PALEONTOLOGICAL INSTITUTE

THE UNIVERSITY OF KANSAS
PALEONTOLOGICAL CONTRIBUTIONS
Serial Number 44

ECOLOGY

ARTICLE 1

Plates 1-90, Figures 1-17, 1-2, Plates 1-21

ECOLOGY OF RHIZOPODEA AND OSTRACODA OF SOUTHERN PAMLICO SOUND REGION, NORTH CAROLINA

STUART GROSSMAN and RICHARD H. BENSON

PART 1

LIVING AND SUBFOSSIL RHIZOPOD AND OSTRACODE POPULATIONS

STUART GROSSMAN

PART 2

HISTORY AND MICROFAUNA OF SOUTHERN "OUTER BANKS" AND OFFSHORE REGION

RICHARD H. BENSON

THE UNIVERSITY OF KANSAS PUBLICATIONS

OCTOBER 18, 1967

FOREWORD

RAYMOND C. MOORE

The microfaunal investigation of the southern Pamlico Sound region reported in these articles by GROSSMAN and BENSON was intended originally to be a joint study, part of which would be organized for submittal by GROSSMAN to the University of Kansas as a doctoral dissertation. The field work was done as planned with support of a National Science Foundation grant which also aided laboratory studies by GROSSMAN and preparation of his report. The research project was proposed by BENSON, who also directed the field program, guided the general method of approach to the study, and supervised writing of the doctoral thesis. This was completed in 1961.

Subsequently, additional field work concerned with the depositional history and microfossils of the "Outer Banks" and offshore region was undertaken by BENSON. This has led to a separate paper by him which is published as Part 2 of this article.

Publication of a joint paper by GROSSMAN and BENSON was planned originally and plates entitled "Rhizopoda and Ostracoda, Pamlico Sound" were printed in 1962. Because of other commitments of both authors the text was not completed until later.

Under urging by me, GROSSMAN in 1964, then in employ of the Esso Production Research Company, undertook the task of reviewing and revising his typescript. This was supervised by Dr. R. M. JEFFORDS of the same company, who contributed highly valued editorial aid. Ostracode identifications were discussed with Prof. H. V. HOWE of Louisiana State University and rhizopod species were checked by several Esso paleontologists. The completed revision was submitted to me in July 1965. With only minor alterations it was very soon made ready for setting in type but held in files awaiting the submittal of a companion paper by BENSON. This typescript and two accompanying illustrations reached me in September, 1966 and publication could proceed. At once it was sent to press.

PART 1

THE UNIVERSITY OF KANSAS PALEONTOLOGICAL CONTRIBUTIONS
Serial Number 44—Ecology, Article 1, Pages 1-90, Figures 1-17, 1-2, Plates 1-21

ARTICLE 1

ECOLOGY OF RHIZOPODEA AND OSTRACODA OF SOUTHERN PAMLICO SOUND REGION, NORTH CAROLINA

STUART GROSSMAN and RICHARD H. BENSON
[Esso Production Research Company]

PART 1

LIVING AND SUBFOSSIL RHIZOPOD AND OSTRACODE POPULATIONS

STUART GROSSMAN
[Esso Production Research Company]

CONTENTS

	PAGE
ABSTRACT	7
INTRODUCTION	7
Previous Studies	8
Description of Study Area	8
Field Methods	10
Laboratory Work	10
Acknowledgments	12
ECOLOGY OF RHIZOPODEA AND OSTRACODA	12
Environmental Factors	12
Salinity	12
Temperature	14
Currents	14
Substratum	17
Turbidity	18
Depth	18
Influence of Environmental Factors on Distribution and Abundance of Rhizopodea and Ostracoda	18
Temperature	18
Salinity	19
Hydrogen-ion Concentration	19
Substratum	20
Depth	20
Turbidity	20
Plants	20
Currents and Waves	21
Distribution of Fauna	21
RHIZOPOD AND OSTRACODE BIOFACIES	21
Estuarine Biofacies	36
Open-sound Biofacies	36
Tidal-delta Biofacies	36
Sound-delta Subfacies	36
Marine-delta Subfacies	39
Salt-water Lagoon Biofacies	39
Salt-marsh Biofacies	39
COMPARISON OF FAUNAL ENVIRONMENTS IN GULF COAST AND SOUTHERN PAMLICO SOUND REGION	40
Geologic Ranges and Stratigraphic Distribution	40
Geologic Ranges of Foraminifera	40
Geologic Ranges of Ostracoda	42
Stratigraphic Distribution	42
Comparison of Cores	42
Summary and Conclusions	44
SYSTEMATIC PALEONTOLOGY	46
General	46
Order Arcellinda Kent, 1888	46
Superfamily Arcellacea Ehrenberg, 1843	46
Family Difflugiidae Wallich, 1864	46
Genus *Difflugia* Leclerc, 1815	46
Order Foraminifera Zborewski, 1834	46
Superfamily Lituolacea Lamarck, 1809	46
Family Rzehakinidae Cushman, 1933	46
Genus *Miliammina* Heron-Allen & Earland, 1930	46
M. fusca (Brady), 1870	46
Family Lituolidae Lamarck, 1809	47
Subfamily Haplophragmoidinae Maync, 1952	47
Genus *Haplophragmoides* Cushman, 1910	47
H. manilaensis Andersen, 1953	47
H. wilberti Andersen, 1953	47
Genus *Ammoastuta* Cushman & Brönnimann, 1948	47
A. inepta (Cushman & McCulloch), 1939	47
Genus *Ammobaculites* Cushman, 1910	48
A. pamlicoensis Grossman, n. sp.	48
A. crassus Warren, 1957	48
A. dilitatus Cushman & Brönnimann, 1948	48
A. exilis Cushman & Brönnimann, 1948	49
A. neusensis Grossman, n. sp.	49

	PAGE
Genus *Ammotium* Loeblich & Tappan, 1953	49
A. salsum Cushman & Brönnimann, 1948	49
Family Trochamminidae Schwager, 1877	50
Genus *Tiphotrocha* Saunders, 1957	50
T. comprimata (Cushman & Brönnimann), 1948	50
Genus *Trochammina* Parker & Jones, 1859	50
T. inflata (Montagu), 1808	50
T. macrescens Brady, 1870	50
Genus *Arenoparella* Andersen, 1951	50
A. mexicana (Kornfeld), 1931	50
Superfamily Miliolacea Ehrenberg, 1839	51
Family Nubeculariidae Jones, 1875	51
Subfamily Spiroloculininae Wiesner, 1931	51
Genus *Spiroloculina* d'Orbigny, 1826	51
S. planulata (Lamarck), 1804	51
Family Miliolidae Ehrenberg, 1839	51
Subfamily Quinqueloculininae Cushman, 1917	51
Genus *Quinqueloculina* d'Orbigny, 1826	51
Q. bicornis (Walker & Jacob), 1798	51
Q. compta Cushman, 1947	51
Q. jugosa Cushman, 1944	51
Q. lamarckiana d'Orbigny, 1839	52
Q. microcostata Natland, 1938	52
Q. poeyana d'Orbigny, 1839	52
Q. seminula (Linné), 1758	53
Q. triloculiniforma McLean, 1956	53
Q. sp.	53
Genus *Triloculina* d'Orbigny, 1826	54
T. oblonga (Montagu), 1803	54
T. rotunda d'Orbigny, 1826	54
T. trigonula (Lamarck), 1804	54
Family Soritidae Ehrenberg, 1839	54
Subfamily Peneroplinae Schultze, 1854	54
Genus *Peneroplis* Montfort, 1808	54
P. proteus d'Orbigny, 1839	54
Superfamily Asteriginacea d'Orbigny, 1839	55
Family Discorbidae Cushman, 1927	55
Subfamily Discorbinae Cushman, 1927	55
Genus *Rosalina* d'Orbigny, 1826	55
R. columbiensis (Cushman), 1925	55
R. floridana (Cushman), 1922	55
Subfamily Eponidinae Hofker, 1951	56
Genus *Poroeponides* Cushman, 1944	56
P. lateralis (Terquem), 1878	56
Superfamily Rotaliacea Ehrenberg, 1839	56
Family Rotaliidae Ehrenberg, 1839	56
Subfamily Rotaliinae Ehrenberg, 1839	56
Genus *Ammonia* Brünnich, 1772	56
A. limbatobeccarii (McLean), 1956	56
A. sobrina (Shupack), 1934	56
A. tepida (Cushman), 1926	56
Family Elphidiidae Galloway, 1933	57
Genus *Protelphidium* Haynes, 1956	57
P. orbiculare (Brady), 1881	57
P. tisburyense (Butcher), 1948	57
P. sp.	57
Genus *Elphidium* Montfort, 1808	57
E. articulatum (d'Orbigny), 1839	57
E. brooklynense Shupack, 1934	58
E. clavatum Cushman, 1930	58
E. discoidale (d'Orbigny), 1839	58
E. gunteri Cole, 1931	59
E. incertum (Williamson), 1858	59
E. galvestonense Kornfeld, 1931	60
E. subarcticum Cushman, 1944	60
E. tumidum Natland, 1938	60
Superfamily Globigerinacea Carpenter, Parker, & Jones, 1862	61
Family Globigerinidae Carpenter, Parker, & Jones, 1862	61
Subfamily Globigerininae Carpenter, Parker, & Jones, 1862	61
Genus *Globigerina* d'Orbigny, 1826	61
G. bulloides d'Orbigny, 1826	61
Superfamily Cassidulinacea d'Orbigny, 1839	61
Family Nonionidae Schultze, 1854	61
Subfamily Nonioninae Schultze, 1854	61
Genus *Pseudononion* Asano, 1936	61
P. atlanticus (Cushman), 1947	61
Family Cibicididae Cushman, 1927	61
Subfamily Cibicidinae Cushman, 1927	61
Genus *Cibicides* Montfort, 1808	61
C. sp. cf. *lobatulus* (Walker & Jacob), 1798	61
Genus *Hanzawaia* Asano, 1944	62
H. concentrica (Cushman), 1918	62
H. sp. cf. *H. strattoni* (Applin), 1925	62
Genus *Planulina* d'Orbigny, 1826	62
P. mera Cushman, 1944	62
Subclass Ostracoda Latreille, 1806	63
Order Podocopida Müller, 1894	63
Suborder Podocopina Sars, 1866	63
Superfamily Cypridacea Baird, 1845	63
Family Cyprididae Baird, 1845	63
Subfamily Cypridopsinae Kaufmann, 1900	63
Genus *Cypridopsis* Brady, 1867	63
C. vidua (O. F. Müller), 1776	63
Family Cyclocyprididae Kaufmann, 1900	63
Genus *Cypria* Zenker, 1854	63
C. ophthalmica (Jurine), 1820	63
Superfamily Cytheracea Baird, 1850	63
Family Cytherettidae Triebel, 1952	63
Genus *Cytheretta* Müller, 1894	63
C. sp. aff. *C. sahni* Puri, 1952	63
Family Cytherideidae Sars, 1925	64
Subfamily Cytherideinae Sars, 1923	64
Genus *Cyprideis* Jones, 1856	64
C. sp. cf. *C. torosa* (Jones), 1850	64
C. sp.	64
Genus *Haplocytheridea* Stephenson, 1936	64a
H. setipunctata (Brady), 1869	64a
H. bradyi (Stephenson), 1938	64a
H. sp.	65
Genus *Perissocytheridea* Stephenson, 1938	65
P. sp.	65
Subfamily Neocytherideidinae Puri, 1957	66
Genus *Cushmanidea* Blake, 1933	66
C. echolsae (Malkin), 1953	66
C. seminuda (Cushman), 1906	66
C. ulrichi (Howe & Johnson), 1935	67
C. sp.	67
Genus *Hulingsina* Puri, 1958	68
H. ashermani (Ulrich & Bassler), 1904	68
H. sandersi Puri, 1958	68

	PAGE
Family Cytheruridae G. W. Müller, 1894	68
Genus *Cytherura* Sars, 1866	68
C.? corensis Grossman, n. sp.	68
C. elongata Edwards, 1944	69
C. forulata Edwards, 1944	69
C. johnsoni Mincher, 1941	70
C. sp.	70
Genus *Paracytheridea* Müller, 1894	70
P. sp. cf. *P. vandenboldi* Puri, 1953	70
Family Hemicytheridae Puri, 1953	71
Genus *Hemicythere* Sars, 1925	71
H. laevicula Edwards, 1944	71
H.? sp.	71
Genus *Aurila* Pokorný, 1955	71
A. conradi littorala Grossman, n. subsp.	71
Family Leguminocytherididae Howe, 1961	71
Genus *Acuticythereis* Edwards, 1944	71
A. laevissima Edwards, 1944	71
A. nelsonensis Grossman, n. sp.	72
A. multipunctata parva Edwards, 1944	72
Genus *Basslerites* Howe, 1937	73
B. giganticus Edwards, 1944	73
B. tenmilecreekensis Puri, 1953	73
Genus *Leguminocythereis* Howe & Law, 1936	73
L. whitei Swain, 1951	73
L. sp.	74
Family Loxoconchidae Sars, 1925	74
Genus *Loxoconcha* Sars, 1866	74
L. matagordensis Swain, 1955	74
L. purisubrhomboidea (Edwards), 1944	74
L. reticularis Edwards, 1944	74
Genus *Cytheromorpha* Hirschman, 1909	75
C. pascagoulaensis Mincher, 1941	75
C. warneri Howe & Spurgeon, 1935	75
Family Paradoxostomatidae Brady & Norman, 1889	75
Subfamily Cytheromatinae Elofson, 1939	75
Genus *Pellucistoma* Coryell & Fields, 1937	75
P. magniventra Edwards, 1944	75
Family Prognocytheridae Sylvester-Bradley, 1948	76
Subfamily Prognocytherinae Sylvester-Bradley, 1948	76
Genus *Neolophocythere* Grossman, n. gen.	76
N. subquadrata Grossman, n. sp.	76
Family Trachyleberididae Sylvester-Bradley, 1948	76
Genus *Actinocythereis* Puri, 1953	76
A. exanthemata exanthemata (Ulrich & Bassler), 1904	76
Genus *Puriana* Coryell & Fields, 1937	77
P. mesacostalis (Edwards), 1944	77
P. rugipunctata (Ulrich & Bassler), 1904	77
P. sp.	77
REFERENCES	78

ILLUSTRATIONS

PLATE		FACING PAGE
1.	*Ammobaculites* and *Difflugia*	48
2.	*Ammotium, Miliammina, Haplophragmoides, Amoastuta, Quinqueloculina*	49
3.	*Quinqueloculina*	52
4.	*Quinqueloculina, Triloculina*	53
5.	*Triloculina, Spiroloculina, Trochammina*	54
6.	*Tiphotrocha, Arenoparella, Protelphidium, Pseudononion, Elphidium*	55
7.	*Elphidium, Protelphidium, Peneroplis*	58
8.	*Elphidium, Rosalina, Protelphidium*	59
9.	*Rosalina, Globigerina, Ammonia, Planulina, Hanzawaia, Cibicides*	60
10.	*Ammonia, Hanzawaia, Cibicides*	61
11.	*Haplocytheridea, Cypria, Cyprideis, Cypridopsis*	62
12.	*Perissocytheridea, Cytheromorpha, Acuticythereis, Paracytheridea, Neolophocythere*	63
13.	*Cytherura, Basslerites, Cytheromorpha, Cytheretta*	64
14.	*Hulingsina, Cushmanidea, Leguminocythereis, Pellucistoma, Puriana*	64a
15.	*Loxoconcha, Actinocythereis, Puriana, Aurila, Hemicythere*	65
16.	*Cypria, Cypridopsis, Cyprideis, Haplocytheridea*	66
17.	*Neolophocythere, Paracytheridea, Acuticythereis, Haplocytheridea, Perissocytheridea*	67
18.	*Acuticythereis, Loxoconcha, Cytheromorpha, Basslerites*	68
19.	*Cytherura, Cushmanidea, Basslerites*	69
20.	*Pellucistoma, Cytheromorpha, Hulingsina, Leguminocythereis, Cushmanidea*	72
21.	*Aurila, Hemicythere, Puriana, Actinocythereis, Cytheretta*	73

FIGURE		PAGE
1.	Location of the study area in the southern Pamlico Sound region in eastern North Carolina	9
2.	Location of traverses and sampling stations in southern Pamlico Sound region	11
3.	Bottom salinity distribution in Pamlico Sound region in June 1959	13
4.	Bottom salinity distribution in Pamlico Sound region in January 1956	15
5.	Bottom salinity distribution in Pamlico Sound region in August 1956	16
6.	Relationship between surface-water temperature in Pamlico Sound and air temperatures at Hatteras	17
7.	Mean monthly surface-water temperature of Pamlico Sound	17
8.	Distribution of *Ammobaculites pamlicoensis* and *Haplocytheridea setipunctata*	23

Figure		Page
9.	Distribution of *Ammobaculites neusensis* and *Haplocytheridea bradyi*	25
10.	Distribution of *Ammobaculites exilis* and *Cushmanidea echolsae*	27
11.	Distribution of *Hulingsina sandersi* and *Ammobaculites crassus*	29
12.	Distribution of the *Elphidium brooklynense-E. clavatum-* and *E. incertum* fauna and *Ammotium salsum*	31
13.	Distribution of *Miliammina fusca* and miliolids	33
14.	Distribution of *Elphidium galvestonense*	35
15.	Distribution of *Protelphidium orbiculare*	37
16.	Numerical distribution of foraminifers in Nelson Bay and Taylor Creek. Figures include both tops and bottoms of core samples	38
17.	Neogene shorelines in southeastern United States as postulated by Cooke (1945)	45

TABLES

Table		Page
1.	Numerical distribution of ostracodes and rhizopods at stations 1-17 (essentially estuarine biofacies)	22
2.	Numerical distribution of ostracodes and foraminifers at stations 18-42 (open-sound biofacies)	24
3.	Numerical distribution of foraminifers at stations 43-78 (tidal-delta biofacies)	26
4.	Numerical distribution of ostracodes at stations 43-78 (tidal-delta biofacies)	28
5.	Numerical distribution of foraminifers at stations 79-102 (essentially salt-water lagoon biofacies)	30
6.	Numerical distribution of ostracodes at stations 79-102 (essentially salt-water lagoon facies)	32
7.	Numerical distribution of rhizopods at stations 103-116 (essentially salt-marsh biofacies)	34
8.	Numerical distribution of ostracodes at stations 103-116 (essentially salt-marsh biofacies)	34
9.	Geologic ranges of the species of foraminifers present in southern Pamlico Sound region	41
10.	Geologic ranges of the species of ostracodes present in southern Pamlico Sound region	41
11.	Species found in Recent of Southern Pamlico Sound region occurring also in Miocene of Florida and Atlantic coastal plain	43
12.	Species found in Recent of southern Pamlico Sound region occurring also in Pliocene and Pleistocene of Florida and Atlantic coastal plain	44
13.	Distribution of foraminifers and ostracodes in Cores 83 and 88	46

PART 1

LIVING AND SUBFOSSIL RHIZOPOD AND OSTRACODE POPULATIONS

STUART GROSSMAN
[Esso Production Research Company]

ABSTRACT

Recent Rhizopodea (thecamoebians and foraminifers) and Ostracoda (97 species, 43 genera) representing five principal biofacies were collected from the southern Pamlico Sound region, North Carolina. The assemblages represent an estuarine biofacies, an open-sound biofacies, a salt-water lagoon biofacies, a tidal-delta biofacies, and a marsh biofacies.

From 159 stations distributed over approximately 1,200 square miles, 57 core, 82 Petersen-dredge, and 20 sieve samples were collected. The 215 samples each consisting of 120 cubic centimeters of sediment were processed and examined for microfauna. The salinity of the area studied ranges from 0.5 ‰ at the heads of the estuaries to 36 ‰ on the marine delta of Ocracoke Inlet and in Cape Lookout Bight. The depth ranges from less than 1 to more than 30 feet, and bottom temperatures at the time of collection ranged from 74° to 78° F. The substratum consists of black organic mud, clay, and silt grading to very fine and medium sand; the sand predominates. The aquatic vegetation is dominantly typical lagoonal grasses including *Spartina* and *Zoostera*.

Salinity, vegetation, and tidal currents are the physical factors examined that apparently have the most effect on distribution of the microfauna. The low pH, currents and waves, and turbid conditions seem to account for the low abundance. The low calcium-carbonate content and low pH apparently are responsible for the lack of calcareous species in the river estuaries and, to a lesser extent, in the marshes. The character of the substratum seems to have little apparent influence on either the distribution or abundance of the Rhizopodea and Ostracoda within the area studied.

The short cores (4 to 15 inches) indicate no change in the microfauna during the recent past for most of the area. The estuaries occasionally are subjected to flooding by water of increased salinity which may remain long enough for a more marine-type microfauna to become established.

INTRODUCTION

This study was undertaken to determine the usefulness of the Rhizopodea and Ostracoda as indicators of the strand-line depositional environments of the Neogene sediments of the Atlantic coastal plain; attention was directed specifically to the southern Pamlico Sound region.

To determine the applicability of this microfauna to the interpretation of past environments, it was necessary first to determine the environmental and geographic boundaries of the species living in the area and then to evaluate the factors that determine distribution and abundance. Many species living in the area also are known as fossils and therefore can be used as biofacies indicators for Neogene sediments. Some species that are restricted or known only from the Recent are useful in determining analogous depositional environments of different or widely separated areas. To test the persistency of the several species as environmental indicators of geologic importance, numerous short cores were taken to determine whether any erratic or insignificant changes in environmental conditions have occurred during a short period of time.

Standard methods of sediment sampling and collecting oceanographic data were used with the exception that 120-cc. samples were collected rather than the 15-cc. samples that are obtained commonly by micropaleontologists working with Recent microfaunal assemblages. The larger samples, however, were collected because this approximates the amount of material generally collected by micropaleontologists working with fossil faunas.

The southern part of Pamlico Sound was chosen for study because 1) oceanographic and sedimentary processes operating at present in the area are presumed to be similar to those that were in effect throughout Cenozoic time along the Atlantic coast; 2) few microfaunal studies have been made in this area previously; 3) the North Carolina coast is characterized by a megafauna that is transitional between species of northern and southern types; 4) environments in the area range from those of fresh-water to normal marine conditions typical of a prograding shoreline; 5) the area is relatively free from industrial and organic pollution; and 6) it is readily accessible.

Previous Studies

The first study of marine ostracodes along the Atlantic coast was by CUSHMAN (1906) who described the fauna of Vineyard Sound, Massachusetts. Subsequent studies were made by BLAKE (1933) at Mount Desert Island, Maine; by TRESSLER (1940) for sand beaches at Beaufort, North Carolina; and by TRESSLER & SMITH (1948) for the seasonal distribution of the fauna of the Solomons Island area of Chesapeake Bay.

SWAIN (1955) and CURTIS (1960), under auspices of the American Petroleum Institute Project 51, published information on the distribution of Ostracoda of San Antonio Bay, Texas, and the eastern Mississippi River delta region, respectively. PURI & HULINGS (1957) summarized ostracode populations of the Panama City and Alligator Harbor areas in the northeastern part of the Gulf of Mexico, and of the Florida Bay area of eastern peninsular Florida. Species were not described in the latter paper, but PURI (1960) subsequently reviewed the taxonomy.

Literature on the environmental and areal distribution of Recent rhizopods is much more extensive than that on ostracodes. CUSHMAN (1918-1931) published a series of eight monographs on the Foraminiferida of the Atlantic Ocean and included several of the forms found in the Pamlico Sound area. Subsequent works by CUSHMAN on Atlantic coast faunas were from southern New England (1944) and the southeastern coast of the United States (1947). In addition to these works, important contributions to the knowledge of Atlantic coast faunas were by SHUPACK (1934) for the New York Harbor region; PHLEGER & WALTON (1950) for Barnstable Bay, Cape Cod; PARKER (1948) for the continental shelf from Maine to Maryland; SAID (1951) for Narragansett Bay; PARKER (1952, *119, 120*), for Portsmouth, New Hampshire, and Long Island Sound; and PARKER & ATHEARN (1959) for Poponesset Bay, Cape Cod.

PHLEGER & PARKER (1951) published a memoir on the ecology of Foraminiferida of the northwest Gulf of Mexico. From 1953 through 1958, under sponsorship of the American Petroleum Institute Project 51, PHLEGER, PARKER, LANKFORD, PEIRSON, and BRADSHAW, published several important papers on the distribution of bay and offshore Rhizopodea of the Gulf Coast. In addition to these workers, LOWMAN (1949), POST (1951), BANDY (1954, 1956), and WALTON (1960) have made significant contributions to the knowledge of the distribution of Gulf species.

DESCRIPTION OF STUDY AREA

Pamlico Sound is a barred estuarine and lagoonal system situated in the eastern portion of North Carolina, just southwest of Cape Hatteras. It is largest of the embayments formed behind barrier beaches along the Atlantic coast of the United States. The Sound is 60 miles long and has a maximum width of 26 miles. The area of study includes the southern portion of the Sound and the surrounding areas between latitudes 34°36′ and 35°30′ N and longitudes 76°45′ and 76° W (Fig. 1). The important bodies of water in the area of investigation, in addition to Pamlico Sound proper, are the lower segments of the Neuse and Pamlico-Tar River systems, Core Sound, Cape Lookout Bight, the tidal inlets, and the marine shoal of Ocracoke Inlet.

The two sounds (Core and Pamlico) are effectively separated from the Atlantic Ocean by a series of low-lying, narrow, elongate barrier beaches and islands, or "outer banks" as they commonly are designated locally. These barriers, from northeast to southwest, are Ocracoke Island, Portsmouth Island, and Core Banks (including Cape Lookout). Another barrier beach, Shackleford Banks, lies near the southern end of Core Banks, is normal to and separated from Core Banks by a narrow inlet, and extends in a westerly direction. Three inlets that for purposes of this study may be termed permanent allow exchange of water between the sounds and the Atlantic Ocean. These are the Ocracoke (between Ocracoke and Portsmouth Islands), Drum (between Portsmouth Island and Core Banks), and Barden (between Core and Shackleford Banks) Inlets. The largest and most important of the inlets is Ocracoke, because it is the only outlet to the ocean for waters of southern Pamlico Sound which receives the fresh-water drainage of the Pamlico-Tar and Neuse River systems. Numerous other inlets may be formed from time to time, generally during large storms, but they are quickly closed by longshore drift and other processes of sedimentation.

The Neuse and Pamlico-Tar River systems originate in the piedmont area of North Carolina, and their 7,500-square mile drainage basin is mainly responsible for the fresh-water acquisitions of Pamlico Sound. Although the watershed is large, it contributes annually less fresh water than the volume of the sound *(144)*, the difference being made up by tidal inflow from the sea. In addition to the major river systems numerous short streams drain the surrounding swampy areas and further contribute to the fresh-water supply of the Sound.

The region has been referred to as a compound coast *(132)*. The drowned river valleys are indicative of an area of submergence. Barrier beaches have been regarded commonly as features of an emergent shoreline, but more recent studies indicate that the development of barrier beaches is related to a still-stand of sea level. The surrounding land areas are low in relief; the entire surface as much as 50 miles inland is less than 50 feet above sea level and is characterized by swamps, salt marshes, and drowned valleys. This low area is covered by Quaternary sediments that are predominantly sand, clay, marl, and gravel *(132)*. At present, the coastline is being prograded.

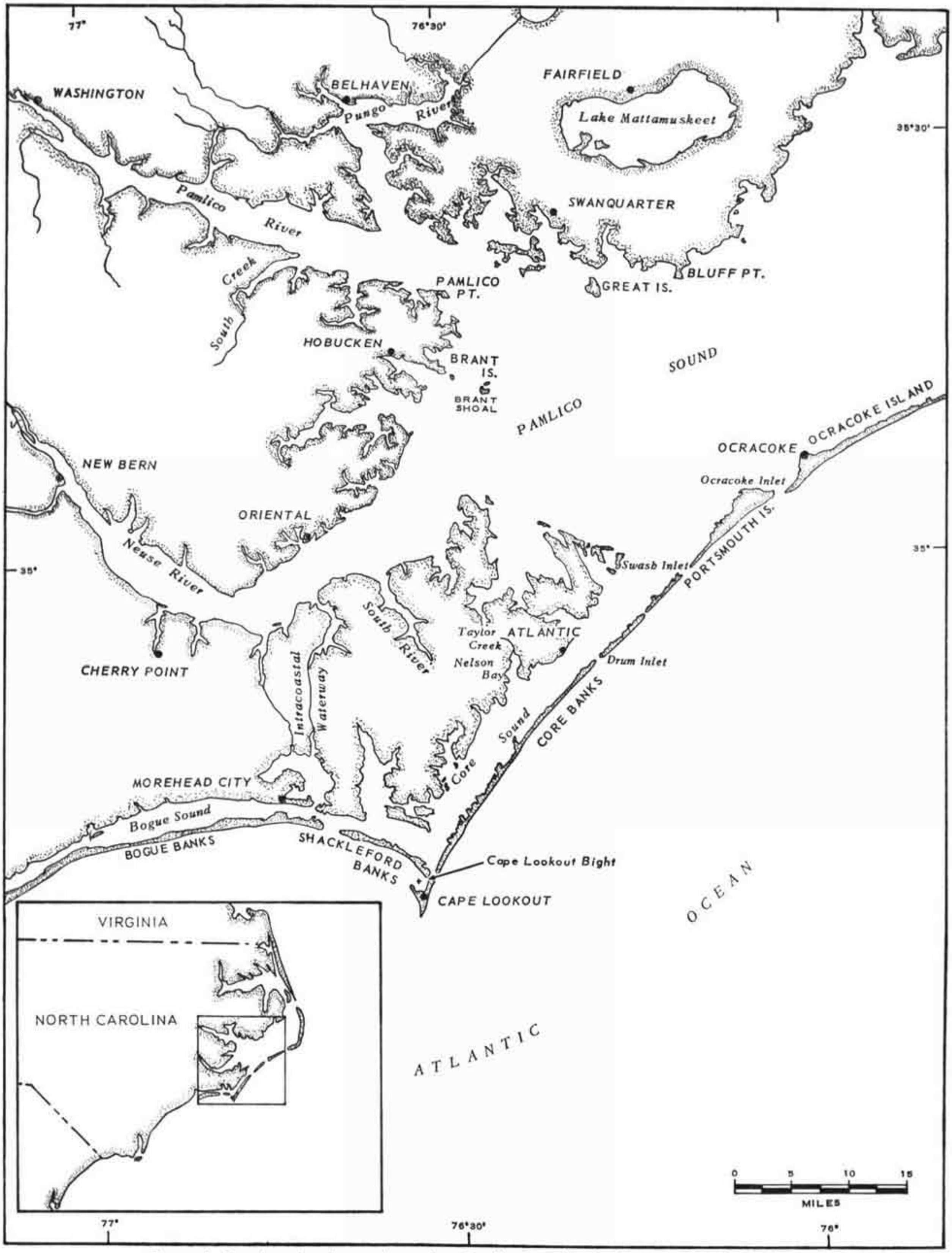


FIGURE 1. Location of study area in southern Pamlico Sound region in eastern North Carolina.

FIELD METHODS

One hundred and fifty-nine samples were collected in the southern Pamlico Sound region. These comprise 57 core samples, 82 Petersen-dredge collections, and 20 non-quantitative samples of water and bottom material taken from small fresh-water ponds and streams in the area. The last-mentioned 20 samples were taken to survey the local occurrence of ostracodes in the fresh-water environments. Because of lack of specimens in these streams and ponds (only two of the samples contained a microfauna), the locations of these 20 samples are not plotted in the final tally and their physical and chemical characteristics are not discussed in detail.

Core and dredge samples were taken carefully from the Neuse, Pamlico, and Pungo Rivers, the southern portion of Pamlico Sound, Core Sound (including one station in Cape Lookout Bight), Nelson Bay (including its tidal stream, Taylor Creek), the marine delta of Ocracoke Inlet, and the marsh near the northern end of Portsmouth Island (Fig. 2).

Sampling was spaced so as to gather material from fresh-water to normal marine environments and from areas where the sediment types ranged from organic mud to sand. Axial traverses were made down the rivers normal to the salinity gradient with cross traverses at intervals so as to include possible sediment and faunal variations across the channels. Sampling in Pamlico Sound was done on a grid pattern modified to permit evaluation of the salinity changes and to reflect any possible effect of Brant Shoal on the fauna. The grid pattern also was interrupted in the vicinity of Ocracoke Inlet and modified or supplanted by a radial pattern over the many shoals of the tidal delta. A relatively greater number of samples was taken from both the Sound side and the open-sea side of the tidal delta of Ocracoke Inlet in order to reflect the abrupt salinity change from brackish- to normal-marine water. An axial traverse in Core Sound and numerous cross traverses anticipated possible faunal changes between the banks and the mainland. Nelson Bay and Taylor Creek, being readily accessible, were selected for a detailed study of a marsh biotope. Several samples of the fauna also were collected for comparative purposes from the marsh near the northern end of Portsmouth Island.

The core samples were obtained by using a coring device developed by R. H. Benson for the specific purpose of sampling sediments in less than 20 feet of water. This apparatus consists of a steel pipe that is 30 inches long and has an internal diameter (2 inches) adequate to hold a plastic core liner (18 by 1⅞ in. I.D.). One end of the core barrel is beveled to a fine edge, and a suction device similar to that used in the Phleger Bottom Sampler is fitted into the opposite (upper) end. At this same upper end a bracket is attached to the pipe and a 10-foot section of aluminum radio antenna is bolted to the bracket. Another 10-foot section of antenna may be added to the first, thus increasing the total length to 20 feet. The plastic core liners are inserted into the core barrel and kept from slipping by two wing nuts attached to the opposite sides of the barrel. The lowermost inch of the liner protrudes from the core barrel in order to facilitate later removal of the liner from the core barrel. The core is lowered into the water and driven or pressed into the sediment, raised until the core barrel just clears the surface, and then the lower end of the liner is fitted with a plastic cap. Later the wing nuts are loosened, the liner is removed, the top is capped, and a label is attached. Then the liner and sediment are placed in a special box that holds all collected cores in a vertical position.

Where the sediment was too coarse or the water too deep for the corer, a Peterson grab sampler was used and a 120-cc. sample was obtained.

All stations were taken either within sight of land or navigation buoys, or were adjacent to the navigation buoys; thus station locations could be fixed directly, or from horizontal sextant angles which were then plotted on U.S. Coast and Geodetic Survey charts. Depths were determined by bathythermograph traces and by soundings; bottom temperatures were estimated from bathythermograph recordings. Surface temperatures were observed using a thermister. Water for salinity determinations was taken with a limnological water sampler and was analyzed at the Marine Institute of the University of North Carolina.

LABORATORY WORK

The Petersen grab samples were wet-sieved through 20-, 40-, and 100-mesh screens. The core samples were extruded and a 2-inch slice was taken from both the top and bottom of the core. Each slice amounted to 120 cc. and thus corresponds in volume to that taken from the dredge samples. The core samples were washed repeatedly with distilled water and shaken until the clay material remained in suspension. The clay-saturated water was pipetted, and the remainder of the sample was wet-sieved through the screens. The residues from both the core and grab samples were dried slowly in an electric oven.

All specimens in each of the samples were picked and mounted on microfossil faunal slides. After the various forms had been identified, the total population of each species at each station was plotted on two-component graphs and the areal distribution of the most numerous species was recorded on charts. Charcoal pencil or shaded drawings were made of the Rhizopodea, and ink outline drawings were made of the interior of the ostracode valves. Ostracode exteriors were photographed after having been stained with a five percent solution of oxidized silver nitrate.

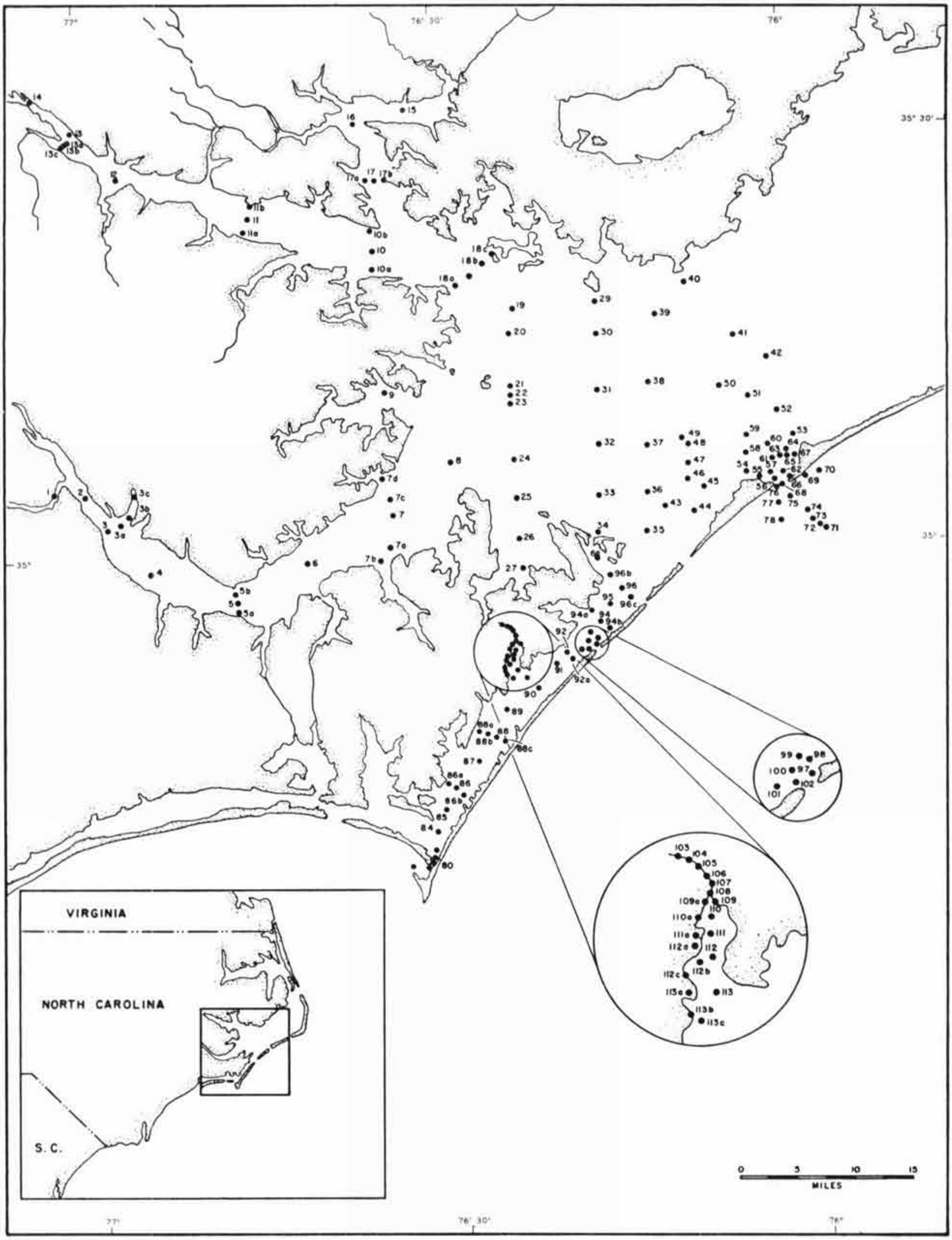


FIGURE 2. Location of traverses and sampling stations in southern Pamlico Sound region.

ACKNOWLEDGMENTS

Appreciation is expressed to DAVID ROCHNA and DAVID DUANE for their assistance in the field and especially to DUANE for his aid in preparation of the sedimentary analyses. Thanks also are extended to the staff of the Marine Institute of the University of North Carolina for advice on the area and for furnishing some equipment. Acknowledgment is extended further to the Commandant of the U.S. Coast Guard Station at Fort Macon, North Carolina, and to the Chief of Staff of the U.S. Marine Corps Air Station at Cherry Point, North Carolina, for their cooperation and aid in making available personnel and equipment. Special acknowledgment is made to HENRY V. HOWE of Louisiana State University for his advice on species and generic assignments of ostracodes and also for granting access to his type collection, and to RUSSELL M. JEFFORDS of Esso Production Research Company, who initially edited the manuscript.

The investigation was supported by National Science Foundation Grant No. G7152, for which R. H. BENSON was named the principal investigator.

ECOLOGY OF RHIZOPODEA AND OSTRACODA

The Ostracoda and Rhizopodea noted in the area of study are typically forms found in both brackish- and shallow-water marine environments. The paucity of specimens, however, is atypical of the populations normally found in such regions. PARKER, PHLEGER, & PEIRSON (1953) reported more than 20,000 specimens in several individual 10-cubic-centimeter samples obtained from the Texas bays; many of their samples contained in excess of 1,000 specimens. PARKER *(120)* found as many as 50,000 specimens in individual samples from the Long Island Sound-Buzzards Bay region. In the area of Pamlico Sound, however, the largest rhizopod assemblage obtained from a single station was 256 specimens and the largest individual ostracode assemblage was 133 specimens. Most samples contained less than 50 individuals of both groups of organisms. This low number is emphasized further by noting that the individual sediment samples from the Pamlico Sound region amounted to 120 cubic centimeters, which is 12 times the amount of sediment in individual samples from the Texas bays. The interpretation of the ecology of a species or a fauna in the present study, therefore, necessitates discussion of the effects of the several ecologic factors not only on distribution but on the abundance as well.

The Pamlico Sound area, although unable either to support or to provide a suitable habitat for this microfauna, is not toxic to them. The valves and tests found in the samples are the hard parts of species still living in the area at the time of collection. Most specimens of ostracodes have both valves intact with appendages protruding between the shells; thus indicating that they were either alive when collected, or had died very recently. The Rose Bengal stain commonly used to delineate protoplasm, that is, to separate living from dead populations, was not used because it fails to stain living ostracodes differentially. Because this stain was not used, the number of living Rhizopodea at the time of collection is unknown. It is a reasonable assumption, however, that a portion of this fauna was living at the time samples were obtained.

The low numbers of both Ostracoda and Rhizopodea may mean that 1) a combination of physical, chemical, and organic factors inhibits the development of large populations, or 2) that either the chemical or physical conditions of the environment destroy the tests and carapaces of the individual. These hypotheses will be explored in a later section.

ENVIRONMENTAL FACTORS

SALINITY

The waters of the southern Pamlico Sound region are subject to considerable lateral variation in salinity. This difference is dependent upon fluctuations in runoff, seasonal changes in rainfall, proximity to inlets, force and direction of wind affecting tides, and evaporation. The parts of the Sound near sources of fresh water differ seasonally in salinity. Salinity gradients are steepest near the inlets where changes, and thus the location of the isohaline contours, are dependent upon the stage of tide. Changes are minimal in the central part of the Sound and result mostly from winds blowing fresher or more saline water into the Sound from the surrounding water masses (ROELOFS & BUMPUS, 1953, p. 194).

Determinations of surface salinities were not made because the microfauna is primarily benthonic. Furthermore, (*144*, p. 180) the differences in temperature and salinity between top and bottom are reported to be so small as to have little significance. The average difference between top and bottom salinity of Sound water is only 0.66 ‰.

In the study area a general east-west salinity gradient exists from 0.5 ‰ in the Neuse River at New Bern and also in the Pamlico River at Washington, to 36 ‰ on the marine delta of Ocracoke Inlet.

Maps showing these salinity gradients as determined in previous studies *(102, 144)* and unpublished maps of the Marine Institute of the University of North Carolina generally have a series of concentric isohaline contours suggesting decreasing salinity values away from the Sound delta of Ocracoke Inlet. This is to be expected because marine waters flowing in through the Inlet mix with fresher Sound waters and cause a general decrease in salinity away from the Inlet. The lateral changes in salinity in the Sound adjacent to Ocracoke Inlet, as shown in

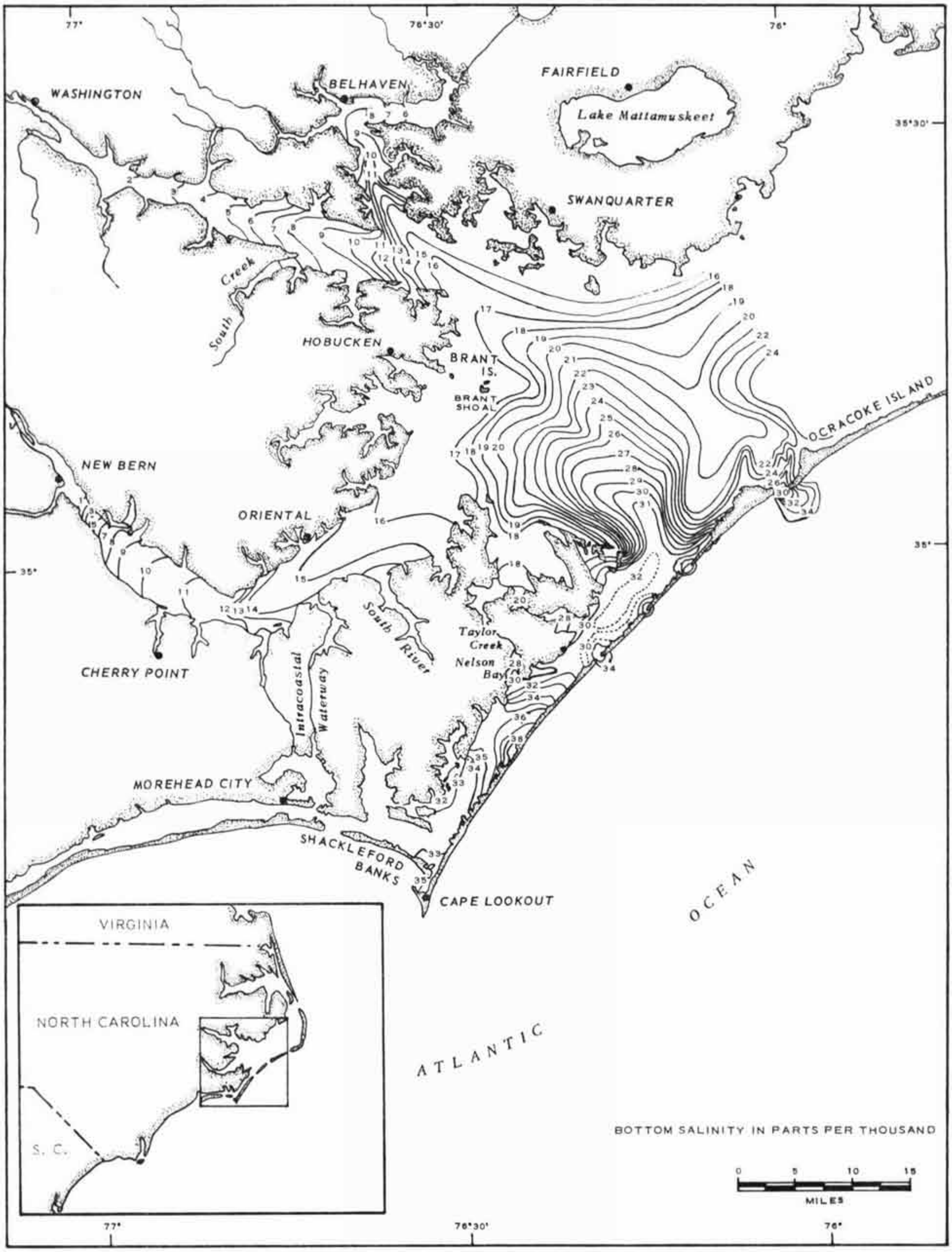


FIGURE 3. Bottom salinity distribution in Pamlico Sound region in June 1959.

the map prepared from data acquired in June 1959 (Fig. 3), reveal little influence of marine waters over bottom waters of the Sound. Unexpectedly, southwest winds (generally prevalent during June) attempted to form high-wind tides and this tended continually to push a saline-water mass out of Core Sound. The salinity of the waters of Core Sound was slightly higher than usual at this time because of a net excess of evaporation over precipitation combined with a lack of runoff just prior to the period of observation. This mass of water spread out over the southern portion of Pamlico Sound and was diluted gradually to the north and west by the fresher river water. Some water from the Neuse River that normally would flow outward toward Ocracoke Inlet was being diverted northward by this saline water body to merge with the diluted water mass of the Pamlico River. The two combined systems flowed eastward across the Sound with only a slight increase in salinity; in the vicinity of Ocracoke Inlet the salinity abruptly increased because of the influence of the Inlet.

Core Sound consistently is more saline than Pamlico Sound and increases in salinity from northeast to southwest. Beaufort Inlet (between Shackleford and Bogue Banks) and Barden Inlet provide the normal marine water for the Sound. Drum Inlet, because of its narrow channel and shallow depth, exerts only a minor local influence on the general salinity pattern of Core Sound. Pamlico Sound is not a source of saline water for Core Sound because east or northeast winds, which are prevalent in the winter months, drive fresher water into the Sound.

January and August commonly are the months during which the bottom salinities of the Sounds are highest and lowest (Figs. 4, 5). In general, an inverse relationship exists between the occurrence of high salinity and the amount of runoff, the average runoff being highest in the winter months and lowest during the summer. Lowest salinities are in March or April, and the highest are in late summer or early fall.

Roelofs & Bumpus (1953, p. 202, 203) have stated that although the amount of water flowing through the inlets is much larger than the river effluent, much of the Inlet water appears to oscillate back and forth through the Inlet and over the shoals immediately inside. The amount of salinity exchange through the Inlets must be small because the average salinity of the Sound is dependent upon the mean monthly runoff from the rivers. The average salinity of Pamlico Sound is about 20 ‰; thus, on an annual basis, the Sound is assumed to comprise three parts of runoff and four parts of sea water. These authors also indicate that 40-50 $\times 10^6$ m^3 of undiluted sea water must be added each day (i.e., one tenth the tidal prism) to maintain the average salinity of the Sound.

According to Valikängas (1933), brackish environments can be subdivided on the basis of salinity values as follows. This classification has advantages in eliminating

Classification of Environments by Valikängas (1933)

Descriptive term	Salinity in ‰
Fresh water	0.5
Oligohaline water	0.5-3.0
Mesohaline water	3.0-16.5
Polyhaline water	11.5-30.0
Marine water	30.0

the necessity for defining all salinity ranges in terms of parts per thousand and in facilitating dimensions of the salinity ranges for brackish-water species.

TEMPERATURE

Water temperatures in Pamlico Sound, according to Roelofs & Bumpus (1953), are closely related to air temperatures, as illustrated in Figure 6. Air and water temperatures are highest during June, July, and August, and are lowest during the winter months. Figure 7 shows the average monthly water temperature of Pamlico Sound as determined by Roelofs & Bumpus for 1951 and the month of January 1953.

No lasting thermal stratification exists within the Sound. Winds and wind-driven currents tend to keep the water agitated, and bottom temperatures generally are within 10° F of surface temperatures. During the month of June 1959 surface temperatures ranged from 74° to 78° F. and averaged about 77°. Bottom temperatures were about the same but locally were 1 to 7 degrees cooler and averaged 2 degrees cooler than the surface.

During the winter months water flowing in the inlets is isothermal and frequently warmer than Sound waters. The reverse situation is present at times in the summer when ocean water is cooler than the waters of the Sound. During the period of investigation, the ocean waters had approximately the same temperature as Sound waters so no lateral temperature gradient was present in the immediate vicinity of Ocracoke Inlet where the tidal influence is strongest.

During June 1959, the waters of Pamlico and Core Sounds were isothermal. In the lower segments of the Neuse and Pamlico estuaries, however, there was a thermocline and a tendency toward stratification. This layering was caused by slightly warmer river water overriding wedges of the slightly cooler and more saline water or "salt wedge" that extended from Pamlico Sound into the estuaries. On the marine delta of Ocracoke Inlet, seaward of the breaker zone a thermocline with a pronounced change in temperature was recognized four feet below the surface. Below this depth the water cooled gradually so that at the bottom it was 2 degrees cooler than the temperature at the 4-foot level. Inside the breaker zone the water was isothermal.

CURRENTS

The currents in the main portions of Pamlico and Core Sounds, although weak oceanographically, are of

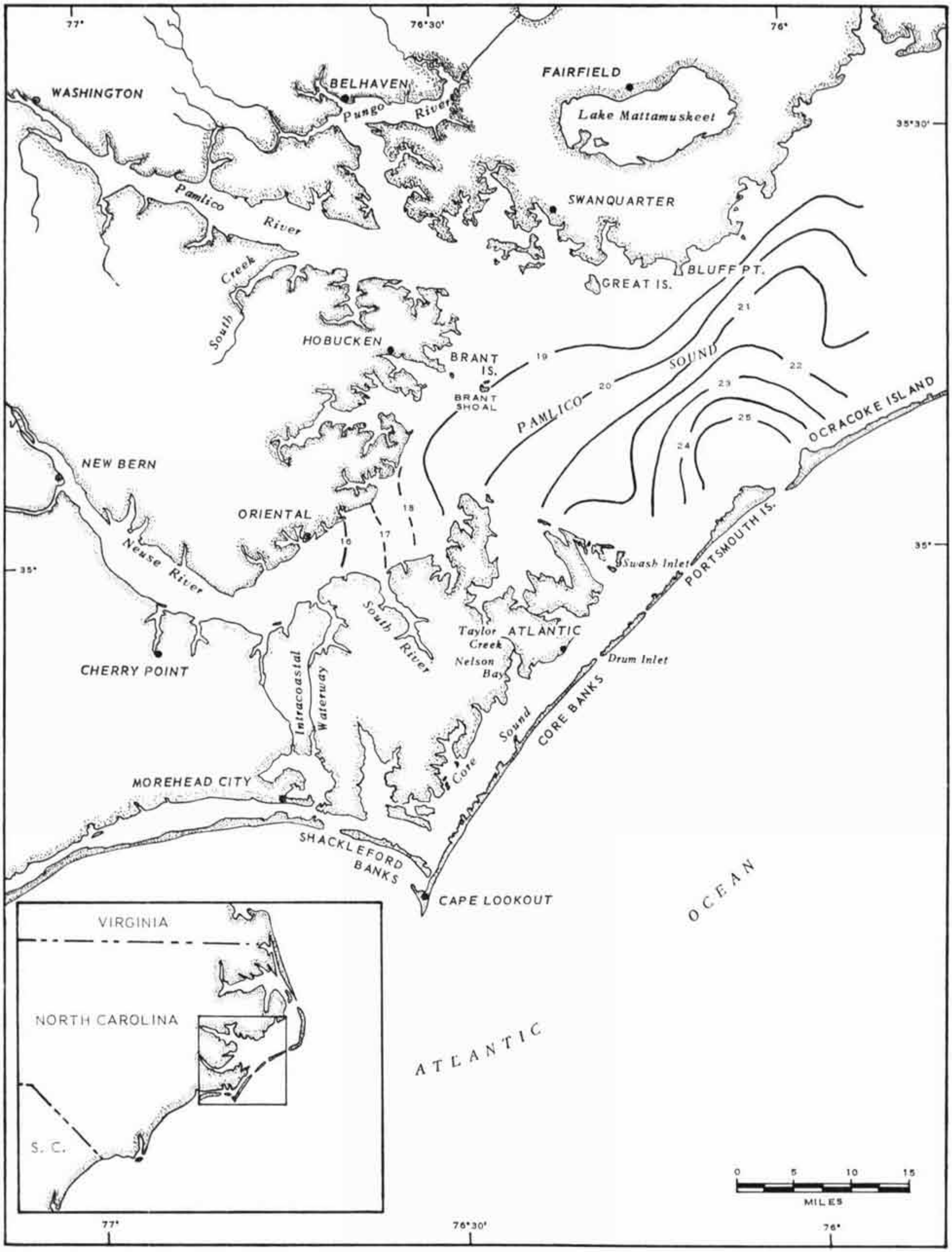


FIGURE 4. Bottom salinity distribution in Pamlico Sound region in January 1956.

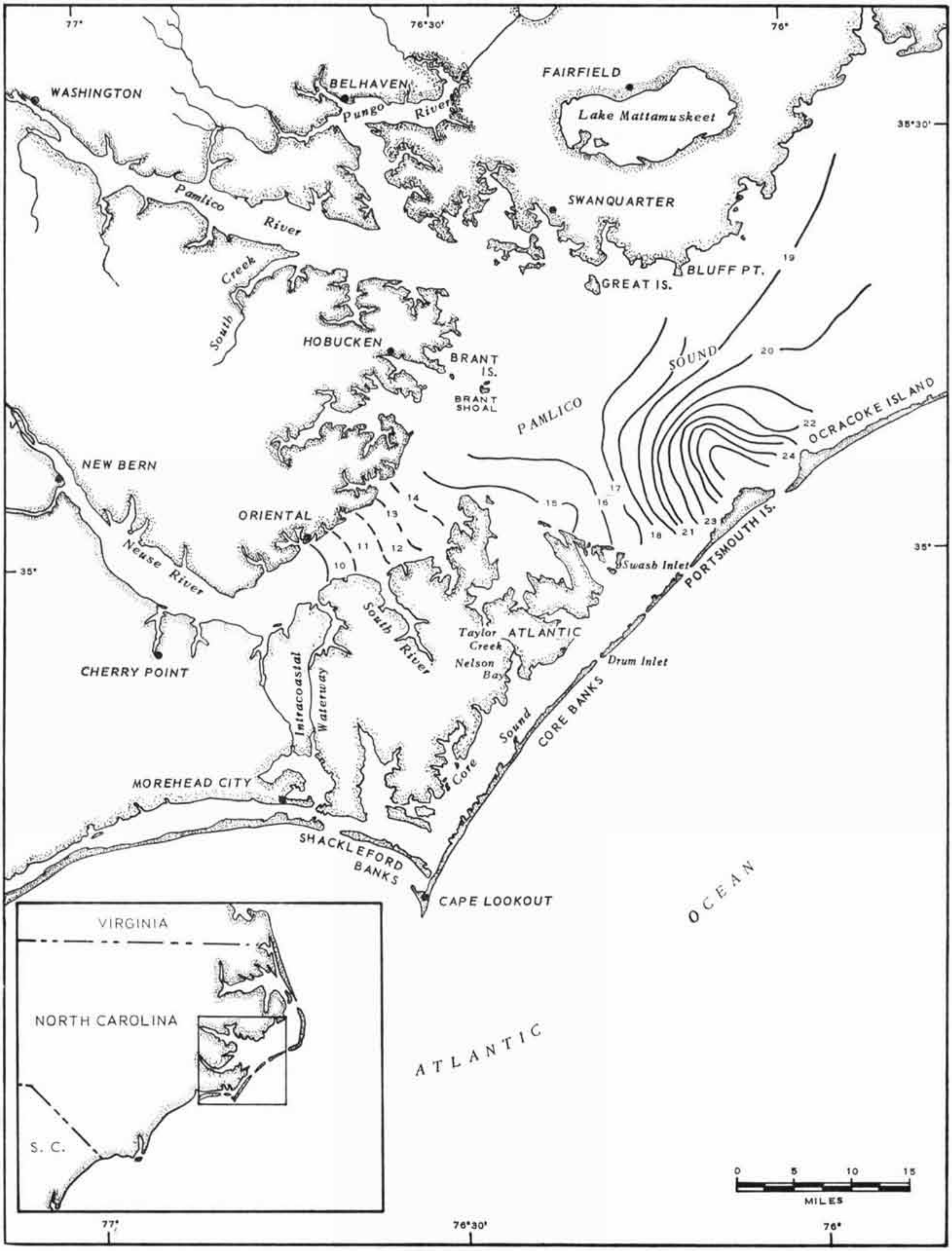


Figure 5. Bottom salinity distribution in Pamlico Sound region in August 1956.

sufficient force to move the finer bottom materials. These currents are dependent upon the direction, duration, and velocity of the wind but not to any great degree upon tidal fluctuation.

WINSLOW (1886) made a number of measurements in the Sound, and although the accuracy of his measurements may be contested because of poor quality of measuring equipment at that time, they do give a rough estimate of the force of the currents. WINSLOW stated that the currents in the Sound seldom exceeded one half knot (26 cm./sec.) and the strongest current recorded was three quarters of a knot (38 cm./sec.) caused by a northeast gale of several days' duration. According to HJULSTROM (1939), a velocity of 38 cm./sec. can move material up to 3 mm. in diameter.

The currents at the Inlets are much greater. ROELOFS & BUMPUS (1953), in measurements made in the Ocracoke channel, found a maximum ebb of 2.6 knots (134 cm./sec.) and a maximum flood of 2.7 knots (137 cm./sec.). The force of these currents, according to HJULSTROM (1939), can move material up to 10 mm. in diameter.

The tidal currents in Barden Inlet perhaps are as swift, but the currents at Drum Inlet probably are less.

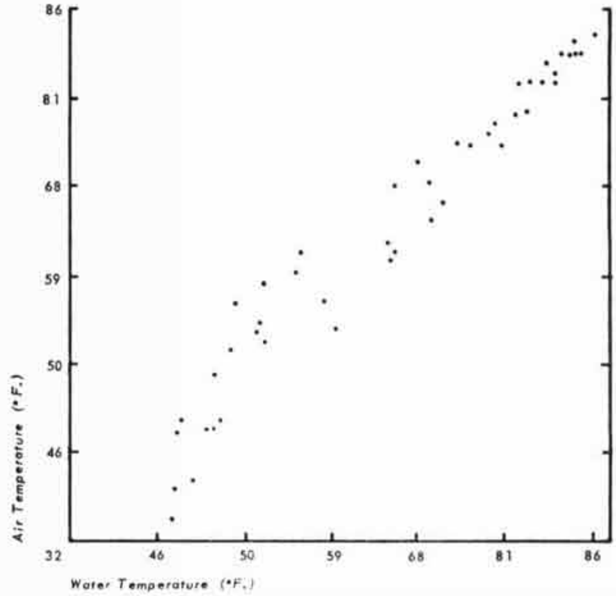


FIGURE 6. Relationship between surface-water temperature in Pamlico Sound and air temperature at Hatteras.

SUBSTRATUM

The sediments in the area of investigation range from dark organic mud to coarse quartz sand. All sediments are well sorted, the sorting factor being less than 2.5 (TRASK, 1932). Fine to medium quartz sand is the predominant sediment type in the area; the color ranges from buff to reddish brown to dark gray. The colors are dependent mainly upon the amount of clay material and to a lesser extent on the organic matter and heavy-mineral content. The clay and the finer silt in the region are gray to bluish black.

Sediments in the river estuaries are predominantly clay and silt in the center of the channels and fine- to medium-sized quartz sand along the edges. Fecal pellets found in the center of the channels comprise the majority of the silt-sized particles and feldspar fragments make up 1 to 7 percent of the sands. Organic detritus is present in most river samples in very minor amounts.

In Pamlico Sound sediments range from silty clay to medium-sized sand. Brant Shoal, a remnant divide, does not seem to control the sediment distribution because the sediments are similar in size and composition both north and south of this shoal. Most of the sands are composed of 95 to 99 percent quartz with the remainder made up of feldspar, heavy minerals, clay, and shell fragments. Fecal pellets are present in very minor amounts in several samples.

The sediments of the tidal-delta shoals are mainly sand with only very minor added amounts of silt-sized material, whereas the tidal distributaries are floored with medium- to coarse-grained sand. The sand is mainly quartz with up to 15 percent shell material present on both the tributary and the distributary shoals. Very minor amounts of feldspar and heavy minerals also are present.

The sediments in Core Sound are mainly silty clay and fine- to medium-sized sand. The finer sediments occur in the region of the *Zoostera* flats adjacent to the barrier beaches and the silt and sand are concentrated more towards the mainland. The sand is predominantly quartz with very minor amounts of feldspar, heavy minerals, and clay.

Nelson Bay generally has dark organic mud adjacent to the flats on which the *Spartina* complex grows, but in several small areas on the north side of the Bay fine sand is adjacent to the marsh. Somewhat coarser sediments are present in the center of the Bay, but these also have considerable amounts of organic material and clay. Taylor Creek has organic mud and silty clay.

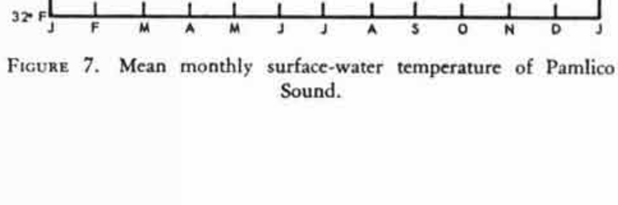


FIGURE 7. Mean monthly surface-water temperature of Pamlico Sound.

TURBIDITY

Secchi disk readings were taken at most stations in the area. The readings in the sounds and rivers, where the depths were great enough, ranged from less than 1 to 2 meters, indicating that the waters in the region are quite turbid and carry a large amount of fine material in suspenpension. In general, the more saline waters were the clearest because most of the suspended clay material apparently had already been flocculated and locally the depth of water was such that slight wave action did not disturb the bottom to any great extent. The water in Cape Lookout Bight was the clearest and the disk could be seen 6 meters below the surface. The water on the Atlantic delta of Ocracoke Inlet also was relatively clear and the disk could be seen four meters below the surface.

DEPTH

The waters of the Pamlico Sound region are very shallow. The average depth of Pamlico Sound is 12 feet; the maximum depth is 22 feet below mean sea level. The average depth of Core Sound is less than 4 feet, and the maximum depth is 12 feet. The river estuaries are somewhat deeper having a maximum depth of 25 feet in the center of the channels. The deepest water encountered in field investigations was about 40 feet in Cape Lookout Bight and seaward of the marine shoal of Ocracoke Inlet.

INFLUENCE OF ENVIRONMENTAL FACTORS ON DISTRIBUTION AND ABUNDANCE OF RHIZOPODEA AND OSTRACODA

According to Benson (1959, p. 26), "The attempt to isolate one factor as the cause of the presence or absence of an organism is usually indecisive." The very low numbers of species present in this region in contrast to the abundance in other areas having comparable environments indicates that certain factors may be controlling abundance whereas others determine the distribution. The possible effects of several physical and organic factors that may control distribution and abundance in the Pamlico Sound area are discussed below.

TEMPERATURE

The species of Rhizopodea in the area of investigation represent a mixing of northern Gulf of Mexico and southern New England forms. This mixing of northern and southern faunas does not imply necessarily that the southern Pamlico Sound region supports both a cold water and tropical fauna. Rather it suggests that waters of the northern Gulf of Mexico are not tropical as is generally assumed but are warm-temperate as are the waters of southern New England and the Pamlico Sound area. Hedgpeth (1951) stated that the fauna of the Gulf of Mexico is not tropical but is similar to that of the coasts of Virginia and the Carolinas. Only the fauna of southern Florida, on the other hand, is tropical and is related to that of the West Indies.

Because environments and temperatures are similar between the North Carolina and Gulf coasts, many species are identical. Southern New England species also are found in the area because the temperatures here are not appreciably lower than along the North Carolina coast.

The following foraminiferal species which occur in the region also are common in more northern waters: *Protelphidium orbiculare, Protelphidium tisburyense, Elphidium articulatum, Elphidium brooklynese, Elphidium incertum, Rosalina columbiensis, Cibicides* sp. cf. *C. lobatulus,* and *Planulina mera.*

Protelphidium tisburyense has been reported from the Rio de la Plata of South America, where the waters and climatic conditions are somewhat similar to those of the North Carolina coast. With exception of *Elphidium incertum*, which has been reported from Mason Inlet, North Carolina, this is the first reported occurrence of these species on the North Carolina coast. Most species occur south of Cape Cod, but *Protelphidium orbiculare* occurs north of the Cape.

The following species that occur in the region are common to more southern waters: *Haplophragmoides manilaensis, H. wilberti, Ammobaculites crassus, A. exilis, Quinqueloculina compta, Q. poeyana, Elphidium tumidum,* and *Peneroplis proteus.*

With exception of *Quinqueloculina poeyana,* which has been reported from near Beaufort and Mason Inlet, North Carolina, this is the first reported occurrence of these species on the North Carolina coast. The one specimen of *Peneroplis proteus* probably was carried north by the Gulf Stream.

Twenty-two species of foraminifers that occur in the area of investigation are known from both southern and northern waters.

Several miliolid species (e.g., *Quinqueloculina lamarckiana, Q. seminula, Q. bicornis*) are found on both the European and American Atlantic coasts; the first two also are present in the Indian Ocean and apparently have worldwide distribution. *Tiphotrocha comprimata* and *T. inflata* are found on both the European and American coasts.

An endemic marsh fauna whose genera are not limited geographically by temperature has been reported from many areas ranging from Trinidad to Cape Cod. Several species are replaced from south to north, but the general faunal aspect remains unchanged. The species found in the area that are common to both northern and southern faunas are *Ammobaculites dilitatus, Ammotium salsum, Arenoparella mexicana, Miliammina fusca, Tiphotrocha comprimata, Trochammina inflata,* and *T. macrescens.*

Species previously limited to southern faunas but also found in the area are *Haplophragmoides wilberti, H. manilaensis, Ammobaculites crassus*, and *A. exilis*. *Ammonia limbatobeccarii* has not been reported previously from Recent sediments and is the only major calcareous member of the marsh fauna in the area of study.

The ostracode fauna of the Pamlico Sound area, as far as can be determined, is a southern fauna. Only two species, *Cushmanidea seminuda* and *Hemicythere* sp., extend into the Pamlico Sound region from more northern areas. Twenty-one species that occur in the Recent of the Gulf of Mexico extend at least as far north as Pamlico Sound. Several species known only from Miocene sediments may have been washed into the inlets from Miocene subsea crops that occur along the North Carolina coast (H. V. Howe, personal communication).

SALINITY

The salinity gradient is of extreme importance in determining the distribution of the microfauna in the area of investigation.

As stated in Part I, the salinity range is from less than 0.5 to 36 ‰, or from fresh to normal marine waters. Species of *Difflugia* are present in the Pamlico River, which has a salinity of 0.5 ‰ near Washington, and in the upper segment of Taylor Creek, which has a salinity range of 2 to 3 ‰. The river estuaries and the western portion of Pamlico Sound having a salinity range of 0.5 to 18 ‰ (fresh to oligohaline water), is dominated by an *Ammobaculites* fauna; the greatest abundance of species is in the mesohaline portions of the estuaries. The main portion of Pamlico Sound (mesohaline to polyhaline water) is dominated by the *Elphidium brooklynense, E. clavatum*, and *E. incertum* fauna. Both the sound and seaward shoals of Ocracoke Inlet show a mixing of brackish and normal marine species; the salinity range of these waters was from 25 to 36 ‰. Core Sound, with normal marine salinities contained polyhaline and normal marine species; the former are more prominent. The salt-marsh fauna at Nelson Bay and Portsmouth Island exhibited salinity zonation although the community structure is not determined by salinity. Parker & Athearn (1959), in their study of the marsh fauna of Poponesset Bay, Massachusetts, found that certain species decreased in abundance with increasing salinity, others increased, and still others apparently were unaffected by salinity changes. The preferences of those marsh species in Nelson Bay and Portsmouth Island that are also present in Poponesset Bay show the same salinity trends.

Both the nearshore marine areas and the fresh-water environments were sampled so as to bracket completely the brackish zone. Most samples taken from the fresh-water lakes and streams in the vicinity lack ostracodes. Two artificial ponds yielded fairly large numbers of *Cypria ophthalmica* and *Cypridopsis vidua*. At a station on the Neuse River (Treets Ferry Landing) about 40 miles upstream from New Bern, one specimen each of *Candona* sp. and *Darwinula aurea* was noted in check samples, but samples taken for laboratory analysis, as with the remainder of the fresh-water samples, were devoid of specimens.

With two exceptions the river estuaries lacked ostracodes. One abraided specimen of *Cytheromorpha pascagoulaensis* was found in a surface sample of a core. The state of preservation indicated, however, that it had been derived from older sediments. The bottom portion of another core contains six species, but they are ostracodes of types that are present only in the more marine areas of the region of study.

The Core and Pamlico Sound faunas are dominated by three genera: *Haplocytheridea, Cushmanidea*, and *Hulingsina*. *Haplocytheridea setipunctata* has approximately the same distribution pattern as the *Elphidium brooklynense, E. clavatum*, and *E. incertum* fauna, although not in such large numbers.

The numbers of specimens of ostracodes are small and it is difficult to obtain satisfactory distribution patterns for the species. The entire rhizopod and ostracode populations were slightly more than 10,000 specimens, and rhizopods constitute 88 percent of this fauna.

HYDROGEN-ION CONCENTRATION

Tressler & Smith (1948), Kornicker (1958), and Benson (1959) have all concluded that hydrogen-ion concentration does not appear to be a factor influencing ostracode distribution.

Parker & Athearn (1959) reported that dead calcareous foraminiferal species were rare in the marsh at Poponesset Bay, Massachusetts. They inferred that the hydrogen-ion concentration at the sediment-water interface or slightly below the sediment surface is sufficiently low to cause dissolution of the tests. Lankford (1959) supported the conclusions of Parker & Athearn by stating that marshes have abundant decaying vegetation and that the resulting acid conditions may dissolve the empty tests.

Parker & Athearn also have stated that living calcareous foraminifers must have some mechanism to resist acidity. Living fresh-water ostracodes were found in relatively large numbers at two acidic artificial ponds in the study area. The sediment, however, contains virtually no empty carapaces. The few valves that were found lack calcium carbonate and have only the chitin liner. An ostracode can apparently regulate the hydrogen-ion concentration in the area of the carapace while alive, but after death the valves are destroyed quickly by the acid waters.

Available data on the effect of hydrogen-ion concentration on ostracodes and foraminifers indicate that pH is not a factor in distribution of living forms but may be important in the preservation of the tests; thus, pH is very important in determining the abundance of specimens encountered in sediment samples.

The pH values obtained in the area of the present study by using short range p Hydrion paper are not accurate in detail. The values do show, however, the general increase in pH from less than 6 (acid) in the Neuse River at New Bern and the Pamlico River at Washington to 7 (neutral) on the Atlantic shoal of Ocracoke Inlet and in Cape Lookout Bight.

Salinities in the estuaries near New Bern and Washington ranged from 0.5 to 5 ‰. The surrounding areas are swampy so that the numerous creeks draining from swamps undoubtedly introduce organic acids into the estuaries so as to lower pH values. The salinities are low enough so that pH values are not immediately neutralized.

Calcium carbonate, carried in solution by rivers, is needed as a raw material by animals that construct shells. Hoskin (1959) stated that the small streams in the headwaters of the Neuse River had an abnormally low calcium carbonate content (28 ppm). This may explain, in part, the lack of fresh-water ostracodes in many of the natural streams, ponds, and upper portions of the estuaries. If the calcium carbonate content does not increase appreciably downstream, the possibility exists that insufficient calcium carbonate is available for the construction of shells and that insufficient bicarbonate ions are in solution to neutralize effectively the acid waters of the estuaries.

In the estuaries calcareous Foraminifera are very rare; the fauna is composed almost entirely of arenaceous Rhizopodea. Ostracodes are virtually nonexistent. The bottom of one core contains a calcareous foraminiferal and ostracode fauna, but the species are forms that lived and were buried under different conditions from those now existing in the estuaries. Diatoms are plentiful, but the siliceous tests are highly resistant to acid conditions.

In the estuaries, the acid conditions and the probable lack of bicarbonate ions either to neutralize the acids or make calcium carbonate available for the construction of shells, are responsible for the lack of ostracodes and calcareous foraminifers.

The marsh fauna is composed mainly of arenaceous foraminifers. Ostracodes also are present in fairly large numbers, but most specimens had both valves intact with appendages protruding between them, indicating that the animals either had been alive at time of collection or had been dead for such a short period that decomposition of the soft parts was not in an advanced stage. Single valves were rare, and most were abraided. *Ammonia limbatobeccarii* was the only calcareous foraminiferal species present in the marsh; it was very abundant. The number of living specimens is not known although the state of preservation of the tests is such that most may have been living at time of collection.

SUBSTRATUM

Studies in Pamlico Sound and Core Sound revealed no important correlation between faunal distribution and sediment type. Both the finer- and coarser-grained sediments within particular environments contain faunas that are similar in species and even in relative abundance of species. The coastal-lagoon environment, which constitutes most of southern Pamlico Sound, is essentially bisected in an east-west direction by Brant Shoal. This shoal, however, does not form a division line for either sediment type or faunal composition, even though it separates the Neuse River drainage from that of the Pamlico-Tar and Pungo Rivers.

The river estuaries have slightly higher populations in the centers of the channels where the finer sediments occur, but the faunal composition is the same as that of the coarser-grained sediments of the estuaries.

The tidal-delta distributaries having bottoms composed of medium- to coarse-grained sand are either barren or contain few individuals. Sediment type alone is not thought to be responsible for lack of fauna, but rather the currents are of sufficient force to winnow out not only the finer sediments but also the microfauna. The three samples taken in Barden Inlet, which probably has the swiftest tidal currents in the area, were barren.

The organic muds adjacent to the marsh contain a characteristic marsh-type fauna, but this same fauna is present also in areas where sands are adjacent to the marsh flats.

DEPTH

The waters of the study area, as stated previously, are extremely shallow and the microfauna has no apparent zoning due to the combination of factors commonly associated with depth. The shoalness of the water, however, possibly has an influence on the distribution of marine plants. This influence is discussed below.

TURBIDITY

The turbidity of the waters caused by their almost constant agitation by winds reduces both light and transparency in the region studied. The depths are so slight that most of the turbidity is caused by the stirring of bottom sediment by wind-generated waves and currents.

Turbidity can reduce the light necessary for the development of a marine bottom flora, which in turn could support a population of certain species of ostracodes and foraminifers. The marine plant *Zoostera* is restricted to waters less than two feet deep. The deeper areas lack bottom plants.

PLANTS

Several marine and semiaquatic plants have a definite influence on the distribution of some species of Foraminiferida and Ostracoda. The most distinctive association is that for the species of Rhizopodea in the *Spartina* complex of the salt marsh. The genera and species of the marsh foraminifers have been mentioned previously in the discussion on temperature. This assemblage is characterized by numerous arenaceous species and few calcareous representatives. In the study area the marsh fauna was sampled at Nelson Bay including its tidal stream, Taylor Creek, and from near the northern end of Portsmouth Island. Of the ostracode fauna present only *Aurila conradi littorala* appeared limited to the marsh. Other species were present, some rather abundantly, but they also were found in equal abundance in some of the other environments in the region.

Patches of *Zoostera* occur in Core Sound adjacent to the barrier beaches. These grasses were relatively inaccessible and the fauna was not studied.

The *Spartina* complex of the salt marsh occurs along most of the low-lying shores of the sounds and estuaries but is replaced locally by beach ridges. *Spartina* and *Zoostera* were the only marine plants of consequence in the area, and they were restricted to the intertidal and shallow-water zones. The main body of Core and Pamlico Sounds is devoid of bottom plants.

CURRENTS AND WAVES

The tidal currents in the inlets are of sufficient force to prevent the establishment of a microfauna in the tidal channel. Samples from three stations in Barden Inlet were barren. The population in the vicinity of Drum Inlet was very small, the specimens found being away from the main channel. The total population in the vicinity of Ocracoke Inlet is fairly large, but most stations were located on the interdistributary flats where the velocity of the tidal currents is less. Samples taken from the channels were either barren or contained only a few isolated specimens.

The currents in the rivers and the main body of the sound normally are very slight and have no apparent affect on the distribution and abundance of the species.

Wave motion is of importance in the area especially in the surf zone at Ocracoke Inlet where the breakers prevent the establishment of a microfauna. Wind-driven waves in the sounds keep the bottom in almost constant agitation.

Ostracode instars were counted to determine if any relationship existed between the percentage of instars and the environmental energy levels within the region. CURTIS (1960) defined environmental energy level as representing the amount of energy (mechanical, chemical, thermal, etc.) used in varying the physical and chemical characteristics of the environment. High-energy environments are unstable, with changing physical and chemical conditions; low-energy environments are relatively more stable, with a less variable physical-chemical character. She related the percentage of instars to the environmental energy levels and found that instars composed 30 percent of the total population in the offshore areas where the energy levels were low. Nearshore, where energy levels are much higher, the instars made up 60 percent of the fauna.

In the Pamlico Sound area, the shallow water, the usually strong winds, and strong tidal currents near the inlets make this a region of generally high environmental energy levels. The percentage of instars to total ostracode population was approximately 50 percent for the whole region, and this same figure was true for the different environments within the region. The constant agitation of the bottom, however, may be a factor accounting for the low abundance.

DISTRIBUTION OF FAUNA

On the following tables (Tables 1-8) are recorded all the specimens found in the area of investigation. The figures show the actual number of individuals obtained at each station. The percentage distribution method of presentation was not used because it does not emphasize the low populations. Each ostracode valve was counted as a specimen, that is, if the carapace was complete it was counted as two valves. The number of ostracode instars are presented at the bottoms of the ostracode charts, although they are not included on the main portions of the tables.

The distribution of the most abundant species, with the exception of the miliolids, which are shown as a group, are plotted on maps (Figs. 8-15). The distribution of species in the marsh foraminiferal assemblage in Nelson Bay and Taylor Creek is indicated on Figure 16.

RHIZOPOD AND OSTRACODE BIOFACIES

The faunules of the southern Pamlico Sound region are divisible into five biofacies, 1) an estuarine biofacies, 2) an open-sound biofacies, 3) a tidal-delta biofacies (including a sound-delta and marine-delta subfacies), 4) a salt-water lagoon biofacies, and 5) a salt-marsh biofacies. The important features of the environments and the characteristic genera and species are given below.

TABLE 1. *Numerical Distribution of Ostracodes and Rhizopods at Southern Pamlico Sound Stations 1-17 (Essentially Estuarine Biofacies).*

STATION NUMBER	1	2	2	3	3	3a	3a	3b	3c	3c	4	4	5	5	5a	5a	5b	5b	6	6	7	7a	7b	7b	7c	7d	8	8
T= TOP B= BOTTOM OF CORE		T	B	T	B	T	B		T	B	T	B	T	B	T	B	T	B	T	B			T	B			T	B
THECAMOEBINA & FORAMINIFERA																												
Difflugia capriolata	1																											
D. oblonga									1																			
D. urceolata																												
Haplophragmoides wilberti																							11	5				4
Ammoastuta inepta																		1		1			1					
Ammobaculites pamlicoensis	7	7	15				7				10						27	8	9	4			47	1				
A. crassus	11	5	16	13	3	4	4		78	40	17	3	5	4			19	15	12	5	2		6	5			2	
A. dilitatus				10								4	5										3				1	
A. exilis		5	5	10			2		25	20	4						1				5		1				6	
A. neusensis	25	28	16	15		18	13				18	15	57	30			105	13	17	20			38	43			57	30
Ammotium salsum									2		2	2		3				4	20	3	3		13	6			42	
Miliammina fusca	36	12	38			4	8		2	5	5		7			1		15	4	3			1					
Trochammina inflata																							2					
T. macrescens																												
Arenoparella mexicana																							3					
Elphidium incertum																		5										
E. tumidum																		2										
Ammonia limbatobeccarii																						2						
A. tepida	1																	8										5
TOTAL	**81**	**57**	**90**	**48**	**3**	**26**	**34**		**108**	**65**	**56**	**24**	**74**	**37**		**1**	**152**	**71**	**62**	**36**	**10**	**2**	**126**	**60**			**108**	**39**
OSTRACODA																												
Cyprideis sp. cf. *C. torosa*																		3										
Perissocytheridea sp.																		6										
Cytheromorpha pascagoulaensis																		16										
Cytherura elongata																		2										
Cushmanidea echolsae																		3										
C. seminuda																		43										
INSTAR																		43										
ADULT																		30										
TOTAL																		**73**										

STATION NUMBER	9	9	10	10	10a	10a	10b	11	11	11a	11a	11b	12	13	13a	13b	13b	13c	13c	14	14	15	15	16	16	17	17a	17b
T=TOP B=BOTTOM OF CORE	T	B	T	B	T	B		T	B	T	B					T	B	T	B	T	B	T	B	T	B			
THECAMOEBINA & FORAMINIFERA																												
Difflugia capriolata																		14										
D. oblonga																		19		8								
D. urceolata																		7										
Haplophragmoides wilberti																												
Ammoastuta inepta				1																				43	16			
Ammobaculites pamlicoensis	5		47	3	48			8	18				3			4	3										1	
A. crassus		80	16	7	73	80		14	15				8			9	43						3	45	9		6	37
A. dilitatus																												
A. exilis		39	6	10	6	39		4					10			18	27							13	5			
A. neusensis	19		14	37	5			36	35				12			12	12										5	
Ammotium salsum	5			2	9			7		17	12					16		27							4		4	5
Miliammina fusca	2	2	2		1	2				1			4			4	10	5				1		29	4		1	
Trochammina inflata																												
T. macrescens																											1	
Arenoparella mexicana																												
Elphidium incertum																												
E. tumidum																												
Ammonia limbatobeccarii																												
A. tepida																												
TOTAL	**31**	**121**	**85**	**60**	**142**	**121**		**69**	**68**	**18**	**12**		**37**			**63**	**95**	**72**		**8**		**1**	**3**	**130**	**38**		**18**	**42**
OSTRACODA																												
Cyprideis sp. cf. *C. torosa*																												
Perissocytheridea sp.																												
Cytheromorpha pascagoulaensis	1																											
Cytherura elongata																												
Cushmanidea echolsae																												
C. seminuda																												
INSTAR	0																											
ADULT	1																											
TOTAL	**1**																											

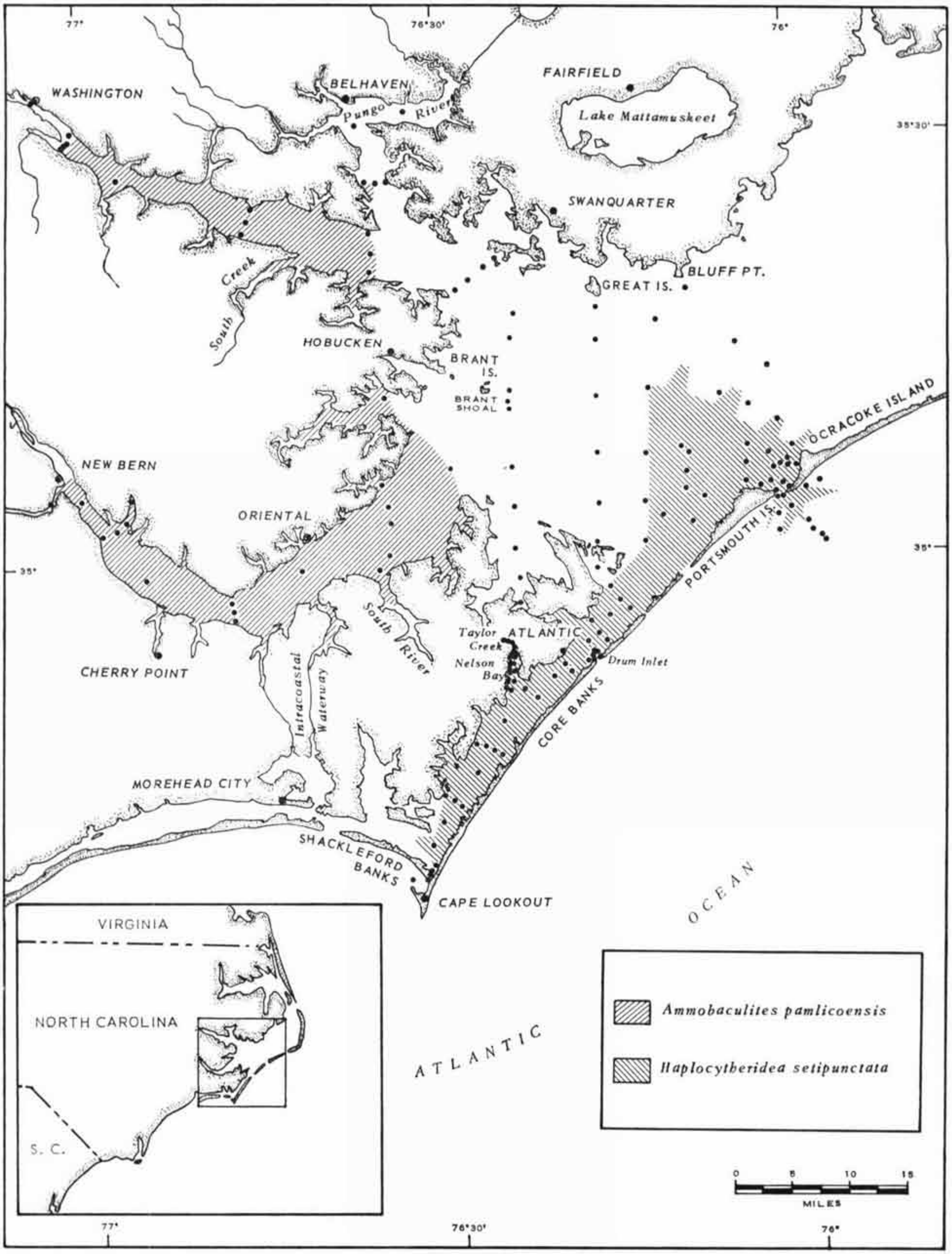


FIGURE 8. Distribution in southern Pamlico Sound region of *Ammobaculites pamlicoensis* and *Haplocytheridea setipunctata*.

TABLE 2. *Numerical Distribution of Ostracodes and Foraminifers at Southern Pamlico Sound Stations 18-42 (Open-sound Biofacies).*

STATION NUMBER	18	18a	18b	18b	18c	18c	19	20	20	21	22	23	23	24	25	26	27	28	29	29
T=TOP B=BOTTOM OF CORE			T	B	T	B		T	B			T	B						T	B
FORAMINIFERA																				
Haplophragmoides wilberti					2															
Ammobaculites pamlicoensis			2					2	27											
A. crassus			5			7			15											
A. dilitatus					2						1					4				
A. exilis						6														
A. neusensis			6					6	38											
Ammotium salsum			1		13	1			14											
Elphidium brooklynese											5									
E. clavatum											34			2						
E. gunteri											4									
E. incertum			1							1	7									
E. galvestonense											1					5		2		
Ammonia limbatobeccarii						1	1									12	2	12		
A. sobrina																				
A. tepida																				
TOTAL			15		17	15	1	8	94	1	52			2		21	2	14		
OSTRACODA																				
Cyprideis sp. cf. *C. torosa*		2																		
Haplocytheridea setipunctata																				
H. bradyi																				
Perissocytheridea sp.																				
Paracytheridea sp. cf. *P. vandenboldi*																				
Cytheromorpha pascagoulaensis																				
C. warneri																				
Acuticythereis multipunctata parva																				
Cytherura elongata																				
Loxoconcha matagordensis											2									
L. purisubrhomboidea																				
Cushmanidea echolsae																	4			
C. seminuda																				
Hulingsina sandersi																				
INSTAR																				
ADULT		2									2						4			
TOTAL		2									2						4			

STATION NUMBER	30	30	31	31	32	33	34	35	36	37	37	38	39	40	41	41	42	42
T=TOP B=BOTTOM OF CORE	T	B	T	B						T	B				T	B	T	B
FORAMINIFERA																		
Haplophragmoides wilberti																		
Ammobaculites pamlicoensis		9																
A. crassus		2																
A. dilitatus										3				1				
A. exilis																		
A. neusensis		18	4															
Ammotium salsum		1	3					1										
Elphidium brooklynese						1		11	7	3	10							
E. clavatum					4	1		87	179	232	175	9	1					7
E. gunteri																		
E. incertum			3	90	9	5	2	38	65	53	93	27						31
E. galvestonense							4					1						
Ammonia limbatobeccarii							1											
A. sobrina									2									
A. tepida				1							1							
TOTAL		30	10	91	13	7	7	137	253	291	279	37	1	1				38
OSTRACODA																		
Cyprideis sp. cf. *C. torosa*																		
Haplocytheridea setipunctata								2	2				1					
H. bradyi							2								4			
Perissocytheridea sp.								2										
Paracytheridea sp. cf. *P. vandenboldi*										2								
Cytheromorpha pascagoulaensis										1								
C. warneri								2	1									
Acuticythereis multipunctata parva								1										
Cytherura elongata												2						
Loxoconcha matagordensis													1					
L. purisubrhomboidea									2	6	1							
Cushmanidea echolsae							1	12	5	1		4	3					
C. seminuda								1										
Hulingsina sandersi										1								
INSTAR								5	3	5			1					
ADULT							3	15	7	6	1	6	4		4			
TOTAL							3	20	10	11	1	6	5		4			

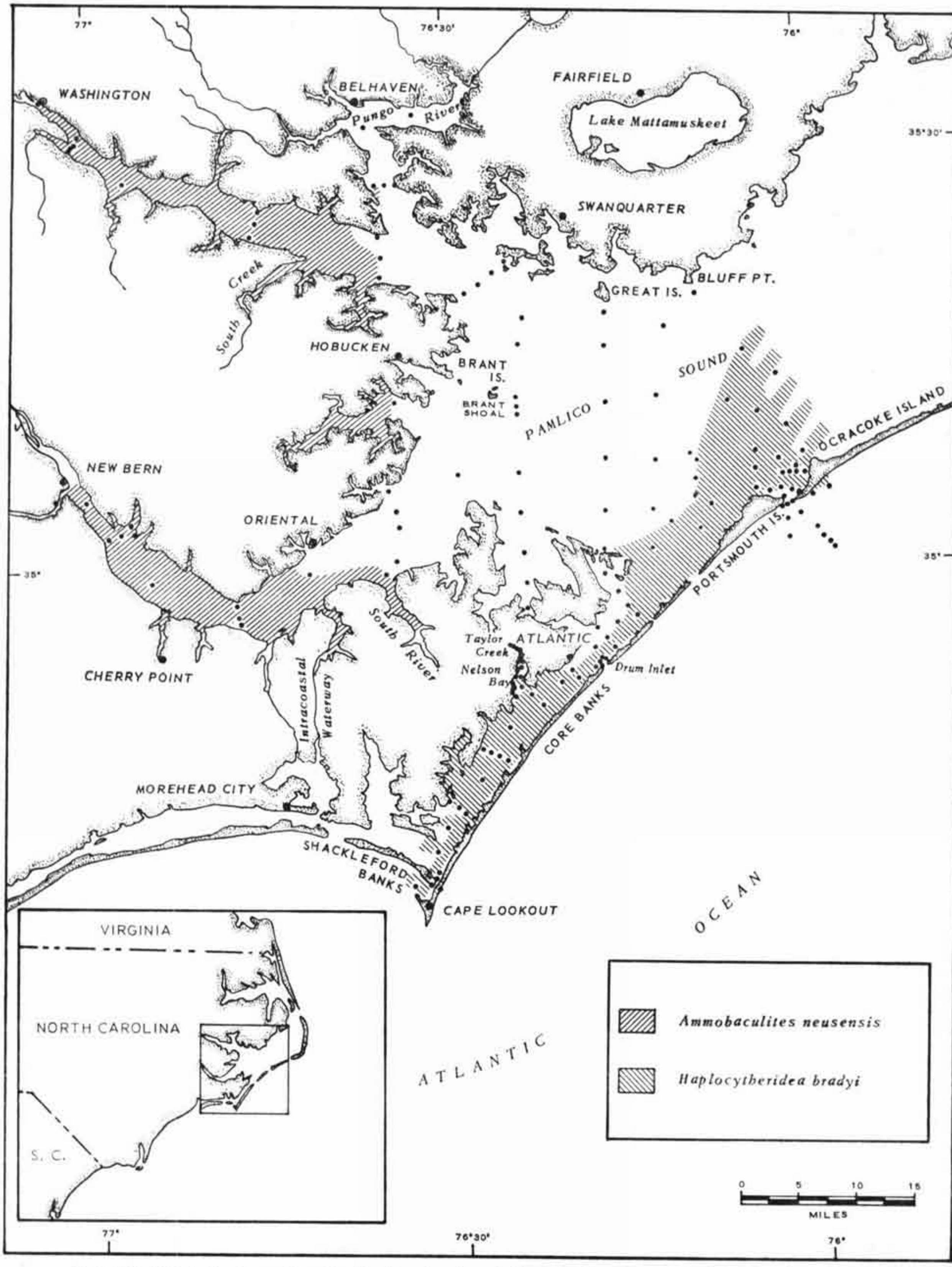


FIGURE 9. Distribution in southern Pamlico Sound region of *Ammobaculites neusensis* and *Haplocytheridea bradyi*.

TABLE 3. *Numerical Distribution of Foraminifers at Southern Pamlico Sound Stations 43-78 (Tidal-delta Biofacies).*

STATION NUMBER	43	44	45	45	46	47	47	48	48	49	50	51	52	53	54	55	56	57	57	58	59
T=TOP B=BOTTOM OF CORE			T	B		T	B	T	B									T	B		
FORAMINIFERA																					
Quinqueloculina compta																					
Q. jugosa																	1				
Q. lamarckiana																	3			1	
Q. microcostata																					
Q. poeyana																					
Q. seminula																	1		1		
Q. triloculiniforma																					
Triloculina oblonga																					
T. trigonula																					
Spiroloculina planulata																					
Pseudononion atlanticus			3	1													1				
Elphidium articulatum			1	1										1							
E. brooklynese				1				12					2		2						
E. clavatum	3		17	27				129	18			3	10	24	7	1		2	6	7	9
E. discoidale																					
E. gunteri			5	4										7							
E. incertum	1		11	16				60	10		2	18	21	16					4	15	7
E. galvestonense	46		92	71	57			1	1		2		1	11			6			4	
E. subarcticum																				2	
Protelphidium orbiculare		1	1	4																	
P. tisburyense														3							
Rosalina columbiensis																					
R. floridana																					
Poroeponides lateralis																	1				
Ammonia limbatobeccarii			5	6									1		1					1	
A. sobrina		11						4													
A. tepida				1																1	
Globigerina bulloides			1																		
Hanzawaia concentrica	1		4	5										1		2		1	2		
H. strattoni																					
Planulina mera														1							
Cibicides lobatulus			6	6										2						2	
Peneroplis proteus																					
TOTAL	**51**	**12**	**146**	**143**	**57**			**206**	**29**		**4**	**21**	**35**	**66**	**10**	**3**	**13**	**3**	**13**	**33**	**16**

STATION NUMBER	60	61	62	63	64	65	65	66	67	68	69	70	71	72	73	74	75	76	77	78
T=TOP B=BOTTOM OF CORE						T	B													
FORAMINIFERA																				
Quinqueloculina compta			2																	
Q. jugosa	1		4						1		2		13	2			1		1	
Q. lamarckiana	1	1							1		1	1	8	1			5		3	
Q. microcostata			5						1											
Q. poeyana																			1	
Q. seminula	1		2								1		1	1			3			
Q. triloculiniforma															1				2	
Triloculina oblonga	1												1							
T. trigonula																			1	1
Spiroloculina planulata																			3	
Pseudononion atlanticus													1						3	
Elphidium articulatum															1		1		2	2
E. brooklynese	9														1		10			
E. clavatum	30	2	3				2	2	3	1	4		2		4				13	
E. discoidale	1																			
E. gunteri				1																
E. incertum	18					1	1		2		1	3					2		1	
E. galvestonense	4	1		8	2	4	2	29	6		6				5	1	4			
E. subarcticum			6												1					
Protelphidium orbiculare																			3	
P. tisburyense																				
Rosalina columbienses																			1	
R. floridana																			3	
Poroeponides lateralis										1		1						1		
Ammonia limbatobeccarii	1								1								2		2	
A. sobrina				1		1														
A. tepida																			1	
Globigerina bulloides																			8	1
Hanzawaia concentrica	3						3						1		3		2		8	
H. strattoni																				1
Planulina mera																				1
Cibicides lobatulus		1	1																	
Peneroplis proteus													1							
TOTAL	**70**	**5**	**23**	**10**	**2**	**6**	**8**	**31**	**15**	**2**	**15**	**5**	**28**	**4**	**16**	**1**	**30**		**56**	**6**

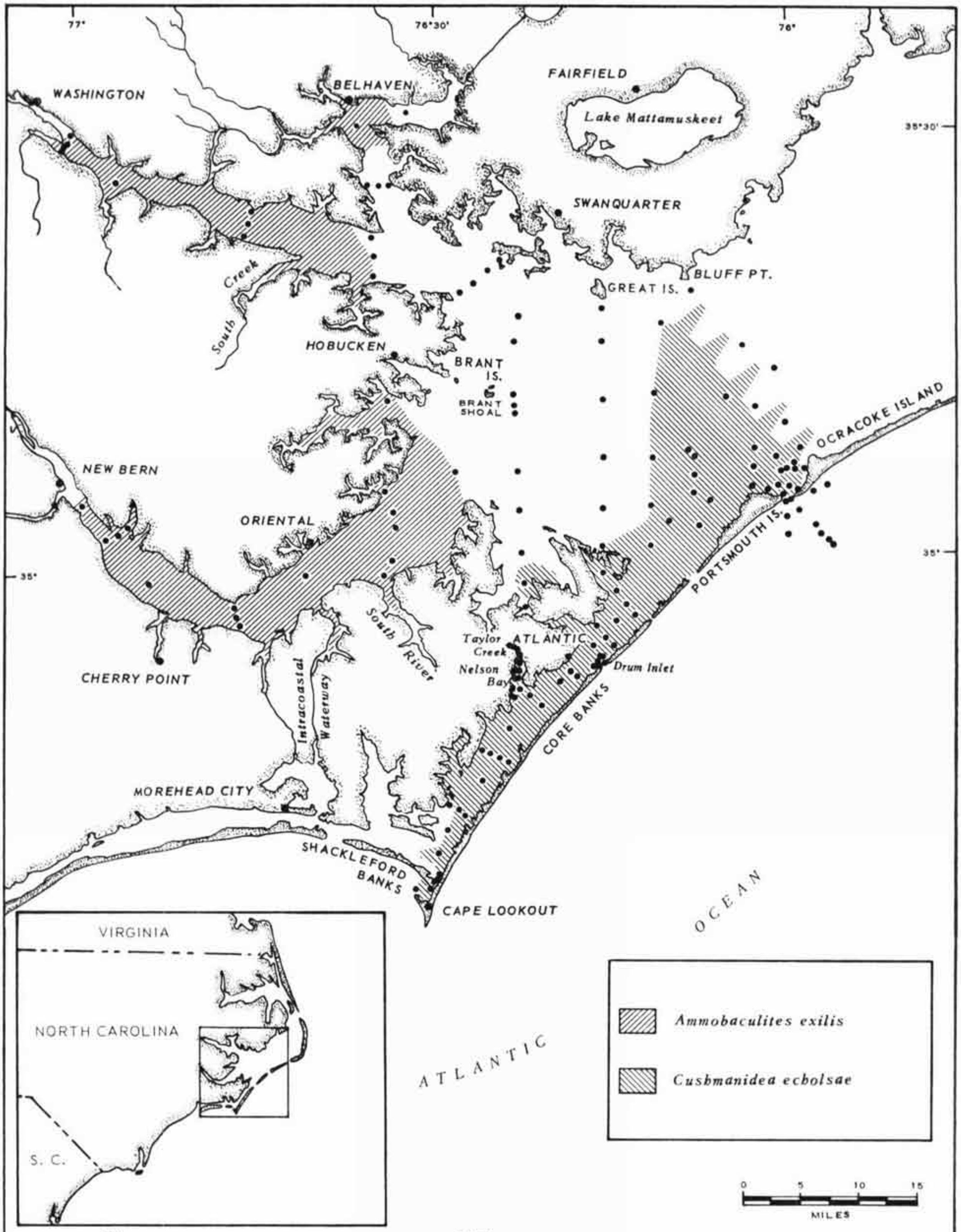


FIGURE 10. Distribution in southern Pamlico Sound region of *Ammobaculites exilis* and *Cushmanidea echolsae*.

TABLE 4. *Numerical Distribution of Ostracodes at Southern Pamlico Sound Stations 43-78 (Tidal-delta Biofacies).*

STATION NUMBER	43	44	45	45	46	47	47	48	48	49	50	51	52	53	54	55	56	57	57	58	59
T=TOP B=BOTTOM OF CORE			T	B		T	B	T	B									T	B		
OSTRACODA																					
Cyprideis sp.																					
Haplocytheridea septipunctata			23	16										3	2		7			4	
H. bradyi				2	10			1			2		2		2						6
H. sp.	2																				
Perissocytheridea sp.														2							
Paracytheridea sp. cf. *P. vandenboldi*				1										1							
Acuticythereis laevissima														2							2
A. nelsonensis			2																		2
A. multipunctata parva			4																	4	
Cytheromorpha pascagoulaensis																					
C. warneri																					
Loxoconcha purisubrhomboidea																					
L. reticularis																					
Basslerites giganticus																					3
B. tenmilecreekensis			8	3													4			4	
Cytherura ? corensis		2	8																	8	
Cytherura elongata																					
C. forulata				1	5								2								8
C. sp.																					
Cushmanidea echolsae			5	12	4			1													
C. seminuda				1	1										1						
C. ulrichi			2																		
Hulingsina ashermani			1	3													1				
H. sandersi	2		2																	2	
Pellucistoma magniventra																					
Hemicythere sp.																					
H. laevicula				2																	
Leguminocythereis whitei																					
Puriana mesacostalis																					
P. rugipunctata			3																		
Cytheretta sp. cf. *C. sahni*																					
INSTAR			30	21	3			1			2			4	1					8	4
ADULT	4	2	28	20	17			1					4	4	4		12			14	17
TOTAL	**4**	**2**	**58**	**41**	**20**			**2**			**2**		**4**	**8**	**5**		**12**			**22**	**21**

STATION NUMBER	60	61	62	63	64	65	65	66	67	68	69	70	71	72	73	74	75	76	77	78
T=TOP B=BOTTOM OF CORE						T	B													
OSTRACODA																				
Cyprideis sp.								2												
Haplocytheridea septipunctata	9		1	1		3	4	3	1						1				8	
H. bradyi	9				2				4			1								
H. sp.																				
Perissocytheridea sp.																				
Paracytheridea sp. cf. *P. vandenboldi*	1																			
Acuticythereis laevissima															2					
A. nelsonensis	2							2												
A. multipunctata parva	4																			
Cytheromorpha pascagoulaensis				2																
C. warneri																				1
Loxoconcha purisubrhomboidea	2					13													2	1
L. reticularis																			2	
Basslerites giganticus																	2		1	
B. tenmilecreekensis	19																		9	
Cytherura ? corensis																			4	
Cytherura elongata						2									2				2	
C. forulata	6																		3	
C. sp.																			1	1
Cushmanidea echolsae	11				2	8		2												
C. seminuda	2																		4	
C. ulrichi																				
Hulingsina ashermani					1							2	6							3
H. sandersi	1																2		4	
Pellucistoma magniventra													1						3	2
Hemicythere sp.																			1	
H. laevicula																				
Leguminocythereis whitei																				1
Puriana mesacostalis																			1	
P. rugipunctata	2			2															3	
Cytheretta sp. cf. *C. sahni*													1					1		
INSTAR	21					9	1	1				2							16	6
ADULT	47		1	5	5	17	3	8	5			1	8		5		4	1	32	3
TOTAL	**68**		**1**	**5**	**5**	**26**	**4**	**9**	**5**			**8**	**8**		**5**		**4**	**1**	**48**	**9**

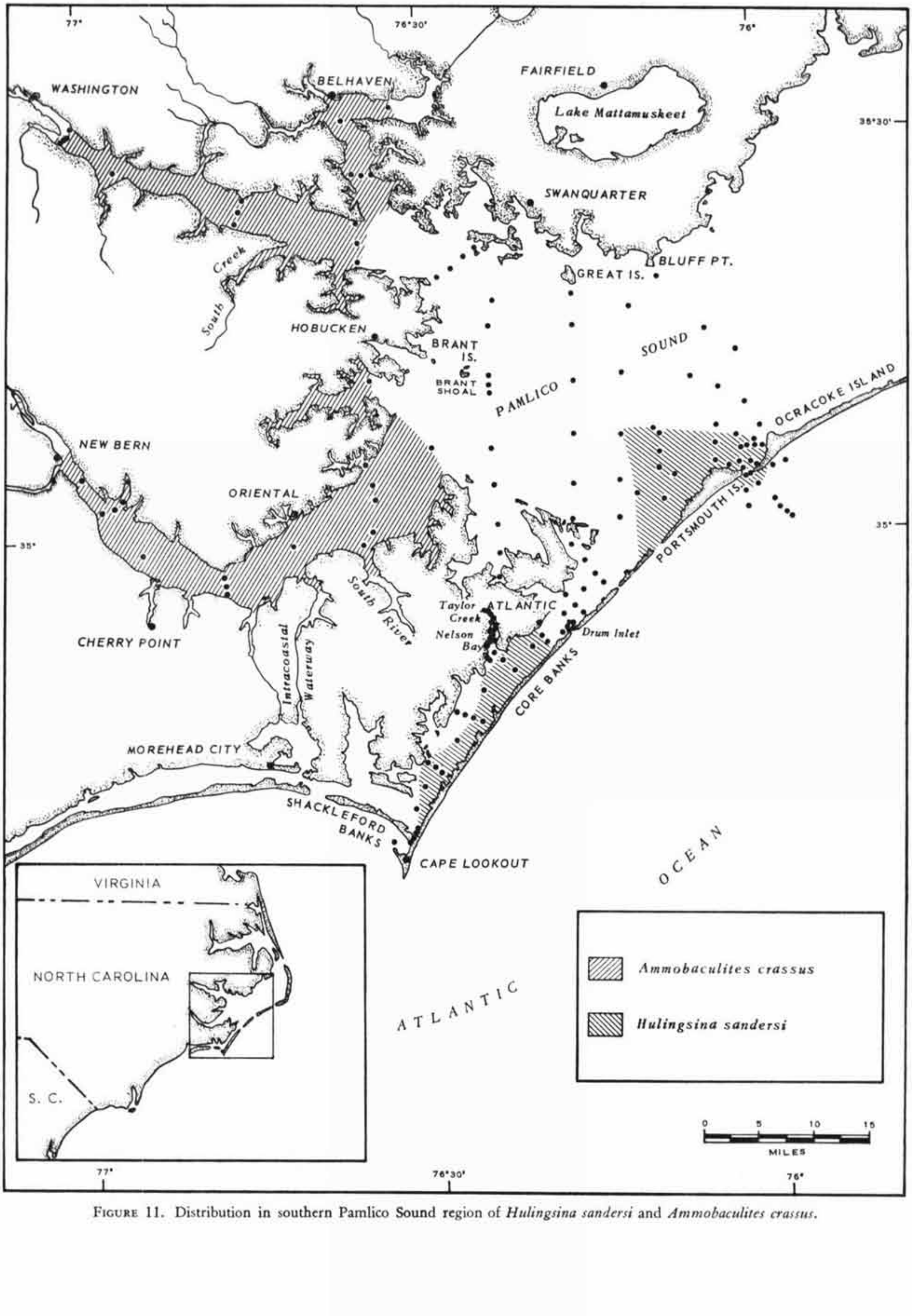


FIGURE 11. Distribution in southern Pamlico Sound region of *Hulingsina sandersi* and *Ammobaculites crassus*.

TABLE 5. *Numerical Distribution of Foraminifers at Southern Pamlico Sound Stations 79-102 (Essentially Salt-water-lagoon Biofacies).*

STATION NUMBER	79	80	81	82	83	83	84	85	86	86	86a	86b	87	87	88	88	88a	88b	88b	88c	88c	89	89	90	90	90a	90a
T=TOP B=BOTTOM OF CORE					T	B			T	B			T	B	T	B		T	B	T	B	T	B	T	B	T	B
FORAMINIFERA																											
Ammobaculites dilitatus																						2				1	
Ammotium salsum																										3	
Quinqueloculina bicornis						3																					
Q. jugosa	1												1	1													
Q. lamarckiana	2																										
Q. microcostata						17																					
Q. poeyana	1					11	4																				
Q. seminula																											
Q. sp.																											
Triloculina oblonga						23																					
T. rotunda						1																					
Trochammina inflata							1										1							1			
Pseudononion atlanticus						1								2		4		1									
Elphidium articulatum	4																					1					
E. brooklynese	1					2								2										1	1		7
E. clavatum	28					2	5	1	8	1			2	12		4		1	6			93	29	37	1	12	82
E. discoidale	1																										
E. gunteri						13	1	1	10	2	4			5		4											
E. incertum								2	13	3		2	9	8					3			43	14	10		8	27
E. galvestonense						7	7	9	9	2	50	5	37	46			2		2			5		11			
E. subarcticum																						7	1				
E. tumidum						67							1			14										1	2
Protelphidium orbiculare						73	2									34											3
P. tisburyense						5																					
P. sp.																1											
Rosalina columbiensis	2					2																					
Ammonia limbatobeccarii							5					2							3					1	7		
A. sobrina											1																
A. tepida	2					9										3							1				
Globigerina bulloides	1															11											
Cibicides lobatulus																1											
Hanzawaia concentrica	1																										
TOTAL	**44**					**236**	**25**	**13**	**40**	**8**	**55**	**9**	**50**	**76**		**76**	**3**	**2**	**14**			**151**	**45**	**62**	**9**	**25**	**121**

STATION NUMBER	91	91	92	92	92a	92a	93	93	94	94a	94a	94b	94b	95	96	96a	96a	96b	96c	97	98	99	100	101	102
T=TOP B=BOTTOM OF CORE	T	B	T	B	T	B	T	B		T	B	T	B			T	B								
FORAMINIFERA	1															1									
Ammobaculites dilitatus																2									
Ammotium salsum																									
Quinqueloculina bicornis																									
Q. jugosa																									
Q. lamarckiana																					1	1			
Q. microcostata																									
Q. poeyana									1																1
Q. seminula								1														1		1	1
Q. sp.							1																		
Triloculina oblonga									6																
T. rotunda																									
Trochammina inflata	1																								
Pseudononion atlanticus																									
Elphidium articulatum				1					1		2				1										
E. brooklynese	5						1				5				5	4									
E. clavatum	51	17	8	35			65	24		24	31			1	10	20						1			2
E. discoidale																									
E. gunteri		2		2			1		3						1				2						
E. incertum	26	8	3	9	2		4	3	2	10	39			1		14									
E. galvestonense	16	2		1	1		6	2	10	4	11	7	7	35	5			12	18	2	10	9	1	3	
E. subarcticum	1										2														
E. tumidum									1																
Protelphidium orbiculare										2						15									1
P. tisburyense																20									
P. sp.																									
Rosalina columbiensis																									
Ammonia limbatobeccarii	3			1						1	5	2			2	6			4						1
A. sobrina																									
A. tepida	1															5									
Globigerina bulloides																									
Cibicides lobatulus																									
Hanzawaia concentrica																					1				
TOTAL	**105**	**29**	**11**	**49**	**3**		**78**	**30**	**24**	**41**	**95**	**9**	**7**	**37**	**24**	**87**		**12**	**24**	**2**	**12**	**12**	**1**	**4**	**6**

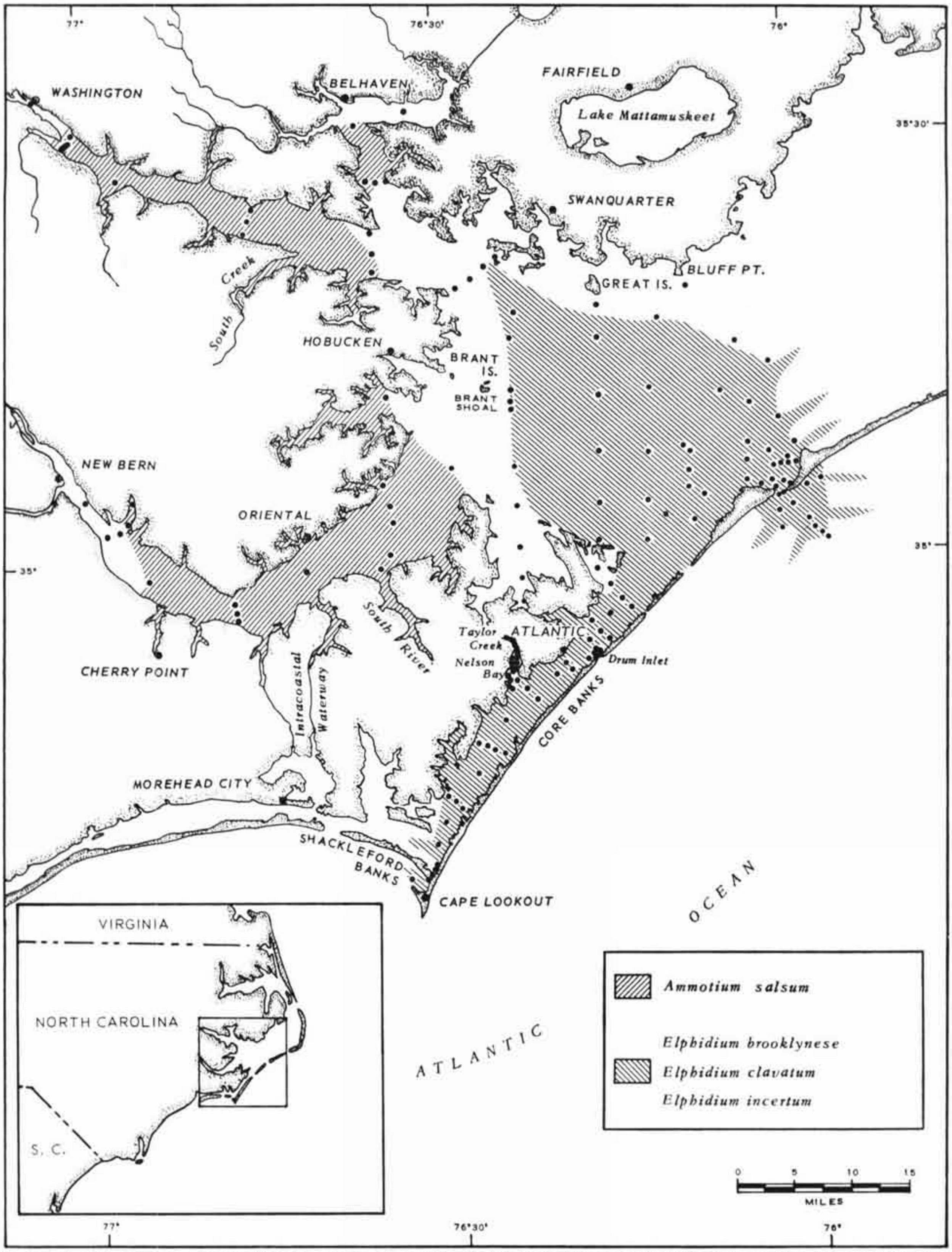


FIGURE 12. Distribution in southern Pamlico Sound region of the *Elphidium brooklynense-Elphidium clavatum-Elphidium incertum* fauna and *Ammotium salsum*.

TABLE 6. *Numerical Distribution of Ostracodes at Southern Pamlico Sound Stations 79-102 (Essentially Salt-water-lagoon Biofacies).*

STATION NUMBER	79	80	81	82	83	83	84	85	86	86	86a	86b	87	87	88	88	88a	88b	88b	88c	88c	89	89	90	90	90a	90a
T=TOP B=BOTTOM OF CORE					T	B			T	B			T	B	T	B		T	B	T	B	T	B	T	B	T	B
OSTRACODA																											
Cyprideis sp. cf. *C. torosa*	2					24										3											
Haplocytheridea setipunctata		1				48	18	3	1		14	5	5	7		9											
H. bradyi	15							7			2		1	2			1										
H. sp.																											
Paracytheridea sp. cf. *P. vandenboldi*	1					1																					
Neolophocythere subquadrata								4			3																
Acuticythereis laevissima							2																				
A. nelsonensis						2	2				3					1											
A. multipunctata parva						2	4																				
Cytheromorpha pascagoulaensis																							2			4	
C. warneri	1					1										1										6	
Loxoconcha purisubrhomboidea	1					15	7																				
L. reticularis																3											
Bassleriles giganticus	3						3																				
B. tenmilecreekensis						2	7															1					
Cytherura ? corensis						14										16											
Cytherura elongata											2																
C. forulata									2																		
C. johnsoni						5	2																				
C. sp.	1															2											
Cushmanidea echolsae	15						16		3	2		16	1			15						2		11			
C. seminuda	3											1															
C. ulrichi	1																										
Hulingsina ashermani	4															5											
H. sandersi						5	15				2	6				2								8		2	
Pellucistoma magniventra	4																										
Hemicythere sp.	1																										
H. laevicula						2																					
Aurila conradi littorala						9										2											
Leguminocythereis whitei	1					1										2											
L. sp.																5											
Puriana mesacostalis	1					2										4						1					
P. sp.	2																										
Cytheretta sp. cf. *C. sahni*	3																										
Actinocythereis exanthemata	1																										
INSTAR	40					84	29	2	2	2	7	10	6	3		48						4	2	2		4	
ADULT	20	1				49	47	12	4		19	18	1	6		22	1							17		8	
TOTAL	**60**	**1**				**133**	**76**	**14**	**6**	**2**	**26**	**28**	**7**	**9**		**70**	**1**					**4**	**2**	**19**		**12**	

STATION NUMBER	91	91	92	92	92a	92a	93	93	94	94a	94a	94b	94b	95	96	96a	96a	96b	96c	97	98	99	100	101	102
T=TOP B=BOTTOM OF CORE	T	B	T	B	T	B	T	B		T	B	T	B			T	B								
OSTRACODA																									
Cyprideis sp. cf. *C. torosa*	1																								
Haplocytheridea setipunctata	6	7	1				1		12	2	1	3	2	1				1	3						
H. bradyi	1														2										
H. sp.															2										
Paracytheridea sp. cf. *P. vandenboldi*																									
Neolophocythere subquadrata	6		1	1																					
Acuticythereis laevissima																									
A. nelsonensis	4	1									2														
A. multipunctata parva	4											2				1									
Cytheromorpha pascagoulaensis															2										
C. warneri																			1						
Loxoconcha purisubrhomboidea	1																								
L. reticularis																									
Bassleriles giganticus																									
B. tenmilecreekensis																									
Cytherura ? corensis																									
Cytherura elongata	6		2																2						
C. forulata	4		2																						
C. johnsoni																									
C. sp.																									
Cushmanidea echolsae	6								3	3				2	2				2						
C. seminuda	3								2					2											
C. ulrichi																									
Hulingsina ashermani	1																								
H. sandersi	6	5		2	2																				
Pellucistoma magniventra																									
Hemicythere sp.																									
H. laevicula																									
Aurila conradi littorala																									
Leguminocythereis whitei																									
L. sp.																									
Puriana mesacostalis																									
P. sp.																									
Cytheretta sp. cf. *C. sahni*																									
Actinocythereis exanthemata																									
INSTAR	8	7	2	3			1		11	5	1	3	2	3					2						
ADULT	41	6	4		2				6		2	2		8	8	1		1	6						
TOTAL	**49**	**13**	**6**	**3**	**2**		**1**		**17**	**5**	**3**	**5**	**2**	**11**	**8**	**1**		**1**	**8**						

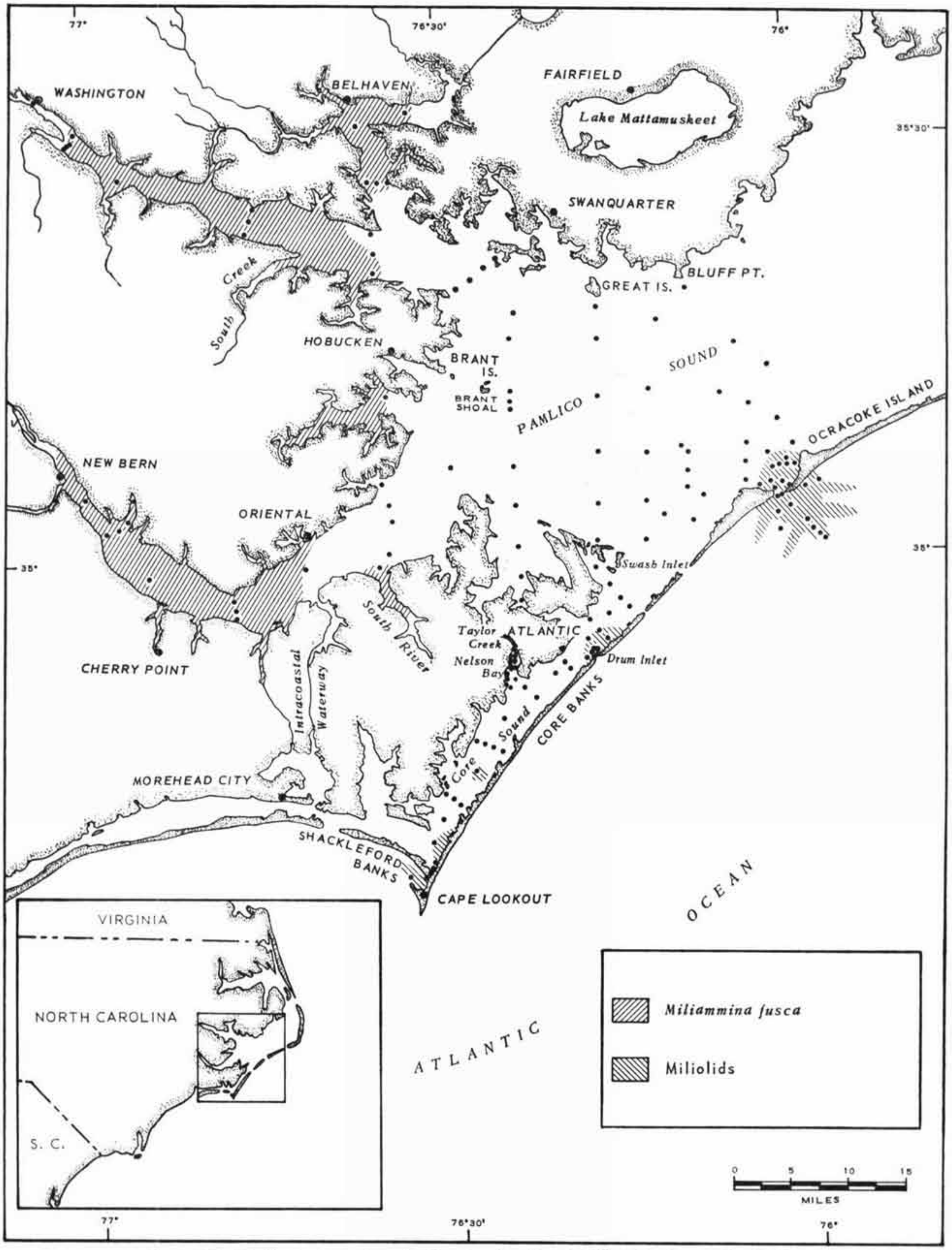


FIGURE 13. Distribution in southern Pamlico Sound region of *Miliammina fusca* and miliolids.

TABLE 7. *Numerical Distribution of Rhizopods at Southern Pamlico Sound Stations 103-116 (Essentially Salt-marsh Biofacies).*

STATION NUMBER	103	104	105	106	107	107	108	109	109 a	110	a	110 a	111	111 a	112 a	112	112 a	112 b	112 c	113	113	113 a	113 b	113 c	114	115	116	
T=TOP B=BOTTOM OF CORE					T	B					T	B			T	B				T	B							
THECAMOEBINA & FORMINIFERA																												
Difflugia oblonga		1																										
D. urceolata		1										1																
Haplophragmoides manilaensis		4	10												1			1		1		2						
H. wilberti		14		8																							1	51
Ammoastuta inepta		2			22	5																				1		
Ammobaculites dilitatus			10						8								1					9	1					2
Ammotium salsum		5	19			2		29	46				3				13			10		14					2	
Miliammina fusca		15	6		11	10	1		8		1																	
Quinqueloculina compta																						3	7					
Q. sp.						1																						
Tiphotrocha comprimata		17	6	3	34	6	15		2									1										
Trochammina inflata	2	4	21	2	45	2	34	3	27		39							26	1			26	12				2	71
T. macrescens		4	4								6																	
Arenoparella mexicana		17	8	6	41	5	31		1								1											
Elphidium brooklynese																6												
E. clavatum										12						45				2	33				3			
E. gunteri									2								2	1				12						
E. incertum						2				4						6					4				2			
E. galvestonense								2	1	2							2	2				13			1		2	12
E. subarcticum										1											1							1
E. tumidum									1	1										1	1							
Protelphidium orbiculare						1																						2
P. tisburyense										1						1												1
Ammonia limbatobeccarii			7	1			5	231	73	1						1	132	175			1	180	7				2	33
A. tepida										1			1			2					1							
TOTAL	**2**	**84**	**91**	**20**	**153**	**34**	**86**	**265**	**169**	**23**	**46**	**1**	**4**		**1**	**61**	**151**	**206**	**1**	**14**	**41**	**259**	**21**		**6**	**1**	**9**	**173**

TABLE 8. *Numerical Distribution of Ostracodes at Southern Pamlico Sound Stations 103-116 (Essentially Salt-marsh Biofacies).*

STATION NUMBER	103	104	105	106	107	107	108	109	109 a	110	110 a	110 a	111	111 a	112	112	112 a	112 b	112 c	113	113	113 a	113 b	113 c	113 c	114	115	115 a	116
T=TOP B=BOTTOM OF CORE					T	B					T	B			T	B				T	B			T	B				
OSTRACODA																													
Cypria opthalmica																											4		
Cyprideis sp. cf. *C. torosa*			2																									2	
Haplocytheridea setipunctata								65	4	1			5				19	2				1							
H. bradyi															2														
Acuticythereis nelsonensis								8	16									2											
A. multipunctata parva								2	4								2	12											
Cytheromorpha warneri								2									2			4		2							
C. pascagoulaensis			2																										
Loxoconcha matagordensis								6																					
L. purisubrhomboidea									5								19	1				1	2	1	2				
Cytherura elongata			2						4																				
Cushmanidea echolsae									9				2				3									2			
C. seminuda																													2
C. sp.							8																						
Hulingsina sandersi																							2						
Aurila conradi littorala								27	22								11	6				14				2			
INSTAR			6				2	38	13	1			1				24	2		2		10		1	2	2			
ADULT							6	72	51				6		2		32	21		2		8	4			2	4	2	3
TOTAL			**6**				**8**	**110**	**64**	**1**			**7**		**2**		**56**	**23**		**4**		**18**	**4**	**1**	**2**	**4**	**4**	**2**	**3**

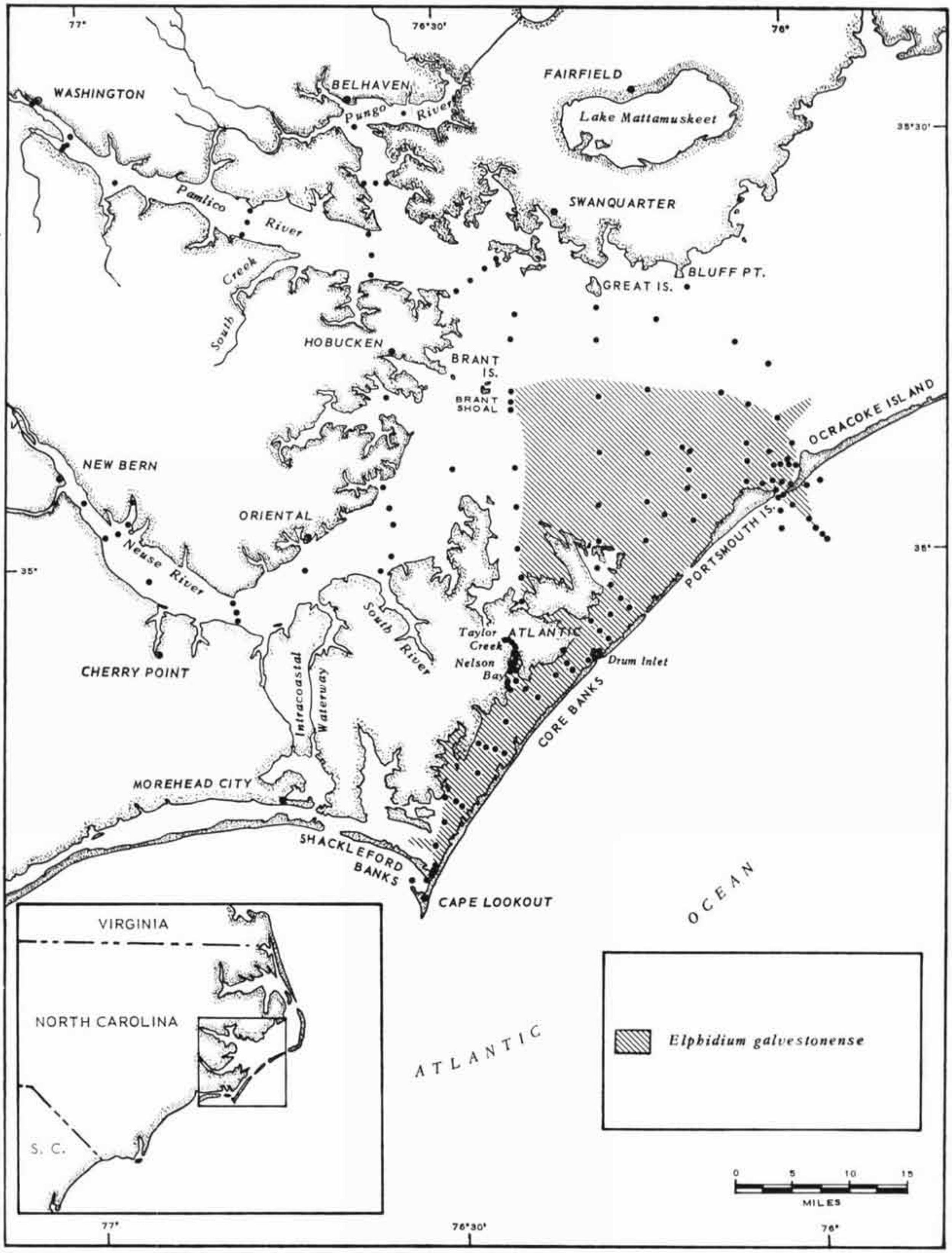


FIGURE 14. Distribution in southern Pamlico Sound region of *Elphidium galvestonense*.

ESTUARINE BIOFACIES

The waters in the estuaries of the Neuse, Pamlico, and Pungo Rivers are characterized by weak currents, high turbidity, slight acidity, and low salinity (0.5 to 12 ‰). The sediments are clay- and silt-sized particles (mainly fecal pellets). Sandy bottoms are present near the river banks.

Arenaceous foraminifers compose the bulk of the microfauna, with *Ammobaculites, Ammotium,* and *Miliammina* the predominant genera. Ostracodes are lacking in the surface sediments except for one observed abraided specimen of *Cytheromorpha pascagoulaensis.*

Core samples indicate that ecologic conditions and the fauna of the recent past are similar to those of the present, although the presence in the bottom segment of a core from the Neuse River (core 5b) of a more marine-type fauna indicates that at times the estuaries are subject to invasions of marine saline water that remains long enough for a polyhaline fauna to become established.

The Rhizopodea are associated with diatoms and highest populations of both groups are in the finer sediments. Three species of *Difflugia* were present at two stations in the Pamlico River, near Washington. These species are found only in areas of low salinity, and near Washington the salinity range was from 0.5 to 2 ‰.

Most Common Species of Estuarine Biofacies.

Ammobaculites pamlicoensis *Ammobaculites crassus* *Ammobaculites dilitatus* *Ammobaculites neusensis*	Essentially limited to estuaries, but also present in western portion of Pamlico Sound.
Ammobaculites exilis	Limited to estuaries.
Ammotium salsum *Miliammina fusca*	Present in other environments, but highest populations in estuaries.

OPEN-SOUND BIOFACIES

The main portion of southern Pamlico Sound is differentiated as an open-sound biofacies. The water in this environment is characterized by weak currents, high turbidity, lack of stratification, and by salinites that range from 12 ‰ near the estuaries to 26 ‰ near the Ocracoke Inlet delta. The substrate consists of fine- to medium-sized sand with minor amounts of clay material.

The open-sound biofacies constitutes a transition zone between the estuarine and tidal-delta biofacies. The western portion of the Sound is dominated by an arenaceous foraminiferal fauna made up chiefly of *Ammobaculites* and *Ammotium.* These forms are gradually replaced eastward by several species of *Elphidium.* Ostracodes are very rare in the western portion of the Sound and more numerous but not abundant in the eastern segment. *Cushmanidea, Loxoconcha,* and *Haplocytheridea* are the predominant genera.

Core samples indicate no important changes either in ecologic conditions or fauna between the present and recent past.

Most Common Species of Open-Sound Biofacies.

Ammobaculites pamlicoensis *Ammobaculites crassus* *Ammobaculites neusensis* *Ammotium salsum*	Present in western portion of Sound.
Elphidium brooklynense *Elphidium clavatum* *Elphidium incertum*	Rare in western portion of Sound; abundant in eastern Sound and other environments.
Loxoconcha purisubrhomboidea *Cushmanidea echolsae*	Present in eastern lagoon; also found in other environments.

The open-sound biofacies is typified by low populations, little species diversity, and the predominance of the *Ammobaculites* fauna in the western portion and the *Elphidium brooklynense, E. clavatum, E. incertum* fauna in the eastern portion.

TIDAL-DELTA BIOFACIES

This biofacies may be divided into two subfacies, a sound-delta subfacies, which includes the sound deltas of Drum and Ocracoke Inlets, and a marine-delta subfacies, which includes the marine delta of Ocracoke Inlet and Cape Lookout Bight.

The tidal-delta biofacies is represented as a whole by the mixing of brackish and marine species. The sound-delta subfacies retains a brackish aspect and the marine-delta subfacies retains a more marine character. Some individuals are carried from one subfacies to another by the strong tidal currents, but many species apparently live in both environments.

SOUND-DELTA SUBFACIES

The water in the sound-delta subfacies is characterized by strong tidal currents (especially in the tidal channels), moderate turbidity, lack of stratification in the water mass, and salinities that range from 24 to 30 ‰. The substrate is composed primarily of medium-sized sand with very minor amounts of clay material.

The sound-delta subfacies is characterized by great species diversity and the mixing of brackish- and normal-marine forms (the brackish-water forms predominate). The foraminiferal fauna is represented mainly by the Elphidiidae and Miliolidae. The *Elphidium brooklynense, E. clavatum,* and *E. incertum* assemblage is important, but is not as abundant as in the open-sound biofacies. *E. galvestonense* is present in large numbers. The miliolids are represented by six species but individuals are not abundant. *Cibicides* sp. cf. *C. lobatulus* and *Hanzawaia concentrica,* both considered to be marine species, are present but rare.

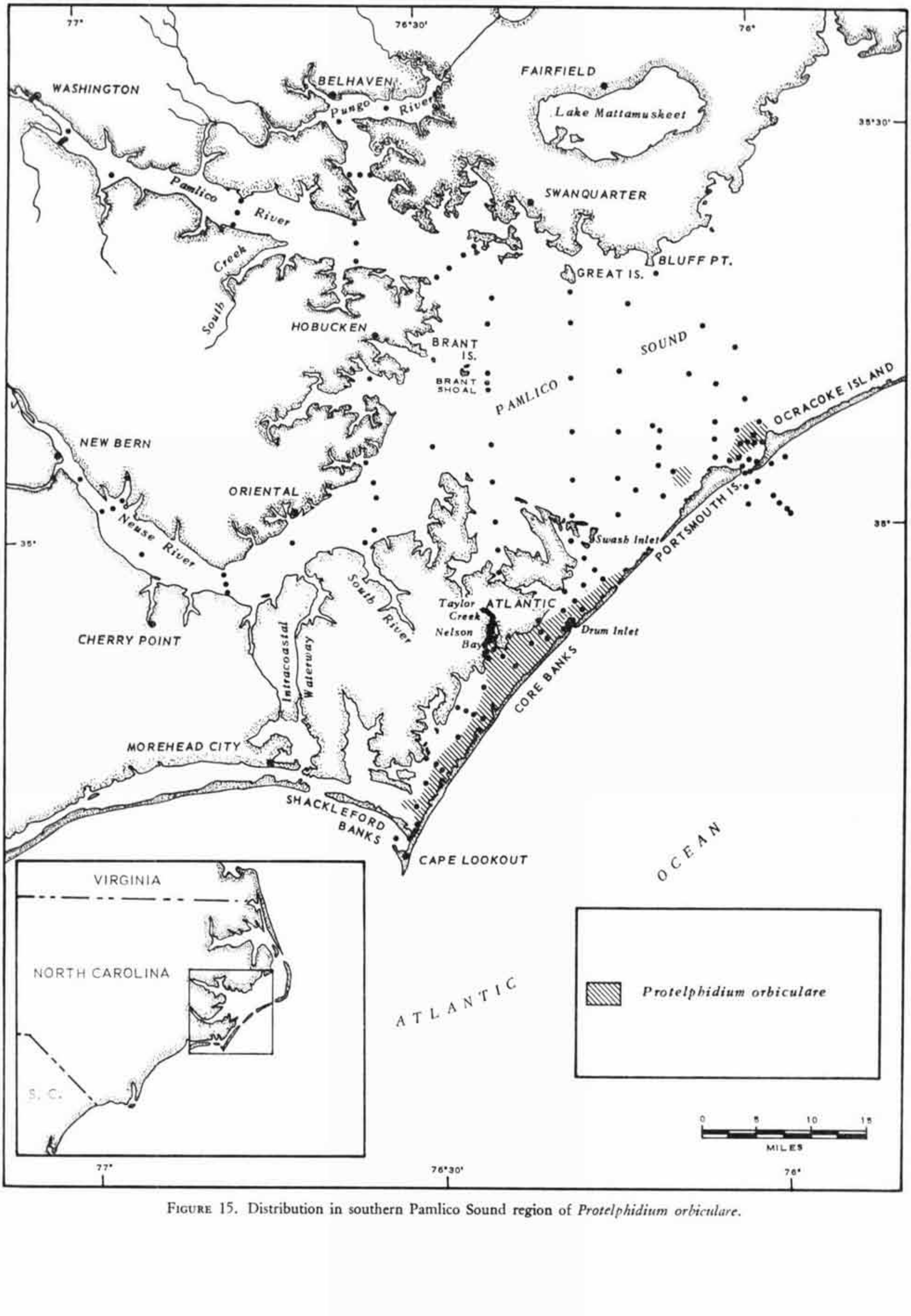


FIGURE 15. Distribution in southern Pamlico Sound region of *Protelphidium orbiculare*.

The ostracodes are represented by a large number of species, but individuals are not numerous. The genera *Haplocytheridea, Basslerites,* and *Cushmanidea* are the most important representatives of this fauna.

The few core samples taken from this biofacies indicate no change in the environment, species diversity, or numbers of individuals between the present and the recent past.

Important Species of Sound-Delta Subfacies.

Elphidium brooklynense *Elphidium clavatum* *Elphidium incertum* *Elphidium galvestonense* *Haplocytheridea setipunctata* *Haplocytheridea bradyi* *Cushmanidea echolsae*	Present at many stations; also found in other environments.
Hanzawaia concentrica	Present at several stations, but in low numbers.

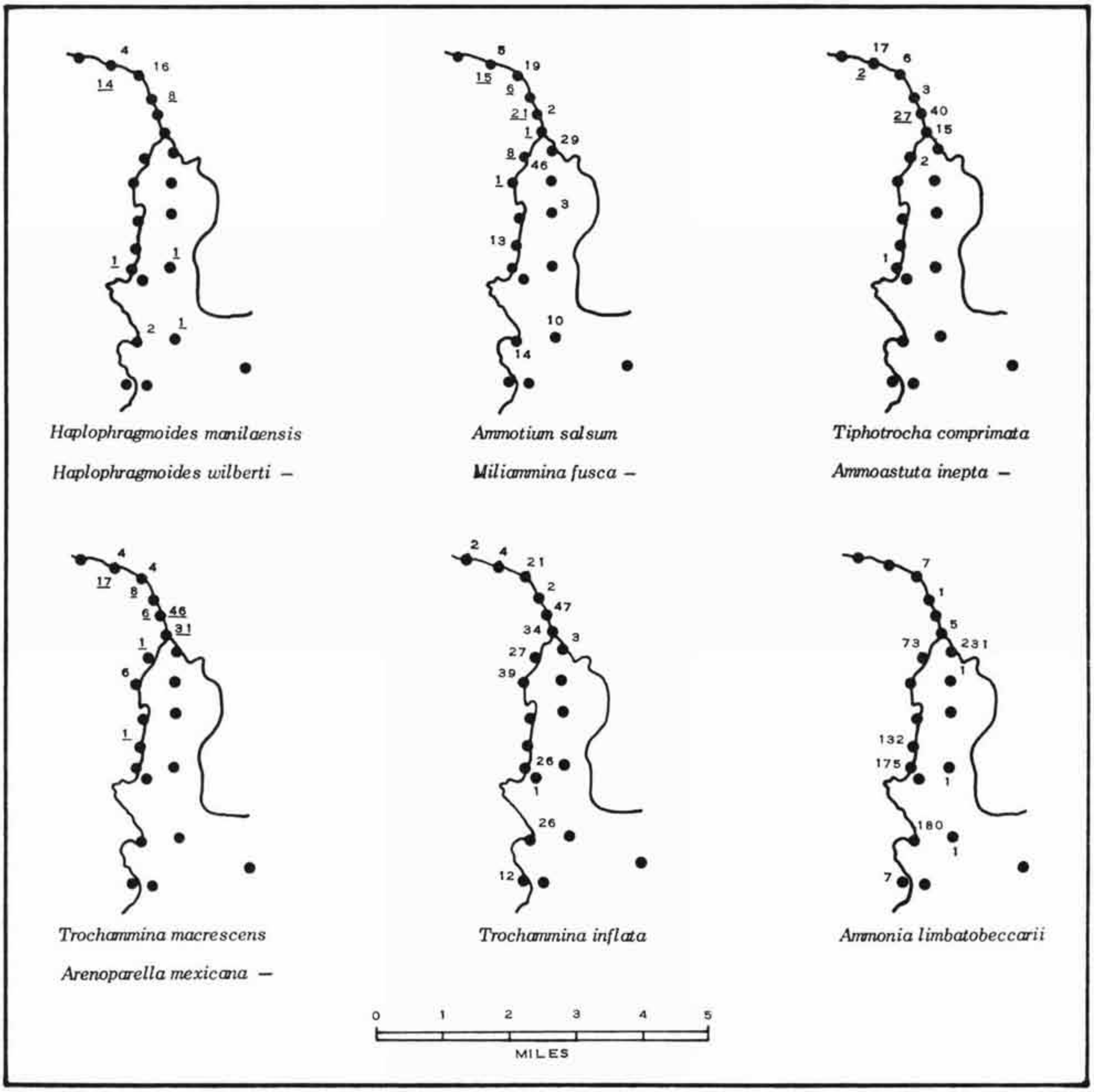


FIGURE 16. Numerical distribution of foraminifers in Nelson Bay and Taylor Creek (figures include both tops and bottoms of core samples).

Basslerites tenmilecreekensis	Present in greatest numbers on sound delta, rare in other environments.

MARINE-DELTA SUBFACIES

The water of the marine-delta environment is characterized by strong tidal currents, fairly clear water, and normal marine salinities. At Ocracoke and Drum Inlets a surface zone occurs on the seaward margin of the delta. The substrate is composed of sand with minor amounts of shell material.

Both the ostracode and foraminiferal faunas exhibit a mixing of shallow-water normal-marine and mesohaline species with the former type predominating. The *Elphidium* fauna is present, but individuals are less numerous than in the sounds. The miliolids are more numerous and are represented by the genera *Quinqueloculina, Triloculina,* and *Spiroloculina.* Marine genera, such as *Rosalina, Poroeponides, Globigerina, Hanzawaia,* and *Planulina,* are represented by few individuals.

The species of ostracodes are numerous, but individual representatives are not present in large numbers. *Haplocytheridea* is the predominant genus, but the species are represented by few individuals. *Cytherura* and *Cushmanidea* are represented by several species. Marine genera, such as *Puriana, Pellucistoma, Actinocythereis,* and *Cytheretta,* are rare.

All samples in this area were obtained through use of the Petersen grab sampler. No species are dominant in this subfacies so that listing of the characteristic species is impractical.

SALT-WATER-LAGOON BIOFACIES

Core Sound is classified as a salt-water lagoon because of the polyhaline to normal-marine salinites. The water mass of this habitat is characterized by extreme shallowness (average depth is less than four feet), by relatively high salinity, and by turbidity.

Several species of *Elphidium* comprise the bulk of the microfauna. In addition to the species of *Elphidium* present in other environments, *E. gunteri* and *E. tumidum* occur here in large numbers. The genus *Protelphidium* is represented by three species. Miliolids are present but are not abundant. Marine genera, such as *Rosalina, Globigerina,* and *Hanzawaia* occur, but individuals are rare.

The ostracode fauna is dominated by *Haplocytheridea* and *Cushmanidea.* Less important genera are *Acuticythereis, Cytherura,* and *Hulingsina.*

Elphidium tumidum and *Protelphidium orbiculare* are most numerous in the bottoms of the cores and are found only occasionally in the surface sediments. With exception of the species just noted and *Triloculina trigonula,* which was fairly abundant in the lower section of a core, no significant change is observed in the fauna of Core Sound between the present and the recent past.

Most Important Species in Salt-water-lagoon Biofacies.

Elphidium clavatum *Elphidium incertum* *Haplocytheridea setipunctata* *Haplocytheridea bradyi* *Cushmanidea echolsae* *Hulingsina sandersi*	Present at many stations; also found in other environments.
Elphidium gunteri	Present in greatest numbers in Core Sound; a few individuals in other environments.
Elphidium tumidum *Protelphidium orbiculare*	Present mainly in bottoms of cores; a few individuals present in surface samples.

SALT-MARSH BIOFACIES

The salt-marsh environment is characterized by very shallow water, the *Spartina* complex, and a salinity range from 0.5 to 26 ‰. The substrate ranges from dark organic mud to silty sand.

The marsh assemblage of foraminifers is one of the best known of all foraminiferal biofacies. The distribution of the marsh species in this region parallels that determined by PARKER & ATHEARN (1959) for Poponesset Bay, Cape Cod. The abundance of *Arenoparella mexicana, Tiphotrocha comprimata,* and *Trochammina macrescens* decreases with increasing salinity; *Trochammina inflata* increases, and *Ammotium salsum* and *Miliammina fusca* are independent of salinity changes. Populations of *Haplophragmoides manilaensis* and *Haplophragmoides wilberti* decrease with increasingly marine conditions, and *Ammonia limbatobeccarii* appears to be essentially independent of salinity changes.

Haplocythereidea setipunctata, Acuticythereis nelsonensis, Acuticythereis multipunctata parva, Loxoconcha purisubrhomboidea, and *Aurila conradi littorala* are found in the marsh; only the last cited species is restricted to the marsh.

A number of species are found in Nelson Bay, but this fauna is allied to that of Core Sound and is not related to the marsh environment.

COMPARISON OF FAUNAL ENVIRONMENTS IN GULF COAST AND SOUTHERN PAMLICO SOUND REGION

PHLEGER *(151)* has published a summary of the foraminiferal investigations conducted along the Gulf Coast of the United States under the sponsorship of the American Petroleum Institute, Project 51. The Gulf Coast lists reproduced below are arranged according to environments and represent a summary of the results of PHLEGER's investigations. The corresponding environments of the southern Pamlico Sound region are recorded opposite those of the Gulf Coast.

Constituents of Gulf Coast and Pamlico Sound Biotas.

Gulf Coast	*Pamlico Sound*
Marsh environment	Marsh environment
1. All benthonic species.	1. All benthonic species.
2. 5-10 genera; 10-20 species.	2. 6 genera; 9 species.
3. Arenaceous foraminifers most important.	3. Arenaceous foraminifers most important.
4. Characteristic genera: *Ammoastuta, Arenoparella, Discorinopsis, Jadammina, Miliammina, Trochammina.*	4. Characteristic genera: *Arenoparella, Miliammina, Trochammina, Haplophragmoides, Ammotium, Ammonia.*
Coastal-lagoon environment	Open-sound environment[1]
1. Planktonic forms lacking.	1. Planktonic forms lacking.
2. 5-10 genera; 10-20 species.	2. 13 genera; 29 species.
3. Arenaceous specimens 5-75 percent of population, with highest population in inner lagoon.	3. Arenaceous specimens 5-85 percent of population, with highest population in inner lagoon.
4. Characteristic genera: *Ammotium, Elphidium, Ammonia, Quinqueloculina, Triloculina.*	4. Characteristic genera: *Ammotium, Ammobaculites, Quinqueloculina, Ammonia, Elphidium.*
Nearshore Turbulent Zone and Beach	Nearshore Turbulent Zone[2]
1. Population size smaller than most other environments.	1. Population size slightly smaller than most other environments.
2. Occasional planktonic species.	2. Occasional planktonic species.
3. Species large, thick-shelled, and water-worn.	3. Some species large and thick-shelled; some water-worn.
4. Characteristic genera: *Elphidium, Quinqueloculina, Ammonia, Textularia.*	4. Characteristic genera: *Quinqueloculina, Triloculina, Elphidium, Hanzawaia.*

In general the corresponding environments of the southern Pamlico Sound region agree rather closely in biofacies characteristics with those of the Gulf Coast. The major difference between the two regions is a difference in the character of the coastal lagoons. Pamlico Sound away from the inlets fits PHLEGER's classification very closely except that *Quinqueloculina* is lacking. The inclusion of the sound delta of Ocracoke Inlet into this classification picks up not only the *Quinqueloculina* fauna but several marine species as well. Ocracoke Inlet exerted such an influence over the distribution of faunal elements that it was included as a separate biofacies in the present study.

[1] The open-sound environment which includes Pamlico Sound and sound delta of Ocracoke Inlet corresponds to PHLEGER's coastal-lagoon environment. Core Sound and the river estuaries were not included in this environment of PHLEGER because they are not typical of coastal lagoons. Core Sound because of its high salinities was classified as a salt-water lagoon. The river estuaries were not included because they maintain a more fluvial than marine character and in addition contain a very diagnostic fauna.

[2] The marine delta of Ocracoke Inlet in the vicinity of the breaker zone is considered as the nearshore turbulent zone. No beach samples were studied from the area.

GEOLOGIC RANGES AND STRATIGRAPHIC DISTRIBUTION

Geologic Ranges of Foraminiferida

The geologic ranges of the 52 foraminiferal species identified in the southern Pamlico Sound region are shown on Table 9 (3 species of *Difflugia* have been omitted). Of these 52 species, 27 are restricted to the Recent, 7 extend into the Pleistocene, 2 into the Pliocene, and 16 into Miocene and older sediments.

The estuarine *Ammobaculites* fauna is limited to the Recent. The tests are so fragile that it is doubtful that they could be preserved and recovered from older, and commonly more compacted and lithified sediments. This is true also of the brackish salt-marsh fauna. Brackish-water arenaceous species in general are extremely delicate compared to their agglutinated marine counterparts.

The species having long ranges, such as *Peneroplis proteus, Quinqueloculina lamarckiana, Cibicides* sp. cf. *C. lobatulus,* and *Triloculina trigonula,* are extremely variable and are in need of redefinition. *C. lobatulus* has become a "catch-all" species.

A number of species, such as *Peneroplis proteus, Hanzawaia* sp. cf. *H. strattoni, Spiroloculina planulata,* and *Quinqueloculina bicornis,* known to be living at present, may have been introduced into the area from deeper waters or eroded from Miocene subsea crops off the North Carolina coast. The above species are represented by only 1 to 3 individuals and were found in high-energy environments. *Globigerina bulloides,* a planktonic species, was undoubtedly washed into the area. *Q. triloculiniforma,* represented by 3 specimens and previously known only from the Miocene of North Carolina, may have been redeposited from offshore Miocene sediments and may not be living at present.

Ammonia limbatobeccarii, also known only from Miocene sediments, was present in moderate abundance in the marsh at Nelson Bay. The fresh appearance of many of the tests indicates that the species is living at present.

In general, the foraminiferal fauna maintains an essentialy modern aspect in that 34 of the 52 species are restricted to Recent or to Pleistocene and Recent sediments.

TABLE 9. *Geologic Ranges of Species of Foraminifers Present in Southern Pamlico Sound Region.*

FORAMINIFERA SPECIES	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE	PLEISTOCENE	RECENT
Haplophragmoides manilaensis						X
H. wilberti						X
Ammoastuta inepta					X	X
Ammobaculites pamlicoensis						X
A. crassus						X
A. dilitatus						X
A. exilis						X
A. neusensis						X
Ammotium salsum						X
Miliammina fusca						X
Quinqueloculina bicornis						X
Q. compta						X
Q. jugosa						X
Q. lamarckiana		X	X	X	X	X
Q. microcostata						X
Q. poeyana				X	X	X
Q. seminula			X	X	X	X
Q. triloculiniforma			X	X	X	X
Q. sp.						X
Triloculina oblonga			X	X	X	X
T. rotunda			X	X	X	X
T. trigonula	X	X	X	X	X	X
Spiroloculina planulata			X	X	X	X
Tiphotrocha comprimata						X
Trochammina inflata						X
T. macrescens						X

FORAMINIFERA SPECIES	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE	PLEISTOCENE	RECENT
Arenoparella mexicana						X
Pseudononion atlanticus						X
Protelphidium orbiculare				X	X	X
P. tisburyense						X
P. sp.						X
Elphidium articulatum						X
E. brooklynese					X	X
E. clavatum					X	X
E. discoidale			X	X	X	X
E. gunteri					X	X
E. incertum					X	X
E. galvestonense					X	X
E. subarcticum						X
E. tumidum						X
Rosalina columbiensis						X
R. floridana			X	X	X	X
Poroeponides lateralis			X	X	X	X
Ammonia limbatobeccarii			X	X	X	X
A. sobrina					X	X
A. tepida			X	X	X	X
Globigerina bulloides						X
Cibicides lobatulus	X	X	X	X	X	X
Hanzawaia concentrica		X	X	X	X	X
H. strattoni		X	X	X	X	X
Planulina mera						X
Peneroplis proteus			X	X	X	X

TABLE 10. *Geologic Ranges of Species of Ostracoodes Present in Southern Pamlico Sound Region.*

OSTRACODE SPECIES	OLIGOCENE	MIOCENE	PLIOCENE	PLEISTOCENE	RECENT
Cypria ophthalmica			X	X	X
Cypridopsis vidua				X	X
Cyprideis sp. cf. *C. torosa*				X	X
C. sp.					X
Haplocytheridea setipunctata		X	X	X	X
H. bradyi		X	X	X	X
H. sp.					X
Perissocytheridea sp.					X
Acuticythereis laevissima		X	X	X	X
A. nelsonensis					X
A. multipunctata parva		X	X	X	X
Neolophocythere subquadrata					X
Paracytheridea sp. cf. *P. vandenboldi*		X	X	X	X
Loxoconcha matagordensis					X
L. purisubrhomboidea		X	X	X	X
L. reticularis		X	X	X	X
Cytheromorpha pascagoulaensis		X	X	X	X
C. warneri		X	X	X	X
Basslerites giganticus		X	X	X	X
B. tenmilecreekensis		X	X	X	X
Cytheretta sp. cf. *C. sahni*		X	X	X	X

OSTRACODE SPECIES	OLIGOCENE	MIOCENE	PLIOCENE	PLEISTOCENE	RECENT
Cytherura ? corensis					X
Cytherura elongata		X	X	X	X
C. forulata		X	X	X	X
C. johnsoni		X	X	X	X
C. sp.					X
Cushmanidea echolsae		X	X	X	X
C. seminuda					X
C. ulrichi		X	X	X	X
C. sp.					X
Hulingsina ashermani		X	X	X	X
H. sandersi					X
Pellucistoma magniventra		X	X	X	X
Leguminocythereis whitei	?	X	X	X	X
L. sp.					X
Puriana mesacostalis		X	X	X	X
P. rugipunctata		X	X	X	X
P. sp.					X
Actinocythereis exanthemata		X	X	X	X
Hemicythere laevicula	X	X	X	X	X
Aurila conradi littorala		X	X	X	X
Hemicythere sp.					X

Geologic Ranges of Ostracoda

The geologic ranges of the 42 species of Ostracoda in this report are shown on Table 10. Of these species, 17 are restricted either to Recent, Pleistocene, or Pliocene sediments; 24 species range into the Miocene and 2 into the Oligocene. In general the ostracode fauna maintains a Miocene aspect.

The ranges of five species that previously were known only from Miocene sediments have been extended to the Recent.

Miocene to Recent Species.
Acuticythereis multipunctata parva
Loxoconcha reticularis
Basslerites giganticus
Basslerites tenmilecreekensis
Leguminocythereis whitei

The presence of a large number of Miocene-type ostracodes in the Recent also has been noted in other Recent assemblages, especially those of the Florida and Gulf coast areas. It was presumed originally that the North Carolina ostracode fauna would bear a strong similarity to Recent European faunas; such was not the case, as the brackish-water North Carolina fauna appears endemic to the Atlantic and Gulf coasts of the United States.

Stratigraphic Distribution

Twenty species of foraminifers and 23 species of ostracodes present in the area of investigation occur also in the Miocene, Pliocene, and Pleistocene formations of the Atlantic coastal plain and the Florida peninsula. The majority of the species occurs in Miocene sediments. Puri (1960, p. 107) stated that the present fauna of the Florida region contains a large percentage of Miocene species and that a number of forms are allied to the Pleistocene Caloosahatchee Marl of south Florida. Curtis (1960) also found a large proportion of Miocene species living in the eastern Mississippi delta region. Swain (1955, p. 60) stated that the Recent San Antonio Bay fauna bears a strong resemblance to that described by Mincher (1941) from the middle Miocene Pascagoula Clay of east-central Mississippi. It is not surprising, therefore, that the present ostracode fauna of the southern Pamlico Sound region has a large percentage of Miocene species. Four of the ostracode species are present in the Miocene sediments of Florida and eight in the Miocene of the Atlantic coastal plain; and 11 species are common to the Miocene sediments of both regions (Table 11).

Six of the foraminiferal species are found in the Miocene of Florida, three in the Miocene formations of the Atlantic coastal plain, and four are common to the Miocene sediments of both areas. Four species are known from the Pliocene of Maryland; two species are present in the Pleistocene of Florida, six in the Long Island Pleistocene, and one species is common to the Pleistocene sediments of both areas (Table 12).

Gulf Coast Miocene faunas in general are similar to those of the Florida peninsula and the Atlantic coastal plain. The similarity between faunas perhaps is due to the lack of a permanent barrier, i.e., the Florida peninsula, from Miocene through Pleistocene times. Figure 17 shows the possible locations of the shoreline at various times from early Miocene to early Pleistocene.

COMPARISON OF CORES

Fifty-seven cores ranging in length from 4 to 15 inches were obtained from various locations within the study area in order to determine that the fauna here changed during a relatively short period of time. The majority of the cores showed no significant change in either species diversity or numbers of individuals between top and bottom samples. It is concluded, therefore, that the environments and their assemblages are sufficiently stable in the area to warrant their use for paleoecologic studies.

Seventeen cores showed moderate changes between top and bottom segments. Most of these changes involved either an increase or decrease in the individuals of *Elphidium brooklynense, E. clavatum,* or *E. incertum*. Neither a total larger or smaller *Elphidium* population was found, however, in the bottoms of the cores than in the tops.

The presence of a polyhaline to normal marine fauna in the bottom of a core taken from the Neuse River (Station 5b) indicates that the microfauna can be used to indicate changes in environment. Core 5b, which is 15 inches long, contains the *Ammobaculites* fauna in the uppermost 2 inches. In addition to the *Ammobaculites* species, the bottom section contained ostracodes. The species of ostracodes present were not endemic to fresh or oligohaline environment but were polyhaline to normal marine forms.

The presence of two species of *Elphidium* and one of *Ammonia* in this lower segment attests further to the past presence of more marine water.

The middle section of the core also was examined for this microfauna, but it was not present. The ostracodes and the more marine types of foraminifers are assumed, therefore, to come from a very thin zone in the bottom section of the core, but are not associated with the *Ammobaculites* fauna that is present also in this lower section.

The presence of this fauna in the estuaries is indicative of a more marine influx of water which remained long enough for a fauna to move in and become temporarily established.

Core 5b was one of a series of three cores taken in a cross traverse on the Neuse River. The other two cores, also 15 inches long, were checked in entirety to see if this

TABLE 11. *Species Found in Recent of Southern Pamlico Sound Region Occurring Also in Miocene of Florida and Atlantic Coastal Plain.*

SPECIES	MIOCENE								
	Fla.		N. C.	Va.		Md.			N. J.
	ALUM BLUFF	CHOCTAWHATCHEE	DUPLIN	ST. MARYS	YORKTOWN	CALVERT	ST. MARYS	YORKTOWN	YORKTOWN
Quinqueloculina seminula		X						X	
Q. triloculiniforma								X	
Triloculina oblonga		X							
T. rotunda		X							
T. trigonula		X							
Spiroloculina planulata		X							
Elphidium discoidale			X				X		
Rosalina floridana		X	X	X	X	X			
Poroeponides lateralis		X		X	X				
Ammonia limbatobeccarii					X				
A. tepida		X							
Hanzawaia concentrica	X	X	X		X	X			
Peneroplis proteus	X								
Haplocytheridea setipunctata	X	X				X			
H. bradyi		X	X						
Acuticytheris laevissima			X		X			X	X
A. multipunctata parva			X						
Paracytheridea sp. cf. *P. vandenboldi*		X			X	X			
Loxoconcha purisubrhomboidea		X	X						
L. reticularis		X	X		X				
Cytheromorpha pascagoulaensis			X						
C. warneri		X			X	X			
Basslerites giganticus	X	X							
B. tenmilecreekensis	X	X							
Cytheretta sp. cf. *C. sahni*		X							
Cytherura elongata			X						
C. forulata					X				
Cushmanidea echolsae					X				
C. ulrichi	X	X			X				
Hulingsina ashermani	X	X	X		X				
Pellucistoma magniventra		X	X						
Puriana mesacostalis			X						
P. rugipunctata	X	X	X	X	X	X	X	X	
Actinocythereis exanthemata	X	X							
Hemicythere laevicula		X							

more marine fauna is present; only the estuarine fauna was found, indicating that this marine zone is probably buried deeper.

These polyhaline to normal marine species are also found in surface samples in the more marine portions of the area.

Two cores (83, 88) both from near the southern portion of Core Sound also are important. The following table lists the number of species and individuals found in the cores (Table 13).

The species of ostracodes and foraminifers found in the bottoms of the above samples are present in the surface samples in other areas of Core Sound. *Protelphidium orbiculare* and *P. tisburyense* are very abundant in the bottoms of these two cores but occur only rarely in surface samples. The upper portion of core 83 is composed of coarse sand with shell fragments; the lower portion is sandy silt. The coarseness of the sediment was caused most probably by a recent shift in the tidal channel which now causes all the fine material, including the microfauna, to be winnowed. Both the top and bottom segments of core 88 are composed of fine-grained sediments. At the present time the lack of specimens in the upper portion of the core has no plausible explanation, but this problem perhaps will be solved when more work is done on the area.

SUMMARY AND CONCLUSIONS

The Ostracoda and Rhizopodea of the southern Pamlico Sound region were studied to determine their usefulness as indicators of strand-line brackish-water environments. The area includes environments that range from fresh to normal marine waters, substrates from mud to

TABLE 12. *Species Found in Recent of Southern Pamlico Sound Region Occurring Also in Pliocene and Pleistocene of Florida and Atlantic Coastal Plain.*

SPECIES	PLIOCENE	PLEISTOCENE		
	Md.	Fla.	Md.	Long Island
	Waccamaw	Caloosahatchee	Talbot	Gardners
Quinqueloculina poeyana		X		
Q. seminula	X	X		X
Triloculina oblonga		X		
Elphidium brooklynese				X
E. clavatum				X
E. discoidale		X	X	
E. gunteri	X			
E. incertum				X
Ammonia sobrina	X			X
A. tepida	X			X

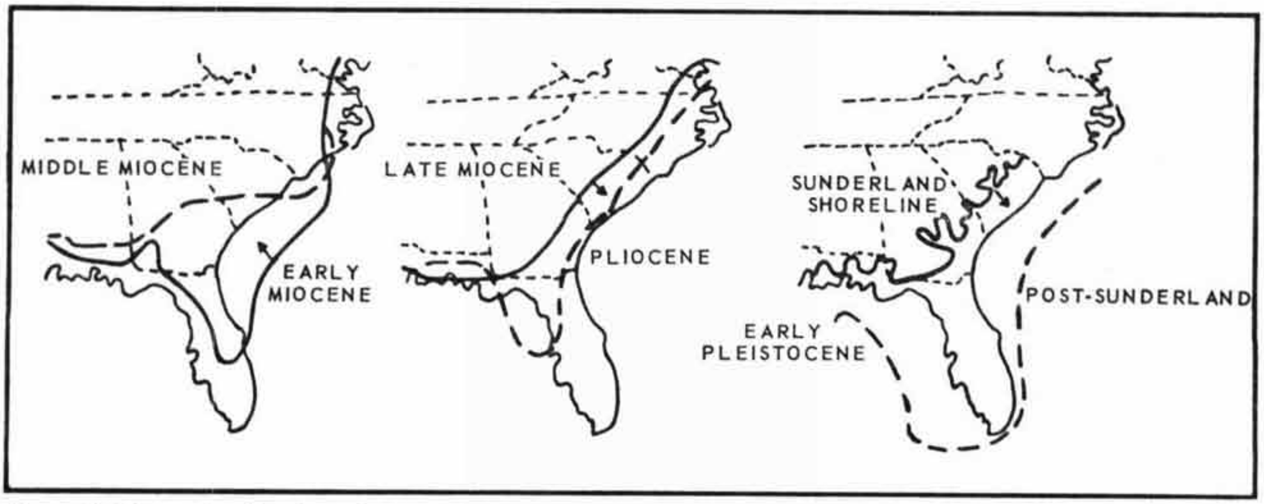


FIGURE 17. Neogene shore lines in southeastern United States as postulated by COOKE (1945). [The solid line indicates the inferred shore line of the earlier interval and the dashed line that of the later interval.]

coarse sand, and areas of aquatic and semiaquatic plants. Five principal biofacies were found dependent mainly on salinity, vegetation, and currents.

From 159 stations, 215 samples were collected, from which 10,490 specimens representing 97 species were identified. Of these specimens, 9,025 represent 55 species of foraminifers. Bathythermograph traces, surface-temperature readings, water for salinity determinations, Secchi disk readings, and samples for sedimentary analysis were taken at most stations.

Conclusions on the distribution and ecology of the Rhizopodea and Ostracoda are as follows:

1) The species and genera of ostracodes and foraminifers in the southern Pamlico Sound region are generally typical of forms found in brackish and nearshore-marine areas. A few genera and species have been introduced into the area, either by subaqueous erosion from Miocene subsea crops, or carried in by currents or waves from deeper waters. These specimens are few and do not greatly alter the general ecologic zonation. Although it was possible to divide the area into five major biofacies, it is doubtful that all of them can be recognized from either core or outcrop data from Neogene sediments. The coastal-lagoon and salt-lagoon biofacies contain essentially the same faunal elements and probably cannot be separated. The tidal-delta biofacies contains mixed assemblages and probably can be classified as nearshore normal marine. The estuarine, marsh, and sound (bay) biofacies can be recognized.

2) The facies based on generic or suprageneric dominance are distinguished as follows: a) Thecamoebinids can be used to indicate fresh to oligohaline environments. b) The *Ammobaculites* fauna can be used as an indicator of oligohaline to mesohaline estuarine (river) environments, as well as to indicate areas of fresh-water influx. c) The *Elphidium, Haplocytheridea, Cushmanidea* fauna can be used to indicate polyhaline (open-bay) environments. d) The fauna composed of *Haplophragmoides, Trochammina, Miliammina,* and other arenaceous foraminifer genera can be used to indicate salt-marsh environments.

3) The foraminiferal fauna of Pamlico Sound is transitional between those typical of northern and southern areas. The present study has served to extend the ranges of 8 northern and 7 southern species to the North Carolina coast. Thirty-two species present in the area are common to either more northerly or more southerly areas. The ostracodes are mainly a southern assemblage, for 21 species present in Recent sediments of the Gulf of Mexico also occur in the Pamlico Sound region. Two northern species have been shown to extend southward to the North Carolina coast.

4) The foraminifers have a Recent aspect, inasmuch as 65 percent of the fauna is restricted to Recent or Pleistocene-and-Recent sediments. The ostracodes present a Miocene aspect, 55 percent of the fauna being known from Miocene sediments.

5) Because of the general uniformity of the substrate, sediment type or composition apparently has had little affect on distribution and abundance of the microfauna.

6) Temperature is of some importance for defining the regional character of the fauna but does not significantly influence either local distribution or abundance.

7) Lateral changes in salinity, tidal currents, and distribution of semiaquatic vegetation are the major controls of microfaunal distribution.

8) Constant agitation of the bottom by currents and waves and consequent high turbidity of Pamlico Sound waters seem to account in part for the low population.

TABLE 13. *Distribution of Ostracodes and Foraminifers in Cores 83 and 88.*

Top (T) or Bottom (B) of Core	Core Number	Ostracode Species	Number of Individuals	Foraminiferal Species	Number of Individuals	Total Species	Total Individuals
T	83	0	0	0	0	0	0
B	83	15	133	15	236	30	369
T	88	0	0	0	0	0	0
B	88	14	77	9	76	23	153

9) Lack of available calcium carbonate and the acidity of the estuarine waters may in part be responsible for lack of ostracodes and calcareous foraminifers in the Neuse, Pamlico, and Pungo Rivers.

10) The depths encountered are so shallow that no depth zonation of the fauna is apparent except as depth influences distribution of vegetation.

11) The microfauna in the cores indicates that environmental conditions have been stable from the recent past to the present, although one core from the Neuse River revealed that estuaries are subject to invasions of higher salinity water that may remain long enough for a more marine-type fauna to become established temporarily.

SYSTEMATIC PALEONTOLOGY

GENERAL

The suprageneric classification of the Rhizopodea is based upon that used by LOEBLICH & TAPPAN (1961). The ostracodes are classified according to the system adopted in the *Treatise on Invertebrate Paleontology* (Q), Arthropoda 3 (1961). Additional data on the foraminifers and ostracodes discussed in the present study are available in standard references, such as ELLIS & MESSINA (1940), POKORNÝ (1958), and MORKHOVEN (1962-63).

The salinity, depth, and substrate data given for the occurrence of each species the Pamlico Sound region are valid only for that region. Most species occur elsewhere under varying ecological conditions.

Phylum PROTOZOA Goldfuss, 1817

Subphylum SARKODINA Hertwig & Lesser, 1874

Class RHIZOPODEA von Siebold, 1845

Subclass LOBOSIA Carpenter, Parker, & Jones, 1862

Order ARCELLINDA Kent, 1888

Superfamily ARCELLACEA Ehrenberg, 1843

Family DIFFLUGIIDAE Wallich, 1864

Genus DIFFLUGIA Leclerc, 1815

Diagnosis.—Test variable in shape, but generally circular in cross section, composed of cemented sand grains, diatoms, and other foreign bodies, aperture terminal (after KUDO, 1954).

Remarks.—Many species of Difflugiidae were described erroneously as foraminifers *(17)* under such generic names as *Proteonina, Lagunculina, Millitella,* and *Urnulina.* Neontologic speciation is based commonly on general shape and the texture and composition of the test material. Biologically, however, species of this family are extremely variable and have little tendency to maintain uniform shape, texture, or composition within a population *(65)*. The species of *Difflugia* noted in the area of investigation are *D. urceolata* CARTER (Pl. 1, fig. 3, 8), *D. capriolata* PENARD (Pl. 1, fig. 2, 7), and *D. oblonga* CARTER (Pl. 1, fig. 9, 13).

Of these three, only specimens of *D. urceolata* are uniform in both size and shape; the other species are extremely variable in size and to a lesser extent in shape.

Occurrence.—Most specimens occur in the fresh to mesohaline waters of the Pamlico River near Washington; a few individuals also were found in the upper segment of Taylor Creek. The salinity ranges in these areas from 0.5 to 2 ‰. Found on mud bottoms in less than 5 feet of water.

Order FORAMINIFERIDA Zborewski, 1834

Superfamily LITUOLACEA Lamarck, 1809

Family RZEHAKINIDAE Cushman, 1933

Genus MILIAMMINA Heron-Allen & Earland, 1930

MILIAMMINA FUSCA (Brady), 1870
Plate 2, figures 3-5

Quinqueloculina fusca BRADY, 1870, p. 286, pl. 11, fig. 2; CUSHMAN, 1929, p. 23, pl. 1, fig. 4a-c.

Miliammina fusca (Brady), HADA, 1936, p. 852; PHLEGER & WALTON, 1950, p. 280, pl. 1, fig. 19a,b; MILLER, 1953, p. 51, pl. 7, fig. 10.

Diagnosis.—Recognized by its elliptical, arenaceous, quinqueloculine test, and by its rounded periphery. *Recent.*

Remarks.—This species is similar to *Miliammina pariaensis* TODD & BRÖNNIMANN (1957), but the latter has a compressed oval test, a smoother wall, and a narrower aperture.

Dimensions.—Length, 0.40 mm.; breadth, 0.21 mm.

Material.—259 tests.

Occurrence.—Reported from brackish waters of the British Isles, from tidal and nearshore zones of the Gulf of Paria, Trinidad, and from brackish-water areas of the Gulf and Atlantic coasts of the United States. In the southern Pamlico Sound region, it is present in the Neuse, Pamlico, and Pungo Rivers, in Taylor Creek, and adjacent to the marsh in Nelson Bay. Salinity range, from 1 to 10 ‰; depth from 2 to 15 feet; substrate organic mud to sandy bottoms, most abundant on a muddy substrate. Associated with other arenaceous foraminifers, mainly with several species of *Ammobaculites* and with *Trochammina inflata*.

Family LITUOLIDAE Lamarck, 1809

Subfamily HAPLOPHRAGMOIDINAE Maync, 1952

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES MANILAENSIS Andersen, 1953

Plate 2, figures 6, 7

Haplophragmoides manilaensis ANDERSEN, 1953, p. 22, pl. 4, fig. 8a,b; TODD & BRÖNNIMAN, 1957, p. 23, pl. 1, fig. 24-26; SAUNDERS, 1957, p. 2-3, pl. 1, fig. 1, 2.

Diagnosis.—Distinguished by its finely arenaceous, inflated lobulate test, by the tendency toward irregular coiling which is especially noticeable in the last few chambers, and by the slightly roughened exterior. *Recent.*

Remarks.—This species is extremely variable in shape. Some specimens are bilaterally symmetrical, whereas others have the last few chambers canted off center. The pronounced lobation and somewhat roughened exterior are persistent features. Similar to *Haplophragmoides mauriciensis* HOWE & ELLIS *(81)*, but much larger and the last-formed chamber is much more prominent. *Trochamminita irregularis* CUSHMAN & BRÖNNIMANN (1948, 57) may well represent an extreme case of warping and distortion in this species.

Dimensions.—Greatest diameter, 0.44 mm.

Material.—14 tests.

Occurrence.—Found in coastal marshes of Louisiana and the tidal zone of the Gulf of Paria, Trinidad. In the area of investigation, present only in Taylor Creek in salinities less than 5 ‰. Depth of water, less than 3 feet; substrate, organic mud. Commonly associated with *Trochammina inflata, Tiphotrocha comprimata,* and *Arenoparella mexicana.*

HAPLOPHRAGMOIDES WILBERTI Andersen, 1953

Plate 2, figures 12-14

Haplophragmoides wilberti ANDERSEN, 1953, p. 21, pl. 4, fig. 7a,b; TODD & BRÖNNIMANN, 1957, p. 23, pl. 1, fig. 28-29; SAUNDERS, 1957, p. 3-4, pl. 2, fig. 1.

Diagnosis.—Recognized by its medium-sized, planispiral, completely involute, smooth test; by the small open umbilicus; by the almost straight sutures; and by the arched aperture at the base of the final chamber. *Recent.*

Remarks.—This species is so finely arenaceous that it appears smooth and glossy. The aperture on the specimens from Pamlico Sound is larger than the opening in specimens illustrated by ANDERSEN but the form is identical in other features. *Haplophragmoides subinvolutum* CUSHMAN & MCCULLOCH (1939) from the Pacific coast is similar but has pronounced sigmoid sutures and a very prominent lip overhanging the aperture.

Dimensions.—Greatest diameter, 0.48 mm.

Material.—50 tests.

Occurrence.—Found in the brackish-water marsh of Barataria Bay, Louisiana, and in tidal and nearshore zones of the Gulf of Paria, Trinidad. Present in Nelson Bay and Taylor Creek and at several stations in the Neuse River; most common in Taylor Creek. Salinity range from less than 1 to 30 ‰, most common between 5 and 10 ‰. Depth range from 2 to 10 feet, generally less than 5 feet. Present on clay to sand substrates. Found in highest numbers nearshore, represented by only a few individuals in the middle of Nelson Bay and the Neuse River. Most commonly associated with several species of *Trochammina.*

Genus AMMOASTUTA Cushman & Brönnimann, 1948

AMMOASTUTA INEPTA (Cushman & McCulloch), 1939

Plate 2, figure 9

Ammobaculites ineptus CUSHMAN & MCCULLOCH, 1939, p. 89, pl. 7, fig. 6.

Ammoastuta salsa CUSHMAN & BRÖNNIMAN, 1948, p. 17, pl. 3, fig. 14-16; PARKER, 1952, *119,* p. 443, pl. 2, fig. 1-2; RONAI, 1955, p. 142, pl. 20, fig. 5.

Ammoastuta inepta (Cushman & McCulloch), PARKER, PHLEGER, & PEIRSON, 1953, p. 4, pl. 1, fig. 12; TODD & BRÖNNIMANN, 1957, p. 23.

Diagnosis.—Recognized by its smooth, finely arenaceous, fan-shaped test. *Pleistocene to Recent.*

Dimensions.—Length, 0.45 mm.; breadth, 0.19 mm.

Material.—89 tests.

Occurrence.—Reported from Pleistocene deposits near Boston, Massachusetts. Present in Recent brackish waters of South America, West Indies, and Gulf, Atlantic, and Pacific coasts of the United States. Found in the Neuse, Pamlico, and Pungo Rivers. Salinity range from less than 1 to 15 ‰ but more common in salinities of less than 10 ‰. Depth range from 2 to 15 feet. Substrate, mud or mud and sand. Associated with *Miliammina fusca* and several species of *Trochammina.*

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES PAMLICOENSIS Grossman, n. sp.

Plate 1, figures 12, 16, 17

Diagnosis.—Recognized by its uncompressed, elongate, arenaceous test; by the straight to very slightly oblique sutures; and by the rounded aperture. *Recent.*

Description.—Test medium-sized, not compressed, early portion close-coiled, and extending out somewhat from later portion which has near-parallel sides; chambers and sutures of coil portion indistinct but with fairly distinct umbonal recess; early chambers of uniserial portion indistinct. Later chambers distinct, moderately wide, somewhat inflated, with slightly impressed sutures, which are straight to slightly oblique; wall rather coarsely arenaceous for size of test; aperture round, terminal, situated on slight neck in some specimens, flush with top of last chamber in others.

Remarks.—This species is similar to *Ammobaculites diversus* CUSHMAN & BRÖNNIMANN (1948, *58*) but differs in being more elongate and in having a more inflated test and a rounded aperture. A considerable amount of variation is noted for this species; some specimens have the terminal end of the last-formed chambers constricted to form a neck, whereas no constriction occurs in others. Sutures range from straight to slightly oblique; the coiled portion may extend slightly out from the uniserial segment or may reach appreciably beyond it.

Dimensions.—Length, 0.75 mm.; breadth, 0.18 mm.; thickness, 0.10 mm.

Material.—360 tests.

Occurrence.—Found in the Neuse, Pamlico, and Pungo Rivers, and at a few stations in the western part of Pamlico Sound. Salinity range from less than 1 to 23 ‰, most common in salinities between 10 and 15 ‰. Depth, 5 to 15 feet. Substrate, clay to sand; more common on clay. Most commonly associated with *Ammobaculites neusensis*.

AMMOBACULITES CRASSUS Warren, 1957

Plate 1, figures 4, 5, 10

Ammobaculites crassus WARREN, 1957, p. 32, pl. 3, fig. 5-7.

Diagnosis.—Recognized by its large test, umbonal recess in initial coil, inflated chambers, and large, round, terminal aperture. *Recent.*

Remarks.—Similar to *Ammobaculites exilis* CUSHMAN & BRÖNNIMANN (1948, *58*) but differs in having a less compressed test and a large, round aperture. Somewhat similar to *Ammotium salsum* (CUSHMAN & BRÖNNIMANN, 1948, *57*) but differs in the less compressed test and much straighter sutures which do not reach toward coil at the inner margin.

Dimensions.—Length, 1.15 mm.; breadth, 0.40 mm.

Material.—664 tests.

Occurrence.—Found in the less-brackish lake bottoms on the coast of Louisiana. Present in the Neuse, Pamlico, and Pungo Rivers. Salinity, 5 to 15 ‰, specimens more common nearer 10 ‰. Depth, 5 to 15 feet. Substrate, clay or sand; most common on a clay bottom. Frequently associated with *Ammobaculites exilis*.

AMMOBACULITES DILITATUS Cushman & Brönnimann, 1948

Plate 1, figures 14, 18

Ammobaculites dilitatus CUSHMAN & BRÖNNIMANN, 1948, *58*, p. 39, pl. 7, fig. 10-11; PARKER, PHLEGER, & PEIRSON, 1953, p. 5, pl. 1, fig. 13-15; RONAI, 1955, p. 142, pl. 20, fig. 2; TODD & BRÖNNIMANN, 1957, p. 23, pl. 2, fig. 4-5.

Ammobaculites sp. cf. *A. dilitatus* Cushman & Brönnimann, PARKER, 1952, *120*, p. 443, pl. 1, fig. 23.

Diagnosis.—Distinguished by its medium-sized and much compressed test, by the indistinct sutures and chambers, and by the narrow, elongate, terminal aperture. *Recent.*

Remarks.—Similar to *Ammobaculites bargmanni* EARLAND (1933) but differs in having less curved sutures, much coarser wall, and more rounded periphery.

EXPLANATION OF PLATE 1

AMMOBACULITES, DIFFLUGIA

(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

1,6. *Ammobaculites neusensis* GROSSMAN, n. sp.; apertural and lateral views, ×87 (p. 49).

2,7. *Difflugia capriolata* PENARD; apertural and lateral views, ×87 (p. 46).

3,8. *Difflugia urceolata* CARTER; apertural and lateral views, ×87 (p. 46).

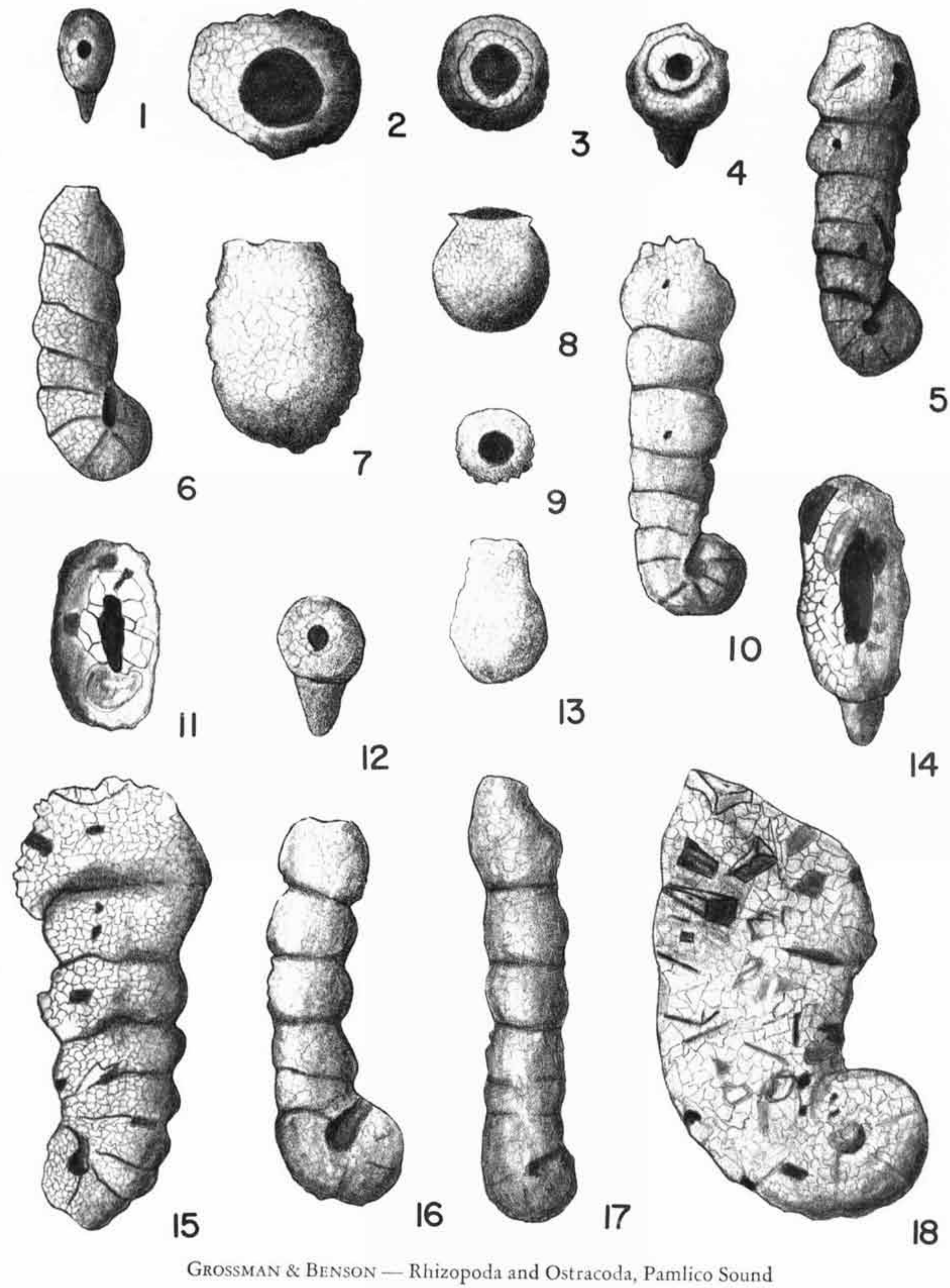
4,5,10. *Ammobaculites crassus* WARREN; *4,5,* apertural and lateral views, *8,* lateral view of variant; all ×60 (p. 48).

9,13. *Difflugia oblonga* CARTER; apertural and lateral views, ×87 (p. 46).

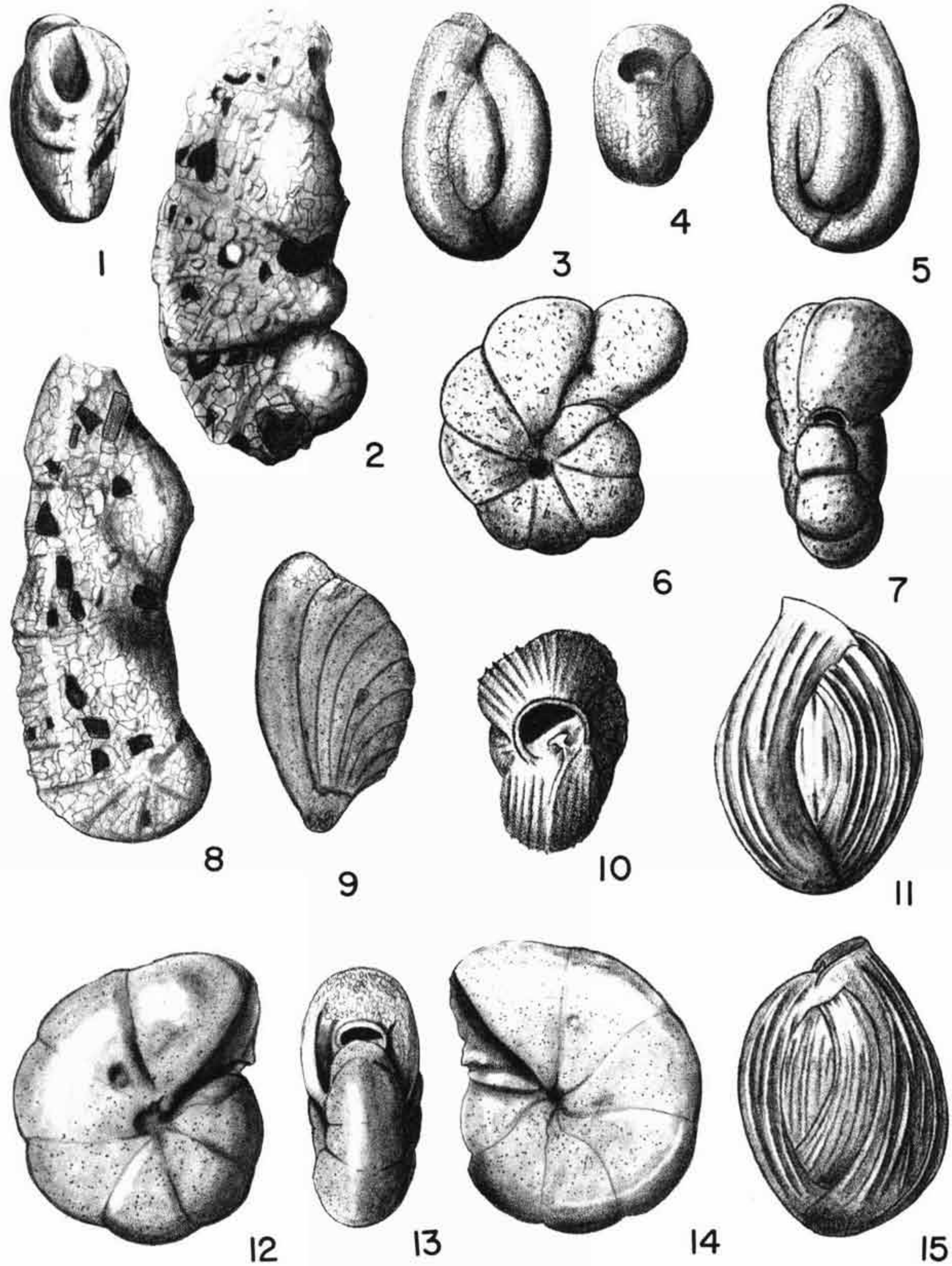
11,15. *Ammobaculites exilis* CUSHMAN & BRÖNNIMANN; apertural and lateral views, ×75 (p. 49).

12,16,17. *Ammobaculites pamlicoensis* GROSSMAN, n. sp.; *12,16,* apertural and lateral views; *17,* lateral view of variant; all ×87 (p. 48).

14,18. *Ammobaculites dilitatus* CUSHMAN & BRÖNNIMANN; apertural and lateral views, ×100 (p. 48).



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound



Grossman & Benson — Rhizopoda and Ostracoda, Pamlico Sound

Dimensions.—Length, 0.75 mm.; breadth, 0.40 mm.
Material.—64 tests.
Occurrence.—Found in nearshore zone of Gulf of Paria, Trinidad, in brackish bays of Louisiana coast, and in near-normal to normal marine waters of Buzzards Bay, Massachusetts. Found in the area of investigation in Neuse River, western portion of Pamlico Sound, Taylor Creek, and Nelson Bay. Salinity, 1 to more than 20 ‰, but mainly 10 to 15 ‰. Depth, 2 to 10 feet. Found on both sand and mud bottoms, individuals on sand bottoms are coarser and stronger than those on mud substrates. This species apparently is more tolerant of salinity changes than other species of *Ammobaculites* but still is limited to oligohaline and mesohaline waters. Most commonly associated with *Ammotium salsum*.

AMMOBACULITES EXILIS Cushman & Brönnimann, 1948
Plate 1, figures 11, 15

Ammobaculites exilis CUSHMAN & BRÖNNIMANN, 1948, *58*, p. 39, pl. 7, fig. 9; BANDY, 1956, p. 192, pl. 30, fig. 3.

Diagnosis.—Recognized by moderately large, compressed, coarsely arenaceous test having moderately distinct chambers and by slitlike terminal aperture. *Recent.*

Remarks.—Similar to *Ammobaculites crassus* WARREN but more compressed and having slitlike aperture.

Dimensions.—Length, 1.24 mm.; breadth, 0.5 mm.
Material.—228 tests.
Occurrence.—Reported from brackish coastal waters of Trinidad and from brackish waters of west coast of Florida. Found in Neuse, Pamlico, and Pungo Rivers. Salinity, 5 to 15 ‰, most common at about 10 ‰. Depth, 5 to 15 feet. Substrate, clay, clay and sand, sand; most common on a clay bottom. Commonly associated with *Ammobaculites crassus*.

AMMOBACULITES NEUSENSIS Grossman, n. sp.
Plate 1, figures 1, 6

Diagnosis.—Recognized by its small, compressed, arenaceous test; by oblique sutures; and by round terminal aperture. *Recent.*

Description.—Test small for genus, fragile, compressed; early portion close-coiled and having umbilical depression, later uncoiled portion with nearly parallel sides; chambers distinct, 4 or 5 on uniserial portion, last-formed chamber usually slightly inflated; sutures oblique and slightly depressed in uniserial portion, indistinct in coiled portion; wall thin, rather coarsely arenaceous for size of test; aperture round, terminal, situated on slight neck.

Remarks.—Similar to *Ammobaculites directus* but differs in having more oblique sutures, rounded aperture, and indistinct sutures in coiled portion of test; also resembles *A. pamlicoensis* but differs in being more compressed and having more oblique sutures.

Dimensions.—Length, 0.55 mm.; breadth, 0.18 mm.; thickness, 0.08 mm.
Material.—760 tests.
Occurrence.—Found in Neuse, Pamlico, and Pungo Rivers, and at several stations in western part of Pamlico Sound. Salinity range from less than 1 to 23 ‰, most common in salinites between 10 and 15 ‰. Depth, 2 to 15 feet. Substrate, mud or sand, but most common on mud bottom. Commonly associated with *Ammobaculites pamlicoensis* and to a lesser extent with *A. crassus* and *A. exilis*.

Genus AMMOTIUM Loeblich & Tappan, 1953

AMMOTIUM SALSUM (Cushman & Brönnimann), 1948
Plate 2, figures 1, 2, 8

Ammobaculites salsus CUSHMAN & BRÖNNIMANN, 1948, *57*, p. 16, pl. 3, fig. 7-9; PARKER, PHLEGER, & PEIRSON, 1953, p. 5, pl. 1, fig. 17-25; BANDY, 1956, p. 192, pl. 30, fig. 4; TODD & BRÖNNIMANN, 1957, p. 24, pl. 2, fig. 8-10; ARNAL, 1958, p. 37, pl. 9, fig. 4-7.
Ammotium salsum (Cushman & Brönnimann), WARREN, 1957, p. 33.

Diagnosis.—Recognized by its moderately compressed, coarsely arenaceous test, by oblique sutures; by decrease in size of last chamber from preceding ones; and by large, circular, terminal aperture. *Recent.*

Remarks.—This species is extremely variable in size and shape. The variation apparently is not environmentally controlled because numerous variants are found in the same sample. *Ammotium salsum* resembles *A. cassis* (WARREN, 1957) but is distinguished by having fewer chambers and a less compressed test.

Dimensions.—Length, 0.81 mm.; breadth, 0.33 mm.
Material.—407 tests.
Occurrence.—Found in the nearshore and tidal zones of the Gulf of Paria, Trinidad, in the marsh and bay areas of the Gulf coast, and in the marshes of Cape Cod. WALTON (1964) stated that

EXPLANATION OF PLATE 2

AMMOTIUM, MILIAMMINA, HAPLOPHRAGMOIDES, AMOASTUTA, QUINQUELOCULINA
(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE
1,2,8. *Ammotium salsum* (CUSHMAN & BRÖNNIMANN); *1,2*, apertural and lateral views; *8*, lateral view of variant; all ×100 (p. 49).
3-5. *Miliammina fusca* (BRADY); lateral and apertural views, ×100 (p. 46).
6,7. *Haplophragmoides manilaensis* ANDERSEN; lateral and apertural views, ×100 (p. 47).
9. *Ammoastuta inepta* (CUSHMAN & MCCULLOCH); lateral view, ×100 (p. 47).
10,11,15. *Quinqueloculina* sp.; apertural and 2 lateral views, all ×150 (p. 53).
12-14. *Haplophragmoides wilberti* ANDERSEN; lateral and apertural views, ×100 (p. 47).

Ammotium salsum made up 50 percent of the entire *Ammotium-Ammobaculites* fauna present in the central half of Mobile Bay and the landward halves of Mississippi and Chandeleur Sounds. Also found by ARNAL (1958) in the Salton Sea, California. In the area of investigation, found in the Neuse, Pamlico, and Pungo Rivers, and at a few stations in the western portion of Pamlico Sound. Also present adjacent to the marsh in Nelson Bay and in Taylor Creek. The salinity range is 1 to 25 ‰, specimens most common near 10 ‰; depth, from less than 1 to 10 feet. Prefers organic mud to mud bottoms, but a few individuals also found on sandy substrates. Associated with several species of *Ammobaculites* in the river estuaries. In Nelson Bay and Taylor Creek, found with *Trochammina* spp., *Arenoparella mexicana, Ammonia limbatobeccarii,* and *Aurila conradi littorala.*

Family TROCHAMMINIDAE Schwager, 1877

Genus TIPHOTROCHA Saunders, 1957

TIPHOTROCHA COMPRIMATA (Cushman & Brönnimann), 1948

Plate 6, figures 1, 5

Trochammina comprimata CUSHMAN & BRÖNNIMANN, 1948, *58,* p. 41, pl. 8, fig. 1-3; PARKER, PHLEGER, & PEIRSON, 1953, p. 14-15, pl. 3, fig. 3-4.

Tiphotrocha comprimata (Cushman & Brönnimann) SAUNDERS, 1957, p. 11, pl. 4, fig. 1-4.

Diagnosis.—Recognized by its arenaceous, very much compressed trochoid test having concave venter and slightly convex dorsum and by increasing irregularity and elongation of later chambers. *Recent.*

Dimensions.—Greatest diameter, 0.37 mm.

Material.—84 tests.

Occurrence.—Reported from mangrove swamps of Gulf of Paria, Trinidad, from brackish marshes of Louisiana and Texas coasts, and from marshes of Cape Cod. Found only in marshes of Nelson Bay and Taylor Creek in salinities 1 to 25 ‰, but commonly in salinities of less than 15 ‰. Depth, from less than 1 to 5 feet; substrate, organic mud. Associated with *Trochammina macrescens* and *Trochammina inflata.*

Genus TROCHAMMINA Parker & Jones, 1859

TROCHAMMINA INFLATA (Montagu), 1808

Plate 5, figures 9-12

Nautilus inflatus MONTAGU, 1808, p. 81, pl. 18, fig. 3.

Rotalina inflata (Montagu), WILLIAMSON, 1858, p. 50, pl. 4, fig. 93-94.

Trochammina inflata (Montagu), CARPENTER, PARKER, & JONES, 1862, p. 141, pl. 11, fig. 5; CUSHMAN, 1920, p. 73; PHLEGER & WALTON, 1950, p. 280, pl. 2, fig. 1-3; MILLER, 1953, p. 54, pl. 8, fig. 9.

Diagnosis.—Recognized by its depressed trochoid test having ventral inflation of chambers, by finely arenaceous wall, deep open umbilicus, and slitlike aperture at base of last-formed chamber. *Recent.*

Remarks. This is a very common and widespread species. It is similar to *Trochammina laevigata* CUSHMAN & BRÖNNIMANN (1948, *58*), but the last formed chamber in the latter species partially covers the umbilicus.

Dimensions.—Greatest diameter, 0.44 mm.

Material.—249 tests.

Occurrence.—Nearly all records for this species are from shallow water. Off Buenos Aires, Argentina, however, it has been recorded from a depth of 1,900 fathoms. It has been reported from brackish waters of Europe, North America, and South America; from the coast of Oregon; and from Todos Santos Bay, Baja California. A few specimens occur in Core Sound, but the highest populations are next to the marsh in Nelson Bay and in shallow waters of Taylor Creek. Salinity, 1 to 25 ‰, most common in salinities of less than 20 ‰; depth, less than 1 to 5 feet; substrate, mud, silty sand, sand, much more common in the highly organic muds adjacent to the marsh. Associated with *Tiphotrocha comprimata, Trochammina macrescens,* and *Haplophragmoides wilberti.*

TROCHAMMINA MACRESCENS Brady, 1870

Plate 5, figure 8

Trochammina inflata (Montagu) *macrescens* BRADY, 1870, p. 57, pl. 11, fig. 5a-c; CUSHMAN, 1920, p. 74-75, pl. 15, fig. 1.

Trochammina macrescens BRADY, 1887, p. 222; PHLEGER & WALTON, 1950, p. 281, pl. 2, fig. 6-9; PARKER, 1952, *119,* p. 408, pl. 4, fig. 8a,b; PARKER, 1952, *120,* p. 460, pl. 3, fig. 3a,b; PARKER, PHLEGER, & PEIRSON, 1953, p. 15, pl. 3, fig. 7, 8; RONAI, 1955, p. 144, pl. 20, fig. 12.

Diagnosis.—Recognized by its partially evolute, planispiral, compressed arenaceous test; by concave chambers; and by curved aperture at base of last-formed chamber. *Recent.*

Remarks.—Specimens of this species differ in the amount of inflation and involution of the test. Thickest specimens generally are involute, and thinner forms are more evolute. Most specimens have concave chambers which may be due to collapse of the fragile wall when the specimens were dried. *Trochammina macrescens* is similar in shape to *Jadammina polystoma* BARTENSTEIN & BRAND (1938) but can be separated readily by the apertural characters. The former species has a slit-like aperture at the base of the last-formed chamber whereas *Trochammina macrescens* has multiple openings in the apertural face.

Dimensions.—Greatest diameter, 0.45 mm.

Material.—14 tests.

Occurrence.—Found in shallow brackish-water regions of Europe and in brackish waters of Gulf and Atlantic coasts of the United States. Present at one station in the Neuse River, more common in Nelson Bay and Taylor Creek. Salinity, 1 to 25 ‰, more common in salinities of less than 15 ‰; depth, less than 5 feet; substrate, organic mud. Associated with *Tiphotrocha comprimata, Trochammina inflata,* and *Arenoparella mexicana.*

Genus ARENOPARELLA Andersen, 1951

ARENOPARELLA MEXICANA (Kornfeld), 1931

Plate 6, figures 2-4

Trochammina inflata (MONTAGU), var. *mexicanum* KORNFIELD, 1931, p. 86, pl. B, fig. 5a-c.

Arenoparella mexicana (Kornfeld) ANDERSEN, 1951 *(1),* p. 31, fig. 1a-c; ANDERSEN, 1951 *(1),* p. 96-97, pl. 11, fig. 4a-c; TODD & BRÖNNIMANN, 1957, p. 30, pl. 4, fig. 23-24; SAUNDERS, 1957, p. 12, 13, pl. 4, fig. 5.

Diagnosis.—Recognized by its moderately globose test, narrowly rounded periphery, closed umbilicus, and slightly curved slit-like aperture which is subparallel to the periphery. *Recent.*

Remarks.—Similar to *Trochammina inflata* but less globose, having a closed umbilicus, and quite different aperture.

Dimensions.—Greatest diameter, 0.38 mm.

Material.—112 tests.

Occurrence.—Present in brackish waters along coasts of Texas and Louisiana, found in mangrove swamps of Gulf of Paria, Trinidad, and reported from marsh areas of Todos Santos Bay, Baja California and from marshes of Cape Cod. Found in Nelson Bay and Taylor Creek and at one station in Neuse River. Salinity, 2 to 25 ‰, most common between 5 and 15 ‰. Depth, 2 to 10 feet; substrate, organic mud to sand. Associated with *Tiphotrocha comprimata, Trochammina inflata*, and *Miliammina fusca*.

Superfamily MILIOLACEA Ehrenberg, 1839

Family NUBECULARIIDAE Jones, 1875

Subfamily SPIROLOCULININAE Wiesner, 1931

Genus SPIROLOCULINA d'Orbigny, 1826

SPIROLOCULINA PLANULATA (Lamarck), 1804
Plate 5, figures 7, 10

Miliolites planulata Lamarck, 1804, p. 352.

Spiroloculina planulata (Lamarck), McDonald, 1857, p. 153, pl. 6, fig. 28; Cushman, 1929, p. 41, pl. 8, fig. 2-5; Cushman, 1933 52, p. 10, pl. 2, fig. 1a,b; Miller, 1953, p. 53, pl. 7, fig. 9. (For a more complete synonomy see Cushman, 1929, p. 41.)

Diagnosis.—Recognized by the medium-sized, irregularly elliptical test having an angular, slightly convex periphery and by chambers that are nearly square in cross section but with initial chambers depressed between the larger and wider final chambers. Aperture large, terminal, with a single elongate tooth. *Miocene to Recent.*

Dimensions.—Length, 0.53 mm.; breadth, 0.33 mm.

Material.—Three tests.

Occurrence.—Reported from the Miocene Choctawhatchee Formation of Florida. There are many records for the Recent distribution of this species from the coasts of Europe and the Mediterranean. It is rare in the western Atlantic Ocean. Hadley (1936) reported it as rare in the beach sands near Beaufort, North Carolina. Present at one station on the Atlantic delta of Ocracoke Inlet. Salinity, 35 ‰; depth, 30 feet, substrate, sand.

Family MILIOLIDAE Ehrenberg, 1839

Subfamily QUINQUELOCULININAE Cushman, 1917

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA BICORNIS (Walker & Jacob), 1798
Plate 3, figures 7-9

Serpula bicornis Walker & Jacob, 1798, p. 633, pl. 14, fig. 2.

Miliolina bicornis (Walker & Jacob), Williamson, 1858, p. 87, pl. 7, fig. 190-194.

Quinqueloculina bicornis (Walker & Jacob), Brady, 1864, p. 472 (table); Cushman, 1929, p. 32, pl. 5, fig. 5-7, pl. 6; fig. 1-2; Cushman, 1944, p. 14, pl. 2, fig. 19. (A more complete synonomy is in Cushman, 1929, p. 32.)

Diagnosis.—Recognized by its large size, very large elongate aperture, and partial costation of its slightly sinuous walls. *Recent.*

Remarks.—Similar to *Quinqueloculina bicornis* var. *angulata* (Williamson, 1858) but the latter has more angular chambers.

Dimensions.—Length, 0.78 mm.; breadth, 0.54 mm.

Material.—Three tests.

Occurrence.—Reported by Cushman (1944) from 1.3 fathoms in Vineyard Sound, Massachusetts. Rare on the American Atlantic coast but apparently more common in the eastern Atlantic where it is recorded frequently off the British Isles; also present in the Mediterranean. Found at one station near the southern end of Core Sound. Salinity, 35 ‰; depth, 10 feet; substrate, sand.

QUINQUELOCULINA COMPTA Cushman, 1947
Plate 4, figures 15-17

Quinqueloculina compta Cushman, 1947, p.87-88, pl. 19, fig. 2; Phleger & Parker, 1951, p. 7, pl. 3, fig. 16a,b, 17a,b; Bandy, 1954, p. 138, pl. 28, fig. 2; Bandy, 1956, p. 196, pl. 29, fig. 5.

Diagnosis.—Recognized by its acutely-angled test which generally is triangular in end view and by the irregularly pitted calcareous wall which contains fine sand grains. *Recent.*

Remarks.—The Pamlico Sound specimens differ from the type in that they lack an extended and slightly constricted neck. They are, however, identical to the specimen illustrated by Phleger & Parker (1951). *Quinqueloculina compta* is similar in shape to *Quinqueloculina funafutiensis* (Chapman, 1901) but is distinguished by its pitted and somewhat arenaceous test.

Dimensions.—Length, 0.48 mm.; breadth, 0.30 mm.

Material.—Six tests.

Occurrence.—Found by Cushman (1947) off Cape Kennedy, Florida, in 45 meters of water and recorded from the shallow water of the Gulf of Mexico. Present at three widely separated stations in the area of investigation; one in Core Sound, one near Ocracoke Inlet, and the third in Nelson Bay. Salinity, 25 to 30 ‰; depth, 5 to 10 feet; substrate, sand or silty sand.

QUINQUELOCULINA JUGOSA Cushman, 1944
Plate 4, figures 7, 11, 12

Quinqueloculina seminulum (Linné) var. *jugosa* Cushman, 1944, p. 13, pl. 2, fig. 15; Miller, 1953, p. 52, pl. 8, fig .5.

Quinqueloculina seminulum jugosa Cushman, Weiss, 1954, p. 162, pl. 33, fig. 10.

Quinqueloculina jugosa Cushman, Bandy, 1956, p. 196, pl. 29, fig. 8.

Diagnosis.—Recognized by ovoid test, narrowly rounded periphery, large aperture having simple tooth, and longitudinal costae on the surface. *Recent.*

Remarks.—Differs from *Quinqueloculina seminula* (Linné) only in the longitudinal costae which ornament the test.

Dimensions.—Length, 0.50 mm.; breadth, 0.35 mm.

Material.—29 tests.

Occurrence.—Found off Atlantic coast of United States south of Cape Cod and in northeastern part of Gulf of Mexico. MILLER (1953) reports this species from brackish waters of Mason Inlet, North Carolina. Found on both Atlantic and Sound deltas of Ocracoke Inlet and at one station in Core Sound. Salinity, 20 to more than 30 ‰, most common in more than 30 ‰. Depth, 5 to more than 30 feet; substrate, clay, sand, or mud. Associated with *Quinqueloculina lamarckiana* and *Quinqueloculina seminulum*.

QUINQUELOCULINA LAMARCKIANA d'Orbigny, 1839
Plate 3, figures 1-3

Quinqueloculina lamarckiana D'ORBIGNY, 1839, p. 189, pl. 11, fig. 14-15; CUSHMAN, 1929, p. 26, pl. 2, fig. 6a-c; CUSHMAN, 1933 *52*, p. 9, pl. 2, fig. 4a-c; PHLEGER & PARKER, 1951, p. 7, pl. 4, fig. 1a,b; MILLER, 1953, p. 51, pl. 7, fig. 8; PARKER, 1954, p. 497, pl. 4, fig. 5-6.

Quinqueloculina auberiana D'ORBIGNY, 1839, p. 193, pl. 12, fig. 1-3; CUSHMAN, 1918 *39*, p. 23, 71, pl. 5, fig. 3, pl. 30, fig. 1.

Quinqueloculina cuvieriana BRADY, 1884, p. 162, pl. 102, fig. 12a-c.

Diagnosis.—Recognized by its large, broad, smooth, polished test which has chambers that are generally triangular in cross section and by the elliptical terminal aperture having an elongate, simple tooth. *Oligocene to Recent.*

Remarks.—Resembles *Quinqueloculina seminula* in lateral view but is distinguished readily by the angular chambers. Somewhat similar to *Quinqueloculina vulgaris* D'ORBIGNY (1839), but has more angular chambers and a simple tooth. The Pamlico Sound specimens are not as angular as typical forms and are essentially identical to those described by MILLER (1953).

Dimensions.—Length, 0.70 mm.; breadth, 0.43 mm.

Occurrence.—Reported from the Oligocene Cipero Formation of Trinidad, and several Miocene formations of the Atlantic coastal plain. Found in the Recent of the West Indies, Indo-Pacific region, and off the British Isles. MILLER (1953) reported this species as occurring commonly in brackish-water and less commonly in normal marine water of Mason Inlet, North Carolina. HADLEY (1936) reported this species as common in beach sands near Beaufort, North Carolina. In the Gulf of Mexico it occurs at depths shallower than 200 m., mostly less than 100 m. Rare, but present, in the Texas bays and reported as rare in the offshore zone of the Gulf of Paria, Trinidad. In the area of investigation, found on both the Sound and Atlantic deltas of Ocracoke Inlet, at Drum Inlet, and at Cape Lookout Bight. Not found in Core or the main body of Pamlico Sound. Salinity, 24 to 35 ‰, most common more than 30 ‰; depth, 1 to more than 30 feet; substrate, sand. Associated with several other species of *Quinqueloculina* and with *Hanzawaia concentrica* and *Cibicides* sp. cf. *C. lobatulus*.

QUINQUELOCULINA MICROCOSTATA Natland, 1938
Plate 3, figures 4-6

Quinqueloculina microcostata NATLAND, 1938, p. 142, pl. 4, fig. 6a-c.

Diagnosis.—Recognized by its elongate, striated, quinqueloculine test with acute periphery and large aperture containing simple tooth. *Recent.*

Remarks.—Similar to *Quinqueloculina lamarckiana* (D'ORBIGNY) in shape, but is striated, also resembles *Q. contorta* D'ORBIGNY (1846) but the chambers are more angular.

Dimensions.—Length, 0.58 mm.; breadth, 0.36 mm.

Material.—18 tests.

Occurrence.—Found off Catalina Island, California, in 9.7 m. of normal marine water. Present in shallow tide pools off La Jolla, California. This is the first record of this species on the Atlantic coast of the United States. Found at one station near the southern end of Core Sound. Salinity, 35 ‰; depth, 10 feet; substrate, sand.

QUINQUELOCULINA POEYANA d'Orbigny, 1839
Plate 4, figures 3, 4, 8

Quinqueloculina poeyana D'ORBIGNY, 1839, p. 191, pl. 11, fig. 25-27; CUSHMAN, 1929, p. 31, pl. 5, fig. 2a-c; COLE, 1931, p. 21, pl. 6, fig. 10; MILLER, 1953, p. 52, pl. 8, fig. 2; PARKER, PHLEGER, & PEIRSON, 1953, p. 12, pl. 2, fig. 13-14; BANDY, 1956, p. 196, pl. 29, fig. 6; TODD & BRÖNNIMAN, 1957, p. 27, pl. 3, fig. 6.

Diagnosis.—Recognized by medium-sized, narrow, elongate test ornamented by distinct longitudinal costae and by nearly circular terminal aperture which is slightly extended and contains narrow simple tooth. *Pliocene to Recent.*

Remarks.—The Pamlico Sound specimens have a slightly shorter neck than typical forms but are similar otherwise. Similar to *Quinqueloculina rhodiensis* PARKER *(123)* but more elongate; also resembles *Q. subpoeyana* CUSHMAN (1922) which has more irregular chambers and indistict sutures.

Dimensions.—Length, 0.43 mm.; breadth, 0.18 mm.

Material.—19 tests.

Occurrence.—Found in the Pleistocene Caloosahatchee Marl of Florida. Distributed in the Recent in the Caribbean region, the Gulf of Mexico, and along coasts of the southern Atlantic states. Occurs in the brackish-water of Mason Inlet, North Carolina, in several of the Texas bays, and in the nearshore zone of the Gulf of Paria, Trinidad. BANDY (1956) has reported it as the dominant species of

EXPLANATION OF PLATE 3

QUINQUELOCULINA

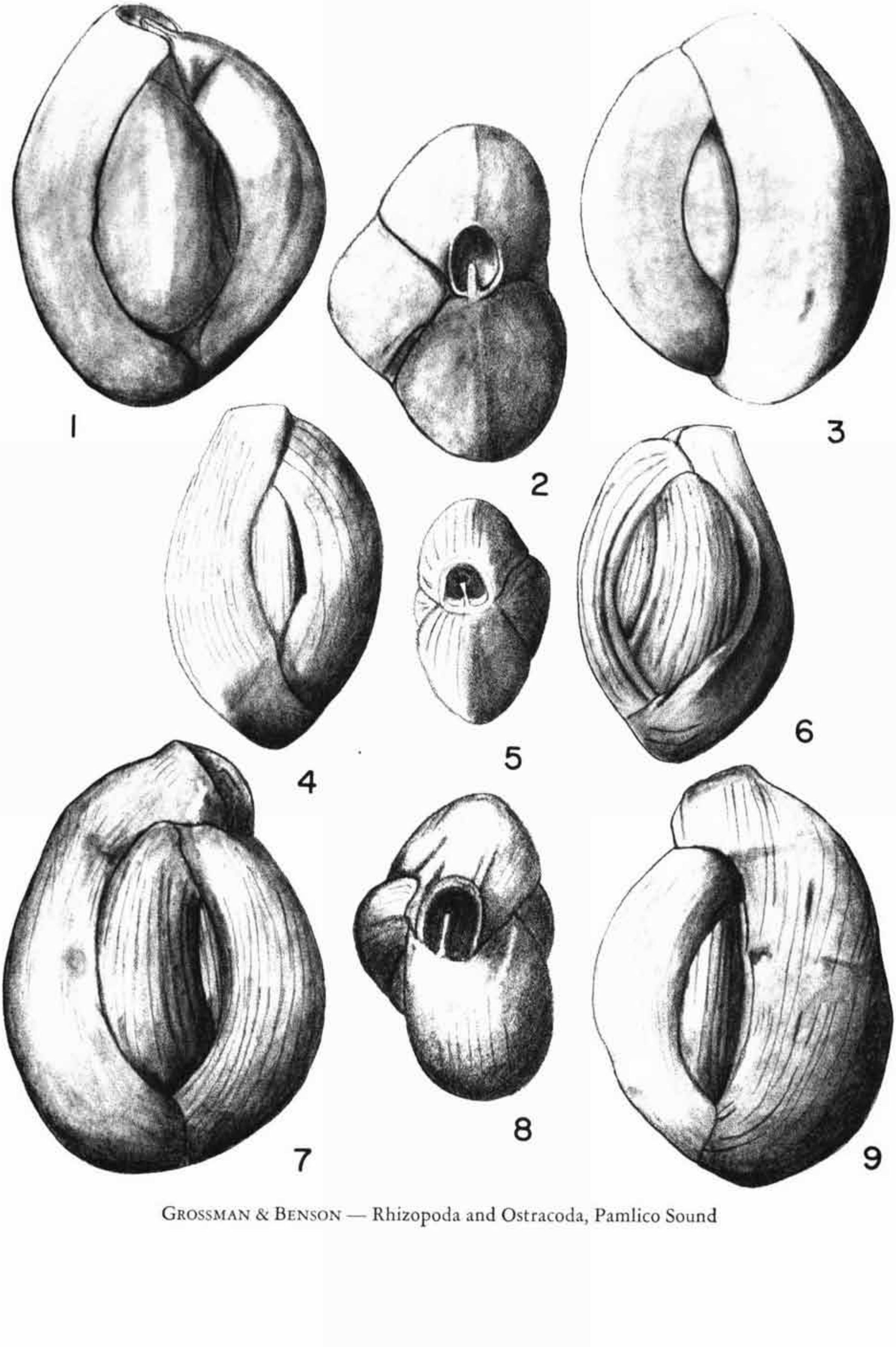
(All illustrated forms are from Southern Pamlico Sound Region; all ×100)

FIGURE

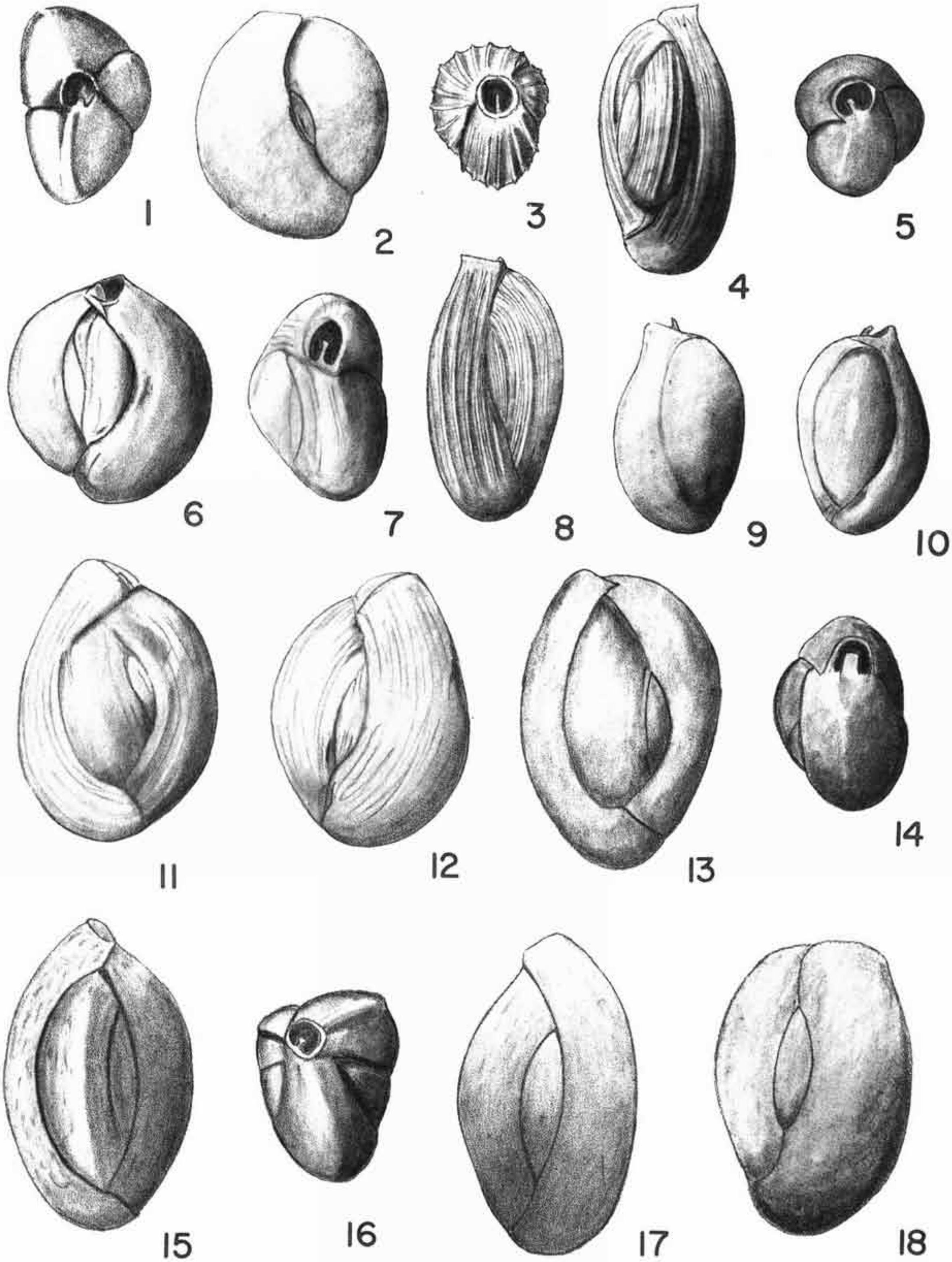
1-3. *Quinqueloculina lamarckiana* D'ORBIGNY; *1,3,* lateral views; *2,* apertural view (p. 52).

4-6. *Quinqueloculina microcostata* NATLAND; *4,6,* lateral views; *5,* apertural view (p. 52).

7-9. *Quinqueloculina bicornis* (WALKER & JACOB); *7,9,* lateral views; *8,* apertural view (p. 51).



Grossman & Benson — Rhizopoda and Ostracoda, Pamlico Sound



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound

his facies 1 (40 to 80 feet) in the northeastern Gulf of Mexico where it is associated with *Elphidium gunteri* COLE, and *Ammonia tepida* (CUSHMAN). Present in the area of investigation, in Cape Lookout Bight, the Atlantic delta of Ocracoke Inlet, and at several stations in Core Sound. Salinity greater than 30 ‰; depth, 2 to more than 30 feet; substrate, sand. Associated with several species of *Quinqueloculina.*

QUINQUELOCULINA SEMINULA (Linné), 1758
Plate 4, figures 13, 14, 18

Serpula seminulum LINNÉ, 1758, p. 786.
Miliolina seminula (Linné), WILLIAMSON, 1858, p. 85, pl. 7, fig. 183-185; HERON-ALLEN & EARLAND, 1932, p. 313-314, pl. 6, fig. 25-40.
Quinqueloculina seminulum (Linné), CUSHMAN, 1929, p. 24, pl. 2, fig. 1-2; KORNFELD, 1931, p. 83-84, pl. 14, fig. 4a-c; WEISS, 1954, p. 161-162, pl. 33, fig. 11.
Quinqueloculina sp. cf. *Q. seminulum* (Linné), MILLER, 1953, p. 52, pl. 8, fig. 1.
Quinqueloculina seminula (Linné), CUSHMAN & COLE, 1930, p. 95, pl. 13, fig. 1a-c; CUSHMAN, 1930, p. 19, pl. 2, fig. 1a-c (*non* fig. 2); MCLEAN, 1956, p. 321-322, pl. 37, fig. 12-14.

Diagnosis.—Recognized by the elongate, porcelaneous test; narrowly rounded periphery; distinct sutures; and large aperture having simple tooth. *Miocene to Recent.*

Remarks.—Differs from *Quinqueloculina jugosa* CUSHMAN (1944) in lacking longitudinal costae.

Dimensions.—Length, 0.50 mm.; breadth, 0.32 mm.

Material.—14 tests.

Occurrence.—Present in the *Arca* and *Cancellaria* facies of the Choctawhatchee Formation of the Miocene of Florida and the Miocene Yorktown Formation of Virginia. Recorded from the Pliocene Waccamaw Formation of North Carolina, the Pleistocene Caloosahatchee Marl of Florida and Gardners Clay of Long Island. One of the most common species of modern oceans and especially prevalent in shallow water. It is known from European waters and is found along both coasts of the United States. Present also in the shallow waters of the Gulf of Mexico and the nearshore zone of the Gulf of Paria, Trinidad. Present in the study area in the vicinity of Drum Inlet and both the Sound and marine deltas of Ocracoke Inlet. Found in salinities greater than 30 ‰; depths, 5 to more than 30 feet; substrate, sand. Associated with *Quinqueloculina jugosa* and *Q. lamarckiana.*

QUINQUELOCULINA TRILOCULINIFORMA McLean, 1956
Plate 4, figures 1, 2, 6

Quinqueloculina triloculiniforma MCLEAN, 1956, p. 322, pl. 37, fig. 9-11.

Diagnosis.—Recognized by small, broad test with third chamber barely showing on 3-chambered side. Chambers distinct; periphery subrounded; sutures distinct and depressed, aperture large with simple tooth. *Miocene to Recent.*

Remarks.—Resembles *Triloculina* except for the small fourth chamber on one side and the small third chamber on the opposite side. The Pamlico Sound specimens closely resemble the type described from the Miocene except that the chambers are slightly more angular and the third and fourth chambers slightly more apparent.

Dimensions.—Length, 0.34 mm.; breadth, 0.30 mm.
Material.—Three tests.

Occurrence.—Found in the Miocene Yorktown Formation of Virginia. This is the first reported occurrence of this species in the Recent. The specimens may have been redeposited from offshore subsea crops of Miocene rocks. Present at two stations on the seaward delta of Ocracoke Inlet. Salinity, greater than 30 ‰; depth, 30 feet; substrate, sand.

QUINQUELOCULINA sp.
Plate 2, figures 10, 11, 15

Diagnosis.—Recognized by ovoid, costate test with very large terminal aperture which contains T-shaped tooth. *Recent.*

Description.—Test small for genus, ovoid in lateral view, quinqueloculine, rounded in section, sutures moderately depressed, surface ornamented by numerous longitudinal costate, apertural end slightly raised, very large aperture nearly circular with single T-shaped tooth.

Remarks.—Similar to *Quinqueloculina poeyana* D'ORBIGNY (1839) but not as elongate and having a larger aperture. *Q. rhodiensis* is similar in shape, but the costae are more irregular and the aperture is much smaller. *Q.* sp. is apparently the same as the specimens figured by TODD & BRÖNNIMANN (1957) for *Q. poeyana.* The aperture and apertural tooth, however, seem to be very different from those of *Q. poeyana.* Insufficient specimens are available now for naming this form.

EXPLANATION OF PLATE 4

QUINQUELOCULINA, TRILOCULINA
(All illustrated forms are from Southern Pamlico Sound Region; all ×100)

FIGURE

1,2,6. *Quinqueloculina triloculiniforma* MCLEAN; *1,* apertural view; *2,6,* lateral views (p. 53).
3,4,8. *Quinqueloculina poeyana* D'ORBIGNY; *3,* apertural view; *4,8,* lateral views (p. 52).
5,9,10. *Triloculina oblonga* (MONTAGU); 5, apertural view; *9,10,* lateral views (p. 54).
7,11,12. *Quinqueloculina jugosa* CUSHMAN; *7,* apertural view; *11,12,* lateral views (p. 51).
13,14,18. *Quinqueloculina seminula* (LINNÉ); *13,18,* lateral views; *14,* apertural view (p. 53).
15-17. *Quinqueloculina compta* CUSHMAN; *15,17,* lateral views; *16,* apertural view (p. 51).

Dimensions.—Length, 0.31 mm.; breadth, 0.22 mm.

Material.—Two tests.

Occurrence.—Found at two stations in Nelson Bay. Salinity, about 25 ‰; depth, less than 1 to 5 feet; substrate, silty sand.

Genus TRILOCULINA d'Orbigny, 1826

TRILOCULINA OBLONGA (Montagu), 1803

Plate 4, figures 5, 9, 10

Vermiculum oblongum MONTAGUE, 1803, p. 522, pl. 14, fig. 9.
Triloculina oblonga (Montagu), D'ORBIGNY, 1839, p. 175, pl. 10, fig. 3-5; CUSHMAN, 1929, p. 57, pl. 13, fig. 4-5; KORNFIELD, 1931, p. 85-86, pl. 14, fig. 7a-c; CUSHMAN & PONTON, 1932, p. 52, pl. 6, fig. 7a-c; PURI, 1953, p. 92-93, pl. 4, fig. 14-16; TODD & BRÖNNIMAN, 1957, p. 27, pl. 3, fig. 15-16; for a more complete synonomy see CUSHMAN, 1929, p. 57.

Diagnosis.—Recognized by its small to medium-sized, smooth, polished, globose to elongate test; inflated chambers; and rounded periphery. Aperture oval with variously shaped tooth. *Miocene to Recent.*

Remarks.—This species is quite variable in shape, size, and character of the apertural tooth. The Pamlico Sound specimens are more globose than typical forms but similar to the specimen illustrated by KORNFELD (1931).

Dimensions.—Length, 0.33 mm.; breadth, 0.21 mm.

Material.—31 tests.

Occurrence.—Reported from Miocene and Pleistocene formations of Florida. In the Recent it has been recorded off the coast of Europe, from the Gulf of Mexico, and from the Caribbean region. Found in the Gulf of Mexico at depths ranging from very shallow to more than 2,800 fathoms; common in the nearshore zone of the Gulf of Paria, Trinidad. Present at widely separated stations in the more marine areas of the study region; in both the Sound and Atlantic deltas of Ocracoke Inlet, and in Core Sound. Salinity, 2 to 35 ‰, but much more abundant greater than 30 ‰; depth, 5 to more than 30 feet; substrate, sand or silty sand.

TRILOCULINA ROTUNDA d'Orbigny, 1826

Plate 5, figures 1-3

Triloculina rotunda D'ORBIGNY, 1826, p. 299; CUSHMAN, 1929, p. 59, pl. 14, fig. 3a-c; CUSHMAN & PONTON, 1932, p. 54, pl. 6, fig. 10a-c.

Diagnosis.—Recognized by its rotund chambers, broadly rounded periphery, and slightly projecting, single, bifid tooth; 2 last-formed chambers compose most of test, which is smooth but may contain a few transverse wrinkles. *Miocene to Recent.*

Dimensions.—Length, 0.46 mm.; breadth, 0.35 mm.

Material.—Two tests.

Occurrence.—Reported from Miocene formations of Florida. Occurs in the Recent of the northeast Atlantic and the Dry Tortugas region. Found at one station in the southern end of Core Sound. Salinity, 35 ‰; depth, 10 feet; bottom, medium-sized sand.

TRILOCULINA TRIGONULA (Lamarck), 1804

Plate 5, figures 4-6

Miliolites trigonula LAMARCK, 1804, p. 351.
Triloculina trigonula (Lamarck), D'ORBIGNY, 1826, p. 299, pl. 16, fig. 5-9; BRADY, 1884, p. 164, pl. 3, fig. 14-16; CUSHMAN, 1929, p. 56, pl. 12, fig. 10-11, pl. 13, fig. 1-2; CUSHMAN & PONTON, 1932, p. 52, pl. 6, fig. 6a-c; PURI, 1953, *138*, p. 94, pl. 4, fig. 11-13; PARKER, PHLEGER, & PEIRSON, 1953, p. 14, pl. 2, fig. 29; BANDY, 1954, p. 139, pl. 28, fig. 5; RONAI, 1955, p. 143-144, pl. 20, fig. 9.

Diagnosis.—Distinguished by its rounded, triangular appearance in end view and by rather broad, bifid tooth in aperture. *Eocene to Recent.*

Remarks.—The angularity of the test differs considerably.

Dimensions.—Length, 0.52 mm.; breadth, 0.35 mm.

Material.—Two tests.

Occurrence.—Known from the Eocene of the Paris Basin, the Miocene of Florida, and the Recent of the Gulf of Mexico and the Atlantic coast of the United States. In the Pamlico Sound region both of the specimens were found on the Atlantic delta of Ocracoke Inlet. Salinity, 35 ‰; depth, 30 feet; sand bottom.

Family SORITIDAE Ehrenberg, 1839

Subfamily PENEROPLINAE Schultze, 1854

Genus PENEROPLIS Montfort, 1808

PENEROPLIS PROTEUS d'Orbigny, 1839

Plate 7, figure 9

Peneroplis protea D'ORBIGNY, 1839, p. 60, pl. 7, fig. 7-11.
Peneroplis proteus (d'Orbigny), CUSHMAN, 1921, p. 75, pl. 18, fig. 13-19; CUSHMAN & PONTON, 1932, p. 71, pl. 10, fig. 7-11, 14; GALLOWAY & HEMINWAY, 1941, p. 316, pl. 5, fig. 7a,b.

Diagnosis.—Recognized by its large, variable, smooth test with close-coiled and involute early portion; strongly

---

EXPLANATION OF PLATE 5

TRILOCULINA, SPIROLOCULINA, TROCHAMMINA

(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

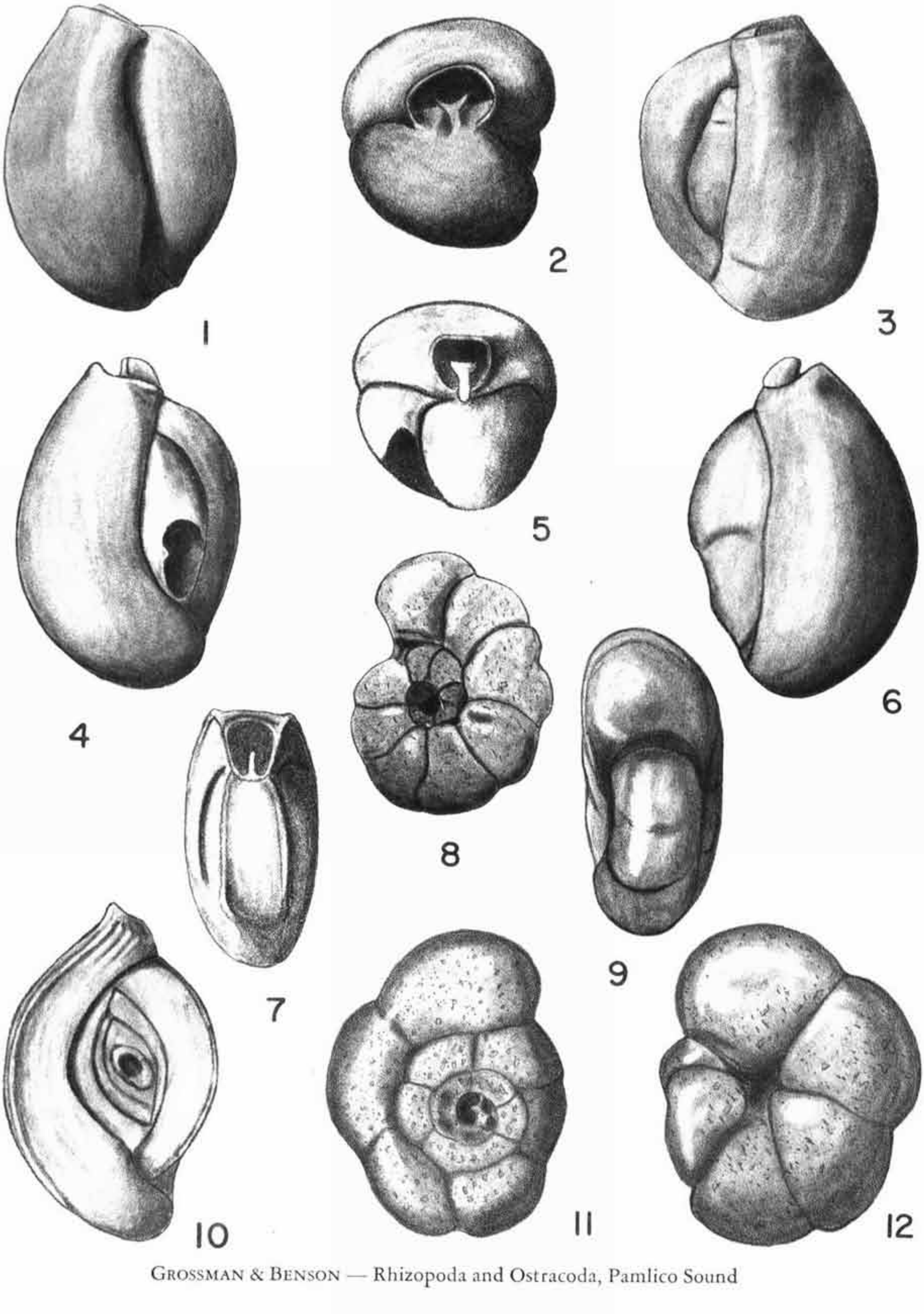
1-3. *Triloculina rotunda* D'ORBIGNY; *1,3,* lateral views; *2,* apertural views; all ×100 (p. 54).

4-6. *Triloculina trigonula* (LAMARCK); *4,6,* lateral views; *5,* apertural view (specimen damaged); all ×100 (p. 54).

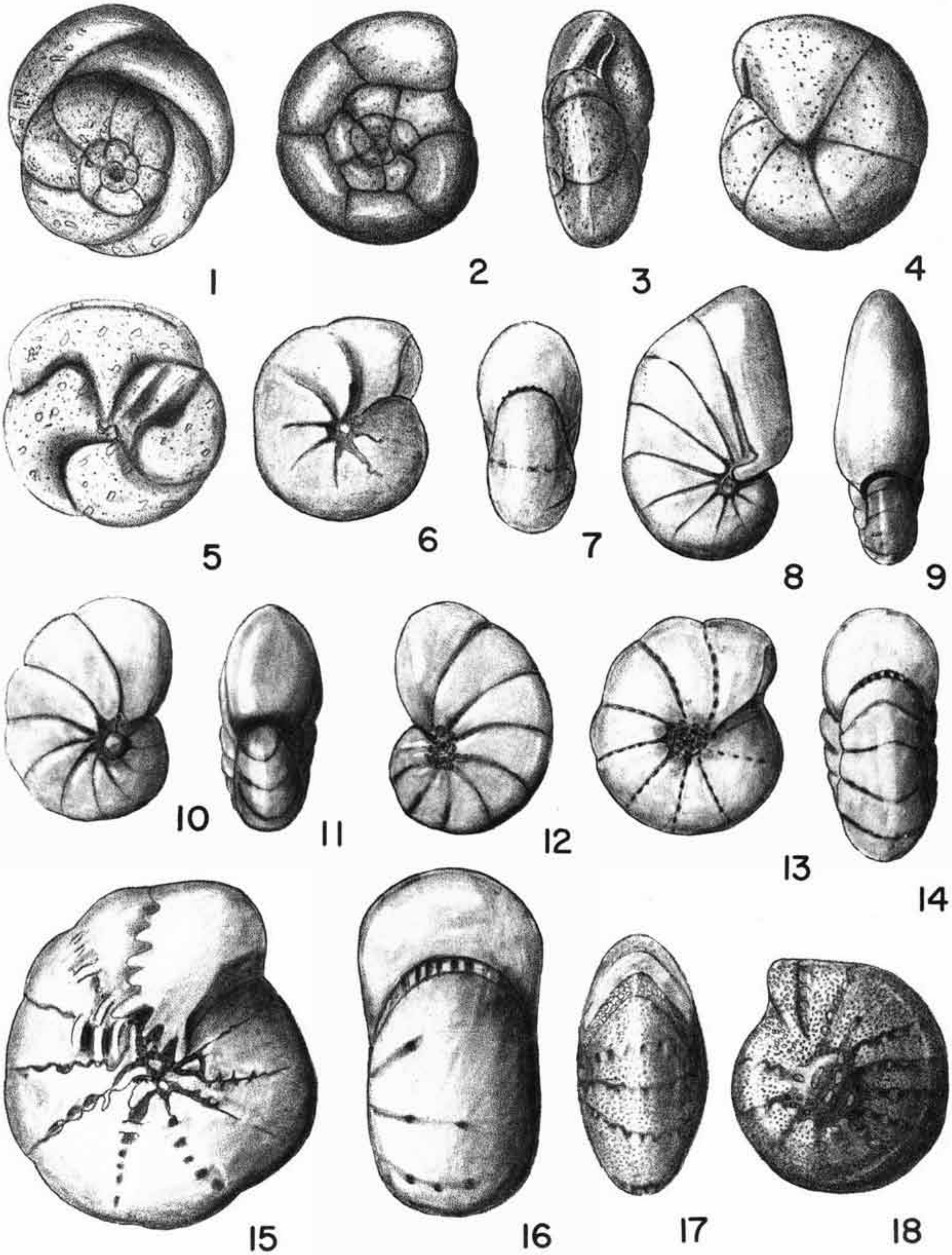
7-10. *Spiroloculina planulata* (LAMARCK); apertural and lateral views, ×100 (p. 51).

8. *Trochammina macrescens* BRADY; lateral views, ×100 (p. 50).

9-12. *Trochammina inflata* (MONTAGU); *9,* apertural view; *11,* dorsal view; *12,* ventral view; all ×120 (p. 50).



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound

curved sutures; and row of pores at base of apertural face. *Middle Oligocene to Recent.*

Remarks.—Similar to *Peneroplis bradyi* CUSHMAN (1930), but the early stages are evolute in the latter whereas *P. proteus* is involute.

Dimensions.—Greatest diameter, 0.80 mm.

Material.—One test.

Occurrence.—Recorded from the middle Oligocene San Sebastian Formation of Puerto Rico and from the Miocene Chipola facies of the Alum Bluff Formation of Florida. Found in the Recent in the warmer waters of the western Atlantic. The single specimen found in the study area is from a station on the marine delta of Ocracoke Inlet. This specimen was probably transported northward by the Gulf Stream. It is a tropical species that cannot tolerate the much colder water off the Carolina coast.

Superfamily ASTERIGINACEA d'Orbigny, 1839

Family DISCORBIDAE Cushman, 1927

Subfamily DISCORBINAE Cushman, 1927

Genus ROSALINA d'Orbigny, 1826

ROSALINA COLUMBIENSIS (Cushman), 1925

Plate 8, figures 7-8

Discorbis columbiensis CUSHMAN, 1925, p. 43, pl. 6, fig. 13a-c; CUSHMAN & TODD, 1947, p. 20, pl. 3, fig. 14-16; PARKER, 1952, *119*, p. 418, pl. 6, fig. 7a,b-8a,b-9a,b.

Discorbis bertheloti (d'Orbigny), var. *floridensis* CUSHMAN, 1944 (*non* Cushman, 1931), p. 31, pl. 4, fig. 17.

Discorbis obtusa CUSHMAN, 1944 (*non Rosalina obtusa* d'Orbigny), p. 31, pl. 4, fig. 15.

Discorbis subaraucana CUSHMAN, 1944 (*non* Cushman, 1922), p. 31, pl. 4, fig. 18.

Diagnosis.—Recognized by its broadly depressed umbilical region, broadening of chambers in last coil, and progressively greater size of punctae. *Recent.*

Remarks.—Thes forms closely resemble PARKER's *(119)* illustrations of the species but differ in shape somewhat from illustrations in CUSHMAN's 1925 paper. The aperture is an elongate slit near the umbilical region; because of this feature the species is assigned to *Rosalina.*

Dimensions.—Greatest diameter, 0.34 mm.

Material.—Five tests.

Occurrence.—Recorded from the shallow waters off the coast of Oregon and in shallow waters of the New England region, both north and south of Cape Cod. Found only at stations in the more marine areas of the Pamlico Sound region. Salinity, 35 ‰; depth, 20 to 30 feet; substrate, sand.

ROSALINA FLORIDANA (Cushman), 1922

Plate 9, figures 1-2

Discorbis floridana CUSHMAN, 1922, p. 39, pl. 5, fig. 11-12; CUSHMAN, 1931, p. 21, pl. 4, fig. 7-8; CUSHMAN & PONTON, 1932, p. 88, pl. 13, fig. 2a-c; CUSHMAN & CAHILL, 1933, p. 29, pl. 9, fig. 12-13; PURI, 1953, *138*, p. 131, pl. 24, fig. 7-9; PHLEGER & PARKER, 1951, p. 20, pl. 10, fig. 4a,b; MCLEAN, 1956, p. 351, 352, pl. 46, fig. 9-12, 15.

Discorbis rosacea CUSHMAN, 1930 (*non* d'Orbigny), p. 51, pl. 9, fig. 13a-c.

Discorbis subaraucana CUSHMAN, 1930 (*non* Cushman, 1923), p. 52, pl. 10, fig. 1a-c.

Discorbis floridanus Cushman, BANDY, 1954, p. 136, pl. 31, fig. 1a-c.

Rosalina floridana (Cushman), PARKER, 1954, p. 524-525, pl. 8, fig. 19-20; TODD & BRÖNNIMANN, 1957, p. 36, pl. 9, fig. 16-21.

Diagnosis.—Distinguished by its plano-convex, rotaliform test having convex dorsal side and flattened ventral side, 5 to 6 elongate chambers forming last whorl with chambers separated by very obliquely curved sutures; wall smooth, finely perforate; aperture, ventral, elongate. *Miocene to Recent.*

Remarks.—The species is variable, ranging from forms having an umbilical flap to those having an open umbilicus.

Dimensions.—Greatest diameter, 0.45 mm.

Material.—Three tests.

Occurrence.—Recorded from the Miocene sediments of the Atlantic coastal plain of the United States and having been found in the Choctawhatchee Formation of Florida, Duplin Marl of North and South Carolina, Yorktown and St. Marys Formations of Virginia, and the Calvert Formation of Maryland. In the Recent it has been reported mainly from the Gulf of Mexico and the Caribbean region but has been found by PARKER (1948) off the coast of Maryland. Although widely distributed, it is a rare species which is found generally in depths of less than 100 feet. Present at one station on the ocean delta of Ocracoke Inlet. Salinity, 35 ‰; depth, 30 feet; substrate, sand.

EXPLANATION OF PLATE 6

TIPHOTROCHA, ARENOPARELLA, PROTELPHIDIUM, PSEUDONONION, ELPHIDIUM

(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

1,5. *Tiphotrocha comprimata* CUSHMAN & BRÖNNIMANN; dorsal and ventral views, ×120 (p. 50).

2-4. *Arenoparella mexicana* (KORNFELD); *2,* dorsal view; *3,* apertural view; *4,* ventral view; all ×100 (p. 50).

6,7. *Protelphidium tisburyense* (BUTCHER); lateral and apertural views, ×100 (p. 57).

8-12. *Pseudononion atlanticus* CUSHMAN; *8,* lateral view of variant; *9,* apertural view of variant; *10,12,* lateral views; *11,* apertural view; ×100 (p. 61).

13-14. *Elphidium articulatum* (D'ORBIGNY); lateral and apertural views, ×120 (p. 57).

15,16. *Elphidium brooklynense* SHUPACK; lateral and apertural views, ×100 (p. 58).

17-18. *Elphidium discoidale* D'ORBIGNY; apertural and lateral views, ×100 (p. 58).

Subfamily EPONIDINAE Hofker, 1951

Genus POROEPONIDES Cushman, 1944

POROEPONIDES LATERALIS (Terquem), 1878

Plate 10, figures 6-8

Rosalina lateralis TERQUEM, 1878, p. 25, pl. 2, fig. 11a-c.

Pulvinulina repanda BRADY, 1884, p. 627, 684-685, pl. 104, fig. 18a-c.

Eponides lateralis (Terquem), CUSHMAN, 1930, p. 55, pl. 10, fig. 7a-c; CUSHMAN & PONTON, 1932, p. 92, pl. 13, fig. 8a-c; CUSHMAN & CAHILL, 1933, p. 31, pl. 11, fig. 1a-c.

Poroeponides lateralis (Terquem), CUSHMAN, 1944, p. 34, pl. 4, fig. 23; PURI, 1953, *138*, p. 134, pl. 24; fig. 10-12; BANDY, 1954, p. 137, pl. 30, fig. 1a-c; McLEAN, 1956, p. 358-359, pl. 47, fig. 9-11, pl. 48, fig. 1-2.

Diagnosis.—Characterized by moderately large, ovate, biconvex test which has subacute and keeled periphery; by oblique, limbate, dorsal sutures; slightly depressed, nearly radial, ventral sutures; and by perforations on ventral side of last-formed chamber. *Miocene to Recent.*

Dimensions.—Greatest diameter, 0.65 mm.

Material.—Four tests.

Occurrence.—Originally described from Pliocene sediments of the Isle of Rhodes. Reported from the *Arca* and *Cancellaria* facies of the Choctawhatchee Formation of the Miocene of Florida and the Miocene Yorktown and St. Marys Formations of Virginia. Reported in the Recent from the southern shores of Cape Cod; Mason Inlet, North Carolina; various areas in the Gulf of Mexico; and Sunset Bay, Oregon. It is a shallow-water, normal-marine species. Found in Ocracoke Inlet and at one station on the Atlantic delta of the Inlet. Salinity, 25 to 35 ‰; depth, 20 to more than 30 feet; substrate, sand.

Superfamily ROTALIACEA Ehrenberg, 1839

Family ROTALIIDAE Ehrenberg, 1839

Subfamily ROTALIINAE Ehrenberg, 1839

Genus AMMONIA Brünnich, 1772

AMMONIA LIMBATOBECCARII (McLean), 1956

Plate 10, figures 1-2

Rotalia limbatobeccarii McLEAN, 1956, p. 537, pl. 47, fig. 5-8.

Diagnosis.—Recognized by its moderately large size, dorsally limbate sutures, glossy knob on center of dorsum, ventrally lobed chambers, and umbilical plug. *Miocene to Recent.*

Remarks.—Similar to *Rotalia beccarii ornata* (D'ORBIGNY, 1839) especially as to development of limbate ribs on the dorsum but differs in the ventral lobation of the chambers and the presence of an umbilical plug. The Pamlico Sound forms appear to be identical to McLEAN's specimens.

Dimensions.—Greatest diameter, 0.47 mm.

Material.—940 tests.

Occurrence.—Found in the Miocene Yorktown Formation of Virginia. This is the first recorded appearance of this species in the Recent. Distributed in low numbers at numerous stations in Core Sound and also found at several localities on both the Atlantic and Sound deltas of Ocracoke Inlet. Found in large numbers next to the marsh in Nelson Bay and adjacent to the marsh on Portsmouth Island. Salinity, 5 to 30 ‰, most common at about 20 ‰; depth, less than 1 to more than 30 feet, but much more abundant at depths of less than 4 feet; substrate, mud to sand, but prefers the highly organic mud adjacent to marshes. Associated with *Tiphotrocha comprimata, Trochammina inflata,* and *Aurila conradi littorala.*

AMMONIA SOBRINA (Shupack), 1934

Plate 9, figures 10-11

Rotalia beccarii (Linné), var. *parkinsoniana* CUSHMAN, 1930, (*non* D'ORBIGNY, 1839), p. 100, pl. 13, fig. 14a-c; COLE, 1931, p. 49, pl. 3, fig. 5-6; KORNFELD, 1931, p. 90, pl. 13, fig. 1a-c; PHLEGER & PARKER, 1951, p. 23, pl. 12, fig. 6a,b.

Rotalia beccarii (Linné) var. *sobrina* SHUPACK, 1934, no. 737, p. 6, fig. 4a-c; BANDY, 1954, p. 138, pl. 30, fig. 7.

Streblus beccarii (Linné), var. *sobrina* (Shupack), TODD & BRÖNNIMANN, 1957, p. 38, pl. 10, fig. 1-2.

Streblus beccarii (Linné) var. *sobrinus* (Shupack), ARNAL, 1958, p. 40, pl. 12, fig. 1-3.

Diagnosis.—Distinguished by its small size and large glassy umbilical plug. *Pleistocene to Recent.*

Remarks.—These specimens are similar to those figured by CUSHMAN (1930) for *Rosalina parkinsoniana* D'ORBIGNY (1826) but CUSHMAN's specimens are not the same species as D'ORBIGNY's; the latter has a pronounced lobulate margin and differs in other features.

Dimensions.—Greatest diameter, 0.37 mm.

Material.—20 tests.

Occurrence.—Found in the Pleistocene of Florida and in the Recent in the shallow waters of New York Harbor, the nearshore regions of the Gulf of Mexico, and commonly in tidal and nearshore zones of the Gulf of Paria, Trinidad. Present on the Sound delta of Ocracoke Inlet and at one station in Core Sound. Salinity, 24 to 31 ‰; depth, 5 to 15 feet; substrate, sand or silty sand.

AMMONIA TEPIDA (Cushman), 1926

Plate 9, figures 5, 9

Rotalia beccarii (Linné) var. *tepida* CUSHMAN, 1926, p. 79, pl. 1; COLE, 1931, p. 50, pl. 3, fig. 3-4.

Rotalia beccarii tepida Cushman, WEISS, 1954, p. 160, pl. 33, fig. 1.

Streblus tepidus (Cushman), BANDY, 1956, p. 197, pl. 31, fig. 2.

Diagnosis.—Recognized by its small, biconvex, trochoid test having slightly limbate dorsal sutures and pronounced open umbilicus. *Miocene to Recent.*

Remarks.—*Ammonia tepida* is similar in size and shape to *A. sobrina* but may be distinguished by its lack of an umbilical plug. It is separated from *A. limbatobeccarii* and *A. beccarii* by much smaller size.

Dimensions.—Greatest diameter, 0.28 mm.

Material.—46 tests.

Occurrence.—Known from the Miocene, Pliocene, and Pleistocene of Florida. Present in the *Cancellaria, Yoldia,* and *Ecphora* facies of the Choctawhatchee Formation of the Miocene of Florida and the Pleistocene Gardners Clay of Long Island. Described from the Recent of the Gulf of Paria, Trinidad, and noted by TODD & BRÖNNI-

MANN (1957) as being abundant in the intertidal, nearshore, and offshore zones of that region. Reported by PARKER (1952) from the Long Island Sound-Buzzards Bay area and occurs sporadically in the shallow, near-normal-marine waters of that area. In the area of investigation, present in low numbers at widely scattered localities. Found in the Neuse River estuary, Core and Pamlico Sounds, and in Nelson Bay. Salinity, 12 to 30 ‰, most common in salinities of less than 20 ‰; depth, 4 to 20 feet; substrate, medium to silty sand. Associated with *Elphidium clavatum*.

Family ELPHIDIIDAE Galloway, 1933

Genus PROTELPHIDIUM Haynes, 1956

PROTELPHIDIUM ORBICULARE (Brady), 1881

Plate 7, figures 7-8

Nonionina orbicularis BRADY, 1881, p. 415, pl. 21, fig. 5a,b.
Nonion orbiculare (Brady), CUSHMAN, 1930, p. 12, pl. 5, fig. 1-3; CUSHMAN, 1939, p. 23; pl. 6, fig. 17-19; CUSHMAN, 1948, p. 53, pl. 6, fig. 3.
Elphidium orbiculare (Brady) LOEBLICH & TAPPAN, 1953, p. 102-103, pl. 19, fig. 1-4; RONAI, 1955, p. 145, pl. 21, fig. 1.

Diagnosis.—Recognized by its lack of retral processes, hyaline surface, granular appearance of umbilical region, and row of pores at base of apertural face. *Pliocene to Recent.*

Dimensions.—Greatest diameter, 0.52 mm.

Material.—143 tests.

Occurrence.—Found in the Pliocene and Pleistocene of Great Britain. Recent specimens are most commonly found in colder waters, especially in the Arctic region. The species has been recorded from Hudson Bay, and off Spitzbergen, Alaska, and Scotland. It was found by RONAI (1955) in brackish waters of the New York Bight region. The depth range is from very shallow water to more than 600 m., and the salinity range is from brackish to normal marine. The geographic range is here extended southward to the southern Pamlico Sound region where it is found in the more marine areas, more specifically in both the Sound and Atlantic deltas of Ocracoke Inlet and at widely separated stations in Core Sound. A few individuals were found near the head of Nelson Bay. Salinity, 20 to 35 ‰, most common at 30 ‰. Depth, 5 to 39 feet; substrate, sand or silty sand. Associated with *Elphidium galvestonense* and several species of *Quinqueloculina*.

PROTELPHIDIUM TISBURYENSE (Butcher), 1948

Plate 6, figures 6-7

Nonion tisburyensis BUTCHER, 1948, p. 22, fig. 1,1a; RONAI, 1955, p. 145, pl. 21, fig. 3; BOLTOVSKY, 1958, p. 18, pl. 6, fig. 1-6.
Protelphidium tisburyense (Butcher), PARKER & ATHEARN, 1959, p. 342, pl. 50, fig. 26-32.

Diagnosis.—Recognized by its nearly circular test, with 7 to 9 chambers in last whorl, opening of sutures near umbilicus, and depressed umbilicus which may or may not have some extraneous calcareous deposits. *Recent.*

Remarks.—This species is quite variable; some specimens have evenly rounded peripheries, others are lobate, and some have deposits of shell material in the umbilicus, whereas in others the umbilicus is open. In general appearance, these specimens are essentially identical to *Protelphidium tisburyense*, but the aperture is a row of pores at the base of the apertural face instead of a curved slit. This division of the apertural wall also was noted by RONAI (1955). On some of the Pamlico Sound specimens traces of pores occur along the sutures in the early chambers but pores are lacking in the later chambers.

Dimensions.—Greatest diameter, 0.30 mm.

Material.—30 tests.

Occurrence.—Found in the brackish tidal pools of Cape Cod, brackish waters of Narragansett Bay, bays of the New York Bight region, and in the Rio La Plata, South America. In the area of investigation, present in Core Sound and in Nelson Bay. Salinity, 20 to 30 ‰; depth, 5 to 15 feet; substrate, sand to silty sand.

PROTELPHIDIUM sp.

Plate 8, figures 9-10

Diagnosis.—Distinguished by lobulate outline, highly inflated chambers, sutural and umbilical granulations, and pores at base of apertural face.

Description.—Test medium-sized, very tumid, planispirally coiled, involute, sides convex, periphery markedly lobulate; 6 chambers in last whorl, increasing gradually in size, chambers distinct, inflated; sutures distinct, curved, markedly depressed, becoming granular near umbilical region; umbilicus depressed with granular surface which grades into sutural granulations; aperture a line of squared pores at base of apertural face; color, white; surface, finely perforate. *Recent.*

Remarks.—No retral processes were observed, but openings at the base of the apertural face and the sutural and umbilical granulations are similar to features found in *Protelphidium orbiculare* (BRADY, 1881). Similar to *P. tisburyense* (BUTCHER, 1948), but more tumid and differing in the aperture. Too few specimens were found to justify naming this form now.

Dimensions.—Greatest diameter, 0.52 mm.

Material.—One test.

Occurrence.—Found at one station in Core Sound.

Genus ELPHIDIUM de Montfort, 1808

ELPHIDIUM ARTICULATUM (d'Orbigny), 1839

Plate 6, figures 13-14

Polystomella articulata D'ORBIGNY, 1839, p. 30, pl. 3, fig. 9-10.
Nonion orbiculare CUSHMAN (*non* H. B. Brady), 1944, p. 24, pl. 3, fig. 24.
Elphidium articulatum (d'Orbigny), CUSHMAN, 1930, p. 26, pl. 10, fig. 6-8; PARKER, 1952, *119*, p. 411, pl. 5, fig. 5-7.

Diagnosis.—Recognized by its small, somewhat compressed test with slightly depressed umbilical region which commonly has numerous very small umbilical bosses and by numerous, short, broad retral processes ranging in number from 6 to 10; usually 9 or 10 chambers are slightly lobulate, somewhat inflated, and rounded; aperture with several rounded openings at base of last chamber. *Recent.*

Remarks.—Similar to *Elphidium bartletti* CUSHMAN (*52*) but has only 9 to 10 chambers in last whorl instead of 12. According to PARKER (*119*, p. 411), *E. articulatum* may represent the more southern development of the Arctic form, *E. bartletti*.

Dimensions.—Greatest diameter, 0.32 mm.

Material.—18 tests.

Occurrence.—This species has been found off the Atlantic coasts of North and South America and has been reported from the California coast. PHLEGER (1952) reported the species as restricted to the sand facies of nearshore and offshore areas of Portsmouth, New Hampshire. Present in low numbers in the more marine areas of the study area; more specifically, both the Sound and Ocean deltas of Ocracoke Inlet, Core Sound, and Cape Lookout Bight. Found in salinities of greater than 30 ‰. Depth, 5 to more than 30 feet; substrate, sand or silty sand. Associated with several species of *Elphidium*.

ELPHIDIUM BROOKLYNENSE Shupack, 1934

Plate 6, figures 15-16

Elphidium brooklynense SHUPACK, 1934, p. 10, fig. 7a,b.
Elphidium florentinae (Shupack), WEISS, 1954, p. 15 *(partim)*.

Diagnosis.—Recognized by its medium-sized, bilaterally symmetrical, slightly compressed test having 10 or 11 chambers in last whorl; by bosses in umbilical region, and especially by sutures which contain pores, except for last 3, which are marked by large irregular retral processes. *Pleistocene to Recent*.

Remarks.—WEISS (1954) suppressed the name *Elphidium brooklynense* by making it a junior subjective homonym of *E. florentinae* (SHUPACK), apparently because he considered the former a younger stage of the latter. The specimens in the Pamlico Sound region, however, have features very similar to those illustrated by SHUPACK for *E. brooklynense* and are rather different from both WEISS' and SHUPACK's illustrations of *E. florentinae*, especially in arrangement of the retral processes over the last 3 sutures. The size of the Pamlico Sound specimens indicates that they are mature rather than immature tests. For this reason and the other stated above, the name *E. brooklynense* is reinstated.

Dimensions.—Greatest diameter, 0.54 mm.

Material.—104 tests.

Occurrence.—Present in the Pleistocene and Recent of the New York Harbor and western Long Island areas. In the area of investigation associated with but less abundant than *Elphidium clavatum* and *E. incertum*. Distributed through Core and Pamlico Sounds and on both the Sound and Ocean deltas of Ocracoke Inlet. Salinity, 20 to 35 ‰, commonly less than 30 ‰; depth, 5 to more than 30 feet; substrate ranges from mud to sand, but species is much more common on sand.

ELPHIDIUM CLAVATUM Cushman, 1930

Plate 8, figures 13-14

Elphidium incertius (Williamson) var. *clavatum* CUSHMAN, 1930, p. 20, pl. 7, figs. 10a,b; CUSHMAN, 1939, p. 57, pl. 16, fig. 1-2; CUSHMAN, 1944, p. 25, pl. 3, fig. 32-33; CUSHMAN, 1948, p. 57, pl. 7, fig. 8; PARKER, 1952, *120*, p. 412, pl. 5, fig. 10-11; PHLEGER, 1952, p. 83, pl. 14, fig. 7; TODD & BRÖNNIMANN, 1957, p. 39, pl. 6, fig. 10.
Elphidium clavatum Cushman, SHUPACK, 1934, p. 11, fig. 8a,b; LOEBLICH & TAPPAN, 1953, p. 98, pl. 19, fig. 8-10; WEISS, 1954, p. 160, pl. 32, fig. 12-14; RONAI, 1955, p. 146, pl. 21, fig. 7.

Diagnosis.—Recognized by its bilaterally symmetrical test, indistinct, depressed sutures, and numerous irregularly arranged bosses in umbilical region. *Pleistocene to Recent*.

Remarks.—Similar to *Elphidium incertum* (WILLIAMSON) but is distinguished by the presence of numerous irregularly arranged bosses filling the umbilical region.

Dimensions.—Greatest diameter, 0.40 mm.

Material.—1,778 tests.

Occurrence.—Recorded from the northern coasts of Europe, from the Atlantic coast of North America, and the Gulf of Paria, Trinidad. Typically a shallow-water species; reported by TODD & BRÖNNIMANN (1957), as common in the nearshore zone of the Gulf of Paria. In the area of investigation, this is the most abundant foraminiferal species, and with its allies *Elphidium brooklynense* and *E. incertum* comprises 25 percent of the total foraminiferal population. Widely distributed through Core and Pamlico Sounds and on both the Sound and Ocean shoals of Ocracoke Inlet. Not present in Nelson Bay or the river estuaries. Salinity, 17 to 35 ‰; depth, 5 to more than 30 feet; found on a variety of bottoms ranging from mud to sand, but species prefers sand. In addition to the associates mentioned above, it is found with *Haplocytheridea setipunctata* and *Cushmanidea echolsae*.

ELPHIDIUM DISCOIDALE (d'Orbigny), 1839

Plate 6, figures 17-18

Polystomella discoidalis D'ORBIGNY, 1839, p. 56, pl. 6, fig. 23-24; CUSHMAN, 1922, p. 56, pl. 10, fig. 3-4; CUSHMAN, 1926, p. 80.
Elphidium discoidale (d'Orbigny), CUSHMAN, 1930, p. 22, pl. 8, fig. 8-9; KORNFELD, 1931, p. 88, pl. 16, fig. 3a,b; COLE, 1931, p. 34; CUSHMAN, 1939, p. 56, pl. 15, fig. 5-7; CUSHMAN, 1944, p. 26, pl. 3, fig. 38-39; PHLEGER & PARKER, 1951, p. 10, pl. 5, fig. 10-11; PARKER, PHLEGER, & PEIRSON, 1953, p. 7, pl. 3, fig. 13-14; BANDY, 1954, p. 136, pl. 30, fig. 4a,b; TODD & BRÖNNIMANN, 1957, p. 39, pl. 6, fig. 8-9.

EXPLANATION OF PLATE 7

ELPHIDIUM, PROTELPHIDIUM, PENEROPLIS
(All illustrated forms are from Southern Pamlico Sound Region)

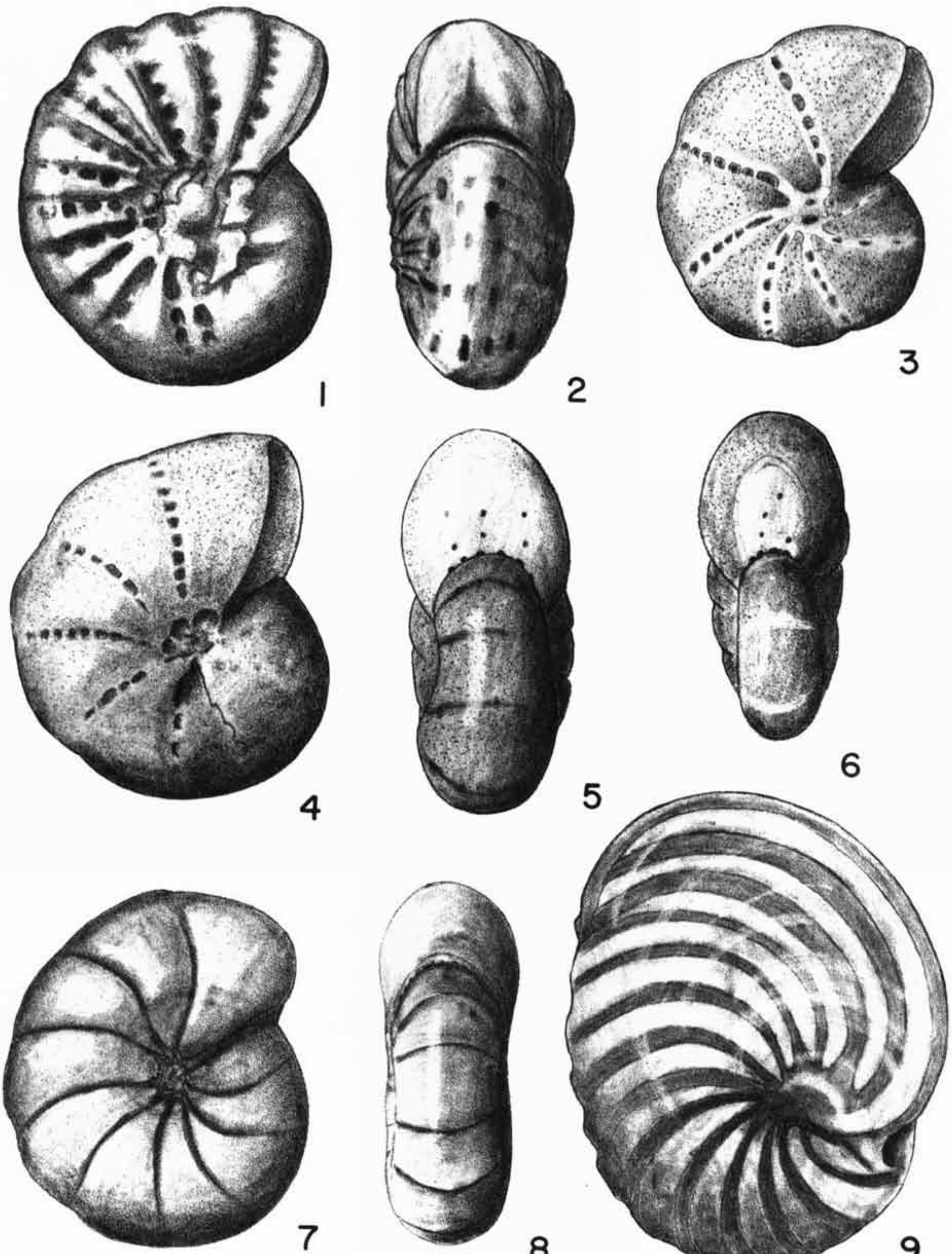
FIGURE

1,2. *Elphidium galvestonense* KORNFELD; lateral and apertural views, ×140 (p. 60).

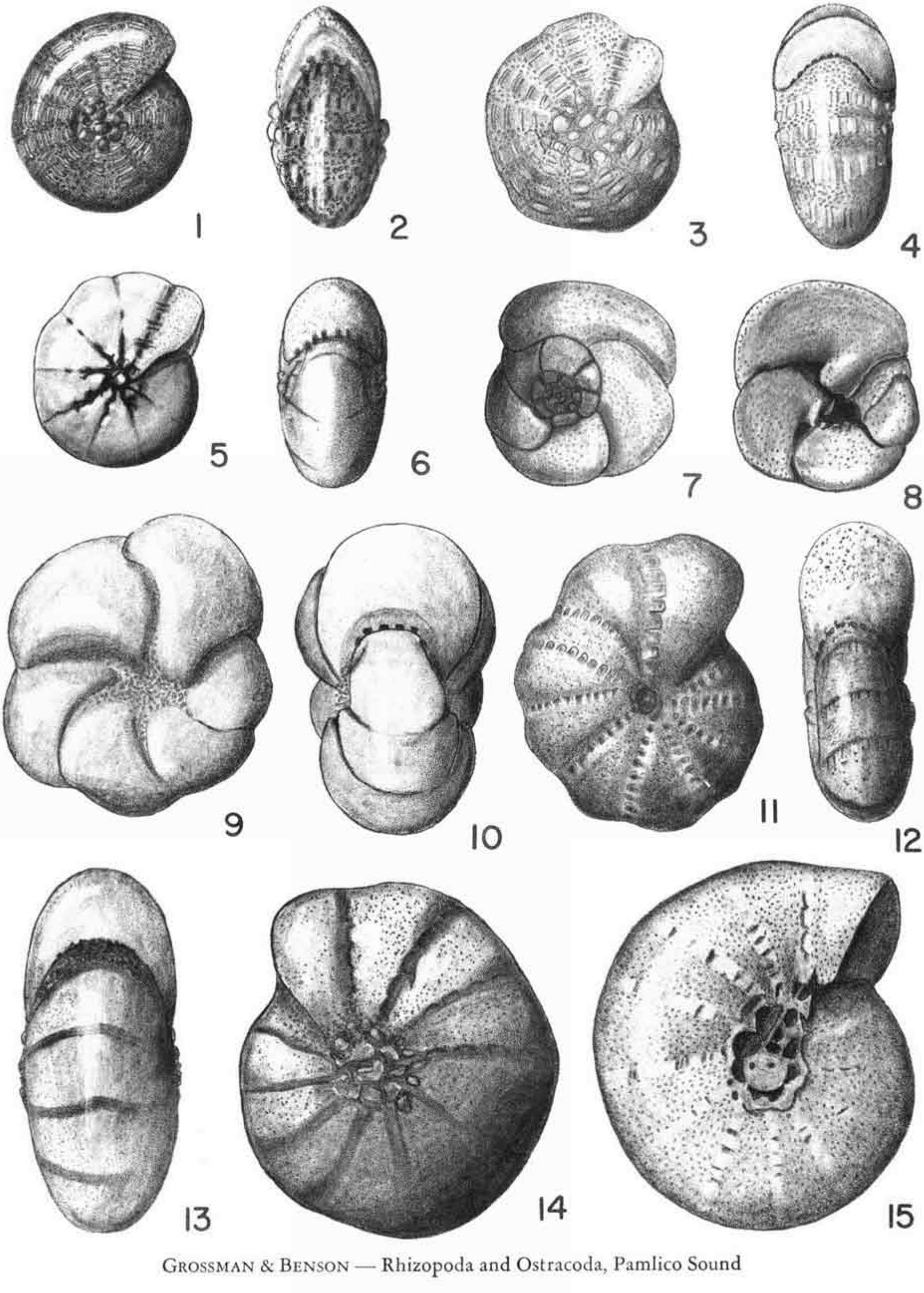
3-6. *Elphidium subarcticum* CUSHMAN; *3*, lateral view; *6*, apertural view; *4*, lateral view of variant; *5*, apertural view of variant; all ×140 (p. 60).

7,8. *Protelphidium orbiculare* (BRADY); lateral and apertural views, ×120 (p. 57).

9. *Peneroplis proteus* D'ORBIGNY; lateral view, ×100 (p. 54).



Grossman & Benson — Rhizopoda and Ostracoda, Pamlico Sound



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound

Diagnosis.—Recognized by medium-sized test, narrowly rounded periphery, large raised umbilical region that gives test strongly biconvex appearance in peripheral view, and numerous and evenly spaced retral processes. *Miocene to Recent.*

Dimensions.—Greatest diameter, 0.48 mm.

Material.—Two tests.

Occurrence.—Found in the Miocene Duplin Marl of North Carolina and St. Marys Formation of Maryland and in the Pleistocene Caloosahatchee Marl of Florida and Talbot Formation of Maryland. Found also in Recent of the Gulf of Mexico, the Caribbean region, and at Newport, Rhode Island. In the study area, one test was found at Ocracoke Inlet and the other in Cape Lookout Bight. *Elphidium discoidale* is found in waters more marine and at greater depths than most of the other species of this genus. It has been found at a depth of 1,500 m. in the West Indies but commonly occurs at depths of 30 and 100 fathoms. It occurs only rarely in shallow, brackish-water bays.

ELPHIDIUM GUNTERI Cole, 1931
Plate 8, figures 1-4

Elphidium gunteri Cole, 1931, p. 34, pl. 4, fig. 9-10; Hadley, 1936, p. 35; Cushman, 1939, p. 49-50; Parker, Phleger, & Peirson, 1953, p. 8, pl. 3, fig. 18-19; Bandy, 1956, p. 194, pl. 30, fig. 19a,b; Arnal, 1958, p. 39, pl. 12, fig. 9-10.

Elphidium gunteri Cole var. *galvestonensis* Kornfeld, 1931, p. 87, pl. 15, fig. 2a,b, 3a,b (*partim, non* fig. 1a,b).

Diagnosis.—Recognized by slightly raised, rectangular-shaped retral processes, beadlike processes filling umbilical area, and coarse perforations. *Pleistocene to Recent.*

Remarks.—Similar to *Elphidium galvestonense* Kornfeld (1931) but the latter species has finer perforations, only one large umbilical plug, and thicker retral processes. Some specimens of *E. gunteri* from the Pamlico Sound region have broad, flattened final chambers which, when combined with the prominent retral processes, superficially give the test the appearance of *E. sagrum* d'Orbigny (1839); closer inspection, however, reveals features that are typical of *E. gunteri.*

Dimensions.—Greatest diameter, 0.33 mm.; greatest diameter of variant, 0.37 mm.

Material.—81 tests.

Occurrence.—Found in the Pleistocene Caloosahatchee Marl of Florida and in the Pliocene Waccamaw Formation of the Carolinas. Present in the Recent in the shallow waters of the Gulf of Mexico. Found by Phleger, Parker, & Peirson (1953) to depths of 100 m. in the northwest part of the Gulf of Mexico, but specimens are more numerous and better developed in the Texas bays, where it is the most abundant *Elphidium* species. Equally abundant in near-shore areas of the northeastern Gulf of Mexico (Walton, 1964). In the area of investigation, present in low numbers at scattered stations in Pamlico Sound and at the Sound shoal of Ocracoke Inlet. Most numerous in Core Sound where it occurs at many stations. Salinity, 24 to 35 ‰, most common near 30 ‰; depth, 5 to 20 feet; substrate, sand to silty sand. Most frequently associated with *E. clavatum* and *E. galvestonense.*

ELPHIDIUM INCERTUM (Williamson), 1858
Plate 8, figures 5-6

Polystomella umbilicata (Walker & Jacob) var. *incerta* Williamson, 1858, p. 44, pl. 3, fig. 82,82a.

Elphidium incertum (Williamson), Cushman, 1930, p. 18, pl. 7, fig. 4-9; Shupack, 1934, p. 12, fig. 1a,b; Cushman, 1939, p. 57, pl. 15, fig. 21-24; Cushman, 1944, p. 25, pl. 3, fig. 28-31; Cushman, 1948, p. 56, pl. 6, fig. 7; Loeblich & Tappan, 1953, p. 101; Parker, 1952, *120,* p. 448, pl. 3, fig. 14, 16-17, pl. 4, fig. 1-2; Miller, 1953, p. 56, pl. 9, fig. 4; Weiss, 1954, p. 159, pl. 32, fig. 7.

Diagnosis.—Recognized by small, compressed, bilaterally symmetrical test having umbilical region either slightly raised owing to single boss of shell material or depressed where no knob exists; by rounded periphery and opening near umbilicus of meandering depressed sutures. Generally 9 chambers in last whorl; retral processes for most part indistinct and few. Aperture comprising line of perforations at base of apertural face. *Pleistocene to Recent.*

Remarks.—*Elphidium incertum* is perhaps one of the most prolific and most variable of all the species of the genus.

Dimensions.—Greatest diameter, 0.36 mm.

Material.—918 tests.

Occurrence.—This species is found commonly in North Atlantic waters; more specifically, it has been recorded from off coasts of Norway and Great Britain, in the Arctic, and on the Atlantic coast of the United States as far south as Mason Inlet, North Carolina. It is also found off the Pacific coast. It is typically a shallow-water, mesohaline to normal marine species, and has been found on bottoms ranging from mud to sand. Widely distributed throughout

---

EXPLANATION OF PLATE 8

Elphidium, Rosalina, Protelphidium

(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

1-4. *Elphidium gunteri* Cole; *1,* lateral view; *2,* apertural view; *3,* lateral view of variant; *4,* apertural view of variant; all ×100 (p. 59).

5,6. *Elphidium incertum* (Williamson); lateral and apertural view, ×100 (p. 59).

7,8. *Rosalina columbiensis* (Cushman); dorsal and ventral views, ×100 (p. 55).

9,10. *Protelphidium* sp.; lateral and apertural views, ×100 (p. 57).

11,12,15. *Elphidium tumidum* Natland; *11,12,* lateral and apertural views, ×120; *15,* lateral view of variant, ×140 (p. 60).

13,14. *Elphidium clavatum* Cushman; apertural and lateral views, ×140 (p. 58).

Core and Pamlico Sounds and on both the Sound and Ocean deltas of Ocracoke Inlet; not found in Nelson Bay or the river estuaries. Its salinity range is from 17 to 35 ‰, but most commonly found between 20 and 30 ‰; depth, 5 to more than 30 feet. Almost always associated with *Elphidium brooklynense* and *E. clavatum*.

ELPHIDIUM GALVESTONENSE Kornfeld, 1931
Plate 7, figures 1-2

Elphidium gunteri Cole var. *galvestonensis* KORNFELD, 1931, p. 87, pl. 15, fig. 1a,b (*partim, non* 2a,b, 3a,b); CUSHMAN, 1939, p. 60, pl. 16, fig. 25; POST, 1951, pl. 1, fig. 14.
Elphidium galvestonense (Kornfeld) PARKER, PHLEGER, & PEIRSON, 1953, p. 7-8, pl. 3, fig. 15-16.

Diagnosis.—Recognized by fine perforations; umbilical area having large plug that may or may not be broken by several large pores; and heavy, widely spaced retral processes. *Pleistocene to Recent.*

Dimensions.—Greatest diameter, 0.73 mm.

Material.—774 tests.

Occurrence.—Present in many bays along the Gulf of Mexico, rare in the open Gulf. Present on the Atlantic delta of Ocracoke Inlet and in Core Sound. A few specimen also occur near the marsh on Portsmouth Island. Salinity, 25 to 35 ‰; depth, 1 to more than 30 feet; substrate, sand or silty sand. Associated with *Elphidium gunteri* and *E. clavatum*.

ELPHIDIUM SUBARCTICUM Cushman, 1944
Plate 7, figures 3, 6

Elphidium subarcticum CUSHMAN, 1944, p. 27, pl. 3, fig. 34-35; CUSHMAN, 1948, p. 58, pl. 6, fig. 12; PARKER, 1952, *119*, p. 412, pl. 5, fig. 9; LOEBLICH & TAPPAN, 1953, p. 412, pl. 5, fig. 9; RONAI, 1955, p. 148, pl. 21, fig. 15.

Diagnosis.—Recognized by planispiral test having 8 or 9 visible chambers with later ones moderately inflated and by small sutural pores having narrow opaque band on either side which stands out markedly from smooth, finely perforate, translucent remainder of test. *Recent.*

Remarks.—Although *Elphidium subarcticum* is typically characterized by its white opaque bands, a variant of this species occurs in the Pamlico Sound region on which these bands are poorly preserved in later chambers and lacking in earlier ones. Also some secondary deposition occurs in the umbilical region. Other features are identical to the typical form. On both the Pamlico Sound forms supplementary apertural pores are scattered over the apertural face. *E. frigidum* CUSHMAN is similar but lacks the white opaque bands, is more coarsely perforate, and has spiraling striae ornamenting the surface.

Dimensions.—Greatest diameter, 0.33 mm.

Material.—16 tests.

Occurrence.—Originally described from the Arctic regions but is now known from the New England region, Long Island Sound, and the New York Bight area. The geographic range of this species has been extended to the Pamlico Sound region. Present in low numbers on both the Sound and Atlantic deltas of Ocracoke Inlet and in Core Sound. Salinity, 25 to 35 ‰; depth, 5 to more than 30 feet; substrate, sand or silty sand.

ELPHIDIUM TUMIDUM Natland, 1938
Plate 8, figures 11-12, 15

Elphidium tumidum NATLAND, 1938, p. 144, pl. 5, fig. 5-6; CUSHMAN, 1939, p. 65, pl. 20, fig. 8a,b; CUSHMAN & MCCULLOCH, 1948, p. 170, pl. 19, fig. 3-5; CUSHMAN & TODD, 1947, p. 14-15, pl. 2, fig. 21; WALTON, 1955, p. 1007, pl. 101, fig. 8-9; TODD & BRÖNNIMANN, 1957, p. 39, pl. 7, fig. 7-9; ARNAL, 1958, p. 39, pl. 12, fig. 7-8.
Elphidium sp. cf. *E. tumidum* (Natland), PARKER, PHLEGER, & PEIRSON, 1953, p. 9, pl. 3, fig. 28-29.

Diagnosis.—Recognized by its somewhat compressed, opaque or translucent, smooth to slightly lobulate perforate test; by slightly roughened umbilical region; and by indistinct somewhat elongate retral processes. *Recent.*

Description (emended).—Test compressed, periphery rounded, smooth to slightly lobulate, umbilical region somewhat depressed, commonly roughened with small papillae which can be fused to form larger rougher mass; chambers slightly inflated, normally 10 to 12 in last whorl; sutures straight to slightly curved, moderately depressed, with small elongate retral processes which may or may not be distinct; walls translucent to opaque, perforate; aperture composed of a row of small openings at the base of the last-formed chamber.

Remarks.—*Elphidium tumidum* is quite variable in the Pamlico Sound region. Some specimens are translucent, slightly lobulate, and contain small papillae in the umbilical region; all features typical of NATLAND's forms. Other specimens are opaque, evenly rounded, and have the papillae fused into an irregular mass. There also are gradations between the above-mentioned forms, some

EXPLANATION OF PLATE 9

ROSALINA, GLOBIGERINA, AMMONIA, PLANULINA, HANZAWAIA, CIBICIDES
(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

1,2. *Rosalina floridana* (CUSHMAN); dorsal and ventral views, ×100 (p. 55).

3,4. *Globigerina bulloides* D'ORBIGNY; dorsal and lateral views, ×100 (p. 61).

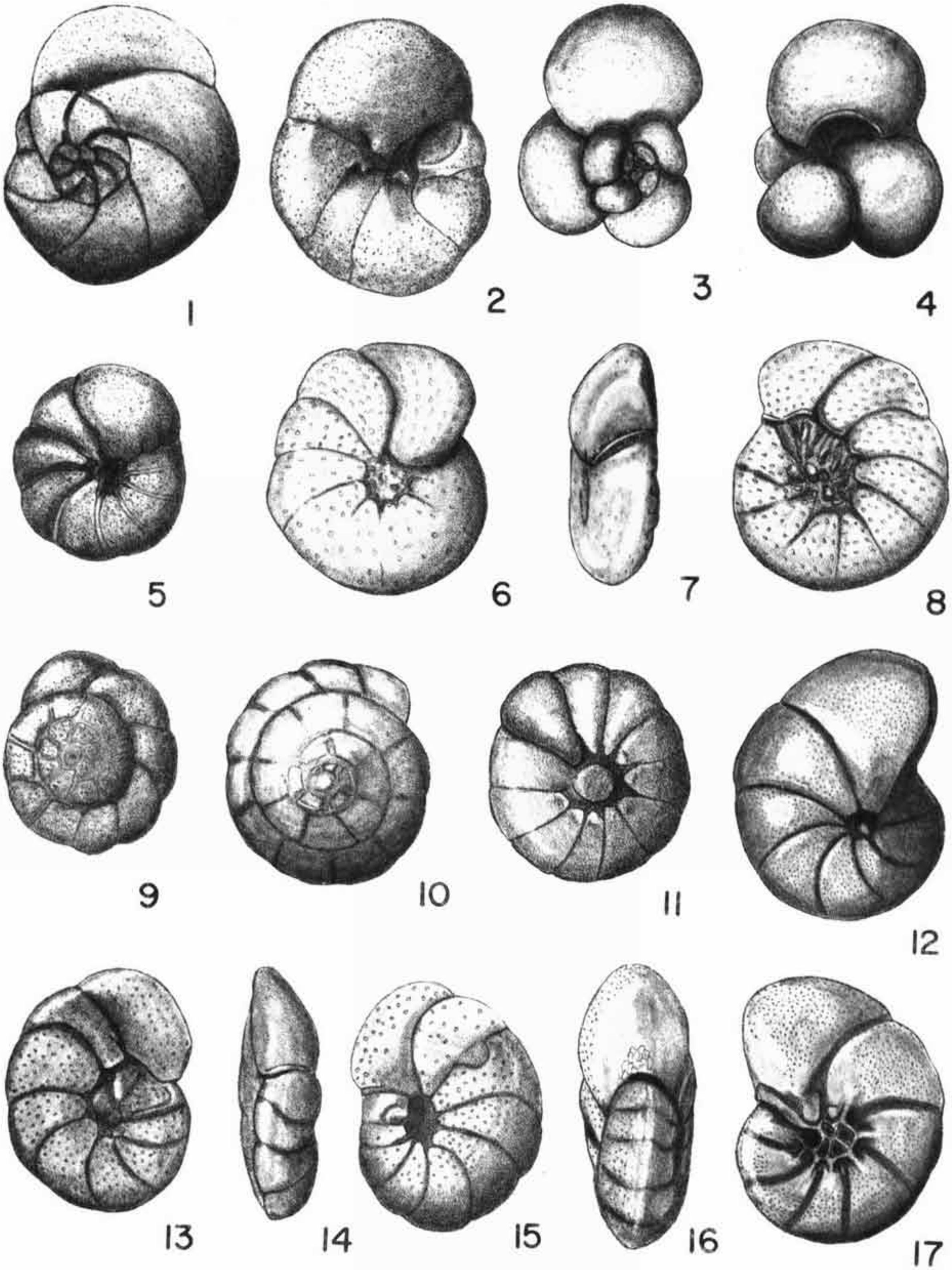
5,9. *Ammonia tepida* (CUSHMAN); ventral and dorsal views, ×120 (p. 56).

6-8. *Planulina mera* CUSHMAN; *6,* ventral view; *7,* apertural view; *8,* dorsal view; all ×100 (p. 62).

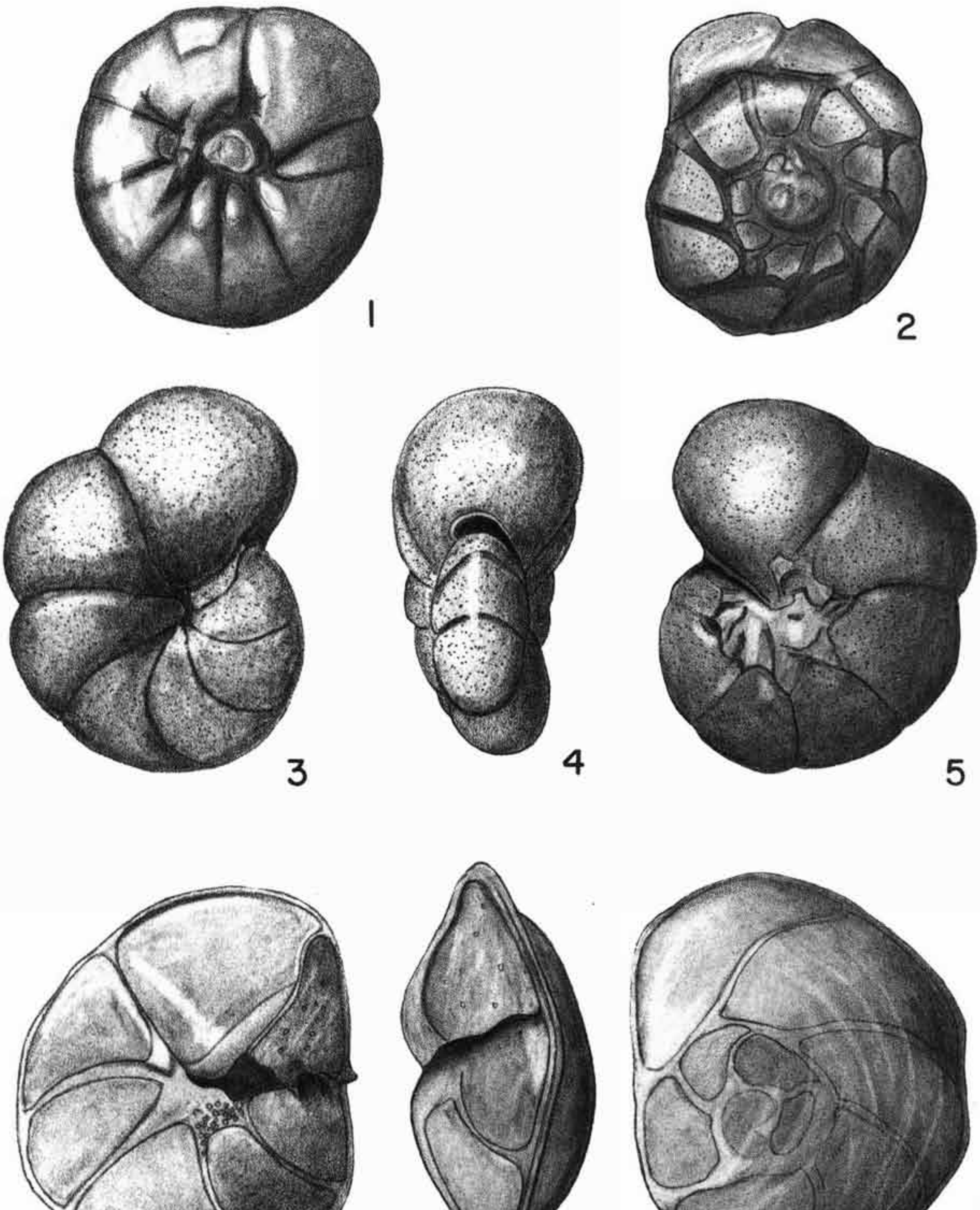
10,11. Ammonia sobrina (S Z$(3x); dorsal and ventral views, ×100 (p. 56).

12,16,17. *Hanzawaia concentrica* (CUSHMAN); *12,* ventral view; *16,* apertural view; *17,* dorsal view; all ×75 (p. 62).

13-15. *Cibisides* sp. cf. *C. lobatulus* (WALKER & JACOB); *13,* dorsal view; *14,* apertural view; *15,* ventral view; all ×100 (p. 61).



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound



Grossman & Benson — Rhizopoda and Ostracoda, Pamlico Sound

specimens being opaque and lobulate and others translucent and smooth, some with distinct retral processes, and others with indistinct cross bars. There is also no ecologic separation of these various forms. NATLAND's original description has been emended, therefore, to include all those variable forms which should be placed in this species.

Dimensions.—Greatest diameter, 0.41 mm.; greatest diameter of variant, 0.36 mm.

Material.—91 tests.

Occurrence.—Found off Catalina Island, California, at depths ranging from 9.7 to 122 m. Present in Todos Santos Bay, Baja California, in shallow marshy areas and at depths up to 30 fathoms. Found also in the bay areas of the Gulf coast and in the shallow water of the Gulf of Paria, Trinidad. In the area of investigation, present only in Core Sound. Salinity, from 25 to 30 ‰, most common near 30 ‰; depth, 5 to 10 feet; substrate, sand to silty sand. Most commonly associated with *Protelphidium orbiculare*.

Superfamily GLOBIGERINACEA Carpenter, Parker, & Jones, 1862

Family GLOBIGERINIDAE Carpenter, Parker, & Jones, 1862

Subfamily GLOBIGERININAE Carpenter, Parker, & Jones, 1862

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA BULLOIDES d'Orbigny, 1826
Plate 9, figures 3-4

Globigerina bulloides D'ORBIGNY, 1826, p. 277, fig. 17, 76.

Remarks.—Representatives of this well known species were present in the more marine portions of the study area.

Occurrence.—Twenty-two specimens were found in the vicinity of Ocracoke Inlet and at one station in Core Sound and undoubtedly were washed into the Sound.

Superfamily CASSIDULINACEA d'Orbigny, 1839

Family NONIONIDAE Schultze, 1854

Subfamily NONIONINAE Schultze, 1854

Genus PSEUDONONION Asano, 1936

PSEUDONONION ATLANTICUS (Cushman), 1947
Plate 6, figures 8-12

Nonionella atlantica CUSHMAN, 1947, p. 90, pl. 20, fig. 4-5; PHLEGER & PARKER, 1951, p. 11, pl. 5, fig. 21a,b; 22a,b; 23a,b; PARKER, PHLEGER & PEIRSON, 1953, p. 11, pl. 3, fig. 30-31; PARKER, 1954, p. 507, pl. 6, fig. 6-7; BANDY, 1954, p. 137, pl. 29, fig. 10; TODD & BRÖNNIMANN, 1957, p. 32, pl. 5, fig. 30-31.

Diagnosis.—Recognized by compressed asymmetrical test with dorsal side exposing some of earlier coils, and by papillate region on ventral side; 10 to 12 chambers in adult whorl increasing gradually in size; sutures slightly depressed and gently curved. *Recent.*

Dimensions.—Greatest diameter, 0.28 mm.

Material.—13 tests.

Occurrence.—Found off the coast of Florida in 45 m. of water and has been recorded from depths as great as 200 m. in the Gulf of Mexico. Reported from the Texas bays and found in the offshore zone of the Gulf of Paria, Trinidad, and found in the Long Island Sound-Cape Cod region. Present in the more marine areas of the study region, particularly on both the Sound and Ocean deltas of Ocracoke Inlet and at several localities in the southern end of Core Sound. Salinity, 25 to 35 ‰; depth, 5 to more than 30 feet; substrate, sand or silty sand. Associated with *Hanzawaia concentrica.*

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE Cushman, 1927

Genus CIBICIDES Montfort, 1808

CIBICIDES sp. cf. C. LOBATULUS (Walker & Jacob), 1798
Plate 9, figures 13-15

Nautilus lobatulus WALKER & JACOB, 1798, p. 642, pl. 14, fig. 36.
Truncatulina lobatulus (Walker & Jacob), CUSHMAN, 1918b, p. 60, 61, pl. 17, fig. 1-3.
Cibicides lobatulus (Walker & Jacob), CUSHMAN, 1927, p. 170, pl. 27, fig. 12-13; CUSHMAN, 1948, p. 78-79, pl. 8, fig. 14; MCLEAN, 1956, p. 366-367, pl. 48, fig. 12-13. For a more complete synonomy, see CUSHMAN, 1931, p. 118-119. *Eocene to Recent.*

Remarks.—No diagnosis of this species has been given because no types are available and authors have not attempted to define the species closely.

Dimensions.—Greatest diameter, 0.38 mm.

Material.—19 tests.

Occurrence.—Reported from several Cenozoic formations of the United States and Europe. Recorded in the Recent from off the coasts of Canada, New England, British Isles, and Norway. It is a very common cool-water species and generally is found attached to hydroid stems or algae. Present in both the Atlantic and Sound deltas of Ocracoke Inlet and at one station in Core Sound. Salinity, 20 to 30 ‰, more common near 30 ‰; depth, 12 to more than 30 feet; substrate, sand or silty sand. Associated with *Elphidium galvestonense* and *Hanzawaia concentrica.*

EXPLANATION OF PLATE 10

AMMONIA, HANZAWAIA, POROEPONIDES
(All illustrated forms are from Southern Pamlico Sound Region; all ×100)

FIGURE
1,2. *Ammonia limbatobeccarii* (MCLEAN); ventral and dorsal views (p. 56).
3-5. *Hanzawaia* sp. cf. *H. strattoni* (APPLIN); *3*, ventral view; *4*, apertural view; *5*, dorsal view (p. 62).
6-8. *Poroeponides lateralis* (TERQUEM); *6*, ventral view; *7*, peripheral view; *8*, dorsal view (p. 56).

Genus HANZAWAIA Asano, 1944

HANZAWAIA CONCENTRICA (Cushman), 1918

Plate 9, figures 12, 16, 17

Truncatulina concentrica CUSHMAN, 1918, *38*, p. 64, pl. 21, fig. 3.
Cibicides concentrica (Cushman), CUSHMAN, 1930, p. 61, pl. 12, fig. 4a-c; CUSHMAN, 1931, p. 120, pl. 21, fig. 4-5, pl. 22, fig. 1-2.
Cibicides concentricus (Cushman), CUSHMAN & PONTON, 1932, p. 101; CUSHMAN, 1944, p. 37, pl. 4, fig. 29; PHLEGER & PARKER, 1951, p. 29, pl. 15, fig. 14-15.
Cibicides cf. *C. concentricus* (Cushman), MILLER, 1953, p. 61, pl. 10, fig. 8.
Cibicidina concentricus (Cushman), PARKER, 1954, p. 544, pl. 13, fig. 7-10.
Hanzawaia concentrica (Cushman), PURI, 1953, *138*, p. 140, pl. 12, fig. 7-9; MCLEAN, 1956, p. 367, pl. 49, fig. 4-6.

Diagnosis.—Recognized by its medium-sized, nearly plano-convex, finely perforate test and by the concentric band which covers the central part of the dorsum and masks the inner whorls. Periphery subcarinate, aperture mainly dorsal with a thin lip. *Oligocene to Recent.*

Remarks.—The Pamlico Sound specimens have a more rounded periphery and a more irregular central band than the type, but otherwise are similar. *Hanzawaia strattoni* (APPLIN, 1925), a similar species, has a much less sharply angled periphery and is nearly bilaterally symmetrical.

Dimensions.—Greatest diameter, 0.60 mm.

Material.—38 tests.

Occurrence.—Recorded from Oligocene sediments of Cuba and present in Miocene formations of the Atlantic coastal plain, particularly in the Chipola facies of the Alum Bluff Formation and the *Arca, Ecphora,* and *Cancellaria* facies of the Choctawhatchee Formation of Florida, in the Duplin Marl of North and South Carolina, in the Yorktown Formation of Virginia, and in the Calvert Formation of Maryland. In the Recent it has been found as far north as the Long Island Sound-Buzzards Bay area and as far south as the Gulf of Mexico. It prefers normal marine waters and generally is found in depths of less than 100 feet. In the area of investigation it is present at many stations on both the Ocean and Sound deltas of Ocracoke Inlet and at Cape Lookout Bight and at one station near Drum Inlet. Salinity, 22 to 35 ‰, most common greater than 30 ‰; depth, 5 to more than 30 feet; substrate, sand or silty sand. Associated with *Cibicides* sp. cf. *C. lobatulus* and several species of *Quinqueloculina.*

HANZAWAIA sp. cf. H. STRATTONI (Applin), 1925

Plate 10, figures 3-5

Truncatulina americana CUSHMAN var. *strattoni* APPLIN, in APPLIN, ELLISOR, & KNIKER, 1925, p. 99, pl. 3, fig. 3.
Cibicidina strattoni (Applin), PARKER, PHLEGER, & PEIRSON, 1953, p. 7, pl. 4, fig. 38-39; PARKER, 1954, p. 544, pl. 13, fig. 8-11.
Hanzawaia strattoni (Applin), BANDY, 1954, p. 136, pl. 31, fig. 4.
Hanzawaia cf. *H. strattoni* (Applin), TODD & BRÖNNIMANN, 1957, p. 41, pl. 12, fig. 16.

Diagnosis.—Recognized by almost equally biconvex test, rounded periphery, and arched aperture on ventral margin of chamber. *Oligocene to Recent.*

Remarks.—This specimen resembles PARKER's (1954) illustrations of the species in most respects but is more inflated. *Hanzawaia strattoni* differs from *H. concentrica* in being more equally biconvex and having a rounded periphery.

Dimensions.—Greatest diameter, 0.58 mm.

Material.—One test.

Occurrence.—Recorded from Oligocene sediments of Louisiana and found in the Recent in the shallower waters of the Gulf of Mexico and the Gulf of Paria, Trinidad. Present in the area of investigation at one station on the seaward delta of Ocracoke Inlet.

Genus PLANULINA d'Orbigny, 1826

PLANULINA MERA Cushman, 1944

Plate 9, figures 6-8

Planulina mera CUSHMAN, 1944, p. 36, pl. 4, fig. 25; PARKER, 1948, p. 239, pl. 6, fig. 9a,b.

Diagnosis.—Recognized by its planispiral, partially evolute, compressed, coarsely perforate test. Aperture near periphery is long narrow opening with narrow overhanging lip. *Recent.*

Remarks.—Specimens are similar to that figured by PARKER (1948) but central part of dorsum is very irregular, being filled with knobs of clear calcite.

Dimensions.—Greatest diameter, 0.40 mm.

Material.—Two tests.

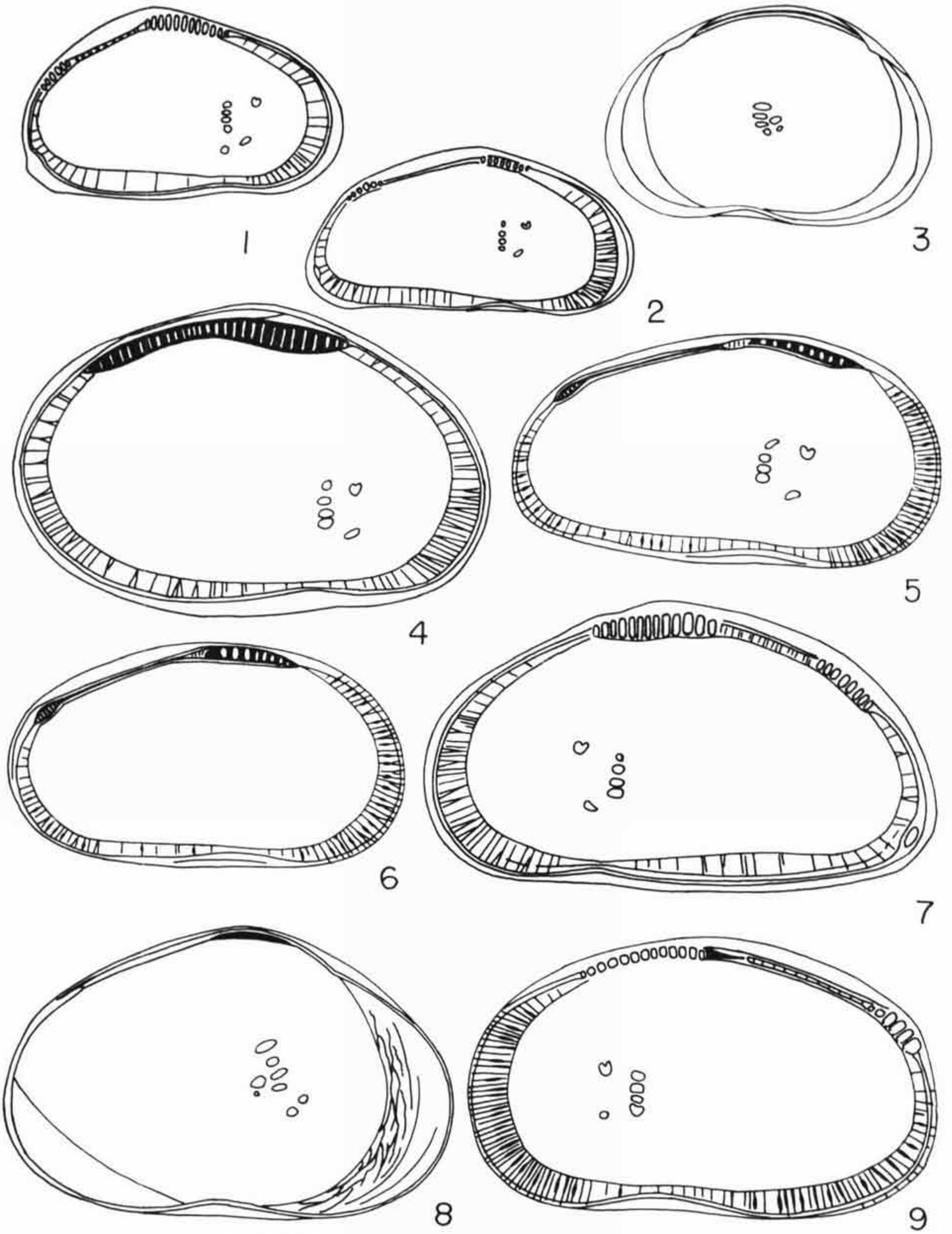
Occurrence.—Found by CUSHMAN (1944) at depths of 10 to 13 fathoms in Vineyard Sound and by PARKER (1948) off the coast of Maryland. Present at two stations in the vicinity of Ocracoke Inlet. Salinity, 35 ‰; depth, 30 feet; substrate, sand.

EXPLANATION OF PLATE 11

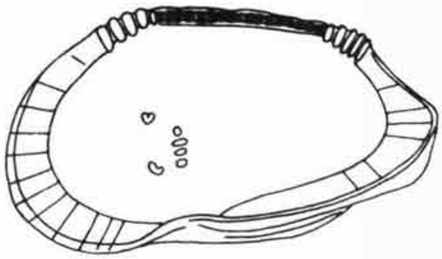
HAPLOCYTHERIDEA, CYPRIA, CYPRIDEIS, CYPRIDOPSIS
(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

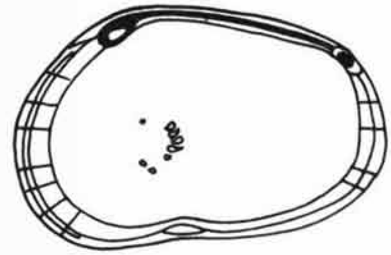
1. *Haplocytheridea* sp.; interior lateral view of LV, ×90 (p. 65).
2. *Haplocytheridea bradyi* (STEPHENSON); interior lateral view of LV, ×90 (p. 64a).
3. *Cypria ophthalmica* (JURINE); interior lateral view of RV, ×120 (p. 63).
4,7. *Haplocytheridea setipunctata* (BRADY); *4,* interior lateral view of LV of female; *7,* interior lateral view of RV of male; ×90 (p. 64a).
5,6. *Cyprideis* sp. cf. *C. torosa* (JONES); *5,* interior lateral view of LV of male; *6,* interior lateral view of LV of female; ×90 (p. 64).
8. *Cypridopsis vidua* (Ö. F. MÜLLER); interior lateral view of LV, ×120 (p. 63).
9. *Cyprideis* sp.; interior lateral view of RV, ×90 (p. 64).



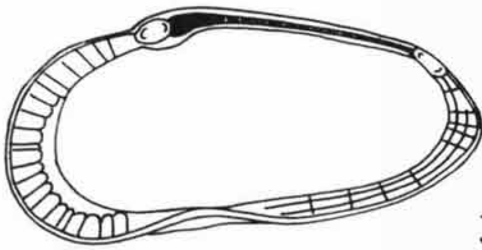
GROSSMAN & BENSON--Rhizopoda and Ostracoda, Pamlico Sound



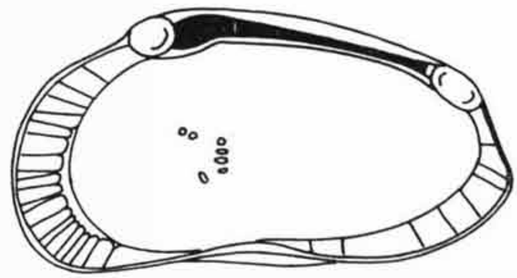
1



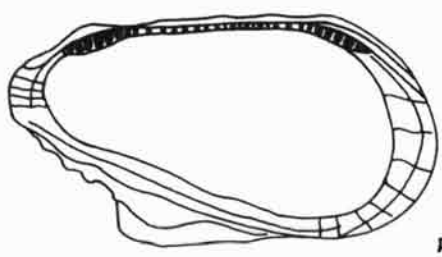
2



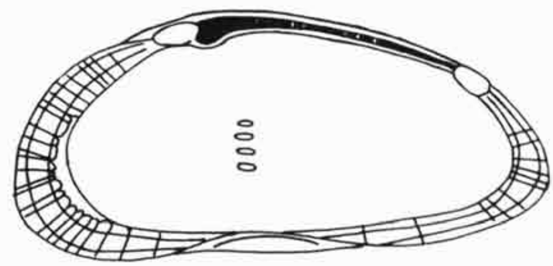
3



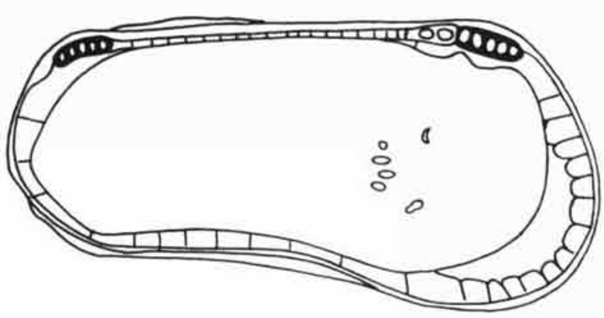
4



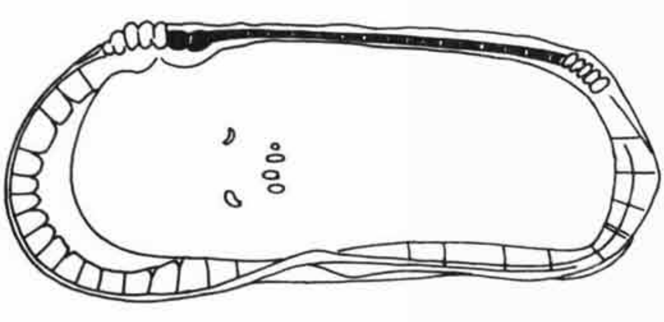
5



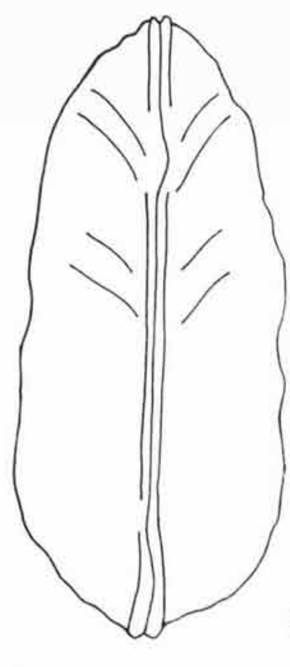
6



7



8



9

Phylum ARTHROPODA Siebold & Stannius, 1845

Class CRUSTACEA Pennant, 1777

Subclass OSTRACODA Latreille, 1806

Order PODOCOPIDA Müller, 1894

Suborder PODOCOPINA Sars, 1866

Superfamily CYPRIDACEA Baird, 1845

Family CYPRIDIDAE Baird, 1845

Subfamily CYPRIDOPSINAE Kaufmann, 1900

Genus CYPRIDOPSIS Brady, 1867

CYPRIDOPSIS VIDUA (Ö. F. Müller), 1776

Plate 11, figure 8; Plate 16, figures 4-6

Cypris vidua Ö. F. Müller, 1776, p. 199.
Monoculus vidua (Ö. F. Müller), Jurine, 1820, p. 175.
Cypridopsis vidua (Ö. F. Müller), Brady, 1867; Kesling, 1951, p. 1-324, fig. 1-36, pl. 1-96. For a more complete synonomy see Kesling, 1951. *Recent.*

Remarks.—Kesling (1951) has published a monograph on this species.

Dimensions.—Length of adult specimen, 0.58 mm.; height, 0.37 mm.; thickness, 0.38 mm.

Occurrence.—This is a very abundant species that is distributed widely in North America and Europe.

Family CYCLOCYPRIDIDAE Kaufmann, 1900

Genus CYPRIA Zenker, 1854

CYPRIA OPHTHALMICA (Jurine), 1820

Plate 11, figure 3; Plate 16, figures 1-3

Monoculus ophthalmica Jurine, 1820, p. 178.
Cypria ophthalmica (Jurine), G. W. Müller, 1894, p. 43; Klie, 1938, p. 84.

Diagnosis.—Distinguished by the highly arched dorsum, somewhat truncated posterior, non-inflated valves, and characteristic muscle-scar pattern. *Pliocene to Recent.*

Dimensions.—Length of adult specimen, 0.47 mm.; height, 0.31 mm.; thickness, 0.20 mm.

Occurrence.—Found in the Pliocene of Europe. Present in the Recent of all parts of the world except Australia. The species inhabits fresh to oligohaline waters.

Superfamily CYTHERACEA Baird, 1850

Family CYTHERETTIDAE Triebel, 1952

Genus CYTHERETTA Müller, 1894

CYTHERETTA sp. aff. C. SAHNI Puri, 1952

Plate 13, figure 9; Plate 21, figure 15

Cytheretta sahni Puri, 1952, *135*, p. 206-207, pl. 39, fig. 7-8, text-fig. 1-2; Puri, 1953, *138*, p. 284-285.
Cytheretta? sahni Puri, Benson & Coleman, 1963, p. 25; pl. 5, fig. 4, 6, 8, 12.

Diagnosis.—Recognized by its moderately large carapace ornamented by 2 fine, sinuous, obliquely longitudinal ribs which are separated by depression; surface below lower rib ornamented with fine longitudinal striations. *Miocene to Recent.*

Remarks.—This species differs from *Cytheretta bassleri* Howe (1936) by having a depression between the two ribs, especially in the posterior portion, and a longitudinally striated venter. Similar to *C. oskaloosensis* Smith (1948) but differs slightly in shape, in lacking a dorsal rib, and in having a striated venter.

Dimensions.—Length of adult specimen, 0.98 mm.; height, 0.50 mm.

Material.—One mature valve.

Occurrence.—Present in the Choctawhatchee Formation of the Miocene of Florida. Reported by Benson & Coleman (1963) as living in the eastern Gulf of Mexico at depths from 20 to 63 feet; most abundant, however, at depths of less than 35 feet and in

---

EXPLANATION OF PLATE 12

Perissocytheridea, Cytheromorpha, Acuticythereis, Paracytheridea, Neolophocythere
(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

1. *Perissocytheridea* sp.; interior lateral view of RV, ×90 (p. 65).
2. *Cytheromorpha pascagoulaensis* Mincher; interior lateral view of RV, ×140 (p. 75).
3. *Acuticythereis multipunctata parva* Edwards; interior lateral view of RV, ×140 (p. 72).
4. *Acuticythereis nelsonensis* Grossman, n. sp.; interior lateral view of RV, ×140 (p. 72).
5. *Paracythereidea* sp. cf. *C. vandenboldi* Puri; anterior lateral view of LV, ×90 (p. 70).
6. *Acuticythereis laevissima* Edwards; interior lateral view of RV, ×140 (p. 71).

7-9. *Neolophocythere subquadrata* Grossman, n. gen., n. sp.; *7,8*, interior lateral views of LV and RV; *9*, dorsal view of both valves; all ×160 (p. 76).

salinities of 36 to 38 ‰. In the area of investigation found only in Cape Lookout Bight. Salinity, 35 ‰; depth, 30 feet; substrate, sand. The specimen is worn and may have been reworked from Miocene subsea deposits.

Family CYTHERIDEIDAE Sars, 1925

Subfamily CYTHERIDEINAE Sars, 1923

Genus CYPRIDEIS Jones, 1856

CYPRIDEIS sp. cf. C. TOROSA (Jones), 1850

Plate 11, figures 5-6; Plate 16, figures 7-9, 12

Candona torosa JONES, 1850, p. 27, pl. 3, fig. 6a-b.
Cyprideis torosa (Jones), JONES, 1856, p. 21, pl. 2, fig. 1a-i, text-fig. 2; GOERLICH, 1952, p. 186, fig. 1-5; WAGNER, 1957, p. 39, pl. 14; SWAIN, 1955, p. 616, pl. 59, fig. 8a,b, text-fig. 32c.
Cytheridea torosa (Jones), BRADY, 1868, *20*, p. 425, pl. 28, fig. 7-12, pl. 39, fig. 5.
Cytheridea littoralis BRADY, 1868b, p. 125.
Cytheridea torosa littoralis (Brady), MÜLLER, 1912, p. 326.
Cyprideis littoralis (Brady), SARS, 1925, p. 155, pl. 71, 72, fig. 1; SWAIN, 1955, p. 615, pl. 59, fig. 11a-c, text-fig. 38,5a,b.
Cyprideis littoralis (Brady), KLIE, 1938, p. 156, fig. 516-517; ELOFSON, 1941, p. 256.
Cyprideis littoralis (Brady) forma *littoralis* (Brady), KRUIT, 1955, p. 479, pl. 4, fig. 5a-f.
Cyprideis littoralis (Brady) forma *torosa* (Jones), KRUIT, 1955, p. 480, pl. 4, fig. 7a-d.

Diagnosis.—Carapace of female subquadrate in lateral view, that of male subelliptical; ventral margin of both male and female almost straight; surface of valves finely pitted, some specimens nodose; faint sulcus on anterodorsal part of shell. *Pleistocene to Recent.*

Remarks.—European forms of this species have a small posteriorly directed spine on the posteroventral border of RV, a structure unknown in North American forms. A small posteroventral flange presumably replaces this spine (SYLVESTER-BRADLEY, personal communication with R. H. BENSON). *Cyprideis torosa* is similar in shape to *C. floridana* HOWE & HOUGH, but the latter species has an essentially smooth surface with a few scattered pores. *C. mexicana* SANDBERG is similar in shape but has fewer pores and a rounded mandibular scar.

Dimensions.—Length of adult male specimen, 0.91 mm.; height, 0.46 mm.; thickness, 0.34 mm.; length of adult female specimen, 0.79 mm.; height, 0.45 mm.

Material.—37 valves; 15 are adult carapaces.

Occurrence.—This species is known in Europe, Asia, North Africa, and North America. REMANE (1940) reported it from both fresh and normal marine water. WAGNER (1957) reported it as living at salinities as high as 30 ‰, and found at depths from 0 to 30 meters. It is found in and on bottoms ranging from clean sand to mud. Present in low numbers in Core Sound in salinities of 12 to 35 ‰ and at depths of 2 to 30 feet. Commonly associated with *Haplocytheridea setipunctata*.

CYPRIDEIS sp.

Plate 11, figure 9; Plate 16, figures 10-11

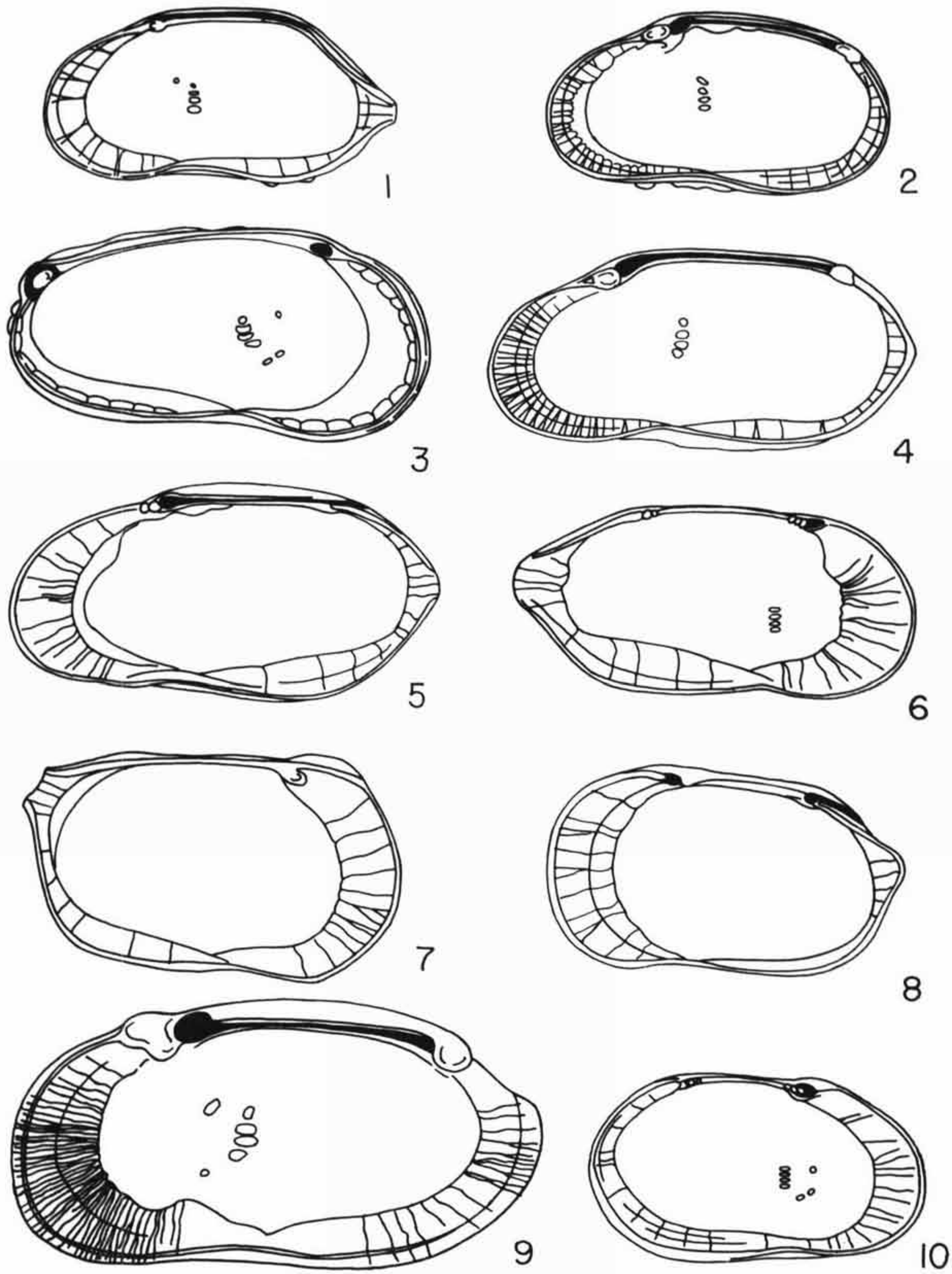
Diagnosis.—Distinguished by subquadrate carapace, glassy, elongate, normal pore canals, narrow well-defined sulcus, and relatively deep valves. *Recent.*

Description.—Carapace moderately large, heavy, subquadrate in lateral view, greatest height just anterior to mid-length, anterior end broadly rounded, posteroventral corner obliquely rounded; dorsum slightly arched, venter of RV slightly sinuate near middle, venter of LV straight, LV slightly larger than RV. Surface slightly irregular, greatest thickness in posterodorsal portion; a sharp narrow sulcus situated just anterior to mid-length extends vertically from mid-height to a point just below the dorsal margin. Surface with numerous, elongate, randomly oriented glassy pores. Valves deep, duplicature welded, relatively narrow, widest on anterior margin; hinge typical of genus, RV with elongate anterior dental area with 13 teeth, a postjacent small, elongate, triangular, denticulated socket followed by an elongate denticulated bar, and terminated by a short broad posterior dental area with 6 teeth, hingement of LV antithesis of RV. Muscle-scar pattern typical for genus; radial pore canals numerous, bulbous.

EXPLANATION OF PLATE 13

CYTHERURA, BASSLERITES, CYTHEROMORPHA, CYTHERETTA
(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE
1. *Cytherura johnsoni* MINCHER; interior lateral view of RV, ×140 (p. 70).
2. *Basslerites giganticus* EDWARDS; interior lateral view of RV, ×90 (p. 73).
3. *Cytheromorpha warneri* HOWE & SPURGEON; interior lateral view of LV, ×160 (p. 75).
4. *Basslerites tenmilecreekensis* PURI; interior lateral view of RV, ×140 (p. 73).
5. *Cytherura forulata* EDWARDS; interior lateral view of RV, ×140 (p. 69).
6. *Cytherura elongata* EDWARDS; interior lateral view of RV, ×140 (p. 69).
7-8. *Cytherura* sp.; *7-8*, interior lateral views of LV and RV, ×160, ×140 (p. 70).
9. *Cytheretta* sp. cf. *C. sahni* PURI; interior lateral view of RV, ×90 (p. 63).
10. *Cytherura? corensis* GROSSMAN, n. sp.; interior lateral view of LV; ×140 (p. 68).


1
2
3
4
5
6
7
8
9
10

Remarks.—The short high test, which is widest at the posterior margin, indicates that the valves described are those of the female. Females of the genus commonly are shorter, stouter, and wider in the posterior than males. The elongate, glassy pores readily separate this species from others within the genus. Lack of a sufficient number of specimens prevents the naming of this species.

Dimensions.—Length of adult specimen, 0.92 mm.; height, 0.56 mm.

Material.—Two adult valves.

Occurrence.—Found at one station on the Sound shoal of Ocracoke Inlet at a depth of 13 feet; salinity, 23 ‰; substrate, sand.

Genus HAPLOCYTHERIDEA Stephenson, 1936

HAPLOCYTHERIDEA SETIPUNCTATA (Brady), 1869

Plate 11, figures 4, 7; Plate 16, figures 13-18

Cytheridea setipunctata BRADY, 1869, p. 124, pl. 14, fig. 15-16. For a more complete synonomy see SANDBERG, 1964, p. 361, 362.

Diagnosis.—Distinguished by large subovate carapace, large number of denticles on both anterior and posterior dental areas, large normal-pore canal pits, and change in slope of dorsal border on posterior third of male carapace. *Miocene to Recent.*

Description.—Male. Carapace large, strong; LV slightly larger than RV, overlapping RV on anterodorsal and ventral margins; highest near mid-line, subovate in lateral view. From broad obtuse angle on center of dorsal margin anterior border slopes anteriorly merging with broadly rounded anterior margin, posterior border slopes posteriorly to dorsal third of carapace where another but less conspicuous obtuse element is formed, from which point dorsal margin slopes rather sharply ventrally merging with rounded posteroventral margin; ventral margin slightly convex except for small sinuation situated anterior to middle; RV similar to LV except that posteroventral margin is more pointed and venter is almost straight. From above, anterior pointed, posterior rather blunt, greatest width behind middle, surface of valves with large circular pits which mark openings of normal pore canals, remainder of carapace smooth. Hinge of RV consists of an anterior dental area which contains 10 to 12 prominent teeth, followed by elongate weakly crenulated bar which merges into short posterior dental area containing 5 or 6 teeth; hingement of LV antithesis of RV; marginal area narrow ventrally and posteriorly, moderately wide on anterior, duplicature welded, near posteroventral margin of RV is a small elongate pit, radial pore canals numerous, straight. Muscle-scar pattern consists of a vertical row of 4 with 2 scars anterior.

Female. Carapace shorter, more ovate than male; LV with moderately convex venter and broadly rounded posterior, venter of RV slightly convex, with small sinuation anterior to middle. From above both extremities bluntly rounded, posterior more so than anterior, greatest width behind middle. Other features identical to that of male.

Remarks.—SANDBERG (1964, p. 362) has discussed in detail problems in recognizing this species, the most abundant ostracode in the Pamlico Sound region.

Dimensions.—Length of adult male specimen, 1.1 mm.; height, 0.65 mm.; thickness, 0.50 mm.; length of adult female specimen, 0.92 mm.; height, 0.60 mm.; thickness, 0.52 mm.

Material.—346 valves of which 122 are adult.

Occurrence.—Present in the Choctawhatchee and Caloosahatchee Formations of Florida and in the Recent of the Gulf coast, Bahamas, Puerto Rico, and possibly Chesapeake Bay. Found at most stations in Core Sound, Nelson Bay, eastern part of Pamlico Sound, and on both the Atlantic and Sound deltas of Ocracoke Inlet. Salinity, 18 to 35 ‰; depth, 2 to more than 30 feet. Bottom sediment ranges from black organic mud to clean sand. Most commonly associated with *Cushmanidea echolsae, Haplocytheridea bradyi,* and *Elphidium clavatum*.

HAPLOCYTHERIDEA BRADYI (Stephenson), 1938

Plate 11, figure 2; Plate 17, figures 15, 16, 18

Cytheridea (Haplocytheridea) bradyi STEPHENSON, 1938, p. 129-132, pl. 23, fig. 22; pl. 24, fig. 5-6; text-fig. 10. (For more complete synonomy see SANDBERG, 1964, p. 362.)

EXPLANATION OF PLATE 14

HULINGSINA, CUSHMANIDEA, LEGUMINOCYTHEREIS, PELLUCISTOMA, PURIANA
(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

1. *Hulingsina sandersi* PURI; interior lateral view of LV, ×90 (p. 68).

2. *Hulingsina ashermani* (ULRICH & BASSLER); interior lateral view of RV, ×90 (p. 68).

3. *Cushmanidea ulrichi* (HOWE & JOHNSON); interior lateral view of LV (specimen damaged), ×90 (p. 67).

4. *Leguminocythereis whitei* SWAIN; interior lateral view of LV, ×90 (p. 73).

5. *Pellucistoma magniventra* EDWARDS; interior lateral view of LV, ×90 (p. 75).

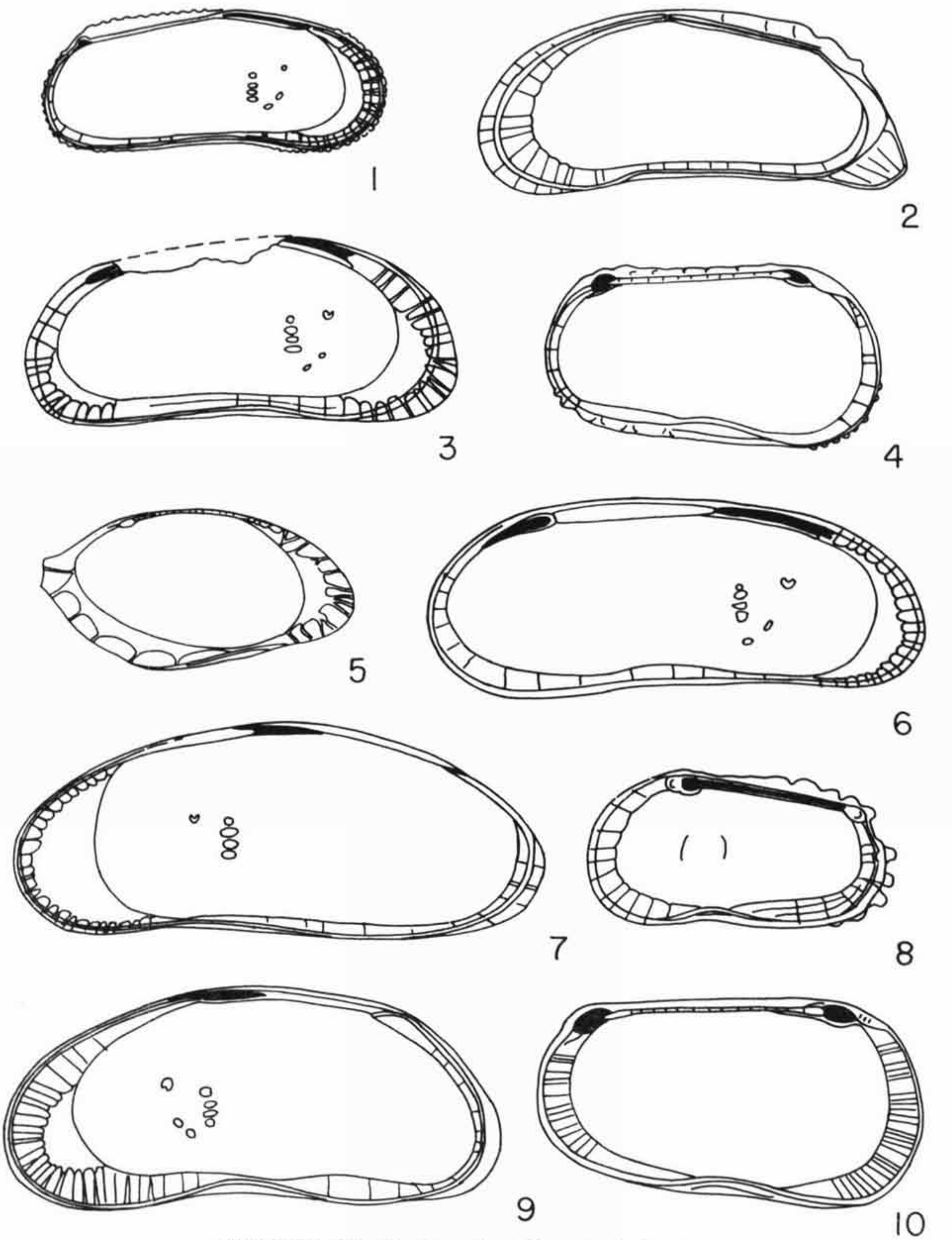
6. *Cushmanidea seminuda* (CUSHMAN); interior lateral view of LV, ×90 (p. 66).

7. *Cushmanidea* sp.; interior lateral view of RV, ×140 (p. 67).

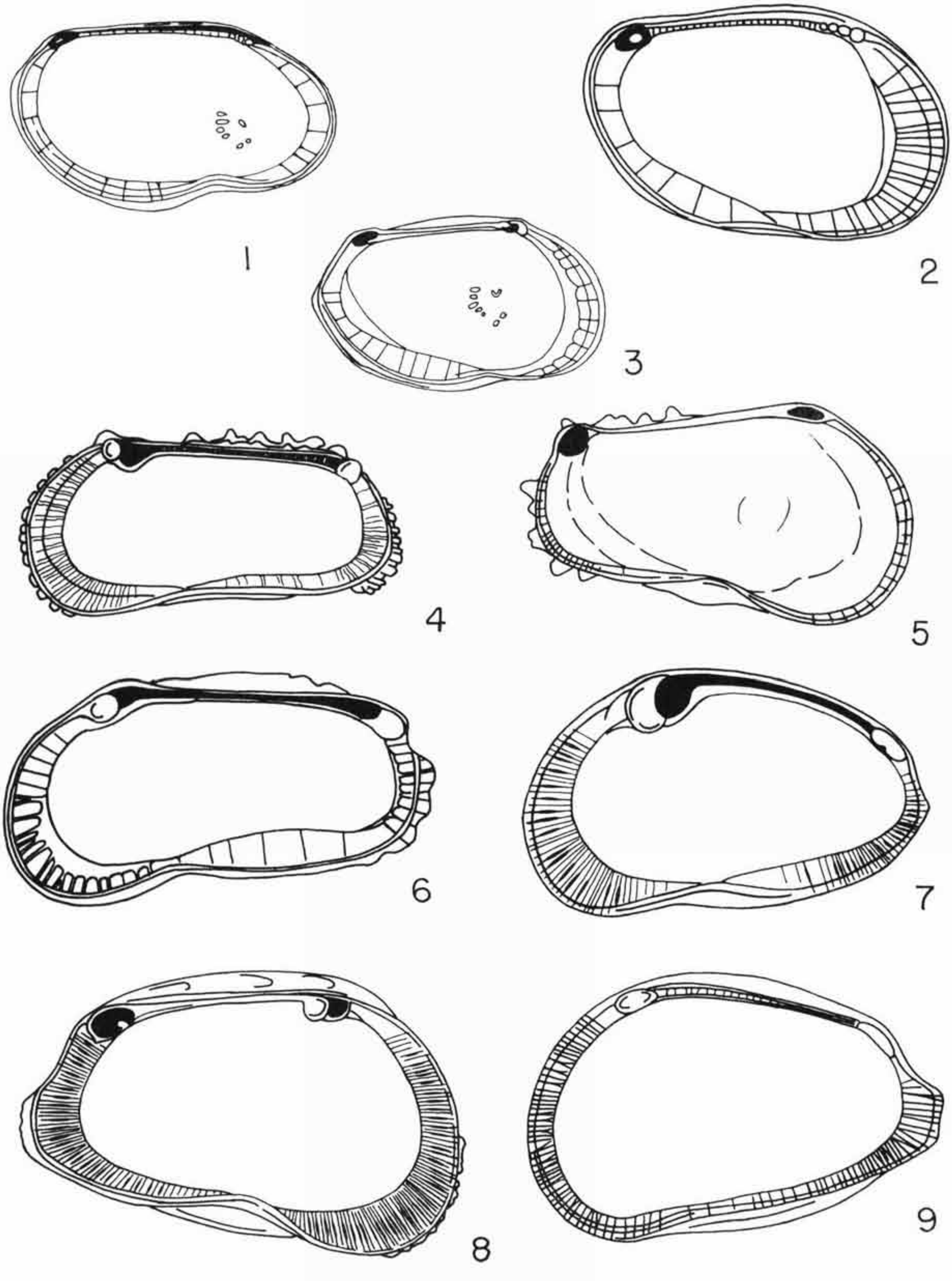
8. *Puriana rugipunctata* (ULRICH & BASSLER); interior lateral view of RV, ×90 (p. 77).

9. *Cushmanidea echolsae* (MALKIN); interior lateral view of RV, ×140 (p. 66).

10. *Leguminocythereis* sp.; interior lateral view of LV, ×90 (p. 74).



GROSSMAN & BENSON--Rhizopoda and Ostracoda, Pamlico Sound



GROSSMAN & BENSON--Rhizopoda and Ostracoda, Pamlico Sound

Diagnosis.—Distinguished by its small size; elongate, ovoid, pitted carapace; and reverse dentition with teeth occurring on LV rather than RV. *Miocene to Recent.*

Remarks.—SANDBERG (1964, p. 362-363) has summarized detailed information on this species.

Dimensions.—Length of adult specimen, 0.67 mm.; height, 0.36 mm.; thickness, 0.35 mm.

Material.—82 valves, of which 53 are adult.

Occurrence.—Present in the Choctawhatchee and Caloosahatchee Formations of Florida, Duplin Marl of North Carolina, and Pleistocene of Louisiana. Present in the Recent of the Gulf coast and in Puerto Rico. Found in the Pamlico Sound region at several stations in Core Sound, eastern portion of Pamlico Sound, and on both the Sound and Atlantic deltas of Ocracoke Inlet. Salinity, 20 to 35 ‰; depth, 5 to more than 30 feet; substrate, sand or silty sand. Commonly associated with *Haplocytheridea setipunctata* but does not have as wide a distribution as the latter species. Associated also with *Cushmanidea echolsae* and *Elphidium clavatum*.

HAPLOCYTHERIDEA sp.

Plate 11, figure 1; Plate 17, figures 12, 14

Diagnosis.—Recognized by its small size, highly arched dorsum on LV, truncate posterior, and reversal of hingement. *Recent.*

Description.—Carapace small, robust, highest posterior to middle, LV subtriangular in lateral view. From narrow obtuse angle on center of dorsum of LV, straight anterior border slopes anteriorly merging with broadly rounded anterior margin, slightly convex posterior border slopes posteriorly to point near posterior margin, from which dorsal margin slopes rather abruptly downward, producing somewhat truncate posterior, ventral margin slightly convex except for small sinuation anterior to middle; RV larger than LV, subovate in lateral view, obtuse angle on dorsal margin not as sharp, and posterior margin not as abruptly truncate as LV. Surface of valves pitted by numerous, circular normal pore canals. Hinge of LV consisting of well-developed broad anterior dental area with 9 or 10 denticles, followed by crenulated bar and terminated by posterior dental area with 5 or 6 denticles. Marginal area narrow on posterior margin, fairly broad on anterior and ventral margins, duplicature welded; marginal pore canals, simple, straight, relatively few, most numerous on anteroventral margin. Muscle-scar pattern vertical row of 4, with 2 scars anterior.

Remarks.—This species has a hinge reversal similar to *Haplocytheridea bradyi* but may be distinguished by shape and having a coarsely pitted surface. *Haplocytheridea* sp. is similar in shape to *Cyprideis curta* EDWARDS but is readily separated from the latter by difference in hinge structure. Too few specimens were found to justify naming this form now.

Dimensions.—Length of adult specimen, 0.66 mm.; height, 0.43 mm.

Material.—Four valves, all of which are adult.

Occurrence.—Found at 2 localities, 1 near the northern end of Core Sound and the other in the southeastern part of Pamlico Sound. Salinity, about 30 ‰; depth, 10 feet; substrate, silty sand.

Genus PERISSOCYTHERIDEA Stephenson, 1938

PERISSOCYTHERIDEA sp.

Plate 12, figure 1; Plate 17, figures 17, 19

Diagnosis.—Recognized by its reticulate, subquadrate-acuminate carapace and by presence of 2 premedian sulci, anterior of which is more pronounced. *Recent.*

Description.—Carapace of moderate size, subquadrate-acuminate, LV larger than RV, highest anterior to middle, dorsal margin nearly straight, ventral margin sinuate just anterior to middle; anterior margin broadly rounded, posterior margin drawn out into small caudal process. Ovate from above, anterior slightly more pointed than posterior, widest just behind middle. Surface irregular, central portion covered by reticulations that become irregular near extremities and are finally replaced by 4 or 5 fine costae which tend to parallel shell margins; 2 sulci located anterior to middle, 1st located behind anterior margin being

---

EXPLANATION OF PLATE 15

LOXOCONCHA, ACTINOCYTHEREIS, PURIANA, AURILA, HEMICYTHERE
(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

1. *Loxoconcha purisubrhomboidea* (EDWARDS); interior lateral view of LV, ×90 (p. 74).
2. *Loxoconcha reticularis* EDWARDS; interior lateral view of LV, ×160 (p. 74).
3. *Loxoconcha matagordensis* SWAIN; interior lateral view of LV, ×90 (p. 74).
4. *Actinocythereis exanthemata exanthemata* (ULRICH & BASSLER); interior lateral view of RV, ×90 (p. 76).
5. *Puriana mesacostalis* (EDWARDS); interior lateral view of LV of late instar, ×140 (p. 77).
6. *Puriana* sp.; interior view of RV, ×140 (p. 77).
7. *Hemicythere laevicula* EDWARDS; interior lateral view of RV, ×140 (p. 71).
8. *Aurila conradi* (HOWE & MCGUIRT) *littorala* GROSSMAN, n. subsp.; interior lateral view of LV; ×140 (p. 71).
9. *Hemicythere* sp.; interior lateral view of RV of late instar, ×140 (p. 71).

broad, well defined, and originating on dorsal margin, swinging downward roughly parallel to anterior margin and ending at position just below mid-height of shell, 2nd sulcus originating just anterior to mid-length on dorsum and extending vertically downward, ending just above mid-height. Hinge antimerodont, that of RV with large raised anterior dental area bearing 5 prominent teeth, followed by straight, elongate, prominently crenulated groove and terminated by curved, raised posterior dental area containing 5 prominent teeth. Marginal area moderately wide, widest on anterior margin, inner margin and line of concrescence coincide, radial pore canals few, simple, widely spaced. Muscle-scar pattern vertical row of 4, with 2 scars anterior.

Remarks.—Similar to *Perissocytheridea rugata* SWAIN but the reticulations are much finer. The valves have an anterior sulcus but no alar extension. This is the first recorded occurrence of this genus on the Atlantic Coast. Too few specimens were found to justify naming this form now.

Dimensions.—Length of adult specimen, 0.67 mm.; height, 0.40 mm.

Material.—Seven valves of which 5 are adult.

Occurrence.—One specimen was found in Core Sound; the remaining valves were from the bottom of a core in the Neuse River estuary.

Subfamily NEOCYTHERIDEIDINAE Puri, 1957

Genus CUSHMANIDEA Blake, 1933

CUSHMANIDEA ECHOLSAE (Malkin), 1953

Plate 14, figure 9; Plate 19, figures 11-13, 15, 16

Cytherideis echolsae MALKIN, 1953, p. 788-789, pl. 78, fig. 14-17.
Cushmanidea echolsae (Malkin), MCLEAN, 1957, p. 78, pl. 9, fig. 1a-c, 2a-d.

Diagnosis.—Recognized by its thick-shelled, moderately elongate carapace; moderately sized subangular pits covering surface; and curved premedian sulcus. Shorter individuals presumably females. *Miocene to Recent.*

Remarks.—Many specimens have elongate ridges on the venter, a feature which MALKIN (1953) did not mention; otherwise these specimens are identical to MALKIN's forms. Similar to *Hulingsina ashermani* (ULRICH & BASSLER), but differs in that the pits are not as coarse.

Dimensions.—Length of adult male specimen, 0.63 mm.; height, 0.27 mm.; thickness, 0.24 mm.; length of adult female specimen, 0.60 mm.; height, 0.30 mm.; thickness, 0.28 mm.

Material.—184 valves of which 115 are adult.

Occurrence.—Reported from the Miocene Yorktown Formation of Virginia. Found in the Recent by CURTIS (1960) in the inshore areas of the eastern Mississippi Delta region. Distributed throughout Core Sound, the marsh side of Nelson Bay, and the Atlantic delta of Ocracoke Inlet. *Cushmanidea echolsae* is one of the most widespread ostracode species in the Pamlico Sound region. The salinity range is from 20 to more than 30 ‰; depth, less than 1 to more than 30 feet; bottom types range from dark, organic mud to clean sand. Associated with *Haplocytheridea setipunctata* and *Elphidium clavatum.*

CUSHMANIDEA SEMINUDA (Cushman), 1906

Plate 14, figure 6; Plate 20, figures 15-16

Cytheridea seminuda CUSHMAN, 1906, p. 374, pl. 33, fig. 62-64; pl. 34, fig. 76-77.
Cushmanidea seminuda (Cushman), BLAKE, 1933, p. 233; PURI, 1958, *139,* p. 172-173, pl. 11, fig. 11-13, pl. 2, fig. 1-4.

Diagnosis.—Recognized by its large elongate carapace which is highest on anterior margin and by linear arrangement of sculpturing on anterior and ventral surfaces. *Recent.*

Remarks.—The Pamlico Sound specimens have two forms. The first has very prominent lineations on the venter similar to topotype material, the second has obscure lineations on the venter and closely resembles PURI's *(139)* figures. *Cushmanidea seminuda* is similar to *C. ulrichi* (HOWE & JOHNSON) but is distinguished from the latter by the ventral sculpturing and slightly more elongate shape.

Dimensions.—Length of adult specimen, 0.88 mm.; height, 0.39 mm.; thickness, 0.37 mm.

Material.—63 valves of which 25 are adult.

EXPLANATION OF PLATE 16

CYPRIA, CYPRIDOPSIS, CYPRIDEIS, HAPLOCYTHERIDEA
(All illustrated forms are from Southern Pamlico Sound Region)

FIGURE

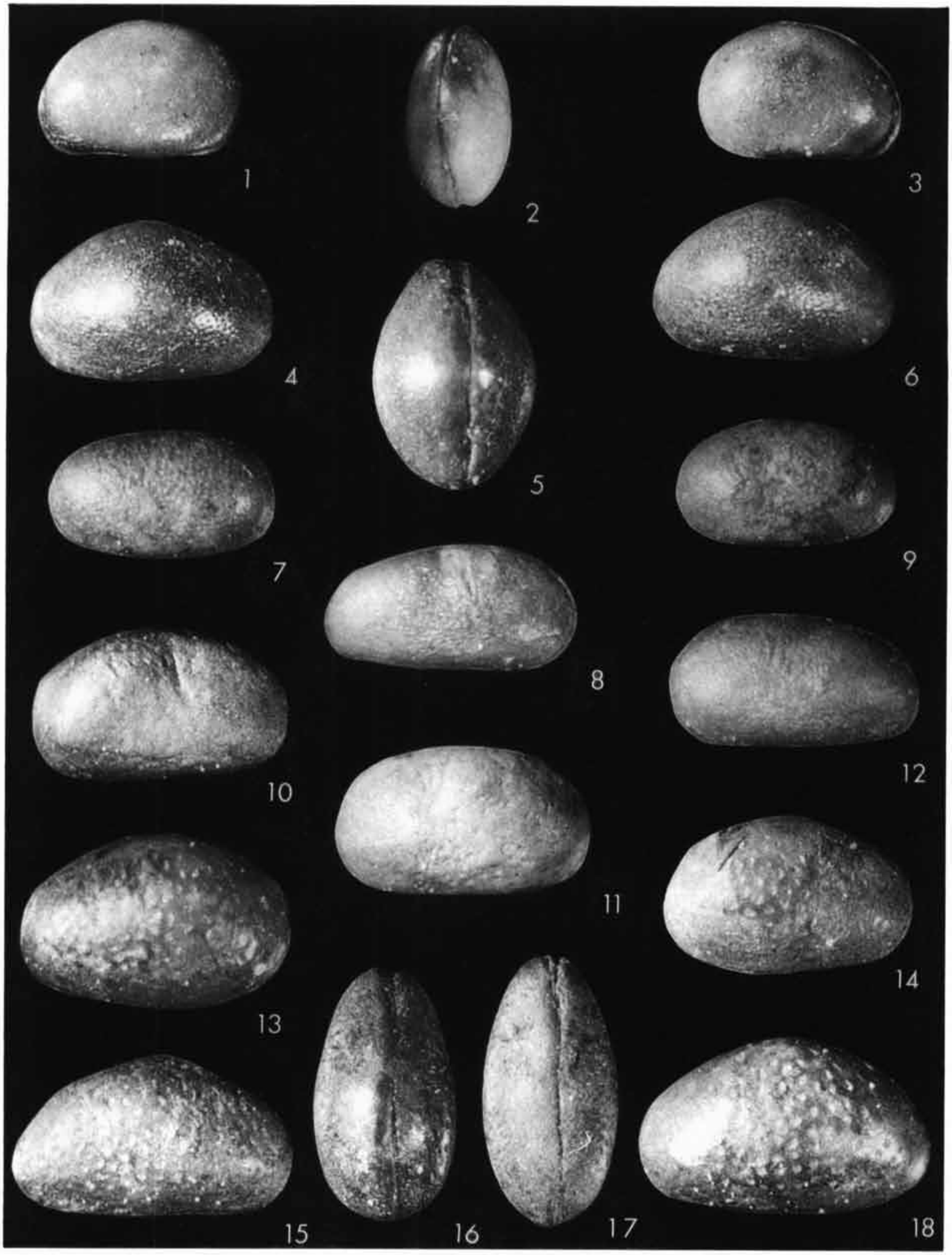
1-3. *Cypria ophthalmica* (JURINE); *1,* external lateral view of LV; *2,* dorsal view of carapace; *3,* external lateral view of RV; all ×75 (p. 63).

4-6. *Cypridopsis vidua* (Ö. F. MÜLLER); *4,* external lateral view of RV; *5,* dorsal view of carapace; *6,* external lateral view of LV; all ×75 (p. 63).

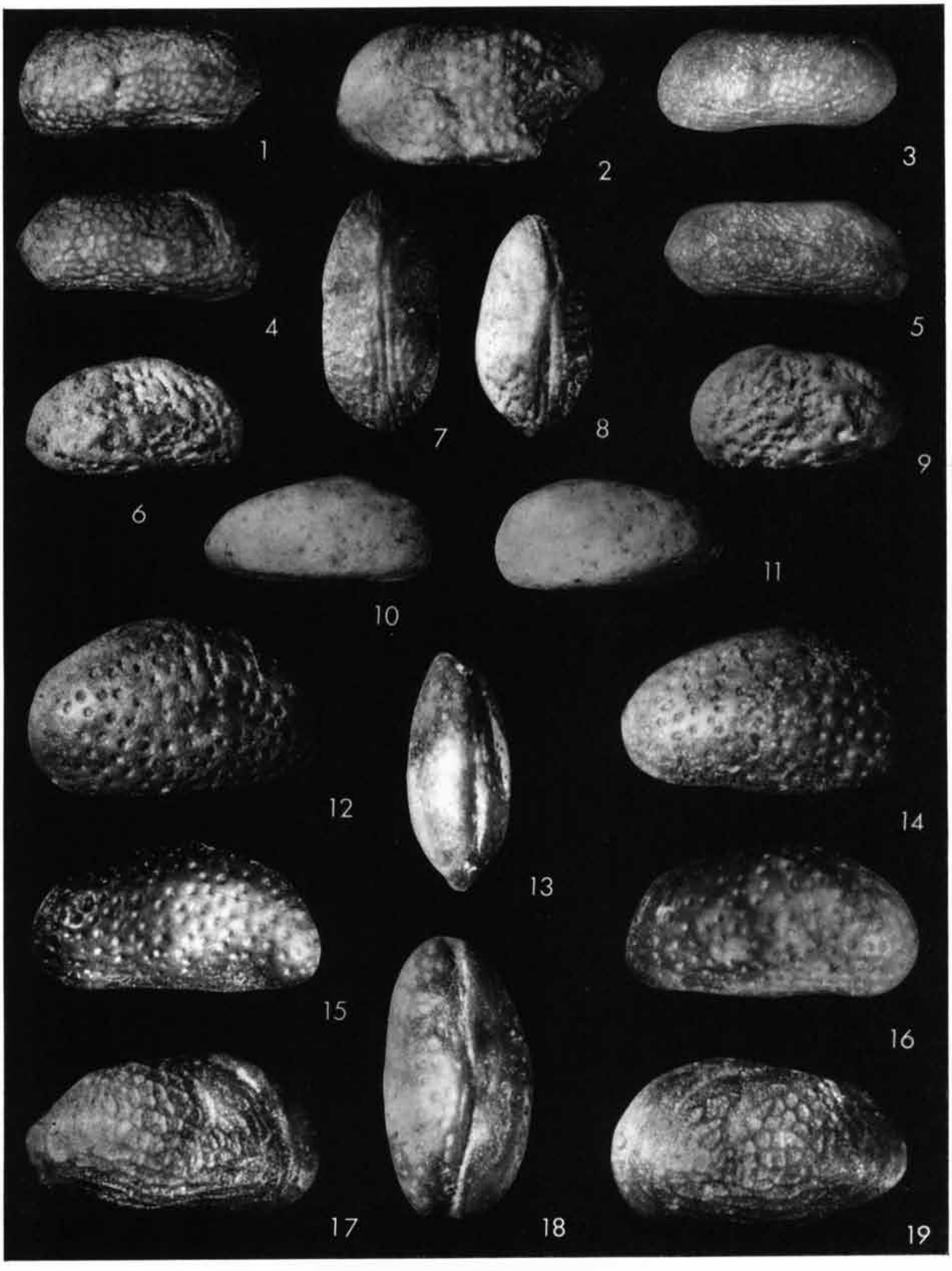
7-9,12. *Cyprideis* sp. cf. *C. torosa* (JONES); *7-8,* external lateral views of RV of female and male; *9,12,* external lateral views of LV of female and male; all ×48 (p. 64).

10-11. *Cyprideis sp.; 10-11,* external lateral views of RV and LV, ×48 (p. 64).

13-18. *Haplocytheridea setipunctata* BRADY; *13-14,* external lateral views of LV and RV of female; *15,* external lateral view of RV of male; *16,* dorsal view of female carapace; *17,* dorsal view of male carapace; *18,* external lateral view of LV of male; all ×48 (p. 64a).



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound

Occurrence.—Found in 8 feet of water off Mt. Desert Island, Maine, and in deeper water in Vineyard Sound, Massachusetts. Present in Core Sound and both the Sound and Atlantic deltas of Ocracoke Inlet. Also found in the bottom of a core from the Neuse River. Salinity, 25 to 35 ‰; depth, 8 to more than 30 feet; substrate, sand. Associated with *Cytheromorpha pascagoulaensis*.

CUSHMANIDEA ULRICHI (Howe & Johnson), 1935

Plate 14, figure 3; Plate 19, figure 2

Cytherideis ulrichi Howe & Johnson in Howe *et al.*, 1935, p. 16, pl. 3, fig. 11-14; Puri, 1952, *134*, p. 911, pl. 130, fig. 11-13, text-fig. 5-6; Puri, 1953, *139*, p. 287, pl. 9, fig. 11-13; McLean, 1957, p. 79, pl. 9, fig. 3a-d.

Cytherideis subequalis ulrichi Howe & Johnson, Malkin, 1953, p. 779, pl. 78, fig. 19.

Cushmanidea ulrichi (Howe & Johnson), Puri, 1958, *139*, p. 175, table 1.

Diagnosis.—Recognized by its large, elongate, smooth carapace with few scattered normal pores and by presence of distinct selvage on LV, high and rounded anteriorly, set in from anterior margin, then merges with outer margin around remainder of free margin. *Miocene to Recent.*

Remarks.—The presence of a prominent selvage on the anterior of the LV and the smooth carapace distinguishes this species from *Cushmanidea seminuda*. Both adult valves had portions of the hinge broken away and only the terminal elements could be studied.

Dimensions.—Length of adult specimen, 0.79 mm.; height, 0.36 mm.

Material.—Three valves of which 2 are adult.

Occurrence.—Present in the *Arca* facies of the Choctawhatchee Formation and the Chipola facies of the Alum Bluff Formation of the Miocene of Florida. Found in the Miocene Yorktown Formation of Virginia. Reported in the Recent by Curtis (1960) from the middle and outer neritic areas of the eastern Mississippi Delta region. Found at one station on the Sound delta of Ocracoke Inlet. Salinity, 30 ‰; depth, about 10 feet; substrate, sand.

CUSHMANIDEA sp.

Plate 14, figure 7; Plate 20, figure 9

Diagnosis.—Recognized by the elongate, very finely pitted carapace and by relatively weak hingement. ***Recent.***

Description.—Carapace, fragile, elongate, dorsal margin arched, ventral margin sinuate anterior to middle, anterior margin rounded, posterior margin more narrowly rounded; elongate-ovoid from above, anterior more pointed than posterior, widest behind middle, somewhat inflated. Surface of carapace very finely pitted, with fine striations developed on anterior and ventral portions of valves. Duplicature on RV very wide anteriorly, narrow on rest of free margin, wide shallow vestibule developed anteriorly, duplicature welded on rest of free margin; narrow selvage originating near anterodorsal margin, following outer anterior and ventral margin, becoming sharper and higher on posterior margin where it swings upward inside posterior margin and then merges with dorsum; radial pore canals short and straight, numbering about 20 on anterior margin, few and widely spaced on remainder of free margin. Hinge of RV consisting of narrow, elongate, terminal flanges, separated by median element composed of narrow groove, long thin bar, and very short posterior groove. Hinge of LV has corresponding flanges and grooves. *Recent.*

Remarks.—This species resembles *Cushmanidea elongata* (Brady) but is distinguished from it by the very finely pitted carapace; also similar to *Hulingsina americana* (Cushman) but has fine surface ornamentation and the hinge structures are different. Too few specimens were found to justify naming of this species now.

Dimensions.—Length of adult specimens, 0.61 mm.; height, 0.28 mm.; thickness, 0.21 mm.

EXPLANATION OF PLATE 17

Neolophocythere, Paracytheridea, Acuticythereis, Haplocytheridea, Perissocytheridea

(All illustrated forms are from Southern Pamlico Sound Region; all ×75)

FIGURE

1,3-5,7. *Neolophocythere subquadrata* Grossman, n. sp.; *1*, external lateral view of LV; *3*, external lateral view of LV of tecnomorph; *4*, external lateral view of RV; *5*, external lateral view of RV of tecnomorph; *7*, dorsal view of carapace (p. 76).

2. *Paracytheridea* sp. cf. *C. vandenboldi* Puri; external lateral view of LV (p. 70).

6,8-9. *Acuticythereis nelsonensis* Grossman, n. sp.; *6*, external lateral view of RV; *8*, dorsal view of carapace; *9*, external view of LV (p. 72).

10-11,13. *Acuticythereis laevissima* Edwards; *10*, external lateral view of LV; *11*, external lateral view of RV; *13*, dorsal view of carapace (p. 71).

12,14. *Haplocytheridea* sp.; *12,14*, external lateral views of RV's; *18*, dorsal view of carapace (p. 65).

15-16,18. *Haplocytheridea bradyi* (Stephenson); *15-16*, external lateral views of LV and RV; *18*, dorsal view of carapace (p. 64a).

17,19. *Perissocytheridea* sp.; *17,19*, external lateral views of RV and LV (p. 65).

Material.—Eight valves, 6 of which are adult.

Occurrence.—Found at one station near the head of Nelson Bay. Salinity, 10 ‰; depth, 2 feet; substrate, silty sand. Not found with other ostracodes but associated with *Tiphotrocha comprimata, Trochammina inflata* and *Arenoparella mexicana.*

Genus HULINGSINA Puri, 1958

HULINGSINA ASHERMANI (Ulrich & Bassler), 1904

Plate 14, figure 2; Plate 20, figures 13-14

Cytherideis ashermani Ulrich & Bassler, 1904, p. 126, pl. 37, fig. 10-16; Howe *et al.*, 1935, p. 14, pl. 3, fig. 8-10; Edwards, 1944, p. 514, pl. 86, fig. 1-4; Swain, 1948, p. 195, pl. 13, fig. 1; Swain, 1951, p. 19; Puri, 1952, *134*, p. 910, pl. 130, fig. 4-8, text-fig. 2; Puri, 1953, *138*, p. 286, 287, pl. 9, fig. 15-17; Malkin, 1953, p. 778, pl. 78, fig. 1-13.

Cytherideis longula Ulrich & Bassler, 1904, p. 128, pl. 37, fig. 21-27; Swain, 1948, p. 195, pl. 13, fig. 2; Swain, 1951, p. 19.

Cytherideis semicircularis Ulrich & Bassler, 1904, p. 127, pl. 37, fig. 18-20.

Cushmanidea ashermani (Ulrich & Bassler), McLean, 1957, p. 77, pl. 8, fig. 5a-f.

Hulingsina ashermani (Ulrich & Bassler), Puri, 1958, *139*, p. 173, table 2; Benson & Coleman, 1963, p. 30, 31, pl. 4, fig. 1-3; fig. 17.

Hulingsina sulcata Puri, 1960, p. 118, pl. 2, fig. 6-7, text-fig. 43-46.

Diagnosis.—Distinguished by its deeply pitted carapace with arched dorsal margin. Selvage of RV quite distinct, high and sharp anteriorly set in from anterior margin, almost at outer margin on venter, swinging sharply upward inside posterior margin, leaving broad flat flange which is bordered by narrow, low posteroventral extension. *Miocene to Recent.*

Remarks.—The posteroventral flange on the Pamlico Sound specimens is more pronounced than the flange on the forms reported from Miocene sediments.

Dimensions.—Length of adult specimen, 0.84 mm.; height, 0.38 mm.

Material.—21 valves, of which 9 are adult.

Occurrence.—Reported from Miocene sediments of Maryland by Ulrich & Bassler (1904), Swain (1948), and Malkin (1953); found in the Duplin Marl of North Carolina by Edwards (1944); in the Yorktown Formation of Virginia (McLean, 1957), and in all facies except the Hawthorn of the Alum Bluff and Choctawhatchee Formations of Florida by Puri (1952, *134*, 1953, *138*). Found by Benson & Coleman (1963) living in the eastern Gulf of Mexico at a depth range from 32 to 329 feet, and a salinity range from 35 to 37 ‰. Benda & Puri (1962) and Hulings & Puri (1964) reported this species from the west coast of Florida. *Cushmanidea* sp. cf. *C. ashermani* was found by Curtis (1960) in the inshore biofacies of the eastern Mississippi Delta region. Found on both the Sound and Atlantic deltas of Ocracoke Inlet and at a few localities in Core Sound. Salinity, 25 to 35 ‰; depth, 5 to over 30 feet; substrate, sand.

HULINGSINA SANDERSI Puri, 1958

Plate 14, figure 1; Plate 20, figures 4, 6, 11

Hemicytherideis sp. aff. *H. mayeri* Swain, 1955, p. 631, pl. 63, fig. 3.

Hulingsina sandersi Puri, 1958, *139*, p. 173-174, pl. 2, fig. 10-14.

Diagnosis.—Recognized by its elongate, tuberculate carapace which has 2 closely spaced sulci in front of middle. Tubercules tend to parallel margin of shell. *Recent.*

Dimensions.—Length of adult specimen, 0.68 mm.; height, 0.27 mm.; thickness, 0.28 mm.

Material.—71 valves of which 51 are adult.

Occurrence.—Found by Puri (1958, *139*) at a depth of 135 feet in the eastern Gulf of Mexico. Present in the eastern part of Pamlico Sound, the Sound and Atlantic deltas of Ocracoke Inlet, and at numerous stations in Core Sound. Salinity, 25 to 35 ‰; depth, 5 to more than 30 feet; substrate, medium-sized sand to organic mud. Commonly associated with *Haplocytheridea setipunctata* and *Cushmanidea echolsae.*

Family CYTHERURIDAE G. W. Müller, 1894

Genus CYTHERURA Sars, 1866

CYTHERURA? CORENSIS Grossman, n. sp.

Plate 13, figure 10; Plate 19, figures 5-6

Diagnosis.—Recognized by 14 or 15 prominent, sinuous, slightly oblique ridges that traverse carapace, by faint sulcus, and by lack of caudal process. *Recent.*

Description.—Carapace, small, short, subquadrate in lateral view, dorsal margin straight, cardinal angles sharp, ventral margin slightly sinuate anterior to middle, anterior margin broadly rounded below, slightly truncate above, posterior margin slightly produced at mid-height, RV slightly larger than LV overlapping around free margins;

EXPLANATION OF PLATE 18

Acuticythereis, Loxoconcha, Cytheromorpha, Basslerites
(All illustrated forms are from Southern Pamlico Sound Region; all ×75)

FIGURE

1,5. *Acuticythereis multipunctata parva* Edwards; *1,5*, external lateral views of RV and LV (p. 72).

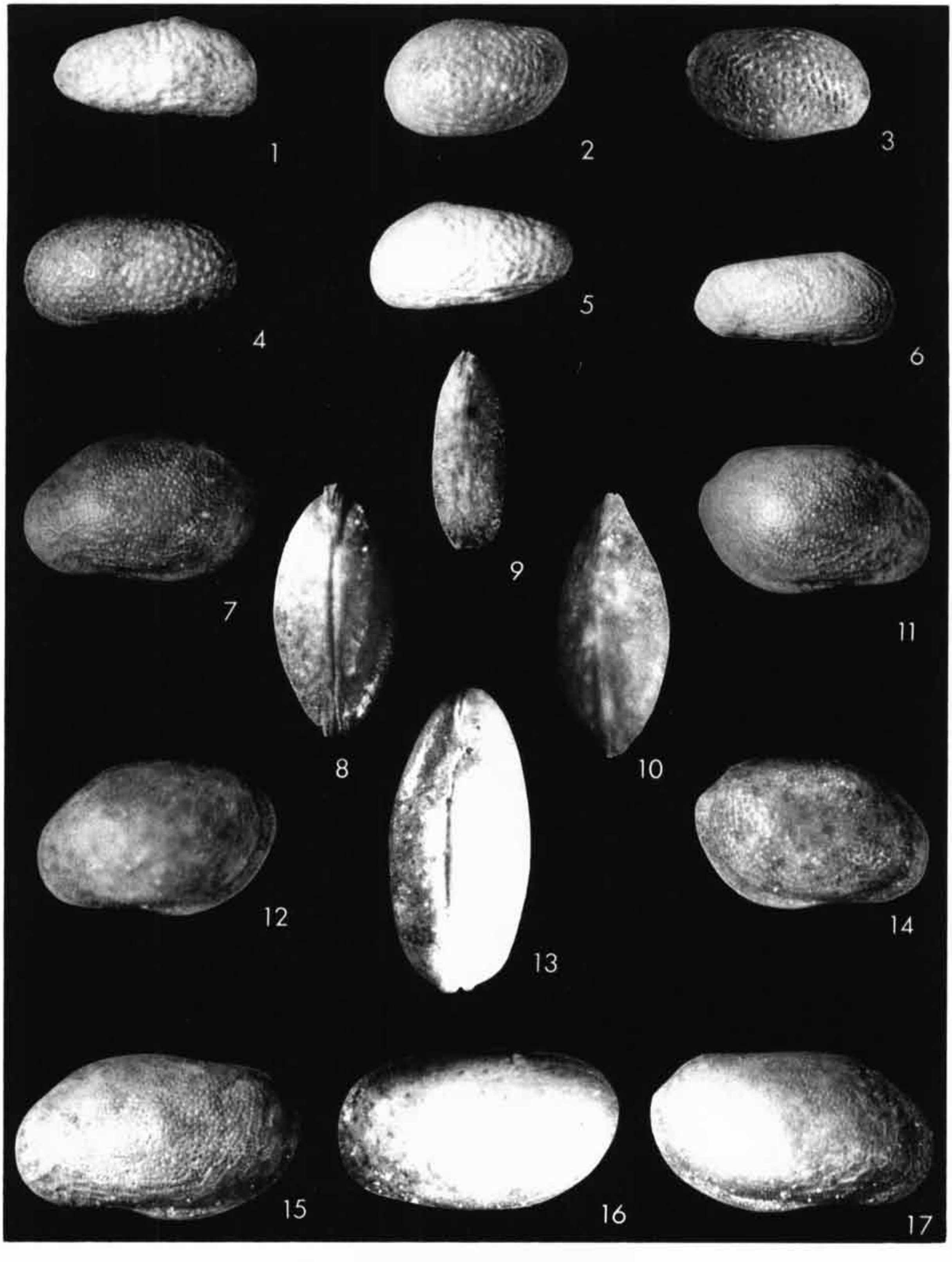
2-3. *Loxoconcha reticularis* Edwards; *2-3*, external lateral views of LV and RV (p. 74).

4,6,9. *Cytheromorpha warneri* Howe & Spurgeon; *4,6*, external lateral views of LV and RV; *9*, dorsal view of carapace (p. 75).

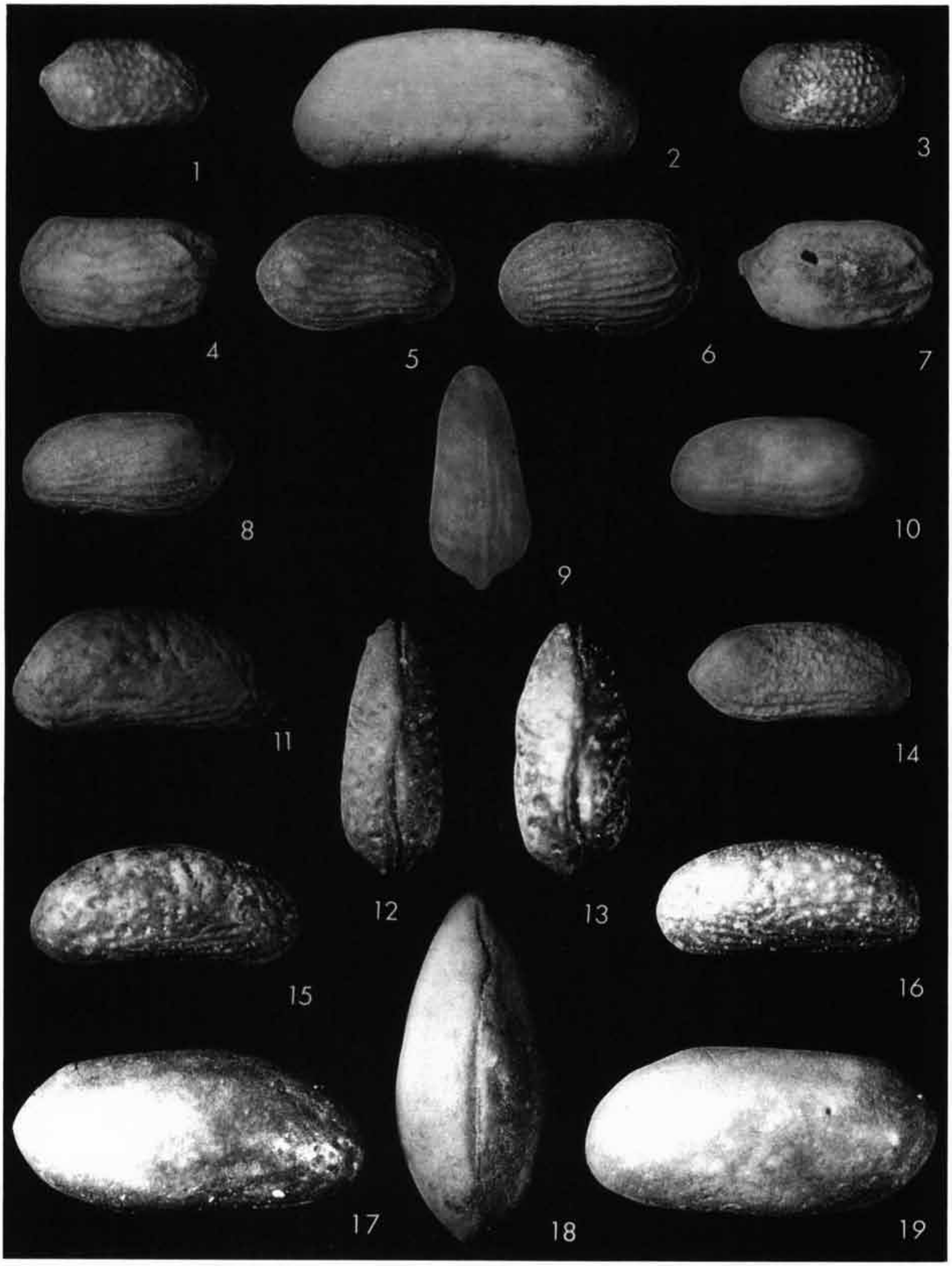
7-8,11. *Loxoconcha matagordensis* Swain; *7*, external lateral view of LV; *8*, dorsal view of carapace; *11*, external lateral view of RV (p. 74).

10,12,14-15,17. *Loxoconcha purisubrhomboidea* (Edwards); *10*, dorsal view of carapace of male; *12,14*, external lateral views of LV and RV of female; *15,17*, external lateral views of LV and RV of male (p. 74).

13,16. *Basslerites giganticus* Edwards; *13*, dorsal view of carapace; *16*, external lateral view of LV (p. 73).



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound

surface ornamented by 12 to 15 slightly oblique sinuous ribs which converge slightly anteriorly and are connected posteriorly; few faint cross ribs present on some specimens but lacking in others. Normal pore canals are small, few, and situated randomly on carapace; faint anteromedian sulcus present. Duplicature relatively narrow for genus, widest anteriorly where narrow vestibule occurs, elsewhere duplicature welded; marginal pore canals, few, simple, slightly wavy, irregularly spaced, about 15 on anterior and 4 or 5 on posterior region. Hingement of LV consisting of anterior flange tooth, postjacent socket, followed by very slightly arched bar that is strongly denticulated at both extremities. Hingement of RV consisting of anterior crenulated tooth, small superjacent socket, followed by long narrow bar located on extreme dorsum of shell, terminated by lower flangelike tooth and short superjacent groove spearating tooth from posterior extension of bar. Muscle-scar pattern posterior row of 4, with 2 anteroventral scars and 1 anterodorsal scar.

Remarks.—*Cytherura? corensis* is similar in shape and general features of ornamentation to *Paracytheroma striata* (Puri) but has 14 or 15 ribs rather than 11 that are present on the latter species. *P. johnsoni* (Mincher) is also similar in shape but has very sinuous and bifurcating ribs. *C.? corensis* has not been placed in *Paracytheroma* because the hingement is more typical of *Cytherura.*

Dimensions.—Length of adult specimen, 0.46 mm.; height, 0.32 mm.; thickness, 0.18 mm.

Material.—48 valves of which 42 are adult.

Occurrence.—Found at widely separated stations in Core Sound and on the Sound delta of Ocracoke Inlet. Salinity, 22 to 30 ‰; depth, 10 feet; substrate, sand or silty sand. Most commonly associated with *Basslerites tenmilecreekensis.*

CYTHERURA ELONGATA Edwards, 1944

Plate 13, figure 6; Plate 19, figures 9-10, 14

Cytherura elongata Edwards, 1944, p. 526, pl. 88, fig. 21-25; Swain, 1951, p. 501, pl. 7, fig. 24-25; Swain, 1955, p. 628, pl. 64, fig. 12a,b.

Diagnosis.—Recognized by its small, elongate, subrectangular carapace, and by prominent longitudinal ribs and delicate transverse ridges which together form faint reticulate pattern. *Miocene to Recent.*

Remarks.—This species is distinguished from *Cytherura forulata* Edwards by having a straighter dorsal margin and better developed cross ribs.

Dimensions.—Length of adult specimen, 0.50 mm.; height, 0.24 mm.; thickness, 0.24 mm.

Material.—26 valves of which 24 are adult.

Occurrence.—Recorded from the Duplin Marl of the Miocene of North Carolina. Reported by Swain (1955) as living in the lower part of San Antonio Bay, Texas. Found in low numbers on the Atlantic delta of Ocracoke Inlet, Core Sound, and Nelson Bay. Also present in the bottom of a core from the Neuse River estuary. Salinity, 15 to 25 ‰; depth, 4 to more than 30 feet; substrate, sand or silty sand.

CYTHERURA FORULATA Edwards, 1944

Plate 13, figure 5; Plate 19, figure 8

Cytherura forulata Edwards, 1944, p. 526, pl. 88, fig. 17-20; Swain, 1951, p. 50; Malkin, 1953, p. 789, pl. 80, fig. 22-24; Swain, 1955, p. 628, pl. 64, fig. 10a-c; text-fig. 392a,b.

Diagnosis.—Distinguished by elongate carapace, slightly curved dorsal margin, and small, blunt, caudal extension dorsal to mid-line; ornamentation consisting of 10 to 12 longitudinal ridges that converge anteroventrally, with scattered cross ribs between. *Miocene to Recent.*

Remarks.—Malkin (1953) stated that *Cytherura forulata* and *C. elongata* were possibly conspecific; however, the cross ribs on the latter are much more prominent.

Dimensions.—Length of adult specimen, 0.49 mm.; height, 0.25 mm.

Material.—35 valves of which 34 are adult.

EXPLANATION OF PLATE 19

Cytherura, Cushmanidea, Basslerites

(All illustrated forms are from Southern Pamlico Sound Region; all ×75)

FIGURE

1,3. *Cytherura johnsoni* Mincher; *1,3,* external lateral views of RV and LV (p. 70).

2. *Cushmanidea ulrichi* (Howe & Johnson); external lateral view of RV (p. 67).

4,7. *Cytherura* sp.; *4,* external lateral view of LV; *7,* external lateral view of RV (specimen damaged) (p. 70).

5-6. *Cytherura? corensis* Grossman, n. sp.; *5-6,* external lateral views of RV and LV (p. 68).

8. *Cytherura forulata* Edwards; external lateral view of LV (p. 69).

9-10,14. *Cytherura elongata* Edwards; *9,* dorsal view of carapace; *10,14,* external lateral views of LV and RV (p. 69).

11-13,15-16. *Cushmanidea echolsae* (Malkin); *11,* external lateral view of LV of tecnomorph; *12,* dorsal view of carapace of tecnomorph; *13,* dorsal view of carapace; *15-16,* external lateral views of RV and LV (p. 66).

17-19. *Basslerites tenmilecreekensis* Puri; *17,* external lateral view of RV; *18,* dorsal view of carapace; *19,* external lateral view of LV (p. 73).

Occurrence.—Present in the Miocene sediments of North Carolina and Virginia, more specifically, the Duplin Marl and the Yorktown Formation. Found by SWAIN (1955) in the lower part of San Antonio Bay, Texas. Present in the open lagoonal facies of the eastern Mississippi Delta region, and in the inner neritic facies of the Alligator Harbor, Florida, area. Present on both the Sound and Atlantic deltas of Ocracoke Inlet and at widely separated stations in Core Sound. Salinity, 20 to 33 ‰; depth, 5 to more than 30 feet; substrate, sand or silty sand.

CYTHERURA JOHNSONI Mincher, 1941

Plate 13, figure 1; Plate 19, figures 1, 3

Cytherura johnsoni MINCHER, 1941, p. 343, pl. 47, fig. 1a-d; SWAIN, 1955, p. 627, pl. 64, fig. 8a-c; text-fig. 35b, 38a,b, 39a-c.

Diagnosis.—Distinguished by subparallel dorsal and ventral margins, by well-defined reticular network which completely covers carapace, and by prominent caudal processes, that of LV more blunt than RV. *Miocene to Recent.*

Remarks.—Similar to *Cytherura wardensis* HOWE & BROWN but the reticulations are much larger; resembles *C. reticulata* EDWARDS but the reticulations on the latter species are absent on the anterior and posterior extremities. *C. forulata* is also similar but the cross ridges are weakly developed.

Dimensions.—Length of adult specimen, 0.38 mm.; height, 0.21 mm.

Material.—Seven adult valves.

Occurrence.—Reported by MINCHER (1941) from the Pascagoula Formation (Miocene) of Mississippi. Found by SWAIN (1955) living in the lower part of San Antonio Bay, Texas, and reported by PURI & HULINGS (1957) from the inner neritic facies of the Alligator Harbor, Florida, area, and from Florida Bay. Present only in the lower end of Core Sound. Salinity, 33 ‰; depth, 2 feet; substrate, sand.

CYTHERURA sp.

Plate 13, figures 7-8; Plate 19, figures 4, 7

Diagnosis.—Distinguished by its small, short, coarsely longitudinally ribbed carapace and by pronounced caudal process. *Recent.*

Description.—Carapace small, subquadrate, dorsal margin straight, ventral margin sinuate in middle, anterior margin abruptly rounded, posterior margin drawn out above mid-line as caudal extension, caudal process of LV more blunt than RV, posterior portion of valves inflated, keel on posteroventral margin. Surface of valves ornamented by prominent costae; one ridge parallels dorsal margin and fades as it swings down both extremities, second ridge arises at mid-height on anterior margin, runs obliquely upward and terminates immediately beneath dorsal rib at point just anterior to eyespot, 2 broad ribs arise near mid-height on anterior margin, more dorsal of which roughly parallels ventral margin, flares slightly near posterior margin and ends beneath caudal process; ventral rib fading at mid-length on venter; third rib inserted between other 2 arising in anterior quarter of carapace, flaring near posterior extremity, narrowing and disappearing on posterior margin; center of carapace ornamented by 6 sinuous ribs that parallel dorsal margin, all terminated by rib that extends from near dorsal border to point on posterior quarter of carapace; numerous weakly developed cross ribs are so faint that carapace does not have reticulated appearance. Hinge of RV consists of elongate bladelike tooth with 1 or 2 crenulations, with short groove above and behind tooth, groove opening to interior of shell, with long, thin, smooth ridge extending to posterior end of shell on dorsal side of groove; subjacent elongate socket at posterior extremity of shell opening to interior, socket located above a long flangelike tooth that extends to end of dorsal part of carapace; hinge of LV consisting of elongate ridge broadest at extremities and extending from anterior cardinal angle to end of dorsal part of caudal process, round tooth situated subjacent to ridge in anterior part of shell; closure accomplished by bar of LV fitting into anterior and posterior grooves of RV, with median part of bar slipping under narrow bar of RV; tooth on LV situated immediately behind anterior flange tooth of RV, presumably locking hingement. Marginal areas broad, widest anteriorly; radial pore canals rare, simple. Muscle-scar pattern not observed. *Recent.*

Remarks.—The hinge of this species resembles hingement of *Semicytherura* WAGNER, but features of the duplicature and marginal pore canals are dissimilar to that genus. The shape of *Cytherura* sp. is similar to *S. acuticostata* (SARS), but the latter species has an alar process and has weaker and fewer ribs. Too few specimens were found to justify naming of this species now.

Dimensions.—Length of adult specimen, 0.42 mm.; height, 0.26 mm.

Material.—Six valves, of which 4 are adult.

Occurrence.—A few specimens were found on the Atlantic delta of Ocracoke Inlet and at the southern end of Core Sound. One specimen was also found in the bottom of a core from the Neuse River. Perhaps this species is limited to waters of near-normal marine salinities.

Genus PARACYTHERIDEA Müller, 1894

PARACYTHERIDEA sp. cf. C. VANDENBOLDI Puri, 1953

Plate 12, figure 5; Plate 17, figure 2

Cytheropteron nodosum ULRICH & BASSLER, 1904, p. 129, pl. 38, fig. 37-40 (*non C. nodosum* BRADY).

Paracytheridea nodosa (Ulrich & Bassler), HOWE *et al.*, 1935, p. 37, pl. 3, fig. 7; VAN DEN BOLD, 1946, p. 86, pl. 16, fig. 7; SWAIN, 1951, p. 51, pl. 3, fig. 19-22.

Paracytheridea vandenboldi PURI, 1953, *135*, p. 751; MALKIN, 1953, p. 780, pl. 79, fig. 5; PURI, 1953, *138*, p. 238-240, pl. 3, fig. 7, text-fig. 5a,b; SWAIN, 1955, v. 29, p. 625, pl. 62, fig. 2a,b; MCLEAN, 1957, p. 75, pl. 8, fig. 4a,b.

Diagnosis.—Recognized by its pitted dorsally caudate carapace which possesses posterodorsal and anteroventral nodes, and by sulcus which originates just posterior to anterior cardinal angle and terminates near front of anteroventral node. *Miocene to Recent.*

Remarks.—*Paracytheridea chipolensis* Howe & Stephenson is similar but has reticulations rather than pits and possesses a bifurcating rib along the ventral keel. *P. washingtonensis* Puri resembles *P. vandenboldi* in general shape but does not have a sulcus. The Pamlico Sound specimens are not as elongate as the holotype, but closely resemble those specimens described and illustrated by Swain (1955).

Dimensions.—Length of adult specimen, 0.63 mm.; height, 0.32 mm.

Material.—Seven valves, of which 4 are adult.

Occurrence.—Found in the Miocene of the Atlantic coastal plain, especially in the Yorktown Formation of Virginia, Calvert Formation of Maryland, and the Choctawhatchee Formation of Florida. Reported by Swain (1955) as living in the brackish waters of San Antonio Bay, Texas. Found in low numbers at widely separated stations in Core Sound and on both the Atlantic and Sound deltas of Ocracoke Inlet. Salinity, 24 to 35 ‰; depth, 10 to more than 30 feet; substrate, medium and fine sand.

Family HEMICYTHERIDAE Puri, 1953

Genus HEMICYTHERE Sars, 1925

HEMICYTHERE LAEVICULA Edwards, 1944

Plate 15, figure 7; Plate 21, figures 6-8

Hemicythere laevicula Edwards, 1944, pl. 86, fig. 27-30; Puri, 1953, *137*, p. 174, pl. 1, fig. 1-2.

Diagnosis.—Distinguished by its small somewhat elongate carapace ornamented by faint pits which become larger and more elongate near margins. *Miocene* to *Recent.*

Remarks.—This species resembles *Aurila amygdala* (Stephenson) but differs in having finer surface pitting and a more elongate carapace.

Dimensions.—Length of adult specimen, 0.50 mm.; height, 0.33 mm.

Material.—Four valves, 2 of which are adult.

Occurrence.—Present in the Duplin Marl of North Carolina, and the Chipola, Oak Grove, and Shoal River facies of the Alum Bluff Formation of Florida. Found at 1 station near Ocracoke Inlet and at 1 station in the southern end of Core Sound. Salinity, about 30 ‰; depth, 8 feet; substrate, sand.

HEMICYTHERE? sp.

Plate 15, figure 9; Plate 21, figure 4

Remarks.—Two immature LV's were found in the Pamlico Sound region. The hinge is archaeodont and the muscle-scar pattern was not observed. The carapace is almond-shaped which is fairly characteristic of *Hemicythere* and for that reason these specimens have been placed under that genus. The valves have the same elongate rounded pits as the forms described by Cushman (1906) as *Cythere albomaculata* (*non Cythere albomaculata* Baird); it is perhaps the same species.

Dimensions.—Length of immature specimen, 0.49 mm.; height, 0.32 mm.

Occurrence.—One valve was found in Cape Lookout Bight and the other on the Atlantic shoal of Ocracoke Inlet. Salinity, greater than 30 ‰; depth, greater than 30 feet; substrate, sand.

Genus AURILA Pokorný, 1955

AURILA CONRADI (Howe & McGuirt, 1935) LITTORALA Grossman, 1965

Plate 15, figure 8; Plate 21, figures 1-3

Hemicythere conradi (Howe & McGuirt), Swain, 1955, p. 635, pl. 62, fig. 3a-c; Puri & Hulings, 1957, p. 183, 187, fig. 11, no. 4.
Aurila conradi (Howe & McGuirt), Puri, 1960, p. 129-130, pl. 3, fig. 9-10.

Diagnosis.—Recognized by medium-sized, almond-shaped carapace ornamented by reticulate pattern of subrounded ridges which separate deep subangular pits. Somewhat prominent ridges are near and roughly parallel to ventral, posterior, and dorsal margins. Another ridge extends obliquely from eyespot to rear of flange on anteroventral margin. *Recent.*

Remarks.—Differs from *Aurila conradi floridana* Benson & Coleman (1963) by not having the ventral margin developed as a pronounced marginal rim; from *A. conradi californica* Benson & Kaesler (1963) by having subangular rather than circular pits, and from *A. conradi conradi* by having a reticulated rather than a pitted appearance.

Dimensions.—Length of adult specimen, 0.54 mm.; height, 0.35 mm.; thickness, 0.26 mm.

Material.—90 valves of which 58 are adult.

Occurrence.—Reported by Swain (1955) from San Antonio Bay, Texas, by Puri & Hulings (1957) from the Panama City, Alligator Harbor, and Florida Bay regions of Florida, and by Grossman (1965) from Redfish Bay, Texas. Present in the marsh at Nelson Bay and at a few stations in Core Sound. Salinity, 2 ‰; depth, less than 1 to 4 feet; substrate, organic mud and silty sand. Associated with *Trochammina inflata* and *Ammonia limbatobeccarii.*

Family LEGUMINOCYTHEREIDIDAE Howe, 1961

Genus ACUTICYTHEREIS Edwards, 1944

ACUTICYTHEREIS LAEVISSIMA Edwards, 1944

Plate 12, figure 6; Plate 17, figures 10-11, 13

Acuticythereis laevissima Edwards, 1944, p. 519-520, pl. 87, fig. 4-11; McLean, 1957, p. 90, pl. 12, fig. 4a-g.
Campylocythere laevissima (Edwards), Malkin, 1953, p. 785.

Diagnosis.—Distinguished by its ovate to pyriform, finely punctate carapace; posterior end of RV pointed, of LV rounded. *Miocene to Recent.*

Remarks.—Specimens collected in the Pamlico Sound region are slightly more elongate than those figured by

EDWARDS (1944) and MALKIN (1953), but all other features appear identical.

Dimensions.—Length of adult specimen, 0.52 mm.; height, 0.26 mm.; thickness, 0.23 mm.

Material.—Eight mature valves.

Occurrence.—Reported from the Miocene Duplin Marl of North Carolina and from the Miocene Yorktown Formation of New Jersey, Maryland, and Virginia. Collected in shallow marine water by PURI & HULINGS (1957) from the Panama City and Alligator Harbor areas of Florida. Reported by BENSON & COLEMAN (1963) from the eastern Gulf of Mexico from depths between 19 and 95 feet, although most abundant at depths less than 25 feet, and a salinity range of 35 to 40 ‰. Distributed in low numbers on the Sound delta of Ocracoke Inlet and at the southern end of Core Sound. Salinity, 30 ‰; depth, 10 to 30 feet; substrate, sand.

ACUTICYTHEREIS NELSONENSIS Grossman, n. sp.

Plate 12, figure 4; Plate 17, figures 6, 8-9

Diagnosis.—Recognized by subquadrate, reticulate carapace with subcentral node and subsidiary protuberances and by strong hingement. *Recent.*

Description.—Carapace subquadrate in lateral view, highest about 0.3 from anterior end, dorsal margin slightly convex, ventral margin slightly sinuate just anterior to middle, anterior margin broadly rounded, posterior margin pointed on RV, more blunt on LV. LV slightly larger than RV, greatest width in posterior portion of carapace. Surface ornamented by rather large closely spaced pits with interstices forming irregular network; small subcentral node and several even smaller nodes are located on posterior portion of carapace. Nodes formed by reticulations where pits are widely spaced. Hinge of RV consists of prominent triangular anterior tooth, deep postjacent socket which merges gradually with long slightly curved median groove, which is terminated by ovate posterior tooth. Hinge of LV antithesis of RV. Duplicature moderately broad, widest on anterior margin; inner margin and line of concrescence coincide except on anteroventral margin where there is narrow vestibule, radial pore canals straight, simple, most common on anterior margin; averaging 20 in number; muscle-scar pattern consists of vertical row of 4 with 3 scars anterior.

Remarks.—*Acuticythereis nelsonensis* is similar to *A. concinnoidea* SWAIN but has reticulations which are larger and more irregular, subsidiary nodes, and a stronger hingement. *A. multipunctata* EDWARDS resembles *A. nelsonensis* but has a longer carapace and the pits are located mainly on the posterior portion of the carapace.

Dimensions.—Length of adult specimen, 0.51 mm.; height, 0.28 mm.; thickness, 0.27 mm.

Material.—49 valves of which 45 are adult.

Occurrence.—Found near the Sound shoal of Ocracoke Inlet, present at several stations in Core Sound, and found next to the marsh in Nelson Bay. Salinity, 25 to 35 ‰; depth, 2 to 15 feet; substrate, organic mud or silty sand.

ACUTICYTHEREIS MULTIPUNCTATA PARVA Edwards, 1944

Plate 12, figure 3; Plate 18, figures 1, 5

Acuticythereis multipunctata parva EDWARDS, 1944, p. 520, pl. 87, fig. 17-18.

Diagnosis.—Recognized by its small, elongate, tapered, pitted carapace, which is highest near anterior. *Miocene to Recent.*

Remarks.—The Pamlico Sound specimens are similar to EDWARD's forms in size and shape, but the carapace is pitted throughout and has a small subcentral node which is not apparent in EDWARD's illustrations. The similarity in shape, size, and other features of the carapace are such that the specimens from Pamlico Sound are placed in *Acuticythereis multipunctata parva*. Similar in shape to *A. multipunctata*, but may be distinguished from it by the smaller size, and more tapering carapace; also resembles *A. concinnoidea* but differs by being smaller, less coarsely ornamented, and possessing an elongate tapering carapace.

Dimensions.—Length of adult specimen, 0.48 mm.; height, 23 mm.

Material.—46 valves, of which 38 are adult.

Occurrence.—Reported by EDWARDS (1944) from the Miocene Duplin Marl of North Carolina. This is the first reported occurrence

---

EXPLANATION OF PLATE 20

PELLUCISTOMA, CYTHEROMORPHA, HULINGSINA, LEGUMINOCYTHEREIS, CUSHMANIDEA
(All illustrated forms are from Southern Pamlico Sound Region; all ×75)

FIGURE

1,3. *Pellucistoma magniventra* EDWARDS; *1*, external lateral view of LV of late instar; *3*, external lateral view of LV of adult (p. 75).

2,5,8. *Cytheromorpha pascagoulaensis* MINCHER; *2*, dorsal view of carapace; *5,8*, external lateral views of RV and LV (p. 75).

4,6,11. *Hulingsina sandersi* PURI; *4,6*, external lateral views of LV and RV; *11*, dorsal view of carapace (p. 68).

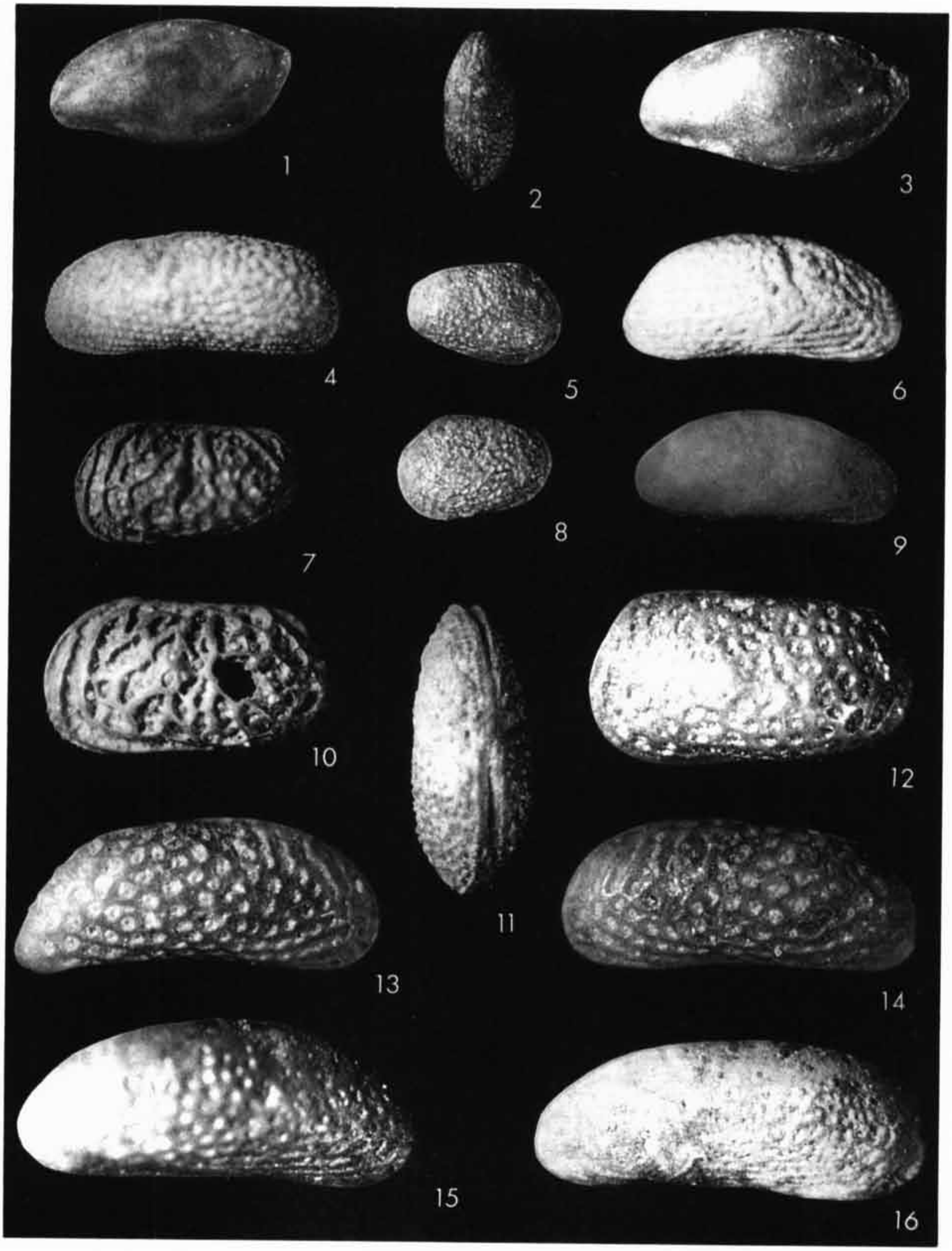
7,10. *Leguminocythereis whitei* SWAIN; *7*, external lateral view of LV of instar; *10*, external lateral view of LV of adult (specimen damaged) (p. 73).

9. *Cushmanidea* sp.; external lateral view of RV (p. 67).

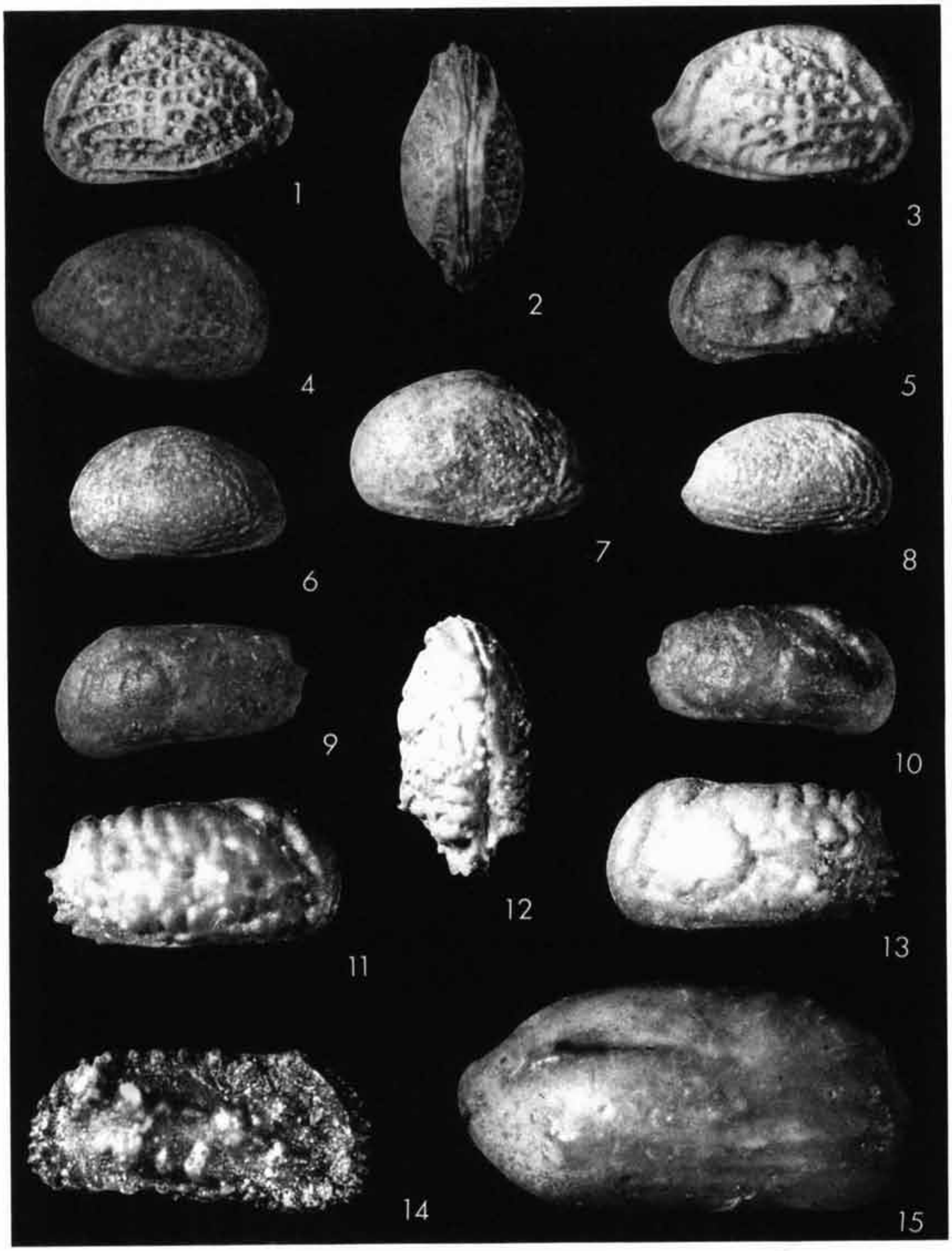
12. *Leguminocythereis* sp.; external lateral view of LV (p. 74).

13-14. *Hulingsina ashermani* (ULRICH & BASSLER); *13-14*, external lateral views of RV and LV (p. 68).

15-16. *Cushmanidea seminuda* (CUSHMAN); *15*, external lateral view of RV; *16*, external lateral view of LV (specimen slightly damaged) (p. 66).



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound



GROSSMAN & BENSON — Rhizopoda and Ostracoda, Pamlico Sound

of this species in the Recent. Present on the Sound delta of Ocracoke Inlet, in Core Sound, and adjacent to the marsh in Nelson Bay. Salinity, 25 to 35 ‰; depth, 2 to 20 feet; substrate, organic mud and silty sand.

Genus BASSLERITES Howe, 1937

BASSLERITES GIGANTICUS Edwards, 1944

Plate 13, figure 2; Plate 18, figures 13, 16

Basslerites giganticus EDWARDS, 1944, pl. 87, fig. 19-23.
Basslerites sp. cf. *B. giganticus* Edwards, PURI, 1953, *138*, p. 280, pl. 8, fig. 12; text-fig. 11L.

Diagnosis.—Recognized by subquadrate carapace, nearly straight dorsum, slightly sinuate ventral margin, broadly rounded anterior and somewhat truncate posterior. Surface smooth except for small scattered normal pore canals. *Miocene to Recent.*

Remarks.—Similar in size to *Basslerites tenmilecreekensis* PURI, but has curved connecting hinge elements and has a much more truncate posterior.

Dimensions.—Length of adult specimen, 0.65 mm.; height, 0.37 mm.; thickness, 0.31 mm.

Material.—12 adult valves.

Occurrence.—Present in the Duplin Marl of North Carolina, and in the *Arca, Ecphora,* and *Cancellaria* facies of the Choctawhatchee Formation of Florida. Found on both the Sound and Atlantic shoals of Ocracoke Inlet and in Cape Lookout Bight. Salinity, 30 to 35 ‰; depth, 10 to more than 30 feet; substrate, sand.

BASSLERITES TENMILECREEKENSIS Puri, 1953

Plate 13, figure 4; Plate 19, figures 17-19

Basslerites tenmilecreekensis PURI, 1953, *138*, p. 280, pl. 8, fig. 13-15; text-fig. 11m.

Diagnosis.—Distinguished by the large, oblong, moderately thick carapace which is smooth except for pitting by normal pore canals; anterior end broadly rounded below, oblique above, posterior end slightly produced. Terminal portion of hinge widely separated and joined by straight connecting element. *Miocene to Recent.*

Remarks.—This species resembles *Basslerites giganticus* EDWARDS in size, but the posterior margin is produced, the terminal hinge elements are farther apart, and the connecting element is straight. The Pamlico Sound specimens are slightly smaller than topotypes but identical in other features. Pamlico Sound specimens are interpreted as reworked Miocene fossils.

Dimensions.—Length of adult specimen, 0.85 mm.; height, 0.41 mm.; thickness, 0.36 mm.

Material.—57 valves, of which 40 are mature.

Occurrence.—Found in the Chipola facies of the Alum Bluff Formation and questionably in the *Arca* facies of the Choctawhatchee Formation of the Miocene of Florida. Not previously reported from Recent sediments. Distributed on both the Sound and Atlantic deltas of Ocracoke Inlet and in the southern portion of Core Sound. Salinity, 25 to 35 ‰, most common about 30 ‰; depth, 10 to more than 30 feet; substrate, sand or silty sand.

Genus LEGUMINOCYTHEREIS Howe & Law, 1936

LEGUMINOCYTHEREIS WHITEI Swain, 1951

Plate 14, figure 4; Plate 20, figures 7, 10

Leguminocythereis whitei SWAIN, 1951, p. 43-44, pl. 3, fig. 14, 16-18, pl. 4, fig. 1; MALKIN, 1953, p. 785-786, fig. 7-12; *non* MCLEAN, 1957, p. 80, pl. 19, fig. 4a,b.
Triginglymus denticulata HULINGS, 1966, p. 53, fig. 3f-j, 8b.

Diagnosis.—Recognized by coarsely reticulate carapace with 2 prominent ridges paralleling free margin, innermost ridge ending at mid-length on venter, outermost ending on posteroventral corner. *Miocene to Recent.*

Remarks.—The specimens figured by MCLEAN (1957) are not *Leguminocythereis whitei*. MCLEAN's forms have the surface ornamented by large pits, whereas *L. whitei* is coarsely reticulate.

EXPLANATION OF PLATE 21

AURILA, HEMICYTHERE, PURIANA, ACTINOCYTHEREIS, CYTHERETTA
(All illustrated forms are from Southern Pamlico Sound Region; all ×75)

FIGURE

1-3. *Aurila conradi* (HOWE & MCGUIRT) *littorala* GROSSMAN, n. subsp.; *1,3,* external lateral views of LV and RV; *2,* dorsal view of carapace (p. 71).

4. *Hemicythere* sp.; external lateral view of RV of immature specimen (p. 71).

5. *Puriana mesacostalis* (EDWARDS); external lateral view of LV of immature specimen (p. 77).

6-8. *Hemicythere laevicula* EDWARDS; *6,* external lateral view of LV of immature specimen; *7,* external lateral view of LV of adult; *8,* external lateral view of RV of immature specimen (p. 71).

9-10. *Puriana* sp.; *9-10,* external lateral views of LV and RV p. ....).

11-13. *Puriana rugipunctata* (ULRICH & BASSLER); *11,13,* external lateral views of RV and LV; *12,* dorsal view of carapace (p. 77).

14. *Actinocythereis exanthemata exanthemata* (ULRICH & BASSLER); external lateral view of RV (p. 76).

15. *Cytheretta* sp. cf. *C. sahni* PURI; external lateral view of RV (p. 63).

Dimensions.—Length of adult specimen, 0.66 mm.; height, 0.37 mm.

Material.—Five valves, of which 2 are adult.

Occurrence.—Present in Miocene sediments of the subsurface of North Carolina and the Miocene Choptank and Yorktown Formations of Virginia. Not previously reported from Recent sediments. Found at several stations in the more marine portions of the area of investigation. Salinity greater than 30 ‰; depth, 10 to more than 30 feet; substrate, sand.

LEGUMINOCYTHEREIS sp.

Plate 14, figure 10; Plate 20, figure 12

Diagnosis.—Recognized by its moderately large, quadrate carapace, and by large ovoid pits that ornament carapace. *Recent.*

Description.—(Based on mature LV.) Carapace moderately large, quadrate, anterior margin broadly rounded, posterior margin more narrowly rounded, dorsum straight, ventral margin almost straight except for slight sinuation just anterior to mid-length; anterior and posterior cardinal angles acute and well defined. Surface ornamented by large, round to ovoid, simple to compound, randomly oriented pits. Interior of valve moderately deep, hinge holamphidont, consisting of large, oval-shaped anterior socket, small postjacent tooth which merges into long, straight crenulated bar, and is terminated by elongate posterior socket; duplicature moderately wide, widest on anterior and posterior margins where vestibule occurs, duplicature welded to venter; marginal pore canals few, simple, straight, greatest number on anterior and posterior parts of valves.

Remarks.—Similar in shape to *Leguminocythereis whitei,* but the carapace has a pitted rather than a reticular surface.

Dimensions.—Length of adult specimen, 0.73 mm.; height, 0.38 mm.

Material.—Five valves, of which 1 is adult.

Occurrence.—Present at one station in Core Sound. Salinity, greater than 30 ‰; depth, 10 feet; substrate, sand.

Family LOXOCONCHIDAE Sars, 1925

Genus LOXOCONCHA Sars, 1866

LOXOCONCHA MATAGORDENSIS Swain, 1955

Plate 15, figure 3; Plate 18, figures 7-8, 11

Loxoconcha matagordensis Swain, 1955, p. 629-630, pl. 63, fig. 9a,b, pl. 64, fig. 1a,b, text-fig. 36b-37a,b.

Diagnosis.—Recognized by subrhomboid shape, slightly caudate posterior, and by finely pitted carapace with superimposed reticulate network which is best developed near margins. *Recent.*

Remarks.—The only difference between this species and *Loxoconcha purisubrhomboidea* (Edwards) appears to be in development of a faint reticulate network covering the surface of the valves. Many specimens of *L. purisubrhomboidea* have faint reticulations along the margins and apparently a transition joins the two species, *L. purisubrhomboidea* representing the unreticulated form and *L. matagordensis* the reticulated form. *L. rhomboidea* Brady is similar but has larger pits.

Dimensions.—Length of adult specimen, 0.50 mm.; height, 0.34 mm.; thickness, 0.24 mm.

Material.—Nine valves, all adult.

Occurrence.—Reported by Swain (1955) from San Antonio Bay and Matagorda Island, Texas, and by Puri & Hulings (1957) from the inner neritic region of Alligator Harbor and Florida Bay. Found at several stations in the western part of Pamlico Sound and at one station in Nelson Bay. Salinity, 12 to 25 ‰; depth, 2 to 10 feet; substrate, organic mud and silty sand.

LOXOCONCHA PURISUBRHOMBOIDEA (Edwards), 1944

Plate 15, figure 1; Plate 18, figures 10, 12, 14-15, 17

Loxoconcha subrhomboidea Edwards, 1944 (not Brady, 1880), p. 527, pl. 88, fig. 28-32; Swain, 1951, p. 25-26, pl. 2, fig. 18-19; Malkin, 1953, p. 787, pl. 80, fig. 13-17 (figured as *L. reticularis*).

Loxoconcha purisubrhomboidea Edwards in Puri, 1953, *135,* p. 750; Puri, 1953, *138,* p. 274, pl. 10, fig. 8, text-fig. 10h; McLean, 1957, p. 71, pl. 7, fig. 4a-e; Grossman, 1965, p. 148-150, text-fig. 3, 20-36, pl. 2, fig. 1-11.

Diagnosis.—Distinguished by its subrhomboidal, faintly caudate, finely pitted carapace. *Miocene to Recent.*

Remarks.—Edwards (1944) described the species as being ornamented only by fine pits. Swain (1951) reported that specimens studied by him had 4 or 5 ridges arranged around the free margins. Many of the Pamlico Sound specimens have these ridges broken up into a faint reticular network. These reticulations, however, are limited to the free margins and do not cover the shell as in *Loxoconcha matagordensis.* The forms that Malkin (1953) figured as *L. reticularis* are closer to *L. purisubrhomboidea,* which has the fine reticulations and straight dorsum observed on specimens illustrated by her. *L. impressa* Baird is similar in shape, but has larger pits which become elongate in the ventral part of the shell.

Dimensions.—Length of adult male specimen, 0.64 mm.; height, 0.37 mm.; thickness, 0.27 mm. Length of adult female specimen, 0.54 mm.; height, 0.35 mm.; thickness, 0.29 mm.

Material.—77 valves, of which 50 are adult.

Occurrence.—Originally described from the Miocene Duplin Marl of North Carolina, found in the *Arca* and *Ecphora* facies of the Choctawhatchee Formation of the Miocene of Florida. Present in the Recent of the inner neritic facies of Alligator Harbor, Florida, in the outer and inner neritic and estuarine facies of the eastern Mississippi Delta region, and in the Texas bays. Widely distributed in Core and eastern Pamlico Sounds, and on both the Atlantic and Sound deltas of Ocracoke Inlet, and also found near the marsh and in the center of Nelson Bay. Salinity, 20 to more than 35 ‰; depth, less than 1 to more than 30 feet; substrate, organic mud or sand. Most commonly associated with *Haplocytheridea setipunctata.*

LOXOCONCHA RETICULARIS Edwards, 1944

Plate 15, figure 2; Plate 18, figures 2-3

Loxoconcha reticularis Edwards, 1944, p. 527, pl. 88, fig. 26-27; Puri, 1953, *138,* p. 274, pl. 10, fig. 7, text-fig. 10e; McLean, 1957, p. 72, pl. 7, fig. 5a,b, *non* Malkin, 1953, p. 787, pl. 80, fig. 13-17.

Diagnosis.—Distinguished by coarse reticulations arranged concentrically about center of valves, by slight concavity of dorsum posterior to middle, and by tumid carapace. *Miocene to Recent.*

Remarks.—Similar to *Loxoconcha jacksoni* HOWE & CHAMBERS (1935) but has coarser reticulations and differs somewhat in outline; also similar to *L. mornhinvegi* HOWE & CHAMBERS, but the reticulations are different. The specimens figured by MALKIN (1953) for *L. reticularis* are almost identical to *L. purisubrhomboidea.*

Dimensions.—Length of adult specimen, 0.41 mm.; height, 0.27 mm.

Material.—Five valves, of which 3 are adult.

Occurrence.—Reported from the Miocene sediments of the Atlantic coastal plain, more specifically from the Duplin Marl of North Carolina, the Yorktown Formation of Virginia, and the *Ecphora* and *Cancellaria* facies of the Choctawhatchee Formation of Florida. Not previously reported from the Recent. Found in the area of investigation at one station on the Atlantic shoal of Ocracoke Inlet and at one station in the central part of Core Sound. Salinity, 35 ‰; depth, 5 to more than 30 feet; substrate, sand.

Genus CYTHEROMORPHA Hirschmann, 1909

CYTHEROMORPHA PASCAGOULAENSIS Mincher, 1941

Plate 12, figure 2; Plate 20, figures 2, 5, 8

Cytheromorpha pascagoulaensis MINCHER, 1941, p. 344-345, pl. 47, fig. 2; SWAIN, 1955, p. 630-631, pl. 63, fig. 4,; pl. 64, fig. 5, text-fig. 34c.

Diagnosis.—Distinguished by small, short, compressed carapace which is highest anteriorly and by moderately coarse pitted surface. *Miocene to Recent.*

Remarks.—Similar to *Cytheromorpha curta* EDWARDS but has a more coarsely pitted carapace.

Dimensions.—Length of adult specimen, 0.35 mm.; height, 0.24 mm.; thickness, 0.14 mm.

Material.—29 valves.

Occurrence.—Present in the Miocene Pascagoula Formation of Mississippi. Found in the Recent of the Texas bays and in the brackish water of the Florida coast. Present in Pamlico and Core Sounds and in the bottom of a core from the Neuse estuary. Salinity, 24 to 30 ‰, most common at about 25 ‰; depth, 5 to 20 feet; substrate, sand or silty sand.

CYTHEROMORPHA WARNERI Howe & Spurgeon, 1935

Plate 13, figure 3; Plate 18, figures 4, 6, 9

Cytheromorpha warneri HOWE & SPURGEON in HOWE *et al.*, 1935, p. 11-12, pl. 2, fig. 5, 8-9, pl. 4, fig. 4; MALKIN, 1953, p. 787, pl. 80, fig. 18-19; PURI, 1953, *138*, p. 277, pl. 6, fig. 5-7, text-fig. 11f,g.

Cytheromorpha sp. cf. *C. warneri* Howe & Spurgeon, SWAIN, 1951, p. 49, pl. 7, fig. 18-18a; MCLEAN, 1957, p. 70-71, pl. 7, fig. 3a,b.

Diagnosis.—Recognized by elongate, ovate carapace with nearly straight dorsal and ventral margins that converge slightly toward posterior end, and by moderate-sized reticulations that are roughly hexagonal in outline in posterior half of carapace, and irregular on anterior half. Slight median sulcus present. *Miocene to Recent.*

Remarks.—The reticulations are more irregular on the anterior portion of the carapace, and the valves are somewhat longer than specimens described by HOWE & SPURGEON *(84).*

Dimensions.—Length of adult specimen, 0.48 mm.; height, 0.30 mm.; thickness, 0.17 mm.

Material.—29 valves.

Occurrence.—Present in the Miocene of the Atlantic coastal plain, more specifically in the *Ecphora, Arca,* and *Cancellaria* facies of the Choctawhatchee Formation of Florida, the Yorktown Formation of Virginia, the Calvert Formation of Maryland and upper Miocene sediments of North Carolina. Found in the Recent by PURI & HULINGS (1957) in the inner neritic zone of the Alligator Harbor, Florida, region and in Florida Bay. In the area of investigation present in Cape Lookout Bight, Core Sound, and on both the Sound and Atlantic deltas of Ocracoke Inlet. Salinity, 30 to 35 ‰; depth, 5 to more than 30 feet; substrate, sand.

Family PARADOXOSTOMATIDAE Brady & Norman, 1889

Subfamily CYTHEROMATINAE Elofson, 1939

Genus PELLUCISTOMA Coryell & Fields, 1937

PELLUCISTOMA MAGNIVENTRA Edwards, 1944

Plate 14, figure 5; Plate 20, figures 1, 3

Pellucistoma magniventra EDWARDS, 1944, p. 528, pl. 88, fig. 33-35; PURI, 1953, *138*, p. 289-290, pl. 15, fig. 4, text-fig. 12a; PURI & HULINGS, 1957, p. 174, 176, 183; PURI, 1960, p. 119, pl. 2, fig. 10, text-fig. 8-9; BENSON & COLEMAN, 1963, p. 41-42, pl. 6, fig. 11, text-fig. 26.

Pellucistoma sp. cf. *P. magniventra* Edwards, SWAIN, 1951, p. 52.

Paradoxostoma ensiforme Brady, SWAIN, 1955, p. 633, pl. 63, fig. 7.

Diagnosis.—Recognized by its smooth, sublanceolate, carapace. Anterior narrowly rounded below, highly oblique above merging gradually with dorsal margin; posteroventral portion of carapace convex, merging with narrowly rounded, somewhat caudate posterior extremity. *Miocene to Recent.*

Remarks.—BENSON & COLEMAN (1963) have adequately discussed the affinities of this species with other closely allied forms.

Dimensions.—Length of adult specimen, 0.64 mm.; height, 0.33 mm.

Material.—Ten valves, of which 8 are adult.

Occurrence.—First described by EDWARDS (1944) from the Miocene Duplin Marl of North Carolina; then by SWAIN (1951) from the Miocene of the subsurface of North Carolina and by PURI (1953, *138*) from the Choctawhatchee Formation of the Miocene of Florida. Found in the Recent by PURI & HULINGS (1957) and PURI (1960) from the Alligator Harbor and Panama City regions of Florida, and by CURTIS (1960) from the inshore areas of the eastern Mississippi Delta region. Reported by BENDA & PURI (1962), BENSON & COLEMAN (1963) and by HULINGS & PURI (1964) from marine areas in the eastern Gulf of Mexico. Present in Cape Lookout Bight and the Atlantic delta of Ocracoke Inlet in salinities greater than 30 ‰; depth, 28 to more than 30 feet; substrate, sand.

Family PROGONOCYTHERIDAE Sylvester-Bradley, 1948

Subfamily PROGONOCYTHERINAE Sylvester-Bradley, 1948

Genus NEOLOPHOCYTHERE Grossman, n. gen.

Type species.—Neolophocythere subquadrata GROSSMAN, n. gen., n. sp.

Diagnosis.—Recognized by reticulate, elongate-quadrate carapace and by its entomodont hinge. *Recent.*

Description.—Carapace elongate-subquadrate ornamented by reticulations. Hinge entomodont, that of RV consisting of prominent anterior dental area with 4 or 5 well-developed denticles, postjacent bifurcate socket which merges with straight, elongate crenulate groove followed by posterior dental area which contains 4 or 5 prominent teeth. Hingement of LV antithesis of right. Duplicature of moderate size, vestibule present, marginal pore canals simple and straight. Muscle-scar pattern irregular vertical row of adductor scars, with small crescent-shaped antennal scar anterodorsal to adductors, and small reniform mandibular scar situated anteroventrally to closing muscle scars.

Remarks.—Similar to *Lophocythere* SYLVESTER-BRADLEY (1948) especially as to details of hinge, but differs from it by having a more quadrate shape and not possessing keels. The presence of such a hinge is rare among living ostracodes. *Xenocythere* SARS is the only other known Recent genus possessing such a hinge but differs from *Neolophocythere* in shell shape and in its less strongly developed hinge structure. *Neolophocythere* is monotypic and the characters given in its description are those assumed to be of generic importance.

Occurrence.—Found only in Core Sound, North Carolina, in shallow waters of near-normal to normal marine salinity.

NEOLOPHOCYTHERE SUBQUADRATA Grossman, n. sp.

Plate 12, figures 7-9; Plate 17, figures 1, 3-5, 7

Diagnosis.—Recognized by its reticulate elongate-subquadrate carapace which contains 2 premedian sulci and by its entomodont dentition. *Recent.*

Description.—Carapace elongate-subquadrate, dorsal and ventral margins subparallel, dorsum straight, ventral margin with pronounced sinuation anterior to middle, anterior margin broadly rounded, posterior margin bluntly pointed just below mid-height, shell highest near anterior end; from above somewhat ovate, both extremities obtusely pointed, posterior more so than anterior, valves equal in size. Surface ornamented with medium-sized reticulations which are polygonal on posterior part of valves, becoming irregular on anterior and elongate on ventral portion of carapace; pits between reticulations, shallow. Pronounced curved sulcus near anterior edge of shell and less prominent sulcus above closing muscle scars. Hinge entomodont, that of RV consisting of prominent anterior dental area with 4 or 5 well developed denticles, postjacent bifurcate socket which merges with straight elongate crenulate groove followed by posterior dental area which has 4 or 5 prominent denticles, posterior dental area slightly smaller than anterior one and also slightly curved. Duplicature of moderate size and separated from inner shell margin by vestibule; marginal pore canals few, simple, straight, most numerous on anterior; adductor muscle scars irregular vertical row of 4, with small crescent-shaped antennal scar situated anterodorsally to adductor scars, and small reniform mandibular scar situated anteroventrally to closing muscle scars. Species dimorphic, carapace of supposed females being almost identical to that of males but slightly shorter and higher.

Dimensions.—Length of adult specimen, 0.55 mm.; height, 0.25 mm.; length of adult tecnomorph, 0.54 mm.; height, 0.26 mm.; thickness, 0.27 mm.

Material.—13 valves, of which 12 are adult.

Occurrence.—Found only in Core Sound. Salinity, 30 to 35 ‰; depth, 5 to 10 feet; substrate, sand.

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948

Genus ACTINOCYTHEREIS Puri, 1953

ACTINOCYTHEREIS EXANTHEMATA EXANTHEMATA (Ulrich & Bassler), 1904

Plate 15, figure 4; Plate 21, figure 14

Cythere exanthemata ULRICH & BASSLER, 1904, p. 117, pl. 36, fig. 1-5.

Cythereis exanthemata (Ulrich & Bassler), VAN DEN BOLD, 1946, p. 88, fig. 2; SWAIN, 1948, p. 204, pl. 12, fig. 14-15.

Trachyleberis exanthemata (Ulrich & Bassler), SWAIN, 1951, p. 37, pl. 6, fig. 5; MALKIN, 1953, p. 791, pl. 81, fig. 16, 19-20.

Actinocythereis exanthemata (Ulrich & Bassler), PURI, 1953, *136*, p. 179-181, fig. 4-8, text-fig. 3f; PURI, 1953, *138*, p. 252-253, pl. 13, fig. 6-13; MCLEAN, 1957, p. 82-83, pl. 10, fig. 1a-c.

Diagnosis.—Recognized by large, oblong, subquadrate carapace obliquely rounded at both extremities and ornamented by 3 longitudinal rows of spines, and single vertical row of nodes that connects dorsal longitudinal row with central row of spines. Anterior end with well-defined marginal rim, posterior with double fringe of spines. *Miocene to Recent.*

Remarks.—*Actinocythereis exanthemata exanthemata* differs from *A. exanthemata marylandica* (HOWE & HOUGH) by being much lower and having finer ornamentation. It differs from *A. exanthemata gomillionensis* (HOWE & ELLIS) in being much larger and more coarsely ornamented.

Dimensions.—Length of adult specimen, 0.71 mm.; height, 0.32 mm.

Material.—One mature valve.

Occurrence.—Found in the Miocene sediments of the Atlantic coastal plain, particularly the Calvert and Choptank Formations of

Maryland, the Yorktown Formation of Virginia, and the *Arca* and *Ecphora* facies of the Choctawhatchee Formation and the Chipola facies of the Alum Bluff Formation of Florida. Present in the Recent in shallow waters of the Gulf of Mexico and rarely in the Texas bays. Found at one station in Cape Lookout Bight. Salinity, 35 ‰; depth, 30 feet; substrate, sand.

Genus PURIANA Coryell & Fields, 1937

PURIANA MESACOSTALIS (Edwards), 1944

Plate 15, figure 5; Plate 21, figure 5

Favella mesacostalis EDWARDS, 1944, p. 524, pl. 88, fig. 1-4, SWAIN, 1951, p. 41.

Diagnosis.—Recognized by prominent subcentral node, posterior median ridge, and by prominent keeled ventral ridge terminating in small node on posterior portion of carapace. Cross ridge along posteroventral portion weakly developed. *Miocene to Recent.*

Remarks.—This species differs from *Puriana rugipunctata* in having fewer ridges and cross ridges reduced to nodes on the posterior portion of the carapace. The part of the carapace in front of the subcentral node is smooth except for the prominent anterior rim and a horizontal ridge that bifurcates posteriorly around the median node. *P. mesacostalis* is distinguished from *P. puella* (CORYELL & FIELDS) by the presence of a median ridge.

Dimensions.—Length of immature specimen, 0.47 mm.; height, 0.25 mm.

Material.—Nine immature valves.

Occurrence.—Originally described by EDWARDS (1944) from the Miocene Duplin Marl of North Carolina. Reported by CURTIS (1960) from the inshore biofacies of the eastern Mississippi Delta region. Found in Cape Lookout Bight, Core Sound, and at one station on the Atlantic delta of Ocracoke Inlet. Salinity, greater than 30 ‰; depth, 10 to more than 30 feet; substrate, sand. Associated with *Puriana rugipunctata.*

PURIANA RUGIPUNCTATA (Ulrich & Bassler), 1904

Plate 14, figure 8; Plate 21, figures 11-13

Cythere rugipunctata ULRICH & BASSLER, 1904, p. 118, pl. 18, fig. 16-17.

Cythereis rugipunctata (Ulrich & Bassler), HOWE *et al.*, 1935, p. 23; CORYELL & FIELDS, 1937, p. 10.

Favella rugipunctata (Ulrich & Bassler), EDWARDS, 1944, p. 524; VAN DEN BOLD, 1946, p. 100, pl. 10, fig. 3; VAN DEN BOLD, 1950, p. 86; MALKIN, 1953, p. 797, pl. 82, fig. 24.

Trachyleberis? rugipunctata (Ulrich & Bassler), SWAIN, 1951, p. 38.

Puriana rugipunctata (Ulrich & Bassler), PURI, 1953, *135*, p. 751; PURI, 1953, *138*, p. 257-258, pl. 12, fig. 18-19, text-fig. 8k; MCLEAN, 1957, p. 89-90, pl. 11, fig. 5a-d; PURI & HULINGS, 1957, p. 174, 176, 183; PURI, 1960, p. 126, pl. 6, fig. 18; BENSON & COLEMAN, 1963, p. 43-44, pl. 18, fig. 1-2, 5, text-fig. 27.

Diagnosis.—Distinguished by rugose ornamentation, consisting of series of rounded ridges and nodes, ridges irregularly arranged anterior and ventral to prominent subcentral tubercle; series of 4 or 5 oblique ridges arising along posterodorsal margin, disappearing at mid-line into irregularly arranged system of ridges or into small tubercles; moderately strong tuberculated node present in posteroventral portion of carapace. *Miocene to Recent.*

Remarks.—The ornamentation of the valves is quite diagnostic for the species; although arrangement of the ridges is somewhat variable, no other species of *Puriana* has oblique ridges along the posterodorsal margin.

Dimensions.—Length of adult specimen, 0.62 mm.; height, 0.31 mm.; thickness, 0.28 mm.

Material.—Ten mature valves.

Occurrence.—Present in the Miocene sediments of the Atlantic and Gulf coastal plains. Found in the Recent in the Alligator Harbor and Panama City regions of Florida, and in Florida Bay by PURI & HULINGS (1957). Reported from the eastern Gulf of Mexico by BENSON & COLEMAN (1963) at depths ranging from 19 to 239 feet, although most abundant at depths less than 50 feet and in salinities between 35 and 40 ‰; present on both the Sound and Atlantic deltas of Ocracoke Inlet. Salinity, 25 to 35 ‰; depth, 10 to more than 30 feet; substrate, sand or silty sand. Associated with *Puriana mesacostalis.*

PURIANA sp.

Plate 15, figure 6; Plate 21, figures 9-10

Diagnosis.—Distinguished by elongate shape, knobby appearance, small caudal process, presence of weak subcentral node, weak anterior marginal rim, and by lack of prominent ridges. *Recent.*

Description.—Carapace elongate, subquadrate; dorsal margin straight, ventral margin sinuate anterior to middle, anterior margin broadly rounded, posterior truncate, with small caudal process developed by presence of 3 low, broad tubercles that extend from posteroventral corner to position above mid-height on posterior margin. Surface of valves knobby in appearance, subcentral tubercle low, difficult to discern; anteromarginal rim weakly developed; normal pore canals scattered over surface. Hinge of RV consisting of triangular anterior tooth, postjacent socket, weakly crenulated groove, and posterior ovate tooth; hinge of LV antithesis of RV. Marginal areas fairly broad, widest anteriorly, vestibules developed on anterior and posterior margins. Marginal pore canals fairly numerous, most common on anterior and posterior margins; muscle scar pattern not observed.

Remarks.—Distinguished from other species of *Puriana* by the lack of prominent ridges and development of a weak caudal process. Lack of sufficient specimens prevented the naming of this species.

Dimensions.—Length of adult specimen, 0.54 mm.; height, 0.28 mm.

Material.—Two adult valves.

Occurrence.—Found at one station in Cape Lookout Bight. Salinity, 30 ‰; depth, 30 feet; substrate, sand.

REFERENCES

(1) Anderson, H. V., 1951, *Two new genera of Foraminifera from Recent deposits in Louisiana:* Jour. Paleontology, v. 24, p. 31-34, fig. 1-2.

(2) ———, 1951, *An addenda [sic] to* Arenoparrella *and* Arenoparrella mexicana *(Kornfeld):* Cushman Found. Foram. Research Contrib., v. 2, p. 96-97, pl. 11.

(3) ———, 1953, *Two new species of* Haplophragmoides *from the Louisiana coast:* Same, v. 4, p. 21-22, pl. 4.

(4) Applin, E. R., Ellisor, A. E., & Kniker, H. T., 1925, *Subsurface stratigraphy of the coastal plain of Texas and Louisiana:* Am. Assoc. Petroleum Geologists, Bull., v. 9, p. 79-122, pl. 3.

(5) Arnal, R. E., 1958, *Rhizopoda from the Salton Sea, California:* Cushman Found. Foram. Research Contrib., v. 9, p. 36-42, pl. 9-12.

(6) Asano, Kiyoshi, 1944, Hanzawaia, *a new genus of Foraminifera from the Pliocene of Japan:* Geol. Soc. Japan, Jour., v. 51, no. 606, p. 97-98, pl. 4.

(7) Bandy, O. L., 1954, *Distribution of some shallow-water Foraminifera in the Gulf of Mexico:* U.S. Geol. Survey, Prof. Paper 254F, p. 125-142, fig. 5-13, pl. 27-31.

(8) ———, 1956, *Ecology of Foraminifera in northeastern Gulf of Mexico:* U.S. Geol. Survey, Prof. Paper 274G, p. 179-204, fig. 25-28, pl. 29-31.

(9) Bartenstein, Helmut, & Brand, Erich, 1938, *Die Foraminiferen-Fauna des Jade-Gebietes:* Senckenbergiana, v. 20, p. 381-385, fig. 1-3.

(10) Benda, W. K., & Puri, H. S., 1962, *The distribution of Foraminifera and Ostracoda off the Gulf Coast of Cape Romano area, Florida:* Gulf Coast Assoc. Geol. Socs., Trans., v. 12, p. 303-341, pl. 1-5.

(11) Benson, R. H., 1959, *Ecology of Recent ostracodes of the Todos Santos Bay region, Baja California, Mexico:* Univ. Kansas Paleont. Contrib., Arthropoda, art. 1, 80 p., 20 fig., 11 pl.

(12) ———, & Coleman, G. L., II, 1963, *Recent marine ostracodes from the eastern Gulf of Mexico:* Same, Arthropoda, art. 2, 52 p., 33 fig., 8 pl.

(13) ———, & Kaesler, R. L., 1963, *Recent marine and lagoonal ostracodes from the Estero de Tastiota region, Sonora, Mexico (northeastern Gulf of California):* Same, Arthropoda, art. 3, 34 p., 20 fig., 4 pl.

(14) Blake, C. H., 1933, *Order Ostracoda:* in William Procter, Biological Survey of the Mount Desert Region, pt. 5, Marine fauna, Wistar Inst. Anatomy and Biol. (Philadelphia), v. 5, pt. 3, p. 229-241, fig. 39-40.

(15) Bold, W. A., van den, 1946, *Contributions to the study of Ostracoda with special reference to the Tertiary and Cretaceous microfauna of the Caribbean region:* Amsterdam, J. H. de Bussey, 167 p., 18 pl.

(16) ———, 1950, *Miocene Ostracoda from Venezuela:* Jour. Paleontology, v. 24, p. 76-88.

(17) Bolli, H. M., & Saunders, J. B., 1954, *Discussion of some Thecamoebina described erroneously as Foraminifera:* Cushman Found. Foram. Research Contrib., v. 5, p. 45-52, fig. 1-2.

(18) Boltovskoy, Esteban, 1958, *The foraminiferal fauna of the Rio de la Plata and its relation to the Caribbean area:* Cushman Found. Foram. Research Contrib., v. 9, p. 17-21, fig. 1-2.

(19) Brady, G. S., 1867, *A synopsis of the Recent British Ostracoda:* Intellectual Observer (London), v. 12, p. 110-130.

(20) ———, 1868a, *A monograph of the Recent British Ostracoda:* Linnean Soc. London, Trans., v. 26, p. 353-495.

(21) ———, 1868b, *On the crustacean fauna of the saltmarshes of Northumberland and Durham:* Nat. History Northumberland and Durham, Trans., v. 3, p. 120-136, pl. 4-5.

(22) ———, 1869, *Les fonds de la mer:* Paris, Folin & Perier, v. 1, 316 p., 32 pl.

(23) ———, 1880, *Report on the Ostracoda dredged by* H. M. S. Challenger *during the years 1873-1876:* Report Sci. Results Voyage of *H. M. S. Challenger*, Zool., v. 1, pt. 3, 184 p., 44 pl.

(24) ———, & Robertson, David, 1870, *The Ostracoda and Foraminifera of tidal rivers:* Ann. Mag. Nat. History, ser. 4, v. 31, p. 1-33, pl. 4-10.

(25) Brady, H. S., 1864, *Contributions to the knowledge of the Foraminifera; on the rhizopodal fauna of the Shetlands:* Linnean Soc. London, Trans., v. 24, p. 463-476, pl. 48.

(26) ———, 1870, *Notes on the Foraminifera of mineral veins and the adjacent strata:* British Assoc. Adv. Sci. London, Rept. 1870, 39th meeting (1869), p. 381-382.

(27) ———, 1881, *On some Arctic Foraminifera from soundings obtained on the Austro-Hungarian North-Polar Expedition of 1872-1874:* Ann. Mag. Nat. History, ser. 5, v. 8, p. 393-418, pl. 21.

(28) ———, 1884, *Report on the Foraminifera dredged by* H. M. S. Challenger *during the years 1873-1876:* Report Sci. Results Voyage of *H. M. S. Challenger*, Zool., v. 9, p. 1-814, pl. 1-115.

(29) ———, 1887, *A synopsis of the British Recent Foraminifera:* Royal Micros. Soc., Jour., p. 872-927.

(30) Butcher, W. S., 1948, *A new species of* Nonion *(Foraminifera) from the Woods Hole region:* Cushman Lab. Foram. Research Contrib., v. 24, p. 21-23, fig. 1-3.

(31) Carpenter, W. B., Parker, W. K., & Jones, T. R., 1862, *Introduction to the study of Foraminifera:* Ray Soc. Publs. (London), 319 p., 22 pl.

(32) Chapman, Frederick, 1901, *Foraminifera from the lagoon at Funafuti:* Linnean Soc. London, Jour., Zool., v. 28, p. 161-210, pl. 19-20.

(33) Cole, W. S., 1931, *The Pliocene and Pleistocene Foraminifera of Florida:* Florida Geol. Survey, Bull. 6, 79 p., 7 pl.

(34) Cooke, C. W., 1945, *Geology of Florida:* Florida Geol. Survey, Bull. 29, 339 p.

(35) Coryell, H. N., & Fields, Suzanne, 1937, *A Gatun ostracode fauna from Cativa, Panama:* Am. Mus. Novitates, no. 956, 18 p., 2 pl.

(36) Curtis, D. M., 1960, *Relation of environmental energy levels and ostracode biofacies in east Mississippi delta area:* Am. Assoc. Petroleum Geologists, Bull., v. 44, p. 471-494, fig. 1-17, pl. 1-3.

(37) Cushman, J. A., 1906, *Marine Ostracoda of Vineyard Sound and adjacent waters:* Boston Soc. Nat. History, Proc., v. 32, p. 359-385, pl. 26-28.

(38) ———, 1918, *Some Pliocene and Miocene Foraminifera of the coastal plain of the United States:* U.S. Geol. Survey, Bull. 676, 100 p., 31 pl.

(39) ———, 1918, *The Foraminifera of the Atlantic Ocean; Part 1, Astrohizidae:* U.S. Natl. Mus., Bull. 104, pt. 1, 111 p., 39 pl.

(40) ———, 1920, *The Foraminifera of the Atlantic Ocean; Part 2, Lituolidae:* Same, Bull. 104, pt. 2, 111 p., 18 pl.

(41) ———, 1921, *Foraminifera of the Philippines and adjacent seas:* Same, Bull. 100, v. 4, 608 p., 52 fig., 100 pl.

(42) ———, 1922, *The Foraminifera of the Atlantic Ocean, Part 3, Textulariidae:* Same, Bull. 104, pt. 3, 143 p., 26 pl.

(43) ———, 1923, *The Foraminifera of the Atlantic Ocean; Part 4, Lagenidae:* Same, Bull. 104, pt. 4, 228 p., 42 pl.

(44) ———, 1924, *The Foraminifera of the Atlantic Ocean; Part 5, Chilostomellidae and Globigerinidae:* Same, Bull. 104, pt. 5, 55 p., 8 pl.

(45) ———, 1925, *Recent Foraminifera from British Columbia:* Cushman Lab. Foram. Research Contrib., v. 1, pt. 2, p. 38-47, pl. 6-7.

(46) ———, 1926, *Recent Foraminifera from Porto Rico:* Carnegie Inst. Washington, Publ. 344, p. 73-84, pl. 1.

(47) ———, 1927, *Some characteristic Mexican fossil Foraminifera:* Jour. Paleontology, v. 1, p. 147-172, pl. 23-28.

(48) ———, 1929, *The Foraminifera of the Atlantic Ocean; Part 6, Miliolidae, Ophthalmiidae, and Fischerinidae:* U.S. Natl. Mus., Bull. 104, pt. 6, 129 p., 22 pl.

(49) ———, 1930, *The Foraminifera of the Atlantic Ocean; Part 7, Nonionidae, Camerinidae, Peneroplidae, and Alveolinellidae:* Same, Bull. 104, pt. 7, 79 p., 18 pl.

(50) ———, 1931, *The Foraminifera of the Atlantic Ocean; Part 8, Rotaliidae, Amphisteginidae, Calcarinidae, Cymbaloporettidae, Globorotaliidae, Anomalinidae, Planorbulinidae, Rupertiidae, and Homotremidae:* Same, Bull. 104, pt. 8, 175 p., 26 pl.

(51) ———, 1933, *New Arctic Foraminifera collected by Capt. R. A. Bartlett from Fox Basin and off the northeast coast of Greenland:* Smithsonian Misc. Coll., v. 89, no. 9, 8 p., 2 pl.

(52) ———, 1933, *The Foraminifera of the tropical Pacific collections of the "Albatross," 1899-1900, pt. 2:* U.S. Natl. Mus., Bull. 161, 79 p., 19 pl.

(53) ———, 1939, *A monograph of the foraminiferal family Nonionidae:* U.S. Geol. Survey, Prof. Paper 191, 100 p., 20 pl.

(54) ———, 1944, *Foraminifera from the shallow water of the New England coast:* Cushman Lab. Foram. Research, Spec. Pub. 12, 37 p., 4 pl.

(55) ———, 1947, *New species and varieties of Foraminifera from off the southeastern coast of the United States:* Same, Contrib., v. 23, p. 86-92, pl. 18-20.

(56) ———, 1948, *Arctic Foraminifera:* Same, Spec. Pub. 23, 79 p., 8 pl.

(57) ———, & Brönniman, Paul, 1948, *Some new genera and species of Foraminifera from the brackish water of Trinidad:* Same, Contrib., v. 24, p. 15-21, pl. 3-4.

(58) ——— & ———, 1948, *Additional new species of arenaceous Foraminifera from shallow waters of Trinidad:* Same, Contrib., v. 24, p. 37-42, pl. 7-8.

(59) ———, & Cahill, E. D., 1933, *Miocene Foraminifera of the coastal plain of the eastern United States:* U.S. Geol. Survey, Prof. Paper 175A, 50 p., 13 pl.

(60) ———, & Cole, W. S., 1930, *Pleistocene Foraminifera from Maryland:* Cushman Lab. Foram. Research, Contrib., v. 6, pt. 4, p. 94-100, pl. 13.

(61) ———, & McCulloch, Irene, 1939, *A report on some arenaceous Foraminifera:* Univ. Southern California Publ., Allan Hancock Pacific Exped., v. 6, no. 1, 113 p., 12 pl.

(62) ——— & ———, 1948, *Three new names for Recent Pacific Foraminifera:* Cushman Lab. Foram. Research, Contrib., v. 24, p. 76.

(63) ———, & Ponton, G. M., 1932, *The Foraminifera of the upper, middle, and part of the lower Miocene of Florida:* Florida Geol. Survey, Bull. 9, 148 p., 17 pl.

(64) ———, & Todd, Ruth, 1947, *Foraminifera from the coast of Washington:* Cushman Lab. Foram. Research, Spec. Pub. 21, 23 p., 4 pl.

(65) Deflandre, Georges, 1952, *Groupe des Thecamoebiens:* in Jean Piveteau, Traité de Paléontologie, Paris, Masson et Cie, v. 1, p. 131-132, 1 fig.

(66) Earland, Arthur, 1933, *Foraminifera, Part III, South Georgia:* Discovery Reports, v. 7, p. 27-138, pl. 1-7.

(67) Edwards, R. A., 1944, *Ostracoda from the Duplin Marl (Upper Miocene) of North Carolina:* Jour. Paleontology, v. 18, p. 505-528, pl. 85-88.

(68) Ellis, Brooks, & Messina, A. R., 1940, *Catalogue of Foraminifera:* Am. Mus. Nat. History (supplements, post-1940).

(69) Elofson, Olof, 1941, *Zur Kenntnis der mariner Ostracoden Schwedens mit besonderer Berücksichtigung des Skageraks:* Zool. Bidr. f. Uppsala, v. 19, p. 215-534, fig. 1-52.

(70) Galloway, J. J., & Heminway, C. E., 1941, *The Tertiary Foraminifera of Puerto Rico, scientific survey of Puerto Rico and the Virgin Islands:* New York Acad. Sci., Trans., v. 3, pt. 4, p. 275-491, pl. 1-36.

(71) Goerlich, Franz, 1952, *Ueber die Genotypen und der Begriff der Gattungen* Cyprideis *und* Cytheridea *(Ostracoden):* Senckenbergiana, v. 33, p. 185-192, fig. 1-12.

(72) Grossman, Stuart, 1965, *Morphology and ecology of two podocopid ostracodes from Redfish Bay, Texas:* Micropaleontology, v. 11, p. 141-150, fig. 1-36, pl. 1-2.

(73) Hada, Yoshira, 1936, *Studies on the Foraminifera of brackish waters:* Zool. Mag. Tokyo, v. 48, p. 847-860.

(74) Hadley, W. A., Jr., 1936, *Recent Foraminifera from near Beaufort, North Carolina:* Elisha Mitchell Sci. Soc., Jour., v. 52, p. 35-37.

(75) Haynes, John, 1956, *Certain smaller British Paleocene Foraminifera, Part 1:* Cushman Found. Foram. Research Contrib., v. 7, p. 79-101, fig. 1-2, pl. 16-17.

(76) Hedgpeth, J. W., 1951, *Ecological and distribution relationships of marine and brackish-water invertebrates of the coasts of Louisiana and Texas:* Univ. California (unpublished doctoral dissertation).

(77) Heron-Allen, Edward, & Earland, Arthur, 1932, *Foraminifera, Part 1; The ice-free area of the Falkland Islands and adjacent seas:* Discovery Reports, v. 4, p. 291-460, pl. 6-17.

(78) Hirschmann, Nikolaj, 1909, *Beiträge zur Kenntnis der Ostrakodenfauna der finnischen Meerbusens:* Soc. pro Fauna-Flora Fennica Medd. (Helsingfors), v. 35, p. 282-289, fig. 1-12.

(79) Hjulstrom, Filip, 1939, *Transportation of detritus by moving water:* in P. D. Trask (ed.), Recent Marine Sediments, a symposium, Tulsa, Oklahoma, Am. Assoc. Petroleum Geologists, p. 5-31.

(80) Hoskin, C. M., 1959, *Studies of oxygen metabolism of streams of North Carolina:* Inst. Marine Sci., Pub., v. 6, p. 186-192.

(81) Howe, H. V., 1939, *Louisiana Cook Mountain Eocene Foraminifera:* Louisiana Dept. Conserv., Geol. Bull. 14, 119 p., 14 pl.

(82) ———, & Chambers, Jack, 1935, *Louisiana Jackson Eocene Ostracoda:* Same, Geol. Bull. 5, 65 p., 6 pl.

(83) ———, & Law, John, 1936, *Louisiana Vicksburg Oligocene Ostracoda:* Same, Geol. Bull. 7, 96 p., 6 pl.

(84) ———, *et al.*, 1935, *Ostracoda from the* Arca *zone of the Choctawhatchee Miocene of Florida:* Florida Geol. Survey, Bull. 2, 37 p., 4 pl.

(85) HULINGS, N. C., 1966, *Marine Ostracoda from western North Atlantic Ocean off the Virginia Coast:* Chesapeake Science, v. 7, no. 1, p. 40-56.

(85a) ———, & PURI, H. S., 1964, *The ecology of shallow-water ostracods of the west coast of Florida:* Pubbl. Stazione zool. Napoli, v. 33, p. 308-344, fig. 1-17.

(86) JONES, T. R., 1850, *Description of the Entomostraca of the Pleistocene beds of Nedberry, Copford, Clacton, and Grays:* Ann. Mag. Nat. History, ser. 2, v. 6, p. 1-25, pl. 3.

(87) ———, 1856, *A monograph of the Tertiary Entomostraca of England:* Palaeontograph. Soc. (London), 68 p., 6 pl.

(88) JURINE, LOUIS, 1820, *Histoire des monocles qui se trouvent aux environs de Génève:* Paris, J. J. Paschoud, 68 p., 22 pl.

(89) KESLING, R. V., 1951, *Morphology of ostracode molt stages:* Illinois Biol. Mon., v. 21, 317 p., 36 fig., 96 pl.

(90) KLIE, WALTER, 1938, *Ostracoda (Muschelkrebse):* in F. Dahl, Die Tierwelt Deutschlands und der angrensenden Meeresteile, v. 34, p. 1-230.

(91) KORNFELD, M. N., 1931, *Recent littoral Foraminifera from Texas and Louisiana:* Stanford Univ. Dept. Geol. Contrib., v. 1, p. 77-101, pl. 13-16.

(92) KORNICKER, L. S., 1958, *Ecology and taxonomy of Recent marine ostracodes in the Bimini area, Great Bahama Bank:* Inst. Marine Sci., v. 5, p. 194-300, fig. 1-89.

(93) KRUITT, CHARLES, 1955, *Sediments of the Rhone delta:* Verh. van het Koninkl. Nederlandsch Geol. Mijnbouwkundig, Genoot.-Geol. serie, 357 p., 7 pl.

(94) KUDO, R. R., 1954, *Protozoology:* Springfield, Thomas, 4th edit., 966 p.

(95) LAMARCK, J. B., 1804, *Sur les fossiles des environs de Paris:* Mus. Nat. d'Histoire Naturelle Paris, Annales, v. 5, p. 237-245, pl. 1-62.

(96) LANKFORD, R. R., 1959, *Distribution and ecology of Foraminifera from east Mississippi delta margin:* Am. Assoc. Petroleum Geologists, Bull., v. 43, p. 2068-2099, fig. 1-11.

(97) LINNÉ, CARL, 1758, *Systema naturae:* edit. 10, Holmiae (Stockholm), v. 1, 823 p.

(98) LOEBLICH, A. R., JR., & TAPPAN, HELEN, 1953, *Studies of Arctic Foraminifera:* Smithsonian Misc. Coll., v. 121, p. 1-150, pl. 1-24.

(99) ——— & ———, 1961, *Suprageneric classification of the Rhizopodea:* Jour. Paleontology, v. 35, p. 245-330.

(100) LOWMAN, S. W., 1949, *Sedimentary facies in Gulf Coast:* Am. Assoc. Petroleum Geologists, Bull., v. 33, p. 1939-1997, fig. 1-35.

(101) MALKIN, D. S., 1953, *Biostratigraphic study of the Miocene Ostracoda of New Jersey, Maryland, and Virginia:* Jour. Paleontology, v. 27, p. 761-799, fig. 1-15, pl. 77-82.

(102) MARSHALL, NELSON, 1951, *Hydrography of North Carolina marine waters:* in H. F. Taylor & Associates, Survey of marine fishes of North Carolina: Chapel Hill, Univ. North Carolina Press, 76 p.

(103) McDONALD, J. D., 1857, *Observations on the microscopic examination of Foraminifera obtained in deep-sea bottoms at the Feejee Islands:* Ann. Mag. Nat. History, ser. 2, v. 20, p. 193-195, pl. 5-6.

(104) McLEAN, J. D., JR., 1956, *The Foraminifera of the Yorktown Formation in the York-James peninsula of Virginia, with notes on associated mollusks:* Bull. Am. Paleontology, v. 36, no. 160, p. 261-394, fig. 1-7, pl. 35-53.

(105) ———, 1957, *The Ostracoda of the Yorktown Formation in the York-James peninsula of Virginia:* Same, v. 38, no. 167, p. 57-103, pl. 7-12.

(106) MILLER, D. N., JR., 1953, *Ecological study of the Foraminifera of Mason Inlet, North Carolina:* Cushman Found. Foram. Research Contrib., v. 4, p. 41-63, fig. 1-4, pl. 7-10.

(107) MINCHER, A. R., 1941, *The fauna of the Pascagoula Formation:* Jour. Paleontology, v. 15, p. 337-338, pl. 46-47.

(108) MONTAGU, GEORGE, 1803, *Testacea Britannica, or natural history of British shells—marine, land, and fresh water including the most minute:* Romsey (England), J. S. Hollis, 606 p., 16 pl.

(109) ———, 1808, *Testacea Britannica* (supplement): Exeter (England), S. Woolmer, 183 p., 30 pl.

(110) MORKHOVEN, F. P. C. M. VAN, 1962-63, *Post-Paleozoic Ostracoda; their morphology, taxonomy, and economic use:* Amsterdam, Elsevier, v. 1, 478 p., 763 fig.

(111) MÜLLER, G. W., 1894, *Die Ostracoden des Golfes von Neapel und der angrenzenden Meeres-abschnitte:* Fauna und Flora des Golfes von Neapel, Zool. Sta. Neapel, Mon., v. 21, 404 p., 40 pl.

(112) ———, 1912, *Ostracoda:* in F. E. Schulze, Das Tierreich, v. 31, p. 1-434, 92 fig.

(113) MÜLLER, Ö. F., 1776, *Zoologiae Danicae Prodromus seu animalium et Norwegia indigenarum characteres, nomina, et synonyma imprimis popularium:* Lipsiae et Havniae, 282 p.

(114) ———, 1785, *Entomostraca seu insecta testacea, quae in aquis daniae et norvegiae reperit, descripsit et inconubus illustravit:* Lipsiae et Havniae, 135 p.

(115) NATLAND, M. L., 1938, *New species of Foraminifera from off the west coast of North America and from the later Tertiary of the Los Angeles basin:* Scripps Inst. Oceanography, Bull., Tech. ser., v. 4, no. 5, p. 137-164, pl. 3-7.

(116) D'ORBIGNY, ALCIDE, 1826, *Tableau méthodique de la classe des Foraminifères:* Ann. Sci. Nat., v. 7, p. 254-314, pl. 10-17.

(117) ———, 1839, *Foraminifères:* in Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba, Paris, A. Bertrand, 222 p., 12 pl.

(118) PARKER, F. L., 1948, *Foraminifera of the continental shelf from the Gulf of Maine to Maryland:* Mus. Comp. Zoology, Harvard College, Bull., v. 100, p. 214-244, pl. 1-7.

(119) ———, 1952, *Foraminifera species off Portsmouth, New Hampshire:* Same, v. 106, p. 391-423, pl. 1-6.

(120) ———, 1952, *Foraminiferal distribution in the Long Island-Buzzards Bay area:* Same, v. 106, p. 427-473, fig. 1-6, pl. 1-5.

(121) ———, 1954, *Distribution of the Foraminifera in the northeastern Gulf of Mexico:* Same, v. 111, p. 453-549, fig. 1-9, pl. 1-13.

(122) ———, & ATHEARN, W. D., 1959, *Ecology of marsh Foraminifera in Poponesset Bay, Massachusetts:* Jour. Paleontology, v. 33, p. 333-343, fig. 1-5, pl. 50.

(123) ———, PHLEGER, F. B., JR., & PEIRSON, J. F., 1953, *Ecology of Foraminifera from San Antonio Bay and environs, southwest Texas:* Cushman Found. Foram. Research, Spec. Pub. 2, 75 p., 4 pl.

(124) PHLEGER, F. B., JR., 1951, *Ecology of Foraminifera, northwest Gulf of Mexico, Pt. 1:* Geol. Soc. America, Mem. 46, 88 p., 33 fig., 2 pl.

(125) ———, 1952, *Foraminifera ecology off Portsmouth, New Hampshire:* Mus. Comp. Zoology, Harvard College, Bull. v. 106, p. 315-390.

(126) ——— & LANKFORD, R. R., 1957, *Seasonal occurrences of living benthonic Foraminifera in some Texas bays:* Cushman Found. Foram. Research, Contrib., v. 8, p. 93-105, fig. 1-6.

(127) ——— & Parker, F. L., 1951, *Ecology of Foraminifera, northwest Gulf of Mexico, Pt. 2:* Geol. Soc. America, Mem. 46, 64 p., 20 pl.

(128) ——— & Walton, W. R., 1950, *Ecology of marsh and bay Foraminifera, Barnstable, Massachusetts:* Am. Jour. Sci., v. 248, p. 274-294, fig. 1-2, pl. 1-2.

(129) Pokorný, Vladimír, 1955, *Contribution to the morphology and taxonomy of the Hemicytherinae Puri:* Univ. Carolinae Acta Geol., no. 111, 35 p., 19 fig.

(130) ———, 1958, *Grundzüge der zoologischen Mikropalaeontologie:* Berlin, Veb deutscher Verlag Wiss., v. 1, 582 p., v. 2, 453 p.

(131) Post, R. J., 1951, *Foraminifera of the south Texas coast:* Inst. Marine Sci., Pub., v. 2, p. 165-176, pl. 1.

(132) Pratt, J. H., 1912, *The coastal plain of North Carolina:* North Carolina Geol. and Econ. Survey, Bull. 3, 552 p.

(133) Puri, H. S., 1952, *Ostracode genera* Cytheretta *and* Paracytheretta *in America:* Jour. Paleontology, v. 26, p. 199-212, fig. 1-14, pl. 39-40.

(134) ———, 1952, *Ostracode genus* Cytherideis *and its allies:* Same, v. 26, p. 902-914, pl. 130-131.

(135) ———, 1953, *Taxonomic comment on "Ostracoda from wells in North Carolina," Part 1: Cenozoic Ostracoda by F. M. Swain:* Same, v. 27, p. 750-752.

(136) ———, 1953, *The ostracode genus* Trachyleberis *and its ally* Actinocythereis: Am. Midland Naturalist, v. 49, p. 171-187, pl. 1-2.

(137) ———, 1953, *The ostracode genus* Hemicythere *and its allies:* Washington Acad. Sci., Jour., v. 43, p. 169-179, pl. 1-2.

(138) ———, 1953, *Contribution to the study of the Miocene of the Florida panhandle:* Florida Geol. Survey, Bull. 36, 354 p., 14 fig., 46 pl.

(139) ———, 1958, *Ostracode genus* Cushmanidea: Gulf Coast Assoc. Geol. Socs., Trans., v. 8, p. 171-180.

(140) ———, 1958, *Ostracode subfamily Cytherettinae:* Same, v. 8, p. 183-194.

(141) ———, 1960, *Recent Ostracoda from the west coast of Florida:* Same, v. 10, p. 107-149, fig. 1-46, pl. 1-6.

(142) ——— & Hulings, N. C., 1957, *Recent ostracode facies from Panama City to Florida Bay area:* Same, v. 7, p. 167-190, fig. 1-11.

(143) Remane, A., 1940, *Einführung in die zoologisches Ökologie der Nord- und Ostsee:* Tierwelt der Nord- und Ostsee, Lief. 34.

(144) Roelofs, E. W., & Bumpus, D. F., 1953, *The hydrography of Pamlico Sound:* Bull. Marine Sci., Gulf and Caribbean, v. 3, p. 181-205.

(145) Ronai, P. H., 1955, *Brackish-water Foraminifera from the New York Bight:* Cushman Found. Foram. Research, Contrib., v. 6, p. 140-149, pl. 20-21.

(146) Said, Rushdi, 1951, *Foraminifera of Narragansett Bay:* Cushman Found. Foram. Research, Contrib., v. 1, p. 9-30, fig. 1-4.

(146a) Sandberg, P. A., 1964, *The Ostracode genus* Cyprideis *in the Americas:* Stockholm Contrib. Geology, v. 12, p. 1-178.

(147) ———, 1964, *Larva-adult relationships in some species of the ostracode genus* Haplocytheridea: Micropaleontology, v. 10, p. 357-368, pl. 1-2.

(148) Sars, G. O., 1866, *Översigt af Norges marine Ostracoden:* Vidensk. Selsk. Christiana Förh., v. 7, p. 130.

(149) ———, 1922-28, *An account of the Crustacea of Norway, v. 9, Ostracoda:* Bergen, Bergen Mus., 277 p., 113 pl.

(150) Saunders, J. B., 1957, *Trochamminidae and certain Lituolidae (Foraminifera) from the Recent brackish-water sediments of Trinidad, British West Indies:* Smithsonian Misc. Coll., v. 134, no. 5, 16 p., 4 pl.

(151) Shepherd, F. P., Phleger, F. B., Jr., & Van Andel, T. H., 1960, *Recent sediments, northwest Gulf of Mexico, a symposium:* Tulsa, Oklahoma, Am. Assoc. Petroleum Geologists, 394 p.

(152) Shupack, Benjamin, 1934, *Some Foraminifera from western Long Island and New York Harbor:* Am. Mus. Novitates, no. 737, 12 p., 2 fig., 1 pl.

(153) Stephenson, M. B., 1936, *Shell structure of the ostracode genus* Cytheridea: Jour. Paleontology, v. 10, p. 695-703, pl. 94.

(154) ———, 1938, *Miocene and Pliocene Ostracoda of the genus* Cytheridea *from Florida:* Same, v. 12, p. 127-148, fig. 1-20, pl. 23-24.

(155) Swain, F. M., 1948, *Ostracoda, Hammond well in Cretaceous and Tertiary subsurface geology:* Maryland Dept. Geol. Mines and Water Res., Bull. 2, p. 187-212, pl. 12-14.

(156) ———, 1951, *Ostracoda from wells in North Carolina, Part 1, Cenozoic Ostracoda:* U.S. Geol. Survey, Prof. Paper 234A, 58 p., 3 fig., 7 pl.

(157) ———, 1955, *Ostracoda of San Antonio Bay, Texas:* Jour. Paleontology, v. 29, p. 561-646, fig. 1-39, pl. 59-64.

(158) Sylvester-Bradley, P. C., 1948, *Bathonian ostracodes from the Boueti bed of Langton-Herring, Dorset:* Geol. Mag., v. 85, p. 185-204, fig. 1-7, pl. 13-15.

(159) Terquem, M. O., 1878, *Les foraminifères et les Entomostracés-Ostracodes du Pliocène supérieur de l'Isle de Rhodes:* Soc. géol. France, Mém., ser. 3, v. 1, p. 81-135, pl. 1-19.

(160) Todd, Ruth, & Brönnimann, Paul, 1957, *Recent Foraminifera and Thecamoebina from the eastern Gulf of Paria:* Cushman Found. Foram. Research, Spec. Pub. 3, 43 p., 12 pl.

(161) Trask, P. D., 1932, *Origin and environment of source sediments of petroleum:* Houston, Gulf Publishing Co., p. 71-72.

(162) Tressler, W. E., 1940, *Ostracoda from Beaufort, North Carolina, sand beaches:* Am. Midland Naturalist, v. 24, p. 365-368.

(163) ——— & Smith, E. M., 1948, *An ecological study of the seasonal distribution of Ostracoda, Solomons Island, Maryland, region:* Chesapeake Biol. Lab., Pub. 71, p. 3-57, 18 fig., 4 pl.

(164) Ulrich, E. O., & Bassler, R. S., 1904, *Systematic paleontology of the Miocene of Maryland; Ostracoda:* Maryland Geol. Survey, Miocene Report, p. 95-192, pl. 35-38.

(165) Valikängas, I., 1933, *Ueber die Biologie der Ostsee als Brackwassergebiet:* Internat. theor. u. angew. Limnologie Verh., v. 6, p. 62-112.

(166) Wagner, C. W., 1957, *Sur les ostracodes de Quaternaire Récent des Pays-Bas et leur utilisation dans l'étude géologique des dépôts Holocènes:* The Hague, Mouton & Co., 259 p., 25 fig., 50 pl.

(167) Walker, George, & Jacob, Edward, 1798, in Frederick Kanmacker, Adam's essays on the microscope: London, Dillon and Keating, 2nd edit., 712 p., 32 pl.

(168) Walton, W. R., 1955, *Ecology of living benthonic Foraminifera, Todos Santos Bay, Baja California:* Jour. Paleontology, v. 29, p. 952-1018, fig. 1-24, pl. 99-104.

(169) ———, 1960, *Diagnostic faunal characteristics on and near a barrier island, Horn Island, Mississippi:* Gulf Coast Assoc. Geol. Socs., Trans., v. 10, p. 7-27, fig. 1-5.

(170) ———, 1964, *Recent foraminiferal ecology and paleontology:* in John Imbrie & Norman Newell, Approaches to paleoecology, New York, John Wiley & Sons, p. 151-237.

(171) WARREN, A. D., 1957, *Foraminifera of the Buras-Scofield Bayou region, southeast Louisiana:* Cushman Found. Foram. Research, Contrib., v. 8, p. 29-40, pl. 3-4.

(172) WEISS, LAWRENCE, 1954, *Foraminifera and origin of the Gardner's Clay (Pleistocene), eastern Long Island, New York:* U.S. Geol. Survey, Prof. Paper 254G, p. 145-163, pl. 32-33.

Dr. STUART GROSSMAN, Esso Production Research Company, Houston, Texas.
Received July 30, 1965.

(173) WILLIAMSON, W. C., 1858, *On the Recent Foraminifera of Great Britain:* Ray Soc. (London), 107 p., 7 pl.

(174) WINSLOW, FRANK, 1886, *Report on the waters of North Carolina with reference to their possibilities for oyster culture:* Raleigh, North Carolina State Printer and Binder, 151 p.

(175) ZENKER, W., 1850, *Monographie der Ostracoden:* Berlin, Wiegmanns Archiv., Naturgeschichte, v. 20, p. 1-87.

PART 2

HISTORY AND MICROFAUNA OF SOUTHERN "OUTER BANKS" AND OFFSHORE REGION

RICHARD H. BENSON
[Smithsonian Institution and Department of Geology, University of Kansas]

CONTENTS

	PAGE
INTRODUCTION	82
DYNAMICS OF PAMLICO SOUND	83
RESULTS OF DEEPER DRILLING	85
COLLECTIONS FROM OFFSHORE	87
REFERENCES	90

FIGURE	PAGE
1. Locations of core samples taken for study of Recent biofacies and sediment changes	86
2. Atlantic shelf off Cape Lookout showing stations where samples were collected by Dr. D. H. Day	89

TABLE	
1. Distribution of ostracode species	89

INTRODUCTION

Originally the study of the ostracode and foraminiferal fauna of Pamlico Sound was to include (1) a survey of the living and subfossil population as presented herein by STUART GROSSMAN, (2) the analysis and mapping of surface sediments in the water and on the barrier islands by DAVID B. DUANE, (3) a general physiographic study of the barrier islands by DAVID ROCHNA, (4) an analysis of their subsurface sediment distribution and stratigraphy by JACK W. PIERCE, and (5) analysis of the subsurface microfaunas by me as principal investigator and director of the project. The purpose of this study was to establish the indicators, sediment and microfossil, of the present environmental facies and then to interpret the history of that section of the Outer Banks from Ocracoke Island through Portsmouth Island and Core Banks to Shackleford Banks as far back in time as driven cores could penetrate into the subsurface. These goals could not all be met, as the geologic record of changes is only partially preserved and many technical difficulties in drilling could not be overcome with the equipment available.

The field work of GROSSMAN, which accompanied that of DUANE (1962) and ROCHNA (1961) preceded that of PIERCE (1964) by two years. These theses projects were sponsored by grants by the National Science Foundation. Others involved were ROGER L. KAESLER and ANTHONY S. NAGLE, who assisted in the later field work. Although the results of the project as a whole have been presented at professional meetings (BENSON, GROSSMAN, DUANE & PIERCE, 1961, and PIERCE, 1966), they have not yet been published. Rather than have a separate report by me covering data and conclusions gained subsequent to his study, Dr. GROSSMAN has consented to allow the inclusion of this discussion with the presentation of his data and ideas (ref. 5).

As can be seen in the ecological study of living and subfossil assemblages by GROSSMAN, physical factors of the marginal areas of a coastal lagoon are the most effective forces determining the distribution of its more abundant and geographically diverstified microfaunal assemblages. The decreased salinity of the lagoon or sound molds the general character of the fauna; that is, its aspect as compared with other lagoons or sounds. The areas along the edge of the sounds that are covered by grasses in marshes or flats and instable bottom conditions formed by tidal flow exert more extreme pressures for establishing populations of the sensitive species, which ultimately may have the greatest value as historical indicators. The consequent distributions of these species provide a record of locally shifting environments as sedimentation progresses. The geographic limits of these biofacies along the inner margin of the Outer Banks are now moving progressively inland with the retreat of the barrier island over the eastern boundary of the sounds.

The principal reason that Pamlico Sound, Core Sound, and southern sections of the Outer Banks were selected over other regions with coastal environments as a site for this study, was the high rate of geologic change that seemed to be indicated by periodic hurricane damage, as well as generally high surf activity. This region differs considerably from the Texas Gulf Coast in that the barrier islands are gradually retreating inland as the sediments migrate alongshore rather than accreting and building seaward. The magnitude of mechanical energy at work in shifting the position of the barriers laterally seems to be much higher in North Carolina than in most other regions thus far studied in North America. It was thought that with such forces presently at work the historical record of changes in offshore bars and barriers would be clearly marked. Much of the concept developed by D. W. Johnson (1919) for the geomorphic cycle of offshore bars originally came from observations made in this area. The faunistic considerations cited by Grossman added to the potential of this particular area as a promising site of paleoecological and sedimentological research. One important factor, that of adequate conditions of preservation, was not given sufficient consideration in the planning of this project and the consequences are discussed herein.

DYNAMICS OF PAMLICO SOUND

Pamlico Sound is located at the confluence of estuarine parts of two important drainage systems in the eastern coastal plain of North Carolina. The complex of Pamlico Sound and its adjacent sounds[1] and estuaries forms a configuration similar to that of a three-fingered hand with the distal parts, that is the thumb and little finger, forming the smaller lagoons or sounds adjacent to the open sea, and the remaining two fingers protruding inland as estuaries. The proximal part of the hand extending from the outside of the little finger to that of the thumb are bounded by the barrier chain, the Outer Banks, which separates the whole complex from the Atlantic. Within these areas are wide expanses of open shallow water affected by minor lunar tides, significant wind tides, and choppy seas.

The Outer Banks constitute a migrating natural dyke system that protects the Sounds from the waves of open sea and is nourished by these waves and longshore drift. The flow of sand alternates seasonally, but the dominant direction is southward. That this system of dykes should isolate a basin of considerable size is the product of 1) the gradual slope of the slowly submerging coastal plain and 2) a continued supply of sand-size sediment moved by long-shore drift from the north and offshore.

The vulnerability of the whole region to high winds is expressed in the control and exaggeration of tides within the distal regions of Pamlico Sound and adjoining sounds. The wind tides can cause multiple breaching of the barriers during hurricane force winds from the west. The normal ebb and flow of the relatively minor tidal fluctuations in the Sounds seems to do little more geologic work than to maintain the opening of the major inlets and spread out the finer sediments in thin aprons of sheet-washed deposits. On the seaward side of the barrier longshore drift tends to straighten the shoreline and extend the spits southward to either seal off the inlets or add to the capes. It is during major storms that the greatest, although frequently temporary changes occur.

When standing on the barrier islands and looking down their axes the effect of wind as an active subaerial force is everywhere apparent. Coarse sands are being carried across open areas close to the ground, and the removal of the finer fraction of sediment from the beach generates a constant cloud of dust in the air. Dunes form and migrate obliquely, but most of them are short-lived. Stabilization of the backshore occurs only when the dunes become arrested by grasses along the inward side of the barrier. Shell pavements collect as a residual protective armor to the underlying sands in the more exposed areas and form an open extended backshore. The process of removal or scalping of the barrier continues as a major destructive process until the water table is reached. This retards deflation by keeping the sand moist. High wind-tides in the sounds find these newly developed low areas suited to the formation of new minor inlets during storms.

Few surface features of the barrier islands are recorded in the stratigraphic sequence of sediments and fossils that remains once this sequence has moved inland or after removal of it by inlet formation. Although they are significant in determining the progress of movement of the barrier, the advancing mill of wave action, migrating inlets, and deflation by wind tend to destroy most of the dune and foreshore and backshore structures. The only deposits left behind are those formed in deep depressions scoured by shifting inlet currents and the sublittoral

[1] The sounds are technically speaking back-bar lagoons and Core Sound, which lies to the southwest of Pamlico Sound, is quite typical as a lagoon. Pamlico Sound is less typical in that it has large estuarine extensions. In this discussion both lagoon and sound are used interchangeably to comply with both local and technical usage.

marine deposits or lag deposits of coarse shells. The lagoonal and marsh deposits buried by the barrier remain long enough to crop out on its foreshore as mattresses of peat resting on fine sands but they are erased by advancing wave erosion.

Aprons of outwash from the minor inlets or little sand valleys a few feet in relief emanate from the backshore of the barrier and project into the sounds. These intertongue with broad sheet-washed flats of medium and fine sand overlying thin strata of organic muds to form a foreland-like deposit along the seaward side of the sounds. Submerged marine grasses in the shallows of this feature blend with emergent coarser grasses *(Zoostera)* near the edges of the sound to entrap sediments and aid in the gradual accretion and filling in of the sounds. In the larger Pamlico Sound area this process is much longer in duration but fundamentally the same, though largely restricted to its edges.

The inlets that replenish the sounds with saline waters as well as migrant faunas serve as inflow and exit valves between bodies of water with independently changing volumes and differing surficial responses to the wind. The size and position of the inlets are determined by the volume of water attempting to pass through peak demand conditions. Exposure of low segments of the barrier to the areas of potential maximum transference of volume from Pamlico Sound outward toward the sea during heavy winds and storms causes the barrier to be breached from the inside to relieve the mounting flood in the sound. Seldom, if ever, is an inlet formed from the seaward side, where the effort of the barrier to heal its wounds by longshore transport is the dominant force. Invaribly the inlets migrate southwestward, filling in on the northeast side with spits and eroding on their southwest sides. This is the consequence of prevailing northeasterlies, which are the dominant winds generating constructional waves in the Atlantic. The inlets move slowly, scouring deep channels into the barrier deposits, removing much of the stratified record of the landward retreating barrier, and replacing it with a monolithic cross-bedded deposit of the advancing spit. When the inlet has moved to the point where it no longer serves effectively to empty and fill the sound, it tends to backfill landward with delta deposits and become sealed off by a spit. As the shape of the larger system of sounds or lagoons, or both of them, begins to change, a particular inlet may disappear altogether. The lack of an adequate escape valve for the building volume of water pushed before an increasing force of the wind may suddenly open up a new inlet to bring the system back into equilibrium.

Such is the observable changing aspect of the seaward perimeter of Pamlico Sound and its barriers. To this must be added the longer-term effect of gradual eustatic change in sea level. Marsh zones, superimposed in the same vertical section, suggest the importance of this change. With possible curtailment of sediment supply in the north, tending to starve the barriers, comes further modification of the general sediment budget that may alter the position and shape of the dyke system. That these longer-term changes have occurred and are continuing is evident in the remains of old beaches, abandoned relic dunes, and lagoonal marsh deposits protruding from beneath the foreshore of present beaches. Progressively fewer deposits indicate change as one goes to the southwest, suggesting a more youthful development of the barriers in this region. The barriers south of Cape Hatteras and along Core Banks are much narrower now than they are remembered by older residents of the area to have been. Overgrazing, dredging, and vehicular beach traffic all tend to alter and perhaps accelerate the events that originally operated to form the deposits that were studied.

The sediments of Pamlico Sound and adjacent sounds and Outer Banks are believed to be derived principally from the headland regions of the Virginia coast around the False Cape region, where one can find tree stumps isolated by erosion on the seaward side of the shore, and to a lesser degree from the scouring by waves of the offshore region. The winds pluck the sands from the foreshore and carry them temporarily to the backshore before eventually depositing them in the sounds. Coarser sands are transported as dunes. The yet coarser shingle deposits, formed primarily from broken or whole shells, become concentrated as pavements until they are reduced in size by the repeated grinding by breaking waves, or they are buried as lag deposits.

There is little evidence of coarse material derived from inland by way of the estuaries, although some clays are coming in by this route. Erosion along the banks of the estuaries supplies not only clay but some microfossil specimens of Pleistocene or older age. Undoubtedly some of these specimens have been recorded as subfossils in the present study, but as the pH of the estuaries is generally low, the longevity of these specimens must be short. The uppermost reaches of the estuaries and their valleys continue gradually into the Neuse and Pamlico Rivers, where there is little change except for dropping off of the influence of tides and narrowing of the water. No deltas are forming. The few small islands that may be present seem well anchored by mature vegetation. One can then generalize that the overall rate of sedimentation in the central and inner areas of the Pamlico Sound is very low, but that by contrast the lagoons such as Core Sound and that part of Pamlico Sound which is marginal to the barrier are filling in at a considerably more rapid rate.

From at least one relatively unpleasant experience in transporting heavy equipment over shallow flats behind the barrier, we began to appreciate the role of marine grasses in arresting the movement of sediments. Apparently the grasses grow quickly in a temporarily stable area, maturing within a single season. With change of season, wind direction and velocity, the shallow sounds, such as Core Sound, experience considerable sheet-flow along the axis of the sound with up to an estimated 30 percent volume transfer of the water mass in a few hours. Sediments, especially fine muds and silts, are swept across shallow flat areas of the lagoons until they become dammed by the grassy areas. A broad, thin deposit of mud and sand is formed with relatively little bearing strength. These deposits may then be covered with new grass, or in the case of some, a thin veneer of sand washed in from the barrier. It is also possible that this veneer of coarser material may result from the winnowing action of subsequent tidal flow. The flats, incidentally, are productive clam grounds.

Such is the picture of present dynamics in the Pamlico Sound area. From examination of aerial photographs and old charts, the filling in of the shallow sounds and the general southward migration of spits, capes, barriers, and lagoons becomes apparent. According to the research of PIERCE (1964), Harkers Island and probably Cedar Island are fragments of abandoned barriers that have been replaced at present by Shackleford Banks as a rampart farther south. Point Lookout seems to have moved all the way from the region of Drum Inlet on the northern end of Core Banks, when the deposits that underlie Cedar Island were the south-facing transverse barrier that is now Shackleford Banks. Whereas the short-term view of the southern Outer Banks is one of a slow retreat westward, the longer-term view is one of extensive building and accretion southward toward Beaufort and Morehead City. Examination of cores along Core Banks bears out this hypothesis. The existence of several superimposed marsh banks in outcrops on the north side of Drum Inlet, which become fewer in number to the southwest and finally disappear, strongly suggests the increasing youthfulness of the deposits from Drum Inlet to Cape Lookout.

RESULTS OF DEEPER DRILLING

During the summer of 1962 J. W. PIERCE and I collected more than 300 feet of core from 38 holes drilled in Core Banks, Core Sound, and Cedar Island (Fig. 1). The cores ranged from a few feet to 20 feet in length, depending on success achieved in cutting through the sand with the coring tool. The cores were taken at locations of environmental change suspected from previous observations and indicated by a series of aerial photographs taken in 1945 to 1962. The purpose of the samples was to obtain sedimentological and microfossil evidence for these changes and to trace the shifting environmental facies.

Of the 38 cores recovered, four were taken from Cedar Island, three from the mainland near Atlantic or Sealevel, five from Core Sound between Atlantic and Core Banks, 13 across Core Banks in three transects, five at Cape Lookout, six around Drum Inlet, and two at Whalebone Inlet on Portsmouth Island (Fig. 1). The cores were taken in typical foreshore, berm crest, backshore, marsh, and sound localities, in transects where former inlets were indicated, or where outcrops of marsh peat were seen. After determining that the drilling apparatus had limited capability to penetrate sandy and shelly strata, the original proposal of establishing comprehensive profiles across the barrier was abandoned in favor of spot-checking changes suggested by surface features.

Two-inch cores were obtained in three-foot sections by driving in the coring tool with a 75- or 150-pound hammer. Sixty cc. samples were taken at one-foot intervals or wherever changes in lithology occurred. Because of the general inaccessibility of most of the localities where information was sought only portable gear could be used. Trying to circulate water was impractical at the time. The drilling technique used will not be discussed here but it may be stated that sand flowed into the casing between runs with the coring tool. Attempts to clear were unsuccessful. Packing between the corer and casing limited the penetration of the corer to about 10 feet under the best conditions and to 6 feet for most attempts.

The quantity of biostratigraphic evidence coming from this effort was very disappointing. Most of the cores were laboriously examined for microfossils and found to be comparatively barren. On the other hand mollusk-shell fragments were abundant in the barrier sediments. Foraminifers and ostracodes either were never present in abundance originally or subsequently they were leached away.

That the lagoonal (sound) deposits were initially so barren is difficult to believe, considering the fauna living in the waters of Core Sound today. Fluctuations in water levels observed in the drill holes suggest free passage of ground water through much of the barrier. Many etched shell fragments are to be found in the cores. Yet it cannot now be established whether this solution took place before deposition or later. The presence of several calcareous species, including abundant specimens of *Elphidium*, in cores from Core Banks poses a problem. If solution is a significant reason for the low populations and few species present, one may ask why a calcareous species should be found more often than any other.

Every piece of organic remains found in the cores was examined. Specimens included ostracodes, foraminifers, fragments of shells, and at least seven types of identifiable whole pelecypods or gastropods of microscopic size. A few echinoid spines were found in predictably marine conditions. This sparse evidence was subsequently tabulated, recording species observed at each core position or locality. Several methods of combining the data were attempted in order to seek out natural assemblages. It was apparent

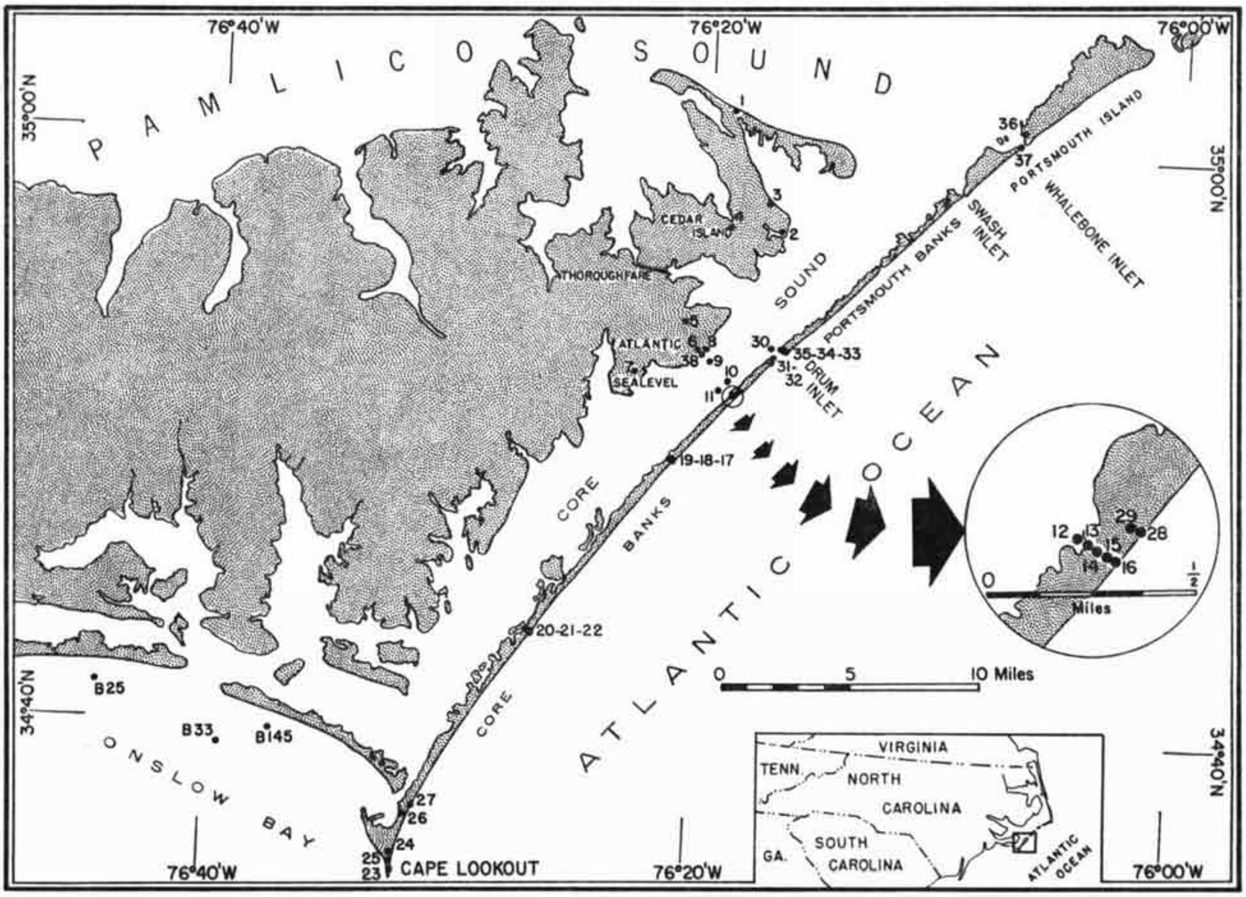


FIGURE 1. Southern end of Pamlico Sound complex, Core Sound and Core Banks in particular, showing locations of core samples taken for study of Recent biofacies and sediment changes.

from the outset that the distribution patterns are very incomplete. The original data are on file in the Smithsonian Institution and are not reproduced here. From simple inspection of the data and with heavy reliance on past experience with certain forms, such as those reported in GROSSMAN's biofacies or otherwise known to be typical marine or marsh species, the following general observations can be made from specimens found in the cores.

Elphidium was found in 45 samples, more commonly than any other form. It was even found in strata beneath the present foreshore on the seaward side of Core Banks. Although present in some shallow marine samples, it is typical of environments behind the barrier island. It was generally considered to be indicative of sound sediments during this study. *Elphidium* was frequently found with species of *Cushmanidea* in the open-sound facies, with the gastropod *Olivella* in sand- and mud-flat deposits, and with *Haplocytheridea setipunctata* or *H. bradyi* and *Ammonia limbatobeccarii* in salt-marsh deposits. *Elphidium* was also frequently found with the tiny mollusk *Gemma* but the environmental significance of this coupled occurrence is not known. One core, on the foreshore north of the Atlantic Coast Guard Station (no. 29), penetrated berm sediments containing the typically marine *Quinqueloculina* and then lagoonal or sound sediments beneath a peat layer at a depth of 7 feet. This layer contained *Ammonia* and *Elphidium*.

Haplophragmoides found with *Ammonia limbatobeccarii* was decisive evidence of a salt-marsh facies. Samples of peat taken from the foreshore of the beach southwest of Drum Inlet were examined, revealing nothing but *Haplophragmoides*. This was the most easily recognized and perhaps the most important zone of those studied.

The influence of the sea through inlets or along the foreshore of the barrier on the character of the fauna was apparent in the greater total number of species present, especially those of *Puriana, Quinqueloculina* and *Globigerina*. Heavy mollusk shells occur as residual pavements on the backshore. Drilling was stopped on several occasions because layers of large mollusk shells could not be penetrated. The layers of broken shells characteristically exposed on the seaward face of the berms did not extend into the barrier. These are typical foreshore deposits.

Only isolated parts of the history of Core Banks are reflected in the biologic remains found in the cores. The southeast end of Cedar Island has changed from open sound to marsh to land, while the large marsh at Thoroughfare, the canal between Cedar Island and the mainland, has been extant for the time recorded in a 12-foot core. Cores taken on the mainland near Atlantic and Sealevel (small towns, Fig. 1) were barren for the most part or indicated marsh where marshes still exist. Segments of the marsh now forming behind Core Banks across from Atlantic and around Drum Inlet and the underlying sound deposits could be traced into the subsurface under the barrier and followed to where they crop out on the seaward foreshore. The marsh and its fauna at Whalebone Inlet on Portsmouth Island could not be traced into the barrier, but it is obvious from surface evidence that this region has been scoured and refilled repeatedly by small inlets. On the north side of Drum Inlet at least three superimposed marsh zones were detected at the surface, but only one could be traced into the barrier. Currents at Drum Inlet scour to a depth of 22 feet in the present channel. This is far deeper than the coring tool penetrated on the adjacent barrier. It is deeper than most of Core Sound and the submerged foreshore slope in front of the barrier for several hundreds of yards offshore. Obviously a migrating inlet erases much of the stratigraphy formed by a stable barrier with its many transverse facies and replaces it with a lens of cross-bedded sand sterile of fossils. This strongly suggests that ancient deposits representing the remains of barrier islands are not necessarily convex upwards and flat on the bottom, as repeatedly stated in older elementary texts, but can look much like discontinuous channel deposits.

A core (no. 30) only 5 feet long on the deltaic sand flats behind Drum Inlet in Core Sound contained 17 species of microfossils. Most of the specimens were lagoonal, but most of the species were marine. The forms in the lower section of the core were more predominantly marine than those in the upper part, suggesting that this area is not as exposed to the sea now as a short time ago. Planktonic foraminifers were found in the lowest part of the core.

Fossil evidence from cores (nos. 17-19) obtained along Core Banks southwest of the principal sampling localities across from Atlantic was very meager and the results uncertain. The fragments of mollusks found suggest marine conditions. No marsh deposits were observed in the subsurface of the area of Cape Lookout. This latter area is one of active sand deposition and not favorable for preservation of microfossils.

In summary, the paucity of microfossil evidence in the many cores taken in the barrier island of Core Banks prohibited the tracing of biofacies to the extent that mapping or construction of profiles is impractical. This was disappointing in view of the great effort expended to drill into the barrier and adjoining environments. The biofacies established by Grossman were helpful, but the assemblages found in the core samples seem to be biased from their original composition by effects of preservation. The most worthwhile stratigraphic correlations seem to be within the marsh zones. The peat representing the seaward extension of these zones from their original formation behind the barrier was clearly visible cropping out in the surf zone; however, it seldom showed any trace in the cores other than the presence of abundant specimens of *Haplophragmoides*. Because marshes form at sea level, their recognition at other levels through the presence of *Haplophragmoides* proved very interesting, especially on the northwest side of Drum Inlet. It is hoped that use of this observation in subsequent studies may add to data on local eustatic changes in sea level, as well as provide a method for tracing the landward migration of the barrier over lagoonal and marsh deposits.

COLLECTIONS FROM OFFSHORE

During the time of the original study of the living and subfossil microfaunas of the area of Pamlico Sound it was not possible to obtain marine samples from offshore except at Ocracoke Inlet. Subsequently, Dr. John H. Day, with whom I have been associated on previous projects, was able to establish a seasonal sampling transect (Beaufort Shelf Transect) off Morehead City extending eastward past Cape Lookout to the 200-meter contour. Dr. Day collected substrate samples for Dr. J. E. Hazel, who is presently working on a comprehensive study of ostracodes of the Atlantic shelf. Dr. Hazel has kindly furnished some of this material for the present analysis.

Samples containing ostracodes were collected during June 1965 from seven localities off Cape Lookout (Fig. 2). These stations range in depth from 10 to 200 meters, with intermediate stations at 20, 40, 80, 130, and 160 meters. The transect line extended from Cape Lookout Lighthouse out to the edge of the continental shelf on a bearing of 120° magnetic. The temperature of the substrate unexpectedly climbed from 11°C. at the nearshore stations to 17°C. at 80 meters to 20°C. at 130 meters to 22°C. at 160° meters before falling off slightly (21°C.) at the edge of the shelf.

A Van Veen grab sampler was used to obtain the bottom samples, which were then sent unsieved to be washed, dried, and picked in the usual manner. The volume of samples was large but not uniform and no attempt is made here to express the relative abundance of species in the fauna. Except for the most landward two samples, which contained only a few specimens, all had more than 150 specimens each. The presence/absence relationships of individuals species in the outer five deeper

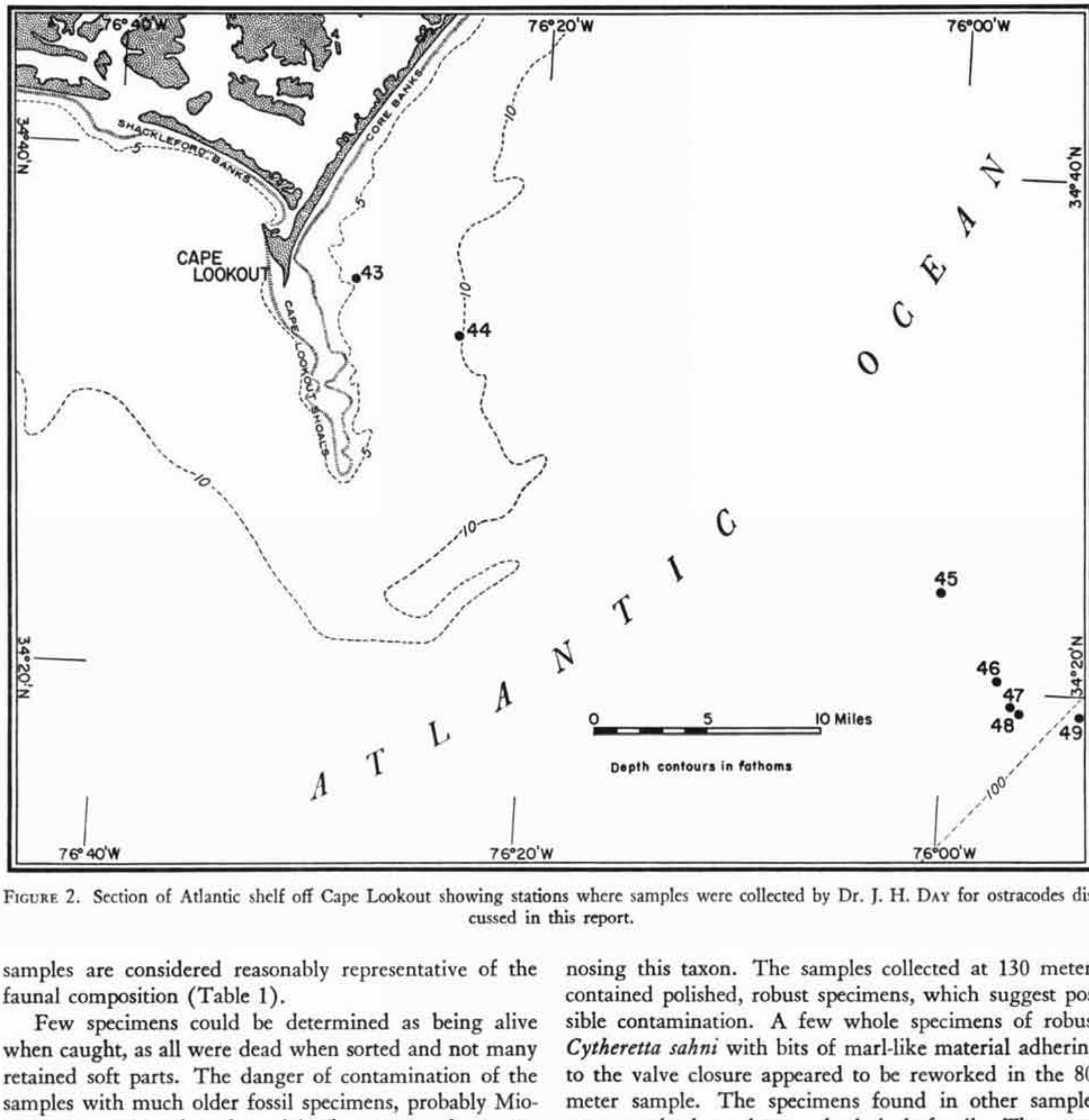


FIGURE 2. Section of Atlantic shelf off Cape Lookout showing stations where samples were collected by Dr. J. H. DAY for ostracodes discussed in this report.

samples are considered reasonably representative of the faunal composition (Table 1).

Few specimens could be determined as being alive when caught, as all were dead when sorted and not many retained soft parts. The danger of contamination of the samples with much older fossil specimens, probably Miocene, was suspected, and special effort was made to consider the condition of preservation of the specimens and to check them for presence of soft parts. Certain forms were examined with the object of trying to establish subtle changes in morphology that are thought to have been introduced between Miocene time and the present. Examples of this include change in size of the valves and coarseness of the reticulations between phyletic subspecies of *Aurila conradi*, and disappearance of a postventral depression thought earlier to be typical of *Protocytheretta karlana* of Miocene age but absent in the younger species *P. daniana*. A living form with the characteristic depression of *P. karlana* was found, suggesting problems of diagnosing this taxon. The samples collected at 130 meters contained polished, robust specimens, which suggest possible contamination. A few whole specimens of robust *Cytheretta sahni* with bits of marl-like material adhering to the valve closure appeared to be reworked in the 80-meter sample. The specimens found in other samples were mostly clear, glassy and relatively fragile. They were cleaned easily during washing. Contamination from fossil deposits does not seem to be important, but until live specimens of all species represented in the samples can be found in the area this factor cannot be wholly assessed.

In general, the fauna collected offshore appears to be an open-shelf assemblage typical of this region since late Miocene (Yorktown) time. There are fewer species living near shore in the water 20 meters or less deep, which is probably due to the comparative instability of the substrate. On the outer shelf typical deeper-water forms, such as *Pseudocythere*, *Echinocythereis*, and *Krithe*, begin to appear. *Pterygocythereis americana* is common offshore.

TABLE 1. *Distribution of Ostracode Species Identified from Stations Shown on Figure 2 Offshore on Atlantic Shelf on Bearing of 120° Magnetic from Cape Lookout.*

[Specimens designated with an asterisk (*) contained specimens with undamaged body soft parts, indicating that they are presently living offshore. Many of the other species may be living but no direct evidence of this was found.]

SPECIES	STATIONS						
	43	44	45	46	47	48	49
**Hulingsina ashermani* (ULRICH & BASSLER)	X	X	X	X	X	X	X
*"*Leguminocythereis*" *whitei* SWAIN	X	..	X	X	..	X	X
**Puriana rugipunctata* (ULRICH & BASSLER)	..	X	..	X	X	X	X
Cytherura johnsoni MINCHER	..	X	..	..	X	X	X
"*Acuticythereis*" *laevissima* EDWARDS	..	X	..	X	X	..	..
**Echinocythereis garretti* (HOWE & MCGUIRT)	..	..	X	X	X	X	..
**Cytheretta sahnii* PURI	..	..	X	X	X	X	..
Cushmanidea ulrichi (HOWE & JOHNSON)	..	..	X	X	X	X	..
Haplocytheridea setipunctata (BRADY)	..	..	X	X	..	..	..
**Aurila conradi floridana* BENSON & COLEMAN	..	..	X	X	X	..	..
Hemicytherura sablensis BENSON & COLEMAN	..	..	X	X	..	X	X
Actinocythereis gomillionensis PURI	..	..	X	X	X	..	X
Puriana mesacostalis (EDWARDS)	..	..	X	X	X	..	X
**Pellucistoma magniventra* EDWARDS	..	..	X	..	..	..	X
**Cytheromorpha warneri* HOWE & SPURGEON	..	..	X	..	..	..	..
Xiphichilus sp.	..	..	X	..	..	..	..
Neocytherideis sp.	..	..	X	..	..	..	..
Loxoconcha reticularis EDWARDS	..	..	X	..	..	X	..

SPECIES	STATIONS						
	43	44	45	46	47	48	49
Pterygocythereis americana (ULRICH & BASSLER)	..	..	X	..	X	X	X
**Protocytheretta daniana* (BRADY)	..	..	X	..	..	X	X
Paracytheridea vandenboldi PURI	..	..	X	..	X	X	X
**Murrayina martini* (ULRICH & BASSLER)	..	..	..	X	..	..	X
**Macrocypris* sp.	..	..	..	X	..	X	X
**Bairdia* sp.	..	..	..	X	X	X	X
Cytherelloidea sp.	..	..	..	X	..	..	..
Cushmanidea echolsae MALKIN	..	..	..	..	X	X	X
Eucythere gibba (EDWARDS)?	..	..	..	..	X	X	X
Pseudocythere caudata (SARS)?	..	..	..	..	X	..	..
Cytherella sp.	..	..	..	..	X	..	X
Pontocypris sp.	..	..	..	..	X	..	X
Cytheropteron sp.	..	..	..	..	..	..	X
Krithe sp.	..	..	..	..	..	..	X
Aurila amygdala (STEPHENSON)	..	..	..	..	..	..	X
Orionina bermudae (BRADY)	..	..	..	..	..	..	X
Mutilus confragosa (EDWARDS)	..	..	..	..	..	..	X
Actinocythereis vineyardensis (CUSHMAN)	..	..	..	..	..	..	X

The rise in temperature in this particular region seems to have brought in *Aurila amygdala*, *Orionina bermudae*, and *Hemicytherura* sp. aff. *H. sablensis*, which are typical of more southern areas. In my opinion, *Aurila conradi littorala* of GROSSMAN has not been shown to be sufficiently distinct from *A. conradi floridana* to warrant recognition of it as a separate subspecies. This form, whether two or one actual subspecies, is typical of the shallower areas of the shelf and some marginal lagoonal areas. *Leguminocythereis? whitei* SWAIN, *Hulingsina ashermani* (called *Pontocythere ashermani* by HULINGS, 1966), *Actinocythereis vinyardensis*, and *Murrayina martini* are known to me from as far north as the southern New England coast.

Undoubtedly the work of Dr. HAZEL (now in progress) will show just how much of a barrier the North Carolina capes are to segments of the shelf ostracode fauna. My experience, on only limited data, suggests that this is not the sharp boundary for ostracodes that it is reputed to be for some other taxa. Furthermore, the fauna seems to have been generally indigenous to this area, as well as the northern Gulf Coast, for some time (at least late Miocene to present). Although it shares common stock among some member species with the fauna from farther north in the Greenland, Iceland, and western European areas, the similarity inferred by past identification of common species is an artifact of the relative lack of taxonomic study of American forms. It is too early to say just how similar these faunas are, but they are not as close as suggested by the recurrence of European names of species in older American faunal lists. GROSSMAN has discussed other ramifications of this relationship, which do not need to be repeated here, except to reaffirm the conclusion that the fauna has more southern than northern affinities.

The influence of the marine shelf fauna on the living and fossil assemblages of the inlet deltas of Pamlico and Core Sounds is pronounced and serves to identify these facies in cores. I believe the evidence provided by the transect offshore indicates that the marine members of these fossil assemblages had been living nearby shortly before their entombment and were seldom if ever derived from Miocene subsea outcrops. To accept the idea of meaningful contamination by fossil material in these areas of active sediment transport one must assume that 1) the specimens could survive abrasion through a vigorously active wave zone and 2) sufficiently strong offshore currents are present to carry them required distances from the subsea outcrops to the inlets.

That Pleistocene eustatic changes caused shifting of the barriers back and forth across the whole area is indicated everywhere. Whether microfossils of Miocene age could survive repeated exposure to changing water chemistry and regeneration of sand deposits constituting the barrier islands in sufficient numbers to affect population counts of Recent forms seems unlikely. There seem to be fossil faunas possible in relic sediments offshore. Their age as Miocene or Pleistocene would be difficult to prove, however, on the basis of ostracodes alone.

The ability of many marine ostracodes to tolerate the reduction of salinity to 25 or 27 ‰ makes one wonder why more marine forms are not found around the inlets, until the high levels of mechanical energy present are considered. The lack of ostracode valves and foraminifer tests in the foreshore beach deposits indicates the local intolerance of living forms to substrate instability, as well as subsequent abrasion and possible solution. GROSSMAN concludes that no important correlation exists between faunal distribution and substrate. I suggest, however, that the low population levels and the absence of microinhabitants are direct results of high mechanical energy levels reflected in the deposition and frequent scouring of the predominantly sand facies.

Lastly, the origin of the sand composing the Outer Banks and subsequently filling much of the Pamlico Sound area is not yet resolved. Whether erosion of headlands to the north or offshore wave scour is the dominant contributor has been debated ever since GILBERT (1885) and JOHNSON (1919) discussed the problem. Perhaps it is to be regretted that the foreshore beach deposits are not rich in microfossils typical of sublittoral regions. Unfortunately, within the zone of active wave base of the Outer Banks the microfaunas are sparse. As one goes farther offshore this is not true, however. An ample supply of microtest or shell material is available from quite diverse populations. If onshore currents sufficiently strong to carry sand are present, why are not remains of deep-water forms found in beach deposits? Some of these forms are light and sufficiently delicate to remain suspended until they could pass through the abrasive sand mill of breakers. I believe that no significant onshore currents exist outside of the breaker zone. The dominant transporting currents are longshore or rips offshore, generated by transformation of wave energy that does not reach bottom offshore.

Dr. RICHARD H. BENSON, Department of Paleobiology, Smithsonian Institution.

Received September 30, 1966.

REFERENCES

(1) BENSON, R. H., GROSSMAN, STUART, DUANE, D. B., & PIERCE, J. W., 1961, *Marine geology and micropaleontology of Pamlico Sound, North Carolina:* Proc. First Natl. Coastal and Shallow Water Res. Conf., p. 508-510.

(2) DARBY, D. G., 1965, *Ecology and taxonomy of Ostracoda in the vicinity of Sapelo Island, Georgia:* Univ. Michigan, Four Repts. Ostracod Invest., p. 1-76.

(3) DUANE, D. B., 1962, *Petrology and Recent bottom sediments of the western Pamlico Sound region, North Carolina:* Univ. Kansas, Ph.D. thesis (unpublished).

(4) GILBERT, G. K., 1885, *The topographic features of lake shores:* U.S. Geol. Survey 5th Ann. Rept., p. 123.

(5) GROSSMAN, STUART, 1967, *Ecology of Rhizopodea and Ostracoda of the Southern Pamlico Sound Region, North Carolina:* Univ. Kansas Paleont. Contrib., Ecology, art. 1, pt. 1, p. 1-82.

(6) HALL, D. D., 1965, *Paleoecology and taxonomy of fossil Ostracoda in the vicinity of Sapelo Island, Georgia:* Univ. Michigan, Four Repts. Ostracod Invest., p. 1-79.

(7) HULINGS, N. C., 1966, *Marine Ostracoda from western North Atlantic Ocean off the Virginia Coast:* Chesapeake Science, v. 7, n. 1, p. 40-56.

(8) JOHNSON, D. W., 1919, *Shore processes and shoreline development:* 584 p., John Wiley & Sons (New York).

(9) MCLEAN, J. D., JR., 1966, *Miocene and Pleistocene Foraminifera and Ostracoda of southeastern Virginia:* Virginia Div. Min. Res., Rept. Invest. 9, 123 p.

(10) PIERCE, J. W., 1964, *Recent stratigraphy and geologic history history of the Core Banks region, North Carolina:* Univ. Kansas, Ph.D. thesis (unpublished).

(11) ———, 1966, *Sediment budget of a part of the North Carolina Coast:* Geol. Soc. America, Southeastern Sec., Program ann. meeting, p. 36 (abs.).

(12) ROCHNA, D. A., 1961, *Physiography and sedimentology of the "Outer Banks" between Cape Lookout and Ocracoke Inlet, North Carolina:* Univ. Kansas, Master's thesis (unpublished).