve, $\times 375$.
10. Tridentate pedicellaria from Carrie Bow Cay specimen. USNM E13747, $\times 25$.
11. Valve of tridentate pedicellaria from Carrie Bow Cay specimen. USNM E13748, $\times 25$.
12. Rostrate pedicellaria from Carrie Bow Cay specimen. USNM E13749, $\times 50$.
13. Valve from rostrate pedicellaria from specimen from Carrie Bow Cay. USNM E13750, $\times 50$.
14. Enlarged view of teeth of same valve, $\times 375$.



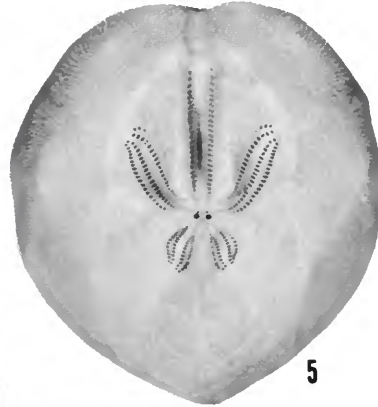
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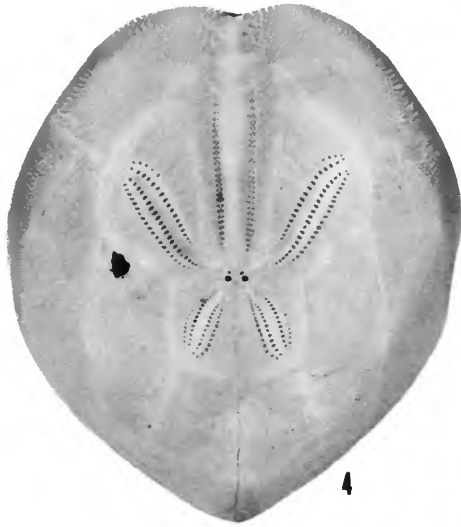
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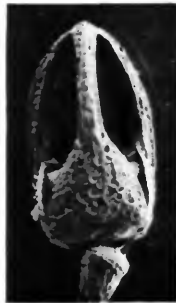
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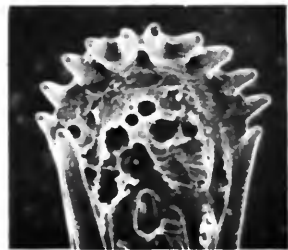
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PLATE 8*Paraster doederleini* Chesher

- 1, 2, 3. Photographs of specimen burrowing into mud at a depth of 15 meters. The pictures were taken over a period of 15 minutes. USNM E13740, 47 mm long.
- 4, 5. Adapical and adoral views of USNM E13760, $\times 1$.

Moira atropos (Lamarck)

- 6, 7. Adapical and adoral views of USNM E13759, $\times 1$.
- 8, 9, 10. Burying sequence at same site as for *P. doederleini* above. The pictures were taken over a period of 15 minutes. USNM E13738, 42 mm long.



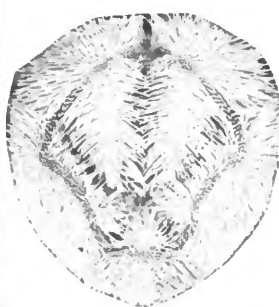
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PLATE 9*Brissopsis elongata* Mortensen

- 1, 2, 3. Adapical, adoral and right side of USNM E13757, $\times 1$.
4, 5, 6. Burying sequence of USNM E13739 at a depth of 15 meters. Pictures taken over a period of 10 minutes. Specimen 58 mm long.

Leodia sexiesperforata (Leske)

7. Adapical view of USNM E13758, $\times \frac{1}{2}$.

Agassizia excentrica Agassiz

- 8, 9. Adapical and right side of USNM E13754, $\times 2$.

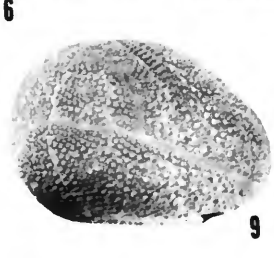
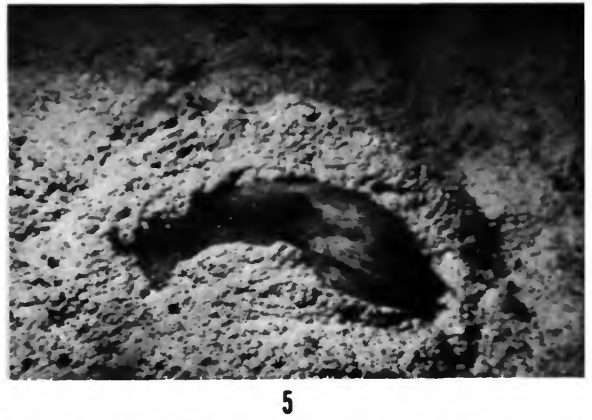
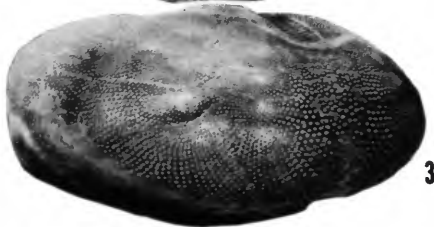
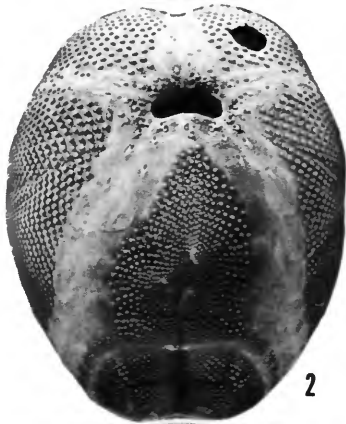


PLATE 10*Paraster cf. Paraster floridiensis* (Kier and Grant)

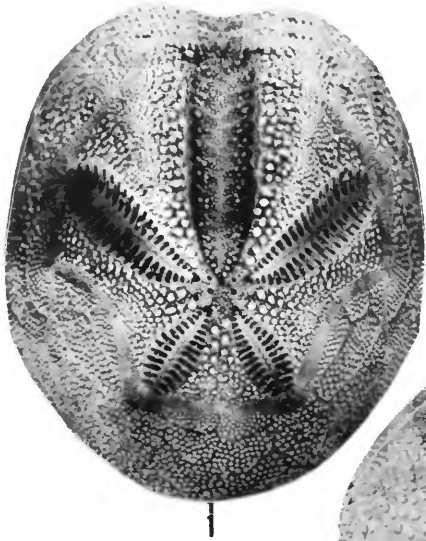
- 1, 2, 3. Adapical left side and adoral views of USNM E13741, $\times 4$.
- 4, 5. Adapical and adoral views of USNM E13742, $\times 4$.

Paraster floridiensis (Kier and Grant)

6. Adapical view of MCZ 8495 from the Florida Keys, $\times 4$.
7. Adapical view of MCZ 8494 from the Florida Keys, $\times 4$.

Paraster cf. Paraster floridiensis (Kier and Grant)

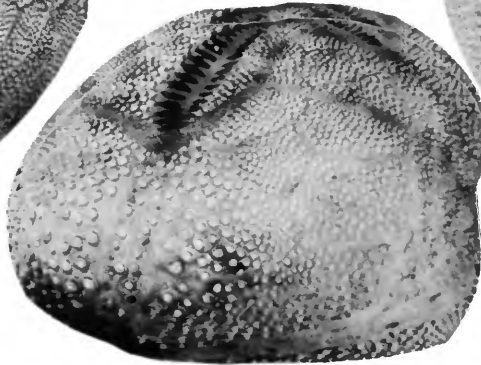
8. Globiferous pedicellaria from USNM E13742, $\times 175$.
9. Valve of globiferous pedicellaria from USNM E13742, $\times 175$.
10. Tridentate pedicellaria from USNM E13742, $\times 90$.
11. Valve of tridentate pedicellaria from USNM E13742, $\times 100$.



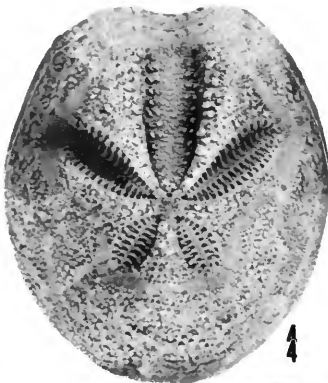
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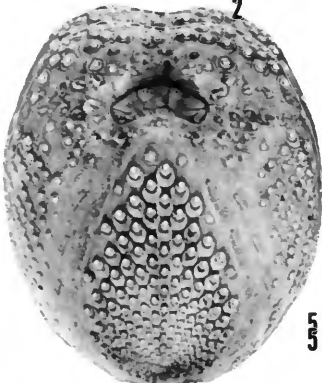
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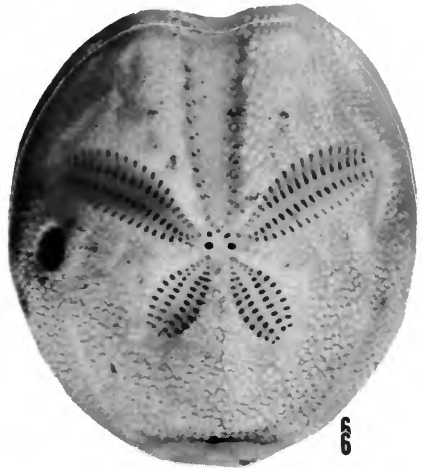
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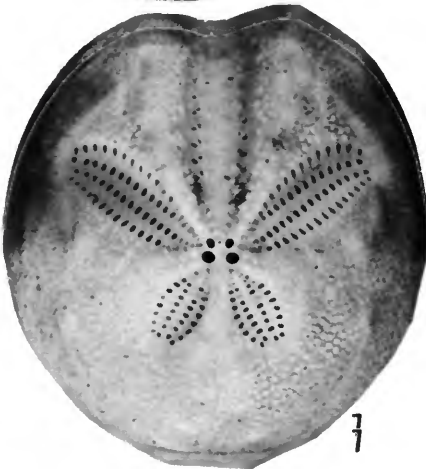
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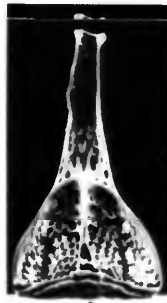
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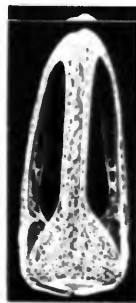
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PLATE 11

Lytechinus variegatus variegatus (Lamarck) and *Arbacia punctulata* Gray

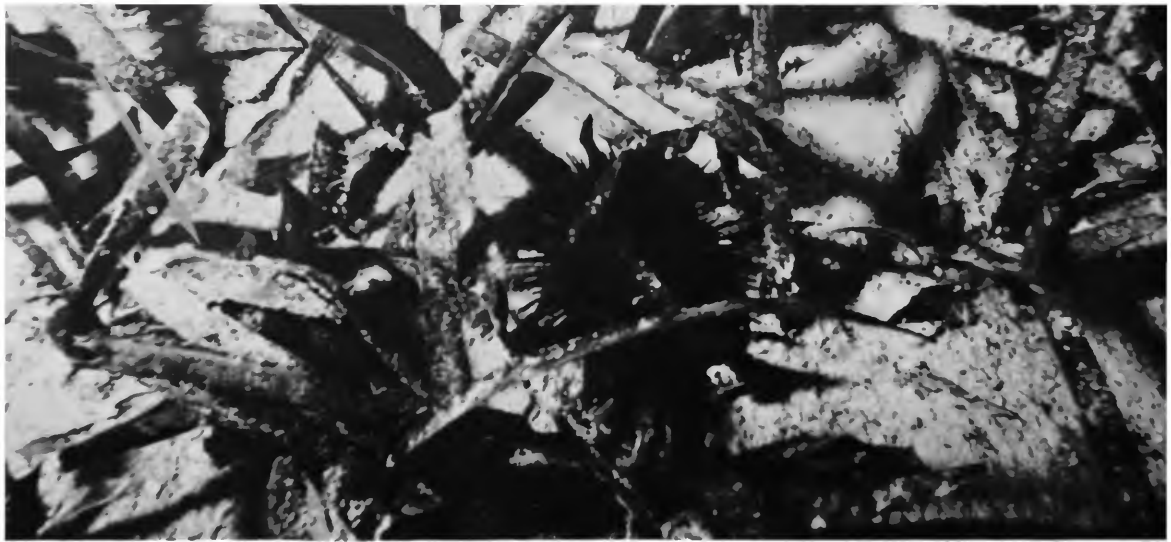
1. The individual on the left (indicated by arrow is *L. variegatus variegatus*. It is commonly found almost completely covered with blades of *Thalassia*. The specimen on the right eating *Thalassia* is *A. punctulata*. Photographed in water 3 meters deep.
2. *Lytechinus variegatus variegatus* browsing on *Thalassia*.

Echinometra viridis Agassiz

3. An individual in one meter of water living in a crevice in coral.

Eucidaris tribuloides (Lamarck)

4. Eating *Thalassia* in water 4 meters deep.
5. Feeding on a sponge.



1

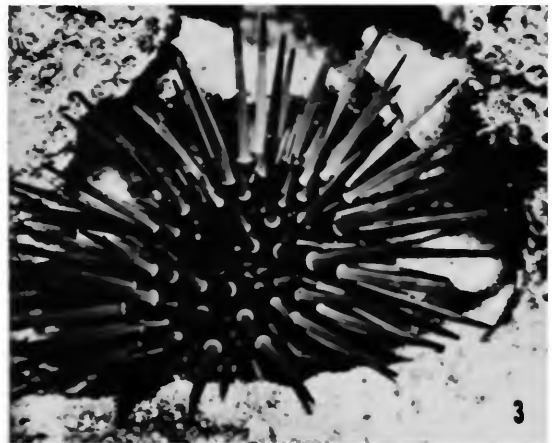


PLATE 12*Clypeaster rosaceus* (Linnaeus)

1. Three individuals (indicated by arrows) covered with blades of *Thalassia*. Photographed in water 4 meters deep.
2. Individual holding over its test blades of *Thalassia* and the dead test of a *Lytechinus variegatus variegatus* (Lamarck).

Tripneustes ventricosus (Lamarck)

3. Individual feeding on *Thalassia* in water 3 meters deep.



1



2



3

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