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## Biostratigraphic Analysis of Southern Florida's Plio-Pleistocene Shell Beds

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BIOSTRATIGRAPHIC ANALYSIS OF SOUTHERN FLORIDA'S PLIO-  
PLEISTOCENE SHELL BEDS

By

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B.A. August 1990, University of Colorado at Boulder

A Thesis submitted to the Faculty of Old Dominion University  
in Partial Fulfillment of the Requirement for the Degree of

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GEOLOGY

OLD DOMINION UNIVERSITY  
May 1997

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## ABSTRACT

### BIOSTRATIGRAPHIC ANALYSIS OF SOUTHERN FLORIDA'S PLIO- PLIESTOCENE SHELL BEDS.

Dalton L. Rasmussen  
Old Dominion University, 1997  
Director: Dr. Carl F. Koch

Four molluscan assemblage zones in southern Florida corresponding to the Pinecrest Sand Member of the Tamiami Formation, and the Caloosahatchee, Bermont and Fort Thompson shell beds were identified following quantitative and qualitative analyses of the fossil molluscan fauna. Twenty-eight bulk sediment samples collected from 16 localities across southern Florida were processed for fossil material, and yielded nearly 60,000 specimens belonging to 311 species. A Q-mode cluster analysis compared sediment samples on the basis of 188 species whose abundances had been converted to binary presence-absence form. The cluster analysis was run four times using the Jaccard and Dice similarity coefficients as well as weighted and unweighted pair-group averaging methods. Results of the analysis remained the same despite these different clustering techniques, and thus supported the robustness of the data. Careful examination of paleoecological and age relationships between clusters and their characteristic taxa revealed that clusters formed as a result of age similarities among collections. Index species for each biostratigraphic unit were identified and provide valuable tools for recognizing

these units in the field. Further study may yield tests on the utility and validity of the suggested index species.

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## INTRODUCTION

The Plio-Pleistocene formations of southern Florida are units of similar lithology separated by disconformities, and are differentiated primarily by their fossil mollusc assemblages. The North American Stratigraphic Code (NASC) (North American Commission on Stratigraphic Nomenclature, 1983), however, states that a formation must be recognized by lithologic characteristics and stratigraphic position, and not by the presence or absence of particular fossil assemblages. Strata assigned to Plio-Pleistocene formations in southern Florida, the Caloosahatchee, Bermont and Fort Thompson, may not be lithostratigraphic units at all. Instead, they may be biostratigraphic units, allostratigraphic units or both. Therefore, a reevaluation of the Plio-Pleistocene stratigraphy of southern Florida is necessary in order to eliminate the confusion surrounding these formations, and to ensure their adherence to NASC guidelines. One step toward achieving this goal is to identify the biostratigraphic units in the near-surface, Plio-Pleistocene deposits of southern Florida.

One of the obstacles to developing a regional litho- and biostratigraphic framework in southern Florida is the infrequency of both natural and man-made exposures (Scott and Wingard, 1995). Due to the relatively flat terrain, natural exposures of Plio-Pleistocene units are rare. Most occur along the banks of major rivers and are not easily

accessible. Man-made exposures are scattered throughout southern Florida in quarries and canals, but are usually only accessible for relatively short periods of time before they are flooded with ground water and overgrown with vegetation.

Over the past 15 years, studies of Plio-Pleistocene stratigraphy have focused on a number of pits comprising two quarry operations, the Quality Aggregates Shell Pit east of Sarasota, and the Leisey Shell Pit on the southeastern edge of Tampa Bay. These quarries provide access to good exposures as they maintain permanent pumping facilities that keep pits undergoing active excavation dry. Publication of several papers has resulted from intense study of the stratigraphy and paleontology in the two quarries (Petuch, 1982; Scott and Allmon, 1992; Hulbert, *et al.*, 1995). During the same time, however, very little emphasis has been placed on the study of strata exposed in numerous, small, shallow quarries that have been excavated across the region.

While the investigation of the Quality Aggregates and Leisey quarries has contributed much to the knowledge of Plio-Pleistocene units in their immediate area, an understanding of these units in a regional sense is still quite limited. In order to enhance this understanding, it is helpful to inspect the stratigraphy and paleontology in the small quarries scattered across southern Florida that have traditionally been neglected.

This study examines the molluscan fauna of 28 bulk samples collected from 16 near-surface localities across southern Florida. Despite all of the emphasis that has been placed on the collection and identification of new species over the last hundred years, only a few biostratigraphic studies have been published and none of these have been quantitative. This study uses a q-mode cluster analysis and associated qualitative analysis to determine biostratigraphic units that are present, and assemblages of characteristic mollusca.

## BACKGROUND

### Study Area

The area of study lies within the southern half of peninsular Florida (Figure 1). The northern boundary of the study area lies along a line running east from the town of Ruskin, situated on the southeastern edge of Tampa Bay, to the town of Okeechobee, lying at the northernmost extent of Lake Okeechobee. The southern boundary runs east from the Gulf of Mexico along the southern margin of the Caloosahatchee River to Lake Okeechobee. The Gulf of Mexico and Lake Okeechobee form the western and eastern boundaries of the study area, respectively. Figure 2 shows numbered localities in the study area.

### Physiographic Setting

The south-central Florida peninsula is predominantly a broad, featureless plain. Natural exposures of strata are rare due to the low relief, and most are confined to the banks of larger rivers such as the Caloosahatchee River, Shell Creek and Alligator Creek. As a consequence, a majority of geological investigations must be conducted in the subsurface.

Geomorphic features that are most easily recognized are relict shorelines along the present coastline that were formed by relatively recent fluctuations in sea level.

**Figure 1: Map of Florida showing the study area.**

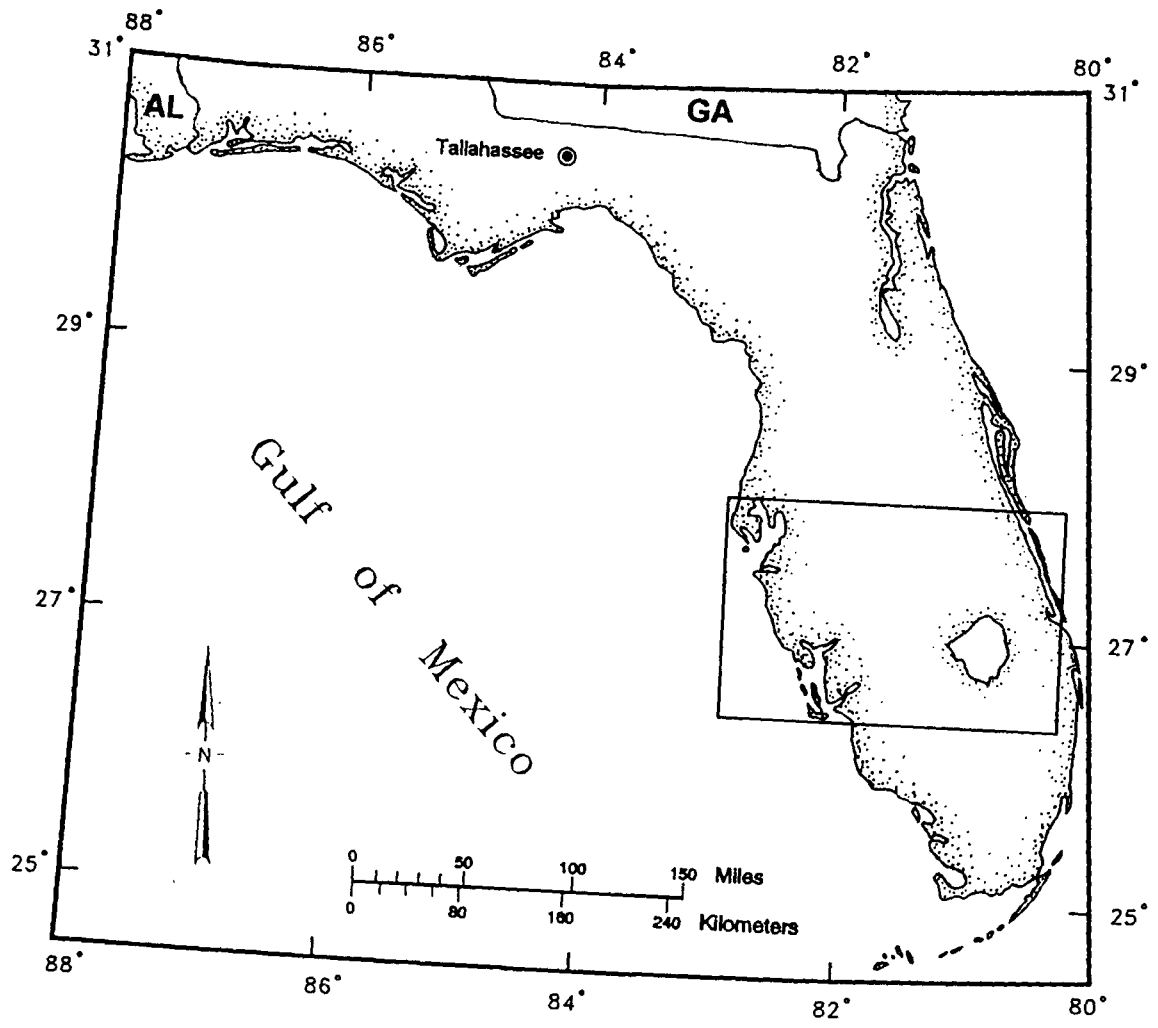
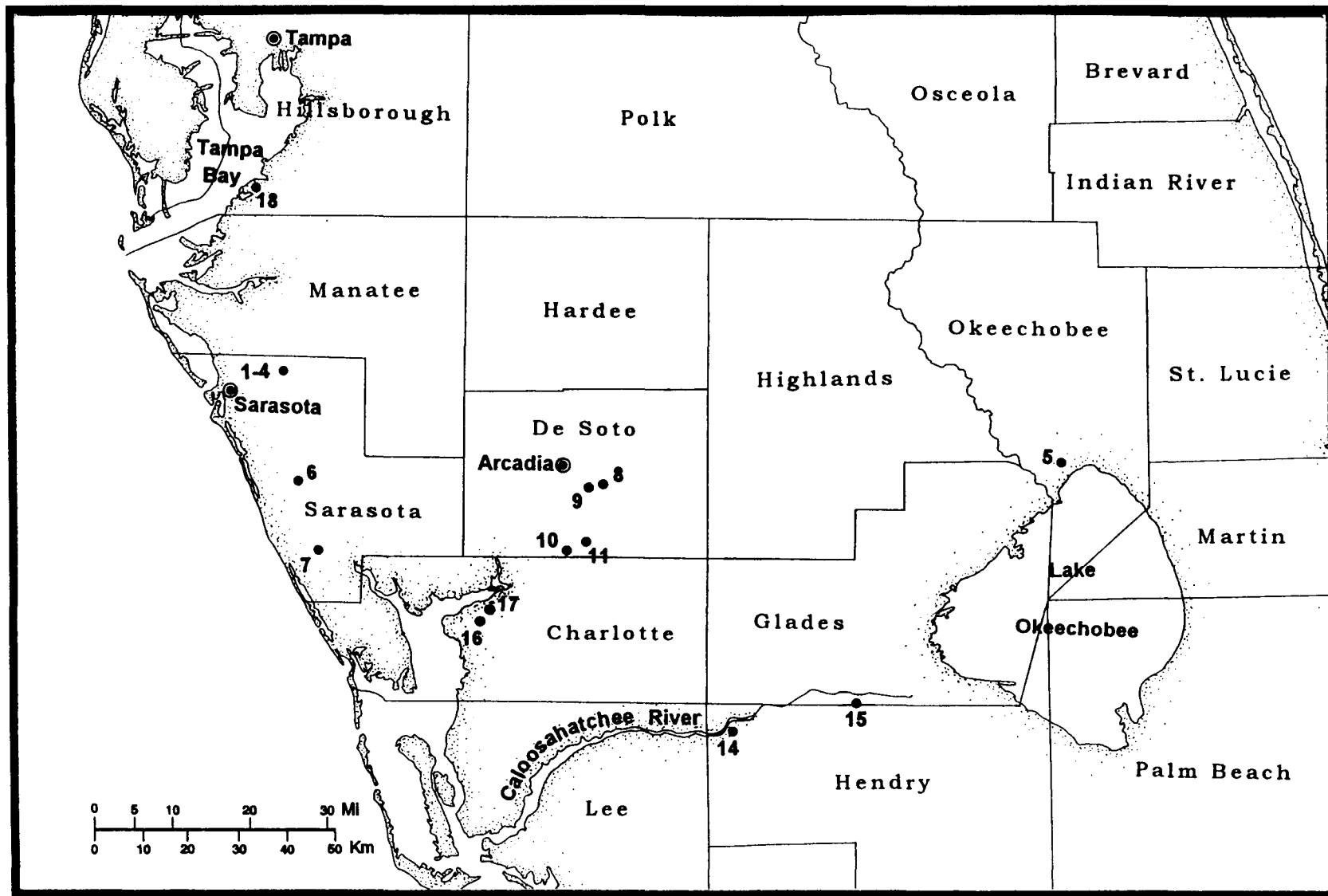


Figure 2: Enlargement of the area outlined in Figure 1 showing localities collected for this study. County names and boundaries are drawn for reference. Measured sections and lithologic descriptions of localities are in Appendix A. Locality names are presented below.

Loc. 1-4 ..... Quality Aggregates Pit  
Loc. 5 ..... Wolf Road Pit  
Loc. 6 ..... Dean's Pit  
Loc. 7 ..... Taylor Ranch Pit  
Loc. 8 ..... Carleton 2x4 Ranch #1  
Loc. 9 ..... Carleton 2x4 Ranch #2  
Loc. 10 ..... Stinson Pit  
Loc. 11 ..... Davis Pit  
Loc. 14 ..... Cochran Pit  
Loc. 15 ..... Highway 80 Pit  
Loc. 16 ..... Punta Gorda Pit  
Loc. 17 ..... Forseberg Pit  
Loc. 18 ..... Leisey Shell Pit





Older features found further inland and at higher elevations have been subject to modification by erosion at the surface and differential dissolution of carbonates below the surface and as a result are more difficult to recognize.

White (1970) divided the Florida Platform into three major physiographic zones: the proximal or northern zone, the mid-peninsular or central zone and the distal or southern zone (Figure 3). The northern zone is a broad upland that lies entirely above the piezometric surface. It is characterized by dry, steep-walled sinkholes, abandoned spring heads, dry stream courses and intermittent lakes. Subparallel ridges with scattered small, deep lakes form the highlands of the central zone, and wide valleys with broad shallow lakes lie between the ridges. The discontinuous highlands of the central zone are generally above the piezometric surface, while the lowlands tend to be below it. The southern zone is nearly everywhere below the piezometric surface and is characterized by broad, flat, gently sloping lowlands that are fenced on the east by the Atlantic Coastal Ridge. Lakes are found in the northernmost part of the southern zone, but swamps dominate the landscape to the south (White, 1970).

White (1970) further subdivided the state into major geomorphologic features (Figure 4). Localities collected for this study are situated in the low-lying coastal areas of the Gulf Coastal Lowlands and the Caloosahatchee Valley,

Figure 3: Map showing the primary physiographic provinces of Florida (after White, 1970).

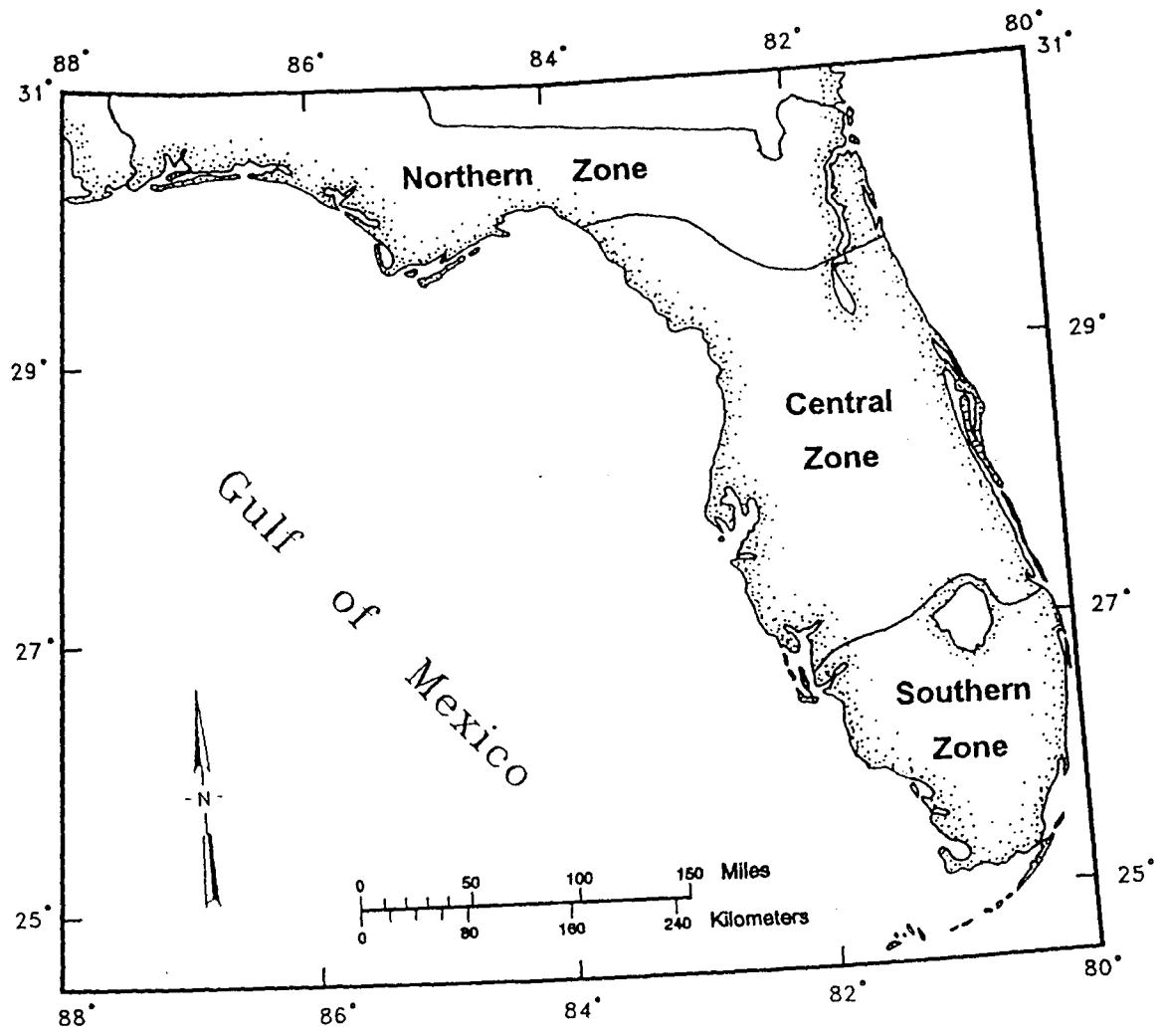
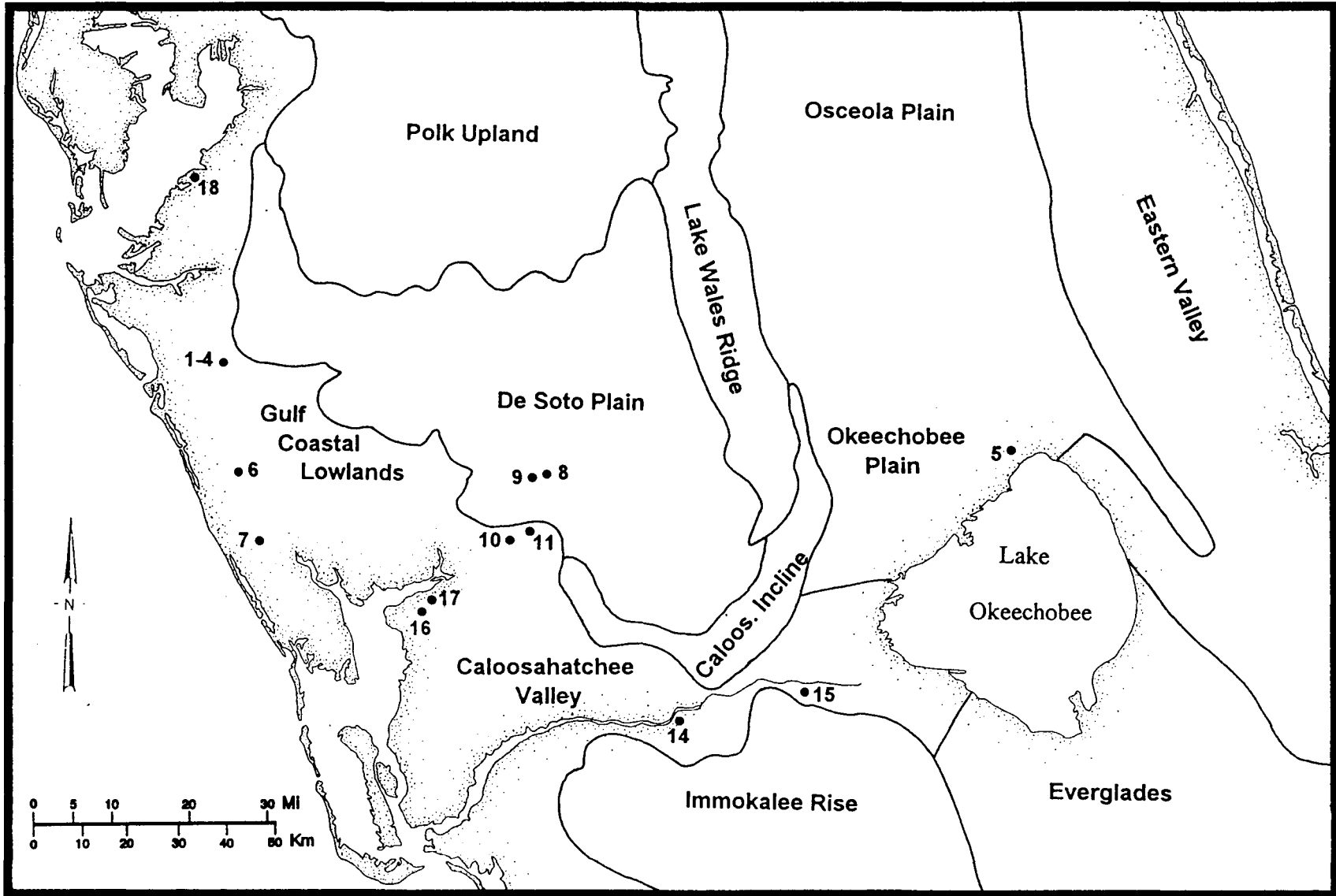


Figure 4: Map showing the major geomorphologic features recognized in south-central Florida (after White, 1970). Localities are posted for reference.



and the slightly higher areas of the lower DeSoto Plain and the Okeechobee Plain. It is evident from published geologic maps (DuBar, 1974; Petuch, 1994) that Neogene shell beds do not occur in higher-elevation areas such as the upper Osceola and DeSoto Plains, the Polk Upland and the Lake Wales Ridge.

### Geological History

Southern Florida consists of a stacked sequence of sedimentary rocks ranging in age from middle Jurassic to Holocene. The basement beneath these sediments lies below a tectonically significant unconformity that is recognized throughout Florida. This unconformity separates rocks that were formed before and during the breakup of Pangea from those that were formed during the post-rift passive margin phase. The top of the basement may be considered the surface separating pre-middle Jurassic rocks from younger rocks (Arthur, 1988).

Post-rift subsidence brought much of Florida south of the Peninsular Arch below sea-level, providing a base for a carbonate platform that existed from the early Cretaceous to the middle Tertiary. Carbonate sedimentation dominated in southern Florida from the Cretaceous through the Paleogene. A structural trough in southern Georgia, called the Suwannee Straits, trapped terrigenous sediment that was being transported south from the denuded Appalachians, and

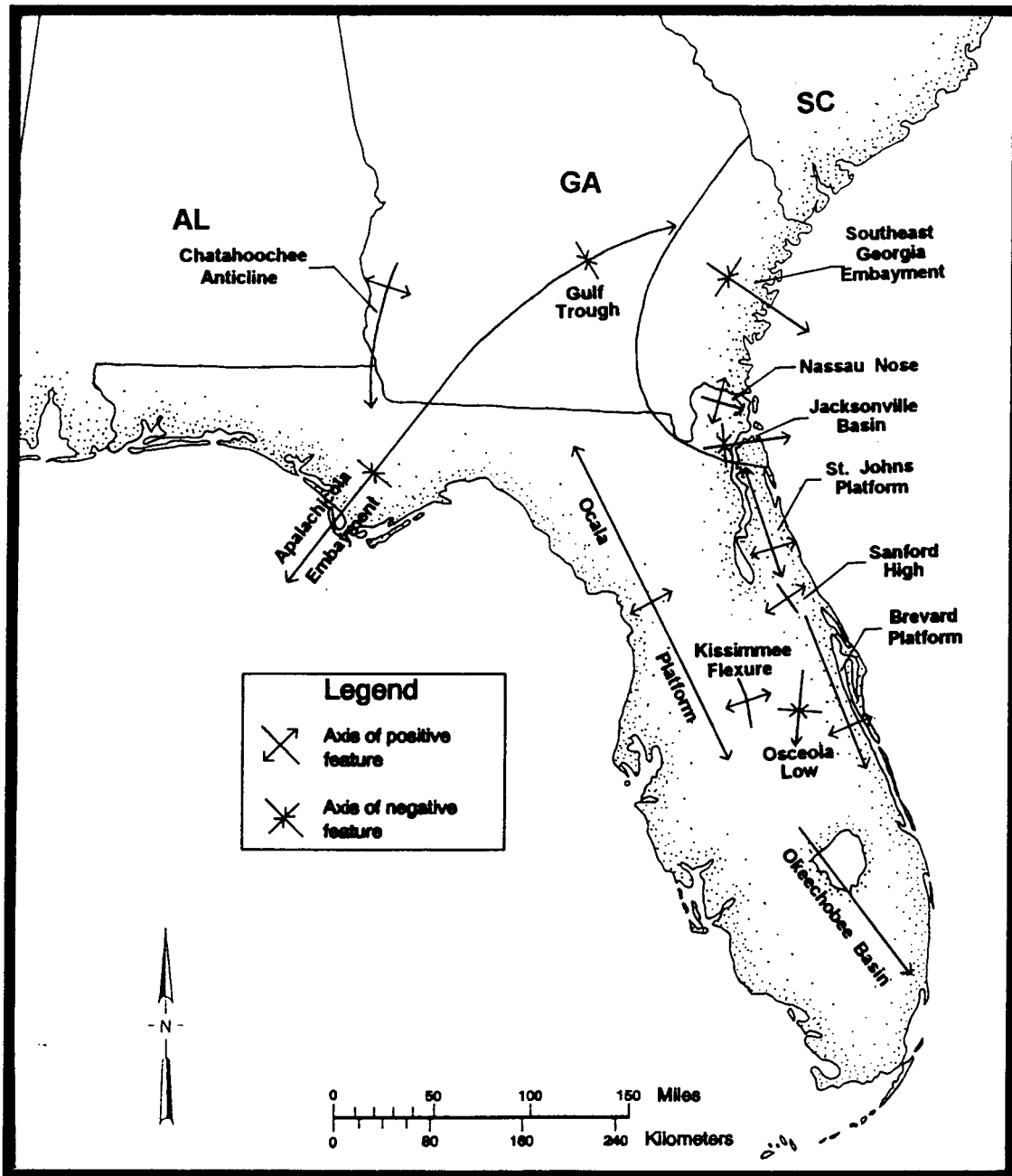
prevented deposition further to the south on the Florida Platform. Siliciclastic sediment began to enter depositional environments in southern Florida by the middle Oligocene, but did not become the dominant sediment type until the end of the early Miocene.

Tectonic movements during the early Miocene produced a number of structural features in Florida including the Ocala Platform, Gulf Trough, Chatahoochee Anticline, Apalachicola Embayment, Jacksonville Basin, Osceola Low and the Okeechobee Basin (Figure 5). Simultaneously, renewed uplift in the Appalachians to the north caused a vast amount of siliciclastic sediment to be transported out onto the shelf. The Gulf Trough in southern Georgia and northern Florida soon became filled, allowing sediment to be bypassed out onto the carbonate platform of the peninsula. Although siliciclastic sedimentation dominated in southern Florida throughout the Neogene and Quaternary, broad areas were periodically subject to carbonate deposition. These carbonates include the various limestone facies of the Pliocene Tamiami Formation, and the Pleistocene Key Largo and Miami Limestones.

The Neogene section in southern Florida is occupied by the Oligocene- to Pliocene-aged Hawthorn Group, the Pliocene Tamiami Formation and Caloosahatchee shell bed, and the Pleistocene Bermont and Fort Thompson shell beds. The Neogene section is capped by undifferentiated, late Pleistocene and Holocene quartz sands. Units that are of

Figure 5: Map showing the mid-Cenozoic structural features of Florida (after Scott, 1992b).





primary interest to this study are the Pinecrest Sand Member of the Tamiami Formation, and the Caloosahatchee, Bermont and Fort Thompson shell beds. Figure 6 correlates these units with age-equivalent units of the Atlantic Coastal Plain.

In southern Florida, deposition of the Hawthorn Group was initiated during the late early Oligocene (Brewster-Wingard, *et al.*, in press) and continued intermittently into the early Pliocene. The Hawthorn Group can be subdivided into lower and upper units based on lithology. The lower section is predominantly phosphatic limestone and dolostone that contains varying amounts of clay, silt and sand, and the upper section is dominated by phosphatic siliciclastics. The top of the Hawthorn is an irregular erosional and karstic surface (Scott, 1992b).

The Pliocene Tamiami Formation lies unconformably on formations of the Oligocene-Pliocene Hawthorn Group in southern Florida. Deposition of the Tamiami is estimated to have occurred between 4.2 and 2.8 million years ago (Missimer, 1992). It is a poorly-defined lithostratigraphic unit that has traditionally been subdivided into three members, the Buckingham Limestone (lower), the Ochopee Limestone (middle) and the Pinecrest Sand (upper). Overall, the Tamiami Formation is a variably fossiliferous unit with lithologies ranging from tan clay and quartz sand, to quartz sand, to well-lithified limestone. Aragonitic fossils of the two lower members are typically dissolved, and only the

Figure 6: Chart correlating Pliocene through Holocene stratigraphic units of southern Florida with stratigraphic units of the Atlantic Coastal Plain. Southern Florida and Georgia columns are modified after Braunstein, et al. (1988); Pleistocene and Holocene columns for South Carolina, North Carolina and Virginia are after Jordan and Smith (1983); Pliocene columns for South Carolina, North Carolina and Virginia are after Ward and Gilinsky (1993).

Ward and Gilinsky (1993)			Jordan & Smith (1983)			Braunstein, et al. (1988)		Scott (1992a)	
Virginia	North Carolina	South Carolina	Virginia	North Carolina	South Carolina	Georgia	Southern Florida		
			unnamed alluvial deposits	undifferentiated Holocene deposits	unnamed Holocene deposits	Satilla Fm	undiff. sand	Lake Flirt Marl	HOLO.
			Tabb Fm	Flanner Beach Fm	Socastee Fm		Anastasia Fm	Miami Ls	Key Largo Ls
			Norfolk Fm		Canepatch Fm	undiff. marine terrace sands	Ft. Thompson Fm	Okeechobee Fm	
				James City Fm	Waccamaw Fm		Bermont Fm		
						Cypresshead Fm	Caloosahatchee Fm		UPPER PLIOCENE
Chowan River Fm		Bear Bluff Fm							
Yorktown Fm	Moore House Mbr					Raysor Fm	Pinecrest Sand Mbr Ochopee Ls Mbr Buckingham Ls Mbr	Tamiami Fm	LOWER PLIOCENE
Yorktown Fm	Morgarts Beach Mbr Rushmere Mbr	Duplin Fm							
Yorktown Fm	Sunken Meadow Mbr					Wabasso Beds	Peace River Fm		
						Hawthorn Gp	Hawthorn Gp		

calcitic skeletons of barnacles, oysters, pectens and echinoids remain intact. The Pinecrest fauna, on the other hand, is generally well preserved when present, containing both aragonitic and calcitic forms. The Pinecrest Sand has been described from several localities in southern Florida and is rather discontinuous, occurring only as isolated pockets beneath younger Plio-Pleistocene units. Excellent exposures of the Pinecrest occur in the Quality Aggregates Shell Pit, where it consists of 8 to 20 meters of very fossiliferous, gray-green, shell and fine quartz sand.

The late Pliocene Caloosahatchee shell bed lies unconformably on the Tamiami Formation or on the Hawthorn Group where the Tamiami is absent, and may lie directly beneath the Bermont or Fort Thompson shell beds where they are present. The Caloosahatchee is believed to have been deposited between 2.5 and 1.8 million years ago (Lyons, 1992). It is a light-colored, highly fossiliferous, shelly sand that is ordinarily unconsolidated, but may be partially indurated to completely lithified into a hard limestone. Lithologically, the Caloosahatchee is nearly identical to Bermont and Fort Thompson sediments, and is only distinguishable from these younger units by its fossil molluscan fauna (DuBar, 1974). Several important papers including Olsson and Harbison (1953), DuBar (1958, 1962, 1974), and Olsson and Petit (1964), discuss the Caloosahatchee fauna and provide lists of characteristic species.

The early Pleistocene Bermont shell bed lies unconformably between the Caloosahatchee and Fort Thompson shell beds. Deposition of this unit took place between 1.66 and 1.2 million years ago (Jones, 1992). The Bermont is a light-colored, highly-fossiliferous, marine sand unit that is typically unconsolidated. It is lithologically indistinguishable from underlying Caloosahatchee sediments (DuBar, 1974), and is only differentiated by the absence of most characteristic Caloosahatchee taxa. Likewise, the presence of numerous extinct taxa in the Bermont allows it to be separated from lithologically similar Fort Thompson sediments which contain a predominantly extant molluscan fauna. Publications that provide faunal lists of the Bermont include DuBar (1974), Hoerle (1970) and Portell, et al. (1992, 1995).

The Pleistocene Fort Thompson shell bed lies unconformably on top of either the Bermont or Caloosahatchee depending on which one is present, and is overlain by non-fossiliferous late Pleistocene to Holocene sand. Deposition is estimated to have taken place between 0.9 and 0.02 million years ago (Lyons, 1992). Like the underlying Bermont and Caloosahatchee shell beds, the Fort Thompson is a predominantly unconsolidated, light-colored, very fossiliferous shelly sand. It has been separated from these units because it lacks fossil mollusc species that are characteristic of Bermont and Caloosahatchee sediments.

## Previous Work

### Tamiami Formation

The Tamiami Limestone was proposed by Mansfield (1939) for a unit exposed during the excavation of the Tamiami Trail in Florida's Collier and Monroe Counties. It was described as a "dirty white to gray, rather hard, porous, nonoolitic limestone with inclusions of clear quartz grains" (p. 8). Mansfield believed that the Tamiami was early Pliocene in age, and he placed it just below the Caloosahatchee Marl. He also proposed the name "Buckingham Limestone" for a limestone thought to be a late Miocene unit lying beneath his Tamiami Limestone.

Parker and Cooke (1944) revised Mansfield's definition of the Tamiami to include the Buckingham Limestone and a sandy fossiliferous unit (Pinecrest sand) described by Mansfield in 1931 from a ditch along the Tamiami Trail west of Pinecrest. It was their belief that the Tamiami was equivalent to the Caloosahatchee and probably interfingered with it.

Olsson (1964) proposed the name Pinecrest Beds for variably fossiliferous sand found below a limestone along the Tamiami Trail from the western part of Dade County into Collier County, Florida. Olsson believed that the Acline fauna described from a few pits near Punta Gorda by Tucker and Wilson (1932, 1933) belonged to the Pinecrest, but he

contended that it represented a different faunal and facies development. He originally declared that the Pinecrest was a lower member of the Caloosahatchee. In a later paper, however, Olsson (1968) treated it as a separate unit that was older than the Caloosahatchee, but younger than the Tamiami Formation.

A publication on the late Cenozoic stratigraphy of southern Florida by Olsson (1968) firmly stated that the Tamiami Formation was late Miocene in age because of direct faunal correlations with the Choctawatchee Formation of northern Florida and the Yorktown Formation of Virginia. Although the Pinecrest was considered to be a separate unit from the Tamiami Formation, it too was believed to be late Miocene. Olsson noted that the most remarkable feature of the Pinecrest was that its fauna contained a mix of northern, boreal, subboreal and tropical elements. He suggested that the Pinecrest contained as many as 1200 species of molluscs, approximately three times the number currently living off the coast of Florida.

Hunter (1968) revised the definition of the Tamiami Formation and its members in lithostratigraphic terms, and identified three concurrent range zones within the Tamiami using characteristic Pectinids. Mansfield's Tamiami Limestone was renamed the Ochopee Limestone by Hunter, and was considered to be laterally equivalent to both the Pinecrest Sand and the Buckingham Limestone. Hunter also described two lower members of the Tamiami, a gray barnacle



hash and thin phosphatic sand termed the Murdock Station Member which rested above a white to tan, phosphatic, sandy clay that she called the Bayshore Clay Member. The Murdock Station and Bayshore Clay Members were later placed into the Hawthorn Group by Scott (1988).

The largest exposure of the Pinecrest Sand occurs in quarries at Quality Aggregates Shell Pit west of Sarasota. Petuch (1982) described eleven biostratigraphic units from outcrops adjacent to this locality at the APAC Shell Pit, and made paleoecologic interpretations of each unit. The molluscan fauna from Units 10 and 11 at the base of the section resembled Miocene faunas of the Chesapeake Bay region and were placed into the Tamiami Formation. Petuch assigned Units 2 through 9 to the Pinecrest Sand and Unit 1 to the Caloosahatchee.

In an attempt to constrain the ages of Petuch's units and to correlate them to Atlantic Coastal Plain formations, Lyons (1991) cited certain age-diagnostic species included in Blackwelder's (1981) molluscan range and interval zones of the Middle Atlantic Coastal Plain. Two of the species occurring in Petuch's Unit 11, *Chesapecten jeffersonius* and *Ostrea compressirostra*, were indicative of Blackwelder's early Pliocene interval zone M6. Several species found in Petuch's Units 10 through 6 were included in Blackwelder's interval zone M5, a unit correlative with the Yorktown Formation of Virginia and North Carolina. Lyons was somewhat ambiguous with respect to Petuch's Units 4 through

2, noting that while they contain many taxa characteristic of the Caloosahatchee, they still retain a few species indicative of the Tamiami Formation. No opinion on the age of Unit 5 was given.

Ward (1992) correlated Petuch's Units 1-11 to strata in Virginia and the Carolinas using biostratigraphically useful molluscs. Ward listed eight species from Unit 11 that make their first appearance in the Rushmere Member of the Yorktown Formation in Virginia, and one species that is restricted to the Rushmere Member. As a result, Unit 11 was correlated with the early Late Pliocene Rushmere Member and the basal Raysor Formation in South Carolina. Although a few species identified from Units 10 through 6 range into the Upper Pliocene Chowan River Formation, Ward believed that these units correlated with the upper Yorktown Formation. Units 4 through 1 all contained a number of species that suggested a correlation with the upper Yorktown Formation or the Chowan River Formation. The *Vermicularia* biostrome making up Unit 5 did not provide sufficient stratigraphic information for correlation with Coastal Plain units to the north.

Zullo and Harris (1992) attempted to place the Tamiami Formation into a sequence stratigraphic framework in order to reduce some of the complexities associated with its many facies. The Tamiami was divided into a lower portion that contained the Ochopee, Buckingham and Murdock Station Members of Hunter (1968), and a conformable upper portion

containing the entire Pinecrest. Zullo and Harris divided the Pinecrest into upper and lower beds to account for a disconformity recognized between Petuch's Units 3 and 4. The lower Tamiami and the lower Pinecrest beds (Petuch's Units 9 through 4) were placed into the Global Coastal Onlap Cycle TB3.6 (Haq, et al., 1987), and were correlated with the Rushmere and Morgarts Beach Members of the Yorktown Formation, respectively. The upper Pinecrest beds (Petuch's Units 3 through 2) were believed to have been deposited during Onlap Cycle TB3.7, and were correlated with the Moore House Member of the Yorktown Formation.

#### Caloosahatchee

Angelo Heilprin discovered the beds that eventually came to be known as the Caloosahatchee in 1886 during his expedition into the Okeechobee Wilderness. Traveling up the Caloosahatchee River, Heilprin noted two fossiliferous units cropping out along its banks. The lower shell bed contained a great number of recent forms intermixed with a number of extinct ones, with scarcely any distinctively Miocene forms. Using Lyell's method of comparing the ratio of extinct to extant molluscs, Heilprin concluded that this lower shell bed was probably Pliocene, and he designated it the "Floridian." Realizing the potential importance of his find, Heilprin (1887) wrote that this lower unit was

...without question the most remarkable  
fossiliferous deposit that has yet been discovered

in the state and from a purely paleontological standpoint, perhaps the most significant in the entire United States east of the Mississippi River. (p. 28)

The upper fossiliferous shell bed along the Caloosahatchee River contained only recent species, leading Heilprin to give it a post-Pliocene age.

A year after Heilprin's expedition, Dall made collections from a variety of localities along the Caloosahatchee River, Shell Creek, Alligator Creek, Myakka River and the Charlotte Harbor area. He agreed with Heilprin's age determination for the lower beds along the Caloosahatchee River, but referred to them informally as the Caloosahatchee beds (Dall, 1887). Between 1890 and 1903, Dall published a series of six monographs in which 639 species from the Caloosahatchee beds were described and figured. Fifty-one percent of the molluscs that Dall identified from the Caloosahatchee were extinct. Not long after the final part of Dall's monograph was published, Matson and Clapp (1909) published the first geological map of Florida and formally described the Caloosahatchee Formation. The type exposures, considered by Olsson (1964) to be at LaBelle on the Caloosahatchee River, have since been destroyed by the channelization of the river.

DuBar (1958) gave a detailed discussion of the Caloosahatchee as it cropped out along the Caloosahatchee River. Descriptions of sediments and fauna were provided for many beds exposed along the river. The Caloosahatchee was divided into the lower Fort Denaud Member, the middle

Bee Branch Member and the upper Ayers Landing Member, and several molluscan biofacies were described from each member. DuBar (1974) believed that the Fort Denaud Member was deposited during the early transgressive phase, the Bee Branch Member was deposited during maximum transgression, and the Ayers Landing Member was deposited during a regressive phase. DuBar tentatively correlated the Caloosahatchee with the Waccamaw Formation of North Carolina.

In a later study of the Caloosahatchee along Shell and Alligator Creeks in the Charlotte Harbor area, DuBar (1962) identified at least six distinct lithologic units and, as he had done for units along the Caloosahatchee River, interpreted the paleoecology for each of these units. The uppermost unit of the Caloosahatchee that he described, Unit F, would later be placed into the Bermont (DuBar, 1974).

Lyons (1991) discussed the age of the Caloosahatchee, as well as its correlation with other Atlantic Coastal Plain units. He placed the Caloosahatchee fauna into Blackwelder's (1981) late Pliocene molluscan interval-zone M4. Lyons listed several molluscan taxa that do not occur above the James City Formation of Virginia, the Waccamaw Formation of the Carolinas or the Caloosahatchee, and concluded that these units were at least partly contemporaneous.

While Zullo and Harris (1992) agreed with the late Pliocene age of the Caloosahatchee, they believed that it

was correlative with the Chowan River Formation of Virginia and North Carolina. They therefore assigned the Caloosahatchee shell bed to the Global Coastal Onlap Cycle TB3.8.

The age of the Caloosahatchee has long been a point of contention among Florida's Plio-Pleistocene scholars. Heilprin used Lyellian percentages to deduce a Pliocene age for the Caloosahatchee beds. This interpretation remained unchanged until DuBar (1958) identified horse teeth that he collected from beds along the Caloosahatchee River as belonging to a species, *Equus leidyi*, that was only known from the late Pleistocene. Brooks (1968) refuted DuBar's findings by citing earlier studies which stated that teeth of *E. leidyi* are virtually indistinguishable from earlier Pleistocene horses. DuBar (1974) later maintained his stand that the Caloosahatchee was Pleistocene by citing the similarity of Caloosahatchee deposits to Pleistocene deposits in the Lower Mississippi Valley, and providing a Th/U date of 400,000 years before present for a sample from his Bee Branch Member. Petuch (1982) gave Unit 1 from the Quality Aggregates Pit, which he believed to be the Caloosahatchee, a Plio-Pleistocene age after finding a single specimen of *Conus waccamawensis*, a supposed Plio-Pleistocene index fossil. Most recently, Lyons (1991) cited a study that used He/U dates of corals as evidence of a Pliocene age for the Caloosahatchee. The oldest corals, dating to 2.5 million years, were collected from north St.

Petersburg, while corals collected from the top of the Caloosahatchee along the Caloosahatchee River yielded the youngest date of 1.8 million years. Assuming the Pliocene-Pleistocene boundary is at 1.64 Ma (Harland, et al., 1990), these dates would place the entire Caloosahatchee within the late Pliocene.

#### Bermont

DuBar (1974) proposed the Bermont Formation for highly-fossiliferous, marine sands that occur throughout southern Florida between the late Pliocene Caloosahatchee and the late Pleistocene Fort Thompson shell beds. Although DuBar noted that the Bermont is lithologically indistinguishable from underlying Caloosahatchee deposits, he separated the two on the basis of comparative faunal analysis.

The Bermont has been referred to by various names in the literature, including the Glades Unit (Vokes, 1963) and Unit A (Olsson, 1964). Olsson's (1964) Unit A was described as a shell marl, largely composed of *Chione cancellata*, that lay between the Caloosahatchee and Fort Thompson shell beds, separated by sharp unconformable contacts. Previously, DuBar (1962) recognized this unit along Shell Creek and in shell pits at Bermont, and called it Unit F. While DuBar remarked that its molluscan fauna differed considerably from typical underlying Caloosahatchee deposits, he considered it to be the uppermost part of the Caloosahatchee shell bed.

McGinty (1970) discussed the Glades Unit as it occurred in the Belle Glade Rock Pit, and listed those species characteristic of and common to it. Hoerle (1970) provided a listing of some 434 species that had been collected over five years from the same pit. Much of the collecting, however, had been done from spoil banks, and it is not clear how much of the material collected came from strata above or below the Glades Unit.

Many authors have discussed the age of the Bermont. Although Olsson (1968) stated that the age of Unit A was uncertain, he gave it a late Pliocene age largely because of its estimated 20-30% extinct species. Hoerle (1970) considered the age of this unit to be early Pleistocene and noted that approximately 15% of its species were extinct. When DuBar described the Bermont in 1974, he estimated its age to be "medial" Pleistocene, which perhaps stemmed from his own belief that the Caloosahatchee was early Pleistocene in age.

Jones (1992) provides a comprehensive study of the age of the Bermont by linking invertebrate and vertebrate biostratigraphy, magnetostratigraphy and strontium isotope chronostratigraphy. Using previous studies by Hulbert and Morgan (1989) and Webb, *et al.* (1989), as well as data from his own research, Jones was able to constrain the timing for deposition of the Bermont shell bed at Leisey Shell Pit. The vertebrate fauna at Leisey Pit suggests that deposition took place during the Sappan substage of the Irvingtonian



Land Mammal Age, approximately 1.5 to 1.2 million years ago. Strontium isotope ratios analyzed from bivalve shells mixed with the mammal bones supports the placement in the late early Irvingtonian. Paleomagnetic samples taken from the entire section are reversed and indicate that the Bermont at Leisey belongs within the Matuyama Magnetochron above the Olduvai subchron and is less than 1.66 million years old. Data suggests that the Bermont at Leisey is no older than 1.66 million years and no younger than 1.2 million years.

Using the dates that were derived by Hulbert and Morgan (1989) and Webb, *et al.* (1989), Lyons (1991) placed the taxa of the Bermont shell bed into Blackwelder's (1981) molluscan interval-zone M3, and correlated it to the early Pleistocene portion of the Waccamaw Formation of the Carolinas. Zullo and Harris (1992) agreed that the Bermont was early Pleistocene in age, and correlated it with Coastal Onlap Cycle TB3.9.

#### Fort Thompson

Heilprin (1887) first observed the Fort Thompson shell bed overlying his "Floridan" (= Caloosahatchee) shell bed along the Caloosahatchee River, and noted that it was most likely post-Pliocene since most of its species were extant. The Fort Thompson Formation was named by Sellards (1919) for fresh, brackish and marine marls and limestones along the Caloosahatchee River.

DuBar (1958, 1962) discussed the Fort Thompson shell bed as it cropped out along the principal rivers of southern Florida, including the Caloosahatchee River, Shell Creek and Alligator Creek. Along the Caloosahatchee River, DuBar recognized two marine units set apart by beds that were dominated by fresh water gastropods. A paleoecological study of Fort Thompson molluscs led DuBar to believe that these marine units were probably deposited in shallow hypersaline bays and lagoons. On the basis of molluscan content and scattered vertebrate remains, and his belief that the Caloosahatchee shell bed belonged to the Sangamonian interglacial, DuBar placed deposition of the Fort Thompson during the late Pleistocene Wisconsin interglacial. He later revised his age estimate for the Fort Thompson to the Sangamonian (DuBar, 1974).

Lyons (1991) provided a summary of age estimates for the Fort Thompson shell bed as well as another unit that he refers to as the Coffee Mill Hammock Formation. This latter unit was originally described by Sellards (1919) as a separate formation overlying the Fort Thompson. For the most part, however, the Coffee Mill Hammock has either been cited as a member of the Fort Thompson Formation, or has not been noted at all in the literature. The two are not considered as separate units for this paper. Age estimates that Lyons provides for both units would establish deposition for the Fort Thompson shell bed during the late Pleistocene between 0.06 and 0.95 million years ago. This

age range places the Fort Thompson into Blackwelder's (1981) mid-Atlantic molluscan range zones M2 and M1, and makes it correlative with several Pleistocene mid-Atlantic units including the Canepatch Formation and the Norfolk Formation (Lyons, 1991).

### The Need for a New Approach

DuBar (1974) discussed many of the problems resulting from earlier studies of the Neogene strata in southern Florida. Due to the abundant and diverse fossil invertebrate faunas, the emphasis of most stratigraphic investigations was placed on the collection and identification of new species. Little regard was made for careful stratigraphic control, and ecologic and sedimentologic studies were neglected. Ages of stratigraphic units were deduced from Lyellian percentages of faunal lists. In turn, taxa restricted to a formation's faunal list were erected as "index" species. DuBar contends:

The flexibility and convenience of this scheme as outlined cannot be denied. Using this technique the age of a fossil species is determined by its association with other species in an unrepresentative collection from a pseudo-stratigraphic unit, and conversely the age of a supposed stratigraphic unit can be determined by the presence of these "key" species. (p. 208)

Scott (1992a, 1993) and Scott and Wingard (1995) echo many of DuBar's concerns. They also argue that the Caloosahatchee, Bermont and Fort Thompson "formations" do not follow guidelines set by the North American

Stratigraphic Code. These units are primarily defined by mollusc assemblages, and they are not distinguishable from one another by lithologic characteristics. Furthermore, complex facies relationships within the units make it nearly impossible to map them for long distances either at the surface or in the subsurface.

Vacher, *et al.* (1992) noted their frustration with the Plio-Pleistocene units during an investigation of the surficial aquifer system in south central Florida. They argued that an examination of lithologic variation might provide clues as to the variability of hydraulic conductivity on local and regional scales. When examining the stratigraphic literature, however, they encountered few geologic descriptions for units. Furthermore, formation definitions appeared to hinge more on fossils than on lithology. Vacher, *et al.* abandoned the literature and constructed their own regional lithofacies map using well logs and site descriptions.

Disconformities that are recognized in southern Florida's Plio-Pleistocene stratigraphic section only add to the confusion. Disconformities have been suggested as a means to divide the strata. Parker and Cooke (1944) recognized four distinct marine units separated by freshwater marls in the Fort Thompson formation. The marine units were believed to represent sea level high stands, while the freshwater units represented low stands. Brooks (1968) divided the Plio-Pleistocene section into six

transgressive to regressive cycles separated by disconformities. Two marine units were recognized in the Caloosahatchee and four were recognized in the Fort Thompson.

Perkins (1977) identified a number of disconformities in the Pleistocene section of south Florida and used them as the basis for defining his "Q" units. He noted that without the disconformities, the lithologically similar "Q" units would most likely be placed into a single formation.

Scott and Wingard (1995) dispute Perkins's assessment that disconformities may act as formational boundaries. They argue that under the NASC, Perkins's "Q" units would be classified as allostratigraphic units rather than lithostratigraphic units.

An early attempt to rectify the state of confusion in southern Florida's Plio-Pleistocene stratigraphy was made by Hunter (1968) during her examination of the Tamiami Formation. She defined five lithologically unique members, and three biostratigraphic units within the Tamiami. Hunter's study was one of the earliest attempts to place any of the Plio-Pleistocene units of southern Florida into a lithostratigraphic context.

Missimer (1992) reexamined some of the stratigraphic problems associated with the Tamiami Formation. He noted that the three members comprising the Tamiami, the Buckingham, Ochopee and Pinecrest, were defined by previous researchers through a mixture of lithostratigraphic and

biostratigraphic criteria. The members are sometimes less than five feet thick and are only mappable over a very limited area. Furthermore, he commented that the entire Tamiami Formation is thinner than most members of similar-aged Gulf Coast formations. Missimer described nine mappable lithofacies within the Tamiami Formation, that were independent of faunal assemblages. These include the Buckingham Limestone Member, a tan clay and quartz sand facies, and a quartz sand facies at the base of the formation, the Ochopee Limestone Member and a quartz sand facies in the middle, and a number of different lithofacies containing the Pinecrest fauna at the top of the formation.

Stratigraphic problems associated with the Caloosahatchee, Bermont and Fort Thompson units of southern Florida were first analyzed in detail by Hunter (1978). Hunter stressed that renaming these units according to lithologic criteria would eliminate much of the confusion encountered when correlating them at the surface and in the subsurface. The Fort Thompson Formation was extended to the base of the Caloosahatchee to include all interbedded marine and freshwater strata above the Tamiami, and five members were described. The Bermont and Caloosahatchee units were reduced to members because neither were lithologically distinct, and because the identification of both was dependent upon the recognition of fossil mollusc assemblages.

Scott (1992a) informally proposed a lithostratigraphic unit that would include the faunally-derived Caloosahatchee, Bermont and Fort Thompson formations. This unit, termed the Okeechobee formation, consists of shelly siliciclastic and carbonate sediments, and is mappable over most of southern Florida at the surface as well as in the subsurface.

Scott and Wingard (1995) contend that in addition to redefining the strata lithostratigraphically, biostratigraphic units should be identified. They note that of the few published biostratigraphic studies, none have been quantitative. Traditional approaches to biostratigraphic studies become increasingly difficult as the number of species being examined increases. Quantitative biostratigraphic analysis for southern Florida's Plio-Pleistocene is more sensible considering the large number of species identified from the strata. Scott and Wingard advocate using cluster analysis to delineate biostratigraphic units.

Recent biostratigraphic studies that have employed cluster analysis include Strickland's (1984) identification of assemblages zones within the Eocene Piney Point Formation of Virginia, and Ward and Gilinsky's (1993) comparison of molluscan assemblages from the Pliocene Chowan River Formation of North Carolina and Virginia with assemblages from adjoining units. Scott and Wingard (1995) demonstrate the cluster analysis technique by comparing complete molluscan faunal lists of Plio-Pleistocene units from

Florida and the southeastern Coastal Plain. Ward and Gilinsky summarize the most beneficial aspects of cluster analysis:

(1) easy revision of biostratigraphic decisions as new data become available or as taxonomic revisions are completed; (2) numerical representation of biostratigraphic relationships among recognizable units, thereby affording accurate assessments of the degree of similarity or difference; and (3) depiction of stratigraphic relationships in clear diagrammatic form. (p. 23)

It is clear from the above discussion that a new approach is needed to investigate the biostratigraphy of southern Florida's Plio-Pleistocene section. The present study is concerned with the identification of biostratigraphic units within these strata, and their relationships to the Tamiami, Caloosahatchee, Bermont and Fort Thompson units. Cluster analysis is used to identify these biostratigraphic units from a number of bulk samples collected across southern Florida. It is hoped that information gained in this study will allow geologists to eliminate much of the confusion still surrounding the Plio-Pleistocene strata, and aid in the redefinition of the stratigraphic nomenclature.



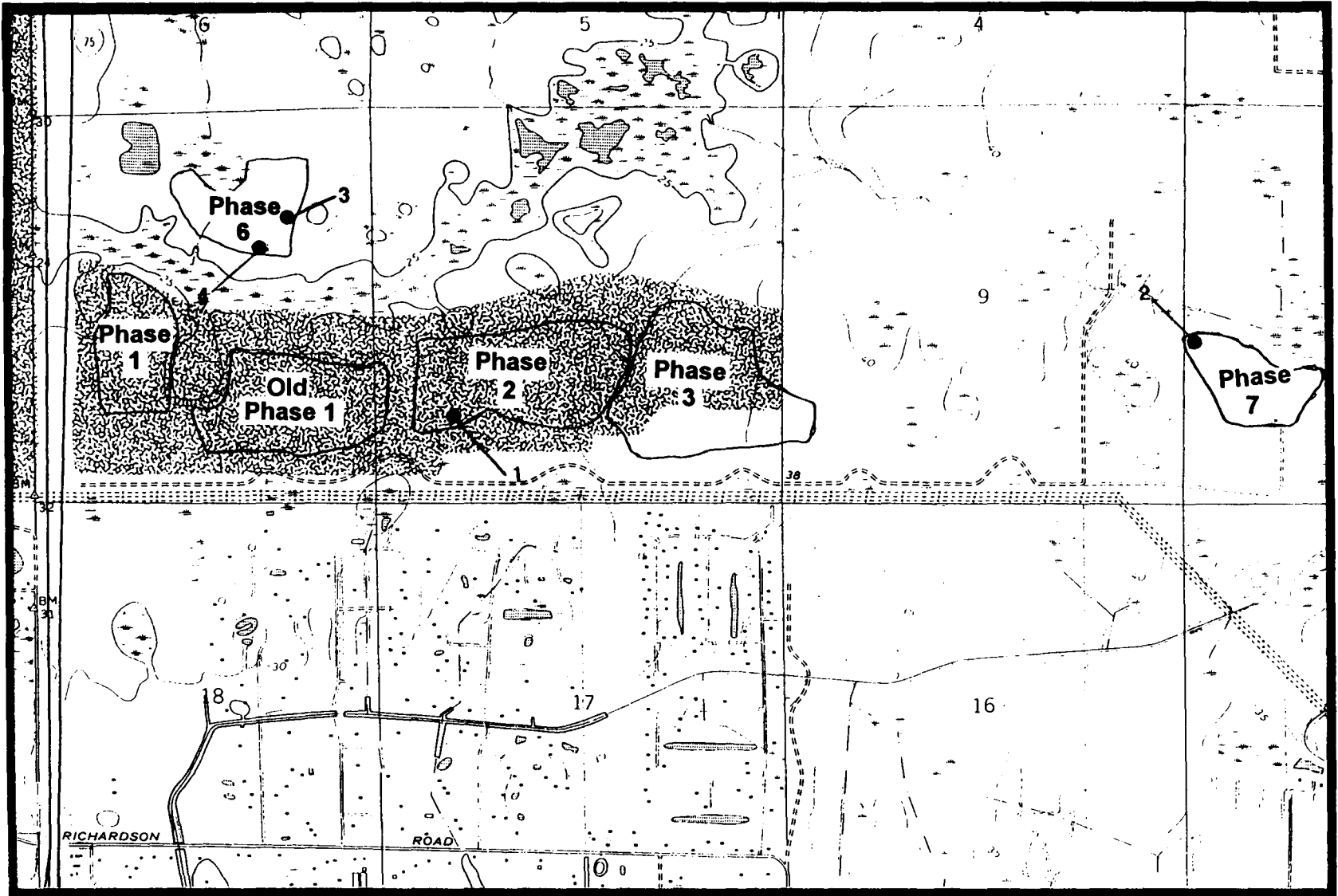
## METHODS

Thirty-two bulk samples were collected between June 6 and June 15, 1994, from 16 localities in south-central Florida. Four localities were within the Quality Aggregates Shell Pit east of Sarasota (Figure 7), and one locality was within the Leisey Shell Pit. The remainder of the samples were collected from scattered small pits throughout the study area. Measured sections and lithology descriptions for localities are detailed in Appendix A. Twenty-eight of the samples were fossiliferous enough to be used for this study.

Before samples were taken, the following criteria were used to determine how many were to be collected from each section. First, the outcrop was scraped down to visually determine whether two or more units were present. Samples were then collected from each unit. When more than one unit could not be visually ascertained one sample was collected for every three feet of vertical section. Uniform-sized bulk samples were collected from each locality in order to reduce sampling bias. Approximately 0.5 cubic feet of matrix was removed with a hand pick and carefully placed into labeled canvas or plastic bags.

Bulk samples were shipped to the U.S. Geological Survey in Reston, Virginia and subsequently transported to laboratory facilities at Old Dominion University in Norfolk,

Figure 7: Portion of the Bee Ridge 7.5 minute topographic quadrangle showing the localities at Quality Aggregates Pit (courtesy of R. Portell). Dots show approximate location where samples were taken.



Virginia. Fossil-bearing matrix was allowed to air-dry for a period of 2-3 days, during which time large and fragile specimens were removed.

After the bulk matrix had dried completely, it was passed through a 3.36 mm mesh sieve. The finer portion was not used for this study. The coarser portion of matrix was placed in a series of stacked mesh sieves, immersed in a bucket of water and gently agitated. Sieves were periodically checked for fragile specimens which were removed when found. Once fossil material appeared sufficiently free of matrix, it was allowed to air-dry for a period of 4-5 days. Matrix remaining in the bucket was air-dried completely, and retained.

All material larger than 9.52 mm was picked for identifiable mollusc shells for every sample. In some samples, however, the volume of material retained in the 4.76 and 3.36 mm sieves was so great that the sample size would need to be further reduced in order to make the task of sorting manageable.

Molluscs were picked, sorted and identified to the species level. The following references were used to identify molluscs to the generic and specific level: Abbott (1974), Dall (1890-1903), Olsson and Harbison (1953), DuBar (1958), Gardner (1943, 1948), Olsson (1967) and Olsson & Petit (1964). Species lists provided by DuBar (1958, 1962), Lyons (1991), and Portell, et al. (1992, 1995) were also particularly useful. Nearly 60,000 specimens belonging to

311 species were identified. Single valves were counted as one specimen. A table showing species abundance versus collection is presented in Appendix B.

One issue that should be of concern in any biostratigraphic analysis is whether the sample size provides an accurate representation of the population being studied. Dennison and Hay (1967) suggest that binomial sampling theory may be used to determine the number of specimens that must be counted to determine with a desired level of confidence the percentage abundance of species. They point out that 300 individuals would be required to record with 95% probability the occurrence of a species comprising 1% of the entire population. Using the same method, Buzas (1990) determined that 300 to 400 individuals would be sufficient for a single sediment sample.

The smallest number of individuals counted from samples used in this study was 516 for collection 2B from Phase 7 of Quality Aggregates Shell Pit. Using the binomial distribution, a count of 500 individuals would be necessary to record with 95% probability the presence of a species comprising 0.4% of the population. It is evident that the number of individuals counted from this study's sample accurately provides a quantitatively reliable census of the fossil mollusc population.

The data were analyzed using a Q-mode cluster analysis that compares samples on the basis of their fauna. Two similarity coefficients with slightly different properties

were used and both weighted and non-weighted pair-group cluster analyses were run in order to determine whether the resulting dendrograms differed significantly. All statistical calculations were run using MVSP version 2.1i (Kovach, 1991) on a 486 33 Mhz PC.

Hazel (1970) suggested that presence-absence data be used and the range-through technique be applied in order to reduce the amount of environmental bias entered into the calculations. Abundance data, therefore, was converted to presence-absence data (Appendix C) for 188 species that occurred in more than one collection. The presence of a species may be temporally significant, while sheer abundance may be more characteristic of the environment in which the species lived. Hazel (1970) warned against the use of abundance data by stating:

...the use of numbers of individuals of species must be minimized in making biostratigraphic inferences because of the danger of correlating strata on the basis of environment rather than sequential similarity. (p. 3237)

The range-through method minimizes the effects of environment on a set of samples. In this technique, a species is counted as being present between its highest and lowest occurrence in a measured section. If this is not done, the calculations will be biased against any factor that is causing the species to be absent, usually an environmental one (Hazel, 1970).

Cluster analyses were run using both the Jaccard and Dice similarity coefficients. The Jaccard coefficient equals:

$$C/(N_1+N_2-C) \quad \text{eq. 1}$$

where C is the number of species common to both samples being compared,  $N_1$  is the total number of species present in the first sample, and  $N_2$  is the total number of species present in the second sample (Cheetham and Hazel, 1969). The Jaccard coefficient is simply the proportion of species in common among the species present in the two samples being compared. It is the most widely used similarity coefficient in biostratigraphic studies. In comparison with other coefficients, it tends to emphasize differences between samples that are being compared.

Dice's coefficient, on the other hand, equals:

$$2C/(N_1+N_2) \quad \text{eq. 2}$$

and is two times the number of species in common among the two samples being compared ( $2C$ ), divided by the total number of species present in both samples ( $N_1+N_2$ ), giving matches twice the weight of mismatches. It has intermediate qualities compared to other coefficients and emphasizes neither similarity nor dissimilarity.

The two most commonly used techniques of clustering are the weighted and unweighted pair-group methods. For the weighted pair-group method a sample joins a cluster and its measure of similarity is averaged with the similarity coefficient of the cluster, regardless of the number of

samples already in that cluster. This may produce distortion in the dendrogram because samples joining the cluster late carry much more weight than those that join earlier. In the unweighted pair-group method, samples are averaged proportionally to the number of samples contained in a cluster. This may have the opposite drawback, however, since late joining samples carry almost no weight in proportion to samples that join the cluster early on (Davis, 1986). The Q-mode cluster analysis for this study was run using both methods of calculation; differences will be discussed in the next section.

Finally, the contribution of a particular species to a cluster was calculated using constancy and biostratigraphic fidelity. Constancy is the percentage of samples in which a species occurs in each biostratigraphic unit or cluster. The biostratigraphic fidelity of a species for a particular biostratigraphic unit is equal to the species' constancy for a cluster divided by the sum of that species' constancy for all clusters, and multiplied by 10. Both constancy and biostratigraphic fidelity are expressed as whole numbers from 1 to 10 (Hazel, 1970). These two calculations allow the biostratigrapher to quickly determine which species are most characteristic of a particular cluster. Constancy and biostratigraphic fidelity may be thought of as a quantification of the guide fossil concept (Hazel, 1970).



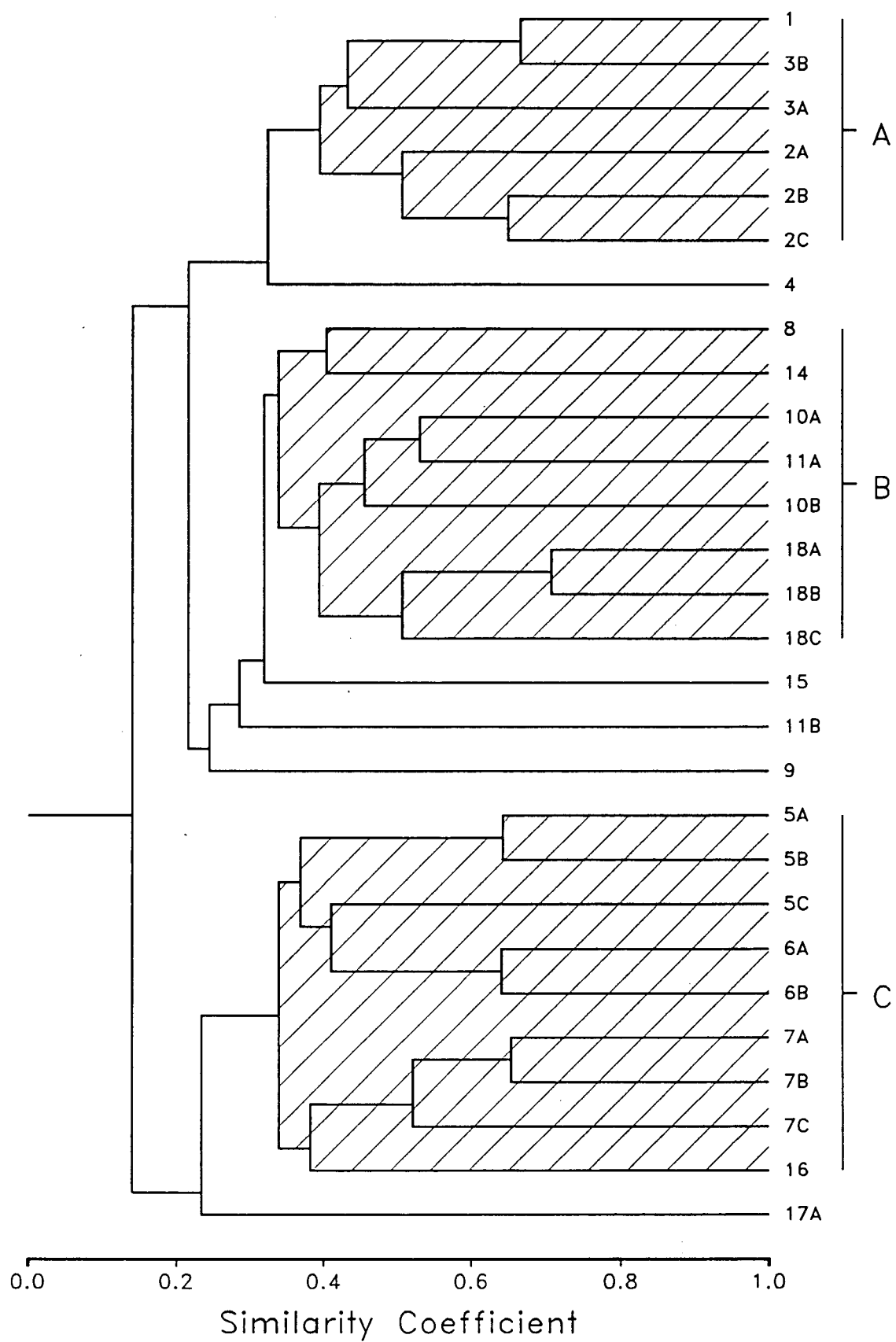
## BIOSTRATIGRAPHIC ANALYSIS

### Results

The Q-mode cluster analysis with range-through produced three distinct clusters. The members forming each cluster remained the same regardless of whether the Jaccard or Dice similarity coefficients were calculated, or whether the weighted or unweighted pair-group methods were used, although members within a cluster shifted around. For this study, therefore, the combination of calculations that result in the final dendrogram is not believed to be highly significant. The fact that each cluster contained the same members regardless of the calculation method used, shows that the clusters are robust and indicates that the relationships between the collections are real. The dendrogram shown in Figure 8 was created by a weighted Q-mode cluster analysis of Jaccard similarity coefficients calculated from presence-absence data.

Cluster A contains (in dendrogram order) collections 1, 3B, 3A, 2A, 2B, and 2C. Cluster B contains collections 8, 14, 10A, 11A, 10B, 18A, 18B, and 18C. Cluster C contains collections 5A, 5B, 5C, 6A, 6B, 7A, 7B, 7C, and 16. One drawback of cluster analysis is that it forces all objects to eventually join a cluster. Collections 4, 15, 11B, 9, and 17A all joined clusters with low similarity coefficients, and for that reason were not included in constancy and biostratigraphic fidelity calculations. The

Figure 8: Cluster dendrogram calculated using the Jaccard similarity coefficient and the weighted pair-group method. The area within clusters A, B and C are cross-hatched. Collections are listed along the right margin of the dendrogram.



significance of these collections will be handled separately.

The collections that make up cluster A were all sampled from the Pinecrest Sand at Quality Aggregates Shell Pit. A total of 136 species from the presence-absence matrix occur in the collections that make up this cluster. Collection 1, sampled from an unknown shelly layer in Phase 2 of the pit, joins collection 3B from Petuch's (1982) *Vermicularia* faunazone in Phase 6, at a similarity level of 0.6667. This joins collection 3A from Petuch's Bed 7 with a similarity coefficient of 0.4324. A second grouping in cluster A is formed by 2A, 2B and 2C, which were collected in Phase 7 of the pit, and believed by Portell (1994, personal communication) to represent Petuch's Bed 3. Collection 2B joins 2C at a similarity level of 0.6500, and these are in turn joined by 2A at a level of 0.5066. This second grouping joins the first grouping with a similarity coefficient of 0.3946. Collection 4, sampled from Phase 6 (approximately one quarter mile from and 10-15 feet above locality 3), joined cluster A with a similarity coefficient of 0.3298 and is not included in the cluster.

The presence-absence matrix contains a total of 144 species that occur in the 8 collections making up cluster B. Three groupings are found in cluster B. The first contains collection 8 from spoil sampled on the Carleton 2x4 Ranch and collection 14 from spoil sampled at Cochran Pit. They join at a similarity level of 0.4040. In the second

grouping, collection 10A from Stinson Pit joins 11A from Davis Pit, with a similarity coefficient of 0.5309. Collection 10B joins this group at a level of 0.4556. The third grouping of cluster B contains all three samples from Leisey Shell Pit. Collection 18A joins 18B at a similarity level of 0.7077 and these are joined by 18C with a similarity coefficient of 0.5071. The second grouping joins the third at a level of 0.3941, and this is joined by the first grouping at 0.3391. Collections 15 from spoil at Highway 80 Pit, 11B from Davis Pit and 9 from an auger sample at Carleton 2x4 Ranch, all join cluster B late at similarity levels of 0.3195, 0.2878 and 0.2487, respectively, and are not considered members of the cluster.

Cluster C contains all of the collections that were made at Wolf Road Pit, Dean's Pit, Taylor Ranch Pit and Punta Gorda Pit. A total of 69 species from the presence-absence matrix occur in the collections that make up this cluster. Collections 5A and 5B of Wolf Road Pit join at a similarity level of 0.6429, and are joined by 5C at 0.3908. Collections 6A and 6B of Dean's Pit cluster with a similarity coefficient of 0.6410. Collections 7A and 7B from Taylor Ranch Pit join at a similarity level of 0.6538, and these cluster with 7C at 0.5210. Dean's Pit and Taylor Ranch Pit collections join with a similarity coefficient of 0.4065, and are subsequently clustered with collection 16 from Punta Gorda at a similarity level of 0.3774, and with Wolf Road collections at 0.3283. Collection 17A from

Forseberg Pit is the last to join cluster C with a similarity coefficient of 0.2444, and it is not included with the cluster.

Constancy and biostratigraphic fidelity were calculated for all species that were included in the cluster analysis (Appendix D). As previously discussed, constancy is the proportion of collections within a single cluster in which a species occurs, and biostratigraphic fidelity is the proportion a species occurs in a cluster relative to all other clusters. A constancy of 10 means that a species occurs in every collection within a cluster, and a biostratigraphic fidelity of 10 means that the species is restricted to a single cluster. For this study, a taxon is considered biostratigraphically important to a cluster if it has a constancy of 4 or greater and a biostratigraphic fidelity of 9 or 10. Following these criteria cluster A has 18 biostratigraphically important taxa (Table 1), cluster B has 9 (Table 2) and cluster C has 5 (Table 3).

Of the 18 taxa in cluster A that have relatively high values of constancy and biostratigraphic fidelity, 14 occur exclusively within the cluster. These are *Anadara scalarina*, *Perna conradina*, *Carolinapecten eboreus*, *Hyotissa hiatensis*, *Ostrea sp. B*, *Sportella sp. B*, *Cymatoica sp. A*, *Cyclinella tenuis*, *Gemma magna*, *Corbula sp. B*, *Pandora sp. A*, *Vermicularia recta*, *Strombus floridanus*, and *Strombina gunteri*. Four of these, *Anadara scalarina*, *Carolinapecten eboreus*, *Cyclinella tenuis*, and *Corbula sp. B*, also occur in

Table 1: Cluster A taxa with values of constancy (C) greater than or equal to 4, and biostratigraphic fidelity (BF) of 9 or 10. See Appendix C for a complete listing of constancy and biostratigraphic fidelity for taxa used in the cluster analysis.

Species	Constancy	Biostratigraphic Fidelity
<i>Anadara scalarina</i> (Heilprin)	10	10
<i>Perna conradina</i> d'Orbigny	8	10
<i>Carolinapecten eboreus</i> (Conrad)	10	10
<i>Hytissa hiatensis</i> (Sowerby)	5	10
<i>Ostrea</i> sp. B	5	10
<i>Sportella</i> sp. B	7	10
<i>Cymatoica</i> sp. A	5	10
<i>Cyclinella tenuis</i> (Recluz)	10	10
<i>Gemma magna</i> Dall	8	10
<i>Corbula</i> sp. B	10	10
<i>Pandora</i> sp. A	5	10
<i>Tegula fasciata</i> (Born)	10	9
<i>Vermicularia recta</i> Olsson &	6	10
<i>Strombus floridanus</i> (Mansfield)	7	10
<i>Calyptraea centralis</i> (Conrad)	7	9
<i>Crucibulum multilineatum</i> (Conrad)	8	9
<i>Natica plicatella</i> Conrad	7	9
<i>Strombina gunteri</i> Mansfield	8	10

Table 2: Cluster B taxa with values of constancy (C) greater than or equal to 4, and biostratigraphic fidelity (BF) of 9 or 10. See Appendix C for a complete listing of constancy and biostratigraphic fidelity for taxa used in the cluster analysis.

Species	Constancy	Biostratigraphic Fidelity
Noetia ponderosa (Say)	5	10
Cumingia tellinoides (Conrad)	6	9
Juliacorbula scutata (Gardner)	4	10
Turritella subannulata Heilprin	6	10
Cerithium litharium Dall	5	10
Trivia quadripunctata (Gray)	8	10
Nassarius albus (Say)	9	10
Atys riiseana Morch	4	10
Helisoma conanti (Dall)	4	10



Table 3: Cluster C taxa with values of constancy (C) greater than or equal to 4, and biostratigraphic fidelity (BF) of 9 or 10. See Appendix C for a complete listing of constancy and biostratigraphic fidelity for taxa used in the cluster analysis.

Species	Constancy	Biostratigraphic Fidelity
<i>Laevicardium mortoni</i> (Conrad)	9	10
<i>Corbula</i> sp. E	4	10
<i>Modulus modulus</i> (Linnaeus)	4	10
<i>Cerithium muscarum</i> Say	9	10
<i>Melongena corona</i> (Gmelin)	6	9

every collection belonging to cluster A. The remainder of the species with high biostratigraphic values are *Barbatia taeniata*, *Tegula fasciata*, *Calyptrea centralis*, *Crucibulum multilineatum*, and *Natica plicatella*.

Taxa in cluster B that have relatively high constancy and biostratigraphic fidelity values include *Noetia ponderosa*, *Cumingia tellinoides*, *Juliacorbula scutata*, *Turritella subannulata*, *Cerithium litharium*, *Trivia quadripunctata*, *Nassarius albus*, *Alys riiseana*, and *Helisoma conanti*. With the exception of *Cumingia tellinoides*, all of these are restricted to cluster B.

Of the 69 taxa that occur within cluster C, only five have relatively high biostratigraphic values. These are *Laevicardium mortoni*, *Corbula sp. E*, *Modulus modulus*, *Cerithium muscarum*, and *Melongena corona*. *Melongena corona* was the only species in this group that did not have a biostratigraphic fidelity value of 10.

### Interpretation

Paleoecological analysis of the molluscan fauna was used to determine whether environmental or temporal similarities between collections were responsible for the resulting clusters. To mitigate the influence of environmental factors on the formation of clusters, data in the form of presence-absence rather than relative abundance were used, as was the range-through technique. However,

further evidence is needed in order to completely resolve the nature of the clusters.

Past paleoecological interpretations of Florida's Plio-Pleistocene shell beds have tended to concentrate on either the most abundant species or the largest and most conspicuous ones. DuBar (1958, 1962) presented a detailed paleoecological analysis of shell beds along the Caloosahatchee River and Shell Creek by comparing fossil assemblages to modern ones. He calculated separate relative abundances for bivalves and gastropods. However, because some of the smallest forms could also be the most numerically abundant, DuBar based his interpretations on both the most conspicuous and the most abundant forms occurring in each bed.

Petuch (1982), on the other hand, used only the largest and most conspicuous species to interpret the paleoecology of the 11 beds he defined at Quality Aggregates Shell Pit. Life habits of fossil molluscs were inferred from modern analogues, and all of the dominant forms combined were used to interpret the past environment. Similarly, Geary and Allmon (1990) largely based their paleoecological interpretation of Petuch's Bed 7 on its most predominant mollusc, *Strombus floridanus*.

For this study, paleoecological interpretations are made using species that have relatively high values of constancy and biostratigraphic fidelity, and species that have a high relative abundance. Juvenile individuals are

not included in the interpretation, because while they may be temporally significant, they may not be environmentally significant. Staff, et al. (1986) points out that juveniles may represent individuals that settled in an unfavorable environment and did not survive to adulthood.

Fossil species are compared with living counterparts to interpret living conditions. Extinct species and specimens that could not be identified to the species level are compared with their most morphologically similar modern forms, whereas extant species are interpreted to have lived in the same way as they do today. Studies by Parker (1956, 1959, 1960), Lewis (1966), Stanley (1970) and Lyons (1989), as well as guidebooks by Andrews (1977), Abbott (1974), Rehder (1981), and Ruppert and Fox (1988), were used to infer the paleoecology from the characteristic and abundant taxa of each cluster. Authors will be cited only when specific reference warrants doing so. A summary of the environments for each cluster as represented by the fauna is presented in Appendix E.

#### Cluster A

Cluster A is represented by 136 species in the presence-absence matrix. On a collection-by-collection basis, the total number of taxa ranges from 45 species in collection 2B from Phase 7 of Quality Aggregates Shell Pit to 98 species in collection 3B from Petuch's *Vermicularia* faunazone in Phase 6 of Quality Aggregates Shell Pit.

Nineteen cluster A species have high biostratigraphic values, including *Anadara scalarina*, *Carolinapecten eboreus*, *Cyclinella tenius* and *Corbula sp. B* which have constancy and biostratigraphic fidelity values equal to 10. Seventeen other species with high relative abundance were recognized, and are discussed below. A shallow bay or lagoon, the shallow inner shelf and possibly an inlet influenced area are interpreted from the characteristic and abundant molluscs.

Important taxa in cluster A that probably lived in a shallow (ca. 1-15 feet deep, Parker (1959)) bay or lagoon are *Nuculana acuta*, *Anadara transversa*, *Perna conradina*, *Hyotissa hiatensis*, *Conradostrea sculpturata*, *Ostrea sp. B*, *Anomia simplex*, *Sportella sp. B*, *Anodontia alba*, *Mulinia lateralis*, *Mulinia sapotilla*, *Chione cancellata*, *Gemma magna*, *Mercenaria campechiensis*, *Cymatoica sp. A*, *Cyclinella tenius*, *Transenella conradina*, *Corbula sp. B*, *Pandora sp. A*, *Tegula fasciata*, *Vermicularia recta*, and *Strombina gunteri*. *Anodontia alba*, *Chione cancellata*, *Transenella conradina*, *Tegula fasciata*, and *Strombina gunteri* favored substrates covered with seagrass. Several species, including *Anadara transversa*, *Cyclinella tenius*, *Corbula sp. B*, and *Pandora sp. A*, may have lived in inlets or inlet-influenced areas.

*Nuculana acuta* probably lived in the bay center (Parker, 1959), as did *Cymatoica sp. A*, a fragile *Tellinid* with feeding habits similar to *Nuculana*. Deposit-feeding bivalves such as *Nuculana* and *Tellina* generally prefer muddy

substrata and may be present alongside suspension-feeding bivalves. Rhoads and Young (1971) stated that the presence of deposit feeders with suspension feeders implies the stability of the substratum.

Bay and lagoon taxa that preferred hard substrates include *Perna conradina*, *Conradostrea sculpturata*, *Ostrea sp. B*, *Hyotissa hiatensis*, *Anomia simplex*, and *Vermicularia recta*. *Perna conradina*, an extinct *Mytilid* bivalve, is interpreted to have lived under similar environmental conditions as *Mytilus edulis*. Petuch (1982) believed that the extinct oyster *Hyotissa hiatensis* lived in a quiet subtidal environment. Modern *Vermicularia* are usually shallow intertidal species that may attach to rocks in mud or live partially embedded in sponges or other colonial animals in bay environments. Petuch envisioned a shallow water (ca. 6 feet deep) setting with a high nutrient level to produce a plankton source rich enough to support the colony of *Vermicularia* found in his Bed 8 at Quality Aggregates Shell Pit.

Several important species from cluster A are interpreted to have lived offshore on the shallow (ca. 6-70 feet deep, Parker (1960)) continental shelf. These are *Anadara scalarina*, *Carolinapecten eboreus*, *Linga amiantus*, *Parvilucina multilineata*, *Chama macerophyla*, *Pleuromeris tridentata*, *Trigoniocardia willcoxi*, *Chione ulocyma*, *Varicorbula caloosae*, *Strombus floridanus*, *Calyptraea centralis*, *Crucibulum multilineatum*, and *Natica plicatella*.

Waller (1969) believed that *Argopecten* [= *Carolinapecten*] *eboreus* was closely related to living *Argopecten gibbus* which is restricted to open marine waters. *Trigoniocardia willcoxi* is interpreted to have occupied an environment similar to that of *Trigoniocardia medium*, a Caribbean species that lives in water at depths of 18 to 1000 feet (Abbott, 1974). A living species morphologically similar to *Chione ulocyma* is *Chione intapurpurea*, which Lyons (1989) found to be the most abundant bivalve in 30+ feet of water off the east coast of Florida near Hutchinson Island. Parker (1960) listed *Chione intapurpurea* as belonging to his inner shelf assemblage. Finally, *Strombus floridanus* was thought by Lyons (1991) to have had a mode of life similar to living *Strombus alatus*, occupying sandy offshore areas carpeted with seagrass.

Taxa believed to have preferred inlets or inlet influenced areas are *Anadara scalarina*, *Linga amiantus*, *Parvilucina multilineata*, and *Natica plicatella*. *Anadara scalarina* is morphologically similar to living *Anadara chemnitzii* and *Anadara brasiliana*. Andrews (1977) reported that both of these species live just offshore in shallow water. Parker (1956) found the center of population for *Anadara brasiliana* to be confined to inlets. The extinct gastropod *Natica plicatella* is similar to *Natica canrena* and *Natica pusilla*, which reportedly live in inlet influenced environments and offshore in shallow water.

Several characteristic and abundant taxa of cluster A are commonly found in hard substrate communities. A community of this type inhabits large, empty mollusc shells or broken shell fragments instead of rock (Lyons, 1989). Species occupying hard substrate communities live either in shallow bays and lagoons, offshore on the inner shelf, or in both of these environments. Important cluster A taxa that lived on this kind of substrate include *Chama macerophyla*, *Calyptrea centralis*, *Crucibulum multilineatum* and possibly juvenile *Carolinapecten eboreus*. Parker (1960) lists *Chama macerophyla*, *Calyptrea centralis* and *Crucibulum sp.* as important constituents of his offshore calcareous bank assemblage. Lyons (1989) noted that juvenile *Pectinids* have an affinity for hard substrates.

Three environments are represented by taxa that are important to cluster A. There are taxa that preferred a shallow bay or lagoon environment, and taxa that favored a shallow inner shelf environment. Within both of these environments there are certain taxa that had a preference for hard, shelly substrates. A third environment is represented by species that preferred to live in inlet or inlet influenced areas.

#### Cluster B

Cluster B contains the highest number of mollusc species of the three clusters, with 144 species represented



in the presence-absence matrix. On a collection-by-collection basis, the total number of species ranges from 56 taxa in collection 18B from Leisey Shell Pit to 84 in collection 8 from Carleton 2x4 Ranch. Nine species with high values of constancy and biostratigraphic fidelity, and 23 species with high relative abundance were identified. There are three shallow water environments represented in cluster B including a brackish bay or lagoon, a shallow, euryhaline bay or lagoon, and the shallow shelf.

The only two fresh/brackish water species that are both characteristic of and abundant in cluster B are the bivalve *Mulinia sapotilla*, and the freshwater snail *Helisoma conanti*. DuBar (1958) noted that *Mulinia sapotilla* most commonly occurs in great abundances in brackish water assemblages that are also characterized by *Rangia* sp. Large numbers of *Helisoma conanti* implies the presence of a nearby fresh water source. Collection 14 from Cochran Pit is the only sample that contains a high relative abundance of both *Mulinia sapotilla* (ca. 17% of the entire collection) and *Helisoma conanti* (ca. 27%). This collection also contains a fair quantity of another freshwater snail *Viviparus georgianus* (ca. 2%), and the brackish water bivalve *Rangia cuneata* (ca. 2%). Collection 14 probably was deposited in a shallow water brackish environment in proximity to a fresh water source.

Important species in cluster B that inhabited shallow, variable-salinity bays and lagoons are *Brachidontes exustus*,

*Conradostrea sculpturata*, *Carditamera arata*, *Cumingia tellinoides*, *Tagelus divisus*, *Anomalocardia caloosana*, *Chione cancellata*, *Transenella conradina*, *Cerithium litharium*, *Nassarius albus*, and *Marginella apicna*. All of these are commonly associated with a sandy substrata carpeted by seagrass. DuBar (1958) listed the extinct oyster *Conradostrea sculpturata* as a common component of the lower oyster biostrome that he described from the Caloosahatchee shell bed. This biostrome lacked many species typical of normal marine conditions, but none of the characteristic species were present in his brackish water assemblage. Therefore, *Conradostrea sculpturata* is believed to have lived in variably saline, shallow bays and lagoons.

Taxa from cluster B that are interpreted to have lived offshore on the shallow shelf include *Parvilucina multilineata*, *Pleuromeris tridentata*, *Raeta plicatella*, *Juliacorbula scutata*, *Varicorbula caloosae*, *Turritella subannulata* and *Atys riiseana*. *Noetia ponderosa*, *Plicatula marginata* (which is probably closely related to living *Plicatula gibbosa*) and *Arcinella cornuta* likely lived offshore in hard substrate communities. As mentioned previously, Parker (1959) considered *Parvilucina multilineata* to be typical of inlet environments along the Texas coast, but it also reportedly lives offshore on the shallow shelf. *Varicorbula caloosae*, an extinct bivalve nearly identical to the modern *Varicorbula operculata*, was cited as evidence by DuBar (1958, 1962) of a relatively deep

(ca. 60-120 feet deep) water assemblage he described from the Caloosahatchee shell bed. Modern *Varicorbula operculata* lives to depths of 1500 feet (Abbott, 1974), but it has also been found living in bamboo-root clumps (Andrews, 1977). *Turritella subannulata*, also extinct, probably lived offshore in the neritic belt (ca. low water to 600 feet deep) where wave and current action was moderate (DuBar, 1958).

Cluster B taxa that lived in hard substrate communities either in bays or offshore are *Anadara transversa*, *Arcopsis adamsi*, *Conradostrea sculpturata*, *Anomia simplex*, *Crepidula aculeata*, *Crepidula fornicata*, and *Trivia quadripunctata*. *Trivia quadripunctata*, an important Cluster B gastropod, is known to feed on animals living in hard substrate communities. Lyons (1989) noted that certain carnivorous gastropods which feed on animals living in these communities are usually included in the death assemblage.

There are three environments represented in cluster B, a brackish bay or lagoon, a shallow, euryhaline bay or lagoon, and the shallow inner continental shelf. Within the shallow, euryhaline bay/lagoon environment there appear to be taxa that prefer a sandy bottom covered with seagrass, as well as those that favor a hard substrate consisting of mixed sand and shell fragments. On the continental shelf there are certain taxa that are typical of a hard substrate community, those that prefer a muddy substrate (i.e., *Varicorbula*), and those that prefer a clean sandy substrate

(i.e., *Raeta*). Some hard substrate dwellers are found both in shallow bays and on the shallow inner shelf including *Anadara transversa*, *Anomia simplex*, *Crepidula fornicata*, *Crepidula aculeata* and *Trivia quadripunctata*.

#### Cluster C

Cluster C is the least taxonomically diverse of the three clusters, represented by 69 species in the presence-absence matrix. On a collection-by-collection basis, the total number of species ranges from a low of 20 in collection 5B from Wolf Road Pit, to a high of 46 in collection 7A from Taylor Ranch Pit. Cluster C also has the fewest number of taxa with relatively high constancy and biostratigraphic fidelity values. Twelve species with high relative abundance are discussed below.

Nearly all of the species in cluster C that have high biostratigraphic values and high relative abundance are found living today in euryhaline, shallow bays or lagoons with sandy bottoms. These include *Anadara transversa*, *Laevicardium mortoni*, *Anomalocardia caloosana*, *Chione cancellata*, *Transenella conradina*, *Corbula sp. E*, *Modulus modulus*, *Cerithium muscarum*, *Nassarius vibex*, *Melongena corona*, *Marginella apicna*, *Bulla striata* and *Pyramidella crenulata*. Of these, *Laevicardium mortoni*, *Anomalocardia caloosana*, *Chione cancellata*, *Transenella conradina*, *Modulus modulus*, *Cerithium muscarum*, *Nassarius vibex*, *Marginella apicna*, *Bulla striata* and *Pyramidella crenulata* all prefer

substrata carpeted by seagrass. *Corbula* sp. E is morphologically similar to *Corbula contracta*, and *Anomalocardia caloosana* is considered analogous to *Anomalocardia auberiana*.

In addition to shallow bays, living *Anadara transversa* is found in inlet-influenced areas and offshore on the shallow shelf, byssally attached to large shell fragments. *Chione cancellata* also lives in inlet environments along the Texas coast (Parker, 1959). *Melongena corona* is a completely estuarine species (Lyons, 1989), and is typically found living among mangroves in muddy sand rather than in seagrass beds (Rehder, 1981; Ruppert and Fox, 1988). Lyons (1989), however, reported that *Melongena corona* shells inhabited by hermit crabs are quite common in the shallow water Indian River estuary, and are therefore not entirely restricted to mangroves. Parker (1959) reported that *Olivella mutica* and *Parvilucina multilineata* are typical of inlet environments along the Texas coast, and he later (Parker, 1960) reported that *Olivella mutica* is also characteristically found in the surf zone of sandy beaches. *Mulinia lateralis* is a fairly ubiquitous species, reportedly found in every shallow water, marine molluscan assemblage (Andrews, 1977). However, it tends to prefer shallow, euryhaline bays and lagoons (Parker, 1959; Lyons, 1989).

Lewis' (1966) paleoecological assessment of a late Pleistocene molluscan assemblage noted that *Laevicardium mortoni*, *Mulinia lateralis*, *Anomalocardia auberiana*, *Chione*

*cancellata*, *Transenella conradina* and *Nassarius vibex* all commonly live together in shallow, hypersaline bays. He reported that *Parvilucina multilineata*, *Pseudomiltha floridana*, *Bulla occidentalis* and *Marginella apicna* occur most commonly together as dead valves in the bay environment, although *Marginella apicna* is also found living offshore. Lewis' example appears to fit well with the above interpretation.

Characteristic and abundant mollusc species belonging to cluster C are interpreted to have lived in shallow, euryhaline bays and lagoons. It is possible that small, inlet- and offshore-dwelling species such as *Olivella mutica* and *Parvilucina multilineata* could have been washed into the bay through inlets or in washover fans. The substrate was most likely sand that was carpeted with seagrass. Currents were probably moderate to strong, depending on the proximity to inlets. The series of shallow back-barrier bays that lie along the southern Texas coastline, or any of the shallow bays that exist off either coast of Florida, may be analogous to the environment represented by the mollusc species of cluster C.

#### Discussion

While it has been shown that there is environmental heterogeneity among the collections that make up a single cluster, there is also apparently heterogeneity within single collections. An example of this is collection 18C

from Leisey Shell Pit which contains a number of important species endemic both to bays (*Anadara transversa*, *Brachidontes exustus*, *Cumingia tellinoides*, *Chione cancellata*, and *Nassarius albus*) and offshore on the shallow continental shelf (*Raeta plicatella*, *Crucibulum striatum*, and *Trivia quadripunctata*). This apparent mixing of faunal elements is due to the effects of time-averaging as discussed by Staff, et al. (1986).

Original community characteristics may become highly obscured if the effects of time-averaging are great enough. This may be responsible for the environmental heterogeneity within a cluster, however, a cluster may still have formed because of a "hidden" overall environmental signature among its collections. Therefore, a discussion of time-averaging is necessary to determine its impact on the original community characteristics of the collections used in this study, and in turn its effect on cluster formation.

Time-averaging is the mixing together of portions of noncontemporaneous populations belonging to separate living communities. In effect, time-averaging tends to obscure the original community characteristics by mixing taxa that lived in a range of conditions more diverse than those present during any relatively short span of time (Staff, et al., 1986). The effect that time-averaging has upon a death assemblage is to give it a greater taxonomic diversity than the potential death assemblage (the potentially preservable

component of a living community), thereby increasing the number of species belonging to different living communities.

One factor that greatly increases the number of species in a death assemblage is the presence of juvenile individuals. Juvenile species may settle into an environment which is unfavorable and may survive for only a short period of time. In comparisons of living communities with death assemblages in Texas bays, Staff, *et al.* (1986) found that when juveniles were not included as part of the death assemblage, the death assemblage became much more similar in taxonomic composition to the living assemblage. As previously noted, shells belonging to juvenile molluscs were not included in the paleoecological interpretations for this study.

Another factor that affects the degree to which time-averaging increases species richness is the interaction of sedimentation rate and physical mixing of individuals from different living communities. Staff, *et al.* (1986) noted this as the primary factor contributing to taphonomic loss. A slow and uniform sedimentation rate is believed to result in the greatest difference between the death assemblage and the potential death assemblage. A slow sedimentation rate punctuated by periods of rapid accumulation may result in the preservation of taxa more indicative of a single community.

The mode of deposition of Florida's Plio-Pleistocene shell beds is therefore quite important to the understanding



of taphonomic loss from time-averaging. The formation of these shell beds has been addressed by Geary and Allmon (1990) and by Allmon (1992, 1993). The number of epibionts on a dense accumulation of Strombid shells was used by Geary and Allmon (1990) to estimate the rapidity of burial. They believed that since the gastropod shells were relatively free of borings and encrusters, the shells sat on the bottom only a short time before they were buried. The number of shells per square meter in the shell bed far exceeded the number of individuals that are found living today within the same area. They concluded, therefore, that sediment covering the Strombids was constantly being winnowed from around the shells, condensing them. The shells were rapidly buried and kept free of epibionts. Evidence of winnowing is supported by Allmon (1992) who pointed out that finer sediments and more fragile ostracodes are usually found within paired bivalves, while the matrix surrounding the shells is generally coarser.

Further evidence of episodic exhumation and rapid burial was provided by Allmon (1992, 1993), who noted that many of the mollusc shells found in Florida's Plio-Pleistocene shell beds show little evidence of abrasion through transport. Similarly, Geary and Allmon (1990) pointed out that bed geometry, which tends to be tabular and laterally continuous, is not what one would expect if the shells had been transported and deposited in a localized

concentration. This evidence seems to suggest a reworking of shell beds in place with little allocthonous input.

While the work of Geary and Allmon (1990) and Allmon (1992, 1993) was largely concerned with formation of the Pinecrest shell beds near Sarasota, it might be extrapolated as a hypothetical explanation for the formation of many or most of the Plio-Pleistocene shell beds of southern Florida. Much of the fossil mollusc material collected for this study was, for the most part, unabraded, and many of the bivalves were paired, indicating that minimal transport had taken place before burial. Furthermore, the shells were largely free of epibionts, suggesting that they did not remain uncovered on the bottom for an extended period of time. Certainly, as Allmon (1992) suggested, detailed examination of the taxonomic composition, fabric, geometry and sedimentology is needed before the formation of post-Pinecrest shell beds of southern Florida can be thoroughly understood.

However, the scenario put forth by Geary and Allmon (1990) and Allmon (1992, 1993) suggests that taphonomic loss through time-averaging was not as great as it could have been. Staff, *et al.* (1986) suggested that a slow sedimentation rate punctuated by periods of rapid sedimentation might result in a distinct horizon dominated by a single community. Such a horizon would therefore have experienced little taphonomic loss. Pinecrest (and possibly younger shell beds) mollusc fossils are believed to have

been periodically uncovered and rapidly buried more or less in place.

Rapid in-situ burial and the exclusion of juveniles from paleoecological analyses have together minimized the effects of time-averaging on the collections used in this study. Therefore, the molluscan assemblages from each collection more closely resemble the living assemblages at the time the shell beds were being deposited. This evidence shows that the environmental differences within clusters as well as the environmental similarities between clusters can be trusted. Furthermore, it confirms that environmental similarity was not the cause of cluster formation. It seems likely, therefore, that temporal similarity between collections is the primary basis for cluster formation.

There were very few age diagnostic species identified from collections. One of only a very few biozonations for Florida's Neogene was done by Hunter (1968), who used species of *Pecten* and *Ecphora* along with other molluscs to divide the Tamiami Formation into three concurrent range zones. Unfortunately, the present study is only concerned with the uppermost member of the Tamiami Formation, the Pinecrest beds. Furthermore, the Pectinids listed by Hunter as characteristic of the Pinecrest were not identified in any of the collections that were made from known Pinecrest beds in Quality Aggregates Pit.

Another study conducted by Lyons (1991) attempted to correlate Florida's Plio-Pleistocene units to molluscan

zones identified by Blackwelder (1981) for late Cenozoic deposits on the Atlantic Coastal Plain. However, while Blackwelder used molluscan assemblages to define his range zones, Lyons, for the most part, excluded faunal comparisons when correlating Pliocene and Pleistocene units of southern Florida with Blackwelder's molluscan zones. Instead, Lyons compared age estimates of southern Florida's Plio-Pleistocene units with revised age estimates for Blackwelder's range zones.

Only a handful of collections made for this study were sampled from strata belonging to known stratigraphic units. Collections 1, 2A-C, 3A and 3B were sampled from Pinecrest beds exposed in Quality Aggregates Shell Pit. Collection 3B was taken from Petuch's (1982) Unit 8, a relatively thin horizon containing clumps of *Vermicularia recta* buried in-situ, overlying a reworked lag of disarticulated valves of *Mercenaria tridacnoides*. This particular bivalve is not found above Unit 10 except as a lag which may be worked up into the lower few inches of Unit 8. Both *Vermicularia recta* and *Mercenaria tridacnoides* were common constituents of collection 3B. Collection 3A was sampled directly above Unit 8 and belongs to Unit 7. Consistent with this view is the fact that the sampled horizon contained a zone of extremely abundant *Strombus floridanus*, a feature characteristic of lower Unit 7 (Allmon, 1993). Collection 1 is also believed to belong to Unit 8. Like collection 3B, it contains abundant *Vermicularia recta* as well as a valve

belonging to *Mercenaria tridacnoides*. Collections 2A-C contain numerous valves of the Mytilid *Perna conradina* and the Pectinid *Carolinapecten eboreus*, both of which are listed by Petuch (1982) as characteristic of Unit 3.

The only other collections sampled from a known stratigraphic horizon are 18A-C from Leisey Shell Pit. Both the Fort Thompson and Bermont shell beds are known from the Leisey Pit, and it was not clear in the field whether one or both of these had been collected. Subsequent faunal comparisons of the material collected for this study with a detailed faunal list of Bermont and Fort Thompson taxa collected over a period of several years from Leisey Pit (Portell, et al., 1995) showed that only the Bermont unit had been collected. A cumulative total of 86 species was identified from collections 18A-C. Twenty-three of these have not been reported above the Bermont at Leisey, and the remainder were either shared by the Bermont and Fort Thompson shell beds, or were not found on the faunal list. There are apparently no species that are exclusively found within the Fort Thompson at Leisey Pit. It is concluded, therefore, that collections 18A-C belong to the Bermont shell bed.

The relative ages of the remainder of the collections must be assessed. The use of Lyellian percentages (the ratio of extinct to extant organisms) was long used to determine the ages of Cenozoic sediments. The ages derived from these percentages, however, were largely overestimated

because the catastrophic extinctions of western Atlantic molluscs that occurred during the Pliocene and Pleistocene have only recently come to light (Stanley and Campbell, 1981). Use of Lyellian percentages in a strict sense has been discontinued. Nevertheless, Lyellian percentages using molluscs may still be used to determine the relative ages of sediments.

Stanley and Campbell (1981) noted that the molluscan fauna of southern Florida has undergone a stepwise impoverishment from the enormous Pliocene Pinecrest fauna, estimated to contain upwards of 1200 species (Olsson, 1968), 15-20% of which are living, to the Pleistocene Fort Thompson shell bed, where nearly all species are extant. Successively younger units in southern Florida contain fewer extinct molluscs than previous ones. Percentages of extinct species for collections should provide insight as to their ages relative to one another.

Ratios of extinct to living species are calculated for collections using presence-absence data (Table 4). Species identified only to the generic level were not included in the calculations. The percent extinct species per collection was calculated by dividing the number of extinct taxa by the total number of taxa in a collection that had been identified to the species level. The percent extinct species per cluster was calculated by dividing the total number of extinct taxa by the total number of taxa in a single cluster that had been identified to the species

Table 4: The percentage of extinct species per collection and per cluster.

Collection	Total # Sp.	# Extinct	# Living	% Extinct Sp.			
1	59	29	30	49%	Cluster A	41% extinct species	
2A	65	27	38	42%			
2B	45	17	28	38%			
2C	43	15	28	35%			
3A	78	33	45	42%			
3B	73	34	39	47%			
4	82	36	46	44%			
8	73	27	46	37%	35% extinct	Cluster B	
14	63	19	44	30%			
10A	67	12	55	18%	19% extinct species		30% extinct species
10B	60	14	46	23%			
11A	53	9	44	17%			
18A	49	6	43	12%			
18B	56	10	46	18%			
18C	49	9	40	18%			
11B	34	7	27	21%			
9	30	12	18	40%			
15	45	15	30	33%			
5A	24	3	21	13%	Cluster C	6% extinct species	
5B	17	2	15	12%			
5C	22	2	20	9%			
6A	30	2	28	7%			
6B	28	2	26	7%			
7A	39	2	37	5%			
7B	39	2	37	5%			
7C	30	2	28	7%			
16	26	4	22	15%			
17A	13	2	11	15%			

level. Taxa from the presence-absence matrix were used for both calculations.

For cluster A, the number of extinct species per collection ranges from 15 to 34, and the total number of species in each collection ranges from 48 to 85. Percent extinct species ranges from 35% in collection 2C to 48% in collection 1. Overall, cluster A contains a total of 122 species, 41% of which are extinct.

Cluster B collections have 9 to 27 extinct species per collection. Total number of species in each collection ranges from 50 in collection 18C to 74 in collection 8. Collections 10A-B, 11A and 18A-C have 12-23% extinct species. Percent extinct species for collections 8 and 14 are slightly higher at 30-37%. Overall, cluster B is represented by 132 species, 30% of which are extinct. Taken separately, collections 8 and 14, which clustered together on the dendrogram, average 35% extinct species. The other collections making up cluster B have an average of only 19% extinct species.

All of the collections making up cluster C have very few extinct species, ranging from 2 to 4 in each collection. The number of species per collection is also relatively small, and ranges from 20 in collection 5B to 44 in collection 7B. Taken as a whole, cluster C contains 63 species, 6% of which are extinct.

The average number of extinct species is greatest for cluster A at 41%, declining to 30% for cluster B, and



bottoming out at 6% for cluster C. Within cluster B there is one group that has an average of 35% extinct species, and a second that averages 20% extinct species. The collections making up cluster A are the oldest, those making up cluster C are the youngest, and collections making up cluster B are intermediate in age.

Collections making up cluster A belong to the Pinecrest member of the Tamiami Formation. Overall, the cluster has 41% extinct species, which is higher than clusters B or C. Lyons (1991), however, indicates that the Pinecrest should contain approximately 95% extinct species. Lyons' estimate is larger partly because the Pinecrest has been much more extensively sampled than was done for this study, and because matrix smaller than 3.3 mm was not sorted for fossils. Allmon (1992) reported that approximately 220 species of bivalves and 500 to 600 species of gastropods are present throughout the Pinecrest. Olsson (1968) estimated the total number of Pinecrest molluscan species to be as many as 1200. Only 167 species (including all of the species that were not used in the numerical analyses) were identified from collections belonging to cluster A. While the samples are thought to be statistically representative of the fauna present, they contain only about 15-20% of the species that are estimated to exist. This seems plausible, because as more samples are taken from a unit, rare species are continuously being found and the total number of species increases (Koch, 1987). This is probably the case with the

Pinecrest, and may explain why the number of extinct species in the cluster A collections is so low relative to the total number of species present.

The age of collection 4 from Quality Aggregates Pit is still uncertain. It was collected from a horizon that is not described in the literature. Alone, it contains 41% extinct species, the same as the average for cluster A. Furthermore, it contains several species that are biostratigraphically important to cluster A including *Anadara scalarina*, *Perna conradina*, *Carolinapecten eboreus*, *Strombus floridanus* and *Strombina gunteri*. However, several species characteristic of younger collections are also present in collection 4 including *Brachidontes exustus*, *Cerithium litharium*, *Crepidula aculeata* and *Marginella eulima* of cluster B and *Cerithium muscarum* of cluster C. This particular unit may be contemporaneous with the Pinecrest, or as Portell (personal communication, 1995) suggested, it might be transitional between the Pinecrest and the overlying Caloosahatchee shell bed.

Cluster B collections are intermediate in age between those of cluster A and cluster C. There are two units in southern Florida that are recognized between the Pinecrest and Fort Thompson, the late Pliocene Caloosahatchee shell bed and the early Pleistocene Bermont shell bed. It is likely that both are represented in collections making up cluster B.

Collections 8 and 14 of cluster B, as well as late-joining collections 9 and 15, are thought to belong to the Caloosahatchee. Together they have an average of 35% extinct species. DuBar (1958) reported that the number of extinct species for the Caloosahatchee ranged from 50% to 65%. Again, the large discrepancy between DuBar's estimate and the one determined here may be explained by the limited amount of sampling that was done for this study. Up to 700 species may be present in the Caloosahatchee (DuBar, 1974), yet only 134 species (including those not used in the cluster analysis) were identified from these four collections.

Two gastropods that Lyons (1991) reported as not occurring above the late Pliocene have been identified from these collections. These are *Caliostoma willcoxianum*, identified from collection 14, and *Cymatocyrix lunata*, identified from collection 8 and collection 15. Similarly, an index gastropod for the Caloosahatchee (Lyons, 1991), *Turbo rhexogrammicus*, was identified from collection 9 (Carleton 2x4 Ranch). None of the collections believed to be correlative with the Caloosahatchee contain any molluscs that are restricted to the Bermont or Fort Thompson units.

Still, some caution must be placed on any conclusions reached with regard to collections 8, 14 and 15. All of these samples were collected from spoil and it is unclear whether they contain faunal elements derived from more than

one unit. Therefore, these collections may only be tentatively correlated with the Caloosahatchee.

Collections 10A-B, 11A and 18A-C are representative of the Bermont. Together they have an average of 20% extinct species. Collections from the classic Bermont locality at Belle Glade Rock Pit were estimated to have 15% extinct species (Hoerle, 1970), while those from Leisey Shell Pit were estimated to have only 5% (Portell, et al., 1992). When the extinct species from a newer Leisey faunal list (Portell, et al., 1995) were taken as a percentage of molluscs named to the species level, the number was closer to 15%. The percent extinct species for collections from this study ranges from 17% to 23%.

None of the Bermont-restricted molluscs listed by DuBar (1974, p. 222) were identified from these collections. However, only one of these species, *Strombus mayacensis*, was reported from Bermont deposits at Leisey Shell Pit, and it was only collected from spoil. Two additional key Bermont taxa, *Semele perlamellosa* and *Conradostrea sculpturata* have been reported from Leisey (Portell, et al., 1992). *Conradostrea sculpturata* was identified from all three collections made from Leisey, but it was present in only one other collection (11A). The collections that belong to the Bermont share two common characteristics. They have a percentage of extinct species that is intermediate between collections thought to belong to the Fort Thompson and those thought to be from the Caloosahatchee, and none of the late

Pliocene or Caloosahatchee index fossils cited by Lyons (1991) occur in collections 10A-B, 11A-B, and 18A-C.

It is likely that collection 11B, which joined cluster B late, also belongs to the Bermont. While it lacks a few of the species responsible for forming cluster B, it contains approximately 20% extinct species. Furthermore, collection 11B shares its most common species with the overlying collection 11A.

The collections that belong to cluster C are correlative with the Fort Thompson. Overall, they contain 6% extinct species. The Canepatch Formation of South Carolina, which Lyons (1991) believed to be contemporaneous with the Fort Thompson, contains approximately 4-6% extinct species. Faunal lists provided by Portell, *et al.*, (1992, 1995) for the Fort Thompson at Leisey Shell Pit contain only 3% extinct mollusc species. Species listed by DuBar (1962, p. 37) as being most important numerically are also the most abundant among the collections making up cluster C. Furthermore, cluster C collections do not contain any species that are restricted to earlier units.

Collection 17A, which joins cluster C late, probably also belongs to the Fort Thompson. Taxa that are most abundant within this collection are also the most abundant within other cluster C collections. However, the fossils in this collection were poorly preserved and it is possible that some of the less stable aragonitic shells were dissolved. As a result, collection 17A contains only 14

species, 2 of which are believed to be extinct. While most of the other collections belonging to cluster C also had 2-3 extinct species, the low total number of species present in collection 17A causes it to have a misleading 15% extinct species.

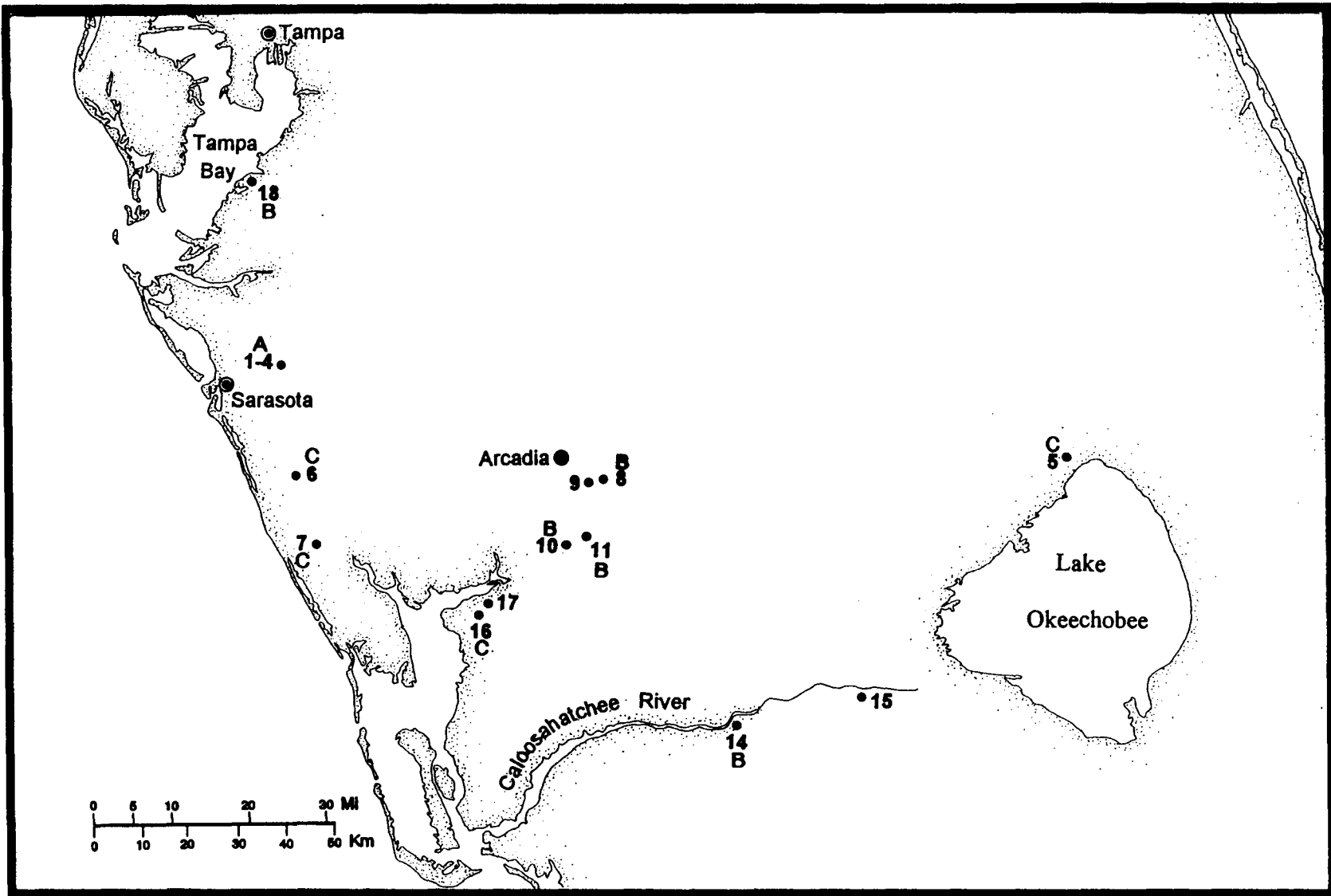
Table 5 lists all of the collections and the stratigraphic units to which they correlate. Uncertain correlations are denoted with a question mark. A map showing the areal distributions of clusters is presented in Figure 9.

Table 5: Correlations of collections to the recognized stratigraphic units of southern Florida. Uncertain correlations are denoted by a question mark.

Collection	Stratigraphic Correlations	
1	Pinecrest Mbr. Tamiami Formation	Cluster A
2A		
2B		
2C		
3A		
3B		
4	Pinecrest Mbr.? or Caloosahatchee?	
8	Caloosahatchee?	Cluster B
14	Caloosahatchee?	
10A	Bermont	
10B		
11A		
18A		
18B		
18C		
11B		
9	Caloosahatchee	
15	Caloosahatchee?	
5A	Fort Thompson	Cluster C
5B		
5C		
6A		
6B		
7A		
7B		
7C		
16		
17A		

Figure 9: Map of showing the areal distribution of cluster members. The letter for each cluster is shown next to its appropriate locality number. Localities that were not included in a cluster are shown, but do not have a letter next to them.





## CONCLUSIONS

Cluster analysis and associated qualitative analysis of fossil molluscs shows that the twenty-seven collections are assignable to four distinct biostratigraphic units (e.g. assemblage zones). The results of the cluster analysis were essentially the same among the four clustering techniques used, thus confirming the robustness of the data. That these units do not merely represent biofacies is evidenced by the presence of faunal elements in each unit that were derived from more than one environment, and by the representation of these environments in more than one unit.

That these four biostratigraphic units are of different age is evidenced by the presence of a few age restricted species, and by the difference in the ratio of extinct to living species. Comparisons of the molluscan fauna to the known fauna of the Pinecrest, Caloosahatchee, Bermont and Fort Thompson suggest that the four units determined by this study are correlative with these four stratigraphic units.

Each biostratigraphic unit contains a unique suite of mollusc species, including some species not previously considered to be index fossils of the Pinecrest, Caloosahatchee, Bermont or Fort Thompson. In spite of the fact that age-diagnostic species are uncommon, mollusc assemblages identified by this study as characteristic of a single biostratigraphic unit provide valuable tools for recognizing these units in southern Florida.

Each of the four biostratigraphic units is confined separately within the Pinecrest, Caloosahatchee, Bermont and Fort Thompson units. However, it is not the purpose of this study to state whether the Caloosahatchee, Bermont and Fort Thompson "Formations" are valid by NASC standards. This must be assessed through a thorough examination of their lithostratigraphy. Further study might also reveal the allostratigraphic nature of these units. Clearly, more work is needed in order to place the Caloosahatchee, Bermont and Fort Thompson into the proper stratigraphic context.

The present research lays the foundation for more extensive biostratigraphic investigations in southern Florida using quantitative and qualitative methods similar to those employed in this study. A broader study encompassing a larger area would be helpful in determining the geographic extents of the biostratigraphic units identified here. Samples collected from smaller short-lived quarries could be used to build upon the data gathered for this research. Further study may provide tests on the utility and validity of mollusc species suggested as indices to the four biostratigraphic units.

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Appendix A: Locational information, lithologic descriptions and measured thicknesses for sampled localities.

Locality 1 (Quality Aggregates Pit): Samples collected from the southern wall of Phase 2 of the Quality Aggregates Pit approximately 5.5 miles east of Sarasota, Sarasota County, Florida (SW  $\frac{1}{4}$  - SW  $\frac{1}{4}$ , Sec. 8, T 36S, R 19E, Bee Ridge, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 1</u> : Very shelly, bioclast-supported, fine to medium quartz sand. Sediment is light olive gray and moderately well-sorted. Very fossiliferous, dominated by <i>Vermicularia recta</i> and <i>Mercenaria sp.</i> Overlain by roughly 15 feet of spoil. Section measured to the base of the pit.	4'2" (1.27m)

Locality 2 (Quality Aggregates Pit): Samples collected from a drainage ditch in the northwestern part of Phase 7 of the Quality Aggregates Pit, Sarasota County, Florida (NW  $\frac{1}{4}$  - SW  $\frac{1}{4}$ , Sec. 10, T 36S, R 19E, Bee Ridge, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 2A (top of section)</u> : Fine to medium quartz sand packed with <i>Carolinapecten eboreus</i> valves. Most valves are unpaired and lie horizontally, but do not show a preference for being either convex- or concave-up. Sediment is light olive gray and well-sorted. Very fossiliferous. Overlain by three feet of spoil.	4'2" (1.27m)
<u>Unit 2B</u> : Fine to very fine, quartz sand and shell. Sediment is light olive gray and well-sorted. Microfossils are fairly common. Mollusc shells are matrix supported. Moderately fossiliferous.	3'6" (1.07m)

Unit 2C (base of section): Very shelly, bioclast-supported, fine to very fine quartz sand. Sediment is light gray and moderately well-sorted. Microfossils are fairly common. Mollusc fossils are very abundant, dominated by *Mercenaria sp.* There is no preferred orientation to the valves. Section measured from the base of Unit 2B to the floor of the pit.

1'1"  
(0.33m)

Locality 3 (Quality Aggregates Pit): Sample collected from a west-facing quarry wall in the eastern part of Phase 6 of the Quality Aggregates Pit, Sarasota County, Florida (SE  $\frac{1}{4}$  - NE  $\frac{1}{4}$ , Sec. 7, T 36S, R 19E, Bee Ridge, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 3A (top of section)</u> : Very shelly, bioclast-supported, fine to medium quartz sand. Sediment is yellowish-gray and moderately well-sorted. Mollusc fossils are extremely abundant and are dominated by <i>Strombus floridanus</i> and <i>Hyotissa hiatensis</i> . This unit sits atop a very dense accumulation of the colonial gastropod <i>Vermicularia recta</i> . Overlain by approximately two feet of spoil.	3'4" (1.02m)
<u>Unit 3B (base of section)</u> : Very shelly, bioclast-supported, fine quartz sand. Sediment is light olive gray and well-sorted. Microfossils are fairly common. <i>Vermicularia recta</i> dominate the upper one to two feet. Mollusc fossils are extremely abundant. Section measured from the base of Unit 3A to the floor of the pit.	4'2" (1.27m)

Locality 4 (Quality Aggregates Pit): Sample collected from a north-facing quarry wall approximately 1/4 mile south of Locality 3 in Phase 6 of Quality Aggregates Pit, Sarasota County, Florida (SW  $\frac{1}{4}$  - NE  $\frac{1}{4}$ , Sec. 7, T 36S, R 19E, Bee Ridge, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 4</u> : Very shelly, bioclast-supported, fine sand. Sediment is pale orange and well-sorted. Mollusc fossils are extremely abundant and are dominated by <i>Crepidula fornicata</i> and <i>Trochita floridana</i> . Large indurated masses up to two feet in diameter occur throughout this unit. Section overlain by approximately two feet of spoil and measured to the floor of the pit.	4'4" (1.32m)

Locality 5 (Wolf Road Pit): Samples collected from an exposure on the south side of a pit located approximately two miles south of State Route 70, one-half mile east of Engine Bay Drive on Wolf Road, Okeechobee County, Florida (NW  $\frac{1}{4}$  - SW  $\frac{1}{4}$ , Sec. 29, T 37S, R 35E, Okeechobee, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 5A (top of section)</u> : Very shelly, bioclast-supported, slightly indurated, fine quartz sand. Sediment is very pale orange and well-sorted. Very fossiliferous, dominated by <i>Chione cancellata</i> and <i>Bulla striata</i> .	1'10" (0.56m)
<u>Unit 5B</u> : Fine quartz sand and shell. Sediment is yellowish gray and well-sorted. Mollusc shells are matrix-supported. Moderately fossiliferous.	1'8" (0.51m)
<u>Unit 5C (base of section)</u> : Very shelly, bioclast-supported, fine quartz sand. Sediment is very pale orange and well-sorted. Very fossiliferous, dominated by <i>Chione cancellata</i> . Fossil material is slightly chalky and less well-preserved than Units 5A or 5B. Section measured from the base of Unit 5B to the floor of the pit.	1'4" (0.41m)

Locality 6 (Dean's Pit): Samples collected from a south-facing exposure on the north side of a pit located 3.5 miles east of Highway 41 at Laurel on Laurel Road, and 1.26 miles north on a dirt road, Sarasota County, Florida (NE  $\frac{1}{4}$  - NW  $\frac{1}{4}$ , Sec. 22, T 38S, R 19E, Laurel, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 6A (top of section)</u> : Very shelly, bioclast-supported, medium to fine quartz sand. Sediment is yellow gray and moderately well-sorted. A few lenses of dark brown, fine sand occur in the upper foot of the section. Very fossiliferous, dominated by <i>Chione cancellata</i> . Overlain by one foot of dark gray, non-fossiliferous, fine sand.	4'6" (1.37m)
<u>Unit 6B (base of section)</u> : Very shelly, bioclast-supported, fine quartz sand. Sediment is light olive gray and moderately well-sorted. Very fossiliferous, dominated by <i>Chione cancellata</i> . Section measured from a notch in the quarry wall that may represent a former water level, to the present water level.	3'4" (1.02m)

Locality 7 (Taylor Ranch Pit): Samples collected from a south-facing exposure on the north side of a pit located on Taylor Ranch, 2.9 miles west of Myakka River on Highway 41, Sarasota County, Florida (NW  $\frac{1}{4}$  - SE  $\frac{1}{4}$ , Sec. 31, T 39S, R 20E, Myakka River, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 7A (top of section)</u> : Very shelly, bioclast-supported, fine quartz sand. Sediment is yellowish-gray and moderately well-sorted. Very fossiliferous, dominated by <i>Chione cancellata</i> . Overlain by two feet of buff, non-fossiliferous, fine sand.	1'6" (0.46m)
<u>Unit 7B</u> : Very shelly, bioclast-supported, fine to medium quartz sand. Sediment is yellowish-gray and moderately well sorted. Very fossiliferous, dominated by <i>Mercenaria campechiensis</i> . Valves are unpaired with no preferred orientation.	1'2" (0.36m)

Unit 7C: Very shelly, bioclast-supported, compact, fine to medium quartz sand. Sediment is yellowish-gray and moderately well-sorted. Very fossiliferous, dominated by *Chione cancellata*. Section measured from the base of Unit 7B to the top of a moderately indurated, sparsely fossiliferous to nonfossiliferous sand. 4'0" (1.22m)

Locality 8 (Carleton 2x4 Ranch #1): Sample collected from a spoil pile adjacent to an abandoned quarry on the Carleton 2x4 Ranch, approximately three miles east of State Route 31, 3.75 miles southeast of Arcadia, De Soto County, Florida (SW  $\frac{1}{4}$  - SW  $\frac{1}{4}$ , Sec. 13, T 38S, R 25E, Arcadia, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 8</u> : Very shelly, fine quartz sand. Sediment is yellowish-gray and moderately well-sorted. Very fossiliferous, <i>Arca wagneriana</i> is fairly common.	N/A

Locality 9 (Carleton 2x4 Ranch #2): Sample collected by a hand auger in a dry canal approximately one mile southwest of Locality 8 on Carleton 2x4 Ranch, De Soto County, Florida (SW  $\frac{1}{4}$  - SW  $\frac{1}{4}$ , Sec. 23, T 38S, R 25E, Arcadia, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 9</u> : Very shelly, fine quartz sand. Sediment is yellowish-gray and moderately well-sorted. Very fossiliferous, dominated by <i>Chione cancellata</i> . Shell first encountered 3'4" below the surface and most likely continued below the sampling depth of 5'. Unit 9 overlain by a fine, yellowish-gray sand.	1'8" (0.51m)

Locality 10 (Stinson Pit): Samples collected from a small pit approximately 2.75 miles west of the intersection of State Routes 31 and 763, De Soto County, Florida (SW  $\frac{1}{4}$  - SE  $\frac{1}{4}$ , Sec. 29, T 39S, R 25E, Arcadia SE, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
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Unit 10A (top of section): Very shelly, 3'4"  
 bioclast-supported, fine quartz sand. (1.02m)  
 Sediment is yellowish-brown and well-sorted.  
 Very fossiliferous. Overlain by four feet of  
 spoil.

Unit 10B (base of section): Very shelly, 2'11"  
 bioclast-supported, slightly indurated, fine (0.89m)  
 quartz sand. Sediment is dark yellowish-brown  
 and moderately well-sorted. Very  
 fossiliferous. Contains fewer large mollusc  
 shells than Unit 10A. Section measured from  
 the base of Unit 10A to the floor of the pit.

Locality 11 (Davis Pit): Samples collected from a small pit  
 approximately one mile west of the intersection of State  
 Routes 31 and 763, De Soto County, Florida (NE  $\frac{1}{4}$  - SW  $\frac{1}{4}$ ,  
 Sec. 27, T 39S, R 25E, Arcadia SE, Florida 7.5-minute  
 quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 11A (top of section):</u> Very shelly, bioclast-supported, fine quartz sand. Sediment is yellowish-gray and well-sorted. Very fossiliferous, dominated by <i>Chione</i> <i>cancellata</i> . Microfossils fairly common. Overlain by six to eight feet of nonfossiliferous sand.	2'9" (0.84m)
<u>Unit 11B (base of section):</u> Fine quartz sand and shell. Sediment is light gray and well- sorted. Moderately fossiliferous, containing mostly small mollusc shells and shell fragments. Mollusc shells are matrix supported. Preservation of fossil material is exceptional. Section measured from the base of Unit 11A to the floor of the pit.	1'10" (0.56m)

Locality 14 (Cochran Pit): Sample collected from spoil  
 adjacent to an abandoned quarry approximately two miles  
 south of Denaud along State Route 80, Hendry County, Florida  
 (NW  $\frac{1}{4}$  - NE  $\frac{1}{4}$ , Sec. 27, T 43S, R 28E, Alva, Florida 7.5-  
 minute quadrangle).

<u>Description</u>	<u>Thickness</u>
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Unit 14: Moderately shelly, slightly muddy, N/A  
 fine quartz sand. Sediment is very light gray  
 and moderately well-sorted. Moderately  
 fossiliferous.

Locality 15 (Highway 80 Pit): Sample collected from spoil adjacent to an abandoned quarry approximately 11 miles east of La Belle along State Route 80, Glades County, Florida (SE  $\frac{1}{4}$  - SE  $\frac{1}{4}$ , Sec. 31, T 42S, R 31E, Goodno, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 15:</u> Moderately shelly, fine quartz sand. Sediment is very light gray and moderately well-sorted. Moderately fossiliferous.	N/A

Locality 16 (Punta Gorda Pit): Sample collected from the eastern wall of a newly excavated quarry approximately 0.7 miles northwest of the intersection of Interstate 75 and State Route 768 on State Route 765, Charlotte County, Florida (SW  $\frac{1}{4}$  - SW  $\frac{1}{4}$ , Sec. 16, T 41S, R 23E, Punta Gorda, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 16:</u> Very shelly, bioclast-supported, fine quartz sand. Sediment is very light gray and moderately well-sorted. Very fossiliferous, dominated by <i>Chione cancellata</i> and <i>Mulinia lateralis</i> . Section measured from ground-level to the base of the pit.	1'6" (0.46m)

Locality 17 (Forseberg Pit): Sample collected from the eastern wall of a recently abandoned quarry approximately 2.7 miles north of James Loop on Piper Road, Charlotte County, Florida (SW  $\frac{1}{4}$  - NW  $\frac{1}{4}$ , Sec. 10, T 41S, R 23E, Punta Gorda, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 17A</u> : Very shelly, bioclast-supported, fine quartz sand. Sediment is yellowish orange and well-sorted. Very fossiliferous, dominated by <i>Chione cancellata</i> . Fossil material is chalky and not very well preserved. Section measured from ground-level to the top of a sparsely fossiliferous, well-indurated, fine sand.	1'4" (0.41m)

Locality 18 (Leisey Shell Pit): Samples collected from Phase 3 of the Leisey Shell Pit approximately two miles west of Highway 41 at Gulf City, Hillsborough County, Florida (SE  $\frac{1}{4}$  - NE  $\frac{1}{4}$ , Sec. 15, T 32S, R 18E, Ruskin, Florida 7.5-minute quadrangle).

<u>Description</u>	<u>Thickness</u>
<u>Unit 18A (top of section)</u> : Very shelly, bioclast-supported, fine quartz sand. Sediment is yellowish-gray and well-sorted. Very fossiliferous, dominated by <i>Carditamera arata</i> and <i>Anadara transversa</i> .	4'2" (1.27m)
<u>Unit 18B</u> : Very shelly, bioclast-supported, slightly muddy, fine quartz sand. Sediment is grayish-brown and moderately well-sorted. Moderately fossiliferous, dominated by <i>Anadara transversa</i> and <i>Carditamera arata</i> . Microfossils are common. Many shells are bored and encrusted with bryozoa.	4'2" (1.27m)
<u>Unit 18C (base of section)</u> : Very shelly, fine quartz sand. Sediment is light olive gray and well-sorted. Very fossiliferous, dominated by paired valves of <i>Raeta plicatella</i> . Fossil material is very well-preserved. Section measured from the base of Unit 18B to the floor of the pit.	1'0" (0.30m)

Appendix B: Abundance matrix of species versus collection. Bivalves are counted such that a single valve represents one individual.

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Nucula proxima</i> Say	2	5	1			2								3	1
<i>Adrana</i> sp. A							6								
<i>Nuculana acuta</i> (Conrad)	16	26	24	56	10	15								1	1
<i>Anadara lienosa</i> (Say)	7	2	4	5	7	3	16								
<i>Anadara petersburgensis</i> (Olsson & Harbison)	2					6									
<i>Anadara propatula</i> (Conrad)						10									
<i>Anadara rustica</i> (Tuomey & Holmes)															
<i>Anadara scalarina</i> (Heilprin)	1	9	2	4	7	6	4								
<i>Anadara transversa</i> (Say)	23	67	20	20	112	47	3	60	1	81	14	21	131	41	75
<i>Anadara</i> sp. A						3									
<i>Anadara</i> sp. B															
<i>Arca irregularis</i> Dall	1														
<i>Arca wagneriana</i> Dall		2			4										
<i>Arca</i> sp. A															
<i>Arca</i> sp. B															
<i>Arca</i> sp. C	2				2										
<i>Arcopsis adamsi</i> (Dall)	10		2	5	12	7									
<i>Barbatia tenera</i> (C.B. Adams)															
<i>Barbatia taeniata</i> Dall	2	8				1									
<i>Barbatia</i> sp. A															
<i>Noetia ponderosa</i> (Say)															
<i>Noetia</i> sp. A						5									
<i>Glycymeris pectinata</i> (Gmelin)	2				7	2					4	8	1		3
<i>Glycymeris americana</i> (DeFrance)						2									
<i>Brachidontes exustus</i> (Linnaeus)							2				1		8		
<i>Modiolus modiolus</i> (Linnaeus)															
<i>Musculus lateralis</i> (Say)							2								
<i>Perna conradina</i> d'Orbigny	2	29	1	50		3	32								
<i>Mytilus</i> sp. A															
<i>Pteria colymbus</i> (Roding)		3				1									
<i>Aequipecten</i> sp. A															
<i>Amusium mortoni</i> (Ravenel)		2			3										

Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Argopecten comparalis</i> (Tuomey & Holmes)	25					33									
<i>Argopecten irradians</i> (Lamarck)								1					7		2
<i>Carolinapeecten eboreus</i> (Conrad)	4	38		7	41	9	4								
<i>Carolinapeecten eboreus solaroides</i> (Heilprin)															
<i>Plicatula marginata</i> Say	6	4	2	7	32	35	7	10					5		1
<i>Spondylus</i> sp. A					1										
<i>Anomia simplex</i> d'Orbigny	12	13	29	10		124		2					37		
<i>Plicunanomia plicata</i> Tuomey & Holmes						1									
<i>Lima</i> sp. A															
<i>Lima</i> sp. B					1										
<i>Conradostrea sculpturata</i> (Conrad)	56	9	3	6	18	23	4								
<i>Crassostrea virginica</i> (Gmelin)															
<i>Hytissa hiatensis</i> (Sowerby)	8		1		12										
<i>Ostrea</i> sp. A							4								
<i>Ostrea</i> sp. B		72	12	23											
<i>Ostreola equestris</i> (Say)								2							
<i>Anodontia alba</i> Link	25	74	8	1	3	31							2		
<i>Cavilinga trisulcata</i> (Conrad)	28	2	1		17	38	95								
<i>Codakia orbicularis</i> (Linnaeus)	6					6									
<i>Divaricella quadrisulcata</i> (Orbigny)	1				5	3									
<i>Linga amiantus</i> Dall	21	62	47	26	27	14	49						6	16	11
<i>Linga pennsylvanica</i> (Linnaeus)					6										1
<i>Lucina amabilis</i> (Dall)															
<i>Lucina nassula</i> (Conrad)						4	9			4	11	3	16	20	6
<i>Lucina radians</i> (Conrad)	3					1									
<i>Lucina</i> sp. A							1								
<i>Parvilucina multilineata</i> (Tuomey & Holmes)	37	357	139	123	52	56	449	419	51	332	44	78	85	58	30
<i>Pseudomiltha floridana</i> (Conrad)						4	177	11	2	12			12	1	2
<i>Cooperella</i> sp. A							6								
<i>Diplodonta acclinis</i> (Conrad)						2	8								
<i>Diplodonta</i> sp. A	4	20	8	2	9	1	1		1				2	2	1
<i>Diplodonta</i> sp. B															

Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Arcinella cornuta</i> Conrad						2				3					
<i>Chama congregata</i> Conrad	22	4	5	3	4	28									
<i>Chama macerophyla</i> (Gmelin)	33			9	3										
<i>Mysella</i> sp. A							3								
<i>Neaeromya floridana</i> (Dall)													11	4	2
<i>Sportella</i> sp. A														4	2
<i>Sportella</i> sp. B	5			3	1	4									
<i>Aligena striata</i> Lea															
<i>Aligena</i> sp. A							6								
<i>Aligena</i> sp. B							8								
<i>Bornia triangula</i> Dall							9								
<i>Erycina carolinensis</i> Dall	2				2	2									
<i>Erycina phaseola</i> Olsson & Harbison							1								
<i>Carditamera arata</i> (Conrad)	4	4	5	16	5	9	52	5		12	8	1	6	2	30
<i>Carditamera catharia</i> Dall							6								
<i>Cyclocardia</i> sp. A						4									
<i>Pleuromeris tridentata</i> (Say)	3	25	11	10	34	3	54				1	5			2
<i>Pteromeris perplana</i> (Conrad)	3				7										
<i>Astarte perplana</i> Conrad							2								
<i>Astarte</i> sp. A															
<i>Crassinella lunulata</i> (Conrad)		1			1	2								1	
<i>Eucrassatella speciosa</i> (A. Adams)		1			1										
<i>Eucrassatella undulata</i> (Tuomey & Holmes)						17									
<i>Americardia guppyi</i> Thiele							8				1		1	1	2
<i>Dinocardium robustum</i> (Lightfoot)							1			1	1				
<i>Laevicardium laevigatum</i> (Linnaeus)	2	3	2		11	6	11								
<i>Laevicardium mortoni</i> (Conrad)								400	61	55	10	20	9	3	3
<i>Trachycardium egmontianum</i> (Shuttleworth)								9			1		8		2
<i>Trachycardium evergaldeensis</i> Mansfield					1	1									
<i>Trachycardium muricatum</i> (Linnaeus)			7	12	3	2	11								
<i>Trigoniocardia willcoxi</i> (Dall)	2	94	27	18	14	2	3								

Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Macra undula</i> Dall				1			9						1		
<i>Mulinia lateralis</i> (Say)	5	102	6	3		205				39	192	349	43	7	216
<i>Mulinia sapotilla</i> Dall		7	12	65			12								
<i>Mulinia</i> sp. A							147								
<i>Raeta plicatella</i> (Lamarck)															
<i>Rangia cuneata</i> (Sowerby)															
<i>Ensis minor</i> Dall															
<i>Cymatoica</i> sp. A		1	3			1									
<i>Cymatoica</i> sp. B															
<i>Tellidora cristata</i> (Recluz)		6	2		3		2					1	17	3	
<i>Tellina aequistriata</i> Say											1				
<i>Tellina agilis</i> Stimpson	1	64	7	10	12	7	76	10	3		10	10		12	3
<i>Tellina alternata</i> Say		15	2			1								1	
<i>Tellina calliglypta</i> Dall															
<i>Tellina dinomera</i> Dall							2								
<i>Tellina</i> sp. B							2	3	7				4	4	
<i>Tellina</i> sp. C							3								
<i>Tellina</i> sp. D		2				1	1								
<i>Tellina</i> sp. E						1									
<i>Tellina</i> sp. F									3						
<i>Tellina</i> sp. G							1								
<i>Tellina</i> sp. H							1								
<i>Tellina</i> sp. J															
<i>Donax</i> sp. A															
<i>Abra aequalis</i> (Say)		71	10	1			2					1			1
<i>Cumingia coarctata</i> Sowerby				2											
<i>Cumingia tellinoides</i> (Conrad)															
<i>Semele bellastriata</i> (Conrad)	7				1	4									
<i>Semele proficua</i> (Pulteney)				3											
<i>Semele</i> sp. A	2				2	2	13								
<i>Semele</i> sp. B						1									
<i>Tagelus divisus</i> (Spengler)		2	1				7				1	6	2	26	

Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Tagelus plebius</i> (Lightfoot)							12								
<i>Anomalocardia auferiana</i> (Orbigny)													28	40	
<i>Anomalocardia caloosana</i> (Dall)							2	736	388	63	184	140			
<i>Chione cancellata</i> (Linnaeus)	22	9	13	18	18	114	34	1468	50	1482	1640	427	861	246	1397
<i>Chione grus</i> (Holmes)	9	6	1	1		17									1
<i>Chione latilirata</i> (Conrad)	16	8	13	9	13	43									
<i>Chione procancellata</i> Mansfield		2													
<i>Chione ulocyma leonensis</i> Mansfield	11					117									
<i>Cyclinella tenuis</i> (Recluz)	1	5	3	14	2	1									
<i>Dosinia elegans</i> Conrad	4		1	3	2	1	22	4			19	3		2	
<i>Gemma magna</i> Dall		2		2	1	1	13								
<i>Gemma</i> sp. A															
<i>Gouldia cerina</i> (C.B. Adams)	6		1			2									
<i>Macrocallista maculata</i> (Linnaeus)	2				1	4	3								
<i>Macrocallista nimbose</i> (Lightfoot)						2	44		1	61	76	30	4	1	3
<i>Mercenaria campechiensis</i> (Gmelin)	12	6	2	33	10	35	2	2		3	3			14	
<i>Mercenaria tridacnoides</i> (Lamarck)	1					6									
<i>Pitar sayana</i> (Conrad)	2					9									
<i>Pitar simpsoni</i> (Dall)				9				38	6			1	53	4	4
<i>Transenella conradina</i> Dall		13	26	8	86	17	203	1276	262	137	824	1603	717	200	120
<i>Pleiorytis</i> sp. A															
<i>Bothrocorbula willcoxi</i> (Dall)															
<i>Caryocorbula leonensis</i> Mansfield	19	8	20	18	19	12									
<i>Corbula</i> sp. A															
<i>Corbula</i> sp. B	5	59	25	18	43	14									
<i>Corbula</i> sp. C				7	6										
<i>Corbula</i> sp. D															
<i>Corbula</i> sp. E											9	4		8	7
<i>Juliacorbula scutata</i> (Gardner)															
<i>Varicorbula caloosae</i> (Dall)	286			2	12	719	1								
<i>Gastrochaena hians</i> (Gmelin)				4	1										
<i>Gastrochaena</i> sp. A					3										



Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Hiatella arctica</i> (Linnaeus)		19													
<i>Pandora</i> sp. A		2	3		2		2								
<i>Cuspidaria</i> sp. A		2	1												
<i>Diodora cayenensis</i> (Lamarck)		1	2	1			7						1	1	
<i>Diodora nucula</i> (Dall)					2										
<i>Diodora sayi</i> (Dall)															
<i>Diodora</i> sp. A	1														
<i>Emarginula</i> sp. A															
<i>Lucapinella talentia</i> Olsson & Harbison							2								
<i>Lucapinella</i> sp. A															
<i>Modulus carchedonius</i> (Lamarck)		1													
<i>Modulus modulus</i> (Linnaeus)								1		1			5		
<i>Calliostoma willcoxianum</i> Dall					1										
<i>Tegula fasciata</i> (Born)	1	1		1	2	1									
<i>Margarites</i> sp. A															
<i>Margarites</i> sp. B															
<i>Turbo rhexogrammicus</i> Dall															
<i>Astraea precursor</i> (Dall)															
<i>Gelasinostoma elegantula</i> (Dall)															
<i>Phenacolepas hamillei</i> (Fischer)					1										
<i>Cochliolepus striata</i> Dall															
<i>Architectonica nobilis</i> Roding							2								
<i>Turritella apicalis</i> Heilprin	5	23		9	9	6	50								
<i>Turritella perattenuata</i> Heilprin															
<i>Turritella pontoni</i> Mansfield							2								
<i>Turritella subannulata</i> Heilprin															
<i>Turritella</i> sp. A															
<i>Turritella</i> sp. E	2					1									
<i>Turritella</i> sp. F					9										
<i>Vermicularia recta</i> Olsson & Harbison	10				10	10									
<i>Cerithidea</i> sp. A															
<i>Cerithium atratum</i> (Born)													6		1

Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Cerithium caloosaense</i> Dall						3									
<i>Cerithium coccodes</i> Dall															
<i>Cerithium litharium</i> Dall							1								
<i>Cerithium muscarum</i> Say							5	2	3	1	4	6	44	6	7
<i>Cerithium preatratum</i> (Olsson & Harbison)					1		3								
<i>Cerithium vicinia</i> Olsson & Harbison															
<i>Cerithium</i> sp. A															
<i>Rhinoclavis caloosaensis</i> (Dall)					5		2								
<i>Seila adamsi</i> (H.C. Lea)															
<i>Epitonium</i> sp. A															
<i>Epitonium</i> sp. B							3								
<i>Niso willcoxiana</i> Dall															
<i>Strombus alatus</i> Gmelin										1					
<i>Strombus floridanus</i> (Mansfield)	1	8			25	6	6								
<i>Calyptraea centralis</i> (Conrad)		6		1	6		52								
<i>Chelia</i> sp. A															
<i>Crepidula aculeata</i> (Gmelin)	2					4	87								
<i>Crepidula fornicata</i> (Linnaeus)	1	50		7	12	14	1377	20	2	1	27	34	30	18	10
<i>Crepidula plana</i> Say					6		20	1		1	9	6	9	8	2
<i>Crepidula</i> sp. A						1									
<i>Crucibulum imbricatum</i> (Sowerby)				3	1										
<i>Crucibulum multilineatum</i> (Conrad)	1	3	1		2	9									
<i>Crucibulum ramosum</i> (Conrad)															
<i>Crucibulum striatum</i> Say		22		2	12		39								
<i>Trochita floridana</i> Olsson & Petit							156								
<i>Xenophora conchyliophora</i> (Born)															
<i>Erato maugeriae</i> Gray															
<i>Trivia pediculus</i> (Linnaeus)															
<i>Trivia quadripunctata</i> (Gray)															
<i>Siphocypraea carolinensis transitoria</i> Olsson & Petit															1
<i>Natica plicatella</i> Conrad	1	3			5	3	5								
<i>Polinices duplicatus</i> Say	1				3		4				1	2			

Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Sinum perspectivum</i> (Say)							1								
<i>Eupleura caudata</i> (Say)		3													
<i>Eupleura</i> sp. B															
<i>Murex selleanus</i> A. Adams		3			1										
<i>Pterorhysis conradi</i> Dall							6								
<i>Trophon lepidota</i> (Dall)		5			1		2								
<i>Typhis floridanus</i> Dall							3								
<i>Urosalpinx perrugata</i> (Conrad)						1		4				1	6	4	
<i>Urosalpinx subsidus</i> Dall							3								
<i>Urosalpinx</i> sp. A							2								
<i>Urosalpinx</i> sp. D															
<i>Cantharus floridanus</i> (Conrad)					1		6						3		
<i>Cantharus mengeana</i> Dall		2					3								
<i>Cantharus multangulus</i> (Philippi)															
<i>Cantharus</i> sp. A		4													
<i>Anachis camax</i> Dall		2					18								
<i>Anachis</i> sp. A		3			1										
<i>Anachis</i> sp. B															
<i>Anachis</i> sp. C											5	13			
<i>Mitrella lunata</i> (Say)					1		1								
<i>Strombina gunteri</i> Mansfield		64		1	6	3	7								
<i>Busycon contrarium</i> (Conrad)							3			1	4	2	1	1	
<i>Busycon echinatum</i> (Dall)							2								
<i>Busycon spiratum pyruloides</i> (Conrad)					1		3			1		3			
<i>Busycon spiratum plagosum</i> (Conrad)					1		2								
<i>Busycon</i> sp. B															
<i>Busycon</i> sp. C							1								
<i>Melongena corona</i> (Gmelin)										5	2	1	3	1	
<i>Melongena</i> sp. A							2								
<i>Nassarius albus</i> (Say)															
<i>Nassarius antillarum</i> (d'Orbigny)															
<i>Nassarius bidentatus</i> (Emmons)							27								

Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
<i>Nassarius locklini</i> Olsson & Harbison		25			5	8	14								
<i>Nassarius rasta</i> Olsson & Harbison												1			
<i>Nassarius vibex</i> (Say)		1					85	38	9	7	39	57	17	7	
<i>Fasciolaria apicna</i> Dall						1									
<i>Fasciolaria distans</i> Linnaeus							1						2		
<i>Fusinus caloosaensis</i> Heilprin					3	3									
<i>Pleuroploca gigantea</i> (Kiener)	2				1	2	3								
<i>Oliva sayana</i> Ravenel	1	3			11		10			1					
<i>Oliva</i> sp. A						5									
<i>Olivella dealbata</i> (Reeve)															
<i>Olivella mutica</i> (Say)					8		149	25	3		5	4	3	2	
<i>Olivella pugilis</i> Olsson & Harbison							52								
<i>Xancus regina</i> (Heilprin)		1					2								
<i>Cancellaria reticulata</i> (Linnaeus)						1									
<i>Cancellaria rotunda</i> Dall		3			1		2								
<i>Cancellaria</i> sp. A		3													
<i>Trigonostoma</i> sp. A															
<i>Marginella apicna</i> Menke	1	3			7	7	94	18	3	15	17	27	25	9	4
<i>Marginella belloides</i> Olsson & Harbison							2								
<i>Marginella eulima</i> Dall					4		12								
<i>Marginella polyspira</i> Olsson & Harbison							3								
<i>Marginella precursor</i> Dall															
<i>Marginella succinea</i> Conrad															
<i>Marginella</i> sp. A															
<i>Persicula ovula</i> Conrad		1					9								
<i>Mitra heilprini</i> Cossman							16								
<i>Mitra silicata</i> Dall		1													
<i>Brachycythara</i> sp. A															
<i>Cerodrilla thea</i> (Dall)															
<i>Cerodrilla</i> sp. A															
<i>Cymatocyrix lunata</i> (Lea)					5		1								
<i>Drillia ebinina</i> Dall							2								

Appendix B (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C
"Drillia" sp. A							3								
"Drillia" sp. B							2								
Ithythythara sp. A	1					1									
Sedilia sp. A															
Conus adversarius (Conrad)					2										
Conus daucus Hwass					1										
Conus floridanus Gabb		2			3		1				1				
Conus spurius Gmelin							1								
Conus spuroides Olsson & Harbison							1								
Conus sternsii Conrad					1		9					2	16	9	4
Conus sp. A					1		1								
Terebra concava Say		5					2								
Terebra dislocata (Say)					3	3	16				4	4		1	
Terebra sp. A							12	2	2				3	1	
Terebra sp. B													1		
Pyramidella crenulata (Holmes)					1			2	1			8	14	5	2
Acteocina candei (Orbigny)						1									
Bulla occidentalis Adams							1								
Bulla striata Bruguiere	1	1		1		1	7	60			2	1	117	6	9
Atys riiseana Morch															
Viviparus georgianus (Lea)				1											
Helisoma conanti (Dall)															
Helisoma disstoni (Dall)					1										
Planorbula sp. A															

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
<i>Nucula proxima</i> Say								2					
<i>Adrana</i> sp. A													
<i>Nuculana acuta</i> (Conrad)	1						4				25	4	
<i>Anadara lienosa</i> (Say)	3	23	4	10	4						2		
<i>Anadara petersburgensis</i> (Olsson & Harbison)													
<i>Anadara propatula</i> (Conrad)													
<i>Anadara rustica</i> (Tuomey & Holmes)							2						
<i>Anadara scalarina</i> (Heilprin)													
<i>Anadara transversa</i> (Say)	28	1	96	27	19	1	1	5	69	29	147	589	161
<i>Anadara</i> sp. A													
<i>Anadara</i> sp. B	4												
<i>Arca irregularis</i> Dall				2									
<i>Arca wagneriana</i> Dall	9							2					
<i>Arca</i> sp. A				1									
<i>Arca</i> sp. B				1									
<i>Arca</i> sp. C													
<i>Arcopsis adamsi</i> (Dall)	45		62	4	15	3	11	7			28	36	
<i>Barbatia tenera</i> (C.B. Adams)												2	
<i>Barbatia taeniata</i> Dall	2												
<i>Barbatia</i> sp. A			1										
<i>Noetia ponderosa</i> (Say)	1		5							4	11	38	
<i>Noetia</i> sp. A													
<i>Glycymeris pectinata</i> (Gmelin)	1		10	2	1		8		3	1	20	84	
<i>Glycymeris americana</i> (DeFrance)													
<i>Brachidontes exustus</i> (Linnaeus)	2		21	7	219	151					5	5	135
<i>Modiolus modiolus</i> (Linnaeus)			1										
<i>Musculus lateralis</i> (Say)													
<i>Perna conradina</i> d'Orbigny													
<i>Mytilus</i> sp. A							1						
<i>Pteria colymbus</i> (Roding)													
<i>Aequipecten</i> sp. A													2
<i>Amusium mortoni</i> (Ravenel)													

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
<i>Argopecten comparalis</i> (Tuomey & Holmes)													
<i>Argopecten irradians</i> (Lamarck)	6		1	19			2				64	16	8
<i>Carolinapecten eboreus</i> (Conrad)													
<i>Carolinapecten eboreus solaroides</i> (Heilprin)												1	2
<i>Plicatula marginata</i> Say	8		19	63			3	1	3		11	10	1
<i>Spondylus</i> sp. A													
<i>Anomia simplex</i> d'Orbigny	12			8	14		3	1	23		7	7	43
<i>Plicunanomia plicata</i> Tuomey & Holmes													
<i>Lima</i> sp. A											1	2	
<i>Lima</i> sp. B													
<i>Conradostrea sculpturata</i> (Conrad)	9				22						99	193	68
<i>Crassostrea virginica</i> (Gmelin)			18										
<i>Hytissa hiatensis</i> (Sowerby)													
<i>Ostrea</i> sp. A													
<i>Ostrea</i> sp. B													
<i>Ostreola equestris</i> (Say)			14	4					6				
<i>Anodontia alba</i> Link	2		1	2			4						
<i>Cavilinga trisulcata</i> (Conrad)		1			1	2	1	1	3				
<i>Codakia orbicularis</i> (Linnaeus)												3	
<i>Divaricella quadrisulcata</i> (Orbigny)					2	5	2						
<i>Linga amiantus</i> Dall	16	14	26	13	4	1	6	10		2	1	1	2
<i>Linga pennsylvanica</i> (Linnaeus)			2										
<i>Lucina amabilis</i> (Dall)							2						
<i>Lucina nassula</i> (Conrad)	17	8	18	25	19			2	3	7	33		26
<i>Lucina radians</i> (Conrad)				2									
<i>Lucina</i> sp. A	1												
<i>Parvilucina multilineata</i> (Tuomey & Holmes)	24	174	60	2	273	218	13	7	114	31	10	2	45
<i>Pseudomiltha floridana</i> (Conrad)	2		9	2	1	3			1	5			
<i>Cooperella</i> sp. A													
<i>Diplodonta acclinis</i> (Conrad)													
<i>Diplodonta</i> sp. A			4						8		4		27
<i>Diplodonta</i> sp. B						2							

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
Arcinella cornuta Conrad	14	10	27	82	4			2			1		
Chama congregata Conrad	27	2	41	17	4	2	5				28	36	
Chama macerophylla (Gmelin)	5												
Mysella sp. A													
Neaeromya floridana (Dall)	1		1			2			2		2		5
Sportella sp. A			2										
Sportella sp. B													
Aligena striata Lea													7
Aligena sp. A													
Aligena sp. B													
Bornia triangula Dall													
Erycina carolinensis Dall	1			1									
Erycina phaseola Olsson & Harbison													
Carditamera arata (Conrad)	4	18	23	46	9	6	8	6	4	4	581	270	6
Carditamera catharia Dall							1						
Cyclocardia sp. A													
Pleuromeris tridentata (Say)	1	1		1			2	1			91	268	1
Pteromeris perplana (Conrad)											32	83	
Astarte perplana Conrad													
Astarte sp. A			1										
Crassinella lunulata (Conrad)											24	76	4
Eucrassatella speciosa (A. Adams)			7		2							2	
Eucrassatella undulata (Tuomey & Holmes)													
Americardia guppyi Thiele			1		2								2
Dinocardium robustum (Lightfoot)			2										2
Laevicardium laevigatum (Linnaeus)			1	4			15	9			2	3	
Laevicardium mortoni (Conrad)													
Trachycardium egmontianum (Shuttleworth)	1		5	14	5			1			10	6	2
Trachycardium evergaldeensis Mansfield													
Trachycardium muricatum (Linnaeus)	3						1						
Trigoniocardia willcoxi (Dall)	38						19						



Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
<i>Mactra undula</i> Dall							1						
<i>Mulinia lateralis</i> (Say)			47						1490	324	8	21	58
<i>Mulinia sapotilla</i> Dall							180						
<i>Mulinia</i> sp. A													
<i>Raeta plicatella</i> (Lamarck)												2	138
<i>Rangia cuneata</i> (Sowerby)							17	2					
<i>Ensis minor</i> Dall													2
<i>Cymatoica</i> sp. A													
<i>Cymatoica</i> sp. B					1								
<i>Tellidora cristata</i> (Recluz)			1	2	1		1	1	1		4		6
<i>Tellina aequistriata</i> Say			1						2		3	1	
<i>Tellina agilis</i> Stimpson	9		23	2	9	14	11	3	26		4	1	11
<i>Tellina alternata</i> Say	2			2			1						5
<i>Tellina calliglypta</i> Dall			1				3						
<i>Tellina dinomera</i> Dall							3						
<i>Tellina</i> sp. B				1		18							
<i>Tellina</i> sp. C													
<i>Tellina</i> sp. D													
<i>Tellina</i> sp. E													
<i>Tellina</i> sp. F													
<i>Tellina</i> sp. G													
<i>Tellina</i> sp. H													
<i>Tellina</i> sp. J									2				
<i>Donax</i> sp. A								3					
<i>Abra aequalis</i> (Say)	18		8		7		7				8	3	5
<i>Cumingia coarctata</i> Sowerby													
<i>Cumingia tellinoides</i> (Conrad)	1				1				3		5		3
<i>Semele bellastriata</i> (Conrad)	1				1		2						
<i>Semela proficua</i> (Pulteney)													
<i>Semele</i> sp. A		6		5			3						
<i>Semele</i> sp. B													
<i>Tagelus divisus</i> (Spengler)			62		2	3	4		2		5	1	9

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
<i>Tagelus plebius</i> (Lightfoot)				1									
<i>Anomalocardia auberiana</i> (Orbigny)													
<i>Anomalocardia caloosana</i> (Dall)	72	2	112	202	60	90	108	62		1			18
<i>Chione cancellata</i> (Linnaeus)	360	904	496	576	1425	39	87	240	95	519	148	148	81
<i>Chione grus</i> (Holmes)	8		3		1		7				1	4	3
<i>Chione latirata</i> (Conrad)	1		1	1									
<i>Chione procancellata</i> Mansfield													
<i>Chione ulocyma leonensis</i> Mansfield													
<i>Cyclinella tenuis</i> (Recluz)													
<i>Dosinia elegans</i> Conrad			3	2	12				1	12	1		3
<i>Gemma magna</i> Dall													
<i>Gemma</i> sp. A							1						
<i>Gouldia cerina</i> (C.B. Adams)	3		2	7			4				20	32	
<i>Macrocallista maculata</i> (Linnaeus)	3		4	2	1		1	1					
<i>Macrocallista nimbose</i> (Lightfoot)			1	3	3	3		1	4	9			14
<i>Mercenaria campechiensis</i> (Gmelin)			4		5					7	6		
<i>Mercenaria tridacnoides</i> (Lamarck)													
<i>Pitar sayana</i> (Conrad)													
<i>Pitar simpsoni</i> (Dall)		4	3	18			5				30	20	1
<i>Tranzenella conradina</i> Dall	178		316	420	539	984	44	302	2	7			
<i>Pleiorytis</i> sp. A													
<i>Bothrocorbula willcoxi</i> (Dall)	1						2	2					
<i>Caryocorbula leonensis</i> Mansfield	16	1	12	12	5		14	3	5		25	11	
<i>Corbula</i> sp. A			2										
<i>Corbula</i> sp. B													
<i>Corbula</i> sp. C													
<i>Corbula</i> sp. D													
<i>Corbula</i> sp. E										23			
<i>Juliacorbula scutata</i> (Gardner)	12				5							2	
<i>Varicorbula caloosae</i> (Dall)	558	58	40	14	3	9	15	23					
<i>Gastrochaena hians</i> (Gmelin)												10	
<i>Gastrochaena</i> sp. A													

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
<i>Hiatella arctica</i> (Linnaeus)											1	1	
<i>Pandora</i> sp. A													
<i>Cuspidaria</i> sp. A													
<i>Diodora cayenensis</i> (Lamarck)	2	1	2	1	8								1
<i>Diodora nucula</i> (Dall)													
<i>Diodora sayi</i> (Dall)				1									
<i>Diodora</i> sp. A													
<i>Emarginula</i> sp. A				1			1						
<i>Lucapinella talentia</i> Olsson & Harbison													
<i>Lucapinella</i> sp. A				1									
<i>Modulus carchedonius</i> (Lamarck)	1		2	1			2	1					
<i>Modulus modulus</i> (Linnaeus)													
<i>Calliostoma willcoxianum</i> Dall							1						
<i>Tegula fasciata</i> (Born)							1						
<i>Margarites</i> sp. A							1						
<i>Margarites</i> sp. B							1						
<i>Turbo rhexogrammicus</i> Dall		9											
<i>Astraea precursor</i> (Dall)								1					
<i>Gelasinostoma elegantula</i> (Dall)								1					
<i>Phenacolepas hamillei</i> (Fischer)													
<i>Cochliolepus striata</i> Dall			1										3
<i>Architectonica nobilis</i> Roding													
<i>Turritella apicalis</i> Heilprin	9	9					3						
<i>Turritella perattenuata</i> Heilprin	5						14						
<i>Turritella pontoni</i> Mansfield	3						2						
<i>Turritella subannulata</i> Heilprin	5	1	6	3				41				2	1
<i>Turritella</i> sp. A											4	26	
<i>Turritella</i> sp. E													
<i>Turritella</i> sp. F													
<i>Vermicularia recta</i> Olsson & Harbison													
<i>Cerithidea</i> sp. A					1	5							
<i>Cerithium atratum</i> (Born)													

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
<i>Cerithium caloosaense</i> Dall													
<i>Cerithium coccodes</i> Dall				2									
<i>Cerithium litharium</i> Dall	2		8	50			20						
<i>Cerithium muscarum</i> Say								2					
<i>Cerithium preatratum</i> (Olsson & Harbison)													
<i>Cerithium vicinia</i> Olsson & Harbison			1										
<i>Cerithium</i> sp. A				1									
<i>Rhinoclavis caloosaensis</i> (Dall)								1					
<i>Seila adamsi</i> (H.C. Lea)													1
<i>Epitonium</i> sp. A												1	
<i>Epitonium</i> sp. B													
<i>Niso willcoxiana</i> Dall	1												
<i>Strombus alatus</i> Gmelin			2	1									
<i>Strombus floridanus</i> (Mansfield)													
<i>Calyptraea centralis</i> (Conrad)											1		
<i>Chelia</i> sp. A				1									
<i>Crepidula aculeata</i> (Gmelin)	6	1	30	6	46	4	1	1			57	26	74
<i>Crepidula fornicata</i> (Linnaeus)	4		32	8	51	27	6	3	5		30	29	260
<i>Crepidula plana</i> Say	1		9		8			1	5				45
<i>Crepidula</i> sp. A													
<i>Crucibulum imbricatum</i> (Sowerby)													
<i>Crucibulum multilineatum</i> (Conrad)	1												
<i>Crucibulum ramosum</i> (Conrad)													
<i>Crucibulum striatum</i> Say	53	5	47	27	134	13	10	29			20	7	147
<i>Trochita floridana</i> Olsson & Petit													
<i>Xenophora conchyliophora</i> (Born)				3				1					
<i>Erato maugeriae</i> Gray							1						
<i>Trivia pediculus</i> (Linnaeus)				2									
<i>Trivia quadripunctata</i> (Gray)	1			3		2	1				2		3
<i>Siphocypraea carolinensis</i> transitoria Olsson & Petit													
<i>Natica plicatella</i> Conrad	4					1							
<i>Polinices duplicatus</i> Say										6	1		

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
<i>Sinum perspectivum</i> (Say)													
<i>Eupleura caudata</i> (Say)			1	2	3						1		
<i>Eupleura</i> sp. B				1									
<i>Murex selleanus</i> A. Adams		1		1									
<i>Pterorhytis conradi</i> Dall													
<i>Trophon lepidota</i> (Dall)		2											
<i>Typhis floridanus</i> Dall													
<i>Urosalpinx perrugata</i> (Conrad)	1			1	1	2					2	5	9
<i>Urosalpinx subsidus</i> Dall													
<i>Urosalpinx</i> sp. A													
<i>Urosalpinx</i> sp. D											1		
<i>Cantharus floridanus</i> (Conrad)	2	4	1		1								
<i>Cantharus mengeana</i> Dall													
<i>Cantharus multangulus</i> (Philippi)													2
<i>Cantharus</i> sp. A													
<i>Anachis camax</i> Dall			1		1							1	17
<i>Anachis</i> sp. A													
<i>Anachis</i> sp. B								1					
<i>Anachis</i> sp. C													
<i>Mitrella lunata</i> (Say)	2						3						
<i>Strombina gunteri</i> Mansfield													
<i>Busycon contrarium</i> (Conrad)				3		1						3	1
<i>Busycon echinatum</i> (Dall)				1									
<i>Busycon spiratum pyruloides</i> (Conrad)			2					2					
<i>Busycon spiratum plagosum</i> (Conrad)				1			1				1	1	
<i>Busycon</i> sp. B								1					
<i>Busycon</i> sp. C													
<i>Melongena corona</i> (Gmelin)						1	1						
<i>Melongena</i> sp. A													
<i>Nassarius albus</i> (Say)	1		2	1	1	1					1	1	5
<i>Nassarius antillarum</i> (d'Orbigny)				1									
<i>Nassarius bidentatus</i> (Emmons)	1					1		2					

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
<i>Nassarius locklini</i> Olsson & Harbison	4						2	1					
<i>Nassarius rasta</i> Olsson & Harbison													
<i>Nassarius vibex</i> (Say)	2	1	16	2	1	8	2		4		1		6
<i>Fasciolaria apicna</i> Dall			3	1								2	
<i>Fasciolaria distans</i> Linnaeus													
<i>Fusinus caloosaensis</i> Heilprin	1												
<i>Pleuroploca gigantea</i> (Kiener)				1									1
<i>Oliva sayana</i> Ravenel	2		5			1						2	2
<i>Oliva</i> sp. A													
<i>Olivella dealbata</i> (Reeve)											1		
<i>Olivella mutica</i> (Say)	5	17	24	13	29	45	6	4	1		1	1	14
<i>Olivella pugilis</i> Olsson & Harbison													
<i>Xancus regina</i> (Heilprin)	1												
<i>Cancellaria reticulata</i> (Linnaeus)		1					1						
<i>Cancellaria rotunda</i> Dall								1					
<i>Cancellaria</i> sp. A													
<i>Trigonostoma</i> sp. A	1												
<i>Marginella apicna</i> Menke	17	30	25	7	20	28	10	9	2		3	2	4
<i>Marginella belloides</i> Olsson & Harbison		1											
<i>Marginella eulima</i> Dall		7	3	4	2	2	3	2			1	1	1
<i>Marginella polyspira</i> Olsson & Harbison													
<i>Marginella precursor</i> Dall	5	1											
<i>Marginella succinea</i> Conrad	1												
<i>Marginella</i> sp. A	1												
<i>Persicula ovula</i> Conrad	2							1					
<i>Mitra heilprini</i> Cossman	1												
<i>Mitra silicata</i> Dall													
<i>Brachycythara</i> sp. A	1												
<i>Cerodrilla thea</i> (Dall)				2									
<i>Cerodrilla</i> sp. A				1									
<i>Cymatocyrix lunata</i> (Lea)	3							1					
<i>Drillia ebinina</i> Dall													

Appendix B (cont.)

Species	8	9	10A	10B	11A	11B	14	15	16	17A	18A	18B	18C
"Drillia" sp. A													
"Drillia" sp. B													
Ithythythara sp. A													
Sedilia sp. A	3												
Conus adversarius (Conrad)													
Conus daucus Hwass													
Conus floridanus Gabb	5												
Conus spurius Gmelin													
Conus spuroides Olsson & Harbison													
Conus sternsii Conrad	5	3					2	2	1				
Conus sp. A				1									
Terebra concava Say					2							1	1
Terebra dislocata (Say)		4	1		6			1					3
Terebra sp. A					1								
Terebra sp. B													
Pyramidella crenulata (Holmes)			1					1	2				
Acteocina candei (Orbigny)													
Bulla occidentalis Adams													
Bulla striata Bruguiere			2	1	1	2	1	2					
Atys riiseana Morch				1	1	20	2						
Viviparus georgianus (Lea)							22						
Helisoma conanti (Dall)			23		19	169	276						
Helisoma disstoni (Dall)			30		6	31	5						
Planorbula sp. A						4							

Appendix C: Presence (1) - absence (0) matrix of species versus collection with range-through applied. Species that occur in every collection or in only one collection are not included here. Extinct species are shown with an asterisk.

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C	8	9	10A	10B	11A	11B
<i>Nucula proxima</i> Say	1	1	1	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
<i>Nuculana acuta</i> (Conrad)	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
<i>Anadara lienosa</i> (Say)*	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	0
<i>Anadara petersburgensis</i> O&H*	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anadara scalarina</i> (Heilprin)*	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arca irregularis</i> Dall*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Arca wagneriana</i> Dall*	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Arca</i> sp. C	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arcopsis adamsi</i> (Dall)	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
<i>Barbatia taeniata</i> Dall*	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Noetia ponderosa</i> (Say)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
<i>Glycymeris pectinata</i> (Gmelin)	1	0	0	0	1	1	0	0	0	0	1	1	1	0	1	1	0	1	1	1	0
<i>Brachidontes exustus</i> (Linnaeus)	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	1	1	1	1
<i>Perna conradina</i> d'Orbigny*	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pteria colymbus</i> (Roding)	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Amusium mortoni</i> (Ravenel)	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Argopecten comparalis</i> (Tuomey & Holmes)*	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Argopecten irradians</i> (Lamarck)	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	0	1	1	0	0
<i>Carolinapecten eboreus</i> (Conrad)*	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carolinapecten eboreus solaroides</i> (Heilprin)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Plicatula marginata</i> Say*	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	1	0	0
<i>Anomia simplex</i> d'Orbigny	1	1	1	1	0	1	0	1	0	0	0	0	1	0	0	1	0	0	1	1	0
<i>Lima</i> sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conradostrea sculpturata</i> (Conrad)*	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0



Appendix C (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C	8	9	10A	10B	11A	11B	
<i>Hytissa hiatensis</i> (Sowerby) *	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ostrea</i> sp. B	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ostreola equestris</i> (Say)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0
<i>Anodontia alba</i> Link	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	1	0	1	1	0	0	0
<i>Cavilinga trisulcata</i> (Conrad) *	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
<i>Codakia orbicularis</i> (Linnaeus)	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Divaricella quadrisulcata</i> (Orbigny)	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
<i>Linga amiantus</i> Dall	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
<i>Linga pennsylvanica</i> (Linnaeus)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
<i>Lucina nassula</i> (Conrad)	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0
<i>Lucina radians</i> (Conrad)	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Lucina</i> sp. A	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Pseudomiltha floridana</i> (Conrad)	0	0	0	0	0	1	1	1	1	1	0	0	1	1	1	1	0	1	1	1	1	1
<i>Diplodonta acclinis</i> (Conrad) *	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diplodonta</i> sp. A	1	1	1	1	1	1	1	0	1	0	0	0	1	1	1	0	0	1	0	0	0	0
<i>Arcinella cornuta</i> Conrad	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	0
<i>Chama congregata</i> Conrad	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
<i>Chama macerophyla</i> (Gmelin)	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Neaeromya floridana</i> (Dall)	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	1
<i>Sportella</i> sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0
<i>Sportella</i> sp. B	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erycina carolinensis</i> Dall *	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
<i>Carditamera arata</i> (Conrad) *	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Carditamera catharia</i> Dall *	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pleuromeris tridentata</i> (Say)	1	1	1	1	1	1	1	0	0	0	1	1	0	0	1	1	1	0	1	0	0	0
<i>Pteromeris perplana</i> (Conrad)	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Crassinella lunulata</i> (Conrad)	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Eucrassatella speciosa</i> (A. Adams)	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0

Appendix C (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C	8	9	10A	10B	11A	11B
<i>Americardia guppyi</i> Thiele	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0	0	1	0	1	0
<i>Dinocardium robustum</i> (Lightfoot)	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0
<i>Laevicardium laevigatum</i> (Linnaeus)	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0
<i>Laevicardium mortoni</i> (Conrad)	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
<i>Trachycardium egmontianum</i> (Shuttleworth)	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1	0	1	1	1	0
<i>Trachycardium evergladeensis</i> Mansfield *	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trachycardium muricatum</i> (Linnaeus)	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Trigoniocardia willcoxi</i> (Dall) *	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Mactra undula</i> Dall	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Mulinia lateralis</i> (Say)	1	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	0	1	0	0	0
<i>Mulinia sapotilla</i> Dall *	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Raeta plicatella</i> (Lamarck)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rangia cuneata</i> (Sowerby)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cymatoica</i> sp. A	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tellidora cristata</i> (Recluz)	0	1	1	0	1	0	1	0	0	0	0	1	1	1	0	0	0	1	1	1	0
<i>Tellina aequistriata</i> Say	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
<i>Tellina agilis</i> Stimpson	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1
<i>Tellina alternata</i> Say	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
<i>Tellina calliglypta</i> Dall *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Tellina dinomera</i> Dall *	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tellina</i> sp. B	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1	0	1
<i>Tellina</i> sp. D	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Abra aequalis</i> (Say)	0	1	1	1	0	0	1	0	0	0	0	1	0	0	1	1	0	1	0	1	0
<i>Cumingia tellinoides</i> (Conrad)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
<i>Semele bellastriata</i> (Conrad)	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
<i>Semele</i> sp. A	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0
<i>Tagelus divisus</i> (Spengler)	0	1	1	0	0	0	1	0	0	0	1	1	1	1	0	0	0	1	0	1	1
<i>Tagelus plebius</i> (Lightfoot)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Appendix C (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C	8	9	10A	10B	11A	11B	
<i>Anomalocardia auferiana</i> (Orbigny)	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
<i>Anomalocardia caloosana</i> (Dall)*	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1
<i>Chione grus</i> (Holmes)	1	1	1	1	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	1	0	0
<i>Chione latilirata</i> (Conrad)	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0
<i>Chione ulocyma leonensis</i> Mansfield*	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cyclinella tenuis</i> (Recluz)	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dosinia elegans</i> Conrad	1	0	1	1	1	1	1	1	0	0	1	1	0	1	0	0	0	1	1	1	1	0
<i>Gemma magna</i> Dall*	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gouldia cerina</i> (C.B. Adams)	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0
<i>Macrocallista maculata</i> (Linnaeus)	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0
<i>Macrocallista nimbose</i> (Lightfoot)	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1
<i>Mercenaria campechiensis</i> (Gmelin)	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	0	0
<i>Mercenaria tridacnoides</i> (Lamarck)*	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pitar sayana</i> (Conrad)*	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pitar simpsoni</i> (Dall)	0	0	0	1	0	0	0	1	1	0	0	1	1	1	1	0	1	1	1	0	0	0
<i>Transenella conradina</i> Dall	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
<i>Bothrocorbula willcoxi</i> (Dall)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Caryocorbula leonensis</i> Mansfield*	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0
<i>Corbula</i> sp. B	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Corbula</i> sp. C	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Corbula</i> sp. E	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0
<i>Juliacorbula scutata</i> (Gardner)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
<i>Varicorbula caloosae</i> (Dall)*	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
<i>Gastrochaena hians</i> (Gmelin)	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hiatella arctica</i> (Linnaeus)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pandora</i> sp. A	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cuspidaria</i> sp. A	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diodora cayenensis</i> (Lamarck)	0	1	1	1	0	0	1	0	0	0	0	0	1	1	0	1	1	1	1	1	1	0

Appendix C (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C	8	9	10A	10B	11A	11B
<i>Modulus carchedonius</i> (Lamarck)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0
<i>Modulus modulus</i> (Linnaeus)	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0
<i>Calliostoma willcoxianum</i> Dall *	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tegula fasciata</i> (Born)	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cochliolepus striata</i> Dall *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Turritella apicalis</i> Heilprin *	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0
<i>Turritella perattenuata</i> Heilprin *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Turritella pontoni</i> Mansfield *	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Turritella subannulata</i> Heilprin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
<i>Turritella</i> sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Turritella</i> sp. E	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vermicularia recta</i> Olsson & Harbison *	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cerithidea</i> sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Cerithium atratum</i> (Born)	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
<i>Cerithium litharium</i> Dall *	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0
<i>Cerithium muscarum</i> Say	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
<i>Cerithium preatratum</i> (O&H) *	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhinoclavis caloosaensis</i> (Dall) *	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Strombus alatus</i> Gmelin	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0
<i>Strombus floridanus</i> (Mansfield) *	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Calyptraea centralis</i> (Conrad)	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Crepidula aculeata</i> (Gmelin)	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1
<i>Crepidula fornicata</i> (Linnaeus)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
<i>Crepidula plana</i> Say	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0
<i>Crucibulum imbricatum</i> (Sowerby) *	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Crucibulum multilineatum</i> (Conrad) *	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Crucibulum striatum</i> Say	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1
<i>Xenophora conchyliophora</i> (Born)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Appendix C (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C	8	9	10A	10B	11A	11B
<i>Trivia quadripunctata</i> (Gray)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
<i>Natica plicatella</i> Conrad*	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
<i>Polinices duplicatus</i> Say	1	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0
<i>Eupleura caudata</i> (Say)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
<i>Murex selleanus</i> A. Adams	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
<i>Trophon lepidota</i> (Dall)*	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Urosalpinx perrugata</i> (Conrad)	0	0	0	0	0	1	0	1	0	0	0	1	1	1	0	1	0	0	1	1	1
<i>Cantharus floridanus</i> (Conrad)	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	1	1	1	0	1	0
<i>Cantharus mengeana</i> Dall*	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anachis camax</i> Dall*	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0
<i>Anachis</i> sp. A	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anachis</i> sp. C	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
<i>Mitrella lunata</i> (Say)	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Strombina gunteri</i> Mansfield*	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Busycon contrarium</i> (Conrad)	0	0	0	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	1	0	1
<i>Busycon echinatum</i> (Dall)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Busycon spiratum pyruloides</i> (Conrad)	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0
<i>Busycon spiratum plagosum</i> (Conrad)	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Melongena corona</i> (Gmelin)	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1
<i>Nassarius albus</i> (Say)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
<i>Nassarius bidentatus</i> (Emmons)*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
<i>Nassarius locklini</i> Olsson & Harbison*	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Nassarius vibex</i> (Say)	0	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
<i>Fasciolaria apicna</i> Dall*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
<i>Fasciolaria distans</i> Linnaeus	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Fusinus caloosaensis</i> Heilprin*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Pleuroploca gigantea</i> (Kiener)	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Oliva sayana</i> Ravenel	1	1	0	0	1	0	1	0	0	1	0	0	0	0	0	1	0	1	0	0	1

Appendix C (cont.)

Species	1	2A	2B	2C	3A	3B	4	5A	5B	5C	6A	6B	7A	7B	7C	8	9	10A	10B	11A	11B	
<i>Olivella mutica</i> (Say)	0	0	0	0	1	0	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1
<i>Xancus regina</i> (Heilprin)*	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Cancellaria reticulata</i> (Linnaeus)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Cancellaria rotunda</i> Dall*	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Marginella apicna</i> Menke	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Marginella belloides</i> Olsson & Harbison*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Marginella eulima</i> Dall*	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
<i>Marginella precursor</i> Dall*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
<i>Persicula ovula</i> Conrad	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Mitra heilprini</i> Cossman*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Cymatocyrix lunata</i> (Lea)*	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Ithythythara</i> sp. A	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Conus floridanus</i> Gabb	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
<i>Conus sternsii</i> Conrad	0	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0
<i>Conus</i> sp. A	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Terebra concava</i> Say	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Terebra dislocata</i> (Say)	0	0	0	0	1	1	1	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0
<i>Terebra</i> sp. A	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	0	1	0	0
<i>Pyramidella crenulata</i> (Holmes)	0	0	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	0	0	0
<i>Bulla striata</i> Bruguiere	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	0	0	1	1	1	1	1
<i>Atyis riiseana</i> Morch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
<i>Viviparus georgianus</i> (Lea)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Helisoma conanti</i> (Dall)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1
<i>Helisoma disstoni</i> (Dall)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1

Appendix C (cont.)

Species	14	15	16	17A	18A	18B	18C
<i>Nucula proxima</i> Say	1	0	0	0	0	0	0
<i>Nuculana acuta</i> (Conrad)	1	0	0	0	1	1	0
<i>Anadara lienosa</i> (Say) *	0	0	0	0	1	0	0
<i>Anadara petersburgensis</i> O&H *	0	0	0	0	0	0	0
<i>Anadara scalarina</i> (Heilprin) *	0	0	0	0	0	0	0
<i>Arca irregularis</i> Dall *	0	0	0	0	0	0	0
<i>Arca wagneriana</i> Dall *	0	1	0	0	0	0	0
<i>Arca</i> sp. C	0	0	0	0	0	0	0
<i>Arcopsis adamsi</i> (Dall)	1	1	0	0	1	1	0
<i>Barbatia taeniata</i> Dall *	0	0	0	0	0	0	0
<i>Noetia ponderosa</i> (Say)	0	0	0	1	1	1	0
<i>Glycymeris pectinata</i> (Gmelin)	1	0	1	1	1	1	0
<i>Brachidontes exustus</i> (Linnaeus)	0	0	0	0	1	1	1
<i>Perna conradina</i> d'Orbigny *	0	0	0	0	0	0	0
<i>Pteria colymbus</i> (Roding)	0	0	0	0	0	0	0
<i>Amusium mortoni</i> (Ravenel)	0	0	0	0	0	0	0
<i>Argopecten comparalis</i> (Tuomey & Holmes) *	0	0	0	0	0	0	0
<i>Argopecten irradians</i> (Lamarck)	1	0	0	0	1	1	1
<i>Carolinapecten eboreus</i> (Conrad) *	0	0	0	0	0	0	0
<i>Carolinapecten eboreus solaroides</i> (Heilprin) *	0	0	0	0	0	1	1
<i>Plicatula marginata</i> Say *	1	1	1	0	1	1	1
<i>Anomia simplex</i> d'Orbigny	1	1	1	0	1	1	1
<i>Lima</i> sp. A	0	0	0	0	1	1	0
<i>Conradostrea sculpturata</i> (Conrad) *	0	0	0	0	1	1	1
<i>Hytissa hiatensis</i> (Sowerby) *	0	0	0	0	0	0	0
<i>Ostrea</i> sp. B	0	0	0	0	0	0	0
<i>Ostreola equestris</i> (Say)	0	0	1	0	0	0	0
<i>Anodontia alba</i> Link	1	0	0	0	0	0	0

Appendix C (cont.)

Species	14	15	16	17A	18A	18B	18C
<i>Cavilinga trisulcata</i> (Conrad)*	1	1	1	0	0	0	0
<i>Codakia orbicularis</i> (Linnaeus)	0	0	0	0	0	1	0
<i>Divaricella quadrisulcata</i> (Orbigny)	1	0	0	0	0	0	0
<i>Linga amiantus</i> Dall	1	1	0	1	1	1	1
<i>Linga pennsylvanica</i> (Linnaeus)	0	0	0	0	0	0	0
<i>Lucina nassula</i> (Conrad)	0	1	1	1	1	1	1
<i>Lucina radians</i> (Conrad)	0	0	0	0	0	0	0
<i>Lucina</i> sp. A	0	0	0	0	0	0	0
<i>Pseudomitha floridana</i> (Conrad)	0	0	1	1	0	0	0
<i>Diplodonta acclinis</i> (Conrad)*	0	0	0	0	0	0	0
<i>Diplodonta</i> sp. A	0	0	1	0	1	1	1
<i>Arcinella cornuta</i> Conrad	0	1	0	0	1	0	0
<i>Chama congregata</i> Conrad	1	0	0	0	1	1	0
<i>Chama macerophyla</i> (Gmelin)	0	0	0	0	0	0	0
<i>Neaeromya floridana</i> (Dall)	0	0	1	0	1	1	1
<i>Sportella</i> sp. A	0	0	0	0	0	0	0
<i>Sportella</i> sp. B	0	0	0	0	0	0	0
<i>Erycina carolinensis</i> Dall*	0	0	0	0	0	0	0
<i>Carditamera arata</i> (Conrad)*	1	1	1	1	1	1	1
<i>Carditamera catharia</i> Dall*	1	0	0	0	0	0	0
<i>Pleuromeris tridentata</i> (Say)	1	1	0	0	1	1	1
<i>Pteromeris perplana</i> (Conrad)	0	0	0	0	1	1	0
<i>Crassinella lunulata</i> (Conrad)	0	0	0	0	1	1	1
<i>Eucrassatella speciosa</i> (A. Adams)	0	0	0	0	0	1	0
<i>Americardia guppyi</i> Thiele	0	0	0	0	0	0	1
<i>Dinocardium robustum</i> (Lightfoot)	0	0	0	0	0	0	1
<i>Laevicardium laevigatum</i> (Linnaeus)	1	1	0	0	1	1	0
<i>Laevicardium mortoni</i> (Conrad)	0	0	0	0	0	0	0



Appendix C (cont.)

Species	14	15	16	17A	18A	18B	18C
<i>Trachycardium egmontianum</i> (Shuttleworth)	0	1	0	0	1	1	1
<i>Trachycardium evergladeensis</i> Mansfield*	0	0	0	0	0	0	0
<i>Trachycardium muricatum</i> (Linnaeus)	1	0	0	0	0	0	0
<i>Trigoniocardia willcoxi</i> (Dall)*	1	0	0	0	0	0	0
<i>Mactra undula</i> Dall	1	0	0	0	0	0	0
<i>Mulinia lateralis</i> (Say)	0	0	1	1	1	1	1
<i>Mulinia sapotilla</i> Dall*	1	0	0	0	0	0	0
<i>Raeta plicatella</i> (Lamarck)	0	0	0	0	0	1	1
<i>Rangia cuneata</i> (Sowerby)	1	1	0	0	0	0	0
<i>Cymatoica</i> sp. A	0	0	0	0	0	0	0
<i>Tellidora cristata</i> (Recluz)	1	1	1	0	1	1	1
<i>Tellina aequistriata</i> Say	0	0	1	0	1	1	0
<i>Tellina agilis</i> Stimpson	1	1	1	0	1	1	1
<i>Tellina alternata</i> Say	1	0	0	0	0	0	1
<i>Tellina calliglypta</i> Dall*	1	0	0	0	0	0	0
<i>Tellina dinomera</i> Dall*	1	0	0	0	0	0	0
<i>Tellina</i> sp. B	0	0	0	0	0	0	0
<i>Tellina</i> sp. D	0	0	0	0	0	0	0
<i>Abra aequalis</i> (Say)	1	0	0	0	1	1	1
<i>Cumingia tellinoides</i> (Conrad)	0	0	1	0	1	1	1
<i>Semele bellastriata</i> (Conrad)	1	0	0	0	0	0	0
<i>Semele</i> sp. A	1	0	0	0	0	0	0
<i>Tagelus divisus</i> (Spengler)	1	0	1	0	1	1	1
<i>Tagelus plebius</i> (Lightfoot)	0	0	0	0	0	0	0
<i>Anomalocardia auberiana</i> (Orbigny)	0	0	0	0	0	0	0
<i>Anomalocardia caloosana</i> (Dall)*	1	1	0	1	0	0	1
<i>Chione grus</i> (Holmes)	1	0	0	0	1	1	1
<i>Chione latilirata</i> (Conrad)	0	0	0	0	0	0	0

Appendix C (cont.)

Species	14	15	16	17A	18A	18B	18C
<i>Chione ulocyma leonensis</i> Mansfield*	0	0	0	0	0	0	0
<i>Cyclinella tenuis</i> (Recluz)	0	0	0	0	0	0	0
<i>Dosinia elegans</i> Conrad	0	0	1	1	1	1	1
<i>Gemma magna</i> Dall*	0	0	0	0	0	0	0
<i>Gouldia cerina</i> (C.B. Adams)	1	0	0	0	1	1	0
<i>Macrocallista maculata</i> (Linnaeus)	1	1	0	0	0	0	0
<i>Macrocallista nimbose</i> (Lightfoot)	0	1	1	1	0	0	1
<i>Mercenaria campechiensis</i> (Gmelin)	0	0	0	1	1	0	0
<i>Mercenaria tridacnoides</i> (Lamarck)*	0	0	0	0	0	0	0
<i>Pitar sayana</i> (Conrad)*	0	0	0	0	0	0	0
<i>Pitar simpsoni</i> (Dall)	1	0	0	0	1	1	1
<i>Transenella conradina</i> Dall	1	1	1	1	0	0	0
<i>Bothrocorbula willcoxi</i> (Dall)*	1	1	0	0	0	0	0
<i>Caryocorbula leonensis</i> Mansfield*	1	1	1	0	1	1	0
<i>Corbula</i> sp. B	0	0	0	0	0	0	0
<i>Corbula</i> sp. C	0	0	0	0	0	0	0
<i>Corbula</i> sp. E	0	0	0	1	0	0	0
<i>Juliacorbula scutata</i> (Gardner)*	0	0	0	0	0	1	0
<i>Varicorbula caloosae</i> (Dall)*	1	1	0	0	0	0	0
<i>Gastrochaena hians</i> (Gmelin)	0	0	0	0	0	1	0
<i>Hiatella arctica</i> (Linnaeus)	0	0	0	0	1	1	0
<i>Pandora</i> sp. A	0	0	0	0	0	0	0
<i>Cuspidaria</i> sp. A	0	0	0	0	0	0	0
<i>Diodora cayenensis</i> (Lamarck)	0	0	0	0	0	0	1
<i>Modulus carchedonius</i> (Lamarck)	1	1	0	0	0	0	0
<i>Modulus modulus</i> (Linnaeus)	0	0	0	0	0	0	0
<i>Calliostoma willcoxianum</i> Dall*	1	0	0	0	0	0	0
<i>Tegula fasciata</i> (Born)	1	0	0	0	0	0	0

Appendix C (cont.)

Species	14	15	16	17A	18A	18B	18C
<i>Cochliolepus striata</i> Dall *	0	0	0	0	0	0	1
<i>Turritella apicalis</i> Heilprin *	1	0	0	0	0	0	0
<i>Turritella perattenuata</i> Heilprin *	1	0	0	0	0	0	0
<i>Turritella pontoni</i> Mansfield *	1	0	0	0	0	0	0
<i>Turritella subannulata</i> Heilprin	0	1	0	0	0	1	1
<i>Turritella</i> sp. A	0	0	0	0	1	1	0
<i>Turritella</i> sp. E	0	0	0	0	0	0	0
<i>Vermicularia recta</i> Olsson & Harbison *	0	0	0	0	0	0	0
<i>Cerithidea</i> sp. A	0	0	0	0	0	0	0
<i>Cerithium atratum</i> (Born)	0	0	0	0	0	0	0
<i>Cerithium litharium</i> Dall *	1	0	0	0	0	0	0
<i>Cerithium muscarum</i> Say	0	1	0	0	0	0	0
<i>Cerithium preatratum</i> (O&H) *	0	0	0	0	0	0	0
<i>Rhinoclavis caloosaensis</i> (Dall) *	0	1	0	0	0	0	0
<i>Strombus alatus</i> Gmelin	0	0	0	0	0	0	0
<i>Strombus floridanus</i> (Mansfield) *	0	0	0	0	0	0	0
<i>Calyptreaea centralis</i> (Conrad)	0	0	0	0	1	0	0
<i>Crepidula aculeata</i> (Gmelin)	1	1	0	0	1	1	1
<i>Crepidula fornicata</i> (Linnaeus)	1	1	1	0	1	1	1
<i>Crepidula plana</i> Say	0	1	1	0	0	0	1
<i>Crucibulum imbricatum</i> (Sowerby) *	0	0	0	0	0	0	0
<i>Crucibulum multilineatum</i> (Conrad) *	0	0	0	0	0	0	0
<i>Crucibulum striatum</i> Say	1	1	0	0	1	1	1
<i>Xenophora conchyliophora</i> (Born)	0	1	0	0	0	0	0
<i>Trivia quadripunctata</i> (Gray)	1	0	0	0	1	1	1
<i>Natica plicatella</i> Conrad *	0	0	0	0	0	0	0
<i>Polinices duplicatus</i> Say	0	0	0	1	1	0	0
<i>Eupleura caudata</i> (Say)	0	0	0	0	1	0	0

Appendix C (cont.)

Species	14	15	16	17A	18A	18B	18C
<i>Murex selleanus</i> A. Adams	0	0	0	0	0	0	0
<i>Trophon lepidota</i> (Dall) *	0	0	0	0	0	0	0
<i>Urosalpinx perrugata</i> (Conrad)	0	0	0	0	1	1	1
<i>Cantharus floridanus</i> (Conrad)	0	0	0	0	0	0	0
<i>Cantharus mengeana</i> Dall *	0	0	0	0	0	0	0
<i>Anachis camax</i> Dall *	0	0	0	0	0	1	1
<i>Anachis</i> sp. A	0	0	0	0	0	0	0
<i>Anachis</i> sp. C	0	0	0	0	0	0	0
<i>Mitrella lunata</i> (Say)	1	0	0	0	0	0	0
<i>Strombina gunteri</i> Mansfield *	0	0	0	0	0	0	0
<i>Busycon contrarium</i> (Conrad)	0	0	0	0	0	1	1
<i>Busycon echinatum</i> (Dall)	0	0	0	0	0	0	0
<i>Busycon spiratum pyruloides</i> (Conrad)	0	1	0	0	0	0	0
<i>Busycon spiratum plagosum</i> (Conrad)	1	0	0	0	1	1	0
<i>Melongena corona</i> (Gmelin)	1	0	0	0	0	0	0
<i>Nassarius albus</i> (Say)	0	0	0	0	1	1	1
<i>Nassarius bidentatus</i> (Emmons) *	0	1	0	0	0	0	0
<i>Nassarius locklini</i> Olsson & Harbison *	1	1	0	0	0	0	0
<i>Nassarius vibex</i> (Say)	1	0	1	0	1	1	1
<i>Fasciolaria apicna</i> Dall *	0	0	0	0	0	1	0
<i>Fasciolaria distans</i> Linnaeus	0	0	0	0	0	0	0
<i>Fusinus caloosaensis</i> Heilprin *	0	0	0	0	0	0	0
<i>Pleuroploca gigantea</i> (Kiener)	0	0	0	0	0	0	1
<i>Oliva sayana</i> Ravenel	0	0	0	0	0	1	1
<i>Olivella mutica</i> (Say)	1	1	1	0	1	1	1
<i>Xancus regina</i> (Heilprin) *	0	0	0	0	0	0	0
<i>Cancellaria reticulata</i> (Linnaeus)	1	0	0	0	0	0	0
<i>Cancellaria rotunda</i> Dall *	0	1	0	0	0	0	0

Appendix C (cont.)

Species	14	15	16	17A	18A	18B	18C
<i>Marginella apicna</i> Menke	1	1	1	0	1	1	1
<i>Marginella belloides</i> Olsson & Harbison*	0	0	0	0	0	0	0
<i>Marginella eulima</i> Dall*	1	1	0	0	1	1	1
<i>Marginella precursor</i> Dall*	0	0	0	0	0	0	0
<i>Persicula ovula</i> Conrad	0	1	0	0	0	0	0
<i>Mitra heilprini</i> Cossman*	0	0	0	0	0	0	0
<i>Cymatocyrix lunata</i> (Lea)*	0	1	0	0	0	0	0
<i>Ithythythara</i> sp. A	0	0	0	0	0	0	0
<i>Conus floridanus</i> Gabb	0	0	0	0	0	0	0
<i>Conus sternsii</i> Conrad	1	1	1	0	0	0	0
<i>Conus</i> sp. A	0	0	0	0	0	0	0
<i>Terebra concava</i> Say	0	0	0	0	0	1	1
<i>Terebra dislocata</i> (Say)	0	1	0	0	0	0	1
<i>Terebra</i> sp. A	0	0	0	0	0	0	0
<i>Pyramidella crenulata</i> (Holmes)	0	1	1	0	0	0	0
<i>Bulla striata</i> Bruguiere	1	1	0	0	0	0	0
<i>Atys riiseana</i> Morch	1	0	0	0	0	0	0
<i>Viviparus georgianus</i> (Lea)	1	0	0	0	0	0	0
<i>Helisoma conanti</i> (Dall)	1	0	0	0	0	0	0
<i>Helisoma disstoni</i> (Dall)	1	0	0	0	0	0	0

Appendix D: Table of occurrence (O), constancy (C) and biostratigraphic fidelity (BF) for all species used in numerical analyses. Occurrence is the number of collections in a given cluster in which a species occurs, constancy is the percentage of collections within a given cluster in which a species occurs, and biostratigraphic fidelity is the percent a species occurs in a cluster relative to all other clusters. Values were calculated using only those collections that were members of clusters.

Species	Zone A			Zone B			Zone C		
	O	C	BF	O	C	BF	O	C	BF
<i>Nucula proxima</i> Say	4	7	7	1	1	1	2	2	2
<i>Nuculana acuta</i> (Conrad)	6	10	6	4	5	3	2	2	1
<i>Anadara lienosa</i> (Say)	6	10	6	5	6	4	0	0	0
<i>Anadara petersburgensis</i> O & H	2	3	10	0	0	0	0	0	0
<i>Anadara scalarina</i> (Heilprin)	6	10	10	0	0	0	0	0	0
<i>Arca irregularis</i> Dall	1	2	7	1	1	3	0	0	0
<i>Arca wagneriana</i> Dall	2	3	8	1	1	3	0	0	0
<i>Arca</i> sp. C	2	3	10	0	0	0	0	0	0
<i>Arcopsis adamsi</i> (Dall)	5	8	5	7	9	5	0	0	0
<i>Barbatia taeniata</i> Dall	3	5	8	1	1	2	0	0	0
<i>Noetia ponderosa</i> (Say)	0	0	0	4	5	10	0	0	0
<i>Glycymeris pectinata</i> (Gmelin)	3	5	3	7	9	5	5	6	3
<i>Brachidontes exustus</i> (Linnaeus)	0	0	0	7	9	8	2	2	1
<i>Perna conradina</i> d'Orbigny	5	8	10	0	0	0	0	0	0
<i>Pteria colymbus</i> (Roding)	2	3	10	0	0	0	0	0	0

Appendix D (cont.)

Species	Zone A			Zone B			Zone C		
	O	C	BF	O	C	BF	O	C	BF
<i>Amusium mortoni</i> (Ravenel)	2	3	10	0	0	0	0	0	0
<i>Argopecten comparalis</i> (Tuomey & Holmes)	2	3	10	0	0	0	0	0	0
<i>Argopecten irradians</i> (Lamarck)	0	0	0	6	8	7	4	4	3
<i>Carolinapecten eboreus</i> (Conrad)	6	10	10	0	0	0	0	0	0
<i>Carolinapecten eboreus solaroides</i> (Heilprin)	0	0	0	2	3	10	0	0	0
<i>Plicatula marginata</i> Say	6	10	4	7	9	4	5	6	2
<i>Anomia simplex</i> d'Orbigny	5	8	4	7	9	5	3	3	2
<i>Lima</i> sp. A	0	0	0	2	3	10	0	0	0
<i>Conradostrea sculpturata</i> (Conrad)	6	10	6	5	6	4	0	0	0
<i>Hytissa hiatensis</i> (Sowerby)	3	5	10	0	0	0	0	0	0
<i>Ostrea</i> sp. B	3	5	10	0	0	0	0	0	0
<i>Ostreola equestris</i> (Say)	0	0	0	2	3	6	2	2	4
<i>Anodontia alba</i> Link	6	10	6	4	5	3	1	1	1
<i>Cavilinga trisulcata</i> (Conrad)	5	8	6	3	4	3	1	1	1
<i>Codakia orbicularis</i> (Linnaeus)	2	3	8	1	1	3	0	0	0
<i>Divaricella quadrisulcata</i> (Orbigny)	3	5	6	2	3	4	0	0	0
<i>Linga amiantus</i> Dall	6	10	4	8	10	4	3	3	1
<i>Linga pennsylvanica</i> (Linnaeus)	1	2	5	1	1	3	1	1	3
<i>Lucina nassula</i> (Conrad)	1	2	1	7	9	5	7	8	4
<i>Lucina radians</i> (Conrad)	2	3	8	1	1	3	0	0	0
<i>Lucina</i> sp. A	0	0	0	1	1	10	0	0	0
<i>Pseudomiltha floridana</i> (Conrad)	1	2	1	4	5	3	7	8	5
<i>Diplodonta acclinis</i> (Conrad)	1	2	10	0	0	0	0	0	0
<i>Diplodonta</i> sp. A	6	10	5	4	5	2	5	6	3
<i>Arcinella cornuta</i> Conrad	1	2	2	5	6	7	0	0	0
<i>Chama congregata</i> Conrad	6	10	5	7	9	5	0	0	0
<i>Chama macerophylla</i> (Gmelin)	3	5	8	1	1	2	0	0	0

Appendix D (cont.)

Species	Zone A			Zone B			Zone C		
	O	C	BF	O	C	BF	O	C	BF
<i>Neaeromya floridana</i> (Dall)	0	0	0	5	6	6	4	4	4
<i>Sportella</i> sp. A	0	0	0	1	1	3	2	2	7
<i>Sportella</i> sp. B	4	7	10	0	0	0	0	0	0
<i>Erycina carolinensis</i> Dall	3	5	6	2	3	4	0	0	0
<i>Carditamera arata</i> (Conrad)	6	10	3	8	10	3	9	10	3
<i>Carditamera catharia</i> Dall	0	0	0	1	1	10	0	0	0
<i>Pleuromeris tridentata</i> (Say)	6	10	5	6	8	4	3	3	1
<i>Pteromeris perplana</i> (Conrad)	2	3	5	2	3	5	0	0	0
<i>Crassinella lunulata</i> (Conrad)	3	5	5	3	4	4	1	1	1
<i>Eucrassatella speciosa</i> (A. Adams)	2	3	4	3	4	6	0	0	0
<i>Americardia guppyi</i> Thiele	0	0	0	3	4	5	4	4	5
<i>Dinocardium robustum</i> (Lightfoot)	0	0	0	2	3	6	2	2	4
<i>Laevicardium laevigatum</i> (Linnaeus)	5	8	6	5	6	4	0	0	0
<i>Laevicardium mortoni</i> (Conrad)	0	0	0	0	0	0	8	9	10
<i>Trachycardium egmontianum</i> (Shuttleworth)	2	3	2	7	9	5	5	6	3
<i>Trachycardium evergladeensis</i> Mansfield	2	3	10	0	0	0	0	0	0
<i>Trachycardium muricatum</i> (Linnaeus)	4	7	7	2	3	3	0	0	0
<i>Trigoniocardia willcoxi</i> (Dall)	6	10	8	2	3	2	0	0	0
<i>Mactra undula</i> Dall	1	2	5	1	1	3	1	1	3
<i>Mulinia lateralis</i> (Say)	5	8	4	4	5	2	7	8	4
<i>Mulinia sapotilla</i> Dall	3	5	8	1	1	2	0	0	0
<i>Ræta plicatella</i> (Lamarck)	0	0	0	2	3	10	0	0	0
<i>Rangia cuneata</i> (Sowerby)	0	0	0	1	1	10	0	0	0
<i>Cymatoica</i> sp. A	3	5	10	0	0	0	0	0	0
<i>Tellidora cristata</i> (Recluz)	3	5	3	7	9	5	4	4	2
<i>Tellina aequistriata</i> Say	0	0	0	3	4	7	2	2	3
<i>Tellina agilis</i> Stimpson	6	10	4	8	10	4	7	8	3



Appendix D (cont.)

Species	Zone A			Zone B			Zone C		
	O	C	BF	O	C	BF	O	C	BF
<i>Tellina alternata</i> Say	3	5	5	4	5	5	1	1	1
<i>Tellina calliglypta</i> Dall	0	0	0	2	3	10	0	0	0
<i>Tellina dinomera</i> Dall	0	0	0	1	1	10	0	0	0
<i>Tellina</i> sp. B	0	0	0	1	1	2	4	4	8
<i>Tellina</i> sp. D	2	3	10	0	0	0	0	0	0
<i>Abra aequalis</i> (Say)	3	5	3	7	9	5	2	2	1
<i>Cumingia tellinoides</i> (Conrad)	0	0	0	5	6	9	1	1	1
<i>Semele bellastrata</i> (Conrad)	3	5	6	3	4	4	0	0	0
<i>Semele</i> sp. A	3	5	6	2	3	4	0	0	0
<i>Tagelus divisus</i> (Spengler)	2	3	2	6	8	5	5	6	4
<i>Tagelus plebius</i> (Lightfoot)	0	0	0	1	1	10	0	0	0
<i>Anomalocardia auberiana</i> (Orbigny)	0	0	0	0	0	0	2	2	10
<i>Anomalocardia caloosana</i> (Dall)	0	0	0	6	8	6	5	6	4
<i>Chione grus</i> (Holmes)	5	8	4	7	9	5	1	1	1
<i>Chione latilirata</i> (Conrad)	6	10	7	3	4	3	0	0	0
<i>Chione ulocyma leonensis</i> Mansfield	2	3	10	0	0	0	0	0	0
<i>Cyclinella tenuis</i> (Recluz)	6	10	10	0	0	0	0	0	0
<i>Dosinia elegans</i> Conrad	5	8	4	6	8	4	5	6	3
<i>Gemma magna</i> Dall	5	8	10	0	0	0	0	0	0
<i>Gouldia cerina</i> (C.B. Adams)	3	5	4	6	8	6	0	0	0
<i>Macrocallista maculata</i> (Linnaeus)	3	5	5	5	6	5	0	0	0
<i>Macrocallista nimbose</i> (Lightfoot)	1	2	1	4	5	3	8	9	6
<i>Mercenaria campechiensis</i> (Gmelin)	6	10	5	3	4	2	5	6	3
<i>Mercenaria tridacnoides</i> (Lamarck)	2	3	10	0	0	0	0	0	0
<i>Pitar sayana</i> (Conrad)	2	3	10	0	0	0	0	0	0
<i>Pitar simpsoni</i> (Dall)	1	2	1	6	8	5	6	7	4
<i>Transenella conradina</i> Dall	5	8	3	5	6	3	9	10	4

Appendix D (cont.)

Species	Zone A			Zone B			Zone C		
	O	C	BF	O	C	BF	O	C	BF
<i>Bothrocorbula willcoxi</i> (Dall)	0	0	0	2	3	10	0	0	0
<i>Caryocorbula leonensis</i> Mansfield	6	10	5	7	9	5	1	1	1
<i>Corbula</i> sp. B	6	10	10	0	0	0	0	0	0
<i>Corbula</i> sp. C	2	3	10	0	0	0	0	0	0
<i>Corbula</i> sp. E	0	0	0	0	0	0	4	4	10
<i>Juliacorbula scutata</i> (Gardner)	0	0	0	3	4	10	0	0	0
<i>Varicorbula caloosae</i> (Dall)	4	7	5	5	6	5	0	0	0
<i>Gastrochaena hians</i> (Gmelin)	2	3	8	1	1	3	0	0	0
<i>Hitella arctica</i> (Linnaeus)	1	2	4	2	3	6	0	0	0
<i>Pandora</i> sp. A	3	5	10	0	0	0	0	0	0
<i>Cuspidaria</i> sp. A	2	3	10	0	0	0	0	0	0
<i>Diodora cayenensis</i> (Lamarck)	3	6	4	5	6	4	2	2	1
<i>Modulus carchedonius</i> (Lamarck)	1	2	3	4	5	7	0	0	0
<i>Modulus modulus</i> (Linnaeus)	0	0	0	0	0	0	4	4	10
<i>Calliostoma willcoxianum</i> Dall	1	2	7	1	1	3	0	0	0
<i>Tegula fasciata</i> (Born)	6	10	9	1	1	1	0	0	0
<i>Cochliolepus striata</i> Dall	0	0	0	2	3	10	0	0	0
<i>Turritella apicalis</i> Heilprin	6	10	8	2	3	2	0	0	0
<i>Turritella perattenuata</i> Heilprin	0	0	0	2	3	10	0	0	0
<i>Turritella pontoni</i> Mansfield	0	0	0	2	3	10	0	0	0
<i>Turritella subannulata</i> Heilprin	0	0	0	5	6	10	0	0	0
<i>Turritella</i> sp. A	0	0	0	2	3	10	0	0	0
<i>Turritella</i> sp. E	2	3	10	0	0	0	0	0	0
<i>Vermicularia recta</i> Olsson & Harbison	3	6	10	0	0	0	0	0	0
<i>Cerithidea</i> sp. A	0	0	0	1	1	10	0	0	0
<i>Cerithium atratum</i> (Born)	0	0	0	0	0	0	3	3	10
<i>Cerithium litharium</i> Dall	0	0	0	4	5	10	0	0	0

Appendix D (cont.)

Species	Zone A			Zone B			Zone C		
	O	C	BF	O	C	BF	O	C	BF
<i>Cerithium muscarum</i> Say	0	0	0	0	0	0	8	9	10
<i>Cerithium preatratum</i> (O&H)	1	2	10	0	0	0	0	0	0
<i>Rhinoclavis caloosaensis</i> (Dall)	1	2	10	0	0	0	0	0	0
<i>Strombus alatus</i> Gmelin	0	0	0	2	3	8	1	1	3
<i>Strombus floridanus</i> (Mansfield)	4	7	10	0	0	0	0	0	0
<i>Calyptraea centralis</i> (Conrad)	4	7	9	1	1	1	0	0	0
<i>Crepidula aculeata</i> (Gmelin)	2	3	2	8	10	8	0	0	0
<i>Crepidula fornicata</i> (Linnaeus)	6	10	3	8	10	3	9	10	3
<i>Crepidula plana</i> Say	1	2	1	4	5	3	9	10	6
<i>Crucibulum imbricatum</i> (Sowerby)	2	3	10	0	0	0	0	0	0
<i>Crucibulum multilineatum</i> (Conrad)	5	8	9	1	1	1	0	0	0
<i>Crucibulum striatum</i> Say	4	7	4	8	10	6	0	0	0
<i>Xenophora conchyliophora</i> (Born)	0	0	0	1	1	10	0	0	0
<i>Trivia quadripunctata</i> (Gray)	0	0	0	6	8	10	0	0	0
<i>Natica plicatella</i> Conrad	4	7	9	1	1	1	0	0	0
<i>Polinices duplicatus</i> Say	2	3	5	1	1	2	2	2	3
<i>Eupleura caudata</i> (Say)	1	2	3	4	5	7	0	0	0
<i>Murex selleanus</i> A. Adams	2	3	8	1	1	3	0	0	0
<i>Trophon lepidota</i> (Dall)	2	3	10	0	0	0	0	0	0
<i>Urosalpinx perrugata</i> (Conrad)	1	2	1	6	8	6	4	4	3
<i>Cantharus floridanus</i> (Conrad)	1	2	3	3	4	6	1	1	1
<i>Cantharus mengeana</i> Dall	1	2	10	0	0	0	0	0	0
<i>Anachis camax</i> Dall	1	2	3	4	5	7	0	0	0
<i>Anachis</i> sp. A	2	3	10	0	0	0	0	0	0
<i>Anachis</i> sp. C	0	0	0	0	0	0	2	2	10
<i>Mitrella lunata</i> (Say)	1	2	4	2	3	6	0	0	0
<i>Strombina gunteri</i> Mansfield	5	8	10	0	0	0	0	0	0

Appendix D (cont.)

Species	Zone A			Zone B			Zone C		
	O	C	BF	O	C	BF	O	C	BF
<i>Busycon contrarium</i> (Conrad)	0	0	0	3	4	4	5	6	6
<i>Busycon echinatum</i> (Dall)	0	0	0	1	1	10	0	0	0
<i>Busycon spiratum pyruloides</i> (Conrad)	1	2	4	1	1	2	2	2	4
<i>Busycon spiratum plagosum</i> (Conrad)	1	2	3	4	5	7	0	0	0
<i>Melongena corona</i> (Gmelin)	0	0	0	1	1	1	5	6	9
<i>Nassarius albus</i> (Say)	0	0	0	7	9	10	0	0	0
<i>Nassarius bidentatus</i> (Emmons)	0	0	0	1	1	10	0	0	0
<i>Nassarius locklini</i> Olsson & Harbison	3	5	6	2	3	4	0	0	0
<i>Nassarius vibex</i> (Say)	1	2	1	8	10	5	8	9	4
<i>Fasciolaria apicna</i> Dall	1	2	3	3	4	7	0	0	0
<i>Fasciolaria distans</i> Linnaeus	0	0	0	0	0	0	1	1	10
<i>Fusinus caloosaensis</i> Heilprin	2	3	8	1	1	3	0	0	0
<i>Pleuroploca gigantea</i> (Kiener)	3	5	6	2	3	4	0	0	0
<i>Oliva sayana</i> Ravenel	3	5	5	4	5	5	1	1	1
<i>Olivella mutica</i> (Say)	1	2	1	8	10	5	7	8	4
<i>Xancus regina</i> (Heilprin)	1	2	7	1	1	3	0	0	0
<i>Cancellaria reticulata</i> (Linnaeus)	1	2	7	1	1	3	0	0	0
<i>Cancellaria rotunda</i> Dall	2	3	10	0	0	0	0	0	0
<i>Marginella apicna</i> Menke	4	7	3	8	10	4	9	10	4
<i>Marginella belloides</i> Olsson & Harbison	0	0	0	0	0	0	0	0	0
<i>Marginella eulima</i> Dall	1	2	2	7	9	8	0	0	0
<i>Marginella precursor</i> Dall	0	0	0	1	1	10	0	0	0
<i>Marginella</i> sp. A	0	0	0	0	0	0	0	0	0
<i>Persicula ovula</i> Conrad	1	2	7	1	1	3	0	0	0
<i>Mitra heilprini</i> Cossman	0	0	0	1	1	10	0	0	0
<i>Cymatocyrix lunata</i> (Lea)	1	2	7	1	1	3	0	0	0
<i>Ithythythara</i> sp. A	2	3	10	0	0	0	0	0	0

Appendix D (cont.)

Species	Zone A			Zone B			Zone C		
	O	C	BF	O	C	BF	O	C	BF
<i>Conus floridanus</i> Gabb	2	3	6	1	1	2	1	1	2
<i>Conus sternsii</i> Conrad	1	2	2	2	3	3	4	4	4
<i>Conus</i> sp. A	1	2	7	1	1	3	0	0	0
<i>Terebra concava</i> Say	1	2	3	3	4	7	0	0	0
<i>Terebra dislocata</i> (Say)	2	3	3	3	4	4	3	3	3
<i>Terebra</i> sp. A	0	0	0	1	1	2	4	4	8
<i>Pyramidella crenulata</i> (Holmes)	1	2	2	1	1	1	7	8	7
<i>Bulla striata</i> Bruguiere	5	8	4	4	5	3	6	7	4
<i>Atys riiseana</i> Morch	0	0	0	3	4	10	0	0	0
<i>Viviparus georgianus</i> (Lea)	1	2	7	1	1	3	0	0	0
<i>Helisoma conanti</i> (Dall)	0	0	0	3	4	10	0	0	0
<i>Helisoma disstoni</i> (Dall)	1	2	3	3	4	7	0	0	0

Appendix E: Listing of environments for each cluster as represented by the fauna. Taxa used include species with high values of constancy and biostratigraphic fidelity (marked with a bullet) and species having high relative abundance.

### Cluster A

#### Shallow Euryhaline Bay/Lagoon

- *Perna conradina* (hard substr.)
- *Hyotissa hiatensis* (hard substr.)
- Conradostrea sculpturata* (hard substr.; also offshore)
- *Ostrea sp. B* (hard substr.)
- Anomia simplex* (hard substr.)
- *Vermicularia recta* (hard substr.)

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*Anodontia alba* (sandy substr. with grass)

*Chione cancellata* (sandy substr. with grass)

*Transenella conradina* (sandy substr. with grass)

- *Tegula fasciata* (sandy substr. with grass)
- *Strombina gunteri* (sandy substr. with grass)

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*Nuculana acuta* (muddy substr.)

- *Cymatoica sp. A* (muddy substr.)

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*Anadara transversa* (also inlets, offshore)

- *Cyclinella tenius* (also inlets)
- *Corbula sp. B* (also inlets)
- *Pandora sp. A* (also inlets)

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*Mulinia lateralis* (ubiquitous)

*Mulinia sapotilla* (brackish)

- *Gemma magna*
- Mercenaria campechiensis*
- *Sportella sp. B*

#### Shallow Continental Shelf

*Chama macerophylla* (hard substr.)

- *Calyptreaea centralis* (hard substr.)
- *Crucibulum multilineatum* (hard substr.)

- 
- *Anadara scalarina* (also inlets)

*Linga amiantus* (also inlets)

*Parvilucina multilineata* (also inlets)

- *Natica plicatella* (also inlets)

- 
- *Carolinapecten eboreus*

*Pleuromeris tridentata*

*Trigoniocardia willcoxi*

## Appendix E (cont.)

## Cluster A (cont.)

*Chione ulocyma**Varicorbula caloosae*

- *Strombus floridanus* (sandy substr. with grass)

Appendix E (cont.)

## Cluster B

Fresh/Brackish*Mulinia sapotilla*

- *Helisoma conanti*

Shallow Euryhaline Bay/Lagoon*Brachidontes exustus* (sandy substr. with grass)*Carditamera arata* (sandy substr. with grass)

- *Cumingia tellinoides* (sandy substr. with grass)

*Tagelus divisus* (sandy substr. with grass)*Anomalocardia caloosana* (sandy substr. with grass)*Chione cancellata* (sandy substr. with grass)*Tranzenella conradina* (sandy substr. with grass)

- *Cerithium litharium* (sandy substr. with grass)

- *Nassarius albus* (sandy substr. with grass)

*Marginella apicna* (sandy substr. with grass)

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*Arcopsis adamsi* (hard substr.; also offshore)*Conradostrea sculpturata* (hard substr.; also offshore)*Anomia simplex* (hard substr.; also offshore)*Crepidula aculeata* (hard substr.; also offshore)*Crepidula fornicata* (hard substr.; also offshore)

- *Trivia quadripunctata* (hard substr.; also offshore)

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*Anadara transversa* (also inlets, offshore)Shallow Continental Shelf

- *Noetia ponderosa* (hard substr.)

*Plicatula marginata* (hard substr.)*Arcinella cornuta* (hard substr.)

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*Parvilucina multilineata* (also inlets)*Pleuromeris tridentata**Raeta plicatella*

- *Juliacorbula scutata*

*Varicorbula caloosae*

- *Turritella subannulata*

- *Atys riiseana*

## Appendix E (cont.)

## Cluster C

Shallow Euryhaline Bay/Lagoon

- *Laevicardium mortoni* (sandy substr. with grass)
- Anomalocardia caloosana* (sandy substr. with grass)
- Chione cancellata* (sandy substr. with grass)
- Tranzenella conradina* (sandy substr. with grass)
- *Modulus modulus* (sandy substr. with grass)
- *Cerithium muscarum* (sandy substr. with grass)
- Nassarius vibex* (sandy substr. with grass)
- Marginella apicna* (sandy substr. with grass; also offshore)
- Bulla striata* (sandy substr. with grass)
- Pyramidella crenulata* (sandy substr. with grass)

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- Anadara transversa* (also inlets, offshore)
- Parvilucina multilineata* (also inlets, offshore)
- Olivella mutica* (also inlets, offshore)
- Mulinia lateralis* (ubiquitous)
- *Corbula* sp. E
- *Melongena corona*



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#### EDUCATION

- 9/93 - 5/97 Old Dominion University, Norfolk, VA  
• GPA: 4.0
- 9/86 - 8/90 Bachelor of Arts in Geology, University of Colorado, Boulder

#### WORK EXPERIENCE

- 9/95 - Present Geologist: Platte River Associates, Inc., Boulder, CO  
• Responsible for testing pre-release versions of 1-D and 2-D basin modelling software, software interface design, technical support and technical documentation
- 5/94 - 8/95 Volunteer: U.S. Geological Survey, Reston, VA  
• Collected, identified and catalogued 60,000 fossil mollusc specimens from southern Florida
- 8/93 - 5/95 Teaching Assistant: Department of Geology, Old Dominion University, Norfolk, VA  
• Reinforced main lecture topics in a laboratory setting
- 4/92 - 6/93 Geologist: Rocky Mountain Geological Databases, Inc., Denver, CO  
• Constructed cross section across Paradox Basin (Western U.S.) using 150 well logs
- 7/91 - 3/92 Geologist: Platte River Associates, Inc., Denver, CO

#### HONORS / AWARDS

- Student Excellence Award: Spring, 1995, SEPM
- Masters Thesis Research Grant: Spring, 1994, Western Interior Paleontological Society
- Masters Teaching Assistantship: Fall, 1993 - Spring, 1995, Old Dominion University