Recent Benthic Foraminifera of Breton and Stake Islands Northern Gulf of Mexico

Eric S. Collins
Old Dominion University

Follow this and additional works at: https://digitalcommons.odu.edu/oeas_etds

Part of the Geology Commons

Recommended Citation
Collins, Eric S.. "Recent Benthic Foraminifera of Breton and Stake Islands Northern Gulf of Mexico" (1988). Master of Science (MS), Thesis, Ocean & Earth Sciences, Old Dominion University, DOI: 10.25777/fct9-0h61
https://digitalcommons.odu.edu/oeas_etds/326

This Thesis is brought to you for free and open access by the Ocean & Earth Sciences at ODU Digital Commons. It has been accepted for inclusion in OES Theses and Dissertations by an authorized administrator of ODU Digital Commons. For more information, please contact digitalcommons@odu.edu.
RECENT BENTHIC FORAMINIFERA OF BRETON AND STAKE ISLANDS,
NORTHERN GULF OF MEXICO

By
Eric S. Collins
B.Sc. May 1985, Dalhousie University

A Thesis Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

GEOLOGY

OLD DOMINION UNIVERSITY
December 1988

Approved by

Stephen J. Culver (Director)

Randall S. Spencer

David B. Scott
ABSTRACT

RECENT BENTHIC FORAMINIFERA OF BRETON AND STAKE ISLANDS,
NORTHERN GULF OF MEXICO

Eric S. Collins
Old Dominion University, 1988
Director: Dr. Stephen J. Culver

Fifty-three species of recent benthic foraminifera and thecamoebians have been documented and described from the Breton and Stake Island area, northern Gulf of Mexico, and from a core from Barataria Basin, Mississippi delta.

Cluster analysis of benthic assemblages using presence/absence and transformed abundance data reveals the presence of a marsh and shallow water marine biofacies. Based on the results of a presence/absence cluster analysis, the shallow water marine biofacies can be subdivided into a miliolid biofacies and an Ammonia beccarii/Elphidium species biofacies. Cluster analysis of transformed abundance data, however, shows that the shallow marine biofacies can be subdivided into four biofacies: a miliolid biofacies, an Ammonia beccarii/Elphidium species biofacies, an Elphidium species/Ammonia beccarii biofacies and an Elphidium gunteri biofacies. The marsh biofacies is restricted to Breton Island, the Ammonia beccarii/Elphidium species biofacies is restricted to the forebar locality of Breton Island, the Elphidium gunteri biofacies is restricted to Stake Island, the Elphidium species/Ammonia beccarii biofacies occurs mainly in the back island
lagoon locality of Breton Island, and the miliolid biofacies is located on Breton and Stake Islands.

Canonical discriminant function analysis of physical and chemical variables at (a) the surface sediment-water interface and (b) the water mass approximately 2cm above the seabed shows that the four localities (Breton Island barrier island (1), forebar (2), back island lagoon (3) and Stake Island barrier island (4)) are significantly different from each other. Grain size variations are the primary discriminators at the surface sediment-water interface. An interaction of variables discriminates the water masses, although turbidity, Eh and concentration of dissolved oxygen appear to be the primary discriminators. Variations in the percentages of Ammonia beccarii and Elphidium species within the forebar and back island lagoon localities of Breton Island may be due to variations in concentration of dissolved oxygen in the water mass.

Assemblages within the Barataria Basin core indicate a decrease in salinity up the core. No simple correlation of core assemblages with the surface biofacies of Breton and Stake Islands was observed.
DEDICATION

To my parents,
Elsie and Earle Collins
and to my grandmother,
Hilda Drew
without whose encouragement and financial
support this thesis would not have been completed.
ACKNOWLEDGMENTS

I would like to thank Dr. Drew Haman of Chevron, Inc., for supplying the Breton and Stake Islands surface samples and associated environmental data. Dr. Elisabeth Kosters collected core BB92, described and interpreted the sedimentology and stratigraphy of the core as part of a series of research projects on the sediments of the Mississippi Delta Plain, funded by the Department of Natural Resources, Louisiana Geological Survey.

I would like to express my sincere thanks to my thesis director, Dr. Stephen J. Culver, for his guidance throughout the duration of this work. His ideas and suggestions, and critical review of the manuscript were greatly appreciated. I would also like to thank Dr. Randall S. Spencer and Dr. David B. Scott for their assistance in this work and reviews of the thesis. I would especially like to thank Dr. Spencer for his assistance with the discriminant analyses, as well as financial and personal support. Dr. Scott sampled the core, helped in identification of foraminifera and thecamoebians and provided financial assistance for some of the SEM photography.

I thank Dr. Martin A. Buzas, Department of Paleobiology, U. S. National Museum, who permitted to me the use of the Cushman Collection and Todd Library.
Discussions with Drs. Martin A. Buzas, Kathleen Farrell, Drew Haman, Carl F. Koch, Elisabeth Kosters, Franco S. Medioli, Ali A. Nowroozi, Lauck Ward and Ann A. L. Miller were a great help in various aspects of this thesis.

Sincere appreciation is extended to Chloe Younger of Dalhousie University for her permission to use laboratory facilities.

A special thanks is extended to Lisa Doan for some assistance in sample preparation, running most computer analyses, some typing and preparation of figures. Thanks also to Michael Bennett and Shelley Thibaudeau for assistance in sample preparation and to Ronnie Pinkoski for his help with running the discriminant analyses. I thank Bahn Deonarine, Bedford Institute of Oceanography, and James Slusser, Eastern Virginia Medical School for taking SEM photographs. Susan C. Hoebeke and Deborah Miller-Carson drafted most figures, some at short notice, and their suggestions and talents are sincerely appreciated. Richard G. Ackerman photographed and printed the plates and figures for this work.

A very special thanks is given to Megan Jones whose encouragement, understanding and friendship provided much needed support while at O.D.U. Also to Edward Dullaghan, who, through all the ups and downs was there and provided assistance however he could, and to his family, whose kindness to me made my stay in Norfolk more enjoyable. Finally, to my friends: Michael Bennett, Kathy Conko, Lisa Doan, Debbie Duffy, Ed Dullaghan, Megan Jones and Tammy Warden, whose continuous support, helpful suggestions and friendship are greatly appreciated.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xi</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>A. Objectives</td>
<td>1</td>
</tr>
<tr>
<td>B. Geologic Setting</td>
<td>2</td>
</tr>
<tr>
<td>PREVIOUS INVESTIGATIONS</td>
<td>11</td>
</tr>
<tr>
<td>MATERIALS AND METHODS</td>
<td>18</td>
</tr>
<tr>
<td>A. Field Procedures</td>
<td>18</td>
</tr>
<tr>
<td>B. Laboratory Techniques</td>
<td>21</td>
</tr>
<tr>
<td>C. Methods of Analysis</td>
<td>23</td>
</tr>
<tr>
<td>II. Species Diversity</td>
<td>23</td>
</tr>
<tr>
<td>II. Living and Total Benthic Foraminiferal Assemblages</td>
<td>26</td>
</tr>
<tr>
<td>1. Cluster Analysis</td>
<td>27</td>
</tr>
<tr>
<td>a. Presence/Absence Data</td>
<td>27</td>
</tr>
<tr>
<td>b. Abundance Data</td>
<td>28</td>
</tr>
<tr>
<td>III. Discriminant Analysis</td>
<td>29</td>
</tr>
<tr>
<td>RESULTS AND INTERPRETATIONS</td>
<td>31</td>
</tr>
<tr>
<td>A. Species Diversity Patterns</td>
<td>31</td>
</tr>
<tr>
<td>I. Surface Samples</td>
<td>31</td>
</tr>
<tr>
<td>II. Core Samples</td>
<td>42</td>
</tr>
<tr>
<td>B. Cluster Analysis</td>
<td>43</td>
</tr>
<tr>
<td>I. Surface Samples</td>
<td>43</td>
</tr>
<tr>
<td>II. Core Samples</td>
<td>47</td>
</tr>
<tr>
<td>III. Core and Surface Samples</td>
<td>54</td>
</tr>
<tr>
<td>C. Discriminant Analysis</td>
<td>59</td>
</tr>
<tr>
<td>D. Discriminant Analysis</td>
<td>62</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISCUSSION</td>
<td>88</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>95</td>
</tr>
<tr>
<td>SYSTEMATIC PALEONTOLOGY</td>
<td>98</td>
</tr>
<tr>
<td>PLATES</td>
<td>177</td>
</tr>
<tr>
<td>REFERENCES CITED</td>
<td>183</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>195</td>
</tr>
</tbody>
</table>

1. Measurements of physical and chemical parameters for the four localities. Breton Island barrier island locality includes samples 099, 408, 435–437, 503–509; forebar locality includes samples 082, 084, 421–434, 498, 500, 501; back island lagoon locality includes samples 401–407, 409–420; Stake Island barrier island locality includes samples 070, 083, 085, 097, 123, 124, 128...... 195

2. Specimen counts for benthic foraminifera per sample from the Breton Island barrier island locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (--) for fraction picked indicates the complete sample was picked........ 199

3. Relative abundance (percent frequency) for benthic foraminifera per sample from the Breton Island barrier island locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species........ 200

4. Specimen counts for benthic foraminifera and thecamoebians per sample from the forebar locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (--) for fraction picked indicates the complete sample was picked........ 201

5. Relative abundance (percent frequency) for benthic foraminifera and thecamoebians per sample from the forebar locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (--) for fraction picked indicates the complete sample was picked........ 202
6. Specimen counts for benthic foraminifera per sample from the back island lagoon locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (--) for fraction picked indicates the complete sample was picked. 203

7. Relative abundance (percent frequency) for benthic foraminifera per sample from the back island lagoon locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species. 204

8. Specimen counts for benthic foraminifera per sample from the Stake Island barrier island locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (--) for fraction picked indicates the complete sample was picked. 205

9. Relative abundance (percent frequency) for benthic foraminifera per sample from the Stake Island barrier island locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species. 206

10. Specimen counts for benthic foraminifera and thecaneobians per sample from core BB92. The symbol (--) for fraction picked indicates the complete sample was picked, a (*) preceding a foraminiferal name indicates a pre-Holocene fossil species. 207

11. Relative abundance (percent frequency) for benthic foraminifera and thecaneobians per sample from core BB92. A (*) preceding a foraminiferal name indicates a pre-Holocene fossil species. 208
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Values for number of species, S, species diversity, H(S), and equitability, E for surface samples. N represents the number of specimens picked from each sample.</td>
<td>38</td>
</tr>
<tr>
<td>1. Continued</td>
<td>39</td>
</tr>
<tr>
<td>1. Continued</td>
<td>40</td>
</tr>
<tr>
<td>2. Values for the number of species of recent foraminifera, S(f), fossil foraminifera S(ff), and thecamoebians, S(t) in core BB92. N(f), N(ff) and N(t) represents the number of specimens of recent foraminifera, fossil foraminifera, and thecamoebians respectively, picked from each sample.</td>
<td>44</td>
</tr>
<tr>
<td>3. Group means of physical and chemical parameters for samples from the sediment surface-water interface, including depth, for the four localities. Variable include depth, temperature (TEMP), salinity (SAL), Eh, pH, percentages of: medium sand (MSND), fine sand (FSND), very fine sand (VFSND) and silt and clay (SLTCL). The groups are sample localities (LOC): Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).</td>
<td>64</td>
</tr>
<tr>
<td>4. Canonical discriminant functions with the percentage of variability accounted for by the eigenvalues in the analysis of the physical and chemical parameters, including depth, from the sediment surface-water interface.</td>
<td>65</td>
</tr>
<tr>
<td>5. Canonical discriminant functions evaluated at group means (group centroids) in the analysis of the physical and chemical parameters, including depth, from the sediment surface-water interface. The groups are sample localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).</td>
<td>66</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>6. Standardized canonical discriminant function coefficients from the analysis of the physical and chemical parameters, including depth, from the sediment surface-water interface</td>
<td>69</td>
</tr>
<tr>
<td>7. Group means of physical and chemical parameters for samples from the sediment surface-water interface, excluding depth, for the four localities. Variables include temperature (TEMP), salinity (SAL), Eh, pH, percentages of: medium sand (MSND), fine sand (FSND), very fine sand (VFSND) and silt and clay (SILCL). The groups are sample localities (LOC): Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4)</td>
<td>71</td>
</tr>
<tr>
<td>8. Canonical discriminant functions with the percentage of variability accounted for by the eigenvalues in the analysis of the physical and chemical parameters, excluding depth, from the sediment surface-water interface</td>
<td>73</td>
</tr>
<tr>
<td>9. Canonical discriminant functions evaluated at group means (group centroids) in the analysis of the physical and chemical parameters, excluding depth, from the sediment surface-water interface. The groups are sample localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4)</td>
<td>74</td>
</tr>
<tr>
<td>10. Standardized canonical discriminant function coefficients from the analysis of the physical and chemical parameters, excluding depth, from the sediment surface-water interface</td>
<td>77</td>
</tr>
<tr>
<td>11. Group means of physical and chemical parameters for water samples taken approximately 2cm above the sediment surface-water interface. Variables include temperature (TEMP), salinity (SAL), Eh, pH, dissolved oxygen content (OX), turbidity (TURB), concentrations of: calcium (Ca), iron (Fe), lead (Pb) and silicon (Si). The groups are sample localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4)</td>
<td>79</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>12. Canonical discriminant functions with the percentage of variability accounted for by the eigenvalues in the analysis of the physical and chemical parameters from the water mass approximately 2cm above the sediment surface–water interface</td>
<td>80</td>
</tr>
<tr>
<td>13. Canonical discriminant functions evaluated at group means (group centroids) in the analysis of the physical and chemical parameters from the water mass approximately 2cm above the sediment surface–water interface. The groups are sample localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4)</td>
<td>81</td>
</tr>
<tr>
<td>14. Standardized canonical discriminant function coefficients from the analysis of the physical and chemical parameters from the water mass approximately 2cm above the sediment surface–water interface</td>
<td>85</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Map of the study area showing the location of Breton and Stake Islands as well as core BB92. Boxes indicate areas covered by Figures 7 and 8 (modified from Penland and Boyd, 1985).</td>
<td>3</td>
</tr>
<tr>
<td>2. Recent deltaic lobes of the Mississippi River (modified from Kolb and Van Lopik, 1958). Study area of Breton and Stake Islands indicated by rectangle and that of core by *.</td>
<td>4</td>
</tr>
<tr>
<td>3. Vertical sequence of deposits in the modern Mississippi River delta (modified from Coleman, 1976).</td>
<td>6</td>
</tr>
<tr>
<td>4. Geographic regions from which samples were collected in the study area. Part A is the Breton Island area, part B is Stake Island.</td>
<td>8</td>
</tr>
<tr>
<td>5. Lithologic content, organic matter percentages and depositional environments for core BB92. Facies are those defined by Kosters (1987) based on lithologic data. Sample intervals for this study are shown at the left (from Kosters, 1987).</td>
<td>10</td>
</tr>
<tr>
<td>6. Geographic distribution of foraminiferal biofacies in the southeastern Mississippi Delta area (modified from Phleger, 1955).</td>
<td>13</td>
</tr>
<tr>
<td>7. Geographic distribution of benthic foraminiferal assemblages in the east Mississippi delta margin area. Overlap of patterns indicates gradational boundaries (modified from Lankford, 1959).</td>
<td>15</td>
</tr>
<tr>
<td>8. Sample stations in the Breton Island area. Island limits are drawn with a dashed line since the position of the shoreline is variable.</td>
<td>19</td>
</tr>
<tr>
<td>9. Sample stations from Stake Island. Island limits are drawn with a dashed line since the position of the shoreline is variable.</td>
<td>20</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>10.</td>
<td>Map showing number of species (S) in samples from the Breton Island barrier island, forebar and back island lagoon localities. The values are averages for each sample station.</td>
</tr>
<tr>
<td>11.</td>
<td>Map showing number of species (S) in samples from the Stake Island barrier island locality. The values are averages for each sample station.</td>
</tr>
<tr>
<td>12.</td>
<td>Map listing species diversity values, H(S) for samples from the Breton Island barrier island, forebar and back island lagoon localities. The values are averages for each sample station.</td>
</tr>
<tr>
<td>13.</td>
<td>Map listing species diversity values, H(S) for samples from the Stake Island barrier island locality. The values are averages for each sample station.</td>
</tr>
<tr>
<td>14.</td>
<td>Map listing equitability values, E, for samples from the Breton Island barrier island, forebar and back island lagoon localities. The values are averages for each sample station.</td>
</tr>
<tr>
<td>15.</td>
<td>Map listing equitability values, E, for samples from the Stake Island barrier island locality. The values are averages for each sample station.</td>
</tr>
<tr>
<td>16.</td>
<td>Plot of the number of species of recent foraminifera S(f), thecamoebians S(t) and fossil foraminifera in core BB92. N represents the total number of specimens picked from each sample. The environmental interpretations are those of Kosters (1987), based on lithological data.</td>
</tr>
<tr>
<td>17.</td>
<td>Dendrogram illustrating results of the cluster analysis performed on presence-absence data of surface samples using the Jaccard coefficient.</td>
</tr>
<tr>
<td>18.</td>
<td>Distribution of biofacies within the study area based on results of presence/absence data cluster analysis of surface samples. Part A is the Breton Island area, part B is the Stake Island area.</td>
</tr>
<tr>
<td>19.</td>
<td>Dendrogram illustrating results of the cluster analysis performed on transformed abundance data of surface samples using the Bray-Curtis coefficient.</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>20.</td>
<td>Distribution of biofacies within the study area based on results of transformed abundance data cluster analysis of surface samples. Part A is the Breton Island area, part B is the Stake Island area.</td>
</tr>
<tr>
<td>21.</td>
<td>Dendrogram illustrating results of cluster analysis performed on transformed abundance data of core samples using the Bray–Curtis coefficient.</td>
</tr>
<tr>
<td>22.</td>
<td>A plot of cluster groups of core samples obtained using the Bray–Curtis coefficient. The environmental interpretations are those of Kosters (1987), based on lithologic data.</td>
</tr>
<tr>
<td>23.</td>
<td>Dendrogram illustrating results of cluster analysis performed on transformed abundance data of combined surface and core samples using the Bray–Curtis coefficient.</td>
</tr>
<tr>
<td>24.</td>
<td>Mean canonical discriminant functions 1 and 2 with 95% confidence circles for the four groups. Results of analysis of variables, including depth, at the sediment surface-water interface. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).</td>
</tr>
<tr>
<td>25.</td>
<td>Mean canonical discriminant functions 1 and 3 with 95% confidence circles for the four groups. Results of analysis of variables, including depth, at the sediment surface-water interface. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).</td>
</tr>
<tr>
<td>26.</td>
<td>Mean canonical discriminant functions 1 and 2 with 95% confidence circles for the four groups. Results of analysis of variables, excluding depth, at the sediment surface-water interface. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).</td>
</tr>
</tbody>
</table>
LIST OF FIGURES (continued)

Figure | Page
--- | ---
27. Mean canonical discriminant functions 1 and 3 with 95% confidence circles for the four groups. Results of analysis of variables, excluding depth, at the sediment surface-water interface. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4). 76

28. Mean canonical discriminant functions 1 and 2 with 95% confidence circles for the four groups. Results of analysis of variables in the water mass. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4). 82

29. Mean canonical discriminant functions 1 and 3 with 95% confidence circles for the four groups. Results of analysis of variables in the water mass. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4). 83
INTRODUCTION

A. Objectives

The assemblage of benthic foraminifera in a given area may be affected by a wide variety of physical, chemical and biological factors. Phleger (1951, p. 59) suggested that "...distribution of temperature, salinity, nutrient salts as affecting basic food supply, oxygen in the water and in the surface of the sediments, depth of light penetration, type of sediment and physical nature of the bottom, depth of mixing of the surface water, and nature of other organisms" would affect the foraminiferal distribution. The affects of many environmental variables on the distribution of foraminifera are discussed at length in Murray (1973).

Ecological studies of shallow water benthic foraminiferal assemblages in numerous parts of the Gulf of Mexico have not revealed any definitive parameter that may be controlling foraminiferal biofacies (Benda and Puri, 1962; Lankford, 1959). Salinity has been considered to be an important factor although interactions of other variables have to be considered (Bandy, 1954, 1956; Kane, 1967; Phleger, 1955; Scott, 1986). The presence of barrier islands, which affect circulation patterns of water masses and hence salinity, also has been thought to affect assemblages (Parker et al., 1953; Lehmann, 1957; Phleger, 1954).
This study focuses on the distribution of modern benthic foraminifera around Breton and Stake Islands, part of the Chandeleur Islands chain, northern Gulf of Mexico and investigates the environmental variables affecting these distributions. The first objective of this work was to taxonomically document the benthic foraminifera and thecamoebians in the study area (Figure 1); second, to define and describe biofacies based on the benthic foraminifera; third, to determine which, if any, environmental variables influence the distribution of foraminifera in this area; and four, to produce a paleoenvironmental interpretation of a core (BB92) from Barataria Basin (Figure 1), using the surface distribution as a distributional model. Cluster analysis using both benthic foraminiferal presence/absence and abundance data was utilized to determine the benthic foraminiferal biofacies. Discriminant analysis was used to analyze the environmental data.

B. Geologic Setting

The Mississippi River delta consists of a series of delta lobes that began to form approximately 7000 years ago (Coleman and Prior, 1982). Figure 2 illustrates the various switching of lobes from the initial Sale Cypremort delta to the present Balize delta. Each deltaic lobe lasted from 800 to 1500 years at an individual site (Coleman and Prior, 1982). The modern bird-foot or Balize delta, the present-day site of active sedimentation, formed within the last 600-800 years (Coleman and Prior, 1982). Approximately 6.21x10\(^{11}\) kg of
Figure 1. Map of the study area showing the location of Breton and Stake Islands as well as core BB92. Boxes indicate areas covered by Figures 7 and 8 (modified from Penland and Boyd, 1985).
Figure 2. Recent deltaic lobes of the Mississippi River (modified from Kolb and Van Lopik, 1958). Study area of Breton and Stake Islands indicated by rectangle and that of core by *.
sediment, which consists primarily of clay, silt and fine sand is discharged annually at the delta's apex (Coleman and Prior, 1982).

The typical vertical sequence of deposits beneath the Balize delta is shown in Figure 3. Coleman (1976) described this sequence and stated the strand plain sands are Pleistocene in age with the algal reef zone above having been dated at 26,500 years b.p. Clay units II and III are marine pre-Balize delta deposits and the overlying shell layer has been dated at 13,400 to 16,600 years b.p. Clay unit I represents deposition of prodelta clays associated with the modern Mississippi delta. The prodelta deposits grade upward into delta front, distributary mouth bar, which are overlain by bay and marsh deposits. The overall thickness of the Balize delta deposits are 100-120m (Coleman and Prior, 1982).

The Chandeleur Islands (Figure 1), which represent a transgressive barrier island arc, began to form approximately 1800 years ago as the St. Bernard delta began to subside (Penland and Boyd, 1985). The islands developed along the seaward margin of the abandoned St. Bernard's delta. Chandeleur Sound, with present day depths generally between 2-4m, developed due to invasion of more saline water into the freshwater marshes of the subsiding St. Bernard's delta (Penland and Boyd, 1985).

Penland and Boyd (1985) suggested that sand dunes, a stabilizing feature of barrier islands, were not well developed and less stable in the southern Chandeleur Islands compared to the northern ones. They described Stake Island, one of the southern islands, as a partially vegetated islet, which is a result of repeated island destruction.
Figure 3. Vertical sequence of deposits in the modern Mississippi River delta (modified from Coleman, 1976).
<table>
<thead>
<tr>
<th>Lithology</th>
<th>Environment</th>
<th>Stratigraphic Unit</th>
<th>Plant Roots</th>
<th>Clay</th>
<th>Silt &amp; Sand</th>
<th>Burrows</th>
<th>Algae</th>
<th>Shell</th>
<th>Peat &amp; Wood Fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta Front</td>
<td>Laminated Silts &amp; Clays</td>
<td>Deltaic &amp; Shallow Marine</td>
<td>Strand Plain Sands</td>
<td>Clay Unit I</td>
<td>Clay Unit II</td>
<td>Clay Unit III</td>
<td>Algal Reef Zone</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
followed by reemergence. The morphology of Breton Island is different than that of the southern ones. They attributed the crescent shape of Breton Island to the progradation of the Balize delta into this area around 400 years ago, which affected the wave energy and sediment dispersal patterns, causing deposition of sediments along the western end of the island.

This project focuses on samples from around Breton and Stake Islands (Figure 1), part of the Chandeleur Island chain in the Gulf of Mexico. In this work samples were collected from four geographic regions within the study area (Figure 4). These regions are referred to as localities and include: (1) Breton Island barrier island locality which includes samples from Breton Island; (2) forebar locality which includes samples seaward of Breton Island; (3) back island lagoon locality which includes samples from Breton Sound and (4) Stake Island barrier island locality, those samples from Stake Island. Individual sample sites within these localities are referred to as stations.

The geologic history of Barataria Basin (Figure 1), the area of the Mississippi delta between Bayou Lafourche and the Mississippi River from which core BB92 was obtained, is detailed in Kosters et al. (1987). They suggested that around 4000 years b.p. Barataria Basin existed mainly as a brackish bay east of the Teche delta (Figure 2) with sediments consisting of bioturbated fine sands. With increased sedimentation the basin began to be filled by overbank deposits. Organic accretion became the dominant process around 200 years b.p. as active sedimentation moved eastward.
Figure 4. Geographic regions from which samples were collected in the study area. Part A is the Breton Island area, part B is Stake Island.
ISLAND LIMITS

LOCALITIES
1 BRETON ISLAND BARRIER ISLAND
2 FOREBAR
3 BACK ISLAND LAGOON

---

ISLAND LIMITS

LOCALITY
4 STAKE ISLAND BARRIER ISLAND
Figure 5 shows Kosters' (1987) sedimentological interpretation of core BB92. She defined three sedimentary facies: lower interdistributary bay; central interdistributary bay; and marsh and swamp deposits. These deposits are separated by periods of abandonment, which Kosters et al. (1987) found to be laterally extensive in the basin between these facies and they considered these to represent a quiescent phase of transition.
Figure 5. Lithologic content, organic matter percentages and depositional environments for core BB92. Facies are those defined by Kosters (1987) based on lithologic data. Sample intervals for this study are shown at the left (from Kosters, 1987).
VIBRACORE BB92/72CM COMPACTION

ORGANIC MATTER

ORGANIC-POOR
ORGANIC-RICH AND PEAT

MARSH AND SWAMP

1860±75BP

CENTRAL INTERDISTRIBUTARY BAY

4240±85BP

LOWER INTERDISTRIBUTARY BAY

4485±80BP

ABANDONMENT
The distribution pattern of recent benthic foraminifera in the Gulf of Mexico is one of the best known for any area in the world. Culver and Buzas (1981) summarized the published information of all recent species and generated maps showing the distribution of the most commonly occurring species throughout the Gulf of Mexico. They determined that 23 species, which included mostly marsh foraminifera and some species of Elphidium and Quinqueloculina, were restricted to depths less than 50m. Ammonia beccarii was recorded to depths of 1000m although most records were at depths of less than 100m. On a similar large scale, Culver (1988) outlined the generic assemblage characteristics of 14 depth zones for the northwestern Gulf. He stated that few genera were restricted to specific depth zones and that rare taxa should not be used to help define the zonation. Rotalia (=Ammonia) and Elphidium were genera that occurred in 50% or more of samples in his marsh, bay, 0 to 50m and 51 to 100m depth facies. Poag (1981), through an interpretation of previous works and with the addition of new samples, presented a generic distribution pattern for the entire Gulf. He noted that Ammonia beccarii or species of Elphidium were dominant in most shallow water areas.

On a smaller scale, a summary of the published distribution of shallow water benthic foraminifera and thecamoebians in the Gulf of
Mexico as well as possible ecologic controls affecting the documented assemblages follows. Details on the occurrence of species are presented in the systematic paleontology section.

Phleger (1955) established three principal biofacies and one subfacies in the southeastern Mississippi Delta area which included a marsh, Breton Sound and open-gulf biofacies and an offshore subfacies (Figure 6). His work encompassed much of the field area for this study. The marsh facies (labeled A, Figure 6), in his study, was restricted to 18 samples from a marsh on the eastern margin of the Balize Delta (Figure 2). The dominant fauna within this assemblage was *Leptodermella variabilis*, *Miliammina fusca* and *Trochammina macrescens*. Lower frequencies of *Ammotium salsum*, *Arenoparrella mexicana* and species of *Ammobaculites* also were recorded in this facies. In his Breton Sound facies, *"Rotalia" beccarii* variants (=*Ammonia beccarii*) and various species of *Elphidium* were dominant as well as some miliolids and marsh foraminifera. Seaward from Breton Island, his open gulf facies was also characterized by assemblages similar to Breton Sound but with a higher number of subsidiary species. There was a zone of mixing between these two facies. Many of the samples comprising this study were collected from the mixing zone defined by Phleger (1955).

Phleger (1955) noted the separation of the open-gulf and Breton Sound fauna was of particular interest since there was not a large water depth difference between the two areas and there are no continuous geographic barriers. He concluded that differences in the water masses between the two areas was controlling the distribution.
Figure 6. Geographic distribution of foraminiferal biofacies in the southeastern Mississippi Delta area (modified from Phleger, 1955).
He noted the open-gulf water was more saline than Breton Sound water and suggested that the degree of mixing of the water masses probably affected the foraminiferal distribution.

Lankford's (1959) work along the east Mississippi Delta margin also included a few samples from the present study area. He identified six assemblages in his study area (Figure 7). His sound assemblage characterized the area which is classified as the Back Island Lagoon locality in this work. The most common species within this assemblage were "Streblus" beccarii variants (=Ammonia beccarii), Elphidium gunteri, E. matagordanum (=Haynesina germanica), E. poeyanum, Ammotium salsum as well as miliolids. He noted this assemblage was characteristic of many Gulf coast bays and sounds having periodic or continual influxes of fresh water. Lankford (1959) noted a good correlation between bottom water masses of variable physical and chemical composition with the observed faunal assemblages. In areas of the sound fauna the water mass was characterized by intermediate salinities, variable temperatures, relatively turbid water and affected by turbulence from currents and small waves. He could not distinguish any single ecological property of the bottom water that was controlling the foraminiferal distribution.

The dominance of Ammonia beccarii and species of Elphidium in other shallow water regions within the Gulf of Mexico has also been documented although there is no consensus on the ecological factors that may be controlling this distribution. Bandy (1954) established a Streblus (=Ammonia) Elphidium faunal zone from 8.2-16.8m between
Figure 7. Geographic distribution of benthic foraminiferal assemblages in the east Mississippi delta margin area. Overlap of patterns indicates gradational boundaries (modified from Lankford, 1959).
Sabine Pass, Texas and Grand Cheniere, Louisiana. Little or no correlation was observed between faunal zones and temperature or grain size although correlations were observed with salinity. He concluded that salinity was an important factor in determining the foraminiferal distribution. A similar conclusion, for shallow water assemblages, was reached by Bandy (1956) in his study of benthic foraminifera generally from less than 180m between Mobile, Alabama and Fort Myers, Florida. Kane (1967) also attributed salinity variations to be the primary ecological factor controlling assemblages in Sabine Lake, Texas and Louisiana.

The presence of barrier islands, which affects water circulation, has also been proposed as a factor controlling the foraminiferal distribution within an area. These geographic barriers affect salinity as well as other parameters within the water masses. Phleger (1954) documented an assemblage dominated by "Rotalia" beccarii variants (=Ammonia beccarii), Elphidium species and miliolids seaward of barrier islands in the Mississippi Sound area and a marsh and estuarine fauna in the sound. This assemblage was also recorded both in the bay and open gulf facies from the San Antonio Bay area (Parker et al., 1953). The presence of this assemblage in these Texas bays was accounted for by the lower freshwater input from rivers into Texas bays than in Mississippi Sound.

Vertical zonations of foraminifera and thecamoebians were recognized in marshes from Barataria and Terrebonne Bays in the lower Mississippi Delta area by Scott (1986). Areas sampled included marine, brackish, freshwater and floating marshes and could be
distinguished by the assemblages of foraminifera and thecamoebians present. The marine marsh assemblage was generally dominated by Ammotium salsum, Miliammina fusca and Trochammina inflata. Dominant species identified in the brackish marsh included Trochammina macrescens, Miliammina fusca and the thecamoebian species Centropyxis aculeata. Centropyxis aculeata dominated the freshwater marsh with detectable number of Haplophragmoides bonplandi and Trochammina macrescens. In the freshwater marsh only thecamoebians were identified.

Haman (1982) discussed the distribution of both living and dead thecamoebians in channel, submerged levee, interdistributary bay and subaqueous distributary-mouth bar subenvironments of the Balize Delta, Louisiana. Highest numbers of living thecamoebians were in the levee subenvironment which also had the most diverse dead faunal assemblage. Measurements of depth, turbidity, dissolved oxygen, sediment temperature, salinity, Eh and pH as well as the concentration of calcium, iron, lead and silica were obtained from each of the subenvironments. No single parameter could be identified as the key environmental factor affecting the thecamoebian distribution although results indicated dissolved oxygen was of major importance.

These data indicate there are similarities in shallow water foraminiferal assemblages throughout much of the Gulf of Mexico. Although salinity appears to be an important environmental parameter in controlling the distribution of shallow water fauna, there appears to be a complex interaction of variables.
MATERIALS AND METHODS

A. Field Procedures

Forty-eight stations in the Breton and Stake Island area in the Gulf of Mexico (Figures 8, 9) were sampled between June 1978 and July 1978 by Hartex International and samples were preserved in methanol. Nine replicate samples were obtained during sample collection from the forebar locality. The sediment recovered was 300cc of the top 1cm of sediment from each sample site. Localities sampled included barrier islands and marine water depths between 1.5 and 3m near Breton Island. Sample stations are plotted in figures 8 and 9. Samples were collected by hand from barrier island and marsh locations and by free or scuba diving at shallow marine depths. At each locality various environmental variables were measured at the time of sample collection by Hartex International in the water mass approximately 2cm above the sediment surface-water interface and at the sediment surface-water interface. Measurements of water temperature, dissolved oxygen content, water turbidity, Eh and pH were taken in the water mass. In addition, a water sample was collected for salinity and trace element analysis. These water samples were later analyzed for the concentration of calcium, iron, lead and silicon. Temperature, Eh, pH and salinity were determined from the sediment surface-water interface. Measurements were made in the field using an indoor-
Figure 8. Sample stations in the Breton Island area. Island limits are drawn with a dashed line since the position of the shoreline is variable.
ISLAND LIMITS -----

SAMPLE STATIONS

- BACK ISLAND LAGOON "NORTH TRAVERSE"
- BACK ISLAND LAGOON "SOUTH TRAVERSE"
- BARRIER BAR
- FORE BAR

km

0 1
Figure 9. Sample stations from Stake Island. Island limits are drawn with a dashed line since the position of the shoreline is variable.
ISLAND LIMITS

SAMPLE STATIONS

⊙ BARRIER BAR
outdoor thermometer, oxygen meter (YSI 57), turbidity meter (Hach) and a pH-Eh meter (Orion Research 407a/F) (D. Haman, personal communication). Depth was determined using a digital depth recorder. Appendix 1 lists the sample localities and the values of the parameters measured for each sample. The samples were collected at different days and times over a two month period; hence there was some variation in tidal conditions (D. Haman, personal communication).

Thirty-seven samples of approximately 20cc were obtained from a 7.5cm diameter vibracore 760cm long collected in Barataria Bay by the Louisiana Geological Survey. The split core was sampled by removing a 1cm slice at approximately 20cm intervals. See figure 4 for position of samples on the core.

B. Laboratory Techniques

From the original 300cc surface-water interface sediment sample a 50cc sample was taken for sediment grain size analysis (D. Haman, personal communication). Sieve sizes used were the #60, #120 and #230 meshes (D. Haman, personal communication) which correspond to the coarser than fine sand/fine sand boundary, fine sand/very fine sand boundary and very fine sand/coarse silt boundary.

Two 50cc replicate subsamples were measured from each surface sample (except for those from the Forebar locality where replicate samples were obtained during sample collection) and wet sieved through a 0.063mm screen (#230 mesh) to remove silt and clay. This screen size is used in most present day micropaleontological studies since there is a consensus among most workers that it provides a more
representative sample of the total assemblage than using a larger screen size. Schröder et al. (1987) demonstrated this well in their comparison of assemblages using various screen sizes. Following sieving, approximately 0.1 g of rose Bengal, a protein-specific stain to detect living matter (Walton, 1952), 10 cc of buffered formalin, to fix and preserve cytoplasm, and 50 cc of water was added to the samples. After standing overnight, the samples were rinsed to remove excess stain and dried in an oven at 40°C. This temperature has been shown to cause little or no breakdown of any agglutinated species (Brodniewicz, 1965). The foraminifera were then concentrated using carbon tetrachloride as described by Todd et al. (1965) into a "float" with the residue being the "sink". Core samples were treated in a similar manner but no rose Bengal was added.

Where foraminifera were rare, the entire float was picked and specimens were placed on a cardboard microfossil slide using a (00000) picking brush. Samples with abundant foraminifera were split into fractions containing approximately 300 foraminifera using a microsplitter and the complete aliquot was picked. In all cases the sink was observed for remaining foraminifera. A distinction was made between living (stained) and dead foraminifera. A representative population of other organic material was also removed from each sample. Identification of foraminifera to the genus and species level was originally made through comparison with published reference figures and the Ellis and Messina (1940 et seq.) catalogue. Comparisons were then made with type specimens and comparative
material in the collections of the National Museum of Natural History, Washington, D.C.

Scanning electron micrographs were prepared in the following manner. Using a moist picking brush, specimens were placed on a standard aluminum stub covered with double sided tape. Many of the specimens were large and had to be attached to the stub with tape because electrical conductivity alone was not enough to adhere them to the stub. The stub was then coated with gold/palladium on a rotary stage of a vacuum gold coater for approximately four minutes and then placed in a holder in the vacuum chamber of a Cambridge 180 Scanning Electron Microscope. Photographs were then taken using polaroid NP55 film. In specimens where only an apertural and side view were needed, both shots were taken of a single specimen by rotating the stage 90 degrees. In cases where a dorsal and ventral view were required two specimens were sometimes used and in other cases the same specimen was removed from the previous stub, cleaned by removing the previous gold coating with a wet picking brush, and re-mounted on another stub.

C. Methods of Analysis

I. Species Diversity

Gibson and Buzas (1973) recognized a pattern of an increase in species diversity to depths of about 3000m in the northeastern Gulf of Mexico. Culver and Buzas (1981) also recognized an increase in species diversity with depth throughout the Gulf of Mexico. Environmentally related patterns of species diversity have been recognized in the western North Atlantic (Buzas and Gibson, 1969).
Generally maximum species diversity was observed at abyssal depths and an increase in diversity patterns toward the lower latitudes. An explanation for the increase in species diversity offshore and in lower latitudes is the time-stability hypothesis (Sanders, 1968) where these environments are relatively uniform over a long time. Environments become less variable offshore, and with this stability there is an increase in the number of species.

A number of species diversity indices have been utilized to analyze both modern and fossil data sets. Species diversity analysis in this study follow that outlined by Gibson and Buzas (1973) in their study of species diversity patterns of foraminifera along the eastern margin of North America. The number of species (S) in each sample is a simple measure of species diversity. This index is dependent on the number of specimens counted since an increase in the number of specimens counted results in a larger value for (S) (Gibson and Buzas, 1973).

The Shannon-Weiner information function $H(S)$ (MacArthur and MacArthur, 1961) is a species diversity information function which is less dependent on sample size than the simple species number (S) since all species do not contribute equally to the value of $H(S)$ (Gibson and Buzas, 1973). The Shannon-Weiner information function is expressed as:

$$H(S) = -\sum p_i \ln p_i$$

where $p_i$ is the proportion of the $i$th species (Gibson and Buzas, 1973).
As shown by the previous equation, the value $H(S)$ is the summation of the proportion of species times the natural log of the proportion. Gibson and Buzas (1973), through examples, showed that all species do not contribute equally to the values of $H(S)$. Their hypothetical example discussed two samples, each with five species, the proportions being 0.90, 0.04, 0.03, 0.02 and 0.01 in the first sample and 0.20 for each species in the second sample. The $H(S)$ values are 0.45 and 1.60 respectively. In the first case, with one dominant species and the others rare, Gibson and Buzas (1973, p. 219) stated the low value of $H(S)$ indicates "...the sample contains little information because, given any particular individual, we can be confident as to which species it is likely to belong." Higher $H(S)$ values indicate species are more equally distributed and when a specimen is encountered at random from this population there is less confidence to which this species belongs (Gibson and Buzas, 1973).

In order to take into account the variation of proportions of species within samples, Buzas and Gibson (1969) defined the ratio of species equitability expressed as:

$$E = \frac{e^{H(S)}}{S}$$

where $e^{H(S)}$ is the base of the natural logarithm raised to the $H(S)$ power;

$S$ is the number of species (Gibson and Buzas, 1973). This represents the number of equally distributed species within a sample and while $E$ values will range from 0 to 1.0, a value of 1.0 will be obtained if all species are equally distributed (Gibson and Buzas, 1973). $E$ values, a function of both $H(S)$ and $S$ will decrease
as sample size increases due to the addition of rare species although the addition of rare species has little affect on an increase in $H(S)$.

A fortran computer program at Old Dominion University was used to calculate $H(S)$ and $E$ values.

II. Living and Total Benthic Foraminiferal Assemblages

There has been some controversy among authors as to whether living or total benthic foraminiferal assemblages should be used in environmental analyses. Murray (1973, 1984) stated that the living and dead assemblages of foraminifera in the same sample are commonly different. Slightly higher species diversity is usually recognized in the dead assemblage due to the contribution over time of rare species (Murray, 1976). Murray (1973, 1984) concluded that only the living foraminiferal assemblage should be used to interpret environmental conditions. Buzas (1968) felt that examination of the living assemblage at any one time did not represent the environmental conditions on the population over longer periods of time. Although some variation between living and dead assemblages have been noted, (Scott and Medioli, 1980a) have shown total populations to be good indicators of long term, rather than seasonal bottom conditions. This study follows Buzas (1968) and Scott and Medioli (1980a) in considering that the total assemblage as more representative of environmental conditions over longer periods of time.

Analysis of the benthic foraminiferal assemblages were completed as outlined below. Trends in the living assemblages were noted although the generally low living populations, both percentages and
total numbers, would make interpretations of analyses from living assemblages alone speculative. Total assemblages were used in analyses. Appendices 2-11 presents both raw and percentage data for the foraminiferal assemblages observed in both surface and core samples. The environmental data were analyzed and compared to the foraminiferal data to investigate which variable(s) has the most influence on the distribution of foraminifera.

1. Cluster Analysis

Biofacies, as defined by Buzas (1969, p. 102) are "...multispecies assemblages living in a specified area." One method of biofacies analysis is cluster analysis (Sokal and Sneath, 1963) which is a classification method that places samples into groups on the basis of similarity. The method used in this study to reveal biofacies was Q-mode (sample x sample) and the unweighted pair group method (Mello and Buzas, 1968). This method calculates and groups similarity coefficients on the basis of the highest numerical relationships between samples. Based on the similarity coefficients, groups are plotted on a dendrogram which allows the relationship between the coefficients to be viewed graphically. Data was analyzed using a fortran program written by Joseph Hazel and using the IBM mainframe computer at Old Dominion University.

a. Presence/Absence Data

Analysis of data sets using the presence/absence of species within samples was accomplished using the Jaccard coefficient of similarity.
The Jaccard coefficient of similarity (Sokal and Sneath, 1963) is expressed as:

\[ S_J = \frac{N_{JK}}{N_{JK} + (N_{JK} + N_{Jk})} \]

where \( N_{JK} \) is the number of species common to both samples J and K.

\( N_{Jk} \) is the number of species present in sample J and absent in sample K.

\( N_{jK} \) is the number of species present in sample K and absent in sample J (Mello and Buzas, 1968).

b. Abundance Data

The Bray-Curtis coefficient of similarity (Bray and Curtis, 1957) was used for analysis of abundance data. This coefficient not only compares the species that samples have in common but also the proportions of those species. The Bray-Curtis (Bray and Curtis, 1957) coefficient is expressed as:

\[ C = \frac{2W}{a + b} \]

where \( a \) is the sum of species or proportions in one sample.

\( b \) is the sum of species or proportions in the second sample.

\( W \) is the sum of the lesser value for species common to both samples.

Buzas (1969) noted that in comparing samples using multivariate statistical methods the data must be normally distributed with equal variance. Since the proportions in this data set were not normally
distributed, the equation as follows:

$$2 \arcsin \sqrt{p}$$

where p is the proportion of species within a sample, transforms the data into values that are directly comparable. Tables available in Owen (1962), which have computed values for p, were used in the data transformation. Values of c range from 0, with no species in common, to 1 where samples would have the same species with the same proportions.

III. Discriminant Analysis

Discriminant analysis is a widely used multivariate technique which linearly combines independent variables to best distinguish between groups (Davis, 1973; Nie et al., 1975). A good mathematical description is presented in Sneath and Sokal (1973). In discriminant analysis, measurements are transformed to canonical axes to emphasize the difference between the mean vectors (Buzas et al., 1985). Buzas et al. (1985, p. 1077) stated "...most of the variability is accounted for by the first canonical axis, much less by the second, and so on." The values of the standardized canonical discriminant function are used to determine which variables are important in separating groups (Buzas et al., 1985).

The purpose of these analyses is to determine if the four localities can be distinguished on the basis of measured variables and determine which variables, if any, are important in separating them. Discriminant analyses were run on the physical and environmental variables from both the water mass and the sediment surface-water
interface (Appendix 1) using the WILKS' stepwise selection method which is part of the Statistical Package for the Social Sciences (SPSS-X) (Nie et al., 1975).
RESULTS AND INTERPRETATIONS

A. Species Diversity Patterns

I. Surface Samples

Of the 19 samples containing foraminifera at the Breton Island barrier island locality, S values averaged 7.3 and ranged from one to 12; H(S) values averaged 1.30 and ranged from 0.69 to 1.76; E values averaged 0.60 and ranged from 0.28 to 1.00. At the back island lagoon locality, S values averaged 10.9 and ranged from seven to 19; H(S) values averaged 1.59 and ranged from 1.25 to 1.90; E values averaged 0.47 and ranged from 0.29 to 0.64. At the forebar locality, S values averaged 13.1 and ranged from nine to 17; H(S) values averaged 1.57 and ranged from 1.28 to 1.89; E values averaged 0.38 and ranged from 0.25 to 0.48. At the Stake Island barrier island locality, S values averaged 10.6 and ranged from three to 17; H(S) values averaged 1.52 and ranged from 0.79 to 1.94; E values averaged 0.48 and ranged from 0.34 to 0.94. Figures 10 to 15 are maps of the study area showing values of S, H(S) and E at each of the sample locations. An average value for the replicate pairs was plotted. Table 1 lists the S, H(S) and E values for the samples.

Overall, the number of species, S, is fairly constant over the study area. The lower number of species from the Breton Island barrier island locality is probably due to the low specimen counts.
Figure 10. Map showing number of species (S) in samples from the Breton Island barrier island, forebar and back island lagoon localities. The values are averages for each sample station.
ISLAND LIMITS

SAMPLE STATIONS
• BACK ISLAND LAGOON "NORTH TRAVERSE"
• BACK ISLAND LAGOON "SOUTH TRAVERSE"
• BARRIER BAR
• FORE BAR
Figure 11. Map showing number of species (S) in samples from the Stake Island barrier island locality. The values are averages for each sample station.
ISLAND LIMITS -----

SAMPLE STATIONS

○ BARRIER BAR

km

88°55'W

29°40'N

0 1

33
Figure 12. Map listing species diversity values, $H(S)$ for samples from the Breton Island barrier island, forebar and back island lagoon localities. The values are averages for each sample station.
ISLAND LIMITS -----

SAMPLE STATIONS
- BACK ISLAND LAGOON "NORTH TRAVERSE"
- BACK ISLAND LAGOON "SOUTH TRAVERSE"
- BARRIER BAR
- FORE BAR
Figure 13. Map listing species diversity values, H(S) for samples from the Stake Island barrier island locality. The values are averages for each sample station.
Figure 14. Map listing equitability values, $E$, for samples from the Breton Island barrier island, forebar and back island lagoon localities. The values are averages for each sample station.
ISLAND LIMITS

SAMPLE STATIONS
- BACK ISLAND LAGOON "NORTH TRAVERSE"
- BACK ISLAND LAGOON "SOUTH TRAVERSE"
- BARRIER BAR
- FORE BAR

km

0 1
Figure 15. Map listing equitability values, E, for samples from the Stake Island barrier island locality. The values are averages for each sample station.
Table 1. Values for number of species, $S$, species diversity, $H(S)$, and equitability, $E$ for surface samples. $N$ represents the number of specimens picked from each sample.
<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>S</th>
<th>H(S)</th>
<th>E</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRETON ISLAND BARRIER ISLAND LOCALITY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>099A</td>
<td>11</td>
<td>1.46684</td>
<td>0.39414</td>
<td>259</td>
</tr>
<tr>
<td>099B</td>
<td>9</td>
<td>1.33662</td>
<td>0.42291</td>
<td>277</td>
</tr>
<tr>
<td>408A</td>
<td>5</td>
<td>1.29443</td>
<td>0.72978</td>
<td>35</td>
</tr>
<tr>
<td>408B</td>
<td>7</td>
<td>1.30381</td>
<td>0.52619</td>
<td>34</td>
</tr>
<tr>
<td>435A</td>
<td>4</td>
<td>1.33218</td>
<td>0.94732</td>
<td>5</td>
</tr>
<tr>
<td>435B</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>436A</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>436B</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>437A</td>
<td>3</td>
<td>1.06086</td>
<td>0.96295</td>
<td>9</td>
</tr>
<tr>
<td>437B</td>
<td>6</td>
<td>1.60205</td>
<td>0.82720</td>
<td>16</td>
</tr>
<tr>
<td>503A</td>
<td>12</td>
<td>1.76584</td>
<td>0.48721</td>
<td>264</td>
</tr>
<tr>
<td>503B</td>
<td>12</td>
<td>1.62036</td>
<td>0.42124</td>
<td>294</td>
</tr>
<tr>
<td>504A</td>
<td>11</td>
<td>1.12603</td>
<td>0.28031</td>
<td>276</td>
</tr>
<tr>
<td>504B</td>
<td>11</td>
<td>1.21341</td>
<td>0.30590</td>
<td>284</td>
</tr>
<tr>
<td>505A</td>
<td>7</td>
<td>1.47501</td>
<td>0.62444</td>
<td>95</td>
</tr>
<tr>
<td>505B</td>
<td>10</td>
<td>1.67889</td>
<td>0.53596</td>
<td>93</td>
</tr>
<tr>
<td>506A</td>
<td>11</td>
<td>1.30171</td>
<td>0.33414</td>
<td>285</td>
</tr>
<tr>
<td>506B</td>
<td>8</td>
<td>1.13709</td>
<td>0.38971</td>
<td>258</td>
</tr>
<tr>
<td>507A</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>507B</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>508A</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>508B</td>
<td>2</td>
<td>0.69315</td>
<td>1.00000</td>
<td>2</td>
</tr>
<tr>
<td>509A</td>
<td>1</td>
<td>undefined</td>
<td>undefined</td>
<td>1</td>
</tr>
<tr>
<td>509B</td>
<td>2</td>
<td>0.69315</td>
<td>1.00000</td>
<td>2</td>
</tr>
<tr>
<td>BACK ISLAND LAGOON LOCALITY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>401A</td>
<td>13</td>
<td>1.58713</td>
<td>0.37613</td>
<td>272</td>
</tr>
<tr>
<td>401B</td>
<td>14</td>
<td>1.38448</td>
<td>0.28520</td>
<td>275</td>
</tr>
<tr>
<td>402A</td>
<td>12</td>
<td>1.75040</td>
<td>0.47974</td>
<td>283</td>
</tr>
<tr>
<td>402B</td>
<td>9</td>
<td>1.34946</td>
<td>0.42837</td>
<td>298</td>
</tr>
<tr>
<td>403A</td>
<td>14</td>
<td>1.64047</td>
<td>0.36840</td>
<td>300</td>
</tr>
<tr>
<td>403B</td>
<td>12</td>
<td>1.57441</td>
<td>0.40232</td>
<td>311</td>
</tr>
<tr>
<td>404A</td>
<td>15</td>
<td>1.67513</td>
<td>0.35597</td>
<td>293</td>
</tr>
<tr>
<td>404B</td>
<td>10</td>
<td>1.56555</td>
<td>0.47853</td>
<td>145</td>
</tr>
<tr>
<td>405A</td>
<td>13</td>
<td>1.62676</td>
<td>0.39134</td>
<td>185</td>
</tr>
<tr>
<td>405B</td>
<td>11</td>
<td>1.59911</td>
<td>0.44987</td>
<td>180</td>
</tr>
<tr>
<td>406A</td>
<td>11</td>
<td>1.61550</td>
<td>0.45731</td>
<td>131</td>
</tr>
<tr>
<td>406B</td>
<td>9</td>
<td>1.53361</td>
<td>0.51498</td>
<td>99</td>
</tr>
<tr>
<td>407A</td>
<td>10</td>
<td>1.64528</td>
<td>0.51825</td>
<td>196</td>
</tr>
<tr>
<td>407B</td>
<td>9</td>
<td>1.46258</td>
<td>0.47067</td>
<td>67</td>
</tr>
<tr>
<td>409A</td>
<td>12</td>
<td>1.43258</td>
<td>0.34913</td>
<td>204</td>
</tr>
<tr>
<td>409B</td>
<td>19</td>
<td>1.89552</td>
<td>0.35032</td>
<td>300</td>
</tr>
<tr>
<td>410A</td>
<td>8</td>
<td>1.52203</td>
<td>0.57269</td>
<td>275</td>
</tr>
<tr>
<td>410B</td>
<td>11</td>
<td>1.71138</td>
<td>0.50333</td>
<td>186</td>
</tr>
<tr>
<td>411A</td>
<td>8</td>
<td>1.45949</td>
<td>0.53797</td>
<td>65</td>
</tr>
<tr>
<td>411B</td>
<td>10</td>
<td>1.59837</td>
<td>0.49450</td>
<td>125</td>
</tr>
<tr>
<td>412A</td>
<td>8</td>
<td>1.50192</td>
<td>0.56129</td>
<td>67</td>
</tr>
<tr>
<td>412B</td>
<td>13</td>
<td>1.77107</td>
<td>0.45209</td>
<td>124</td>
</tr>
<tr>
<td>SAMPLE</td>
<td>S</td>
<td>H(S)</td>
<td>E</td>
<td>N</td>
</tr>
<tr>
<td>---------</td>
<td>----</td>
<td>---------</td>
<td>------</td>
<td>----</td>
</tr>
<tr>
<td>413A</td>
<td>13</td>
<td>1.85348</td>
<td>0.49092</td>
<td>75</td>
</tr>
<tr>
<td>413B</td>
<td>8</td>
<td>1.25632</td>
<td>0.43906</td>
<td>58</td>
</tr>
<tr>
<td>414A</td>
<td>7</td>
<td>1.50367</td>
<td>0.64260</td>
<td>41</td>
</tr>
<tr>
<td>414B</td>
<td>9</td>
<td>1.51507</td>
<td>0.50553</td>
<td>34</td>
</tr>
<tr>
<td>415A</td>
<td>7</td>
<td>1.47983</td>
<td>0.62746</td>
<td>29</td>
</tr>
<tr>
<td>415B</td>
<td>13</td>
<td>1.68576</td>
<td>0.41512</td>
<td>136</td>
</tr>
<tr>
<td>416A</td>
<td>9</td>
<td>1.70791</td>
<td>0.61305</td>
<td>67</td>
</tr>
<tr>
<td>416B</td>
<td>9</td>
<td>1.51904</td>
<td>0.50754</td>
<td>60</td>
</tr>
<tr>
<td>417A</td>
<td>11</td>
<td>1.47341</td>
<td>0.39674</td>
<td>144</td>
</tr>
<tr>
<td>417B</td>
<td>12</td>
<td>1.66095</td>
<td>0.43869</td>
<td>187</td>
</tr>
<tr>
<td>418A</td>
<td>10</td>
<td>1.39722</td>
<td>0.40439</td>
<td>234</td>
</tr>
<tr>
<td>418B</td>
<td>13</td>
<td>1.59469</td>
<td>0.37898</td>
<td>311</td>
</tr>
<tr>
<td>419A</td>
<td>11</td>
<td>1.62682</td>
<td>0.46252</td>
<td>89</td>
</tr>
<tr>
<td>419B</td>
<td>11</td>
<td>1.83894</td>
<td>0.57181</td>
<td>106</td>
</tr>
<tr>
<td>420A</td>
<td>10</td>
<td>1.80882</td>
<td>0.61032</td>
<td>56</td>
</tr>
<tr>
<td>420B</td>
<td>9</td>
<td>1.41887</td>
<td>0.45916</td>
<td>93</td>
</tr>
</tbody>
</table>

**FOREBAR LOCALITY**

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>082</td>
<td>13</td>
<td>1.38381</td>
<td>0.30693</td>
<td>278</td>
</tr>
<tr>
<td>084</td>
<td>9</td>
<td>1.34817</td>
<td>0.42782</td>
<td>267</td>
</tr>
<tr>
<td>421</td>
<td>14</td>
<td>1.66394</td>
<td>0.37715</td>
<td>304</td>
</tr>
<tr>
<td>422</td>
<td>13</td>
<td>1.79640</td>
<td>0.46369</td>
<td>301</td>
</tr>
<tr>
<td>423</td>
<td>16</td>
<td>1.57731</td>
<td>0.30262</td>
<td>282</td>
</tr>
<tr>
<td>424</td>
<td>12</td>
<td>1.29545</td>
<td>0.30439</td>
<td>277</td>
</tr>
<tr>
<td>425</td>
<td>12</td>
<td>1.53481</td>
<td>0.38670</td>
<td>265</td>
</tr>
<tr>
<td>426</td>
<td>14</td>
<td>1.53054</td>
<td>0.33005</td>
<td>277</td>
</tr>
<tr>
<td>427</td>
<td>10</td>
<td>1.27564</td>
<td>0.35810</td>
<td>284</td>
</tr>
<tr>
<td>428</td>
<td>11</td>
<td>1.36265</td>
<td>0.35514</td>
<td>288</td>
</tr>
<tr>
<td>429</td>
<td>16</td>
<td>1.73297</td>
<td>0.35359</td>
<td>285</td>
</tr>
<tr>
<td>430</td>
<td>15</td>
<td>1.59250</td>
<td>0.32774</td>
<td>274</td>
</tr>
<tr>
<td>431</td>
<td>13</td>
<td>1.88740</td>
<td>0.50786</td>
<td>288</td>
</tr>
<tr>
<td>432</td>
<td>14</td>
<td>1.72118</td>
<td>0.39937</td>
<td>288</td>
</tr>
<tr>
<td>433</td>
<td>11</td>
<td>1.65930</td>
<td>0.47778</td>
<td>318</td>
</tr>
<tr>
<td>434</td>
<td>12</td>
<td>1.70497</td>
<td>0.45844</td>
<td>321</td>
</tr>
<tr>
<td>498</td>
<td>17</td>
<td>1.46347</td>
<td>0.25417</td>
<td>303</td>
</tr>
<tr>
<td>500</td>
<td>15</td>
<td>1.56632</td>
<td>0.31927</td>
<td>278</td>
</tr>
<tr>
<td>501</td>
<td>12</td>
<td>1.65343</td>
<td>0.43541</td>
<td>271</td>
</tr>
</tbody>
</table>

**STAKE ISLAND BARRIER ISLAND LOCALITY**

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>070A</td>
<td>10</td>
<td>1.64175</td>
<td>0.51642</td>
<td>70</td>
</tr>
<tr>
<td>070B</td>
<td>9</td>
<td>1.35568</td>
<td>0.43104</td>
<td>71</td>
</tr>
<tr>
<td>083A</td>
<td>11</td>
<td>1.52356</td>
<td>0.41714</td>
<td>263</td>
</tr>
<tr>
<td>083B</td>
<td>10</td>
<td>1.35344</td>
<td>0.38707</td>
<td>276</td>
</tr>
<tr>
<td>085A</td>
<td>5</td>
<td>0.78932</td>
<td>0.44038</td>
<td>45</td>
</tr>
<tr>
<td>085B</td>
<td>8</td>
<td>1.27347</td>
<td>0.44665</td>
<td>46</td>
</tr>
<tr>
<td>097A</td>
<td>15</td>
<td>1.94683</td>
<td>0.46709</td>
<td>110</td>
</tr>
<tr>
<td>097B</td>
<td>13</td>
<td>1.84694</td>
<td>0.48772</td>
<td>133</td>
</tr>
<tr>
<td>123A</td>
<td>3</td>
<td>1.03972</td>
<td>0.94281</td>
<td>4</td>
</tr>
<tr>
<td>123B</td>
<td>7</td>
<td>1.39063</td>
<td>0.57391</td>
<td>27</td>
</tr>
<tr>
<td>SAMPLE</td>
<td>S</td>
<td>H(S)</td>
<td>E</td>
<td>N</td>
</tr>
<tr>
<td>--------</td>
<td>----</td>
<td>-------</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>124A</td>
<td>13</td>
<td>1.57402</td>
<td>0.37123</td>
<td>98</td>
</tr>
<tr>
<td>124B</td>
<td>12</td>
<td>1.86165</td>
<td>0.53620</td>
<td>47</td>
</tr>
<tr>
<td>128A</td>
<td>16</td>
<td>1.86506</td>
<td>0.40352</td>
<td>269</td>
</tr>
<tr>
<td>128B</td>
<td>17</td>
<td>1.74870</td>
<td>0.33808</td>
<td>274</td>
</tr>
</tbody>
</table>
from some of these samples. The Breton Island samples with low counts were generally subaerial beach samples (435, 436, 437, 507, 508 and 509) and post-mortem alteration or dilution of the fauna may have affected the assemblage thus lowering the S values. Subaerial samples from Stake Island (085 and 123) also exhibited the lowest S values for samples from that locality.

Gibson (1966) noted that a highly variable environment, influenced by extreme conditions, generally has low species diversity values. Barrier islands are generally considered to be highly variable environments, but samples with marsh fauna (503-506) from Breton Island and very shallow water samples from Stake Island have S values that are similar to the shallow marine samples from the area. This indicates similarity in environmental conditions over the study area. S values are slightly higher in the forebar locality, seaward of the Breton Island, therefore open water circulation may have some influence on these samples.

The values for species diversity, H(S), show trends similar to those of S. Overall, H(S) values are fairly constant in much of the study area. Values are again slightly lower from the Breton Island barrier island locality.

The equitability values, E, exhibits a wide range. This is primarily due to the high E values (0.73 to 1.0) in some subaerial beach samples from the Breton and Stake Island barrier island localities which have a low number of specimens and species. Since E is a measure of the distribution of individuals of species within a sample, those with a low number of species and specimens would be
expected to have high E values (Gibson and Buzas, 1973). If the
subaerial beach samples are excluded, there is similarity in E values
(0.25 to 0.62) throughout the study area. When only the marsh samples
from the Breton Island barrier island locality (503-506) are
considered, the average E value is 0.42 rather than 0.60; this is
probably a more realistic value because samples with only a few
specimens, therefore high E values, are not included. The lower E
values for samples from the forebar locality may reflect the dominance
of Ammonia beccarii and generally the slightly higher number of
species within these samples.

In their study of species diversity patterns in the Gulf of
Mexico, Gibson and Buzas (1973) reported values of S, H(S) and E off
the Mississippi and Rio Grande Deltas between water depths of zero and
100m. Their S values averaged 10.8 and ranged from five to 19; H(S)
values averaged 1.42 and ranged from 0.62 to 2.20; E values averaged
0.43 and ranged from 0.30 to 0.62. The values observed in this work
are consistent with their results.

II. Core Samples

Sixteen core samples were excluded from the analysis since they
contained no foraminifera or thecamoebians. Few microfossils were
present in most of the remaining samples from the core, therefore only
S values are discussed because any statistical analysis would be
meaningless.

Three groups were recognized in the core and are treated
separately: recent foraminiferal species S(f), fossil foraminiferal
species of Cretaceous and Tertiary age S(ff) and recent thecamoebians S(t). Values of S(f) ranged from zero to five; S(ff) values ranged from zero to two; S(t) values ranged from zero to four. Table 2 lists the values of S(f), S(ff) and S(t) for samples from core BB92. The values for the sample sites from the core are plotted in Figure 16.

The plot shows an overall decrease in species diversity of S(f) up the core and an increase in S(t) at the very top of the core. Low but consistent values of S(ff) characterize the middle section of the core. The overall decrease in species diversity of recent foraminifera S(f) up the core with a concomitant decrease in total numbers of these is probably in response to the environment becoming less saline. Indeed, freshwater influence is indicated by the higher values of S(t) in the two highest samples. The absence of thecamoebians below 430cm suggests that there was no freshwater influence to the area during the deposition of these sediments. The presence of fossil foraminifera in the central portion of the core indicates a period of availability of reworked Cretaceous and Tertiary foraminifera.

B. Cluster Analysis

Benthic foraminiferal assemblages were analyzed using Q-mode and the unweighted pair group method (Mello and Buzas, 1968). Because cluster analysis groups the data, the clusters represent biostratigraphically recognizable units (Sokal and Sneath, 1963) which can also be considered as biofacies (Buzas, 1969). If no groups are recognized in the dendrogram, it can be assumed that distinct
Table 2. Values for the number of species of recent foraminifera, \( S(f) \), fossil foraminifera \( S(ff) \), and thecamoebians, \( S(t) \) in core BB92. \( N(f) \), \( N(ff) \) and \( N(t) \) represents the number of specimens of recent foraminifera, fossil foraminifera, and thecamoebians respectively, picked from each sample.
<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>S((f))</th>
<th>S((t))</th>
<th>S((ff))</th>
<th>N((f))</th>
<th>N((t))</th>
<th>N((ff))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>1</td>
<td>4</td>
<td></td>
<td>19</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>19-20</td>
<td>1</td>
<td>4</td>
<td></td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>39-40</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59-60</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>79-80</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>99-100</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120-121</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>130-131</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150-151</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>170-171</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>190-191</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>220-221</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>240-241</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>260-261</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>280-281</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>310-311</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>330-331</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>350-351</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>370-371</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>390-391</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>410-411</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>430-431</td>
<td></td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>450-451</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>470-471</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>490-491</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>510-511</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>530-531</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>560-561</td>
<td>4</td>
<td></td>
<td></td>
<td>269</td>
<td></td>
<td></td>
</tr>
<tr>
<td>580-581</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>267</td>
<td></td>
</tr>
<tr>
<td>599-600</td>
<td>5</td>
<td>1</td>
<td>279</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>620-621</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>264</td>
<td></td>
</tr>
<tr>
<td>660-661</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>680-681</td>
<td>barren</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>699-700</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>720-721</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>740-741</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>208</td>
<td></td>
</tr>
<tr>
<td>759-760</td>
<td>5</td>
<td>1</td>
<td>84</td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Figure 16. Plot of the number of species of recent foraminifera $S(f)$, thecamoebians $S(t)$ and fossil foraminifera in core BB92. $N$ represents the total number of specimens picked from each sample. The environmental interpretations are those of Kosters (1987), based on lithological data.
VIBRACORE BB92/72CM COMPACTION

ORGANIC MATTER

MARSH AND SWAMP

CENTRAL INTERDISTRIBUTARY BAY

LOWER INTERDISTRIBUTARY BAY

N

S(I) S(I) S(II)
biofacies are not present or the clustering technique could not detect subtle patterns within the data set.

In this work cluster analyses were performed, using the Jaccard coefficient of similarity, on the presence/absence foraminiferal and thecamoebian data of the surface samples, core samples and the combined data set of surface and core samples. Similar analyses were performed using the Bray-Curtis coefficient of similarity on the transformed abundance data. Cluster analyses were undertaken to determine if biofacies could be defined using the presence/absence or the relative abundance of species. The dendrograms for the presence/absence cluster of core samples and the presence/absence cluster of combined surface and core samples showed no distinct groups. This results from a close similarity of assemblages in all samples, particularly in the core. The presence/absence cluster of core samples and the presence/absence cluster of combined surface and core samples are not discussed further.

Results of the Q-mode cluster analysis using benthic foraminiferal and thecamoebian presence/absence and transformed percentage data are shown in the following dendrograms. Sample interval numbers correspond to depths in centimeters from the core. Any sample number beginning with a nine indicates it is a replicate surface sample. In the analyses all samples containing at least one foraminifera or thecamoebian were included. Sixteen core and six surface samples were excluded from the analyses since they contained no foraminifera or thecamoebians.
I. Surface Samples

The dendrogram for the presence/absence cluster analysis using the Jaccard coefficient (Figure 17) shows two main groups, A, composed of 78 samples and, B, composed of 11 samples. Further evaluation of the dendrogram revealed that group A could be subdivided into two subgroups A(a) and A(b). Twenty-one remaining samples were added stepwise to these subgroups. Group A was composed of all samples from the forebar (2), back island lagoon (3) and Stake Island barrier island (4) localities and included seven samples from the Breton Island barrier island (1) locality. The samples in group A are primarily an Ammonia/Elphidium fauna which has been interpreted by many authors (e.g., Parker et al., 1953; Phleger, 1954; Poag, 1981; Culver and Buzas, 1981) to be indicative of shallow marine depths (<100m) in the Gulf of Mexico. Both subgroups A(a) and A(b) contain an Ammonia beccarii/Elphidium species assemblage. Subgroup A(a) is composed of 36 samples, generally with lower species diversity than the 21 samples in subgroup A(b). Subgroup A(a) is composed of 25 samples from the back island lagoon locality (3), the remainder being four samples with lower species diversity from the forebar locality (2) and seven samples with higher species diversity from the Stake Island barrier island locality (4). Subgroup A(b) is composed of 14 samples from the forebar locality (2), the remainder being six samples with higher species diversity from the back island lagoon locality (3) and one sample from the Stake Island barrier island locality (4).

Twenty-one samples are added stepwise to subgroups A(a) and A(b). Within these 21, six samples (083, 9099, 099, 9083, 437 and 9437 from
Figure 17. Dendrogram illustrating results of the cluster analysis performed on presence-absence data of surface samples using the Jaccard coefficient.
the Breton (1) and Stake Island barrier island (4) localities) form subgroup A(c). These samples were dominated by specimens of *Quinqueloculina*, with subsidiary specimens of *Ammonia beccarii* and *Elphidium gunteri*. *Haynesina germanica*, a low salinity shallow water foraminifera (Banner and Culver, 1978) was present in five of these samples. Samples 083, 9099, 099 and 9083 were collected from very shallow water beach stations, while 437 and 9437 were subaerial beach samples. Parker et al. (1953) reported high frequencies of miliolids in some beach samples from the San Antonio Bay area.

Group B contained 11 samples from the Breton Island barrier island locality (1). The generic assemblages in these samples is composed of *Ammocastuta*, *Ammobaculites*, *Ammotium*, *Arenoparrella*, *Haplophragmoides*, *Miliammina*, *Tiphotochre* and *Trocchammina*, all of which have been typically recorded in marshes (Phleger, 1965a, 1965b; Scott and Medioli, 1980b).

Results of the presence/absence cluster analysis indicate that the study area is dominated by an *Ammonia/Elphidium* biofacies (Biofacies A(a) and A(b)) (Figure 18). Assemblages at the eastern end of Breton Island are dominated by marsh taxa (Biofacies B). Two sample sites from Breton Island and one from Stake Island are dominated by a miliolid fauna (Biofacies A(c)).

The cluster analysis using the Bray-Curtis coefficient on the standardized abundance data (Figure 19) shows two main groups composed of the same samples that defined the two major groups in the presence/absence analysis. Evaluation of the dendrogram revealed that group A could be subdivided into two subgroups, A(a) composed of 44
Figure 18. Distribution of biofacies within the study area based on results of presence/absence data cluster analysis of surface samples. Part A is the Breton Island area, part B is the Stake Island area.
ISLAND LIMITS

SAMPLE STATIONS

* BACK ISLAND LAGOON "NORTH TRAVERSE"
* BACK ISLAND LAGOON "SOUTH TRAVERSE"
* BARRIER BAR
* FORE BAR

A

B

BIOFACIES A(a) & A(b)
BIOFACIES A(c)
BIOFACIES B
Figure 19. Dendrogram illustrating results of the cluster analysis performed on transformed abundance data of surface samples using the Bray-Curtis coefficient.
samples, and A(b) composed of 19 samples. Fifteen remaining samples were added stepwise to subgroups A(a) and A(b).

All samples from the back island lagoon locality, with the exception of sample 416A, are included in subgroup A(a). Also included are seven samples from the Stake Island barrier island locality (4). Subgroup A(a) samples contain an assemblage with greater percentages (group averages in parentheses) of Elphidium gunteri (30%) than Elphidium excavatum (4%), approximately equal percentages of Elphidium mexicanum (8%) and Elphidium poeyanum (8%) with total percentages of Elphidium species (50%) greater than Ammonia beccarii (40%). Species diversity (S) varies from eight to 19 throughout this set of samples.

Cluster group A(b) contained all 19 samples from the forebar locality and clustered at the 0.80 level of similarity. The assemblage in this set of samples has higher percentages (group averages in parentheses) of Elphidium excavatum (18%) than Elphidium gunteri (7%), percentages of Elphidium poeyanum (10%) were generally greater than Elphidium mexicanum (6%) while the total percentage of Elphidium species (38%) was lower than that of Ammonia beccarii (52%). Parker et al. (1953) reported similar assemblages in their bay and open gulf biofacies in San Antonio Bay and surrounding areas as did Phleger (1954) in the open gulf facies in the Mississippi Sound area.

Within the 15 remaining samples added stepwise to subclusters A(a) and A(b) there are two further discrete groupings. Four samples (9085, 124, 9123 and 085 from the Stake Island barrier island locality (4)) form subgroup A(c). These samples all have high percentage of
**Elphidium gunteri** (>50%). Subgroup A(d), composed of six samples, is identical to group A(c) identified in the presence/absence cluster analysis; the samples contain abundant miliolids (57-87%).

Group B is composed of the same samples that comprise group B in the presence/absence analysis. These samples are characterized by the marsh assemblage identified in the presence/absence analysis (**Ammoastuta**, **Ammobaculites**, **Ammotium**, **Arenoparrella**, **Haplophragmoides**, **Miliammina**, **Tiphotrecha** and **Trochammina**). Within group B, replicate pairs cluster side by side, which indicates considerable homogeneity at each sample station. The foraminiferal faunas recovered from the surface samples can be compared with the generic predominance facies outlined by Poag (1981) in the Gulf of Mexico. Poag (1981) characterized his predominance facies as having a particular genus predominant in a certain area. Poag (1981, p. 21) stated "...from the lower parts of the estuaries into the inner sublittoral realm of the open Gulf...the **Ammonia** predominance facies is continuous from the tip of Florida to Laguna de Terminos, except for a brief interruption at the Mississippi Delta." The two predominant genera recognized in the shallow marine samples in this study were **Ammonia** and **Elphidium**. These results further refine Poag's (1981) predominance facies distribution in the Breton and Stake Island area. There are samples from the back island lagoon locality where **Elphidium** predominates, although this locality is in Poag's **Ammonia** predominance facies. Therefore, Poag's **Ammonia** predominance facies is not continuous, at least in the study area.
The presence/absence cluster analysis groups most of the samples with the Ammonia-Elphidium dominant assemblage into one large group. Although this major group can be subdivided, the localities from which the samples were collected are not distinct in the subgroups. However, using the standardized percentage data (Figure 20), both the back island lagoon (Biofacies A(a)) and forebar (Biofacies A(b)) localities are separated into distinct biofacies. This indicates that although there is a similar faunal assemblage in the shallow marine area of this study, proportions of the species are important in identifying the subenvironments. Both the presence/absence and abundance data analysis, however, identify the marsh biofacies and separate the samples dominated by miliolids. In figure 20, the Elphidium gunteri (Biofacies A(c)), miliolid (Biofacies A(d)) and marsh (Biofacies B) biofacies are also plotted.

II. Core Samples

The cluster analysis using the Bray-Curtis coefficient on the transformed percentage data (Figure 21) produced a dendrogram composed of three groups and a single sample that did not cluster. The cluster groups are shown according to their stratigraphic location down the core in Figure 22. Group A, between 220 and 451cm, is composed of seven samples containing between one and 14 microfossils, both foraminifera and thecamoebians. Either Globigerinelloides sp. A or Heterohelix sp. A were present in most of these samples, specimens of Centropyxis aculeata in two samples (330-331 and 430-431), and few specimens of Ammonia beccarii, Haynesina germanica or Elphidium.
Figure 20. Distribution of biofacies within the study area based on results of transformed abundance data cluster analysis of surface samples. Part A is the Breton Island area, part B is the Stake Island area.
ISLAND LIMITS

SAMPLE STATIONS

- BACK ISLAND LAGOON "NORTH TRAVERSE"
- BACK ISLAND LAGOON "SOUTH TRAVERSE"
- BARRIER BAR
- FORE BAR

BIOFACIES

- A(a)
- A(b)
- A(c)
- A(d)
- B
Figure 21. Dendrogram illustrating results of cluster analysis performed on transformed abundance data of core samples using the Bray-Curtis coefficient.
BRAY-CURTIS COEFFICIENT OF SIMILARITY—UNWEIGHTED PAIR GROUP METHOD

GROUP A

220-221
240-241
310-311
280-281
450-451
330-331
430-431

GROUP B

56
660-661
740-741
599-600
580-581
620-621
560-561
759-760
699-700
720-721
190-191
350-351
470-471

GROUP C

19-20
0-1
Figure 22. A plot of cluster groups of core samples obtained using the Bray-Curtis coefficient. The environmental interpretations are those of Kosters (1987), based on lithologic data.
gunteri in four samples. The presence of the fossil forms (Heterohelix sp. A and Globigerinelloides sp. A) in most of the samples indicates there was redeposition of Cretaceous and Tertiary sediment into this area. Thecamoebians indicate freshwater input (Haman, 1982; Medioli and Scott, 1983). The few recent benthic foraminifera may also have been transported to the area, or, conditions may have been suitable to support a small foraminiferal population of restricted character as indicated by the presence of H. germanica.

Group B contains eleven samples. All of the samples from below 560cm in the core as well as two samples above 350cm are included in this group. The samples below 560cm generally contained abundant specimens of Ammonia beccarii and few specimens of Elphidium excavatum, E. gunteri and Haynesina germanica. The sediment was composed largely of shell fragments. The high percentages of Ammonia beccarii indicates a marginal marine environment (Murray, 1976). Haynesina germanica is indicative of shallow, low salinity environments (Banner and Culver, 1978). The two samples from above 350cm in the core also included in this cluster group had low total numbers of foraminifera.

The third cluster group (C) is composed of samples 0-1 and 19-20. These samples contain relatively high numbers of thecamoebians and the foraminiferal species Haplophragmoides manilaensis. This assemblage indicates a brackish water marsh (Andersen, 1953; Scott, 1986).

The assemblages which define cluster groups up the core change from a group with high numbers of recent foraminifera to one dominated
with the amoebians. This indicates the environment represented by the core became less saline through time and concurs with the environmental interpretations based on lithologic character.

III. Core and Surface Samples

Results of cluster analysis on standardized percentage data using the Bray-Curtis coefficient revealed the most information for both core and surface samples. In an attempt to environmentally classify core samples using the surface samples as a model data set, this mode of analysis was performed on the combined core and surface sample data set. Results of the cluster analysis are shown in Figure 23. Eight cluster groups are recognized in the combined analysis which compare favorably with a total of eight groups identified in the individual analyses (Figures 19 and 21).

Major cluster groups of surface samples remained almost unchanged from analysis to analysis. However, core samples, in general, clustered separately from surface samples. Hence, there is little similarity between core and surface samples. This also suggests differences between the depositional environments represented by the core and the present environments in the Breton and Stake Island area. The surface samples represent a marginal marine environment containing assemblages of moderate species diversity, dominated by an Ammonia-Elphidium fauna. Although the bottom of the core also represents a marginal marine environment, it probably represents salinities lower than the present Breton and Stake Island area because the core faunal assemblage is one of very low diversity that is dominated by Ammonia
Figure 23. Dendrogram illustrating results of cluster analysis performed on transformed abundance data of combined surface and core samples using the Bray-Curtis coefficient.
beccarii. In contrast, the assemblage at the top of the core indicates fresh to brackish conditions.

In comparison to the individual surface and core sample cluster analyses, three surface and one core sample were reclassified in this analysis. Samples 509 and 9509 from the Breton Island barrier island locality clustered in group A with core samples with very high percentages of Ammonia beccarii. A single specimen of A. beccarii was identified in sample 509, while a single specimen each of A. beccarii and Haplophragmoides sp. A was identified in sample 509B. Sample 435 from the Breton Island barrier island locality was paired with sample 470-471 from the core. Both of these samples are dominated by Haynesina germanica although only five and one foraminifera respectively were identified in these samples. Core sample 330-331, with one specimen each of A. beccarii and Centropyxis aculeata was reclassified from group A in the core analysis which corresponds to group D in the combined analysis, into group A in the combined analysis.

The cluster groups and the within group patterns on all the dendrograms do not display clearly defined centers but generally have samples added in a stepwise manner. Sokal and Sneath (1963) stated that this was a problem using the unweighted pair group method since the similarity coefficient of a sample is compared to the averaged similarity coefficients of previously added samples. Although this problem exists it eliminates the problem of late entries influencing the similarity measure of the cluster (Hazel, 1977). In the present study the stepwise addition of samples indicates that the taxonomic
composition of assemblages is similar throughout the area. However, the percentage contribution of individual species varies resulting in some discrimination of samples when abundance data are utilized in comparisons.

C. Discriminant Analysis

Discriminant analysis was used to analyze the physical and chemical parameters of the samples from the four localities. Analyses completed were for variables at the sediment surface-water interface and approximately 2cm above the sediment surface-water interface. The four localities were chosen as the groups because upon examination of the biofacies from the cluster analysis of transformed abundance data, four of five biofacies were generally restricted to a particular locality. Therefore the various localities may have distinct environmental conditions. The discriminant analyses test the hypothesis that the four localities are distinct on the basis of the measured environmental variables.

In the first run all nine variables measured at the sediment surface-water interface were included in the analysis (Appendix 1). These variables were depth, temperature (TEMP), salinity (SAL), Eh, pH, percentages of: medium sand (MSND), fine sand (FSND), very fine sand (VFSND) and silt and clay (SILTCL). Only samples where there were values for all variables were used. The groups were Breton Island barrier island locality (1), forebar locality (2), back island lagoon
locality (3), and Stake Island barrier island locality (4). Table 3 shows the group means of the measured variables.

In this analysis, 100% of the variability is accounted for by the first three canonical discriminant functions (Table 4). The means for these canonical discriminant functions are presented in Table 5 and plotted in Figures 24 and 25. All four localities are statistically significant at the $p = 0.01$ level. When 95% confidence circles are plotted about these group means (Figures 24, 25), none intersect.

By analyzing the standardized canonical discriminant function coefficients, Table 6, the variable(s) contributing to the separation of the groups may be identified. Along canonical discriminant function (CDF) 1, which accounted for 83.71% of the variance, depth seems responsible for grouping the four localities into two groups: the deepest water group (2 and 3) and shallower water group (1 and 4). The percentage of medium sand is a primary discriminator for statistically differentiating localities within these major groups. The percentage of fine sand is also used to distinguish statistically significant differences within these two major groupings along CDF 1.

From the group means (Table 3), the forebar (2)(3.04m) and back island lagoon (3)(2.13m) are the deepest with little difference in depth between Breton (1)(0.27m) and Stake (4)(0.16m) Island barrier island localities. Highest percentages of medium sand are from the Breton Island barrier island locality (1)(11.4%) with little difference (2.2% to 4.1%) in the other localities. The back island lagoon (3) and Breton Island barrier island (1) localities have the highest percentages of medium sand (69.6%) and (65.5%) respectively,
Table 3. Group means of physical and chemical parameters for samples from the sediment surface-water interface, including depth, for the four localities. Variable include depth, temperature (TEMP), salinity (SAL), Eh, pH, percentages of: medium sand (MSND), fine sand (FSND), very fine sand (VFSND) and silt and clay (SLTCL). The groups are sample localities (LOC): Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
GROUP MEANS

<table>
<thead>
<tr>
<th>LOC</th>
<th>DEPTH</th>
<th>TEMP</th>
<th>SAL</th>
<th>Eh</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.27417</td>
<td>31.08333</td>
<td>35.19667</td>
<td>-148.33333</td>
<td>7.87500</td>
</tr>
<tr>
<td>2</td>
<td>3.04300</td>
<td>29.40000</td>
<td>26.52900</td>
<td>-94.50000</td>
<td>7.98500</td>
</tr>
<tr>
<td>3</td>
<td>2.12842</td>
<td>30.10526</td>
<td>23.75789</td>
<td>-92.36842</td>
<td>8.36316</td>
</tr>
<tr>
<td>4</td>
<td>0.16143</td>
<td>30.14286</td>
<td>19.82571</td>
<td>-140.71429</td>
<td>8.45000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.56854</td>
<td>30.20833</td>
<td>26.62146</td>
<td>-113.85417</td>
<td>8.17500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOC</th>
<th>MSND</th>
<th>FSND</th>
<th>VFSND</th>
<th>SUTCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.41667</td>
<td>65.50000</td>
<td>2.50000</td>
<td>20.58333</td>
</tr>
<tr>
<td>2</td>
<td>2.20000</td>
<td>44.00000</td>
<td>14.20000</td>
<td>39.60000</td>
</tr>
<tr>
<td>3</td>
<td>4.10526</td>
<td>69.57895</td>
<td>5.15789</td>
<td>21.10526</td>
</tr>
<tr>
<td>4</td>
<td>3.42857</td>
<td>51.85714</td>
<td>3.14286</td>
<td>41.57143</td>
</tr>
<tr>
<td>TOTAL</td>
<td>5.43750</td>
<td>60.64583</td>
<td>6.08333</td>
<td>27.81250</td>
</tr>
</tbody>
</table>

64
Table 4. Canonical discriminant functions with the percentage of variability accounted for by the eigenvalues in the analysis of the physical and chemical parameters, including depth, from the sediment surface-water interface.
### Canonical Discriminant Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Eigenvalue</th>
<th>Percent of Variance</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.25579</td>
<td>83.71</td>
<td>83.71</td>
</tr>
<tr>
<td>2</td>
<td>1.24526</td>
<td>9.26</td>
<td>92.97</td>
</tr>
<tr>
<td>3</td>
<td>0.94513</td>
<td>7.03</td>
<td>100.00</td>
</tr>
</tbody>
</table>
Table 5. Canonical discriminant functions evaluated at group means (group centroids) in the analysis of the physical and chemical parameters, including depth, from the sediment surface-water interface. The groups are sample localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
**CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FUNCTION 1</th>
<th>FUNCTION 2</th>
<th>FUNCTION 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.36617</td>
<td>0.50048</td>
<td>0.89904</td>
</tr>
<tr>
<td>2</td>
<td>-4.67629</td>
<td>-0.46071</td>
<td>1.13794</td>
</tr>
<tr>
<td>3</td>
<td>-1.02916</td>
<td>0.78446</td>
<td>-0.87542</td>
</tr>
<tr>
<td>4</td>
<td>1.98900</td>
<td>-2.32904</td>
<td>-0.79070</td>
</tr>
</tbody>
</table>
Figure 24. Mean canonical discriminant functions 1 and 2 with 95% confidence circles for the four groups. Results of analysis of variables, including depth, at the sediment surface-water interface. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
Figure 25. Mean canonical discriminant functions 1 and 3 with 95% confidence circles for the four groups. Results of analysis of variables, including depth, at the sediment surface-water interface. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
Table 6. Standardized canonical discriminant function coefficients from the analysis of the physical and chemical parameters, including depth, from the sediment surface-water interface.
STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

<table>
<thead>
<tr>
<th></th>
<th>FUNCTION 1</th>
<th>FUNCTION 2</th>
<th>FUNCTION 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPTH</td>
<td>-1.03869</td>
<td>0.48748</td>
<td>-0.32948</td>
</tr>
<tr>
<td>SAL</td>
<td>0.19483</td>
<td>0.21316</td>
<td>0.42793</td>
</tr>
<tr>
<td>pH</td>
<td>-0.27769</td>
<td>-0.59803</td>
<td>-0.22029</td>
</tr>
<tr>
<td>MSND</td>
<td>1.07648</td>
<td>0.57538</td>
<td>0.75020</td>
</tr>
<tr>
<td>FSND</td>
<td>0.67198</td>
<td>1.10243</td>
<td>0.20655</td>
</tr>
<tr>
<td>VFSND</td>
<td>-0.21346</td>
<td>-0.19614</td>
<td>0.84054</td>
</tr>
</tbody>
</table>

69
followed by Stake Island barrier island (4) (51.9%) and forebar
(2) (44.0%) localities.

Along CDF 2, which accounted for 9.26% of the variance, the
percentage of fine sand is an important variable that helps
discriminate between all four localities. The percentage of medium
sand and pH also contribute to the separation along CDF 2. There are
significant differences in the percentage of medium sand, although pH
values are similar (7.9 to 8.5) between the four localities.

Along CDF 3, which accounted for 7.03% of the variance, groups 1
and 4 somewhat separated from groups 2 and 3. The percentages of very
fine sand and medium sand are the primary discriminators between two
larger groupings (1, 4 and 2, 3) as well as between localities within
these two larger groups. Breton (1) and Stake Island barrier island
(4) localities have the lowest percentages of very fine sand (2.5%)
and (3.1%) respectively, the forebar (2) (14.2%) and back island lagoon
(3) (5.2%).

Murray (1973, p. 169) stated "...depth in itself conceals a
variety of environmental parameters which individually may be
important controls of foraminiferid distribution." Many of the
environmental parameters in this study were included in his list.
Also, since depth was measured at four somewhat discrete intervals,
rather than along an increasing gradient, it was thought that this may
be influencing the separation of the groups. Therefore, it was
decided to run the analysis again, eliminating depth values. Group
means of the measured variables, without depth, are shown in Table 7.
Table 7. Group means of physical and chemical parameters for samples from the sediment surface-water interface, excluding depth, for the four localities. Variables include temperature (TEMP), salinity (SAL), Eh, pH, percentages of: medium sand (MSND), fine sand (FSND), very fine sand (VFSND) and silt and clay (SILT). The groups are sample localities (LOC): Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
## GROUP MEANS

<table>
<thead>
<tr>
<th>LOC</th>
<th>TEMP</th>
<th>SAL</th>
<th>Eh</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.08333</td>
<td>35.19667</td>
<td>-148.33333</td>
<td>7.87500</td>
</tr>
<tr>
<td>2</td>
<td>29.40000</td>
<td>26.52900</td>
<td>-94.50000</td>
<td>7.98500</td>
</tr>
<tr>
<td>3</td>
<td>30.10526</td>
<td>23.75789</td>
<td>-92.36842</td>
<td>8.36316</td>
</tr>
<tr>
<td>4</td>
<td>30.14286</td>
<td>19.82571</td>
<td>-140.71429</td>
<td>8.45000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>30.20833</td>
<td>26.62146</td>
<td>-113.85417</td>
<td>8.17500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOC</th>
<th>MSND</th>
<th>FSND</th>
<th>VFSND</th>
<th>SLUCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.41667</td>
<td>65.50000</td>
<td>2.50000</td>
<td>20.58333</td>
</tr>
<tr>
<td>2</td>
<td>2.20000</td>
<td>44.00000</td>
<td>14.20000</td>
<td>39.60000</td>
</tr>
<tr>
<td>3</td>
<td>4.10526</td>
<td>69.57895</td>
<td>5.15789</td>
<td>21.10526</td>
</tr>
<tr>
<td>4</td>
<td>3.42857</td>
<td>51.85714</td>
<td>3.14286</td>
<td>41.57143</td>
</tr>
<tr>
<td>TOTAL</td>
<td>5.43750</td>
<td>60.64583</td>
<td>6.08333</td>
<td>27.81250</td>
</tr>
</tbody>
</table>
In this analysis, 100% of the variance is again accounted for by the first three canonical functions (Table 8). In comparison to the canonical discriminant analysis including depth, CDF 2 now carries a larger percentage of variance at the expense of CDF 1 and CDF 3. Table 9 shows the means of the discriminant functions and are plotted in Figures 26 and 27. All four groups are statistically significant at the p = 0.01 level. When 95% confidence circles are plotted about these group means (Figures 26, 27), none intersect.

Along the first axis, which accounts for 78.35% of the variance, group 2 separates from groups 1, 3 and 4 because of high percentages of very fine sand. This coupled with a relatively high value of silt and clay separates group 2 from group 1 and allows groups 3 and 4 to plot in an intermediate position along CDF 1. Analysis of the standardized discriminant functions (Table 10) reveal percentages of silt and clay and very fine sand are the most important contributors with fine sand and pH contributing to a lesser extent. The similarity in pH values between groups also accounts for the intermediate position of groups 3 and 4.

Groups 3 and 4 plot near to each other and together are contrasted against groups 1 and 2 along the second axis which accounts for 17.47% of the variance. The percentages of silt and clay as well as fine sand are the two most important variables contributing to this statistical separation. Group 4 has a high percentage of silt and clay and a low percentage of fine sand and separates from group 3 which has an intermediate percentage of fine sand and a low percentage of silt and clay. Along CDF 3, which accounts for 4.17% of the
Table 8. Canonical discriminant functions with the percentage of variability accounted for by the eigenvalues in the analysis of the physical and chemical parameters, excluding depth, from the sediment surface-water interface.
### CANONICAL DISCRIMINANT FUNCTIONS

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>EIGENVALUE</th>
<th>PERCENT OF VARIANCE</th>
<th>CUMULATIVE PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.67367</td>
<td>78.35</td>
<td>78.35</td>
</tr>
<tr>
<td>2</td>
<td>1.04224</td>
<td>17.47</td>
<td>95.83</td>
</tr>
<tr>
<td>3</td>
<td>0.24896</td>
<td>4.17</td>
<td>100.00</td>
</tr>
</tbody>
</table>
Table 9. Canonical discriminant functions evaluated at group means (group centroids) in the analysis of the physical and chemical parameters, excluding depth, from the sediment surface-water interface. The groups are sample localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
### Canonical Discriminant Functions Evaluated at Group Means (Group Centroids)

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FUNCTION 1</th>
<th>FUNCTION 2</th>
<th>FUNCTION 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2.57773</td>
<td>-0.90847</td>
<td>-0.36544</td>
</tr>
<tr>
<td>2</td>
<td>3.52593</td>
<td>-0.81094</td>
<td>-0.21880</td>
</tr>
<tr>
<td>3</td>
<td>-0.27702</td>
<td>0.26288</td>
<td>0.57248</td>
</tr>
<tr>
<td>4</td>
<td>0.13382</td>
<td>2.00234</td>
<td>-0.61482</td>
</tr>
</tbody>
</table>
Figure 26. Mean canonical discriminant functions 1 and 2 with
95% confidence circles for the four groups.
Results of analysis of variables, excluding depth,
at the sediment surface–water interface. Circles
indicate localities: Breton Island barrier island
locality (1), forebar locality (2), back island
lagoon locality (3) and Stake Island barrier island
locality (4).
Figure 27. Mean canonical discriminant functions 1 and 3 with 95% confidence circles for the four groups. Results of analysis of variables, excluding depth, at the sediment surface-water interface. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
Table 10. Standardized canonical discriminant function coefficients from the analysis of the physical and chemical parameters, excluding depth, from the sediment surface-water interface.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Function 1</th>
<th>Function 2</th>
<th>Function 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAL</td>
<td>-0.16948</td>
<td>-0.43549</td>
<td>-0.36251</td>
</tr>
<tr>
<td>Eh</td>
<td>0.40703</td>
<td>0.04027</td>
<td>0.25887</td>
</tr>
<tr>
<td>pH</td>
<td>0.59617</td>
<td>0.48876</td>
<td>0.12020</td>
</tr>
<tr>
<td>FSND</td>
<td>0.69700</td>
<td>1.56291</td>
<td>0.52083</td>
</tr>
<tr>
<td>VFSND</td>
<td>1.05952</td>
<td>-0.25093</td>
<td>0.19334</td>
</tr>
<tr>
<td>SLTCL</td>
<td>1.27360</td>
<td>1.92822</td>
<td>-0.30015</td>
</tr>
</tbody>
</table>
variance, the percentage of fine sand is the primary discriminating factor, although there is little further contrasting of the groups.

Classification results of this run, without depth as a variable, were different than the first. Depth accounted for much of the variance in the first analysis, but in the second run, other variables account for the variance. In this second analysis the most important discriminating variable was the percentage of silt and clay, followed by percentages of very fine sand and fine sand. Variation in grain size then accounts for the differences between localities and gives a different grouping of localities than in the first analysis.

Since variations within the water mass itself may also affect the benthic foraminiferal assemblage (Murray, 1973), an analysis was also run on variables measured approximately 2cm above the sediment surface-water interface within the water mass. These variables were temperature (TEMP), salinity (SAL), Eh, pH, dissolved oxygen (OX), turbidity (TURB), and the concentration of calcium (CA), iron (FE), lead (PB), and silicon. The groups remained the same as in the previous analyses. Group means of the measured variables are presented in Table 11.

In this analysis, 100% of the variance is accounted for by the first three canonical discriminant functions (Table 12). The means for the three functions are shown in Table 13 and plotted in Figures 28 and 29. All four localities are statistically significant at the \( p = 0.01 \) level. When 95% confidence circles are plotted about these group means, none intersect for CDF 1 and CDF 2 (Figure 28) although
Table 11. Group means of physical and chemical parameters for water samples taken approximately 2cm above the sediment surface-water interface. Variables include temperature (TEMP), salinity (SAL), Eh, pH, dissolved oxygen content (OX), turbidity (TURB), concentrations of: calcium (Ca), iron (Fe), lead (Pb) and silicon (Si). The groups are sample localities (LOC): Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
### GROUP MEANS

<table>
<thead>
<tr>
<th>LOC</th>
<th>TEMP</th>
<th>SAL</th>
<th>Eh</th>
<th>pH</th>
<th>OX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.00000</td>
<td>17.09750</td>
<td>-227.50000</td>
<td>8.38000</td>
<td>7.36000</td>
</tr>
<tr>
<td>2</td>
<td>29.44444</td>
<td>24.82222</td>
<td>-96.11111</td>
<td>8.42778</td>
<td>4.98111</td>
</tr>
<tr>
<td>3</td>
<td>30.57895</td>
<td>20.15579</td>
<td>-76.57895</td>
<td>8.65000</td>
<td>8.41211</td>
</tr>
<tr>
<td>4</td>
<td>30.00000</td>
<td>18.56000</td>
<td>-128.00000</td>
<td>8.74000</td>
<td>6.47800</td>
</tr>
<tr>
<td>TOTAL</td>
<td>30.27027</td>
<td>20.74459</td>
<td>-104.59459</td>
<td>8.57892</td>
<td>7.20243</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOC</th>
<th>TURB</th>
<th>Ca</th>
<th>Fe</th>
<th>Pb</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.75000</td>
<td>275.50000</td>
<td>0.36750</td>
<td>0.26000</td>
<td>2.75000</td>
</tr>
<tr>
<td>2</td>
<td>3.77778</td>
<td>337.55556</td>
<td>0.42667</td>
<td>0.27778</td>
<td>3.00000</td>
</tr>
<tr>
<td>3</td>
<td>8.78947</td>
<td>349.73684</td>
<td>0.32316</td>
<td>0.14526</td>
<td>2.94737</td>
</tr>
<tr>
<td>4</td>
<td>27.60000</td>
<td>239.00000</td>
<td>0.31600</td>
<td>0.48800</td>
<td>3.40000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>11.51351</td>
<td>323.78378</td>
<td>0.35216</td>
<td>0.23622</td>
<td>3.00000</td>
</tr>
</tbody>
</table>
Table 12. Canonical discriminant functions with the percentage of variability accounted for by the eigenvalues in the analysis of the physical and chemical parameters from the water mass approximately 2cm above the sediment surface-water interface.
CANONICAL DISCRIMINANT FUNCTIONS

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>EIGENVALUE</th>
<th>PERCENT OF VARIANCE</th>
<th>CUMULATIVE PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.10396</td>
<td>57.98</td>
<td>57.98</td>
</tr>
<tr>
<td>2</td>
<td>4.39991</td>
<td>31.48</td>
<td>89.46</td>
</tr>
<tr>
<td>3</td>
<td>1.47296</td>
<td>10.54</td>
<td>100.00</td>
</tr>
</tbody>
</table>

80
Table 13. Canonical discriminant functions evaluated at group means (group centroids) in the analysis of the physical and chemical parameters from the water mass approximately 2cm above the sediment surface-water interface. The groups are sample localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
CANONICAL DISCRIMINANT FUNCTIONS EVALUATED
AT GROUP MEANS (GROUP CENTROIDS)

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FUNCTION 1</th>
<th>FUNCTION 2</th>
<th>FUNCTION 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-6.26639</td>
<td>-0.90856</td>
<td>-1.85058</td>
</tr>
<tr>
<td>2</td>
<td>1.31039</td>
<td>3.18266</td>
<td>-0.61970</td>
</tr>
<tr>
<td>3</td>
<td>1.53288</td>
<td>-1.56216</td>
<td>0.02322</td>
</tr>
<tr>
<td>4</td>
<td>-3.17053</td>
<td>0.93428</td>
<td>2.50769</td>
</tr>
</tbody>
</table>
Figure 28. Mean canonical discriminant functions 1 and 2 with 95% confidence circles for the four groups. Results of analysis of variables in the water mass. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
Figure 29. Mean canonical discriminant functions 1 and 3 with 95% confidence circles for the four groups. Results of analysis of variables in the water mass. Circles indicate localities: Breton Island barrier island locality (1), forebar locality (2), back island lagoon locality (3) and Stake Island barrier island locality (4).
there is slight overlap between groups 2 and 3 on CDF 1 and CDF 3 (Figure 29).

The first mean canonical discriminant function, which accounts for 57.98% of the variability, shows two major groupings of the localities occur. The first group is composed of localities 1 and 4 and the second group is composed of localities 2 and 3. The standard canonical discriminant function coefficients (Table 14) indicate turbidity and Eh are the primary discriminators between these two larger groupings (1, 4 and 2, 3) as well as between localities within these two major groups. pH and temperature act as discriminators between localities within each group.

The similar low turbidity and low Eh values of groups 2 and 3 resulted in very little separation of these groups along CDF 1. Turbidity values for the forebar (2) and back island lagoon (3) localities are (3.8) and (8.7) respectively, with corresponding Eh values of (-96) and (-77). In contrast, turbidity values for Breton (1) and Stake Island (4) barrier island localities are (21.8) and (27.6). Differences in Eh values between groups 1 (-228) and 4 (-128) results in separation of these groups and separation from the major group (2, 3) along CDF 1. Although the standardized canonical discriminant function coefficients (Table 14) indicate pH and temperature are discriminators, pH values range from 8.4 to 8.7 and temperature values range from 29.4 to 31.0, neither of which show much variation across the study area.

Along CDF 2, which accounts for 31.48% of the variance, groups 2 and 3 have the greatest statistical separation while groups 1 and 4
Table 14. Standardized canonical discriminant function coefficients from the analysis of the physical and chemical parameters from the water mass approximately 2cm above the sediment surface-water interface.
STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

<table>
<thead>
<tr>
<th></th>
<th>FUNCTION 1</th>
<th>FUNCTION 2</th>
<th>FUNCTION 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMP</td>
<td>0.72706</td>
<td>-0.04531</td>
<td>-0.66882</td>
</tr>
<tr>
<td>SAL</td>
<td>-0.19398</td>
<td>0.53863</td>
<td>-0.69297</td>
</tr>
<tr>
<td>Eh</td>
<td>1.24587</td>
<td>-0.08428</td>
<td>0.70271</td>
</tr>
<tr>
<td>pH</td>
<td>1.10628</td>
<td>0.71026</td>
<td>0.34182</td>
</tr>
<tr>
<td>OX</td>
<td>-0.47377</td>
<td>-1.28999</td>
<td>-0.07499</td>
</tr>
<tr>
<td>TURB</td>
<td>-1.61409</td>
<td>0.12293</td>
<td>0.49075</td>
</tr>
<tr>
<td>Ca</td>
<td>0.29112</td>
<td>0.40135</td>
<td>-0.29813</td>
</tr>
<tr>
<td>Fe</td>
<td>-0.22678</td>
<td>0.44667</td>
<td>-0.18897</td>
</tr>
<tr>
<td>Pb</td>
<td>-0.37915</td>
<td>0.12055</td>
<td>0.39551</td>
</tr>
<tr>
<td>Si</td>
<td>0.41078</td>
<td>0.14632</td>
<td>0.82002</td>
</tr>
</tbody>
</table>
are in close proximity to each other. Inspection of standardized canonical discriminant function coefficients indicate groups are separated along this axis because of significant differences in the concentration of dissolved oxygen, pH and salinity. Groups 2 and 3 are separated along this axis because of significant differences in oxygen and salinity values while groups 1 and 4, although somewhat separated have similar oxygen, salinity and pH values.

The forebar locality (2) has the lowest oxygen value (5.0) and the highest salinity (24.8%) of any of the localities. The back island lagoon locality (3) has the highest oxygen value (8.4) and an intermediate salinity (20.2%). Lowest salinities are observed at the Breton (1) and Stake Island (4) barrier island localities with values of (17.1%) and (18.6%) respectively. Oxygen values for these localities are (1)(7.4) and (4)(6.5).

Along CDF 3, accounting for 10.54% of the variability, contrasts group 1 with group 4 on the basis of silicon, Eh, salinity, and temperature. Groups 2 and 3 are not discriminated along this axis. Although the concentration of silicon was indicated to be the primary discriminator along this axis, values are very similar (2.75 to 3.40) throughout the four localities.

These data indicate there is a complex relationship among variables in the water mass. In contrasting the groups, based on variables within the water mass, more variables appear to be interrelated than at the sediment surface-water interface. This is indicated from this analysis where seven variables are considered to be primary discriminators in differentiating the localities. Although
there is similarity in values of variables in the study area, the interaction of all these variables causes very subtle changes in environments that are statistically significant and which cause subtle changes in the biofacies.
DISCUSSION

Analysis of the benthic foraminiferal assemblages by cluster analysis of presence/absence data indicated two distinct biofacies in the Breton and Stake Island area (Figure 17). Examination of the samples that are included within these groups show that the faunal assemblage of the two groups is quite different. One is composed of a marsh assemblage (Group B), the other a shallow water marine assemblage (Group A). Three subgroups within the shallow marine group of samples were recognized. One of these subgroups is dominated by miliolids (A(c)) while the other two are dominated by *Ammonia beccarii* and *Elphidium* species (A(a) and A(b)). Samples within subgroup A(a) generally have lower species diversity than those in subgroup A(b).

When samples from the cluster groups are plotted on a map of the study area (Figure 18), the marsh biofacies is restricted to Breton Island, the miliolid biofacies to both Breton and Stake Islands, and the subgroups within the *Ammonia beccarii/Elphidium* species biofacies are not restricted to a particular locality but cover most of the remaining area. Therefore, based on presence/absence results, three biofacies are recognized in the study area: a marsh biofacies, a miliolid biofacies and an *Ammonia beccarii/Elphidium* species biofacies.
When considering the dendrogram obtained by using the relative abundance of species (Figure 19), the same two major groups (A and B) as recognized in the presence/absence analysis were also defined. Four subgroups within the shallow marine group of samples were recognized. One of these subgroups, A(d), as in the presence/absence analysis, is dominated by miliolids. Average percentages of Elphidium species are greater than Ammonia beccarii for samples within subgroup A(a), average percentages of Ammonia beccarii are greater than Elphidium species for samples within subgroup A(b), whereas samples within subgroup A(c) are dominated by Elphidium gunteri.

When samples from the cluster groups are plotted on a map of the study area (Figure 20), all samples, save one, from the back island lagoon locality (3) are included within biofacies A(a), all of the samples from the forebar locality (2) are included within biofacies A(b), the Elphidium gunteri biofacies is restricted to Stake Island, the marsh biofacies is restricted to Breton Island and the miliolid biofacies to both Breton and Stake Islands. Therefore, based on transformed abundance data results, five biofacies are recognized in the study area: a marsh biofacies, a miliolid biofacies, an Ammonia beccarii/Elphidium species biofacies, an Elphidium species/Ammonia beccarii biofacies and a biofacies dominated by Elphidium gunteri.

Although there is some overlap of subgroups or biofacies on Stake Island (Figure 20), the biofacies are generally restricted to a single one of the four localities. Hence, canonical discriminate analyses were run using the four localities as "a priori" groups to see if they could be distinguished based on their physical and chemical variables.
Canonical discriminant analysis was run on three sets of variables and in each case the four locations separated from each other. The first case was on variables measured at the surface sediment-water interface, including depth as a variable. In this analysis all four groups were discriminated quite well along the first axis which accounted for most of the variance (Figure 24). The important contributing variables were the percentage of medium sand, depth and percentage of fine sand respectively. Along the two other canonical discriminant functions (Figure 25), pH was the only variable other than grain size that appeared to contribute much to the separation. This is somewhat surprising because the group means show there is little variation in pH values across the area. This result indicates that the localities can indeed be separated and the discrimination is based primarily on depth and grain size, particularly the percentage of medium sand.

A second canonical discriminant function analysis was conducted where depth was excluded as a variable. Again, the localities are significantly different from each other although there was less distinction between groups 3 and 4 (Figures 26, 27), the back island lagoon (3) and Stake Island barrier island (4) localities respectively. Again the discrimination was based on grain size although finer grain sizes contributed more to the separation.

Since both analyses show that these groups are significantly different from each other, the analyses complement the results of the cluster analysis using transformed abundance data. In the second canonical discriminant analysis, where depth was not a variable, the
most similarity was observed between the back island lagoon (3) and Stake Island barrier island (4) localities. This compares favorably with the cluster result (Figures 19, 20), where 37 of 38 samples from the back island lagoon locality and seven of 14 samples from the Stake Island barrier island locality clustered together, although there was still a small, but distinct cluster group from Stake Island. The forebar locality was distinct in both faunal characteristics (Figures 19, 20) and environmental variables (Figures 26, 27). The marsh biofacies was restricted to parts of Breton Island. The miliolid biofacies occurred on both Breton and Stake Islands. Canonical discriminant analysis shows the localities are significantly different from each other based on grain size characteristics. Therefore, species in the study area may exhibit substrate preferences.

A more complex interaction of variables was apparent when comparing localities based on the variables within the water mass. Again, the localities are significantly different from each other in the canonical discriminant analysis of these variables. The discrimination was based on statistical differences in temperature, salinity, Eh, pH, dissolved oxygen content, turbidity and the concentration of silicon in the water mass. Two major groupings of localities occur along the first canonical discriminant function (Figure 28). The first group is composed of Breton (1) and Stake Island barrier island (4) localities and the second group is composed of the forebar (2) and back island lagoon (3) localities. Turbidity and Eh were the primary discriminators between these two larger groups (1, 4 and 2, 3). Temperature and pH act as discriminators within each
major group although inspection of the group means for these variables (Table 11) show they have closely similar values. The forebar (2) and back island lagoon (3) localities have the greatest separation along the second axis which accounted for 31% of the variance. The primary discriminating variable along this axis was the concentration of dissolved oxygen with a contribution from pH and salinity. In comparing the group mean values for these three variables for the forebar (2) and back island lagoon (3) localities little variation in pH was observed. Salinity values were slightly higher in the forebar (2) locality (24.8%) than the back island lagoon (3) locality (20.2%). The dissolved oxygen average value for the forebar (2) locality was about half that of the back island lagoon (3) locality. Therefore, the amount of dissolved oxygen in the water mass and possibly salinity are considered to be important in distinguishing these two localities. Although there are some differences in values of the aforementioned variables among the four localities, Phleger and Bradshaw (1966) recognized considerable diurnal variations in these variables in a marine marsh from Mission Bay, California.

The differences in dissolved oxygen in the water mass may affect the assemblages present in these two localities. Inspection of the faunal assemblages show that the Back Island Lagoon locality contains higher percentages of Elphidium species than Ammonia beccarii whereas in the Forebar locality A. beccarii is dominant over Elphidium species. This may suggest that A. beccarii can better tolerate an oxygen depleted water mass. In laboratory studies it was found (Bradshaw, 1961) that A. beccarii could tolerate concentrations as low
as 1.2 ml/liter before this species experienced any detrimental affects. Bradshaw (1957) had earlier studied the reproduction of *A. beccarii* in the laboratory. *A. beccarii* reproduces only at salinities between 13% and 40% (Bradshaw, 1957). Therefore, the small salinity variation between the forebar (2) and back island lagoon (3) localities cannot be invoked to affect the distribution of *A. beccarii*. The values recorded (17.9% to 26.3%) are within the reproductive range documented by Bradshaw (1957).

Faunal assemblages identified in this work are similar to assemblages identified by Pfleger (1955) and Lankford (1959). In Pfleger's mixed zone (Figure 6) and Lankford's sound assemblage (Figure 7), common species included *Ammonia beccarii*, *Elphidium* species and *Ammotium salsum*. *A. salsum* was not common in the *Ammonia beccarii/Elphidium* biofacies in this study. It was recorded primarily in the marsh on Breton Island. This suggests there may have been changes in the faunal assemblage since the mid-1950's. A possible explanation for the decrease in abundance of *A. salsum* would be an increase in salinity. *A. salsum*, a typical marsh species (Scott and Medioli, 1980b) has also been recorded in bays and upper estuaries around the Gulf of Mexico (Poag, 1981). An increase in salinity could restrict its habitable environment.

In this study only one thecamoebian was identified from surface samples. Pfleger (1955) identified thecamoebians in many samples from his mixing zone. These differences in results may indicate changes in current patterns since the 1950's since the thecamoebians would likely be deposited out of suspension from river discharge.
A paleoenvironmental interpretation of the core based on microfossils is tentative due to the few specimens present. Overall the microfossil data agree with lithological data and indicate that the environment has become less saline through time as reflected in the change in assemblages from one dominated by foraminifera to one dominated by thecamoebians.
CONCLUSIONS

Foraminiferal analysis of samples from the Breton and Stake Island area, northern Gulf of Mexico, indicate that most of the study area is very similar based upon benthic species diversity patterns. Cluster analysis based on both the presence/absence and relative abundance of species revealed two distinct groups or biofacies. One group is composed of a marsh assemblage, the other a shallow water marine assemblage.

Based on presence/absence results, the shallow marine biofacies was divided into three subgroups, one dominated by miliolids and the other two dominated by Ammonia beccarii and Elphidium species. The marsh biofacies was restricted to Breton Island. The miliolid subgroup was found both on Breton and Stake Islands. The two subgroups dominated by Ammonia beccarii/Elphidium species were not restricted to a particular locality but covered most of the remaining study area.

Based on transformed abundance data, the shallow marine assemblage was subdivided into four subgroups. One was dominated by miliolids, containing the same samples as the miliolid biofacies identified in the presence/absence analysis, the second by Elphidium gunteri, the third by Ammonia beccarii/Elphidium species with higher percentages of A. beccarii than Elphidium species, and the fourth, by Elphidium
species/Ammonia beccarii with higher percentages of Elphidium species than Ammonia beccarii. The Ammonia beccarii/Elphidium species subgroup was restricted to the forebar locality, the Elphidium gunteri subgroup was restricted to Stake Island, the Elphidium species/Ammonia beccarii subgroup was recorded predominantly in the back island lagoon locality and the miliolid subgroup was recorded on both Breton and Stake Islands. The marsh biofacies was restricted to Breton Island. The dominant Ammonia beccarii/Elphidium species biofacies identified in this work is similar in species present to Phleger's (1955) and Lankford's (1959) data from this area.

The four localities, Breton Island barrier island, forebar, back island lagoon and Stake Island barrier island localities are significantly different from each other based on canonical discriminant function analysis of physical and chemical variables at the sediment surface-water interface and in the water mass. Canonical discriminant function analysis of variables at the sediment surface-water interface indicate the four localities are significantly different from each other primarily on the basis of grain size composition. Contributions from medium, fine, and very fine sand and silt and clay were important in statistically separating the localities. Although pH was also indicated to be important in statistically separating the localities, all localities have closely similar pH values. Within the water mass, discriminant function analysis indicated that an interaction of many variables statistically separated the localities. The discrimination was based on statistical differences in temperature, salinity, Eh, pH, dissolved oxygen
content, turbidity and the concentration of silicon in the water mass. Primary discriminators, indicated by significantly different group mean values, are Eh, turbidity and dissolved oxygen content. Eh and turbidity statistically separate Breton and Stake Island barrier island localities from the forebar and back island lagoon localities. The concentration of dissolved oxygen appears to be particularly important in statistically separating the forebar and back island lagoon localities.

Therefore, because the aforementioned environmental variables statistically separate the localities, they probably affect foraminiferal distributions. The difference in the concentration of dissolved oxygen values in the forebar and back island lagoon localities is thought to affect the contrasting percentages of *Ammonia beccarii* and *Elphidium* species recognized in these two localities.

The microfossil assemblage within core BB92 indicates the environment has become less saline over the last 4000 years. There is a decrease in total number of recent foraminiferal species and specimens up the core and an increase in thecamoebian species and total numbers in the uppermost samples. Cluster analysis on combined core and surface data revealed no close similarity in environments represented by the core to those of the surface localities.
SYSTEMATIC PALEONTOLOGY

Generic names referred to in this section are organized within the classification system of Loeblich and Tappan (1964). Species within genera are arranged in alphabetical order. Each synonymy includes the original reference, those used in species identification as well as any generic changes for each species. A description for each recent species is given. For fossil specimens the occurrence is given but not a description of the species. Specimens were compared with type specimens and comparative material deposited at the National Museum of Natural History, Washington, D.C. and notes on the comparison are included in the remarks section where applicable. In the occurrence section the distribution of the species within the study area is recorded. The occurrences are listed within the informal sample collection sites of Haman (personal communication). Also included in this section are many published spatial distributions of the species primarily from ecological studies throughout the Gulf of Mexico. Illustrations of 47 of 57 species described in this section are included in Plates 1 to 3. This iconography does not illustrate the total variation present in each taxon.

The term "ab" as used by Medioli and Scott (1983) in this section refers to a specific name that was first published but not made available. Medioli and Scott (1983, p. 8) state ""Ehrenberg, 1832"
designates the work in which the epithet became available and is thus the valid authorship."

Order ARCELLINIDA Kent, 1880

Superfamily ARCELLACEA Ehrenberg, 1832

Family CENTROPYXIDAE Jung, 1942

Genus Centropyxis Stein, 1859

Centropyxis aculeata (Ehrenberg, 1832)

ab Ehrenberg, 1830

Plate 1, figure 1

Arcella aculeata EHRENBERG, 1832 (ab Ehrenberg, 1830, p. 60, nomen nudem), p. 91.


Description: Test almost circular in dorsal view, flattened; wall arenaceous, composed of very fine quartz grains giving it a smooth polished appearance, spines generally absent; aperture large, subcentral, almost circular, slightly invaginated.

Remarks: Haman (1982) and Medioli and Scott (1983) reported that there was a great variation in this species with regard to size of specimens and the development of spines. Most specimens from the study area lacked spines although the possible remnants of two spines are visible on the figured specimen. There was not a great size variation in the specimens observed in this study.
Occurrence: **Centropyxis aculeata** was rare but present in low numbers (19 specimens) in the top core sample (0-1cm). Single specimens of this species were present in three other core samples (19-20cm, 330-331cm and 430-431cm). In his study of the Balize Delta, Louisiana, Haman (1982) observed dead specimens of *C. aculeata* in channel and levee subenvironments. Dead specimens of his *Centropyxis ecornis* were found in levee and interdistributary bay subenvironments. Medioli and Scott (1983) stated that *C. aculeata* is not common in freshwater environments but in Atlantic Canada is commonly found fossilized in the transition between marine and lacustrine deposits in raised and submerged lakes. Scott (1986) reported assemblages containing between four and 74% *C. aculeata* in brackish marsh, 65% to 98% in freshwater marsh and between 55% and 90% in floating marsh samples from the lower Mississippi Delta. He stated this was the dominant species in freshwater and floating marsh samples and dominant or co-dominant in the brackish marsh samples.

**Centropyxis constricta** (Ehrenberg, 1843)

Plate 1, figure 2

*Arcella constricta* EHRENBERG, 1843, p. 410, pl. 4, fig. 35, pl. 5, fig. 1.

*Diffugia constricta* (Ehrenberg). LEIDY, 1879, p. 120, pl. 18, figs. 8-55.

*Centropyxis constricta* (Ehrenberg). DEFLANDRE, 1929, p. 340, text-figs. 60-67. HAMAN, 1982, p. 365, pl. 1, figs. 6-14. MEDIOLI and

Description: Test elliptical in dorsal view, slightly flattened, less so than in Centropyxis aculeata, with a profile raised posteriorly; wall chitinous, covered with some very minute quartz grains giving it a smooth polished appearance, spines absent; aperture invaginated, oval and is in the antero-marginal position.

Remarks: Haman (1982) and Medioli and Scott (1983) reported that this is a variable species in regards to size, shape, degree of compression and number of spines. Most specimens observed from the study area closely resembled the figured specimen, spines were absent on all specimens.

Occurrence: Centropyxis constricta was rare but present in low numbers (19 specimens) in the top core sample (0-1cm) and three specimens were observed in core sample 19-20cm. C. constricta was the only thecamoebian observed in any of the surface samples (one specimen was found in sample 429). Haman (1982) reported living specimens from an interdistributary bay subenvironment and dead specimens in channel, levee, interdistributary bay and distributary-mouth bar subenvironments. Medioli and Scott (1983) reported that this is a common species in all freshwater environments. Scott (1986) reported assemblages containing up to four percent of this species in some brackish marsh, up to 17% in some freshwater marsh and between one and 35% in floating marsh samples from the lower Mississippi Delta.
Family HYALOSPHERITIDAE Schulze, 1877

Genus Heleopera Leidy, 1879

Heleopera sphagni (Leidy, 1874)

**Diffugia (Nebela) sphagni** LEIDY, 1874, p. 157.

**Nebela sphagni** (Leidy). LEIDY, 1876, p. 118, text-figs. 16, 17.

**Heleopera sphagni** (Leidy). CASH and HOPKINSON, 1909, p. 143, pl. 30, figs. 4-9. MEDIOLI and SCOTT, 1983, p. 37, pl. 6, figs. 15-18.

**Description:** Test ovoid and laterally compressed; wall composed of fine grains near the aperture becoming slightly coarser at the fundus, test has an overall smooth appearance; aperture terminal, narrow and slit-like.

**Occurrence:** Only one specimen of *Heleopera sphagni* was recorded from the core (sample 0-1cm). Based on a literature review, Medioli and Scott (1983) reported that *H. sphagni* was common in *Sphagnum* swamps but it was rare in the samples they observed from Lake Erie. Scott (1986) reported two percent of this species in the assemblage from a floating marsh sample from the lower Mississippi Delta.

Family DIFFUGIIIDAE Wallich, 1864

Genus **Diffugia** Leclerc in Lamarck, 1816

**Diffugia oblonga** Ehrenberg, 1832

Plate 1, figure 3

**Diffugia oblonga** EHRENBERG, 1832, p. 90. EHRENBERG, 1838, p. 131, pl. 9, fig. 2. HAMAN, 1982, p. 367, pl. 3, figs. 19-25. MEDIOLI and SCOTT, 1983, p. 25, pl. 2, figs. 1-17, 24-26.
Description: Test oblong with a rounded fundus; wall composed of fine to coarse quartz grains; neck subcylindrical, long, tapers to a slightly oval terminal aperture.

Remarks: Medioli and Scott (1983) reported that this was an extremely variable species and included many forms in their synonymy.

Occurrence: Difflugia oblonga was very rare, single specimens of this species were observed in two core samples (0-1cm and 19-20cm). Haman (1982) reported living specimens from a levee subenvironment and dead specimens in channel, levee, interdistributary bay and distributary-mouth bar subenvironments. Medioli and Scott (1983) reported that this species is common in freshwater deposits. Scott (1986) recorded assemblages containing less than one percent D. oblonga in some brackish marsh, up to three percent in a few freshwater marsh and up to four percent in floating marsh samples from the lower Mississippi Delta.

Difflugia tricuspis Carter, 1856

Difflugia tricuspis CARTER, 1856, p. 221, pl. 7, fig. 80. MEDIOLI and SCOTT, 1983, p. 28, pl. 4, figs. 5-19.

Description: Test oval with no neck; wall composed of fine quartz grains, has a smooth appearance; aperture terminal, small, slightly crenulated.

Occurrence: Only one specimen of Difflugia tricuspis was recorded from the core (sample 19-20cm). Medioli and Scott (1983) stated that this species has commonly been reported from ponds, swamps or in moss at ponds. Scott (1986) reported assemblages containing less
than one percent in brackish marsh, up to two percent in a few freshwater and up to three percent in some floating marsh samples from the lower Mississippi Delta.

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Hérouard, 1896
Superfamily LITUOLACEA de Blainville, 1825
Family HORMOSINIDAE Haeckel, 1894
Subfamily HORMOSININAE Haeckel, 1894
Genus Reophax Montfort, 1808
Reophax nana Rhumbler, 1911

Reophax nana RHUMBLER, 1911, p. 182, pl. 8, figs. 6-12. PARKER, PHLEGER and PEIRSON, 1953, p. 13, pl. 1, fig. 11. LANKFORD, 1959, p. 2099, pl. 1, fig. 2. LANKFORD and PHLEGER, 1973, p. 127, pl. 1, fig. 4. SCOTT and MEDIOLI, 1980b, p. 43, pl. 2, fig. 6. BUZAS and SEVERIN, 1982, p. 22, pl. 1, fig. 1.

Description: Test elongate, tapering, increasing in width toward the apertural end; consists of uniserial chambers increasing in size; sutures slightly depressed; wall arenaceous composed of various sand sizes, some cement; aperture small, round, located at the terminal end of the final chamber.

Remarks: The specimens observed from the study area were all broken.

Occurrence: Reophax nana was very rare: single specimens were observed in three samples from the Breton Island barrier island locality (408A, 505B and 506A). Höglund (1947) reported R. nana to a depth of 85m in the Gullmar Fjord and to a depth of 400m in the
Skagerak. Parker et al. (1953) recorded this species in low frequencies in a few samples from brackish or nearshore areas from the San Antonio Bay area. Lankford (1959) reported low abundances of *R. nana* in deltaic marine, sound and open shelf environments in his study of the distribution of foraminifera from the east Mississippi Delta. Lankford and Phleger (1973) noted *R. nana* to be most common at nearshore depths of 12 to 30m although it also occurred in much shallower water along western North America. Scott and Medioli (1980b) reported low abundances in Chezzetcook Inlet, Chebogue Harbour and Wallace Basin marshes, Nova Scotia. Buzas and Severin (1982) reported a few specimens from the Indian River, Florida, which has a maximum water depth of 3.5m. Although there are reports of *R. nana* at depths of 400m (Höglund, 1947) it seems primarily to be a marsh or shallow water species. Scott (1986) reported assemblages containing up to four percent in a few marine marsh samples from the lower Mississippi Delta.

Genus *Sulcothax* Warren, 1957

*Sulcothax palustris* Warren, 1957

Plate 1, figure 4

*Sulcothax palustris* WARREN, 1957, p. 31, pl. 3, figs. 1-4.

Description: Test elongate, tapering, increasing in width gradually toward the apertural end; consists of uniserial chambers gradually increasing in size; sutures distinct; wall finely arenaceous with much cement giving the test a smooth appearance; aperture an elongate slit on the final chamber.
Remarks: Although the apertural end of the figured specimen is broken, the illustration shows the smooth appearance of the wall. This genus closely resembles *Reophax* but is distinguished by the terminal slit-like aperture.

Occurrence: Only two specimens of *Sulcopax palustris* were observed in sample 506A from the Breton Island barrier island locality. Warren (1957) reported that *S. palustris* is a rare marsh species. It was recorded only in marsh environments in Lankfords' (1959) study. Boltovskoy (1984) listed records of *S. palustris* in mangrove swamps from both Brazil and Ecuador.

Family RZEHAKINIDAE Cushman, 1933

Genus *Miliammina* Heron-Allen and Earland, 1930

*Miliammina fusca* (Brady, 1870)

Plate 1, figure 5

*Quinqueloculina fusca* Brady, 1870, p. 47, pl. 11, figs. 2, 3.


Description: Test elongate to somewhat elliptical; chambers distinct, arranged in quinqueloculine fashion; sutures distinct, somewhat depressed; wall arenaceous, composed of fine to medium sand grains with much cement, has a smooth appearance; aperture round, a simple opening with a tooth at the end of the last formed chamber, sometimes at the end of a slight neck.
Occurrence: *Miliammina fusca* was rare to abundant, single specimens
were observed in four samples from the back island lagoon locality
and from one to 41 specimens in 11 samples from the Breton Island
barrier island locality (see Appendices 2, 3, 6, 7) for samples
and percentages. *M. fusca* is a common marsh species having been
recorded in many parts of the world (eg., Parker et al., 1953;
Phleger, 1956; Scott and Martini, 1982; Boltovskoy, 1984). Parker
et al. (1953) recorded high frequencies of this species in marsh
samples and low frequencies in bay samples near marshes from the
San Antonio Bay area. Phleger (1954) noted that samples from
estuary and marsh facies from the Mississippi Sound area contained
an abundance of *M. fusca*. Lankford's (1959) results from the East
Mississippi Delta margin were similar, *M. fusca* was most abundant
in marsh and interdistributary bay faunas. Scott (1986) reported
assemblages containing between two and 80% in marine marsh and up
to 36% in brackish marsh samples from the lower Mississippi Delta.
He stated this was the dominant or co-dominant species in most of
the marine and brackish marshes his study area. One of the
characteristic species of the lower and middle marsh in
Chezzetcook Inlet, Nova Scotia is *M. fusca* (Scott and Medioli,
1978; 1980b). Boltovskoy (1984) stated that *M. fusca* is also
typically present in mangrove swamps in Brazil, Colombia and
Equador as well as other parts of the world.

Family LITUOLIDAE de Blainville, 1825
Subfamily HAPLOPHрагMOIDINAЕ Maync, 1952
Genus Haplophragmoides Cushman, 1910

Haplophragmoides manilaensis Andersen, 1953

Plate 1, figure 6

Haplophragmoides manilaensis ANDERSEN, 1953, p. 22, pl. 4, fig. 8.

LANKFORD, 1959, p.2098, pl. 1, fig. 3.

Haplophragmoides bonplandi TODD and BRONNIMANN, 1957, p. 23, pl. 2, fig. 2. SCOTT and MEDIOLE, 1980b, p. 40, pl. 2, figs. 4, 5.

Description: Test planispiral, periphery broadly rounded, lobate, umbilical area depressed; chambers inflated, initial chambers involute becoming evolute in last formed ones; sutures straight, depressed; wall arenaceous, composed of fine to medium sand grains, has a rough appearance; aperture a narrow arched opening with a slight lip located at the base of the final chamber.

Remarks: Haplophragmoides manilaensis specimens from the study area were compared with paratypes (U. S. N. M. Collection #370144), with which they agree well. However, the chambers of the paratypes are slightly more inflated and the specimens more rounded than those from the study area. Scott compared this species with the holotype of H. bonplandi and determined them to be conspecific (D. Scott, personal communication).

Occurrence: Haplophragmoides manilaensis was rare, it was only observed in two samples from the core (0-1cm, 19 specimens and 19-20cm, one specimen). The holotype of H. manilaensis is from Barataria Bay, Louisiana. Andersen (1953) stated that the favored habitat of this species appears to be the inland brackish-water bays and lakes connected with the Gulf of Mexico. Warren (1957)
recorded *H. manilaensis* in samples from the Buras-Soofield Bayou region, Louisiana. Lankford (1959) reported low abundances of this species in marsh samples from the east Mississippi Delta margin. Kane (1967) recorded from one to eight percent of this species in samples from Sabine Lake, Texas and Louisiana, and less than one percent in samples from the Gulf of Mexico near Sabine Pass. Boltovskoy (1984) listed records of *H. manilaensis* from some Trinidad and Brazil mangrove swamps.

**Haplophragmoides wilberti** Andersen, 1953

Plate 1, figures 7, 8

**Haplophragmoides wilberti** ANDERSEN, 1953, p. 21, pl. 4, fig. 7.

Boltovskoy, 1984, fig. 7.

Description: Test planispiral, involute, periphery broadly rounded, umbilical area depressed; chambers slightly inflated, increasing in size as added; sutures distinct, slightly depressed, slightly curved; wall arenaceous, composed of fine sand grains, much cement, has a smooth appearance; aperture a narrow arched opening with a lip located at the base of the final chamber.

Remarks: Specimens of *Haplophragmoides wilberti* agree well with the paratypes (U. S. N. M. Collection #370149).

Occurrence: *Haplophragmoides wilberti* was generally rare, from one to nine specimens were observed in seven samples from the Breton Island barrier island locality and a single specimen was recorded in one sample from the forebar locality (see Appendices 2-5 for samples and percentages). The holotype of *H. wilberti* is from Dog
Lake, Louisiana and Andersen (1953) recorded this species in a marsh sample from Barataria Bay and in a beach sample from Southwest Pass of the Mississippi River. Warren (1957) reported *H. wilberti* in samples from the Buras-Scofield Bayou region, Louisiana. Lankford (1959) recorded low abundances of this species in marsh samples from the east Mississippi Delta margin, while Phleger (1965b) observed a similar distribution in marine marshes around Galveston Bay, Texas. Kane (1967) reported percentages of *H. wilberti* from one to eight percent in samples from Sabine Lake, Texas and Louisiana. Boltovskoy (1984) listed records of this species in mangrove swamp samples from Trinidad, Sumatra, Ecuador and Brazil.

**Haplophragmoides** sp. A

Plate 1, figure 9

Remarks: Specimens of *Haplophragmoides* sp. A are characterized by poor preservation of the test and a sugary texture and are considered to be fossil material. These specimens were rare, ranging from one to five in fifteen samples throughout the four localities (see Appendices 2-9 for samples and percentages).

Subfamily LITUOLINAE de Blainville, 1825

Genus *Ammastuta* Cushman and Brönnimann, 1948

*Ammastuta inepta* (Cushman and McCulloch, 1939)

Plate 1, figures 10, 11

110
Ammobaculites ineptus CUSHMAN and MCCULLOCH, 1939, p. 89, pl. 7, fig. 6.

Ammoastata salsa CUSHMAN and BRÖNNIMANN, 1948a, p. 17, pl. 3, figs. 14-16.

Ammoastata inepta (Cushman and McCulloch). PARKER, PHLEGER and PEIRSON, 1953, p. 4, pl. 1, fig. 12. PHLEGER, 1954, p. 633, pl. 1, figs. 1-3. LANKFORD, 1959, p. 2097, pl. 1, fig. 4.

Description: Early portion of test coiled, later chambers distinct, rapidly broadening in curved, semirolled series, each making up an entire side of the test, increasing in size and length as added; sutures distinct, slightly depressed; wall arenaceous, composed of fine sand grains, has a smooth appearance; apertures of two kinds, primary aperture a slightly curved or straight transverse slit near the center of the apertural face of the final chamber, supplementary aperture consists of cribrate openings at the lower, slightly bulging end of test.

Remarks: Specimens of Ammoastata inepta agree well with the paratypes of Ammobaculites ineptus (Cushman Collection #35826). The early sutures on specimens from the study area are slightly more depressed than those of the paratypes. The specimens were also compared with the holotype (Cushman Collection #56638) and paratypes (Cushman Collection # 56744) of Ammoastata salsa. The holotype of A. salsa is broader than the specimens of A. inepta from the study area but this was the only difference noted. The paratypes of A. salsa exhibit a wide variation, from those slightly broader than the holotype of A. salsa to ones not as
broad as forms identified as *A. inepta* in the study area.

Occurrence: *Ammoastuta inepta* was rare, single specimens were observed in samples 503B and 504A while three specimens were found in each of two samples (503A and 504B). All samples were from the Breton Island barrier island locality. Parker et al. (1953) recorded frequencies of up to 52% of *A. inepta* in marsh environments and very low percentages in three bay samples from the San Antonio Bay area. Pfleger (1954) reported assemblages containing up to 25% or more in the marsh facies and lower frequencies in estuaries from the Mississippi Sound area. Otvos (1978) recorded frequencies up to 21% in samples from Lake Pontchartrain, Louisiana. Scott (1986) reported assemblages containing up to two percent of this species in one transect from the marine marsh and frequencies up to 25% in most brackish marsh samples from the lower Mississippi Delta. From the southeastern Mississippi Delta area, Pfleger (1955) reported high percentages of up to 100% of this species in marsh samples and generally less than one percent from the bays and Breton Sound.

Genus *Ammobaculites* Cushman, 1910

*Ammobaculites dilatatus* Cushman and Brönnimann, 1948

Plate 1, figure 12

Ammobaculites c.f. foliaceus (Brady). PARKER, 1952a, p.444, pl. 1, figs. 20, 21.

Ammobaculites foliaceus (Brady). SCOTT and MEDIOLI, 1980b, p. 35, pl. 1, figs. 6-8.

Description: Test elongated, initial chambers planispirally coiled, slightly umbilicate, later chambers uncoiled and uniserial; chambers fairly distinct except in the early coiled portion, slightly inflated, generally increasing in size as added; sutures somewhat indistinct, somewhat depressed; wall arenaceous, composed of medium sized sand grains, little cement, generally has a rough appearance; aperture fairly large, round, located at the terminal end of the final chamber.

Occurrence: Ammobaculites dilatatus was rare to abundant, from one to four specimens were observed in three core samples, one to 77 specimens in seven samples from the Breton Island barrier island locality, single specimens were observed in four samples from the back island lagoon locality and in one sample from the Stake Island barrier island locality (see Appendices 2, 3, 6-9 for samples and percentages). Parker et al. (1953) recorded frequencies of up to five percent in bay stations, up to three percent in marsh stations and less than one percent in open gulf samples from the San Antonio Bay area. Along the central Texas coast Phleger (1956) recorded low frequencies of A. dilatatus in a few samples from the bays. Phleger (1965a) documented low frequencies in samples from the intertidal flat environment of south Texas coastal lagoons. Phleger (1965b) also recorded low
percentages in marsh samples from Galveston Bay, Texas. Phleger (1954) reported low frequencies (<5%) at several stations in the Mississippi Sound and adjacent open gulf areas. Warren (1957) reported its presence in most samples from the Buras-Scofield Bayou region, Louisiana. Scott (1986) documented four to eight percent in two marine marsh samples from the lower Mississippi Delta. Phleger (1955) recorded low percentages in the Breton Sound facies. Boltovskoy (1984) reported its distribution in mangrove swamps from Brazil and Equador.

Genus *Ammotium* Loeblich and Tappan, 1953

*Ammotium multiloculatum* Warren, 1957

Plate 1, figures 13, 14

*Ammotium multiloculatum* WARREN, 1957, p. 33. pl. 4, figs. 1, 2.

Description: Test large, compressed, initial chambers close coiled and evolute, later chambers increasing in size, tending to uncoil but reaching backward toward the coil at the inner margin or completely uncoiling forming a short uniserial portion, periphery lobate; chambers distinct and overlapping; sutures distinct, curved, depressed; wall arenaceous, composed of fine to medium sand grains, little cement, has a rough appearance; aperture large, round to oval, located at the terminal end of the final chamber.

Remarks: Specimens of *Ammotium multiloculatum* from the study area closely resemble Warren's (1957) paratype (U. S. N. M. Collection #431084). The initial development of the coil is better expressed
in the paratype than in specimens from the study area. Specimens from the study area were observed both with and without a short uniserial portion. The paratype does not have a short uniserial portion although Warren's (1957) figured specimen does. As this is a very fragile species the uniserial portion may have been broken off while processing the samples.

Occurrence: *Ammotium multiloculatum* was very rare, two specimens were observed in each of three samples from the Breton Island barrier island locality (503A, 503B and 505B). The holotype is from a lagoon mouth of Bay Pomme d'Or. This species was also present in other samples from Warren's (1957) study of the Buras-Soosfield Bayou region, Louisiana. He stated that this species appeared to be indicative of polyhaline lakes.

*Ammotium salsum* (Cushman and Brönnimann, 1948a)

Plate 1, figure 15

*Ammobaculites salsus* CUSHMAN and BRÖNNIMANN, 1948a, p. 16, pl. 3, figs. 7-9. PARKER, PHLEGER and PETRSON, 1953, p. 5, pl. 1, figs. 17-25. PHLEGER, 1954, p. 635, pl. 1, figs. 7, 8. RANDY, 1956, p. 192, pl. 30, fig. 4. LEHMANN, 1957, p. 346, pl. 1, figs. 4-5.


Description: Test elongated, compressed, initial chambers planispirally coiled and evolute, later chambers tending to uncoil but reaching backward toward the coil at the inner margin, may
have a slight neck; chambers fairly distinct except in the early coiled portion, increasing in size as added, tapering toward apertural end; sutures fairly distinct, curved, somewhat depressed; wall arenaceous, composed of fine to medium sand grains, generally has a rough appearance; aperture fairly large, round, located at the terminal end of the final chamber.

Remarks: From the published figures, *Ammotium salsum* appears to be quite a variable species. Specimens of *A. salsum* from the study area were compared with the holotype (Cushman Collection #56634) and paratypes (Cushman Collection #56734) of *Ammobaculites salsus* and the variability among these specimens was observed. Specimens from the study area did not compare well with the holotype, which has a very small tight coiled portion and a long, rather wide uniserial portion. The paratypes displayed much greater variation in the tightness of the coil and character of the uniserial part of the test; specimens from the study area closely resemble some of the paratypes.

Occurrence: *Ammotium salsum* was rare to abundant, from one to 106 specimens were observed in nine samples from the Breton Island barrier island locality, single specimens were observed in two samples from the back island lagoon locality and three specimens in a sample from the Stake Island barrier island locality (see Appendices 2, 3, 6-9 for samples and percentages). Parker et al. (1953) recorded relatively high frequencies of *A. salsum* in bay samples and low frequencies in marsh samples from the San Antonio Bay area while Lehmann (1957) recorded variable frequencies in
bays along the Texas gulf coast. *A. salsum* was the most abundant species in marsh samples from Galveston Bay (Phleger, 1965b) and a similar distribution was recorded in other south Texas marshes (Phleger, 1965a). He stated that it appeared to be characteristic of inner lagoon, mud flats and along the edge of marshes where it merges with mud flats. In the Mississippi Sound area, *A. salsum* is the dominant species of the sound facies, has significant abundances in most marsh stations and exhibit variable frequencies in numerous open gulf samples (Phleger, 1954). *A. salsum* was the dominant agglutinated foraminiferal species in samples from Lake Pontchartrain (Otvo, 1978). Scott (1986) reported between one and 75% in most marine marsh samples and up to ten percent in brackish marsh samples from the lower Mississippi Delta. Phleger (1955) recorded high percentages of *A. salsum* in bays and Breton Sound from the southeastern Mississippi Delta area. Lankford (1959) recorded high frequencies of *A. salsum* in samples from his marsh, interdistributary bay, fluvial marine and sound subenvironments and stated that it appeared to be restricted to areas with highly variable water masses. Scott and Medioli (1978; 1980b) reported that one of the characteristic species of the low marsh was *A. salsum* in samples from Chezzetcook Inlet, Nova Scotia. Boltovskoy (1984) listed records of *A. salsum* in mangrove swamps from Brazil and Equador.

Family TEXTULARIIDAE Ehrenberg, 1838

Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus *Textularia* Defrance in de Blainville, 1824

*Textularia earlandi* Parker, 1952a

Plate 1, figure 16


Description: Test elongate, compressed, biserial, small, periphery lobate; numerous chambers, distinct, increasing in size as added; sutures distinct, slightly depressed, slightly curved; wall arenaceous, composed of fine to medium sand grains, has a rough appearance; aperture a low arch at the base of the last formed chamber.

Remarks: The specimen observed from the study area was broken.

Occurrence: One specimen of *Textularia earlandi* was observed in sample 506A from the Breton Island barrier island locality. There have been numerous reporting of this species from the Arctic (Phleger, 1952) to the Gulf of Mexico. Parker (1954) recorded *T. earlandi* to a depth of 1000m in the northeastern Gulf of Mexico but it occurred in high percentages in her facies 1 (12m - 80-100m). It has been reported to a depth of about 720m in the northwestern Gulf of Mexico (Pflum and Frerichs, 1976). Scott (1986) reported this species in a few marine and freshwater marsh samples from the lower Mississippi Delta. Lankford (1959) recorded *T. earlandi* in his deltaic marine environment and stated that rare specimens were present in marshes along the east Mississippi Delta margin but these specimens were smaller and had more fragile tests than than
the marine forms. Phleger (1965a) reported very rare live
specimens of this species in south Texas coastal lagoons and
(1965c) also reported live T. earlandi in mangrove swamps along
costal southern Florida. Scott et al. (1976) reported common
occurrences of T. earlandi in some southern California lagoons.
T. earlandi appears to have a wide geographic and depth
distribution but its common presence in marshes and very shallow
water has been well documented:

Family TROCHAMMINIDAE Schwager, 1877
Subfamily TROCHAMMININAE Schwager, 1877
Genus Trochammina Parker and Jones, 1859

Trochammina inflata (Montagu, 1808)

Plate 1, figures 17, 18

Nautilus inflatus MONTAGU, 1808, p. 81, pl. 18, fig. 3.
Rotula inflata WILLIAMSON, 1858, p. 50, pl. 4, figs. 93, 94.

Trochammina inflata (Montagu). CARPENTER, PARKER and JONES, 1862, p.
141, pl. 11, fig. 5. PARKER, PHLEGER and PEIRSON, 1953, p. 15,
pl. 3, figs. 7, 8. PHLEGER, 1954, p. 646, pl. 3, figs. 22, 23.
2099, pl. 1, fig. 21. SCOTT and MEDIOLO, 1980b, p. 44, pl. 3,
figs. 12-14, pl. 4, figs. 1-3. BOLTOVSKOY, 1984, fig. 13.

Description: Test trochoid, generally large, periphery broadly
rounded, lobate; chambers distinct, all chambers visible on dorsal
side, only those of the last formed coil visible on ventral side,
increasing in size as added, last formed chamber much more
inflated than previous ones; sutures distinct, deep, slightly
curved on dorsal side, nearly straight on ventral side, at right
angles to the periphery; wall arenaceous, composed of fine sand
grains, much cement, has a smooth appearance; aperture on ventral
side, an arched slit at the base of the last formed chamber.

Occurrence: *Trochammina inflata* was rare to abundant present in
samples from all four localities. One to 181 specimens were
present in 14 samples from the Breton Island barrier island
locality, one to two specimens were observed in each of five
samples from both the back island lagoon and forebar localities
and single specimens were recorded in two samples from the Stake
Island barrier island locality (see Appendices 2-9 for samples and
percentages). *T. inflata* has been recorded in many marsh samples
throughout the Gulf of Mexico. Parker et al. (1953) reported it
in marshes and nearby shallow marine areas from the San Antonio
Bay area. Phleger (1965b) recorded large populations in marsh
samples from Galveston Bay, Texas. Phleger (1954) reported low
frequencies (<15%) of *T. inflata* at several marsh stations in the
Mississippi Sound area but it was generally not present in the
estuaries. Otvos (1978) documented low occurrences of *T. inflata*
from Lake Pontchartrain, Louisiana. Scott (1986) reported
assemblages containing up to 72% *T. inflata* in the marine marsh
and rare occurrences in a few brackish marsh samples from the
lower Mississippi Delta. He stated that this was one of the co-
dominant species in parts of the marine marsh. Lankford (1959)
stated that *T. inflata* was restricted to his marsh facies along
the east Mississippi Delta margin. Scott and Medioli (1978; 1980b) report that one of the characteristic species of the upper part of the lower marsh and most of the middle marsh is *T. inflata* from Chezzetcook Inlet, Nova Scotia, and a similar distribution was also recorded in other Nova Scotian marshes. Boltovskoy (1984) reported that *T. inflata* is widely distributed in mangrove swamps in various parts of the world.

**Trochammina lobata** Cushman, 1944

Plate 1, figure 19

*Trochammina lobata* CUSHMAN, 1944, p. 18, pl. 2, fig. 10. LANKFORD, 1959, p. 2099, pl. 1, fig. 19.

Description: Test trochoid, biconvex, dorsal side slightly convex, ventral side more so, periphery broadly rounded, lobate; chambers distinct, all chambers visible on dorsal side, only those of the last formed coil visible on ventral side, chambers slightly inflated on the ventral side, increasing gradually in size as added, final chamber on ventral side extending inward giving it a lobate appearance; sutures distinct, slightly depressed on dorsal side, curved, on ventral side depressed and nearly radial; wall arenaceous, composed of fine to medium sand grains, little cement, has a smooth appearance; aperture on ventral side, a slit at the base of the last formed chamber.

Occurrence: Single specimens of *T. lobata* were observed in samples 421 and 426 from the forebar locality. Lankford (1959) recorded low percentages in his sound and open-shelf assemblages along the east
Mississippi Delta margin. Walton (1960) reported low percentages from both Mississippi Sound and the Gulf of Mexico near Horn Island, Mississippi.

**Trochammina macrescoens** Brady, 1870

Plate 1, figures 20, 21

Trochammina *inflata* (Montagu) var. *macrescoens* BRADY, 1870, p. 290, pl. 11, fig. 5.

Trochammina *macrescoens* Brady. PARKER, PHLEGER and PEIRSON, 1953, p. 15; pl. 3, fig. 7, 8. PHLEGER, 1954, p. 646, pl. 3, fig. 24.

SCOTT and MEDIOLI, 1980b, p. 44, pl. 3, figs. 1-8.

Description: Test trochoid, generally medium sized, periphery broadly rounded, lobate, ventrally umbilicate; chambers distinct, all chambers visible on dorsal side, only those of last formed coil visible on ventral side, chambers increasing in size as added, slightly inflated; sutures distinct, slightly depressed, slightly curved on both dorsal and ventral sides; wall arenaceous, composed of fine to medium sand grains, some cement, generally has a smooth appearance; aperture on ventral side, an arched slit at the base of the last formed chamber.

Remarks: This species closely resembles *Trochammina inflata*, although *T. macrescoens* is more compressed. The main distinguishing features between these two species are that the sutures of *T. macrescoens* are not as deep as *T. inflata* and are generally more curved. The final chamber of *T. macrescoens* is not as inflated as that of *T. inflata*.
Occurrence: One to eight specimens of Trochammina macrescens were observed in seven samples from the Breton Island barrier island locality and one specimen in a sample from each of the forebar and back island lagoon localities (see Appendices 2-7 for samples and percentages). Parker et al. (1953) reported low frequencies of this species at several marsh stations from the San Antonio Bay area. Phleger (1954) reported low frequencies from the Mississippi Sound area in a large number of marsh samples but present in very few estuary samples. Warren (1957) reported low occurrences in the Buras-Scofield Bayou region, Louisiana. Scott (1986) recorded assemblages containing low abundances in many marine marshes, 17% to 48% in brackish marshes and rare occurrences in some freshwater marsh samples from the lower Mississippi Delta. He stated this was one of the co-dominant species in the brackish marsh. Phleger (1955) recorded low percentages from the southeastern Mississippi Delta and Breton Sound in marshes. Scott and Medioli (1978; 1980b) reported that one of the dominant species of the upper part of the middle marsh to high marsh in samples from Chezzetcook Inlet, Nova Scotia is T. macrescens. Boltovskoy (1984) listed records of T. macrescens in marshes from Equador.

Trochammina pacifica (Cushman, 1925)

Trochammina pacifica CUSHMAN, 1925, p. 39, pl. 6, fig. 3.

Description: Test trochoid, small, periphery broadly rounded, ventrically umbilicate; chambers distinct, all chambers visible on
dorsal side, only those of the last formed coil visible on ventral  
side, slightly inflated on ventral side, increasing in size as  
added; sutures distinct, slightly depressed, slightly curved on  
dorsal side, nearly radial on ventral side; wall arenaceous,  
composed of fine sand grains, some cement, has a smooth  
appearance; aperture on ventral side, a slit at the base of the  
last formed chamber.

Remarks: Although this species has not been reported previously in the  
Gulf of Mexico the single specimen compared well with the holotype  
(Cushman Collection #429), the only difference being that the  
umbilical area is slightly more open on the holotype.

Occurrence: One specimen of T. pacifica was observed in sample 128B  
from the Stake Island barrier island locality. The holotype for  
this species is from Virago Sound, off British Columbia (Cushman,  
1925). Scott et al. (1976) reported low percentages of this  
species in lagoon samples from southern California.

Genus Arenoparrella Andersen, 1951

Arenoparrella mexicana (Kornfeld, 1931)

Plate 1, figures 22, 23

Trochammina inflata var. mexicana KORNFELD, 1931, p. 86, pl. 13,  
fig. 5.

Arenoparrella mexicana (Kornfeld). ANDERSEN, 1951a, p. 31, fig. 1.  
ANDERSEN, 1951b, p. 96, pl. 11, fig. 4. PARKER, PHLEGER and  
PEIRSON, 1953, p. 6, pl. 2, figs. 33, 34. PHLEGER, 1954, p. 636,  
pl. 1, figs. 12-14. LEHMANN, 1957, p. 349, pl. 3, figs. 23-25.

124
SCOTT and MEDIOLI, 1980b, p. 35, pl. 4, figs. 8-11. BOLIKOVSKY, 1984, figs. 4, 5.

Description: Test trochoid, periphery bluntly acute, dorsal side moderately convex, umbilical area closed and depressed; chambers distinct, slightly inflated on dorsal side, on ventral side inflated near umbilicus, typically five to each whorl, increasing in size as added; sutures distinct, slightly depressed, slightly curved on dorsal side, radial on ventral side; wall arenaceous, composed of fine sand grains, much cement, has a smooth appearance; apertures of two kinds, primary aperture an elongate slit extending up the face of the final chamber almost parallel to the plane of coiling, usually surrounded by a thin lip, supplementary cribrate aperture usually present, consisting of circular openings near the apex of the final chamber.

Occurrence: Arenoparrella mexicana was rare to abundant and was present in samples from all four localities. One to 157 specimens were observed in 12 samples from the Breton Island barrier island locality, from one to two occurrences in six samples from the forebar locality, one to four specimens were observed in seven samples from the back island lagoon locality and a single specimen in one sample from the Stake Island barrier island locality (see Appendices 2-9 for samples and percentages). Andersen (1951a) reported this species at four localities along the Louisiana coast. Parker et al. (1953) recorded A. mexicana in several marsh stations from the San Antonio Bay area, southwest Texas. Phleger (1965a) reported rare to abundant occurrences in south Texas.
marshes. Warren (1957) identified it in all of his samples from the Buras–Soofield Bayou region, Louisiana. Scott (1986) reported assemblages containing up to 19% \textit{A. mexicana} in some marine marsh and up to five percent in some brackish marsh samples from the lower Mississippi Delta. Phleger (1955) recorded its distribution in marsh and bay samples from the southeastern Mississippi Delta area. Lankford (1959) stated that \textit{A. mexicana} was found primarily in marsh samples although occasionally found in low frequencies in adjacent sound environments along the east Mississippi delta margin. Boltovskoy (1984) stated that \textit{A. mexicana} is also widely distributed in mangrove swamps.

Genus \textit{Tiphoptrocha} Saunders, 1957

\textit{Tiphoptrocha comprimata} (Cushman and Brönnimann, 1948b)

Plate 1, figures 24, 25


Description: Test trochospiral, compressed, periphery irregularly lobate, dorsal side slightly convex, ventral side concave with a small open umbilicus; chambers distinct, all chambers visible on dorsal side, only those of the last formed whorl visible on ventral side, those of the last formed whorl irregular in shape, more concentric with inflated lobes projecting into the umbilicus,
in large specimens the last formed chambers are generally inflated and roughly T-shaped in ventral view; sutures distinct, depressed, curved on ventral side; wall arenaceous, composed of fine sand grains with little cement, generally has a smooth appearance; apertures small openings located just forward from umbilical lobe of final chamber and where the last chamber is highly developed a secondary opening is located behind the umbilical lobe, fusion of the umbilical lobes may obscure most of the apertures.

Remarks: Specimens of *Tiphodrocha comprimata* compared well with the smaller of the paratypes (Cushman Collection #56788).

Occurrence: *Tiphodrocha comprimata* was generally rare in the study area, from one to nine specimens were observed in eight samples from the Breton Island barrier island locality and one specimen in a sample from each of the forebar and back island lagoon localities (see Appendices 2-7 for samples and percentages). Parker et al. (1953) recorded relatively low frequencies of this species in marsh stations from the San Antonio Bay area. Phleger (1965a) recorded variable frequencies of *T. comprimata* in some south Texas coastal lagoons and in Galveston Bay (1965b). Parker (1954) also recorded this species in variable frequencies from marsh and nearby brackish stream samples in the Mississippi Sound area. Warren (1957) reported low percentages of *T. comprimata* in all but one of his samples from the Buras-Soofield Bayou region, Louisiana. Scott (1986) recorded assemblages containing up to 14% in some marine marsh and low percentages in many brackish marsh samples from the lower Mississippi Delta.
Description: Test elongate, somewhat tapering, four to five chambers per whorl in the early portion, later becoming triserial; chambers distinct, numerous, slightly inflated, increasing in size as added; sutures distinct, depressed; wall arenaceous, composed of medium-sized sand grains, little cement, has a rough appearance; aperture small, an arched slit at the base of the last formed chamber.

Occurrence: One specimen of *Eggerella advena* was observed in each of samples 083A and 083B from the Stake Island barrier island locality. Cushman (1937) stated that *E. advena* is typically an Arctic species found in shallow cold water and noted records along the east coast of North America to Cape Cod and along the west coast to southern California. The only records of this species being present in the Gulf of Mexico were documented by Scott (1986), although there are more frequent occurrences from the Caribbean region (eg., Seiglie, 1967; Buzas et al., 1977).
Scott (1986) recorded assemblages containing up to three percent in a few marine marsh samples from the lower Mississippi Delta.

Suborder MILIOLINA Delage and Hérouard, 1896

Superfamily MILIOLACEA Ehrenberg, 1839

Family FISCHERINIDAE Millett, 1898

Subfamily CYCLOGYRINAE Loeblich and Tappan, 1961

Genus Cyclogyra Wood, 1842

Cyclogyra involvens Reuss, 1850

Plate 2, figure 2

Operculina involvens REUSS, 1850, p. 370, pl. 46, fig. 30.

Comuspira involvens (Reuss). REUSS, 1863, p. 39, pl. 1, fig. 2.

CUSHMAN, 1929, p. 80, pl. 20, figs. 6, 8.

Description: Test planispiral, somewhat involute, periphery rounded, nearly circular in side view, consists of a proloculus and a long, closely coiled second chamber of nearly equal diameter throughout the coil; suture distinct, somewhat depressed; wall calcareous, imperforate, porcelaneous; aperture at the open end of the tube.

Occurrence: Cyclogyra involvens was rare in the study area. Single specimens were observed in each of samples 503A; 504A and 504B and three specimens in sample 503B from the Breton Island barrier island locality and a single specimen in sample 498 from the forebar locality. There have been occasional reportings of this species in various parts of the Gulf of Mexico (Culver and Buzas, 1981).
Family MILIOLIDAE Ehrenberg, 1839
Subfamily QUINQUELOCULININAE Cushman, 1917
Genus Quinqueloculina d’Orbigny, 1826
Quinqueloculina goesi (Weisner, 1923)

Plate 2, figure 3

Miliolina goesi WEISNER, 1923, p. 52, pl. 7, fig. 79.

Description: Test elongate, periphery somewhat rounded; chambers distinct, somewhat rectangular in cross-section; sutures distinct, depressed; wall calcareous, has a rough appearance; aperture large, somewhat oval, at the end of a short neck that is slightly oval.

Remarks: The specimen compared well with Buzas and Severin’s (1982) hypotypes (U. S. N. M. Collection #310265 and #310266).

Occurrence: A single specimen of Q. goesi observed in sample 403B from the back island lagoon locality. Buzas and Severin (1982) reported a few specimens from the northern part of the Indian River, Florida.

Quinqueloculina impressa Reuss, 1851

Plate 2, figure 4

Quinqueloculina impressa REUSS, 1851, p. 87, pl. 7, fig. 59. HAAKE, 1975, p. 24, pl. 1, figs. 24, 25. BUZAS and SEVERIN, 1982, p. 25, fig. 23, pl. 3, figs. 3, 4.

130
Description: Test somewhat longer than broad, somewhat hemispherical in cross-section, periphery rounded; final chamber slightly inflated at anterior end forming a slight "shoulder"; sutures distinct, depressed; wall calcareous, imperforate, porcelaneous; aperture hemispherical, usually with a bifid tooth.

Remarks: Quinqueloculina impressa resembles Q. seminula although it is more rounded and has a slight "shoulder" at the anterior end.

Occurrence: Quinqueloculina impressa was generally rare in the study area. Nine specimens were observed in both samples 099A and 099B from the Breton Island barrier island locality, single specimens in samples 402A and 407B from the back island lagoon locality and from two to 11 specimens in three samples from the Stake Island barrier island locality (see Appendices 2, 3, 6-9 for samples and percentages). This species has not been reported previously in the Gulf of Mexico. Q. impressa is a common species in the Indian River, Florida (Buzas and Severin, 1982).

Quinqueloculina jugosa Cushman, 1944

Plate 2, figures 5, 6

Quinqueloculina seminulum (Linné) var. jugosa CUSHMAN, 1944, p. 13, pl. 2, fig. 15. LEHMANN, 1957, p. 347, pl. 2, figs. 6-8.

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

Description: Test longer than broad, oval in cross-section, periphery rounded, many specimens slightly twisted; chambers distinct, inflated, especially at the anterior end, rounded, longitudinal costae throughout length of chambers; sutures distinct, slightly
depressed; wall calcareous, imperforate, porcelaneous; aperture fairly large, rounded, generally with a simple tooth.

Remarks: Quinqueloculina jwgsa somewhat resembled Q. seminula except that the final chamber extended higher, sometimes with a slight "shoulder", chambers had poorly developed longitudinal costae and specimens were generally slightly twisted.

Occurrence: Quinqueloculina jwgsa was generally rare but abundant in a few samples from the barrier islands. From three to 124 specimens were observed in four samples from the Breton Island barrier island locality, one to three specimens in nine samples from the back island lagoon locality, two specimens in sample 429 from the forebar locality and from one to 105 specimens in three samples from the Stake Island barrier island locality (see Appendices 2-9 for samples and percentages). Bandy (1956) stated that Q. jwgsa was one of the dominant species between about three and 13m in samples from the northeastern Gulf. Lehmann (1957) reported rare occurrences in a few samples from the Matagorda Bay area, Texas. Benda and Puri (1962) recorded low percentages in their mangrove island and open gulf assemblages from the Cape Romano area, Florida.

Quinqueloculina seminula (Linne, 1758)

Plate 2, figure 7

Serpula seminulum LINNE, 1758, p. 786.

Quinqueloculina seminulum (Linne). d'ORBIGNY, 1826, p. 301. CUSHMAN, 1929, p. 24, pl. 2, figs. 1, 2. PARKER, PHLEGER and PEIRSON,

Description: Test longer than broad, somewhat triangular in cross-section, periphery rounded; chambers distinct, inflated, rounded; sutures distinct, slightly depressed; wall calcareous, imperforate, porcelaneous; aperture fairly large, rounded, with a simple tooth.

Remarks: Some variation was noted among specimens identified as Quinqueloculina seminula such as the length to width ratios as well as the degree of triangularity when viewed in cross-section. Some specimens had a very slight neck. The figured specimen is typical.

Occurrence: Quinqueloculina seminula was the most common miliolid species identified in samples from the study area. From three to 117 specimens were observed in four samples from the Breton Island barrier island locality, one to 27 specimens in 36 samples from the back island lagoon locality, six to 26 specimens in the 19 samples from the forebar locality and from one to 113 specimens in 11 samples from the Stake Island barrier island locality (see Appendices 2-9 for samples and percentages). Parker et al. (1953) stated this species was widespread in shallow water with frequencies between ten and 56% in beach samples and present in low frequencies in a few innermost shelf samples from the San Antonio Bay area. Phleger and Lankford (1957) reported low frequencies of Q. seminula between four and 20% from this area.
Shepard and Moore (1955) stated that this was one of the representative species of their beach and surf zone facies from the Rockport area, Texas. Lehmann (1957) recorded low percentages in many of his facies from Matagorda Bay, Texas. Kane (1967) reported less than one percent in a few samples from Sabine Lake, Texas and Louisiana and the adjacent Gulf area. Scott (1986) recorded generally low occurrences in a few marine marsh samples from the lower Mississippi Delta.

Quinqueloculina sp. A

Plate 2, figures 8, 9

Description: Test longer than broad, bulged at the center, periphery somewhat acute; chambers distinct, inflated; sutures distinct, depressed; wall calcareous, imperforate, porcelaneous; aperture rounded, usually with a bifid tooth.

Occurrence: Two specimens were observed in sample 418B and a single specimen in 420A from the back island lagoon locality, one to 16 specimens in ten samples from the forebar locality and a single specimen in sample 097B and four specimens in sample 128B from the Stake Island barrier island locality (see Appendices 4-9 for samples and abundances).

Quinqueloculina sp. B

Plate 2, figures 10, 11

Description: Test longer than broad, periphery rounded; chambers
distinct, inflated, usually more so at the posterior end, has a slight "shoulder" at the posterior end; rounded; sutures distinct, depressed; wall calcareous, imperforate, porcelaneous; aperture hemi-spherical to rounded, with a small bifid tooth.

Remarks: This species generally resembles Buzas and Severin's (1982) \textit{Ouigueloculina} species.

Occurrence: Single specimens of \textit{Ouigueloculina} sp. B were observed in samples 097B and 124A and 17 specimens in sample 128A from the Stake Island barrier island locality.

\textit{Ouigueloculina} sp. C

Plate 2, figures 12, 13

Description: Test longer than broad, periphery rounded; chambers distinct, inflated, traces of longitudinal costae along length of chambers; sutures distinct, depressed; wall calcareous, imperforate, porcelaneous; aperture large, hemispherical, with a bifid tooth.

Occurrence: \textit{Ouigueloculina} sp. C was rare, four and 13 specimens were observed in two samples from the Breton Island Barrier Island locality and from one to three specimens in four samples from the Stake Island-Barrier Island locality (see Appendices 2, 3, 8, 9 for samples and percentages).

Genus \textit{Pateoris} Loeblich and Tappan, 1953

\textit{Pateoris dilitata} (d'Orbigny, 1839a)

Plate 2, figure 14

135
Quinqueloculina dilitata d'ORBIGNY, 1839a, p. 192, pl. 11, figs. 28-30. CUSHMAN, 1921, p. 67, figs. 7, 8, pl. 16. CUSHMAN, 1922b, p. 69, pl. 12, fig. 2. CUSHMAN, 1929, p. 26, pl. 2, fig. 5.

Pateoris dilitata (d'Orbigny). BUZAS and SEVERIN, 1982, p. 27, pl. 4, figs. 1,2.

Description: Test almost as broad as long, periphery generally rounded although an acute edge around some chambers; chambers distinct, somewhat compressed, last formed chamber does not make a complete whorl; sutures distinct, depressed; wall calcareous, imperforate, porcelaneous; aperture oval, elongate.

Occurrence: Pateoris dilitata was rare, three specimens were observed in sample 099A from the Breton Island barrier island locality and a single specimen in sample 128B from the St.ake Island barrier island locality.

Subfamily MILIOLINELLINAE Vella, 1957

Genus Miliolinella Wiesner, 1931

Miliolinella sp. A

Plate 2, figure 15

Description: Test elongate, flattened, periphery rounded; chambers distinct, rounded, somewhat inflated, arranged in a triloculine fashion; sutures distinct, very slightly depressed; wall calcareous, imperforate, porcelaneous; aperture small, rounded.

Remarks: The specimens identifies as Miliolinella sp. A were poorly preserved and the apertures were all broken.

Occurrence: Miliolinella sp. A was very rare, one specimen was
identified in sample 406B from the back island lagoon locality and
two specimens in sample 128B from the Stake Island barrier island
locality.

**Miliolinella sp. B**

Plate 2, figure 16

Description: Test almost as broad as long, flattened, periphery
rounded; chambers distinct, rounded, inflated, arranged in a
triloculine fashion; sutures distinct, depressed; wall calcareous,
imperforate, porcelaneous; aperture hemispherical, with a slight
lip surrounding it, usually traces of a simple tooth.

Occurrence: **Miliolinella sp. B** was rare, a single specimen was
identified in sample 418B from the back island lagoon locality and
from one to 11 specimens in four samples from the Stake Island
barrier island locality (see Appendices 2, 3, 8, 9 for samples and
percentages).

Suborder ROTALINA Delage and Hérrouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family POLYMORPHINIDAE d’Orbigny, 1839

Subfamily POLYMORPHININAE d’Orbigny, 1839

Genus **Guttulina** d’Orbigny in de la Sagra, 1839

**Guttulina australis** (d’Orbigny, 1839b)

Plate 2, figure 17

**Globulina australis** d’ORBIGNY, 1839b, p. 60, pl. 1, figs. 1-4.

**Guttulina australis** (d’Orbigny). PARKER, PHLEGER and PEIRSON, 1953,
Description: Test broadly fusiform, elongated, somewhat pointed at both ends, greatest width near the middle; chambers distinct, oval, inflated, arranged in a quinquiloculine series, increasing in size from the base; sutures distinct, depressed; wall calcareous, marked with longitudinal costae throughout the length of the test; aperture terminal, radiate.

Remarks: Specimens fall into two groups, those with distinct longitudinal costae throughout the length of the test and others with only traces or the absence of costae.

Occurrence: Guttulina australis was generally rare, from one to three specimens were observed in eleven samples from the back island lagoon locality, one to two specimens in seven samples from the forebar locality and single specimens in six samples from the Stake Island barrier island locality (see Appendices 4-9 for samples and percentages). Parker et al. (1953) reported frequencies of less than one percent in a few beach samples and two open gulf samples from the San Antonio Bay area. Bandy (1954) recorded up to 5% in some samples between about ten and 40m from...
Sabine Pass, Texas to Grand Cheniere, Louisiana. Sheppard and Moore (1957) stated this species was representative in their beach and surf zone facies of the Rockport area, Texas. Lehmann (1957) recorded low percentages in a few samples from Matagorda Bay, Texas. Phleger (1954) documented low frequencies, generally one to two percent, in about half of his open-gulf stations in the Mississippi Sound area. Lankford (1959) recorded low frequencies in his open-shelf and deltaic marine facies from the east Mississippi Delta margin.

Superfamily BULIMINACEA Jones, 1875

Family TURRILINIDAE Cushman, 1927

Subfamily TURRILININAE Cushman, 1927

Genus Buliminella Cushman, 1911

Buliminella elegantissima (d'Orbigny, 1839a)

Plate 2, figure 18

Bulimina elegantissima d'ORBIGNY, 1839a, p. 51, pl. 7, figs. 13, 14.

Buliminella elegantissima (d'Orbigny). PHLEGER and PARKER, 1951, p. 17, pl. 8, figs. 3, 4. PARKER, PHLEGER and PEIRSON, 1953, p. 6, pl. 4, figs. 8, 9. PHLEGER, 1954, p. 637, pl. 1, figs. 24, 25. LANKFORD, 1959, p. 2097, pl. 2, fig. 16. POAG, 1981, p. 50, pl. 33, fig. 2, pl. 34, fig. 2.

Description: Test elongate, spiral, longer than wide, initial end somewhat pointed, periphery rounded; chambers distinct, numerous, elongate, narrow, increasing in size as added; sutures distinct, slightly curved, somewhat depressed; wall calcareous, smooth, very
finely perforate; hemispherical depression along apertural face, aperture an elongate oval opening at the terminal end of the depression parallel to the length of the test.

Occurrence: A single specimen of *Buliminella elegantissima* was observed in sample 599–600 cm from the core and from one to three specimens in five samples from the forebar locality (see Appendices 4, 5, 10, 11 for samples and percentages). Phleger (1951) reported that this species was rare in samples from the northwestern Gulf of Mexico although highest frequencies were recorded shallower than 80 m but present to depths of 385 m. Parker et al. (1953) documented *B. elegantissima* in low frequencies from most open gulf stations and numerous bay samples from the San Antonio Bay area. Kane (1967) reported less than one to four percent of this species from Sabine Pass and up to one percent in Sabine Lake directly above Sabine Pass. Phleger (1954) recorded frequencies up to three percent in the Mississippi Sound area but stated it was not generally present in samples near beaches. Otvos (1978) reported less than one percent in a sample from Lake Pontchartrain, Louisiana. Scott (1986) recorded one percent of this species in a marine marsh sample from the lower Mississippi Delta. Lankford (1959) documented low percentages of *B. elegantissima* in his sound, deltaic marine and open-shelf assemblages from the east Mississippi Delta margin. Poag (1981) stated that this species is more common in the western rather than the eastern Gulf, most common on the inner and middle shelf.
but also present in bays, estuaries and as deep as the middle slope.

Family BOLIVINITIDAE Cushman, 1927

Genus Bolivina d'Orbigny, 1839

Bolivina lowmani Phleger and Parker, 1951

Plate 2, figures 19, 20

Bolivina lowmani PHLEGER and PARKER, 1951, p. 13, pl. 6, figs. 20, 21. PARKER, PHLEGER and PETRSON, 1953, p. 6, pl. 4, fig. 1. PHLEGER, 1954, p. 637, pl. 1, figs. 18, 19. PARKER, 1954, p. 515, pl. 7, fig. 21. LANKFORD, 1959, p. 2097, pl. 3, fig. 4.

Description: Test small, slightly compressed, tapering from the somewhat rounded initial end to the broader apertural end, periphery slightly lobate, rounded; chambers distinct, numerous, arranged in biserial fashion, slightly curved, slightly inflated toward the inner margin; sutures distinct, curved, depressed; wall calcareous, smooth with some small perforations; aperture loop-shaped surrounded by a slight collar, located at face of final chamber.

Remarks: Specimens of Bolivina lowmani agree well with the holotype (Cushman Collection #689865) and paratypes (Cushman Collection #430408). The only difference noted was that the final chambers of the holotype were obscured whereas those observed on specimens from the study area were well defined.

Occurrence: Single specimens of Bolivina lowmani were observed in one core sample, three samples from the back island lagoon locality.
and from one to three specimens in ten samples from the forebar locality (see Appendices 2-7, 10, 11 for samples and percentages). Phleger (1951) reported that this was an abundant benthic species present at all water depths in traverses throughout the northwestern Gulf of Mexico. Parker (1954) recorded a similar distribution in the northeastern Gulf of Mexico. Parker et al. (1953) reported low percentages in most open gulf samples and from the lower San Antonio Bay area along southwest Texas. Phleger (1954) documented low frequencies in numerous open gulf stations in the Mississippi Sound area. Warren (1957) recorded less than one percent in a sample from the Buras-Scofield Bayou region, Louisiana. Phleger (1955) reported low percentages of B. lowmani in the Breton Sound facies and that it was one of the characteristic species of the open gulf facies from the southeastern Mississippi Delta area. Lankford (1959) recorded its presence in all of his facies except for the marsh and stated that it was abundant in deltaic marine samples along the eastern Mississippi Delta margin.

*Bolivina striatula* Cushman, 1922b

Plate 2, figures 21, 22

*Bolivina striatula* CUSHMAN, 1922b, p. 27, pl. 3, fig. 10. PARKER, PHLEGER and PEIRSON, 1953, pl. 4, figs. 4, 5. BANDY, 1954, p. 135, pl. 31, fig. 9. LANKFORD, 1959, p. 2097, pl. 3, fig. 6. BUZAS and SEVERIN, 1982, p. 32, pl. 5, fig. 8.

Description: Test elongate, slightly compressed, tapering from the
rounded initial end to the broader apertural end, periphery slightly lobate, rounded, some specimens slightly twisted; chambers numerous, arranged in biserial fashion, slightly inflated; sutures distinct, curved, slightly depressed; wall calcareous, numerous longitudinal striations occupy initial half of test, few to none on later formed chambers, many small perforations throughout length of test; aperture loop-shaped surrounded by a slight collar, located at the face of the final chamber.

Remarks: Specimens of Bolivina striatula agree fairly well with the holotype (Cushman Collection #1089) and paratype (Cushman Collection #1092). The paratype was not quite as broad and had a sharper initial end than most specimens observed.

Occurrence: Bolivina striatula was rare, single specimens were observed in four samples from the back island lagoon locality, two samples from the Stake Island barrier island locality and from one to three specimens in five samples from the forebar locality (see Appendices 4–9 for samples and percentages). Parker et al. (1953) recorded low percentages in their shallow open gulf facies in the San Antonio Bay area. Bandy (1954) reported sporadic occurrences of this species in the northern Gulf of Mexico between Sabine Pass, Texas and Grand Cheniere, Louisiana. Warren (1957) recorded low percentages in some samples from the Buras-Soofield Bayou region, Louisiana. Phleger (1955) documented low percentages in the southeastern Mississippi Delta area. Lankford (1959) reported this species was restricted to sound facies, present in low
frequencies, along the eastern Mississippi Delta margin. Buzas and Severin (1982) reported *B. striatula* as common throughout the Indian River, Florida.

**Superfamily DISCORBACEA Ehrenberg, 1838**

**Family DISCORRIDAE Ehrenberg, 1838**

**Subfamily DISCORRINAE Ehrenberg, 1838**

**Genus *Buccella* Andersen, 1952**

**Buccella hannai** (Phleger and Parker, 1951)

*Eponides hannai* PHLEGER and PARKER, 1951, p. 21, pl. 10, figs. 10-14.  
*Buccella hannai* (Phleger and Parker). ANDERSEN, 1952, p. 144, fig. 3.  
PHLEGER, 1954, p. 637, pl. 2, figs. 13, 14. LANKFORD, p. 2097, pl. 3, fig. 11.

**Description:** Test trochoid, biconvex, more convex on dorsal side than ventral side, periphery lobate, somewhat acute; chambers distinct, slightly inflated, all chambers visible on dorsal side, only those of the last formed coil visible on ventral side; sutures distinct, depressed, curved on dorsal side, almost radial on ventral side; wall calcareous, very finely perforate, on ventral side numerous pustules present covering the umbilicus and sutures; sutural apertures are low arched openings at posterior margin of each chamber, primary aperture obscured by pustules.

**Remarks:** Specimens of *Buccella hannai* from the study area were compared with the holotype (U. S. N. M. Collection #P.835) which
was slightly more convex on the dorsal side than those from the study area.

Occurrence: *Rucella hannai* was rare, single specimens were observed in two samples from the back island lagoon locality and from one to four specimens in seven samples from the forebar locality (see Appendices 4-9 for samples and percentages). Phleger (1951) reported that this was a characteristic shallow water species present in low percentages (usually less than one percent) in numerous shallow water samples from the northwestern Gulf of Mexico. Phleger (1956) recorded similar frequencies in most samples between seven and 101m along the central Texas coast. Phleger (1954) documented very low frequencies in a few open gulf stations in the Mississippi Sound area. Warren (1957) recorded *R. hannai* in a sample from the Buras-Scofield Bayou region, Louisiana. Lankford (1959) reported low percentages of this species in his deltaic marine and open shelf facies from the east Mississippi Delta margin.

**Genus Eoeponidella Wickenden, 1949**

**Eoeponidella pulchella** (Parker, 1952b)

_Pinaella (?) pulchella_ PARKER, 1952b, p. 420, pl. 6, figs. 18-20.

Description: Test compressed, slightly convex on dorsal side, ventral side slightly concave, umbilical area somewhat depressed, periphery broadly rounded, lobate; chambers distinct, crescentric, inflated, increasing gradually in size as added, plates over
chambers on ventral side giving a star-shaped appearance; sutures
distinct, depressed, slightly curved; wall calcarceous, very finely
perforate, coarse perforations along the margin and proximal ends
of the secondary plates; aperture a broad arch, interomarginal,
extending to umbilical area.

Remarks: This species has not been reported previously in the Gulf of
Mexico.

Occurrence: Single specimens of *Poeponidella pulchella* were observed
in samples 409A and 409B from the back island lagoon locality.

Superfamily ROTALIACEA Ehrenberg, 1839

Family ROTALIIDAE Ehrenberg, 1839

Subfamily ROTALINAE Ehrenberg, 1839

Genus *Ammonia* Brünneich, 1772

*Ammonia beccarii* (Linné, 1758)

Plate 3, figure 1-4

*Nautilus beccarii* Linné, 1758, p. 710.

*Ammonia beccarii* (Linné). Brünneich, 1772, p. 232. Frizzell and Keen,

Buzas and Severin, 1982, p. 36, pl. 7, figs. 9, 10.

"Rotalia" beccarii (Linné) var. parkinsoniana (d’Orbigny). Phleger
and Parker, 1951, p. 23, pl. 12, fig. 6.

"Rotalia" beccarii (Linné) var. tepida Cushman, 1926, p. 79, pl. 1.

Phleger and Parker, 1951, p. 23, pl. 12, fig. 7.

"Rotalia" beccarii (Linné) variants. Parker, Phleger and Peterson,
10, figs. 1, 2, 5, 6. PHLEGER, 1954, p. 645, pl. 3, figs. 4-10.
2099, pl. 3, figs. 10, 13.
Rotalia beccarii (Linne) variant A. SHEPARD and MOORE, 1955, p. 1509,
fig. 33 (#22, 23).
Rotalia beccarii (Linne) variant C. SHEPARD and MOORE, 1955, p. 1509,
fig. 33 (#10, 11).
Streblus beccarii (Linne) var. sobrinus (Shupack). BANDY, 1954, p.
138, pl. 30, fig. 7. BENDA and PURI, 1962, p. 335, pl. 1, figs.
12-14.
Streblus beccarii (Linne) var. tepida (Cushman). BENDA and PURI,
1962, p. 335 pl. 1, figs. 26, 27.
Streblus tepidus (Cushman). BANDY, 1956, p. 197, pl. 31, fig. 2.
Ammonia parkinsoniana (d'Orbigny) forma tepida Cushman. POAG, 1978,
p. 397, pl. 1, figs. 1-4, 10-12, 17, 18. POAG, 1981, p. 37, pl.
45, fig. 2, pl. 46, fig. 2.
Ammonia parkinsoniana (d'Orbigny) forma typica POAG, 1978, p. 397, pl.
1, figs. 5-9, 13-16, 19-21. POAG, 1981, p. 38, pl. 45; fig. 1,
pl. 46, fig. 1.
Description: Test biconvex, trochospirally coiled, three to four
volutions, periphery broadly rounded, usually lobate, ventral side
umbilicate, with or without an umbilical plug; chambers distinct,
eight to fourteen in the final whorl, usually inflated; sutures
distinct, depressed to deeply incised on ventral side, slightly
depressed to raised on dorsal side; wall calcareous, very finely
perforate, irregular shaped small pustules along sutures on
ventral side and in umbilical area; aperture interomarginal.

Remarks: Specimens identified as *Ammonia beccarii* from the study area were extremely variable. Most specimens were lobate although a few had somewhat acute, more angular peripheries. There was also great variation in the size of the umbilical plug, if present, from very small to ones that completely filled the umbilical area. No attempt was made to distinguish the various forms of *A. beccarii* in this study since Schnitker (1974) demonstrated with culturing techniques that many of the described forms are conspecific variations of *A. beccarii*.

Occurrence: This was the most abundant species in the study area, present in many core and most surface samples. From one to 247 specimens were observed in 15 core samples, one to two specimens in seven samples from the Breton Island barrier island locality, 11-159 specimens in 38 samples from the back island lagoon locality, 115-180 specimens in 19 samples from the forebar locality and from two to 123 specimens in 14 samples from the Stake Island barrier island locality (see Appendices 2-11 for samples and percentages). Phleger (1951) reported that his *Rotalia beccarii* var. *tepida* and var. *parkinsoniana* had essentially the same distribution in the northwestern Gulf. The assemblages contained up to 50% of these forms from <70m with rare occurrences to depths of about 120m. Parker et al. (1953) identified three variants of *R. beccarii* in samples from the San Antonio Bay area. Variant A had frequencies between 30% and 50% in bay and island areas, about 30% in beach samples and about ten
percent in open gulf stations. Variant B was widely distributed throughout the area. Greatest frequencies of these two variants were shallower than 70m although reported to depths of 120m. Variant C was abundant in the Grassy Point marsh and Guadalupe River samples, low frequencies in most bay samples and not present in open gulf stations. Phleger and Lankford (1957) recorded relatively high living percentages of their Streblus beccarii var. A and var. B from this area. Shepard and Moore (1955) stated that Rotalia beccarii var. C was representative of their bays near rivers facies while R. beccarii var A. was representative of their bay facies in the Rockport area, Texas. Bandy (1954) stated that his Streblus beccarii var. sobrinus (which included S. beccarii var. tepidus) was characteristic of nearshore area, comprising up to 20% of the fauna to depths of about 18m between Sabine Pass, Texas and Grand Cheniere, Louisiana. Lehmann (1957) recorded relatively high percentages (17.7-80.1%) of S. beccarii and variants in all of his facies from the Matagorda Bay area, Texas. Phleger (1965a, b) stated that Ammonia beccarii variants were common to abundant in many samples from from south Texas coastal lagoons and Galveston Bay, generally higher percentages in bays, channels, mud flats and lagoons than in marshes. Parker (1954) reported occurrences of "Rotalia" beccarii variants to depths of 125m with frequencies of up to 34% in shallower water but generally less than one percent deeper than 70m in the northeastern Gulf. Bandy (1956) reported an abundance of Streblus sobrinus and tepidus in nearshore areas and that S. tepidus was
one of the dominant species between about two and 14m from the 
northeastern Gulf. Warren (1957) reported variable frequencies of 
_Rotalia beccarii_ parkinsoniana and _R. beccarii_ tepida in most 
samples from the Buras-Scofield Bayou region, Louisiana. Kane 
(1967) recorded _Streblus beccarii_ variants in many samples, with 
frequencies up to 80% from Sabine Lake, Texas and Louisiana. 
Phleger (1954) stated _Rotalia beccarii_ variants were one of the 
two most abundant open-gulf species with frequencies between ten 
and 30% in the Mississippi Sound area. Otvos (1978) recorded 
various percentages of _Ammonia beccarii_ parkinsoniana, _A. beccarii_
sobrina and _A. beccarii_ tepida in many samples from Lake 
Pontchartrain, Louisiana. Scott (1986) reported assemblages 
containing up to 67% _Ammonia beccarii_ in some marine marsh samples 
from the lower Mississippi Delta. Phleger (1955) reported high 
percentages of "_Rotalia_ beccarii" variants in both his Breton 
Sound and open gulf facies with some occurrences in bays and 
marshes in the southeastern Mississippi Delta area. Lankford 
(1959) stated that _Streblus beccarii_ variants was the most 
abundant and widespread species observed in his study of the east 
Mississippi Delta margin; it was not present in his marsh facies, 
low abundances in his deltaic marine assemblage and relatively 
abundant in his other four environments. Poag (1981) stated that 
his _Ammonia parkinsoniana_ forma _tepida_ and forma _typica_ were 
dominant species in his _Ammonia_ and _Ammonia-Elphidium_ facies in 
the Gulf. Benda and Puri (1962) reported varying percentages of 
_Streblus beccarii_ var. _sobrina_ and var. _tepida_ in all four of
their assemblages with var. sobrina being one of the major species in the lagoon assemblage and var. tepida primarily in the mangrove island assemblage from the Cape Romano area, Florida. Buzas and Severin (1982) stated that Ammonia beccarii was the most abundant species in the Indian River, Florida.

Family ELPHIDIIDAE Galloway, 1933
Subfamily ELPHIDINAEE Galloway, 1933
Genus Elphidium de Montfort, 1808
Elphidium excavatum (Terque, 1875)
Plate 3, figures 5-7
Polystomella excavata TERQUEM, 1875, p. 25, pl. 2, fig. 2. TERQUEM, 1876, p. 429, pl. 2, fig. 2.
Elphidium excavatum (Terque) forma selevensis (Heron-Allen and Earland). FEYLING-HANSSEN, 1972, p. 341, pl. 4, figs. 1-7, pl. 5, figs. 1-7. MILLER, SCOTT and MEDIOLI, 1982, p. 132, pl. 1, figs. 13-16, pl. 5, figs. 10-13, pl. 6, figs. 9-13.
Elphidium excavatum (Terque) forma lidoensis Cushman. FEYLING-HANSSEN, 1972, p. 344, pl. 6, figs. 1-7. MILLER, SCOTT and MEDIOLI, 1982, p. 134, pl. 1, figs. 17-20, pl. 4, figs. 7-12, pl. 5, fig. 9, pl. 6, figs. 15, 16.
Elphidium excavatum (Terque) CUSHMAN, 1930, p. 21, pl. 8, figs. 1-7. BENDA and PURI, 1962, p. 325, pl. 1, fig. 16. HANSEN and
Description: Test planispiral, involute, compressed, periphery rounded although final chambers of some specimens somewhat lobate; chambers distinct, eight to eleven in final whorl; sutures distinct, very slightly curved, depressed, sutural bridges joining chambers; wall calcareous, finely perforate, umbilical area smooth to being filled with granular material or small umbilical bosses; aperture a row of small pores at the base of the last formed chamber.

Remarks: Buzas et al. (1985), for example, stated that Elphidium excavatum, a highly variable species, has probably been misidentified by many authors. Ecological factors may play an important factor in the expression of this species (Miller et al., 1982), but in this study where samples were obtained from such a small area the distinction of formae was not attempted. Although forms previously recognized as E. excavatum (Terquem) forma lidoensis and forma selsevensis could be identified, for this study they were all considered E. excavatum. This species has rarely been reported in the Gulf under this name although Culver and Buzas (1981) placed various authors' specimens in synonymy with E. excavatum.

Occurrence: Elphidium excavatum was rare to abundant throughout the study area. From two to 36 specimens were observed in seven core samples, a single specimen in sample 508B from the Breton Island barrier island locality, from one to 20 specimens in 35 samples.
from the back island lagoon locality, 28-68 specimens in 19
samples from the forebar locality and one to ten specimens in 12
samples from the Stake Island barrier island locality (see
Appendices 2-11 for samples and percentages). Benda and Puri
(1962) recorded low percentages in a few samples from the Cape
Romano area, Florida. They stated that *E. excavatum* occurred
primarily in the mangrove island region but was also present in
lagoons and the open gulf. Culver and Buzas (1981) documented
this species primarily in the northwestern Gulf and a few
occurrences in the Mississippi Delta area; all occurrences in
samples from <50m water depths. Poag (1981) stated that his
*Elphidium gunteri* forma *salsum* was abundant in coastal lagoons,
bays and estuaries with lower frequencies observed in the inner
shelf facies in the Gulf.

**Elphidium galvestonense** Kornfeld, 1931

Plate 3, figures 8-10

*Elphidium gunteri* Cole var. *galvestonensis* Kornfeld, 1931, p. 87,
pl. 15, fig. 1.

*Elphidium galvestonense* Kornfeld forma *typicum* POAG, 1978, p. 403, pl.
3, figs. 13-16, 22, 23. POAG, 1981, p. 60, pl. 35, fig. 3, pl.
36, fig. 3.

*Elphidium galvestonense* Kornfeld. PARKER, PHLEGAR and PEIRSON, 1953,
p. 7, pl. 3, figs. 15, 16. PHLEGAR, 1954, p. 639, pl. 2, figs. 1,
2. SHEPARD and MOORE, 1955, p. 1509, fig. 33 (#20). LEHMANN,
1957, p. 348, pl. 2, figs. 37-40. BENDA and PURI, 1962, p. 335,
pl. 1, figs. 9, 10.

Description: Test somewhat biconvex, involute, periphery rounded; chambers distinct, very slightly inflated, more than ten in the final whorl; sutures distinct, almost radial, depressed, some well defined large sutural bridges joining chambers; wall calcareous, finely perforate, a single large umbilical boss present, generally some small pustules at the base of the last formed chamber; aperture a series of small rounded openings above and at the base of the last formed chamber, sometimes obscured by pustules.

Occurrence: Elphidium galvestonense was present in low numbers in many samples from the study area. A single specimen was observed in sample 437B from the Breton Island barrier island locality, from one to four specimens in 26 samples from the back island lagoon locality, one to two specimens in four samples from the forebar locality and from one to four specimens in 11 samples from the Stake Island barrier island locality (see Appendices 2-9 for samples and percentages). Parker et al. (1953) recorded low percentages in most bay and beach stations, some marsh and few nearshore open gulf samples from the San Antonio Bay area. Lehmann (1957) stated this was one of the diagnostic species of the assemblage occurring between five and eight percent in his marginal brackish lake facies from Matagorda Bay, Texas. Shepard and Moore (1957) stated that it was one of the representative species of their bay assemblage in the Rockport area, Texas. Phleger (1965a) reported low percentages from south Texas coastal lagoons. Phleger reported (1965b) varying abundances from
Galveston Bay, Texas. He also stated that this species was rare to common in northern Gulf bays. Phleger (1954) recorded this species in a few open gulf and sound samples from the Mississippi Sound area. Poag (1981) stated that his *E. galvestonense* forma *typicum* was abundant in coastal lagoons, bays and inner shelf areas all around the Gulf. Benda and Puri (1962) reported that *E. galvestonense* occurred in greatest numbers in their lagoon assemblage but was also present in their marsh river and mangrove island assemblages from the Cape Romano area, Florida.

**Elphidium gunteri** Cole, 1931

Plate 3, figures 11-13

*Elphidium gunteri* COLE, 1931, p. 34, pl. 4, figs. 9, 10. PARKER,

PHLEGER and PEIRSON, 1953, p. 8, pl. 3, figs. 18, 19. PARKER,

1954, p. 508, pl. 6, fig. 16. PHLEGER, 1954, p. 639, pl. 2, figs. 3, 4. SHEPARD and MOORE, 1955, p. 1509, fig. 33 (#19). BANDY,

1956, p. 194, pl. 30, fig. 19. LEHMANN, 1957, p. 348, pl. 3, figs. 1-4. LANKFORD, 1959, p. 2098, pl. 2, fig. 7. BENDA and

PURI, 1962, p. 335, pl. 1, fig. 11.

*Elphidium gunteri* Cole forma *typicum* POAG, 1978, p. 402, pl. 2, figs. 13-16, 22, 23. POAG, 1981, p. 61, pl. 37, fig. 1, pl. 38, fig. 1.

Description: Test planispiral, involute, periphery broadly rounded; chambers distinct, generally not inflated, usually more than ten in the final whorl; sutures distinct, almost radial, depressed, numerous regular sutural bridges joining chambers; wall calcareous, coarsely perforate, numerous irregularly shaped large
umbilical bosses present; aperture consists of several rounded
openings at the base of the last formed chamber.

Remarks: There was a great variation in the number of umbilical bosses
observed on specimens from the study area. Some specimens had few
irregularly shaped large bosses while others had many smaller
irregular to regular shaped bosses.

Occurrence: Elphidium gunteri was common to abundant throughout the
study area. From one to 15 specimens were observed in nine core
samples, one to 15 specimens in three samples from the Breton
Island barrier island locality, five to 100 specimens in the 38
samples from the back island lagoon locality, ten to 39 specimens
in 19 samples from the forebar locality and from one to 93
specimens in 14 samples from the Stake Island barrier island
locality (see Appendices 2-9 for samples and percentages). Except
for a few marsh samples, Parker et al. (1953) reported frequencies
of E. gunteri generally between 20% and 30% in most samples to a
depth of 100m from the San Antonio Bay area. Phleger and Lankford
(1957) reported high living percentages of E. gunteri in this
area. Shepard and Moore (1955) stated that this was one of the
representative species of their bay facies of the Rockport area,
Texas. Phleger (1965a) recorded frequent occurrences in many
samples from south Texas coastal lagoons. Bandy (1956) stated
that this was one of the dominant species between about one and
14m from the northeastern Gulf. Parker (1954) reported
frequencies up to 9% shallower than 55m and less than one percent
to depths of 185m from the northeastern Gulf. Phleger (1954)
recorded varying percentages in a few sound samples and generally under 15% in many open gulf samples from the Mississippi Sound area. Scott (1986) documented assemblages containing up to 29% of his Elphidium excavatum forma gunteri in a few marine marsh samples from the lower Mississippi Delta. Phleger (1955) reported that E. gunteri was common in his Breton Sound and open gulf facies and present in some bay samples from the southeastern Mississippi Delta margin. Lankford (1959) stated this was one of the most widespread species along the east Mississippi Delta margin, abundant in his interdistributary bay, fluvial marine and sound assemblages with lower frequencies in his deltaic marine and open-shelf faunas. Poag (1981) stated that his E. gunteri forma typicum was abundant in coastal lagoons, bays and estuaries around the Gulf and in lower frequencies in the inner shelf facies. Benda and Puri (1962) stated this species was most abundant in their lagoon assemblage but also present in their mangrove island assemblage from the Cape Romano area, Florida.

Elphidium kugleri (Cushman and Brønnimann, 1948a)

Cribroelphidium kugleri CUSHMAN and BRØNNIMANN, 1948a, p. 18, pl. 4, fig. 4. LEHMAN, 1957, p. 348, pl. 2, figs. 21-24.

Elphidium kugleri (Cushman and Brønnimann). HANSEN and LYKKE-ANDERSEN, 1976, p. 12, pl. 9, figs. 4-8.

Description: Test planispiral, involute, periphery broadly rounded, umbilical area somewhat depressed; chambers distinct, moderately inflated, increasing in size as added, seven to nine in the final
whorl; sutures distinct, almost radial, depressed, small sutural bridges joining chambers; wall calcareous, very finely perforate; aperture a row of pores at the base of the last formed chamber, a few additional round openings present in the apertural face.

Remarks: Specimens of *E. kugleri* from the study area were compared with the holotype (Cushman Collection #56642) and paratypes (Cushman Collection #56746). The umbilical area of the holotype was much more depressed than observed on specimens from the study area but was similar to some of the paratypes. Cushman and Bronnimann (1948a, p. 18) in their type description of this species, stated "... aperture consisting of several very small openings at the peripheral margin of the last-formed chamber with several rounded openings in the apertural face tending to be in a horizontal series ...". These additional openings in the apertural face were not in a horizontal series on specimens from the study area, nor were they present on some of the paratypes.

Occurrence: Single specimens of *Elphidium kugleri* were observed in each of seven samples from the back island lagoon locality and a single specimen in sample 124B from the Stake Island barrier island locality (see Appendices 6-9 for samples and percentages). Lehmann (1957) recorded low percentages of *E. kugleri* in a few samples from the Matagorda Bay area, Texas. Warren (1957) reported few specimens in some samples from the Buras-Scotfield Bayou region, Louisiana.
Elphidium mexicanum Kornfeld, 1931

Plate 3, figures 14, 15


Elphidium mexicanum Kornfeld. Bandy, 1956, p. 194, pl. 30, fig. 20.

BuZas, Culver and Isham, 1985, p. 1087, figs. 7.7, 7.8.

Description: Test planispiral, involute, periphery somewhat lobate, narrowly rounded; chambers distinct, nine to eleven in the final whorl; sutures distinct, slightly curved, depressed, few small short sutural bridges joining chambers; wall calcareous, smooth, very finely perforate, has a milky appearance, umbilical area with several umbilical bosses; aperture a row of small pores at the base of the last formed chamber.

Remarks: In his type description of this species Kornfeld (1931) described specimens having a single central boss or multiple bosses. Most of the specimens observed in this study had several umbilical bosses.

Occurrence: Elphidium mexicanum was common in many samples from the study area. A single specimen was observed in one sample from the Breton Island barrier island locality, one to 36 specimens in 38 samples from the back island lagoon locality, six to 26 specimens in 19 samples from the forebar locality and from two to 14
specimens in ten samples from the Stake Island barrier island locality (see Appendices 2-9 for samples and percentages).

Phleger (1951) stated that this was a characteristic shallow water species in the northwestern Gulf found in frequencies less than two percent in water depths to 100m. Parker et al. (1953) reported frequencies of three to eight percent in many beach samples and less than one percent in a few gulf and marsh samples from the San Antonio Bay area. Phleger (1956) reported scattered occurrences to depths of about 40m from this area. Shepard and Moore (1955) stated this was one of the representative species in their beach and surf zone assemblage from the Rockport area, Texas. Lehmann (1957) recorded low percentages of this species in all of his facies from the Matagorda Bay area, Texas. Phleger (1954) recorded varying percentages in some sound and most open gulf samples from the Mississippi Sound area. Bandy (1956) documented fairly low consistent occurrences of *E. mexicanum* in water depths between about one and 14m in samples from the northeastern Gulf. Otvos (1978) recorded low percentages in a few samples from Lake Pontchartrain, Louisiana. Phleger (1955) stated this species was largely confined to his Breton Sound facies, but also present in his open gulf facies in the southeastern Mississippi Delta area. Benda and Puri (1962) reported varying numbers of this species in some of their mangrove and open gulf assemblage.
Elphidium poeyanum (d'Orbigny, 1839b)

Plate 3, figures 16-18

Polystomella poeyana d'ORBIGNY, 1839b p. 55, pl. 6, figs. 25, 26.


Description: Test planispiral, involute, slightly compressed, periphery broadly rounded, final chambers slightly lobate, umbilical area not depressed although a depression in umbilical area on some specimens; chambers distinct, usually nine to ten in the final whorl; sutures distinct, slightly curved, depressed, small sutural bridges joining chambers; wall calcareous, numerous perforations; aperture a few pores at the base of the last formed chamber.

Remarks: This species is similar in outline to Elphidium kuwleri but is distinguished by the greater number of chambers that are more inflated and an umbilicus that is not depressed. The specimens observed seemed to fall into two groups, those that had a milky appearance and other that were more translucent.

Occurrence: Elphidium poeyanum was common in many samples from the study area. From one to 45 specimens were observed in 37 samples from the back island lagoon locality, two to 56 specimens in 19
samples from the forebar locality and from one to 19 specimens in
nine samples from the Stake Island barrier island locality (see
Appendices 4-9 for samples and percentages). Parker et al. (1953)
recorded between one and five percent in most bay stations and its
presence in a few marsh and beach and most open gulf samples from
the San Antonio Bay area. Phleger (1956) recorded occurrences to
about 55m from this area. Lehmann (1957) reported few occurrences
in the Matagorda Bay area, Texas. Bandy (1954) recorded high
percentages of this species between ten and 17m from Sabine Pass,
Texas to Grand Cheniere, Louisiana. In the northeast Gulf, Parker
(1954) documented this species to depths of 145m with frequencies
of up to two percent in shallow water and less than one percent in
deeper water. *E. poeyanum* was one of the dominant species between
about one and 14m in samples from the northeastern Gulf (Bandy,
1956). Phleger (1954) reported low percentages predominately in
his open gulf facies but also present in his sound facies from the
Mississippi Sound area. Warren (1957) documented low percentages
in some samples from the Buras-Scotfield Bayou region, Louisiana.
Phleger (1955) recorded varying percentages in his Breton Sound
and open gulf facies in the southeastern Mississippi Delta area.
Lankford (1959) stated this species was most abundant in his sound
assemblage from the east Mississippi Delta margin. Varying
percentages of *E. poeyanum* were identified in samples from the
Cape Romano area, Florida in Benda and Puri's (1962) study of this
area.
Genus *Haynesina* Banner and Culver, 1978

*Haynesina germanica* (EHRENBERG, 1840)

Plate 3, figures 19, 20

*Nonionina germanica* EHRENBERG, 1840, p. 23. EHRENBERG, 1841, pl. 2, fig. 1.

*Nonion tiburyvensis* BUTCHER, 1948, p. 22, figs. 1-3.

*Protelphidium anglicum* MURRAY, 1965, p. 149, pl. 26, figs. 1-6.

*Haynesina germanica* (EHRENBERG). BANNER and CULVER, 1978, p. 191, pl. 4, figs. 1-6, pl. 5, figs. 1-8, pl. 6, figs. 1-7, pl. 7, figs. 1-6, pl. 8, figs. 1-10, pl. 9, figs. 1-11, 15, 18. BUZAS, CULVER and ISHAM, 1985, p. 1089, figs. 8.4, 8.5.

Description: Test planispiral, involute, periphery slightly lobate, rounded, umbilical area depressed; chambers distinct, somewhat inflated, increasing in size as added, seven to nine in the final whorl; sutures distinct, curved, depressed to deeply incised near the umbilical area; wall calcareous, perforate, small pustules present along sutures and in umbilical area; aperture interiomarginal, a low arch extending almost to the umbilicus, often obscured by pustules.

Remarks: *Haynesina germanica* lacks sutural bridges; this is the main distinguishing feature between this genus and *Elphidium*. Varying degrees of pustules were observed on specimens ranging from very few to specimens where the umbilicus and sutures were almost completely obscured. Specimens of *H. germanica* from the study area were compared with the holotype (Cushman Collection #51893) and paratypes (Cushman Collection #51894 and #51895) of *Nonion*
tisburyensis which were larger and had more curved sutures than those from the study area. They were also compared with Buzas and Severin's (1982) hypotype of H. germanica (U. S. N. M. Collection #310211) with which they compared well. Haynesina germanica had not been reported in the Gulf of Mexico prior to 1981; at that time Culver and Buzas (1981) placed Elphidium matagordanum in synonymy with H. germanica.

Occurrence: Haynesina germanica was present in many samples from the study area. From one to 19 specimens were observed in ten core samples, one to 15 specimens in four samples from the Breton Island barrier island locality, one to nine specimens in 23 samples from the back island lagoon locality, one to 13 specimens in 16 samples from the forebar locality and from one to three specimens in six samples from the Stake Island barrier island locality (see Appendices 2-11 for samples and abundances). Culver and Buzas (1981) reported H. germanica in the Gulf of Mexico at depths of <100m.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862
Family HETEROHELICIDAE Cushman, 1927
Subfamily HETEROHELICINAE Cushman, 1927
Genus Heterohelix Ehrenberg, 1843

Heterohelix sp. A

Occurrence: These Cretaceous specimens were rare, ranging from one to five in eight samples from the core (see Appendices 10, 11 for samples and percentages).
Family PIANOMALINIDAE Bolli, Loeblie and Tappan, 1957

Genus Globigerinelloides Cushman and Ten Dam, 1948

Globigerinelloides sp. A

Occurrence: These fossil specimens were rare, single specimens were observed in core samples 240-241 cm, 350-351 cm and 430-431 cm and two specimens were observed in each of core samples 190-191 cm and 310-311 cm.

Family GLOBIGERINIDAE Carpenter, Parker and Jones, 1862

Subfamily GLOBIGERININAE Carpenter, Parker and Jones, 1862

Genus Globigerinoides Cushman, 1927

Globigerinoides ruber (d'Orbigny, 1839a)

Globigerina rubra d'ORBIGNY, 1839a, p. 82, pl. 4, figs. 12-14.

Globigerinoides rubra (d'Orbigny). Cushman, 1927, p. 86. BERMUDEZ, 1949, p. 281, pl. 21, fig. 52. PHLEGER and PARKER, 1951, p. 35, pl. 19, fig. 16. BANDY, 1954, p. 136, pl. 31, fig. 6.

Globigerinoides ruber (d'Orbigny). KENNEIT and SRINIVASAN, p. 78, pl. 10, fig. 6, pl. 17, figs. 1-3.

Description: Test large, moderately trochospiral; three subspherical chambers in final whorl, increasing in size as added; sutures distinct, depressed, radial; wall calcitic, coarsely perforate, has a rough appearance; primary aperture interiomarginal, large, arch-shaped, supplementary apertures smaller, situated above sutures of earlier chambers.

Occurrence: Three specimens of Globigerinoides ruber observed in a sample from the Breton Island barrier island locality, three
specimens in a sample from the back island lagoon locality and from one to four specimens in six samples from the forebar locality (see Appendices 2–7 for samples and percentages). Phleger and Parker (1951) stated that this was the most abundant planktonic species in their study of the Gulf of Mexico foraminifera. Bandy (1954) observed a similar distribution but stated that it generally first appears between about 20 and 23m depth and becomes progressively more abundant offshore.

Superfamily ORBITOIDACEA Schwager, 1876
Family CIBICIDIDAE Cushman, 1927
Subfamily CIBICIDINAE Cushman, 1927
Genus Cibicides de Montfort, 1808

*Cibicides lobatulus* (Walker and Jacob, 1798)

*Nautilus lobatulus* WALKER and JACOB, 1798, p. 642, pl. 14, fig. 36.

*Truncatulina lobatula* (Walker and Jacob). d'ORBIGNY, 1839a, p. 134, pl. 2, figs. 22–24. BRADY, 1884, p. 660, pl. 92, fig. 10, pl. 93, fig. 1. CUSHMAN, 1918, p. 16, pl. 1, fig. 10, p. 60, pl. 17, figs. 1–3.

*Cibicides lobatulus* (Walker and Jacob). CUSHMAN, 1927b, p. 170, pl. 27, figs. 12, 13. CUSHMAN, 1935, p. 52, pl. 22, figs. 4–6.

Description: Test plano-convex, somewhat compressed, dorsal side flattened, ventral side moderately convex, periphery slightly lobate, acute; chambers distinct, increasing rapidly in size, all chambers visible on dorsal side, only those of last formed coil visible on ventral side; sutures distinct, curved, depressed; wall
calcarea.JS, SDXJth, nw:xterately perforate; aperture a low opening at the peripheral base of the final chamber extending slightly along the periphery into the ventral side.

Occurrence: A single specimen of Cibicides lobatulus was observed in sample 506A from the Breton Island barrier island locality. Benda and Puri (1962) reported a few specimens of C. lobatulus in samples from the Cape Romano area, Florida. Pflum and Frerichs (1976) recorded very low percentages of it between about 200 and 300m in samples from the continental slope off Louisiana.

Superfamily CASSIDULINACEA d'Orbigny, 1839
Family CAUCASINIDAE Bykova, 1959
Subfamily FURSENKOININAE Loeblich and Tappan, 1961
Genus Fursenkoina Loeblich and Tappan, 1961
Fursenkoina pontoni (Cushman, 1932)
Virgulina pontoni CUSHMAN, 1932, p. 17, pl. 3, fig. 7. PHLEGER and PARKER, 1951, p. 19, pl. 9, figs. 9, 10. PARKER, PHLEGER, and PETRSON, 1953, p. 15, pl. 4, figs. 14, 15. PARKER, 1954, p. 513, pl. 7, fig. 9. PHLEGER, 1954, p. 646, pl. 3, fig. 25. SHEPPARD and MOORE, 1955, p. 1509, fig. 33 (#56, 57). LANKFORD, 1959, p. 2099. pl. 2, fig. 17.
Fursenkoina pontoni (Cushman). FOAG, 1981, p. 66, pl. 33, fig. 5, pl. 34, fig. 5.
Description: Test elongate, tapering, widest part above middle, periphery somewhat lobate, rounded; chambers distinct, arranged in biserial fashion, very twisted in early stage becoming less so

167
towards terminal end, chambers inflated, increasing in size as added; sutures distinct, depressed, straight to slightly curved; wall calcareous, smooth, very finely perforate; aperture an arched opening in a depressed apertural face at terminal end of final chamber, a tooth present at base of aperture.

Remarks: Specimens from the study area were compared with the holotype (Cushman Collection #16298) and paratypes (Cushman Collection #16297). The holotype was slightly larger and its chambers more inflated than specimens from the study area. Specimens from this study were very similar to the paratypes.

Occurrence: One specimen of Forsenkina pontoni was observed in sample 404A from the back island lagoon locality, a single specimen in sample 421 from the forebar locality and one specimen in sample 097A from the Stake Island barrier island locality. Phleger (1951) reported this species was abundant in the northwest Gulf, comprising up to 35% of the assemblage at depths less than 125m and with rare occurrences to 1000m. Parker et al. (1953) recorded very low frequencies in most open gulf stations and few beach samples from the San Antonio Bay area. Phleger (1956) reported frequencies of less than one percent in samples shallower than 15m, up to 15% in samples to 75m and dropping off to between one and five percent at 75-110m in this area. Shepard and Moore (1957) stated this species was representative in their open shelf facies of the Rockport area, Texas. In the northeastern Gulf, Parker (1954) reported frequencies of up to four percent from depths to 105m and less than one percent in deeper samples. Scott
(1986) documented assemblages containing up to four percent in a few marine marsh samples from the lower Mississippi Delta. Phleger (1954) recorded occurrences of up to one percent in open gulf samples from the Mississippi Sound area. Phleger (1955) stated that this was one of the characteristic species of his open-gulf facies from the southeastern Mississippi Delta area. Lankford (1959) recorded F. pontoni in his deltaic marine assemblage from the east Mississippi Delta margin. Poag (1981) stated that F. pontoni is found predominantly in the western Texas shelf although present in lower frequencies in other shelf area around the Gulf.

Family CASSIDULINIDAE d'Orbigny, 1839

Genus Cassidulina d'Orbigny, 1826

Cassidulina cf. Cassidulina laevigata d'Orbigny, 1826

Plate 3, figure 21

Cassidulina laevigata d'ORBIGNY, 1826, p. 282, pl. 15, figs. 4, 5. BRADY, 1884, p. 428, pl. 54, figs. 1-3. CUSHMAN, 1911, p. 96, fig. 150. CUSHMAN, 1918, p. 9, pl. 1, fig. 5. PHLEGER and PARKER, 1951, pl. 14, fig. 6. PARKER, 1954, p. 536, pl. 11, fig. 2.

Description: Test biconvex, nearly circular in outline, lenticular in side view, periphery somewhat angled; chambers indistinct; sutures flush; wall calcareous, smooth; aperture a narrow elongate slit close to the periphery and parallel to the margin.
Remarks: The tentative identification of this species was due to the poor preservation of the specimen.

Occurrence: A single specimen of Cassidulina cf. C. laevigata was observed in sample 082 from the forebar locality. Phleger and Parker (1951) stated that this was an abundant species in restricted areas in the northwest Gulf of Mexico. Parker (1954) reported frequencies of up to six percent shallower than 150m and less than one percent to a depth of 3000m in samples from the northwestern Gulf.

Family NONIONIDAE Schultze, 1854
Subfamily NONIONINAE Schultze, 1854
Genus Nonionella Cushman, 1926
Nonionella atlantica Cushman, 1947
Plate 3, figures 22, 23

Nonionella atlantica CUSHMAN, 1947, p. 90, pl. 20, figs. 4, 5.
PHLEGER and PARKER, 1951, p. 11, pl. 5, figs. 21-23. PARKER,
PHLEGER and PETRSON, 1953, p. 11, pl. 3, figs. 30, 31. PARKER,
1954, p. 507, pl. 6, figs. 6, 7. PHLEGER, 1954, p. 642, pl. 2,
figs. 25, 26. LANKFORD, 1959, p. 2098, pl. 2, fig. 13. BUZAS and
SEVERIN, 1982, p. 41, pl. 10, figs. 10-12.

Description: Test trochospiral, asymmetrical, longer than broad,
slightly compressed, periphery rounded; chambers distinct,
numerous, all chambers visible on dorsal side, partially evolute,
ventral side involute, only chambers of the last formed coil
visible, chambers slightly inflated, increasing in size as added;
sutures distinct, slightly curved, slightly depressed; wall
calcareous, smooth, some very small pustules extending into the
sutures on dorsal side of some specimens, on ventral side
umbilical area somewhat papillate; aperture a low arch near
periphery extending along dorsal margin of the last-formed
chamber.

Remarks: Specimens of Nonionella atlantica from the study area
compared well with the holotype (Cushman Collection #49133).

Occurrence: Nonionella atlantica was generally rare, from one to four
specimens were observed in each of sixteen samples from the back
island lagoon and forebar localities and from four to nine
specimens in three samples from the Stake Island barrier island
locality (see Appendices 4-9 for samples and percentages).

Phleger and Parker (1951) reported that this was the most abundant
species of the genus comprising up to ten percent of the samples
throughout the northwestern Gulf of Mexico. They also stated that
it was most abundant at depths less than 70m. Parker et al.
(1953) reported frequencies of up to seven percent in open gulf
stations and lower frequencies from shallower depths in the San
Antonio Bay area. Phleger (1956) reported abundant living
specimens between ten and 73m from this area. Parker (1954)
recorded frequencies of up to ten percent in samples from less
than 140m while less than one percent in samples greater than 140m
from the northeastern Gulf of Mexico. Phleger (1954) stated that
N. atlantica was confined to the open-gulf facies in the
Mississippi Sound area, present in frequencies averaging between
five and ten percent. Otvos (1978) recorded low percentages of *N. atlantica* in two samples from Lake Pontchartrain, Louisiana. An assemblage containing three percent of *N. atlantica* was documented by Scott (1986) in a marine marsh sample from the lower Mississippi Delta. Phleger (1955) recorded its presence in his Breton Sound and open-gulf facies in the southeastern Mississippi Delta area. Lankford (1959) reported that *N. atlantica* was most abundant in the open-shelf environment but also rarely observed in the deltaic marine environment. Buzas and Severin (1982) recorded a few specimens of *N. atlantica* in several samples from the Indian River, Florida.

**Nonionella opima** Cushman, 1947

Plate 3, figures 24, 25


Description: Test trochoespiral, asymmetrical, longer than broad, periphery broadly rounded; chambers distinct, numerous, slightly inflated, increasing in size as added, all chambers visible on dorsal side, partially evolute, ventral side involute, only chambers of last formed coil visible, final chamber very inflated and extending over the umbilical region; sutures distinct, slightly curved, slightly depressed; wall calcareous, smooth;
aperture a low arch near periphery extending below the overhanging part of the last formed chamber.

Remarks: Specimens of *Nonionella ovima* from the study area were compared with the holotype (Cushman Collection #49130) and paratypes (Cushman Collection #49132). The only difference noted was that the final chamber on specimens from the study area was not as inflated as those of the holotype and paratypes.

Occurrence: *Nonionella ovima* was rare, a single specimen was observed in a sample from the back island lagoon locality, from one to two specimens in three samples from the forebar locality and from one to three specimens in two samples from the Stake Island barrier island locality (see Appendices 4–9 for samples and percentages). Parker et al. (1953) reported that this was a common species to depths of 100m, present in frequencies of up to five percent in open gulf stations and also reported its occurrence in a few bay samples San Antonio Bay. Phleger (1956) reported abundant living specimens between seven and 79m offshore from this area. Parker (1954) recorded frequencies of up to 31% in samples from less than 100m and variable frequencies to depths greater than 400m in samples from the northeastern Gulf of Mexico. Phleger (1954) documented the presence of *N. ovima* in the open-gulf facies from the Mississippi Sound area and stated that it had the same distribution as *N. atlantica* in this area. Phleger (1955) also recorded a similar distribution in the southeastern Mississippi Delta area as *N. atlantica*. Lankford (1959) reported *N. ovima* was very abundant in the deltaic marine environment with lower
frequencies in the sound and fluvial marine assemblages. Buzas and Severin (1982) recorded low numbers of this species throughout the Indian River, Florida.

Family ANOMALINIDAE Cushman, 1927

Subfamily ANOMALINI NAE Cushman, 1927

Genus Hanzawaia Asano, 1944

Hanzawaia strattoni (Applin, 1925)

Plate 3, figures 26, 27

Truncatulina americana Cushman var. strattoni APPLIN, 1925, p. 99, pl. 3, fig. 3.


Hanzawaia strattoni (Applin). BANDY, 1954, p. 136, pl. 31, fig. 4.

LANKFORD, 1959, p. 2098, pl. 3, fig. 16.

Description: Test nearly plano-convex, longer than broad, dorsal side planar, partially involute, usually with open umbilicus, ventral side involute, large umbilical boss present, periphery subrounded to angular; chambers distinct, slightly inflated, increasing in size as added; on dorsal side flaps extending from each chamber fusing with flaps from adjacent chambers; sutures distinct, curved, thick, almost flush; wall calcareous, smooth, finely perforate; aperture an arch on the periphery extending somewhat into the ventral side but also laterally continuous with opening on dorsal side.
Occurrence: *Hanzawaia strattoni* was generally rare but occurred in a large number of samples. A single specimen was observed in sample 504B from the Breton Island barrier island locality, one to five specimens in 21 samples from the back island lagoon locality, one to three specimens in 15 samples from the forebar locality and from one to seven specimens in nine samples from the Stake Island barrier island locality (see Appendices 2-9 for samples and percentages). *H. strattoni* was named from Miocene material drilled from coastal Texas and Louisiana (Applin et al., 1925). Parker et al. (1953) recorded frequencies of up to 11% in open gulf samples, low frequencies in beach samples and present in some bay samples from the San Antonio Bay area. Phleger (1956) reported frequencies between five and ten percent of the fauna between ten and 110m along the central Texas coast. Bandy (1954) recorded between ten and 45% of *H. strattoni* between about 17m and 43m from Sabine Pass, Texas to Grand Cheniere, Louisiana and Bandy (1956) reported a similar distribution in the northeastern Gulf of Mexico. Phleger (1954) stated that this was one of the dominant species in the fauna from the open-gulf samples in the Mississippi Sound area. Phleger (1955) recorded this species in his Breton Sound and open-gulf facies from the southeastern Mississippi Delta margin. Lankford (1959) recorded it in his open-gulf facies from this same area.

**Indeterminate Miliolids**

Remarks: This category includes any fragments or specimens of
miliolids that could not be identified due to the poorly preserved nature of the test. These specimens were included to obtain an accurate total count of foraminifera per sample. Numbers of specimens included in this category ranged from one to ten in 25 samples from all four of the localities (see Appendices 2–9 for samples and percentages).

Indeterminate Rotalids

Remarks: This category includes any fragments or specimens of rotalids that could not be identified due to the poorly preserved nature of the test. These specimens were included to obtain an accurate total count of foraminifera per sample. Numbers of specimens ranged from one to four in 13 samples in all localities except the Breton Island Barrier Island locality (see Appendices 4–9 for samples and percentages). One specimen was observed in core sample 310–311cm.

Indeterminate Textularids

Remarks: This category includes any fragments or specimens of textularids that could not be identified due to the poorly preserved nature of the test. These specimens were included to obtain an accurate total count of foraminifera per sample. Two specimens were recorded from sample 504A and three specimens in sample 506A from the Breton Island Barrier Island locality.
Figures

1. *Centropyxis aculeata* (Ehrenberg)
   1) ventral view of specimen with the possible remnants of two spines, specimen from core sample 0-1cm

2. *Centropyxis constricta* (Ehrenberg)
   2) ventral view, specimen from core sample 0-1cm

3. *Diffugia oblonga* Ehrenberg
   3) side view, specimen from core sample 0-1cm

4. *Sulcophax palustris* Warren
   4) side view, apertural end broken, specimen from sample 503A

5. *Miliammina fusca* (Brady)
   5) side view, specimen from sample 503B

6. *Haplophragmoides manilaensis* Andersen
   6) side view, specimen from core sample 0-1cm

7,8. *Haplophragmoides wilberti* Andersen
   7) side view
   8) apertural view, both specimens from sample 504A

9. *Haplophragmoides* sp. A
   9) side view, specimen from sample 504A

10,11. *Ammocastuta inepta* (Cushman and Brönnimann)
   10) side view, specimen from sample 503B
   11) side view, specimen from sample 503A

12. *Ammobaculites dilatatus* Cushman and Brönnimann
   12) side view, specimen from sample 503B

13,14. *Ammotium multiloculatum* Warren
   13) side view of specimen with well developed coil, specimen from sample 503B
   14) side view, specimen from sample 503A
Figures

15  *Ammotium salsum* (Cushman and Brönnimann)  
   15) side view, specimen from sample 506B

16  *Textularia earlandi* Parker  
   16) side view of broken specimen, specimen from sample 506A

17,18  *Trochammina inflata* (Montagu)  
   17) dorsal view, specimen from sample 506A  
   18) ventral view, specimen from sample 503B

19  *Trochammina lobata* Cushman  
   19) ventral view, specimen from sample 426

20,21  *Trochammina macrescens* Brady  
   20) dorsal view  
   21) ventral view, both specimens from sample 506A

22,23  *Arenoparrella mexicana* Andersen  
   22) dorsal view  
   23) ventral view, both specimens from sample 506A

24,25  *Tiphotrecha comprimata* (Cushman and Brönnimann)  
   24) dorsal view, specimen from sample 506B  
   25) ventral view, specimen from sample 506A
Figures

1. *Eggerella advena* (Cushman)
   1) side view, specimen from sample 083B

2. *Cyclocyra involvens* Reuss
   2) side view, specimen from sample 498

3. *Quinqueloculina goesi* Weisner
   3) side view, specimen from sample 403B

4. *Quinqueloculina impressa* Reuss
   4) side view, specimen from sample 099A

5, 6. *Quinqueloculina jugosa* Cushman
   5) side view, specimen from sample 099A
   6) side view of specimen with attached sand grains, specimen from sample 437A

7. *Quinqueloculina seminula* (Linné)
   7) side view, specimen from sample 405B

8, 9. *Quinqueloculina* sp. A
   8) side view
   9) apertural view of specimen in fig. 8, specimen from sample 128A

10, 11. *Quinqueloculina* sp. B
    10) side view
    11) apertural view of specimen in fig. 10, specimen from sample 128A

12, 13. *Quinqueloculina* sp. C
    12) side view
    13) apertural view of specimen in fig. 12, specimen from sample 099A

14. *Pateoris dilitata* (d'Orbigny)
    14) side view, specimen from sample 128B

15. *Miliolinella* sp. A
    15) side view, specimen from sample 406B
PLATE 2 (con't)

Figures

16  Miliolinella sp. B
    16) side view, specimen from sample 128A

17  Guttulina australis (d'Orbigny)
    17) side view, specimen from sample 128A

18  Buliminella elegantissima (d'Orbigny)
    18) side view, specimen from sample 430

19,20  Bolivina lowmani Phleger and Parker
    19) side view, specimen from sample 084
    20) edge view, specimen from sample 423

21,22  Bolivina striatula Cushman
    21) side view, specimen from sample 421
    22) side view, specimen from sample 426

23,24  Buccella hannai (Phleger and Parker)
    23) dorsal view
    24) ventral view of specimen in fig. 23, specimen from sample 416A

25,26  Eoependella pulchella (Parker)
    25) dorsal view
    26) ventral view of specimen in fig. 25, specimen from sample 409B
Figures

1-4

*Ammonia beccarii* (Linne)
1) dorsal view of typical specimen, specimen from sample 082
2) dorsal view of ornamented specimen, specimen from sample 411B
3) ventral view of specimen with umbilical boss, specimen from sample 501
4) ventral view of specimen without umbilical boss, specimen from sample 082

5-7

*Elphidium excavatum* (Terquem)
5) side view
6) side view, both specimens from sample 421
7) apertural view, specimen from sample 422

8-10

*Elphidium galvestonense* Kornfeld
8) oblique side view, specimen from sample 417A
9) side view, specimen from sample 124B
10) apertural view, specimen from sample 070A

11-13

*Elphidium gunteri* Cole
11) side view, specimen from sample 406A
12) side view, specimen from sample 070B
13) apertural view, specimen from sample 070A

14,15

*Elphidium mexicanum* Kornfeld
14) oblique side view, specimen from sample 406B
15) apertural view, specimen from sample 421

16-18

*Elphidium poeyanum* (d'Orbigny)
16) side view, specimen from sample 421
17) oblique apertural view, specimen from sample 406B
18) apertural view, specimen from sample 422

19,20

*Haynesina germanica* (Ehrenberg)
19) side view, specimen from sample 500
20) side view, specimen from sample 082

21

*Cassidulina* cf. *Cassidulina laevigata* d'Orbigny
21) side view, specimen from sample 082
Figures

22,23 Nonionella atlantica Cushman
   22) ventral view, specimen from sample 082
   23) dorsal view, specimen from sample 084

24,25 Nonionella opima Cushman
   24) ventral view
   25) dorsal view of specimen in fig. 24, specimen from sample 084

26,27 Hanzawaia strattoni (Applin)
   26) ventral view, specimen from sample 128A
   27) dorsal view, specimen from sample 412B
REFERENCES CITED

Andersen, H. V., 1951a. Two new genera of foraminifera from recent deposits in Louisiana. Journal of Paleontology, v. 25, p. 31-34.


____, 1961. Laboratory experiments on the ecology of foraminifera. Contributions from the Cushman Foundation for Foraminiferal Research, v. 12, p. 87-106.


Kornfeld, M. M., 1931. Recent littoral foraminifera from Texas and Louisiana. Contributions from the Department of Geology, Stanford University, v. 1, p. 77-107.


Saunders, J. B., 1957. Trochamminidae and certain Lituolidae (Foraminifera) from the recent brackish-water sediments of Trinidad, British West Indies. Smithsonian Miscellaneous Collections, v. 134, p. 1-16.


Appendix 1. Measurements of physical and chemical parameters for the four localities. Breton Island barrier island locality includes samples 099, 408, 435-437, 503-509; forebar locality includes samples 082, 084, 421-434, 498, 500, 501; back island lagoon locality includes samples 401-407, 409-420; Stake Island barrier island locality includes samples 070, 083, 085, 097, 123, 124, 128.
<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>DEPTH (m)</th>
<th>T°C</th>
<th>St. (%)</th>
<th>Eh (mv)</th>
<th>pH</th>
<th>O₂</th>
<th>TURB</th>
<th>Ca mg/l</th>
<th>Fe mg/l</th>
<th>Pb mg/l</th>
<th>Si mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>099</td>
<td>0.15</td>
<td>31</td>
<td>22.56</td>
<td>-185</td>
<td>9.40</td>
<td>9.80</td>
<td>37</td>
<td>328</td>
<td>0.30</td>
<td>0.54</td>
<td>3</td>
</tr>
<tr>
<td>408</td>
<td>2.74</td>
<td>35</td>
<td>2.01</td>
<td>-250</td>
<td>8.52</td>
<td>5.34</td>
<td>50</td>
<td>265</td>
<td>0.23</td>
<td>0.08</td>
<td>2</td>
</tr>
<tr>
<td>435</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>436</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>437</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>503</td>
<td>0.15</td>
<td>29</td>
<td>20.92</td>
<td>-195</td>
<td>7.50</td>
<td>7.53</td>
<td>0</td>
<td>247</td>
<td>0.64</td>
<td>0.16</td>
<td>3</td>
</tr>
<tr>
<td>504</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>505</td>
<td>0.25</td>
<td>29</td>
<td>22.90</td>
<td>-280</td>
<td>8.10</td>
<td>6.77</td>
<td>0</td>
<td>262</td>
<td>0.30</td>
<td>0.26</td>
<td>3</td>
</tr>
<tr>
<td>506</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>507</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>508</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>509</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SEDIMENT-WATER INTERFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T°C</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>32</td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>33</td>
</tr>
<tr>
<td>29</td>
</tr>
<tr>
<td>33</td>
</tr>
<tr>
<td>33</td>
</tr>
<tr>
<td>29</td>
</tr>
<tr>
<td>32</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>29</td>
</tr>
<tr>
<td>29</td>
</tr>
<tr>
<td>29</td>
</tr>
<tr>
<td>SAMPLE</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>082</td>
</tr>
<tr>
<td>084</td>
</tr>
<tr>
<td>421</td>
</tr>
<tr>
<td>422</td>
</tr>
<tr>
<td>423</td>
</tr>
<tr>
<td>424</td>
</tr>
<tr>
<td>425</td>
</tr>
<tr>
<td>426</td>
</tr>
<tr>
<td>427</td>
</tr>
<tr>
<td>428</td>
</tr>
<tr>
<td>429</td>
</tr>
<tr>
<td>430</td>
</tr>
<tr>
<td>431</td>
</tr>
<tr>
<td>432</td>
</tr>
<tr>
<td>433</td>
</tr>
<tr>
<td>434</td>
</tr>
<tr>
<td>498</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>501</td>
</tr>
<tr>
<td>SAMPLE</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>401</td>
</tr>
<tr>
<td>402</td>
</tr>
<tr>
<td>403</td>
</tr>
<tr>
<td>404</td>
</tr>
<tr>
<td>405</td>
</tr>
<tr>
<td>406</td>
</tr>
<tr>
<td>407</td>
</tr>
<tr>
<td>408</td>
</tr>
<tr>
<td>409</td>
</tr>
<tr>
<td>410</td>
</tr>
<tr>
<td>411</td>
</tr>
<tr>
<td>412</td>
</tr>
<tr>
<td>413</td>
</tr>
<tr>
<td>414</td>
</tr>
<tr>
<td>415</td>
</tr>
<tr>
<td>416</td>
</tr>
<tr>
<td>417</td>
</tr>
<tr>
<td>418</td>
</tr>
<tr>
<td>419</td>
</tr>
<tr>
<td>420</td>
</tr>
<tr>
<td>SAMPLE</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>070</td>
</tr>
<tr>
<td>083</td>
</tr>
<tr>
<td>085</td>
</tr>
<tr>
<td>097</td>
</tr>
<tr>
<td>123</td>
</tr>
<tr>
<td>124</td>
</tr>
<tr>
<td>128</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WATER MASS</th>
<th>SEDIMENT-WATER INTERFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T°C</td>
</tr>
<tr>
<td>070</td>
<td>30</td>
</tr>
<tr>
<td>083</td>
<td>31</td>
</tr>
<tr>
<td>085</td>
<td></td>
</tr>
<tr>
<td>097</td>
<td>33</td>
</tr>
<tr>
<td>123</td>
<td>27</td>
</tr>
<tr>
<td>124</td>
<td>29</td>
</tr>
<tr>
<td>128</td>
<td>30</td>
</tr>
</tbody>
</table>
Appendix 2. Specimen counts for benthic foraminifera per sample from the Breton Island barrier island locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (--) for fraction picked indicates the complete sample was picked.
<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Final Score</th>
<th>Severity</th>
<th>Time</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table Notes:**
- **Final Score:** The overall score given to the sample.
- **Severity:** Indicates the level of severity related to the sample.
- **Time:** The time duration associated with the sample.
- **Score:** Additional scores or metrics related to the sample.

*Legend for Score Values:*

- 0: Non-applicable
- 1: Low
- 2: Medium
- 3: High
- 4: Very High

**Sample Example:**

- Sample 1 has a final score of 3, with severity at high level, and a time duration of 2 hours.

*Further Analysis:* The table provides a comprehensive framework to evaluate and categorize samples based on their scores and severity levels.
Appendix 3. Relative abundance (percent frequency) for benthic foraminifera per sample from the Breton Island barrier island locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species.
<table>
<thead>
<tr>
<th>Sample Number</th>
<th>(1000-9999999)</th>
<th>(9999999-999999999)</th>
<th>(999999999-99999999999)</th>
<th>(99999999999-9999999999999)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Species (L/M/L/M)</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20</td>
<td>21 22 23 24 25 26 27 28 29 30</td>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
<tr>
<td>No. of Individuals (L/M/L/M)</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20</td>
<td>21 22 23 24 25 26 27 28 29 30</td>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
<tr>
<td>Adults</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20</td>
<td>21 22 23 24 25 26 27 28 29 30</td>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
<tr>
<td>Individuals (L/M/L/M)</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20</td>
<td>21 22 23 24 25 26 27 28 29 30</td>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
<tr>
<td>L. loewi</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20</td>
<td>21 22 23 24 25 26 27 28 29 30</td>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
<tr>
<td>L. punicea</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20</td>
<td>21 22 23 24 25 26 27 28 29 30</td>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
<tr>
<td>L. semen</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20</td>
<td>21 22 23 24 25 26 27 28 29 30</td>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
<tr>
<td>L. semen</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>11 12 13 14 15 16 17 18 19 20</td>
<td>21 22 23 24 25 26 27 28 29 30</td>
<td>31 32 33 34 35 36 37 38 39 40</td>
</tr>
</tbody>
</table>

200
Appendix 4. Specimen counts for benthic foraminifera and thecamoebians per sample from the forebar locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (—) for fraction picked indicates the complete sample was picked.
Appendix 5. Relative abundance (percent frequency) for benthic foraminifera and thecamoebians per sample from the forebar locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species.
Appendix 6. Specimen counts for benthic foraminifera per sample from the back island lagoon locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (—) for fraction picked indicates the complete sample was picked.
Appendix 7. Relative abundance (percent frequency) for benthic foraminifera per sample from the back island lagoon locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species.
Appendix 8. Specimen counts for benthic foraminifera per sample from the Stake Island barrier island locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species, the symbol (—) for fraction picked indicates the complete sample was picked.
Appendix 9. Relative abundance (percent frequency) for benthic foraminifera per sample from the Stake Island barrier island locality. L indicates living specimens, T includes both living and dead specimens, a (*) preceding a foraminiferal name indicates a fossil species.
Appendix 10. Specimen counts for benthic foraminifera and thecamoebians per sample from core BB92. The symbol (—) for fraction picked indicates the complete sample was picked, a (*) preceding a foraminiferal name indicates a pre-Holocene fossil species.
.. •

-

,------------,---.-----.---,---,---,,.--... --~- . -- ,--,---,---~-.-~--.---.-~-.---.-~-~DEl'III Dl<IR (ml
It- ,._ 59- ,,_ ,._ 120-- no-- Ho- no- ,.,. 220- :ato- HO-- ao-- Jl► no- ,,. no-, no-- uo- uo-- •~ no-- •-- sao-- s10- ,-.

--

~ ,,,_ AO-- MO- uo-- fft- no- Ho- 1s,l
•-mmmmmmrnmmmmmmmmmmmmmm~~-wmm-mm----------1--+-+--,1--+-+--'I-- --+----,t--+--+----,t--t---+---it--+---+--lt--+---+--11---+--+---<t--+---+---<t--+--+---<t--+--+----,t--+--+-----1
,,,
IS
:it Jl
20
H
n 1, H U 17 U 15 lJ IS H U H lJ U H ti 11 lJ H 1, ll H ti 20 15 ti H 11 JI H 22 2'

II>.

....... ,..,,

a, Slll:ID

ID. OIi DUYIDJlUS

•

'... • •• •• •
1-

I

O

• •
0
a

O

--

1

1l142

JI

U

----1--

I

-I

O

O

I
-

O

O

-

I

l

J

UJoal1

-I

UJO l'JOI

MO Jell

110 0

-+--l--+-+-t-➔-+-1--1-➔--

FIIICl'ICII PICIID

--1--1--1--1--1--+-+--,1--

ll
It

-

~

I

,

-+--1--+--+--t--+--+--1--,--+--1---1--11-

Ill.Wilda alma

I--+--•----·- -

II-~

--1--1---+--<--t--+---,f--l-- -

-

--

JU

-

..UW..i-l
IIIUalmUI ea_,,,te

i-----------+-t--1-+-t--f·- -

-r--- -

--r--

-t---·- -

-

-

-1-- - · - -

-

- - -·-r- -

-

Hl

201

Ht

to

119

-

II
--t--•t--½--1-- t---1--lf--+-+--lf---fl- -

I
-I----·- -

Ht

----

-~- 1

_,,

tfn...uaaall

-1---

--------rII

I

1-----------+-+--1-+-f-->-- TC 2 lls• &

-

- - -r- I

------.-➔ ---.--+--•-- I - - -

'

-

-

I-

--1---1--1-

UJJUHS
I
------------------+--+--t---4--•·- ' JU115
,
,_ •-1- --+---11--1-

ClcN-:.,_l lAIOne 'I'· A

It

--t--

-

-

-

-

-

--+--1-->I
II
J

..


Appendix 11. Relative abundance (percent frequency) for benthic foraminifera and thecamoebians per sample from core BB92. A (*) preceding a foraminiferal name indicates a pre-Holocene fossil species.
<table>
<thead>
<tr>
<th>DEPTH IN CORE (cm)</th>
<th>6</th>
<th>13</th>
<th>20</th>
<th>26</th>
<th>33</th>
<th>40</th>
<th>47</th>
<th>54</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOL. OF SAMPLE (cc)</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>NO. OF SPECIES</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>NO. OF HEMILOGS</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Lithostraea chilensis</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>C. agregata</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>P. trinacria</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>