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# CHAPTER 12

# OSTRACODE SHELL CHEMISTRY AS A PALEOSALINITY PROXY IN FLORIDA BAY

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## ABSTRACT

We investigated the use of ostracode metal/calcium ratios (Mg/Ca, Sr/Ca, and Na/Ca) to reconstruct the salinity history of central Florida Bay from its sedimentary record. We first developed provisional partition coefficients ($K_{D\text{-}Mg}$ and $K_{D\text{-}Sr}$) from the average me/Ca ratio for modern Florida Bay water and 171 modern shells of *Loxoconcha matagordensis* at a mean Florida Bay water temperature of 26.5°C. Trends in Mg/Ca ratios for *L. matagordensis* and *Peratocytheridea setipunctata* from radiometrically dated sediment cores from Russell Bank, Park Key, and Bob Allen Keys appear to provide a reasonable estimate of Florida Bay salinity history for the past 130 years. The most complete Mg/Ca record from Russell Bank extends back to 1875 and shows a good correspondence between estimated paleosalinity and measured annual rainfall in south Florida. Paleosalinity estimates for the Russell Bank area range from ~13 to ~55 ppt. Estimates for the post-1950s period are comparable to instrumental measurements of salinity near the Russell Bank site. The overall record indicates a decadal-scale variability in salinity in which large amplitude shifts in ostracode Mg/Ca ratios with high Mg/Ca (higher salinity) values corresponding to periods of low rainfall from ~1895 to ~1920 and from 1940 to present. The intervening 20 years (~1920–1940) are characterized by relatively low amplitude shifts in Mg/Ca and rainfall. Since 1950, periods of high salinity (~45 to ~55 ppt) occur during each decade. Prior to 1940, salinity never exceeded ~45 ppt and generally remained below 40 ppt, despite evidence in the rainfall record of dry intervals in the early 1900s equivalent to those of the last 50 years. Salinity minima associated with the decadal-scale oscillations range from ~15 to ~25 ppt. Four of the five extreme low values (~1915, ~1940, ~1983, ~1998) appear to correspond with times of strongly negative values of the Southern Oscillation Index, that is, El Nino conditions that bring anomalously high winter rainfall in the southeastern U.S.

These results support the hypothesis that seasonal and decadal-scale salinity fluctuations are a natural part of the Florida Bay ecosystem, and that these fluctuations are largely a function of natural variability of regional climate (rainfall). The relatively low peak salinity values associated with apparent dry periods in the early 1900s suggests that, since ~1950, anthropogenic factors may have played a role in the magnitude of the salinity fluctuations in more recent times.

## INTRODUCTION

Salinity variations play an important role in the physical and biogeochemical processes of estuaries and marine embayments. Within these marginal marine settings, either directly or indirectly, spatial and temporal variations in salinity control turbidity and sedimentation, the distribution of dissolved inorganic and organic constituents, and the distribution and abundance of flora and fauna (reviews in Chester, 1990; Berner and Berner, 1996).

Recently, Florida Bay—an estuarine-like, shallow marine embayment that receives significant terrestrial runoff from peninsular Florida—has experienced dramatic ecosystem changes including sea-grass die-offs, decreases in populations of fishes, pink shrimp, and water birds, and increased blooms of algae (Boesch *et al.*, 1993). At the same time, the frequency and intensity of hypersaline events in Florida Bay have apparently increased leading to the hypothesis that the recent ecosystem changes in the bay have resulted from changes in salinity (McIvor *et al.*, 1994). Further, it has been hypothesized that salinity variations within the bay are the result of anthropogenic factors, such as diversion of freshwater runoff from the Everglades, freshwater that would otherwise have drained into Florida Bay (McIvor *et al.*, 1994). Hydrologic modeling studies support this hypothesis, showing that

large-scale decreases in freshwater influx to Florida Bay from the Everglades will lead to extreme fluctuations in salinity and an increased occurrence of hypersaline conditions, especially in near-shore sub-basins of central and northeastern Florida Bay (Fennema *et al.,* 1994).

While it is clear from historical accounts that the bay has experienced hypersaline events in the last few decades, very little is known about the long-term salinity history of Florida Bay and whether or not the recent events of hypersalinity are unprecedented prior to human activities in South Florida. Unfortunately, only short and discontinuous instrumental records of Florida Bay salinity have been obtained over the last 50 years, and only anecdotal salinity data exists prior to this time. In place of instrumental data, longer records of Bay salinity have been reconstructed from fossil material deposited and preserved in the bay. For example, on the basis of an oxygen isotopic ($\delta^{18}O$) record from a Florida Bay coral, Swart *et al.* (1996) postulated that there has been no major long-term increase in salinity in Florida Bay, implying that the events of hypersalinity are part of the natural variability of Florida Bay. They concluded, however, that following construction of the Miami-to-Key West railroad (1905–1910) there was a decrease in the variability of the $\delta^{18}O$ signal, suggesting a stabilization of salinity conditions in Florida Bay during the period 1905-present relative to 1825–1905. Brewster-Wingard *et al.* (1998) and Brewster-Wingard and Ishman (1999) interpreted molluscan and foraminiferal assemblages from Florida Bay sediment cores to indicate progressively increasing salinity during the later part of the 20th century and an increase in the amplitude of salinity variability about 1940.

The coral record of Swart *et al.* (1996) is from Lignumvitae Basin near the southwestern bay-ocean boundary where seasonal and inter-annual salinity variations are substantially lower than in central Florida Bay. Although they argue that salinity variations in Lignumvitae Basin are representative of salinity changes throughout most of Florida Bay, no comparable studies from interior-basins (where corals are rare) have confirmed this hypothesis. Further, Swart *et al.* (1996) noted the complexity of the coral $\delta^{18}O$ signal, which is controlled by temperature, rainfall, relative fluxes to the bay of freshwater and seawater, and evaporation, and, consequently, the difficulty in interpreting this record without ambiguity.

In contrast to the coral $\delta^{18}O$-based salinity record, paleoecological studies of salinity-dependent fauna and flora from sediment cores suggest multi-decadal scale fluctuations of Florida Bay salinity superimposed on an overall increase in salinity during the last 200 years (Wingard *et al.,* 1995). Like the $\delta^{18}O$ record, interpreting paleoecological signals may also be complicated by a number of factors, including changes over time in bottom sediment type, temperature, subaquatic vegetation, food availability, and predation, leading to uncertainty in paleoecological-based salinity reconstructions.

Here we develop a new geochemical proxy of Florida Bay salinity—the metal/Ca ratios preserved in fossil ostracode shells—and use it to reconstruct the salinity of Florida Bay for the last 180 years. We also compare the paleosalinity record to instrumental rainfall records of South Florida to examine the effects of regional climate variability on Florida Bay salinity.

## ACKNOWLEDGEMENTS

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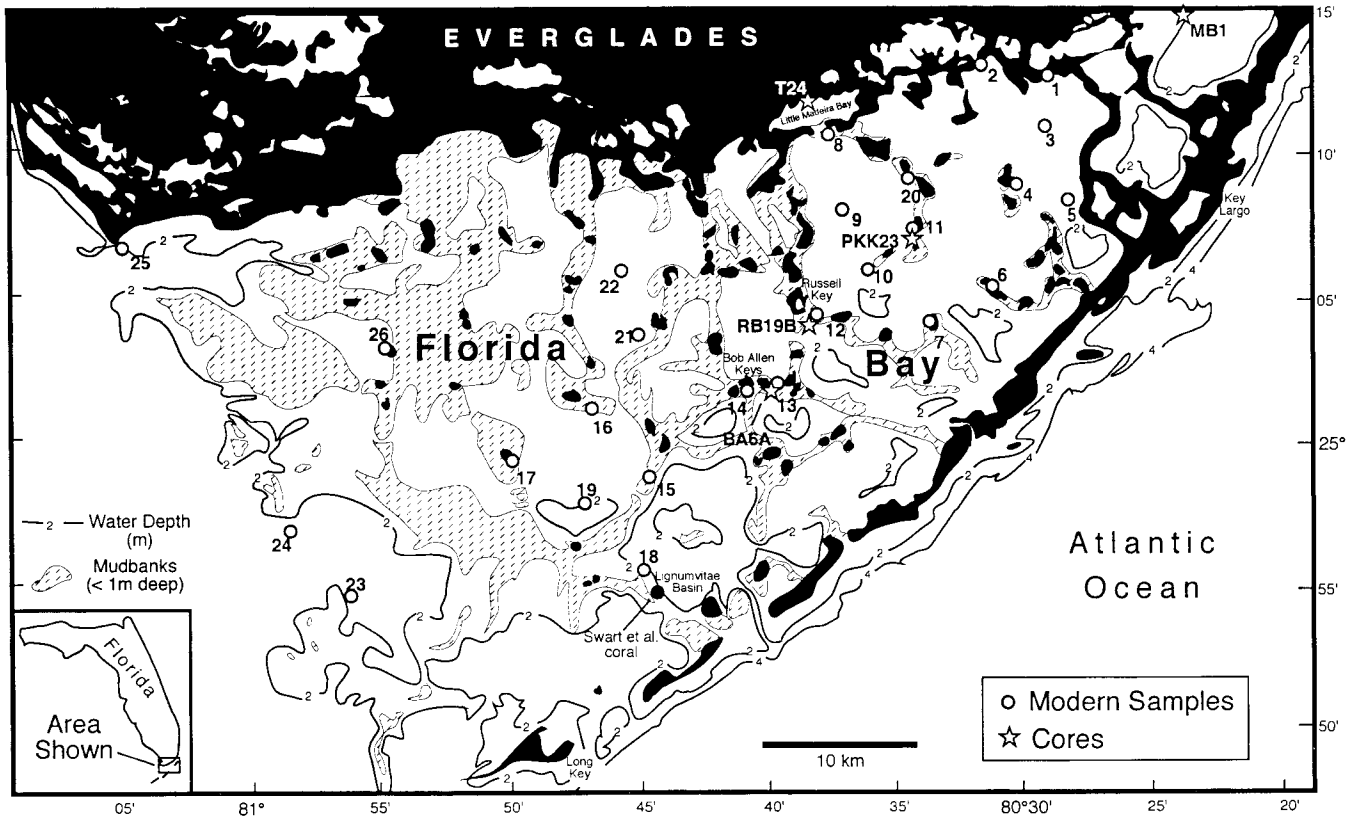
## REGIONAL SETTING

Florida Bay (Text-fig. 1) is a triangular-shaped, shallow, restricted marine embayment bounded to the north by the coastal wetlands of the Everglades and to the south by the Florida Keys which separate the bay from open ocean waters of the Straits of Florida. The western boundary of the bay is less distinct, made up of a system of shallow sediment banks that restrict exchange between Florida Bay and the Gulf of Mexico. Water depths range from less than 1 m to about 3 m generally deepening to the south and west (Text-fig. 1). Tidal effects are minimal throughout much of the bay.

Within the bay are a series of sub-basins separated by a network of small islands, called keys, and mudbanks. The mudbanks are submerged, accretionary features and are the primary sites in the bay for the accumulation of sediment, most of which is fine-grained calcium carbonate (mud) derived from calcareous organisms living within the bay (Stockman *et al.,* 1967; Enos and Perkins, 1979).

Waters of Florida Bay are composed primarily of a mixture of two salinity end-members: fresh, terrestrial runoff/discharge from the Everglades with a salinity of less than 1 ppt, and saline, surface waters from the Gulf of Mexico and Straits of Florida with salinity around 36 ppt. Mixing of these two end members leads to a general northeast-to-southwest salinity gradient.

The bay's salinity can also greatly exceed 36 ppt as a result of evaporation. Evaporative concentration of Florida Bay waters generally occurs during the dry season (~November to May) and salinity values ex-




Text-figure 1.—Map showing Florida Bay region and location of sample sites for this study. Also shown is the location of the coral studied by Swart *et al.* (1996).

ceeding 50 ppt have been reported in interior portions of the Bay (Ginsburg, 1972, and see reviews in Swart *et al.*, 1996 and McIvor *et al.*, 1994). Wet season (~May to October) rains bring new runoff from the Everglades and reverse the dry season trend of increasing salinity.

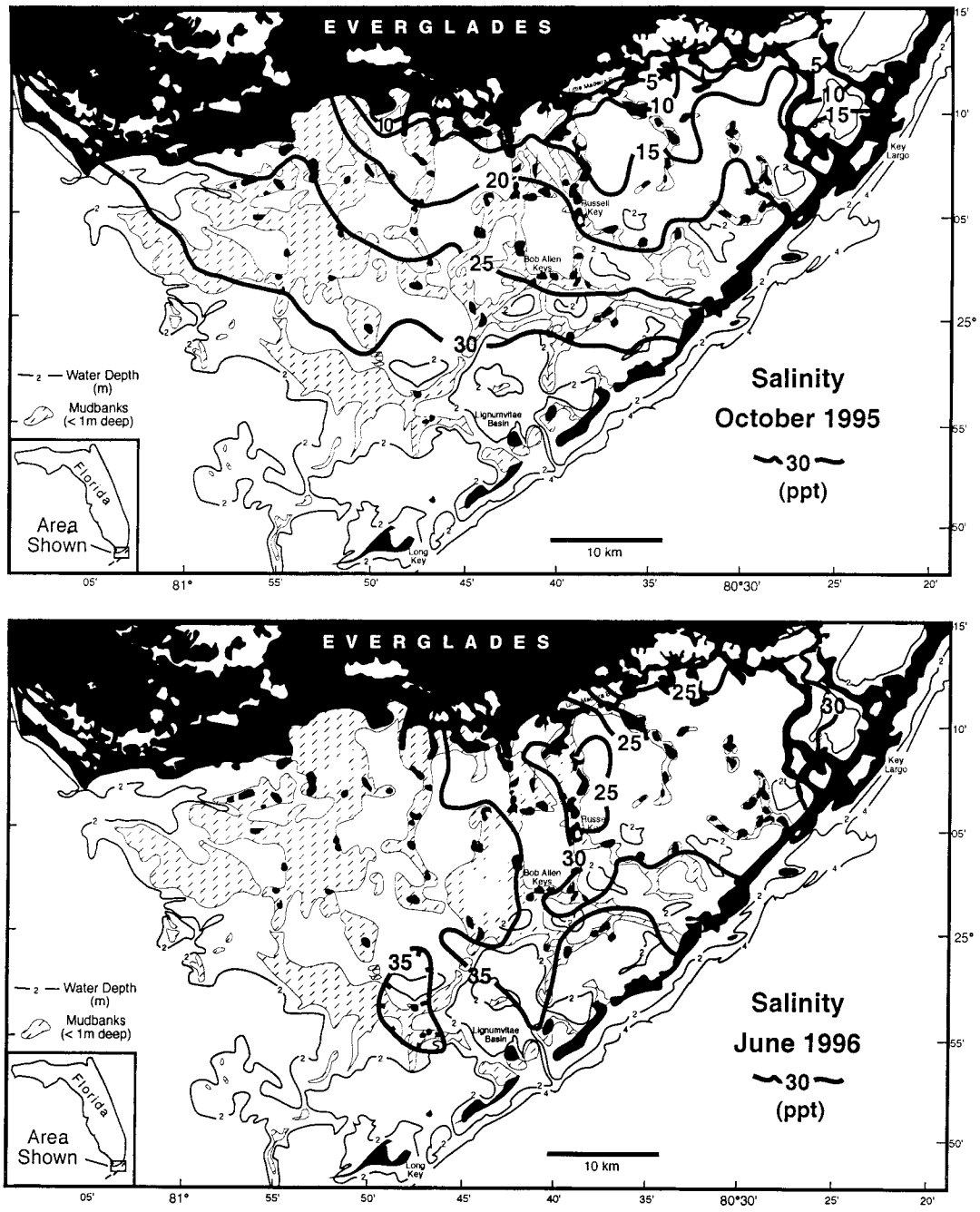
The strong influence of rainfall/runoff on the salinity of Florida Bay is evident from recent monitoring studies and varies in magnitude and timing with distance from the mainland (Text-fig. 2, Text-fig. 3). Shallow groundwater levels in the Everglades, which are largely controlled by rainfall, show a significant correlation with Florida Bay salinity providing further evidence of the impact rainfall/runoff on the salinity of Florida Bay (Tabb, 1967; White, 1983; as reviewed in McIvor *et al.*, 1994).

Unfortunately, these studies were conducted after significant modifications were made to the natural runoff system in South Florida, which previously was characterized by sheet flow south from Lake Okeechobee through the Everglades to Florida Bay (Miller, 1997). During this century, a complex network of canals and levees has been constructed in order to control flooding and to drain wetlands for agriculture, ultimately resulting in a lowering of the water table and an alteration of the near-surface hydrogeology over much of in southern Florida (RAIL, 1973; Miller, 1997). Just after the onset of canal construction around the turn of the century, the Miami to Key West railroad was completed, resulting in partial or complete closing of many of the ocean inlets between the Florida Keys. This has led to the hypothesis that the salinity of Florida Bay may have been markedly different prior to large-scale human activities in south Florida, an idea which we evaluate here by reconstructing the salinity history of central Florida Bay using the chemistry of fossil ostracode shells.

## CONTROLS ON OSTRACODE SHELL CHEMISTRY

### PREVIOUS STUDIES

Ostracodes are microcrustaceans that inhabit freshwater, brackish, marine, and hypersaline environments. They secrete a bivalved carapace, or shell, that is commonly preserved in sediments and whose chemistry is increasingly being used for paleoenvironmental reconstructions in various aquatic ecosystems (Chivas *et al.*, 1983; Holmes, 1996). The shell is composed mostly of the mineral calcite ($CaCO_3$), which co-precipitates minor amounts of foreign metals such as magnesium



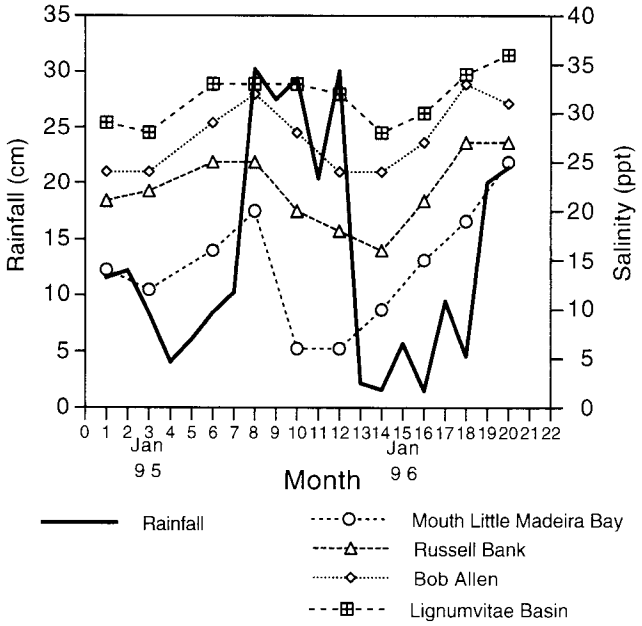

Text-figure 2.—Examples of salinity distribution in Florida Bay near the end of the wet (October) and dry (June) seasons. Contoured from Halley *et al.* data (1995).

and strontium, that substitute into the crystal lattice in place of calcium. The uptake of Mg or Sr into the calcitic ostracode shell can be described by the following equation:

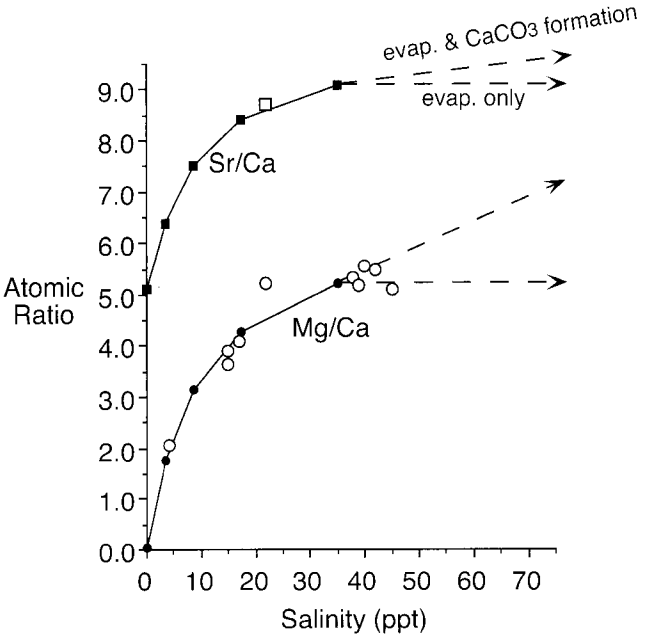
$$(\text{me/Ca})_{\text{ostracode calcite}} = (K_{\text{D-me}})(\text{me/Ca}_{\text{water}})$$

where me/Ca represents the atomic ratio of Mg (or Sr) to Ca, and $K_{\text{D-me}}$ is the element-specific partition coefficient. Thus, if $K_{\text{D-me}}$ is constant or can be constrained, then the me/Ca ratio in ostracode calcite can be used to determine the me/Ca ratio of the water in which the shell was secreted (see Wansard, 1996).

In the waters of Florida Bay, me/Ca ratios appear to vary with salinity as a result of mixing of freshwater runoff and discharge from the Everglades, and seawater (Text-fig. 4). Thus, $(\text{me/Ca})_{\text{water}}$, as calculated from $(\text{me/Ca})_{\text{ostracode calcite}}$, could be used to estimate Florida Bay salinity.




Text-figure 3.—Time series of monthly rainfall in South Florida (Florida Area 5, NOAA Data Archive) and bi-monthly salinity (Halley *et al.*, 1995) at four locations in Florida Bay for the period from November 1994 to June 1996. Note apparent amplitude decrease and delayed response of salinity change to rainfall with increased distance from mainland.




Text-figure 4.—Model data (connected filled symbols) showing the salinity dependence of Mg/Ca (mol/mol) and Sr/Ca (mmol/mol) in waters of Florida Bay. The model assumes conservative mixing of freshwater from the South Florida surficial aquifer system and seawater with the following elemental concentrations (ppm):

| | Ca | Mg | Sr | Na |
|---|---|---|---|---|
| Freshwater (Sonntag, 1987) | 90 | 5.6 | 0.8 | 26 |
| Seawater (salinity = 35 ppt, Chester, 1990) | 412 | 1290 | 7.9 | 10,770 |

Open symbols are ratios calculated from Florida Bay water analyses reported by Berner (1966) and Burns and Swart (1992), and they generally agree with the model data. At salinity above normal seawater, me/Ca ratios of Florida Bay waters may behave in a number of ways. Under simple evaporative concentration, ratios will remain unchanged. However, if evaporation concentration is accompanied by significant amounts of $CaCO_3$ precipitation (biogenic or inorganic), me/Ca ratios of bay waters will continue to increase along with salinity. Relative to Mg/Ca, this effect may be diminished for Sr/Ca because of the relatively high Sr/Ca ratio of aragonite, a mineral that makes up around 60% of the sediments deposited in Florida Bay (Burns and Swart, 1992).

In addition to $(me/Ca)_{water}$, other factors potentially control the uptake of foreign ions into calcite. From experimental and field studies with inorganic and biogenic calcite, $K_{D\text{-}Mg}$ has been shown to have a strong thermodependence (Chave, 1954; Chivas *et al.*, 1983; Cadot and Kaesler, 1977; Burton and Walter, 1991; Dwyer *et al.*, 1995). And $K_{D\text{-}Sr}$ appears to be controlled primarily by calcite precipitation rate (reviewed in Morse and McKenzie, 1990).

Aside from temperature and $Mg/Ca_{water}$, salinity may independently affect $K_{D\text{-}Mg}$. While most workers have concluded that $K_{D\text{-}Mg}$ is constant or increases with increasing salinity, two survey studies of shells of ostracode genus *Cyprideis* from shallow coastal ponds of widely varying salinity (0 to >120 ppt) indicated a negative relationship between $K_{D\text{-}Mg}$ and salinity (Teeter and Quick, 1990; Bodergat, 1985). Similarly, Wansard (1996) noted the apparent nonlinearity in $K_{D\text{-}Mg}$ for *Cyprideis* when comparing $K_{D\text{-}Mg}$ calculated for freshwater specimens from Lake Banyoles, Spain (0.0169) to the $K_{D\text{-}Mg}$ calculated for marine specimens by Chivas *et al.* (1986) (0.0045). Unfortunately, results of empirical field studies from sites with significant inter-annual environmental variability often are inconclusive because, even for live specimens, it is difficult to verify that the ostracode shells grew under the environmental conditions measured at the time of collection (*e.g.*, Xia *et al.*, 1997). To avoid the inherent uncertainties associated with field studies, DeDeckker *et al.* (1999) analyzed the chemistry of *Cyprideis* shells raised in laboratory cultures under controlled temperature, salinity, and $Mg/Ca_{water}$ conditions. Their results confirm the strong effects of water temperature and $Mg/Ca_{water}$ on the uptake of Mg and the lack of any salinity effect, positive or negative.

In addition to magnesium and strontium, ostracode shell calcite coprecipitates minor amounts of sodium. However, unlike Mg and Sr, Na is not incorporated in the calcite crystal lattice, but instead resides in crystal defect sites (Busenberg and Plummer, 1985). Evidently sodium uptake is controlled by the sulfate ($SO_4^{2-}$) concentration of the mother solution (Busenberg and

Plummer, 1985). As a conservative ion in estuarine settings (Chester, 1990), $SO_4^{2-}$ likely covaries with salinity in Florida Bay much like Ca, Mg, Sr, and Na. Therefore, the Na/Ca ratio of ostracode calcite may also be indirectly controlled by salinity and be useful for paleosalinity reconstructions in Florida Bay.

Phylogenetic and ontogenetic factors also influence $K_{D\text{-}Mg}$ and $K_{D\text{-}Sr}$ of ostracode calcite (Chave, 1954; Cadot and Kaesler, 1977; Chivas *et al.,* 1983), requiring the use of shells of same genus and of the same ontogenetic stage for meaningful paleoenvironmental reconstructions based on shell chemistry. Thus it is necessary to calibrate $K_{D\text{-}me}$ for shells of the species selected for paleoenvironmental reconsrtructions.

### Strategy to Develop Paleosalinity Equations

Our strategy was to determine partition coefficients ($K_{D\text{-}me}$) for foreign metals for adult shells of the common species *Loxoconcha matagordensis* on the basis of average me/Ca ratios for Florida Bay water and for average me/Ca ratios in modern specimens of *Loxoconcha matagordensis.* $K_{D\text{-}me}$ would then be used in conjunction with fossil shell me/Ca ratios to calculate past values of $me/Ca_{water}$ which in turn would be used to estimate salinity based on the relationship displayed in Text-figure 4.

This modern-average calibration method was preferred over a site-by-site direct calibration of measured salinity to modern shell Mg/Ca at the site (*i.e.,* Dwyer *et al.,* 1995) for three reasons. First, it is difficult to separate the effects of water temperature, which annually varies from about 15–33°C in Florida Bay, from those of salinity. Previous studies, as well as our own data shown below, suggest strong thermodependence of ostracode Mg/Ca ratios. Separating salinity and temperature effects in coastal environments is difficult for most geochemical and faunal proxies of past environmental conditions. However, because temperature and salinity are often positively correlated in Florida Bay waters (Swart *et al.,* 1996; results below), it is quite probable that downcore variability in ostracode shell Mg/Ca is due to changes in both factors (see discussion).

Second, although salinity and temperature were measured at the time of collection of modern *L. matagordensis,* the exact time that each individual ostracode secreted its adult shells was not known. Because adults of *L. matagordensis* live for several months and this species secretes its adult shells year round (King and Kornicker, 1970; Kamiya, 1988), then many adults, in fact, did not secrete their shell at the time of collection. Because salinity and temperature vary temporally and spatially, it is possible only to obtain a range of possible salinities and temperatures for the site for the previous few months.

Third, during our period of sampling, the mean salinity in the study area varied from ~23.9 ppt (February 1998) to ~33.6 ppt (July 1998). With few exceptions, our material does not include individuals that lived in extremely high (>40 ppt) or low (<18 ppt) salinity environments such as those experienced by Florida Bay historically (Robblee *et al.,* 1991). Consequently, a revised calibration should be developed in the future using individuals grown in cultures at known temperatures, over the widest salinity range possible, which for *L. matagordensis* is 10 to >50 ppt.

## METHODOLOGY

### Analyses of Water and Living Ostracode Shells

Water and ostracode samples for this study were collected from 25 U.S. Geological Survey sites across most of Florida Bay (Text-fig. 1). As part of a larger study to characterize the Florida Bay ecosystem, most of these sites have been sampled seasonally (February and July) since 1994 (Wingard *et al.,* this volume).

Water samples, filtered in the field using disposable 0.45 μm syringe filters, were collected from each of the 25 sites in July 1998 and February 1999. In addition, water samples (unfiltered) were collected in August 1997 from 51 sites in Biscayne Bay and the small bays that lie between Biscayne and Florida Bays. At each site, water temperature and salinity were measured in the field using routinely-calibrated YSI or Hydrolabs brand field instruments (Brewster-Wingard *et al.,* this volume).

Ca, Mg, Sr, and Na concentrations of the water samples were measured by direct current plasma atomic emission spectrophotometry (DCP) in the Plasma Lab at Duke University Earth and Ocean Sciences to determine the relationship between water me/Ca ratios and salinity of south Florida's coastal waters. Final data are reported as Mg/Ca, Sr/Ca, and Na/Ca atomic ratios with analytical precision, based on replicate analysis of IAPSO standard seawater, of ±1%, ±2%, and ±3%, respectively.

Ninety-seven living (whole carapaces with visible soft parts), adult specimens of *Loxoconcha matagordensis,* a cosmopolitan phytal ostracode in Florida Bay (Keyser, 1975; Cronin *et al.,* this volume), were collected from sub-aquatic vegetation from 16 of the 25 USGS sites in Florida Bay in February 1998, July 1998, and February 1999. Shell Mg/Ca, Sr/Ca, and Na/Ca ratios of these specimens were measured by DCP. Procedures follow those in Dwyer *et al.* (1995). An additional step included an overnight soaking of shells in full-strength commercial bleach to remove organic

matter prior to triple rinsing in deionized water. Results are reported as atomic ratios of Mg/Ca, Sr/Ca, and Na/Ca in mmol/mol. Analytical precision, based on replicate analysis of internal-consistency standards is less than ±2% for Mg/Ca and Sr/Ca ratios, and around ±8% for Na/Ca.

From six of the sites we also analyzed the Mg/Ca, Sr/Ca, and Na/Ca ratios of shells of dead adult specimens *of L. matagordensis* collected from the upper 10 cm of sediment push cores. These core-top specimens allowed a comparative evaluation of possible post-mortem alteration effects on shell chemistry.

### FOSSIL MATERIAL FROM SEDIMENT CORES

Mg/Ca, Sr/Ca, and Na/Ca ratios were measured on fossil ostracode shells from five 1 to 2 m long sediment cores. Four cores lie along a roughly north-south transect in central Florida Bay (Text-fig. 1). These include mudbank cores BA-6A, RB-19B, and PKK-23 collected in 1994 near Bob Allen, Russell, and Park Keys, respectively, and core T-24 collected from within Little Madeira Bay along the coast of the Everglades near the freshwater outflow region of Taylor Slough. The fifth core, MB-1, is from Manatee Bay in Barnes Sound, an adjacent embayment northeast of Florida Bay.

Chronstratigraphy for the cores was determined by uranium disequilibrium series methods (Wingard *et al.*, 1995; Brewster-Wingard *et al.*, 1997; Robbins *et al.*, in press) and preliminarily corroborated with exotic pollen horizon studies (Wingard *et al.*, 1995). Calculated linear sediment accumulation rates for BA-6A, RB-19B, and PKK-23A are 1.04, 1.22, and 0.78 cm/year, respectively, and were applied to the entire length of the core. Chronstratigraphic information for core T-24 and core MB-1 are still under development.

Samples for ostracode analysis were collected at approximately 2-cm intervals. Most intervals in the 5 cores contained ostracodes and the majority of these yielded adult valves for geochemical analysis. Shells of *Loxoconcha matagordensis* were sufficiently abundant to produce continuous records in the Russell and Park Key cores and the upper half of MB-1. $K_{D\text{-}me}$ values for *L. matagordensis* calculated from modern studies were then used to estimate salinity from fossil me/Ca ratios. In cores or intervals with insufficient numbers of *L. matagordensis* in (Bob Allen, T-24, and the lower half of MB-1; Cronin *et al.*, this volume) we analyzed adult shells of second genus, *Peratocytheridea.* However, no $K_{D\text{-}me}$ values are available for *Peratocytheridea,* so any down-core trends *Peratocytheridea* me/Ca ratios can only be interpreted qualitatively. Shells were prepared and analyzed for Ca, Mg, Sr, and Na by DCP as for modern specimens discussed above.

## RESULTS AND DISCUSSION

### WATER CHEMISTRY

The results of water chemistry analysis are listed in Table 1 and summarized in Text-figure 5. As shown in Text-figure 5, Mg/Ca and Sr/Ca ratios of Florida and Biscayne Bay decrease with decreasing salinity, shifting gradually from 35 ppt and 15 ppt and more steeply from 15 ppt to 0 ppt. Na/Ca ratios (not shown) behave similarly.

The trends observed are similar to that predicted from the preliminary water chemistry data presented in Text-figure 4 and the assumption of conservative mixing of Ca, Mg, Sr, and Na between seawater and freshwater runoff from southern peninsular Florida. Mg/Ca values overlap directly with Mg/Ca ratios calculated from the data of Berner (1966) who measured Mg and Ca concentrations at salinity ~5, 17, and 43 ppt in the 1960's.

The steep decrease in me/Ca ratios with salinity is not typical of estuaries of the eastern United States. More typically, estuarine waters show little or no change in Mg/Ca, Sr/Ca, or Na/Ca ratios, retaining seawater-like values well below 15 ppt. This occurs because, relative to South Florida runoff, terrestrial runoff is generally far more depleted in Ca, Mg, Sr, and Na and me/Ca ratios are thus overwhelmed by seawater. The relatively high concentration of these elements, especially Ca, in south Florida runoff is likely the result of interaction between surface water and upper Tertiary carbonate rocks of southern Florida.

Most importantly for this study, the similarities in water chemistry between Florida and Biscayne Bay sampled from 1997 to 1999 and the comparable Mg/Ca ratios obtained by Berner (1966) for Florida Bay suggest that the relationships between $me/Ca_{water}$ and salinity are regionally and temporally persistent.

### MODERN SHELL CHEMISTRY

Results of shell chemistry analyses of modern specimens of adult *Loxoconcha matagordensis* from vegetation samples and sediment core tops are listed in Table 2 and the results of vegetation specimens are summarized in Text-figure 6. Text-figure 6 shows shell Mg/Ca and Sr/Ca ratios versus measured ambient water salinity and temperature from sampling trips in February 1998, July 1998 and February 1999.

It is clear from Text-figure 6 that there are no obvious trends between modern shell me/Ca ratios across the entire range of measured water temperature and salinity. Mg/Ca ratios range from 23 to 54 mmol/mol. Shells from February 1999, covering the fewest number of sites in the three seasonal data sets, appear to show a positive correlation with both salinity and tem-

Table 1.—Chemistry of waters from Florida and Biscayne Bays. Calcium, magnesium, strontium, and sodium concentrations reported in ppm; Mg/Ca and Na/Ca as mol/mol, and Sr/Ca as mmol/mol. * Salinity determined using sodium concentration. Florida Bay sites correspond to map (Text-fig. 1). Biscayne Bay sample locations available from the authors.

| Sample site | Salinity (ppt) | Ca | Mg | Sr | Na | Mg/Ca | Sr/Ca | Na/Ca |
|---|---|---|---|---|---|---|---|---|
| *Florida Bay (July 1998)* | | | | | | | | |
| 1 | 26.9 | 332 | 1005 | 6 | 7792 | 4.99 | 8.39 | 40.86 |
| 2-Top | 23.96 | 333 | 972 | 6 | 6098 | 4.81 | 8.59 | 31.89 |
| 3-Top | 29.1 | 362 | 1105 | 7 | 8303 | 5.04 | 8.44 | 40.02 |
| 4 | 32.45 | 401 | 1272 | 8 | 9561 | 5.23 | 8.61 | 41.54 |
| 5 | 32.45 | 400 | 1249 | 7 | 9343 | 5.15 | 8.49 | 40.72 |
| 6 | 35.94 | 436 | 1379 | 8 | 10657 | 5.22 | 8.58 | 42.63 |
| 6-Top | 35.31 | 436 | 1370 | 8 | 10545 | 5.18 | 8.53 | 42.20 |
| 7 | 37.13 | 457 | 1431 | 8 | 10745 | 5.17 | 8.50 | 41.01 |
| 8 | 23.51 | 319 | 914 | 6 | 5824 | 4.72 | 8.37 | 31.78 |
| 9 | 28.24 | 412 | 1196 | 8 | 5831 | 4.79 | 8.52 | 24.67 |
| 10 | 34.63 | 435 | 1342 | 8 | 9860 | 5.08 | 8.48 | 39.47 |
| 11 | 30.78 | 380 | 1192 | 7 | 9161 | 5.17 | 8.56 | 41.98 |
| 12 | 36.85 | 432 | 1363 | 8 | 10523 | 5.20 | 8.60 | 42.42 |
| 13 | 40.12 | 503 | 1573 | 10 | 11372 | 5.16 | 8.67 | 39.45 |
| 14 | 40.1 | 498 | 1538 | 9 | 11400 | 5.09 | 8.66 | 39.91 |
| 15 | 36.75 | 453 | 1386 | 8 | 10512 | 5.04 | 8.48 | 40.42 |
| 15-Top | 36.18 | 450 | 1379 | 8 | 10684 | 5.05 | 8.61 | 41.41 |
| 16-Top | 38.77 | 432 | 1327 | 8 | 10424 | 5.07 | 8.58 | 42.10 |
| 17-Top | 34.61 | 422 | 1290 | 8 | 9573 | 5.04 | 8.46 | 39.52 |
| 18 | 36.74 | 438 | 1352 | 8 | 10454 | 5.09 | 8.56 | 41.63 |
| 20 | 27.82 | 349 | 1054 | 6 | 8023 | 4.97 | 8.29 | 40.03 |
| 21 | 39.34 | 469 | 1441 | 9 | 10946 | 5.06 | 8.67 | 40.66 |
| 21-Top | 38.72 | 459 | 1405 | 9 | 10764 | 5.05 | 8.54 | 40.86 |
| 22-Top | 38.56 | 469 | 1455 | 9 | 11104 | 5.11 | 8.69 | 41.24 |
| 23-Top | 36.25 | 433 | 1368 | 8 | 10639 | 5.21 | 8.65 | 42.84 |
| 24 | 35.93 | 423 | 1307 | 8 | 10191 | 5.10 | 8.51 | 42.03 |
| 24-Top | 35.65 | 431 | 1337 | 8 | 10326 | 5.12 | 8.50 | 41.80 |
| 25 | 35.57 | 427 | 1301 | 8 | 10126 | 5.02 | 8.46 | 41.31 |
| 26-Top | 35.18 | 420 | 1304 | 8 | 10320 | 5.12 | 8.63 | 42.82 |
| *Florida Bay (February 1999)* | | | | | | | | |
| 1 | 28.16 | 298 | 824 | 6 | 5704 | 4.55 | 8.45 | 33.32 |
| 1 | 28.16 | 299 | 814 | 5 | 5384 | 4.48 | 8.24 | 31.34 |
| 2 | 25.24 | 359 | 1026 | 7 | 6205 | 4.71 | 8.35 | 30.14 |
| 3 | 29.27 | 385 | 1145 | 7 | 8520 | 4.90 | 8.30 | 38.54 |
| 4 | 27.81 | 366 | 1090 | 7 | 8281 | 4.91 | 8.33 | 39.43 |
| 5 | 29.35 | 389 | 1145 | 7 | 8470 | 4.85 | 8.22 | 37.93 |
| 6 | 28.87 | 374 | 1111 | 7 | 8317 | 4.90 | 8.25 | 38.75 |
| 7 | 30.47 | 383 | 1160 | 7 | 9021 | 4.99 | 8.30 | 41.02 |
| 8 | 19.38 | 286 | 795 | 5 | 5003 | 4.59 | 8.19 | 30.51 |
| 9 | 24.06 | 343 | 996 | 6 | 6141 | 4.79 | 8.35 | 31.23 |
| 10 | 26.86 | 367 | 1078 | 7 | 6357 | 4.84 | 8.38 | 30.19 |
| 11 | 27.04 | 358 | 1058 | 6 | 8047 | 4.88 | 8.24 | 39.22 |
| 12 | 28.61 | 370 | 1106 | 7 | 8362 | 4.94 | 8.38 | 39.45 |
| 13 | 33.17 | 418 | 1262 | 8 | 9454 | 4.97 | 8.21 | 39.41 |
| 14 | 32.94 | 422 | 1287 | 8 | 9735 | 5.03 | 8.37 | 40.24 |
| 15 | 34.62 | 443 | 1340 | 8 | 9880 | 4.99 | 8.34 | 38.87 |
| 16 | 35.34 | 447 | 1363 | 8 | 10012 | 5.03 | 8.50 | 39.06 |
| 17 | 32.54 | 427 | 1308 | 8 | 9953 | 5.05 | 8.65 | 40.63 |
| 17-banktop* | 31.3 | 417 | 1262 | 8 | 9583 | 4.99 | 8.40 | 40.03 |
| 18 | 35.76 | 455 | 1401 | 9 | 10250 | 5.08 | 8.57 | 39.31 |
| 20 | 24.97 | 347 | 1023 | 6 | 6154 | 4.85 | 8.53 | 30.89 |
| 21 | 34.72 | 440 | 1313 | 8 | 9618 | 4.92 | 8.18 | 38.09 |
| 21 | 34.72 | 443 | 1333 | 8 | 9633 | 4.96 | 8.25 | 37.91 |
| 21-lake* | 36.9 | 543 | 1646 | 11 | 11288 | 5.00 | 8.86 | 36.27 |
| 21-lake* | 35.4 | 544 | 1638 | 10 | 10841 | 4.97 | 8.70 | 34.75 |
| 22 | 35.11 | 427 | 1302 | 8 | 9753 | 5.03 | 8.56 | 39.81 |
| 23 | 34.04 | 428 | 1298 | 8 | 9707 | 5.00 | 8.49 | 39.54 |
| 24 | 35.13 | 416 | 1257 | 8 | 9426 | 4.98 | 8.37 | 39.48 |
| 26 | 33.51 | 409 | 1223 | 8 | 9414 | 4.93 | 8.40 | 40.15 |
| 26 | 33.51 | 408 | 1215 | 7 | 9201 | 4.91 | 8.29 | 39.34 |

Table 1.—Continued.

| Sample site | Salinity (ppt) | Ca | Mg | Sr | Na | Mg/Ca | Sr/Ca | Na/Ca |
|---|---|---|---|---|---|---|---|---|
| *Biscayne Bay (August 1997)* | | | | | | | | |
| MR06 | 0.3 | 64 | 9 | 1 | 3 | 0.23 | 4.35 | 0.07 |
| TM02 | 0.3 | 66 | 8 | 1 | −1 | 0.20 | 4.02 | −0.04 |
| MR07 | 0.4 | 60 | 11 | 1 | 11 | 0.31 | 5.71 | 0.33 |
| MR05 | 0.5 | 66 | 14 | 1 | 43 | 0.34 | 4.88 | 1.13 |
| MR04 | 0.7 | 71 | 26 | 1 | 172 | 0.60 | 5.05 | 4.23 |
| MR03 | 1.2 | 76 | 39 | 1 | 306 | 0.85 | 5.20 | 7.08 |
| WC02 | 1.4 | 80 | 42 | 1 | 367 | 0.87 | 5.68 | 8.05 |
| SP01 | 2.3 | 88 | 65 | 1 | 562 | 1.21 | 4.65 | 11.10 |
| SK01 | 2.7 | 92 | 94 | 1 | 771 | 1.68 | 5.72 | 14.58 |
| MR02 | 2.8 | 93 | 94 | 1 | 787 | 1.67 | 5.91 | 14.81 |
| LR03 | 3.8 | 96 | 87 | 1 | 723 | 1.49 | 5.50 | 13.11 |
| PR01 | 5.1 | 141 | 172 | 2 | 1380 | 2.01 | 6.11 | 17.08 |
| BL02 | 9.4 | 174 | 334 | 3 | 2099 | 3.17 | 7.24 | 21.04 |
| AR01 | 10.9 | 190 | 387 | 3 | 3020 | 3.37 | 7.32 | 27.76 |
| BL01 | 12.4 | 203 | 469 | 3 | 3478 | 3.80 | 7.63 | 29.84 |
| MW01 | 12.6 | 198 | 449 | 3 | 3370 | 3.74 | 7.59 | 29.70 |
| GL02 | 13.4 | 205 | 459 | 3 | 3408 | 3.69 | 7.71 | 28.94 |
| MR01 | 16.4 | 142 | 279 | 2 | 2411 | 3.24 | 7.12 | 29.66 |
| BB51 | 17.4 | 233 | 632 | 4 | 4418 | 4.46 | 8.19 | 32.99 |
| BB01 | 18.2 | 267 | 697 | 5 | 4658 | 4.31 | 8.05 | 30.45 |
| LR01 | 19.1 | 126 | 209 | 2 | 1835 | 2.74 | 6.45 | 25.36 |
| MI01 | 20.8 | 269 | 708 | 5 | 5047 | 4.34 | 8.01 | 32.71 |
| CG01 | 23.3 | 290 | 755 | 5 | 5253 | 4.29 | 8.04 | 31.54 |
| BB03 | 23.6 | 328 | 918 | 6 | 5775 | 4.61 | 8.16 | 30.71 |
| CD01 | 23.7 | 319 | 874 | 6 | 5680 | 4.52 | 8.14 | 31.06 |
| BB50 | 24.1 | 317 | 891 | 6 | 5798 | 4.64 | 8.33 | 31.90 |
| BB48 | 26 | 320 | 945 | 6 | 7464 | 4.88 | 8.39 | 40.71 |
| BB48 | 26 | 317 | 938 | 6 | 7537 | 4.88 | 8.46 | 41.49 |
| BB09 | 26.4 | 314 | 919 | 6 | 7353 | 4.82 | 8.32 | 40.82 |
| BB39A | 26.9 | 346 | 1029 | 6 | 7903 | 4.91 | 8.37 | 39.87 |
| BB34 | 29 | 327 | 964 | 6 | 7562 | 4.86 | 8.29 | 40.29 |
| BB47 | 30.2 | 366 | 1110 | 7 | 8686 | 5.00 | 8.41 | 41.39 |
| BB10 | 31.1 | 384 | 1166 | 7 | 8912 | 5.00 | 8.35 | 40.41 |
| BB27 | 31.7 | 386 | 1174 | 7 | 9009 | 5.02 | 8.48 | 40.68 |
| BB5A | 31.9 | 398 | 1220 | 7 | 9292 | 5.06 | 8.46 | 40.75 |
| BB23 | 32 | 383 | 1165 | 7 | 9009 | 5.01 | 8.51 | 40.98 |
| BB29 | 32.1 | 392 | 1191 | 7 | 9114 | 5.01 | 8.47 | 40.55 |
| BB31 | 32.4 | 393 | 1206 | 7 | 9233 | 5.06 | 8.57 | 41.01 |
| BB28 | 32.6 | 394 | 1200 | 7 | 9122 | 5.03 | 8.39 | 40.38 |
| BB44 | 32.9 | 397 | 1219 | 7 | 9338 | 5.06 | 8.54 | 40.99 |
| BB41 | 33 | 390 | 1210 | 7 | 9274 | 5.12 | 8.59 | 41.48 |
| BB45 | 33.1 | 400 | 1220 | 7 | 9240 | 5.04 | 8.41 | 40.31 |
| BB45 | 33.1 | 393 | 1218 | 7 | 9362 | 5.11 | 8.57 | 41.51 |
| BB32 | 33.8 | 372 | 1151 | 7 | 8917 | 5.10 | 8.53 | 41.78 |
| NNH | 33.9 | 412 | 1273 | 8 | 9538 | 5.10 | 8.53 | 40.41 |
| BB25 | 35.2 | 413 | 1283 | 8 | 10087 | 5.13 | 8.47 | 42.60 |
| BB46 | 35.2 | 416 | 1305 | 8 | 10320 | 5.18 | 8.62 | 43.29 |
| BB07 | 35.6 | 427 | 1330 | 8 | 10513 | 5.14 | 8.62 | 42.94 |
| BB35 | 35.8 | 420 | 1322 | 8 | 10265 | 5.18 | 8.59 | 42.56 |
| BB42 | 36.1 | 428 | 1353 | 8 | 10615 | 5.22 | 8.78 | 43.28 |
| BB36 | 36.4 | 430 | 1335 | 8 | 10174 | 5.12 | 8.41 | 41.25 |
| BB43 | 36.7 | 433 | 1354 | 8 | 10474 | 5.15 | 8.40 | 42.16 |
| BB37 | 37.3 | 436 | 1374 | 8 | 10707 | 5.19 | 8.67 | 42.81 |
| BB39* | 33.9 | 425 | 1329 | 8 | 10377 | 5.16 | 8.63 | 42.57 |
| *Standards** | | | | | | | | |
| IAPSO | 33.4 | 422 | 1314 | 8 | 10235 | 5.14 | 8.28 | 42.29 |
| IAPSO | 33.0 | 424 | 1310 | 8 | 10093 | 5.10 | 8.14 | 41.54 |
| IAPSO | 32.7 | 432 | 1328 | 8 | 10015 | 5.07 | 8.33 | 40.43 |
| IAPSO | 35.1 | 430 | 1334 | 8 | 10740 | 5.12 | 8.57 | 43.57 |
| IAPSO | 33.5 | 440 | 1345 | 8 | 10247 | 5.05 | 8.38 | 40.64 |
| IAPSO | 32.9 | 436 | 1349 | 8 | 10077 | 5.10 | 8.38 | 40.26 |

Table 2.—Chemistry of living and sediment coretop shells of adult specimens of *Loxoconcha matagordensis*. Mg/Ca, Sr/Ca, and Na/Ca ratios reported as mmol/mol. * Salinity determined using sodium concentration. Florida Bay sites correspond to map (Text-fig. 1). Sample descriptors (e.g. #1, A) refer to separate subsamples from the sites. Biscayne Bay sample BB51 is located near the MB1 core site (Text-fig. 1). VPI (visual preservation index) is a measure of shell clarity ranging from 1 (clear, unaltered) to 7 (opaque, highly altered).

| Sample Site | Temp. (°C) | Salinity (ppt) | VPI | Mg/Ca | Sr/Ca | Na/Ca |
|---|---|---|---|---|---|---|
| Florida Bay Living Specimens | | | | | | |
| *February 1998* | | | | | | |
| 17 | 25.9 | 31.7 | 4 | 29.13 | 3.47 | 14.18 |
| 17 | 25.9 | 31.7 | 4 | 26.06 | 3.39 | 12.21 |
| 17 | 25.9 | 31.7 | 4 | 35.64 | 3.46 | 15.41 |
| 17 | 25.9 | 31.7 | 4 | 37.78 | 3.65 | 15.04 |
| 17 | 25.9 | 31.7 | 4 | 29.20 | 3.34 | 13.77 |
| 17 | 25.9 | 31.7 | 4 | 43.08 | 3.70 | 17.56 |
| 1 | 21 | 15.8 | 4 | 37.70 | 3.79 | 15.70 |
| 1 | 21 | 15.8 | 4 | 36.59 | 3.57 | 16.03 |
| 1 | 21 | 15.8 | 3 | 38.64 | 3.86 | 15.85 |
| 1 | 21 | 15.8 | 2 | 46.84 | 3.29 | 17.03 |
| 1#1 | 21 | 15.8 | 2.5 | 37.14 | 3.98 | 16.78 |
| 1#1 | 21 | 15.8 | 2.5 | 27.01 | 4.18 | 14.53 |
| 1#1 | 21 | 15.8 | 2.5 | 28.18 | 3.60 | 18.45 |
| 4#4 | 21.6 | 16.7 | 2.5 | 29.85 | 3.81 | 26.86 |
| 4#4 | 21.6 | 16.7 | 2.5 | 35.58 | 4.10 | 16.43 |
| 5#5 | 21.9 | 17.6 | 2.5 | 40.34 | 3.68 | 14.57 |
| 5#5 | 21.9 | 17.6 | 2.5 | 39.68 | 4.05 | 15.44 |
| 5#5 | 21.9 | 17.6 | 2.5 | 26.70 | 4.19 | 13.95 |
| 8#1 | 20 | 15.2 | 2.5 | 26.50 | 4.10 | 13.67 |
| 8#1 | 20 | 15.2 | 2.5 | 25.59 | 4.01 | 11.88 |
| 8#1 | 20 | 15.2 | 2.5 | 30.56 | 4.23 | 14.78 |
| 11#5 | 19.4 | 19.3 | 2.5 | 37.53 | 3.69 | 15.44 |
| 11#5 | 19.4 | 19.3 | 2.5 | 44.98 | 3.99 | 13.96 |
| 11#5 | 19.4 | 19.3 | 2.5 | 35.34 | 3.86 | 16.02 |
| 12#2 | 21.6 | 20.7 | 2.5 | 29.20 | 3.93 | 16.55 |
| 12#2 | 21.6 | 20.7 | 2.5 | 25.94 | 3.78 | 14.04 |
| 14#1 | 23.8 | 26.9 | 2.5 | 29.85 | 3.76 | 15.56 |
| 14#1 | 23.8 | 26.9 | 2.5 | 27.73 | 3.53 | 16.77 |
| 16#1 | 26.3 | 30.1 | 2.5 | 28.17 | 3.91 | 15.74 |
| 16#1 | 26.3 | 30.1 | 2.5 | 28.81 | 3.93 | 18.28 |
| 16#1 | 26.3 | 30.1 | 2.5 | 26.42 | 3.58 | 14.84 |
| 17#3 | 25.9 | 31.7 | 2.5 | 24.46 | 3.67 | 14.87 |
| 17#3 | 25.9 | 31.7 | 2.5 | 30.07 | 3.59 | 16.97 |
| 18#2 | 24.9 | 29.7 | 2.5 | 26.12 | 3.64 | 15.24 |
| 18#2 | 24.9 | 29.7 | 2.5 | 29.74 | 3.76 | 16.13 |
| 20#1 | 19.9 | 17.1 | 2.5 | 25.33 | 4.01 | 14.61 |
| 20#1 | 19.9 | 17.1 | 2.5 | 31.13 | 4.01 | 15.61 |
| 20#1 | 19.9 | 17.1 | 2.5 | 29.91 | 3.86 | 14.23 |
| 21 Shell | 24 | 28.9 | 2.5 | 29.53 | 4.02 | 15.79 |
| 21 Shell | 24 | 28.9 | 2.5 | 29.02 | 3.70 | 15.36 |
| 21 Shell | 24 | 28.9 | 2.5 | 29.93 | 3.70 | 14.06 |
| 22#1 | 24.9 | 30.2 | 2.5 | 23.41 | 3.70 | 12.31 |
| 22#1 | 24.9 | 30.2 | 2.5 | 22.53 | 3.91 | 13.93 |
| 22#1 | 24.9 | 30.2 | 2.5 | 30.89 | 3.54 | 14.83 |
| 23#1 | 23.5 | 33 | 2.5 | 26.94 | 3.53 | 15.56 |
| 26#1 | 27.6 | 31.6 | 2.5 | 36.37 | 3.70 | 14.94 |
| 26#1 | 27.6 | 31.6 | 2.5 | 34.11 | 3.45 | 14.50 |

Table 2.—Continued.

| Sample Site | Temp. (°C) | Salinity (ppt) | VPI | Mg/Ca | Sr/Ca | Na/Ca |
|---|---|---|---|---|---|---|
| *July 1998* | | | | | | |
| 17#1 | 28.42 | 36.25 | 2.5 | 40.70 | 4.05 | 14.71 |
| 1A#3 | 31.3 | 26.9 | 2.5 | 39.71 | 4.31 | 17.09 |
| 1A#3 | 31.3 | 26.9 | 2.5 | 35.88 | 3.96 | 13.99 |
| 23#1 | 31.94 | 36.76 | 2.5 | 44.49 | 3.68 | 17.00 |
| 22#1 | 30.42 | 39.93 | 2.5 | 36.11 | 4.20 | 14.34 |
| 22#1 | 30.42 | 39.93 | 2.5 | 42.48 | 4.27 | 15.17 |
| 8A#2 | 30.86 | 23.88 | 2.5 | 38.22 | 3.97 | 16.45 |
| 8A#2 | 30.86 | 23.88 | 2.5 | 43.36 | 4.16 | 14.66 |
| 16#2 | 29.38 | 38.73 | 2.5 | 37.85 | 4.01 | 21.72 |
| 16#2 | 29.38 | 38.73 | 2.5 | 32.71 | 3.77 | 17.22 |
| 11A#2 | 32.99 | 33.13 | 2.5 | 39.95 | 3.83 | 14.00 |
| 11A#2 | 32.99 | 33.13 | 2.5 | 35.85 | 3.92 | 13.38 |
| 11A#2 | 32.99 | 33.13 | 2.5 | 41.72 | 3.75 | 16.57 |
| 5A#2 | 33.42 | 31.94 | 2.5 | 39.79 | 3.55 | 15.46 |
| 12A#2 | 34.58 | 36.97 | 2.5 | 38.14 | 3.83 | 16.53 |
| 12A#2 | 34.58 | 36.97 | 2.5 | 35.41 | 4.02 | 14.87 |
| 18#1 | 29.25 | 37.15 | 2.5 | 37.98 | 3.89 | 14.65 |
| 18#1 | 29.25 | 37.15 | 2.5 | 44.97 | 3.84 | 18.69 |
| 18#1 | 29.25 | 37.15 | 2.5 | 43.09 | 3.65 | 16.34 |
| 20A#3 | 32.02 | 28.15 | 2.5 | 35.31 | 4.23 | 16.91 |
| 20A#3 | 32.02 | 28.15 | 2.5 | 38.60 | 4.62 | 18.97 |
| 26#2 | 33.26 | 35.43 | 2.5 | 32.89 | 3.72 | 17.12 |
| 26#2 | 33.26 | 35.43 | 2.5 | 34.51 | 3.33 | 16.87 |
| 26#2 | 33.26 | 35.43 | 2.5 | 35.40 | 3.41 | 16.32 |
| 6A | 33.29 | 35.94 | 2.5 | 39.06 | 3.97 | 16.24 |
| 6A | 33.29 | 35.94 | 2.5 | 41.54 | 3.93 | 15.68 |
| 6A | 33.29 | 35.94 | 2.5 | 42.19 | 4.03 | 15.23 |
| 4A#1 | 32.88 | 32.15 | 2.5 | 38.18 | 3.90 | 14.24 |
| 4A#1 | 32.88 | 32.15 | 2.5 | 45.04 | 3.84 | 16.89 |
| 4A#1 | 32.88 | 32.15 | 2.5 | 42.49 | 3.79 | 14.55 |
| 14#1 | 33.01 | 41.03 | 2.5 | 30.04 | 3.69 | 17.62 |
| 14#1 | 33.01 | 41.03 | 2.5 | 29.70 | 3.90 | 18.85 |
| 14#1 | 33.01 | 41.03 | 2.5 | 34.29 | 4.23 | 14.39 |
| 22 | 30.4 | 39.9 | 3 | 38.82 | 4.00 | 16.63 |
| 22 | 30.4 | 39.9 | 3 | 35.30 | 4.18 | 16.90 |
| 22 | 30.4 | 39.9 | 5 | 37.46 | 4.32 | 27.50 |
| 8 | 30.9 | 23.9 | 4 | 44.42 | 3.86 | 13.72 |
| 8 | 30.9 | 23.9 | 4 | 37.95 | 4.47 | 16.25 |
| 8 | 30.9 | 23.9 | 1 | 50.39 | 4.02 | 16.04 |
| 8 | 30.9 | 23.9 | 4 | 41.77 | 4.11 | 14.16 |
| 8 | 30.9 | 23.9 | 4 | 44.62 | 3.75 | 12.76 |
| *February 1999* | | | | | | |
| 18 | 22.6 | 35.8 | 3 | 44.99 | 3.32 | 15.30 |
| 18 | 22.6 | 35.8 | 3 | 33.53 | 3.45 | 15.60 |
| 18 | 22.6 | 35.8 | 3 | 46.06 | 3.75 | 17.42 |
| 18 | 22.6 | 35.8 | 3 | 38.74 | 3.74 | 16.33 |
| 18 | 22.6 | 35.8 | 3 | 53.83 | 3.36 | 14.16 |
| 8 | 20 | 19.4 | 3 | 31.73 | 4.35 | 15.87 |
| 8 | 20 | 19.4 | 3 | 37.92 | 4.03 | 18.78 |
| 8 | 20 | 19.4 | 3 | 38.77 | 4.05 | 15.60 |
| 8 | 20 | 19.4 | 2 | 37.34 | 4.42 | 15.65 |
| 8 | 20 | 19.4 | 3 | 33.99 | 4.25 | 15.35 |

Table 2.—Continued.

| Sample Site | Temp. (°C) | Salinity (ppt) | VPI | Mg/Ca | Sr/Ca | Na/Ca |
|---|---|---|---|---|---|---|
| Coretop Specimens | | | | | | |
| *Florida Bay (July 1998)* | | | | | | |
| 22 | 30.42 | 39.93 | 2.5 | 35.87 | 3.85 | 16.27 |
| 22 | 30.42 | 39.93 | 2.5 | 36.09 | 3.58 | 18.30 |
| 26 | 33.26 | 35.43 | 2.5 | 33.85 | 3.90 | 15.77 |
| 26 | 33.26 | 35.43 | 2.5 | 39.68 | 3.61 | 14.73 |
| 26 | 33.26 | 35.43 | 2.5 | 35.75 | 3.76 | 16.99 |
| 26 | 33.26 | 35.43 | 2.5 | 34.83 | 3.73 | 15.50 |
| 21 | 30.34 | 39.34 | 2.5 | 35.93 | 3.96 | 17.47 |
| 21 | 30.34 | 39.34 | 2.5 | 24.22 | 3.69 | 15.52 |
| 21 | 30.34 | 39.34 | 2.5 | 30.81 | 3.66 | 15.40 |
| 21 | 30.34 | 39.34 | 2.5 | 39.53 | 4.13 | 16.69 |
| 23 | 31.94 | 36.76 | 2.5 | 34.42 | 3.95 | 15.97 |
| 23 | 31.94 | 36.76 | 2.5 | 37.62 | 3.84 | 16.73 |
| 1B | 31.3 | 26.9 | 2.5 | 40.72 | 3.85 | 16.13 |
| 1B | 31.3 | 26.9 | 2.5 | 42.00 | 3.77 | 17.44 |
| 1B | 31.3 | 26.9 | 2.5 | 36.14 | 3.69 | 15.89 |
| 1B | 31.3 | 26.9 | 2.5 | 37.58 | 3.69 | 14.73 |
| 1B | 31.3 | 26.9 | 2.5 | 42.42 | 3.80 | 17.89 |
| 1B | 31.3 | 26.9 | 2.5 | 33.82 | 3.76 | 14.98 |
| 1B | 31.3 | 26.9 | 2.5 | 33.10 | 3.81 | 16.75 |
| 1B | 31.3 | 26.9 | 2.5 | 38.18 | 3.67 | 15.50 |
| 1B | 31.3 | 26.9 | 2.5 | 30.27 | 3.21 | 15.15 |
| 1B | 31.3 | 26.9 | 2.5 | 49.81 | 4.14 | 13.99 |
| 1B | 31.3 | 26.9 | 2.5 | 46.15 | 4.02 | 16.34 |
| 1B | 31.3 | 26.9 | 2.5 | 41.46 | 3.71 | 14.84 |
| 20A | 32.02 | 28.15 | 2.5 | 36.25 | 3.75 | 15.06 |
| 9 | 31.32 | 28.8 | 2.5 | 37.35 | 3.46 | 16.03 |
| 9 | 31.32 | 28.8 | 2.5 | 52.15 | 3.31 | 11.09 |
| 9 | 31.32 | 28.8 | 2.5 | 48.07 | 4.02 | 15.59 |
| 9 | 31.32 | 28.8 | 2.5 | 39.17 | 3.52 | 15.57 |
| 9 | 31.32 | 28.8 | 2.5 | 42.45 | 4.28 | 14.08 |
| 9 | 31.32 | 28.8 | 2.5 | 40.73 | 3.68 | 14.37 |
| 15 | 28.54 | 36.75 | 2.5 | 48.59 | 3.38 | 14.35 |
| 15 | 28.54 | 36.75 | 2.5 | 50.19 | 3.76 | 14.20 |
| 15 | 28.54 | 36.75 | 2.5 | 46.59 | 3.80 | 17.16 |
| 15 | 28.54 | 36.75 | 2.5 | 34.57 | 3.83 | 17.11 |
| 15 | 28.54 | 36.75 | 2.5 | 36.45 | 4.11 | 17.40 |
| 22 | 30.42 | 39.93 | 2.5 | 36.07 | 3.77 | 16.75 |
| 22 | 30.42 | 39.93 | 2.5 | 36.67 | 3.86 | 14.84 |
| 26 | 33.26 | 35.43 | 2.5 | 51.86 | 2.90 | 12.46 |
| 26 | 33.26 | 35.43 | 2.5 | 44.47 | 3.24 | 15.40 |
| 26 | 33.26 | 35.43 | 2.5 | 34.52 | 3.39 | 15.53 |
| 26 | 33.26 | 35.43 | 2.5 | 32.05 | 3.74 | 14.71 |
| 26 | 33.26 | 35.43 | 2.5 | 43.11 | 3.59 | 15.46 |
| 21 | 30.34 | 39.34 | 2.5 | 43.41 | 3.71 | 16.24 |
| 21 | 30.34 | 39.34 | 2.5 | 36.39 | 3.26 | 16.21 |
| 21 | 30.34 | 39.34 | 2.5 | 39.86 | 3.75 | 13.33 |
| 23 | 31.94 | 36.76 | 2.5 | 43.07 | 4.04 | 17.16 |
| 23 | 31.94 | 36.76 | 2.5 | 39.89 | 3.75 | 15.58 |
| 23 | 31.94 | 36.76 | 2.5 | 39.55 | 3.98 | 17.76 |
| 23 | 31.94 | 36.76 | 2.5 | 36.94 | 3.57 | 15.11 |
| 1B | 31.3 | 26.9 | 2.5 | 44.04 | 4.06 | 17.16 |
| 1B | 31.3 | 26.9 | 2.5 | 45.40 | 3.39 | 16.51 |
| 1B | 31.3 | 26.9 | 2.5 | 39.83 | 3.70 | 16.01 |
| 1B | 31.3 | 26.9 | 2.5 | 34.23 | 3.51 | 13.89 |
| 1B | 31.3 | 26.9 | 2.5 | 33.38 | 4.17 | 13.38 |
| 1B | 31.3 | 26.9 | 2.5 | 42.95 | 3.96 | 14.50 |
| 20A | 32.02 | 28.15 | 2.5 | 36.22 | 3.37 | 15.86 |
| 20A | 32.02 | 28.15 | 2.5 | 42.39 | 4.12 | 15.89 |
| 20A | 32.02 | 28.15 | 2.5 | 46.61 | 3.69 | 15.99 |

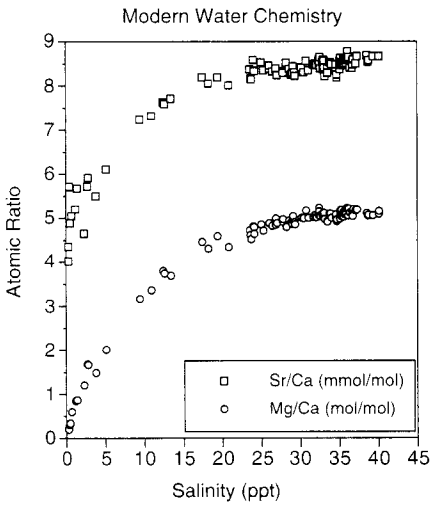
Table 2.—Continued.

| Sample Site | Temp. (°C) | Salinity (ppt) | VPI | Mg/Ca | Sr/Ca | Na/Ca |
|---|---|---|---|---|---|---|
| 9 | 31.32 | 28.8 | 2.5 | 48.09 | 3.89 | 13.58 |
| 9 | 31.32 | 28.8 | 2.5 | 38.72 | 3.89 | 16.57 |
| 9 | 31.32 | 28.8 | 2.5 | 38.89 | 4.01 | 13.27 |
| 9 | 31.32 | 28.8 | 2.5 | 28.74 | 3.90 | 15.20 |
| 9 | 31.32 | 28.8 | 2.5 | 37.77 | 3.53 | 14.71 |
| 15 | 28.54 | 36.75 | 2 | 40.00 | 3.71 | 16.54 |
| *Biscayne Bay (August 1997)* | | | | | | |
| BB51 | 31.35 | 17.4 | 3 | 33.14 | 3.64 | 16.39 |
| BB51 | 31.35 | 17.4 | 3 | 30.81 | 3.73 | 17.43 |
| BB51 | 31.35 | 17.4 | 3 | 37.59 | 4.11 | 15.76 |
| BB51 | 31.35 | 17.4 | 4 | 42.50 | 3.91 | 14.98 |
| BB51 | 31.35 | 17.4 | 3 | 32.50 | 3.46 | 15.52 |
| BB51 | 31.35 | 17.4 | 2 | 31.02 | 3.55 | 16.47 |
| BB51 | 31.35 | 17.4 | 3 | 40.05 | 3.64 | 16.55 |
| BB51 | 31.35 | 17.4 | 2 | 41.04 | 3.83 | 17.35 |

perature. There also seems to be broad positive correlation between Mg/Ca and temperature. Furthermore, shells collected from July 1998, when both salinity and temperature were relatively high, all have Mg/Ca ratios > ~30 mmol/mol.

Sr/Ca ratios range from 3.3 to 4.6 mmol/mol and appear to display a broad negative correlation with both salinity and temperature, especially within the February data. Na/Ca ratios (not shown) range from 12 to 19 mmol/mol and show no variation with salinity or temperature.

Core-top specimens (Table 2), consisting of both articulated and disarticulated valves, yield Mg/Ca, Sr/Ca, and Na/Ca ratios that are indistinguishable from those of vegetation samples. This implies that post-mortem effects on shell me/Ca ratios in Florida Bay are neg-




Text-figure 5.—Mg/Ca and Sr/Ca ratios of waters from Florida and Biscayne Bays collected in 1997–99.

Table 3.—Chemistry of fossil shells of *Loxochoncha matagordensis* and *Peratocytheridea setipunctata* from downcore portions of sediment cores from Florida Bay. Core numbers correspond to map (Text-fig. 1). Mg/Ca, Sr/Ca, and Na/Ca ratios reported as mmol/mol. Intra-sample average ratios reported in right three columns. Most shells analyzed were adult stage, though some juvenile molts were also analyzed. VPI (visual preservation index) is a measure of shell clarity ranging from 1 (clear, unaltered) to 7 (opaque, highly altered).

| Depth (cm) | Year | Genus | Species | Molt | VPI | Mg/Ca | Sr/Ca | Na/Ca | Mg/Ca (avg.) | Sr/Ca (avg.) | Na/Ca (avg.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Russell Bank Core 19B* | | | | | | | | | | | |
| Site 12* | 1998.0 | *L.* | *matagord.* | A | 2.5 | 29.20 | 3.93 | 16.55 | 32.17 | 3.89 | 15.50 |
| Site 12* | 1998.0 | *L.* | *matagord.* | A | 2.5 | 25.94 | 3.78 | 14.04 | | | |
| Site 12* | 1998.0 | *L.* | *matagord.* | A | 2.5 | 38.14 | 3.83 | 16.53 | | | |
| Site 12* | 1998.0 | *L.* | *matagord.* | A | 2.5 | 35.41 | 4.02 | 14.87 | | | |
| 1 | 1994.2 | *L.* | *matagord.* | A | 1 | 40.57 | 4.07 | 16.60 | 37.84 | 4.03 | 16.25 |
| 1 | 1994.2 | *L.* | *matagord.* | A | 2 | 37.07 | 4.17 | 16.81 | | | |
| 1 | 1994.2 | *L.* | *matagord.* | A | 1 | 35.89 | 3.85 | 15.34 | | | |
| 3 | 1992.5 | *L.* | *matagord.* | A | 3 | 39.82 | 4.08 | 15.67 | 38.39 | 3.95 | 16.88 |
| 3 | 1992.5 | *L.* | *matagord.* | A | 3 | 36.97 | 3.81 | 18.10 | | | |
| 5 | 1990.9 | *L.* | *matagord.* | A | 3 | 40.19 | 3.44 | 16.04 | 39.46 | 3.78 | 15.64 |
| 5 | 1990.9 | *L.* | *matagord.* | A | 2 | 36.97 | 3.98 | 16.23 | | | |
| 5 | 1990.9 | *L.* | *matagord.* | A | 1 | 41.22 | 3.93 | 14.66 | | | |
| 7 | 1989.3 | *L.* | *matagord.* | A | 3 | 36.87 | 3.90 | 15.27 | 39.61 | 3.94 | 15.67 |
| 7 | 1989.3 | *L.* | *matagord.* | A | 3 | 42.35 | 3.98 | 16.07 | | | |
| 9 | 1987.6 | *L.* | *matagord.* | A | 2 | 32.10 | 3.60 | 16.63 | 36.08 | 3.74 | 15.95 |
| 9 | 1987.6 | *L.* | *matagord.* | A | 4 | 36.94 | 3.56 | 15.48 | | | |
| 9 | 1987.6 | *L.* | *matagord.* | A | 4 | 39.19 | 4.06 | 15.74 | | | |
| 11 | 1986.0 | *L.* | *matagord.* | A | 2 | 31.43 | 4.18 | 17.40 | 32.48 | 4.09 | 16.50 |
| 11 | 1986.0 | *L.* | *matagord.* | A | 3 | 31.39 | 3.72 | 16.68 | | | |
| 11 | 1986.0 | *L.* | *matagord.* | A | 4 | 34.61 | 4.37 | 15.42 | | | |
| 13 | 1984.3 | *L.* | *matagord.* | A | 2 | 29.87 | 3.83 | 18.11 | 34.92 | 3.78 | 16.09 |
| 13 | 1984.3 | *L.* | *matagord.* | A | 4 | 36.75 | 3.68 | 15.44 | | | |
| 13 | 1984.3 | *L.* | *matagord.* | A | 4 | 38.14 | 3.84 | 14.71 | | | |
| 15 | 1982.7 | *L.* | *matagord.* | A | 4 | 41.81 | 3.97 | 13.13 | 35.10 | 3.91 | 14.79 |
| 15 | 1982.7 | *L.* | *matagord.* | A | 2 | 33.30 | 3.75 | 15.58 | | | |
| 15 | 1982.7 | *L.* | *matagord.* | A | 3 | 30.17 | 4.01 | 15.65 | | | |
| 17 | 1981.1 | *L.* | *matagord.* | A | 4 | 31.30 | 3.73 | 13.99 | 34.99 | 3.56 | 14.97 |
| 17 | 1981.1 | *L.* | *matagord.* | A | 4 | 39.24 | 3.18 | 15.58 | | | |
| 17 | 1981.1 | *L.* | *matagord.* | A | 3 | 34.42 | 3.76 | 15.33 | | | |
| 19 | 1979.4 | *L.* | *matagord.* | A | 2 | 35.40 | 3.79 | 15.73 | 40.09 | 3.64 | 15.12 |
| 19 | 1979.4 | *L.* | *matagord.* | A | 4 | 44.78 | 3.50 | 14.50 | | | |
| 21 | 1977.8 | *L.* | *matagord.* | A | 3 | 36.75 | 4.27 | 18.29 | 36.75 | 4.27 | 18.29 |
| 23 | 1976.1 | *L.* | *matagord.* | A | 3 | 32.97 | 3.68 | 16.25 | 38.00 | 3.51 | 15.14 |
| 23 | 1976.1 | *L.* | *matagord.* | A | 3 | 43.43 | 3.36 | 15.78 | | | |
| 23 | 1976.1 | *L.* | *matagord.* | A | 3 | 37.60 | 3.51 | 13.40 | | | |
| 25 | 1974.5 | *L.* | *matagord.* | A | 3 | 37.30 | 3.85 | 13.09 | 36.02 | 3.74 | 14.76 |
| 25 | 1974.5 | *L.* | *matagord.* | A | 3 | 35.18 | 3.60 | 15.08 | | | |
| 25 | 1974.5 | *L.* | *matagord.* | A | 3 | 35.59 | 3.75 | 16.12 | | | |
| 27 | 1972.9 | *L.* | *matagord.* | A | 3 | 36.44 | 3.95 | 16.60 | 36.67 | 3.68 | 15.13 |
| 27 | 1972.9 | *L.* | *matagord.* | A | 3 | 31.25 | 3.60 | 16.36 | | | |
| 27 | 1972.9 | *L.* | *matagord.* | A | 3 | 42.33 | 3.50 | 12.42 | | | |
| 29 | 1971.2 | *L.* | *matagord.* | A | 3 | 30.07 | 3.55 | 16.42 | 31.95 | 3.78 | 16.92 |
| 29 | 1971.2 | *L.* | *matagord.* | A | 3 | 33.82 | 4.02 | 17.42 | | | |
| 31 | 1969.6 | *L.* | *matagord.* | A | 3 | 28.06 | 3.52 | 17.19 | 37.85 | 3.78 | 15.53 |
| 31 | 1969.6 | *L.* | *matagord.* | A | 4 | 42.47 | 4.13 | 14.05 | | | |
| 31 | 1969.6 | *L.* | *matagord.* | A | 3 | 43.01 | 3.68 | 15.36 | | | |
| 33 | 1968.0 | *L.* | *matagord.* | A | 4 | 33.07 | 3.88 | 15.93 | 36.21 | 4.09 | 15.39 |
| 33 | 1968.0 | *L.* | *matagord.* | A | 3 | 39.89 | 4.24 | 15.71 | 39.59 | 3.78 | 15.11 |
| 33 | 1968.0 | *L.* | *matagord.* | A | 2 | 35.68 | 4.13 | 14.53 | | | |
| 35 | 1966.3 | *L.* | *matagord.* | A | 3 | 41.36 | 4.06 | 15.71 | | | |
| 35 | 1966.3 | *L.* | *matagord.* | A | 3 | 41.07 | 3.52 | 15.71 | 41.37 | 4.03 | 15.63 |
| 35 | 1966.3 | *L.* | *matagord.* | A | 3 | 36.34 | 3.77 | 13.92 | | | |
| 37 | 1964.7 | *L.* | *matagord.* | A | 3 | 39.80 | 4.01 | 15.87 | 46.37 | 3.92 | 15.11 |
| 37 | 1964.7 | *L.* | *matagord.* | A | 3 | 42.94 | 4.05 | 15.38 | | | |
| 39 | 1963.0 | *L.* | *matagord.* | A | 3 | 48.80 | 4.05 | 12.16 | | | |
| 39 | 1963.0 | *L.* | *matagord.* | A | 3 | 46.63 | 3.74 | 15.77 | 41.16 | 4.09 | 15.29 |

Table 3.—Continued.

| Depth (cm) | Year | Genus | Species | Molt | VPI | Mg/Ca | Sr/Ca | Na/Ca | Mg/Ca (avg.) | Sr/Ca (avg.) | Na/Ca (avg.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | 1963.0 | L. | matagord. | A | 4 | 43.68 | 3.97 | 17.39 | | | |
| 41 | 1961.4 | L. | matagord. | A | 2 | 41.97 | 3.94 | 17.50 | | | |
| 41 | 1961.4 | L. | matagord. | A | 3 | 40.36 | 4.25 | 13.08 | | | |
| 43 | 1959.8 | L. | matagord. | A | 3 | 33.40 | 4.17 | 15.75 | 41.29 | 3.92 | 16.19 |
| 43 | 1959.8 | L. | matagord. | A | — | 49.18 | 3.66 | 16.63 | | | |
| 45 | 1958.1 | L. | matagord. | A | 3 | 35.52 | 3.82 | 14.83 | 35.52 | 3.82 | 14.83 |
| 47 | 1956.5 | L. | matagord. | A | 3 | 39.51 | 3.27 | 17.12 | 42.27 | 3.77 | 15.51 |
| 47 | 1956.5 | L. | matagord. | A | 3 | 48.59 | 4.00 | 13.49 | | | |
| 47 | 1956.5 | L. | matagord. | A | 3 | 38.70 | 4.02 | 15.93 | | | |
| 49 | 1954.8 | L. | matagord. | A | 3 | 36.08 | 3.93 | 15.54 | 42.15 | 3.81 | 14.81 |
| 49 | 1954.8 | L. | matagord. | A | 3 | 46.31 | 3.44 | 14.75 | | | |
| 49 | 1954.8 | *L.* | *matagord.* | A | 3 | 44.06 | 4.04 | 14.15 | | | |
| 51 | 1953.2 | *L.* | *matagord.* | A | 3 | 28.07 | 3.65 | 17.61 | 33.74 | 3.90 | 15.53 |
| 51 | 1953.2 | *L.* | *matagord.* | A | 4 | 28.57 | 3.98 | 13.90 | | | |
| 51 | 1953.2 | *L.* | *matagord.* | A | 3 | 44.57 | 4.05 | 15.09 | | | |
| 53 | 1951.6 | *L.* | *matagord.* | A | 3 | 31.80 | 3.48 | 15.48 | 37.71 | 3.80 | 14.54 |
| 53 | 1951.6 | *L.* | *matagord.* | A | 3 | 40.79 | 4.20 | 14.00 | | | |
| 53 | 1951.6 | *L.* | *matagord.* | A | 3 | 40.54 | 3.73 | 14.15 | | | |
| 55 | 1949.9 | *L.* | *matagord.* | A | 3.5 | 36.35 | 3.88 | 13.88 | 35.38 | 3.86 | 14.96 |
| 55 | 1949.9 | *L.* | *matagord.* | A | 3.5 | 35.20 | 3.92 | 16.28 | | | |
| 55 | 1949.9 | *L.* | *matagord.* | A | 3.5 | 34.60 | 3.77 | 14.73 | | | |
| 57 | 1948.3 | *L.* | *matagord.* | A | 3.5 | 42.42 | 4.05 | 13.05 | 37.10 | 3.98 | 15.25 |
| 57 | 1948.3 | *L.* | *matagord.* | A | 3.5 | 31.49 | 3.80 | 14.80 | | | |
| 57 | 1948.3 | *L.* | *matagord.* | A | 3.5 | 37.39 | 4.09 | 17.92 | | | |
| 59 | 1946.6 | *L.* | *matagord.* | A | 3.5 | 44.98 | 3.33 | 14.41 | 41.53 | 3.65 | 15.12 |
| 59 | 1946.6 | *L.* | *matagord.* | A | 3.5 | 36.70 | 3.88 | 16.87 | | | |
| 59 | 1946.6 | *L.* | *matagord.* | A | 3.5 | 42.90 | 3.76 | 14.08 | | | |
| 61 | 1945.0 | *L.* | *matagord.* | A | 3.5 | 34.42 | 3.89 | 13.72 | 41.67 | 3.57 | 14.99 |
| 61 | 1945.0 | *L.* | *matagord.* | A | 3.5 | 48.91 | 3.25 | 16.26 | | | |
| 63 | 1943.4 | *L.* | *matagord.* | A | 3.5 | 33.84 | 3.72 | 18.16 | 32.01 | 3.86 | 16.41 |
| 63 | 1943.4 | *L.* | *matagord.* | A | 3.5 | 26.60 | 3.93 | 15.67 | | | |
| 63 | 1943.4 | *L.* | *matagord.* | A | 3.5 | 35.59 | 3.93 | 15.39 | | | |
| 65 | 1941.7 | *L.* | *matagord.* | A | 3.5 | 42.19 | 4.19 | 15.56 | 35.44 | 3.70 | 15.63 |
| 65 | 1941.7 | *L.* | *matagord.* | A | 3.5 | 25.77 | 3.22 | 15.40 | | | |
| 65 | 1941.7 | *L.* | *matagord.* | A | 3.5 | 38.35 | 3.68 | 15.92 | | | |
| 67 | 1940.1 | *L.* | *matagord.* | A | 3.5 | 26.85 | 3.75 | 14.89 | 33.16 | 3.91 | 15.45 |
| 67 | 1940.1 | *L.* | *matagord.* | A | 3.5 | 39.48 | 4.08 | 16.00 | | | |
| 69 | 1938.4 | *L.* | *matagord.* | A | 3.5 | 31.24 | 3.94 | 16.06 | 38.52 | 3.62 | 15.15 |
| 69 | 1938.4 | *L.* | *matagord.* | A | 3.5 | 36.77 | 3.60 | 17.20 | | | |
| 69 | 1938.4 | *L.* | *matagord.* | A | 3.5 | 47.54 | 3.31 | 12.18 | | | |
| 71 | 1936.8 | *L.* | *matagord.* | A | 3.5 | 35.45 | 3.94 | 20.43 | 32.76 | 4.06 | 17.27 |
| 71 | 1936.8 | *L.* | *matagord.* | A | 3.5 | 32.04 | 4.15 | 14.21 | | | |
| 71 | 1936.8 | *L.* | *matagord.* | A | 3.5 | 33.75 | 4.25 | 17.10 | | | |
| 71 | 1936.8 | *L.* | *matagord.* | A | 3.5 | 29.80 | 3.89 | 17.35 | | | |
| 73 | 1935.2 | *L.* | *matagord.* | A | 3.5 | 43.92 | 3.77 | 15.55 | 39.82 | 3.74 | 15.44 |
| 73 | 1935.2 | *L.* | *matagord.* | A | 3.5 | 29.10 | 3.94 | 18.92 | | | |
| 73 | 1935.2 | *L.* | *matagord.* | A | 3.5 | 46.43 | 3.50 | 11.85 | | | |
| 75 | 1933.5 | *L.* | *matagord.* | A | 3.5 | 33.46 | 3.66 | 13.69 | 34.40 | 3.57 | 14.66 |
| 75 | 1933.5 | *L.* | *matagord.* | A | 3.5 | 33.55 | 3.39 | 15.08 | | | |
| 75 | 1933.5 | *L.* | *matagord.* | A | 3.5 | 36.18 | 3.67 | 15.22 | | | |
| 77 | 1931.9 | *L.* | *matagord.* | A | 3.5 | 34.49 | 4.19 | 16.18 | 39.61 | 3.97 | 14.41 |
| 77 | 1931.9 | *L.* | *matagord.* | A | 3.5 | 44.74 | 3.75 | 12.64 | | | |
| 79 | 1930.2 | *L.* | *matagord.* | A | 3.5 | 36.38 | 3.85 | 14.29 | 38.18 | 3.85 | 15.18 |
| 79 | 1930.2 | *L.* | *matagord.* | A | 3.5 | 29.62 | 3.81 | 15.96 | | | |
| 79 | 1930.2 | *L.* | *matagord.* | A | 3.5 | 48.54 | 3.89 | 15.30 | | | |
| 81 | 1928.6 | *L.* | *matagord.* | A | 3.5 | 32.32 | 4.21 | 15.21 | 39.08 | 3.85 | 14.61 |
| 81 | 1928.6 | *L.* | *matagord.* | A | 3.5 | 42.56 | 3.57 | 14.32 | | | |
| 81 | 1928.6 | *L.* | *matagord.* | A | 3.5 | 42.35 | 3.77 | 14.30 | | | |
| 83 | 1927.0 | *L.* | *matagord.* | A | 3.5 | 32.54 | 3.91 | 14.71 | 35.98 | 3.96 | 15.62 |
| 83 | 1927.0 | *L.* | *matagord.* | A | 3.5 | 42.88 | 3.98 | 16.96 | | | |

Table 3.—Continued.

| Depth (cm) | Year | Genus | Species | Molt | VPI | Mg/Ca | Sr/Ca | Na/Ca | Mg/Ca (avg.) | Sr/Ca (avg.) | Na/Ca (avg.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 83 | 1927.0 | L. | matagord. | A | 3.5 | 32.53 | 4.00 | 15.20 | | | |
| 85 | 1925.3 | L. | matagord. | A | 3.5 | 34.11 | 3.47 | 17.69 | 32.88 | 3.73 | 15.55 |
| 85 | 1925.3 | L. | matagord. | A | 3.5 | 31.65 | 3.99 | 13.42 | | | |
| 87 | 1923.7 | L. | matagord. | A | 3.5 | 33.59 | 3.83 | 16.18 | 39.36 | 3.70 | 16.40 |
| 87 | 1923.7 | L. | matagord. | A | 3.5 | 41.05 | 3.80 | 17.83 | | | |
| 87 | 1923.7 | L. | matagord. | A | 3.5 | 43.44 | 3.47 | 15.19 | | | |
| 89 | 1922.0 | L. | matagord. | A | 3.5 | 37.86 | 4.20 | 14.07 | 35.43 | 4.12 | 14.22 |
| 89 | 1922.0 | L. | matagord. | A | 3.5 | 34.23 | 4.05 | 14.43 | | | |
| 89 | 1922.0 | L. | matagord. | A | 3.5 | 34.21 | 4.12 | 14.16 | | | |
| 93 | 1918.8 | L. | matagord. | A | 3.5 | 34.39 | 3.84 | 15.34 | 38.23 | 3.67 | 15.30 |
| 93 | 1918.8 | L. | matagord. | A | 3.5 | 52.25 | 3.40 | 15.10 | | | |
| 93 | 1918.8 | L. | matagord. | A | 3.5 | 28.03 | 3.77 | 15.48 | | | |
| 95 | 1917.1 | *L.* | *matagord.* | A | 3.5 | 32.87 | 4.12 | 14.68 | 32.87 | 4.12 | 14.68 |
| 97 | 1915.5 | *L.* | *matagord.* | A | 3.5 | 28.97 | 3.60 | 14.84 | 28.97 | 3.60 | 14.84 |
| 99 | 1913.9 | *L.* | *matagord.* | A | 3.5 | 32.60 | 3.98 | 16.64 | 32.60 | 3.98 | 16.64 |
| 101 | 1912.2 | *L.* | *matagord.* | A | 3.5 | 36.37 | 3.59 | 15.51 | 36.37 | 3.59 | 15.51 |
| 103 | 1910.6 | *L.* | *matagord.* | A | 3.5 | 36.49 | 3.65 | 14.09 | 33.22 | 3.68 | 13.85 |
| 103 | 1910.6 | *L.* | *matagord.* | A | 3.5 | 32.29 | 3.79 | 13.60 | | | |
| 103 | 1910.6 | *L.* | *matagord.* | A | 3.5 | 30.87 | 3.60 | 13.84 | | | |
| 105 | 1908.9 | *L.* | *matagord.* | A | 3.5 | 32.82 | 3.98 | 13.66 | 37.66 | 3.84 | 15.23 |
| 105 | 1908.9 | *L.* | *matagord.* | A | 3.5 | 45.68 | 3.70 | 16.77 | | | |
| 105 | 1908.9 | *L.* | *matagord.* | A | 3.5 | 34.47 | 3.84 | 15.25 | | | |
| 107 | 1907.3 | *L.* | *matagord.* | A | 3.5 | 31.31 | 4.03 | 16.13 | 36.32 | 4.11 | 15.14 |
| 107 | 1907.3 | *L.* | *matagord.* | A | 3.5 | 41.34 | 4.20 | 14.15 | | | |
| 109 | 1905.7 | *L.* | *matagord.* | A | 3.5 | 36.09 | 3.76 | 16.67 | 33.07 | 3.73 | 16.11 |
| 109 | 1905.7 | *L.* | *matagord.* | A | 3.5 | 35.36 | 3.80 | 17.91 | | | |
| 109 | 1905.7 | *L.* | *matagord.* | A | 3.5 | 27.76 | 3.64 | 13.76 | | | |
| 113 | 1902.4 | *L.* | *matagord.* | A | 3.5 | 32.15 | 3.66 | 13.96 | 32.33 | 3.67 | 14.69 |
| 113 | 1902.4 | *L.* | *matagord.* | A | 3.5 | 32.52 | 3.68 | 15.43 | | | |
| 115 | 1900.7 | *L.* | *matagord.* | A | 3.5 | 32.88 | 3.88 | 17.37 | 32.88 | 3.88 | 17.37 |
| 119 | 1897.5 | *L.* | *matagord.* | A | 3.5 | 48.35 | 3.43 | 15.21 | 48.35 | 3.43 | 15.21 |
| 121 | 1895.8 | *L.* | *matagord.* | A | 3.5 | 33.64 | 3.64 | 15.28 | 33.64 | 3.64 | 15.28 |
| 123 | 1894.2 | *L.* | *matagord.* | A | 3.5 | 37.04 | 3.84 | 15.89 | | | |
| 123 | 1894.2 | *L.* | *matagord.* | A | 3.5 | 35.54 | 3.60 | 15.10 | | | |
| 125 | 1892.5 | *L.* | *matagord.* | A | 3.5 | 36.19 | 4.05 | 13.33 | 35.35 | 3.80 | 16.59 |
| 125 | 1892.5 | *L.* | *matagord.* | A | 3.5 | 32.70 | 4.08 | 22.80 | | | |
| 125 | 1892.5 | *L.* | *matagord.* | A | 3.5 | 37.16 | 3.26 | 13.63 | | | |
| 129 | 1889.3 | *L.* | *matagord.* | A | 3.5 | 38.87 | 3.52 | 15.02 | 33.40 | 3.70 | 15.61 |
| 129 | 1889.3 | *L.* | *matagord.* | A | 3.5 | 29.21 | 3.84 | 15.13 | | | |
| 129 | 1889.3 | *L.* | *matagord.* | A | 3.5 | 32.13 | 3.74 | 16.69 | | | |
| 131 | 1887.6 | *L.* | *matagord.* | A | 3.5 | 34.92 | 3.82 | 18.10 | 37.87 | 3.86 | 18.63 |
| 131 | 1887.6 | *L.* | *matagord.* | A | 3.5 | 40.82 | 3.90 | 19.15 | | | |
| 137 | 1882.7 | *L.* | *matagord.* | A | 3.5 | 47.33 | 3.78 | 15.79 | 37.57 | 3.74 | 14.52 |
| 137 | 1882.7 | *L.* | *matagord.* | A | 3.5 | 28.12 | 3.99 | 14.54 | | | |
| 137 | 1882.7 | *L.* | *matagord.* | A | 3.5 | 37.26 | 3.45 | 13.22 | | | |
| 137 | 1882.7 | *L.* | *matagord.* | A | 3.5 | 35.56 | 3.72 | 12.33 | | | |
| 141 | 1879.4 | *L.* | *matagord.* | A | 3.5 | 34.89 | 3.87 | 17.01 | 34.89 | 3.87 | 17.01 |
| 143 | 1877.8 | *L.* | *matagord.* | A | 3.5 | 39.58 | 3.99 | 15.32 | 40.26 | 3.84 | 14.80 |
| 143 | 1877.8 | *L.* | *matagord.* | A | 3.5 | 42.35 | 3.89 | 13.19 | | | |
| 143 | 1877.8 | *L.* | *matagord.* | A | 3.5 | 38.87 | 3.65 | 15.90 | | | |
| *Bob Allen Keys Core 6A* | | | | | | | | | | | |
| 1 | 1994.0 | *P.* | *setipunct.* | A or A-1 | 1 | 18.70 | 4.35 | 11.43 | 18.70 | 4.35 | 11.43 |
| 1 | 1994.0 | *P.* | *setipunct.* | A or A-1 | 2 | 31.30 | 3.91 | 12.76 | | | |
| 1 | 1994.0 | *P.* | *setipunct.* | A or A-1 | 2 | 30.50 | 4.03 | 13.05 | | | |
| 1 | 1994.0 | *P.* | *setipunct.* | A-2? | 2 | 25.22 | 4.11 | 12.52 | | | |
| 3 | 1992.1 | *P.* | *setipunct.* | A | 2 | 20.27 | 3.93 | 11.57 | 20.27 | 3.93 | 11.57 |
| 3 | 1992.1 | *P.* | *setipunct.* | A-1 or A-2 | 1 | 20.88 | 4.58 | 12.25 | | | |
| 3 | 1992.1 | *P.* | *setipunct.* | A-3 | 1 | 20.12 | 3.99 | 12.55 | | | |
| 3 | 1992.1 | *P.* | *setipunct.* | A-2 | 1 | 22.82 | 4.16 | 12.61 | | | |

Table 3.—Continued.

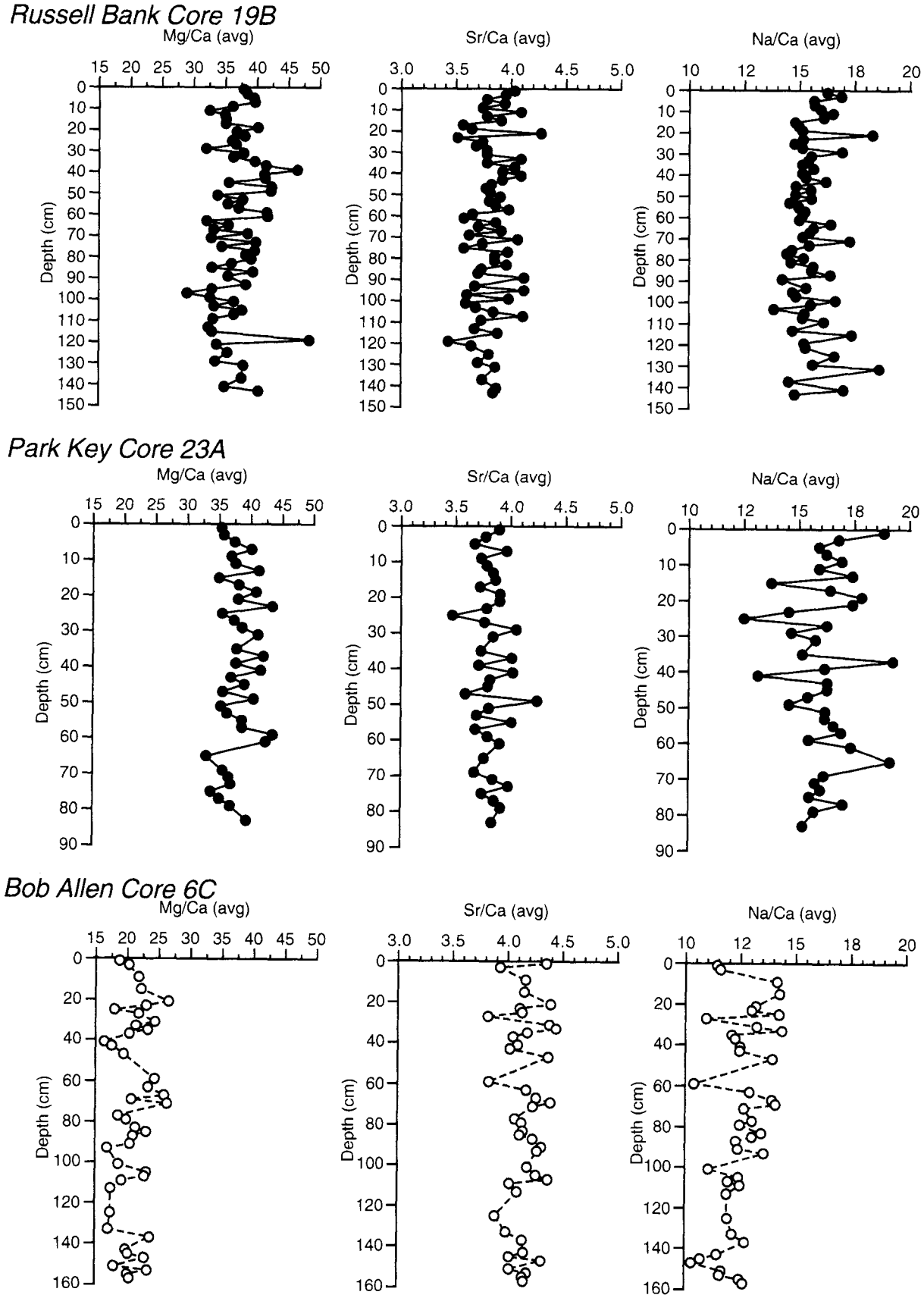
| Depth (cm) | Year | Genus | Species | Molt | VPI | Mg/Ca | Sr/Ca | Na/Ca | Mg/Ca (avg.) | Sr/Ca (avg.) | Na/Ca (avg.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 1986.3 | P. | setipunct. | A or A-1 | 2 | 21.97 | 4.14 | 13.92 | 21.81 | 4.16 | 14.15 |
| 9 | 1986.3 | P. | setipunct. | A or A-1 | 2 | 21.65 | 4.18 | 14.39 | | | |
| 9 | 1986.3 | P. | setipunct. | A-2 | 2 | 31.15 | 4.11 | 11.82 | | | |
| 15 | 1980.6 | P. | setipunct. | A | 1 | 22.22 | 4.15 | 14.27 | 22.22 | 4.15 | 14.27 |
| 15 | 1980.6 | *P.* | *setipunct.* | A-1 | 1 | 17.69 | 4.14 | 11.27 | | | |
| 15 | 1980.6 | *P.* | *setipunct.* | A-4 | 1 | 27.89 | 3.98 | 8.85 | | | |
| 17 | 1978.7 | *P.* | *setipunct.* | A-2 | 1 | 32.08 | 4.44 | 13.65 | | | |
| 19 | 1976.7 | *P.* | *setipunct.* | A-2? | 2 | 26.26 | 3.99 | 11.79 | | | |
| 19 | 1976.7 | *P.* | *setipunct.* | A-3 | 2 | 19.93 | 3.94 | 11.08 | | | |
| 21 | 1974.8 | *P.* | *setipunct.* | A? | 1 | 22.57 | 4.30 | 12.83 | 26.53 | 4.39 | 13.19 |
| 21 | 1974.8 | *P.* | *setipunct.* | A | 1 | 30.49 | 4.48 | 13.54 | | | |
| 23 | 1972.9 | *P.* | *setipunct.* | A | 1 | 23.03 | 4.11 | 13.00 | 23.03 | 4.11 | 13.00 |
| 25 | 1971.0 | *P.* | *setipunct.* | A | 2 | 17.63 | 4.11 | 14.17 | 17.97 | 4.13 | 14.24 |
| 25 | 1971.0 | *P.* | *setipunct.* | A | 2 | 18.31 | 4.16 | 14.31 | | | |
| 27 | 1969.0 | *P.* | *setipunct.* | A | 1 | 22.56 | 4.12 | 11.35 | 21.82 | 3.82 | 10.94 |
| 27 | 1969.0 | *P.* | *setipunct.* | A | 2 | 21.08 | 3.51 | 10.53 | | | |
| 31 | 1965.2 | *P.* | *setipunct.* | A | 2 | 24.66 | 4.55 | 13.69 | 24.41 | 4.38 | 13.24 |
| 31 | 1965.2 | *P.* | *setipunct.* | A or A-1 | 2 | 24.15 | 4.21 | 12.79 | | | |
| 33 | 1963.3 | *P.* | *setipunct.* | A | 2 | 21.70 | 4.41 | 14.40 | 21.42 | 4.44 | 14.38 |
| 33 | 1963.3 | *P.* | *setipunct.* | A | 2 | 21.15 | 4.46 | 14.36 | | | |
| 35 | 1961.3 | *P.* | *setipunct.* | A | 2 | 24.04 | 4.24 | 12.34 | 23.27 | 4.18 | 12.11 |
| 35 | 1961.3 | *P.* | *setipunct.* | A | 2 | 22.50 | 4.13 | 11.87 | | | |
| 37 | 1959.4 | *P.* | *setipunct.* | A | 2 | 20.44 | 4.00 | 10.83 | 20.35 | 4.05 | 12.25 |
| 37 | 1959.4 | *P.* | *setipunct.* | A | 2 | 20.26 | 4.11 | 13.67 | | | |
| 41 | 1955.6 | *P.* | *setipunct.* | A | 2 | 16.36 | 4.09 | 12.47 | 16.36 | 4.09 | 12.47 |
| 43 | 1953.7 | *P.* | *setipunct.* | A | 2 | 17.39 | 3.82 | 12.50 | 17.54 | 4.02 | 12.45 |
| 43 | 1953.7 | *P.* | *setipunct.* | A | 2 | 17.69 | 4.22 | 12.40 | | | |
| 47 | 1949.8 | *P.* | *setipunct.* | A | 2 | 19.61 | 4.36 | 13.72 | 19.46 | 4.37 | 13.96 |
| 47 | 1949.8 | *P.* | *setipunct.* | A | 2 | 19.32 | 4.38 | 14.20 | | | |
| 59 | 1938.3 | *P.* | *setipunct.* | A | 2 | 24.36 | 3.83 | 10.39 | 24.36 | 3.83 | 10.39 |
| 63 | 1934.4 | *P.* | *setipunct.* | A | 1 | 24.49 | 4.12 | 12.59 | 23.34 | 4.17 | 12.91 |
| 63 | 1934.4 | *P.* | *setipunct.* | A | 2 | 22.19 | 4.21 | 13.23 | | | |
| 67 | 1930.6 | *P.* | *setipunct.* | A | 2 | 25.86 | 4.26 | 13.93 | 25.86 | 4.26 | 13.93 |
| 69 | 1928.7 | *P.* | *setipunct.* | A | 1 | 20.71 | 4.39 | 14.09 | 20.71 | 4.39 | 14.09 |
| 71 | 1926.7 | *P.* | *setipunct.* | A | 2 | 29.29 | 4.22 | 13.29 | 26.33 | 4.23 | 12.66 |
| 71 | 1926.7 | *P.* | *setipunct.* | A | 2 | 23.36 | 4.25 | 12.02 | | | |
| 77 | 1921.0 | *P.* | *setipunct.* | A | 2 | 18.58 | 4.07 | 13.04 | 18.58 | 4.07 | 13.04 |
| 79 | 1919.0 | *P.* | *setipunct.* | A | 2 | 18.91 | 3.94 | 12.13 | 19.93 | 4.13 | 12.48 |
| 79 | 1919.0 | *P.* | *setipunct.* | A | 1 | 20.96 | 4.32 | 12.82 | | | |
| 83 | 1915.2 | *P.* | *setipunct.* | A | 2 | 21.36 | 4.14 | 13.46 | 21.36 | 4.14 | 13.46 |
| 85 | 1913.3 | *P.* | *setipunct.* | A | 2 | 23.06 | 4.11 | 13.03 | 23.06 | 4.11 | 13.03 |
| 87 | 1911.3 | *P.* | *setipunct.* | A | 2 | 21.83 | 4.11 | 12.43 | 20.96 | 4.23 | 12.29 |
| 87 | 1911.3 | *P.* | *setipunct.* | A | 2 | 20.09 | 4.35 | 12.16 | | | |
| 91 | 1907.5 | *P.* | *setipunct.* | A | 2 | 24.06 | 4.73 | 12.07 | 20.53 | 4.31 | 12.40 |
| 91 | 1907.5 | *P.* | *setipunct.* | A | 2 | 17.00 | 3.90 | 12.73 | | | |
| 93 | 1905.6 | *P.* | *setipunct.* | A | 2 | 16.90 | 4.27 | 13.58 | 16.90 | 4.27 | 13.58 |
| 101 | 1897.9 | *P.* | *setipunct.* | A | 2 | 17.82 | 4.03 | 11.15 | 18.64 | 4.18 | 11.06 |
| 101 | 1897.9 | *P.* | *setipunct.* | A | 2 | 19.45 | 4.34 | 10.96 | | | |
| 105 | 1894.0 | *P.* | *setipunct.* | A | 2 | 23.10 | 4.26 | 12.42 | 23.10 | 4.26 | 12.42 |
| 107 | 1892.1 | *P.* | *setipunct.* | A | 1 | 22.67 | 4.43 | 11.92 | 22.79 | 4.37 | 11.95 |
| 107 | 1892.1 | *P.* | *setipunct.* | A | 1 | 22.90 | 4.32 | 11.98 | | | |
| 109 | 1890.2 | *P.* | *setipunct.* | A | 2 | 19.20 | 4.02 | 12.49 | 19.20 | 4.02 | 12.49 |
| 113 | 1886.3 | *P.* | *setipunct.* | A | 2 | 15.02 | 4.08 | 11.43 | 17.44 | 4.09 | 11.89 |
| 113 | 1886.3 | *P.* | *setipunct.* | A | | 19.87 | 4.11 | 12.35 | | | |
| 117 | 1882.5 | *P.* | *setipunct.* | A | 2 | 22.47 | 4.29 | 13.09 | | | |
| 121 | 1878.7 | *P.* | *setipunct.* | A | 2 | 19.04 | 4.05 | 12.17 | | | |
| 125 | 1874.8 | *P.* | *setipunct.* | A | 2 | 16.69 | 3.31 | 10.27 | 17.43 | 3.89 | 11.93 |
| 125 | 1874.8 | *P.* | *setipunct.* | A | 2 | 18.18 | 4.48 | 13.59 | | | |
| 127 | 1872.9 | *P.* | *setipunct.* | A | 2 | 20.75 | 4.03 | 12.62 | | | |
| 133 | 1867.1 | *P.* | *setipunct.* | A | 1 | 16.55 | 4.18 | 12.81 | 17.07 | 3.99 | 12.14 |

Table 3.—Continued.

| Depth (cm) | Year | Genus | Species | Molt | VPI | Mg/Ca | Sr/Ca | Na/Ca | Mg/Ca (avg.) | Sr/Ca (avg.) | Na/Ca (avg.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 133 | 1867.1 | *P.* | *setipunct.* | A | 1 | 17.59 | 3.80 | 11.47 | | | |
| 135 | 1865.2 | *P.* | *setipunct.* | A | 2 | 24.55 | 4.05 | 9.88 | | | |
| 137 | 1863.3 | *P.* | *setipunct.* | A | 2 | 24.10 | 4.23 | 12.76 | 23.69 | 4.14 | 12.72 |
| 137 | 1863.3 | *P.* | *setipunct.* | A | | 23.29 | 4.05 | 12.68 | | | |
| 139 | 1861.3 | *P.* | *setipunct.* | A | 2 | 21.34 | 4.30 | 13.07 | | | |
| 141 | 1859.4 | *P.* | *setipunct.* | A | 2 | 17.08 | 4.09 | 13.10 | | | |
| 141 | 1859.4 | *P.* | *setipunct.* | A | | 16.73 | 4.14 | 12.24 | | | |
| 141 | 1859.4 | *P.* | *setipunct.* | A | 2 | 24.98 | 4.18 | 10.84 | | | |
| 143 | 1857.5 | *P.* | *setipunct.* | A | 2 | 20.78 | 4.25 | 12.39 | 19.82 | 4.15 | 11.46 |
| 143 | 1857.5 | *P.* | *setipunct.* | A | 2 | 16.66 | 3.61 | 9.63 | | | |
| 143 | 1857.5 | *P.* | *setipunct.* | A | 2 | 22.02 | 4.59 | 12.36 | | | |
| 145 | 1855.6 | *P.* | *setipunct.* | A | 2 | 19.00 | 4.56 | 11.44 | 20.21 | 4.02 | 10.71 |
| 145 | 1855.6 | *P.* | *setipunct.* | A | 2 | 21.42 | 3.48 | 9.98 | | | |
| 147 | 1853.7 | *P.* | *setipunct.* | A | 2 | 22.82 | 4.31 | 10.31 | 22.82 | 4.31 | 10.31 |
| 151 | 1849.8 | *P.* | *setipunct.* | A | 2 | 17.94 | 4.02 | 11.66 | 17.94 | 4.02 | 11.66 |
| 153 | 1847.9 | *P.* | *setipunct.* | A | 2 | 27.13 | 4.39 | 12.71 | 23.29 | 4.18 | 11.58 |
| 153 | 1847.9 | *P.* | *setipunct.* | A | 2 | 19.46 | 3.97 | 10.46 | | | |
| 155 | 1846.0 | *P.* | *setipunct.* | A | 2 | 22.78 | 4.11 | 12.68 | 20.11 | 4.14 | 12.47 |
| 155 | 1846.0 | *P.* | *setipunct.* | A | 2 | 17.44 | 4.17 | 12.26 | | | |
| 157 | 1844.0 | *P.* | *setipunct.* | A | 2 | 20.48 | 4.15 | 12.64 | 20.48 | 4.15 | 12.64 |
| *Little Madeira Core T24* | | | | | | | | | | | |
| 1 | 1991.4 | *P.* | *setipunct.* | A | 2 | 21.07 | 3.23 | 8.64 | 26.66 | 3.58 | 9.59 |
| 1 | 1991.4 | *P.* | *setipunct.* | A | 2 | 32.26 | 3.93 | 10.54 | | | |
| 11 | 1955.7 | *P.* | *setipunct.* | A | 1 | 30.72 | 3.58 | 10.00 | 30.70 | 3.60 | 10.13 |
| 11 | 1955.7 | *P.* | *setipunct.* | — | — | 30.68 | 3.62 | 10.26 | | | |
| 27 | 1898.6 | *P.* | *setipunct.* | A? | 3 | 23.17 | 4.12 | 9.96 | 23.17 | 4.12 | 9.96 |
| 33 | 1877.1 | *P.* | *setipunct.* | A | 3 | 25.03 | 3.97 | 8.64 | 25.03 | 3.97 | 8.64 |
| 37 | 1862.9 | *P.* | *setipunct.* | A | 3 | 19.53 | 4.28 | 8.23 | 21.47 | 4.25 | 9.64 |
| 37 | 1862.9 | *P.* | *setipunct.* | A | 3 | 23.41 | 4.22 | 11.05 | | | |
| 39 | 1855.7 | *P.* | *setipunct.* | A | 3 | 27.55 | 4.21 | 10.19 | 27.55 | 4.21 | 10.19 |
| 49 | 1820.0 | *P.* | *setipunct.* | A | 3 | 23.32 | 4.16 | 6.74 | 23.32 | 4.16 | 6.74 |
| 53 | 1805.7 | *P.* | *setipunct.* | A | 3 | 29.65 | 4.44 | 10.03 | 29.65 | 4.44 | 10.03 |
| 59 | 1784.3 | *P.* | *setipunct.* | A | 3 | 25.26 | 3.82 | 8.92 | 25.26 | 3.82 | 8.92 |
| 79 | 1712.9 | *P.* | *setipunct.* | A? | 3 | 25.60 | 4.61 | 8.49 | 25.60 | 4.61 | 8.49 |
| *Park Key Core 23A* | | | | | | | | | | | |
| Site 11 | 1998.0 | *L.* | *matagord.* | | — | 39.23 | 3.839 | 14.895 | 39.23 | 3.839 | 14.895 |
| 1 | 1993.7 | *L.* | *matagord.* | A | — | 37.168 | 3.839 | 15.444 | 35.29 | 3.89 | 18.82 |
| 1 | 1993.7 | *L.* | *matagord.* | A | — | 31.848 | 4.021 | 17.609 | | | |
| 1 | 1993.7 | *L.* | *matagord.* | A | — | 36.855 | 3.822 | 23.407 | | | |
| 3 | 1991.2 | *L.* | *matagord.* | A | — | 32.279 | 3.735 | 16.441 | 35.69 | 3.77 | 16.78 |
| 3 | 1991.2 | *L.* | *matagord.* | A | — | 37.027 | 3.769 | 16.880 | | | |
| 3 | 1991.2 | *L.* | *matagord.* | A | — | 37.754 | 3.801 | 17.019 | | | |
| 5 | 1988.6 | *L.* | *matagord.* | A | — | 32.898 | 3.698 | 14.916 | 37.42 | 3.67 | 15.89 |
| 5 | 1988.6 | *L.* | *matagord.* | A | — | 32.463 | 3.391 | 14.189 | | | |
| 5 | 1988.6 | *L.* | *matagord.* | A | — | 46.902 | 3.919 | 18.559 | | | |
| 7 | 1986.0 | *L.* | *matagord.* | A | — | 35.742 | 4.021 | 19.459 | 40.07 | 3.96 | 16.22 |
| 7 | 1986.0 | *L.* | *matagord.* | A | — | 46.036 | 3.907 | 14.429 | | | |
| 7 | 1986.0 | *L.* | *matagord.* | A | — | 38.435 | 3.956 | 14.765 | | | |
| 9 | 1983.5 | *L.* | *matagord.* | A | — | 37.972 | 3.931 | 17.307 | 36.89 | 3.73 | 16.92 |
| 9 | 1983.5 | *L.* | *matagord.* | A | — | 31.471 | 3.517 | 17.574 | | | |
| 9 | 1983.5 | *L.* | *matagord.* | A | — | 41.234 | 3.749 | 15.879 | | | |
| 11 | 1980.9 | *L.* | *matagord.* | A | — | 35.527 | 3.609 | 15.149 | 37.56 | 3.78 | 15.90 |
| 11 | 1980.9 | *L.* | *matagord.* | A | — | 33.892 | 3.804 | 13.350 | | | |
| 11 | 1980.9 | *L.* | *matagord.* | A | — | 43.266 | 3.941 | 19.202 | | | |
| 13 | 1978.3 | *L.* | *matagord.* | A | — | 33.939 | 3.853 | 14.738 | 41.27 | 3.84 | 17.41 |
| 13 | 1978.3 | *L.* | *matagord.* | A | — | 48.610 | 3.831 | 20.084 | | | |
| 15 | 1975.8 | *L.* | *matagord.* | A | — | 34.569 | 4.039 | 14.296 | 34.92 | 3.86 | 13.74 |
| 15 | 1975.8 | *L.* | *matagord.* | A | — | 35.272 | 3.687 | 13.189 | | | |
| 17 | 1973.2 | *L.* | *matagord.* | A | — | 36.764 | 3.692 | 19.534 | 38.09 | 3.72 | 16.40 |

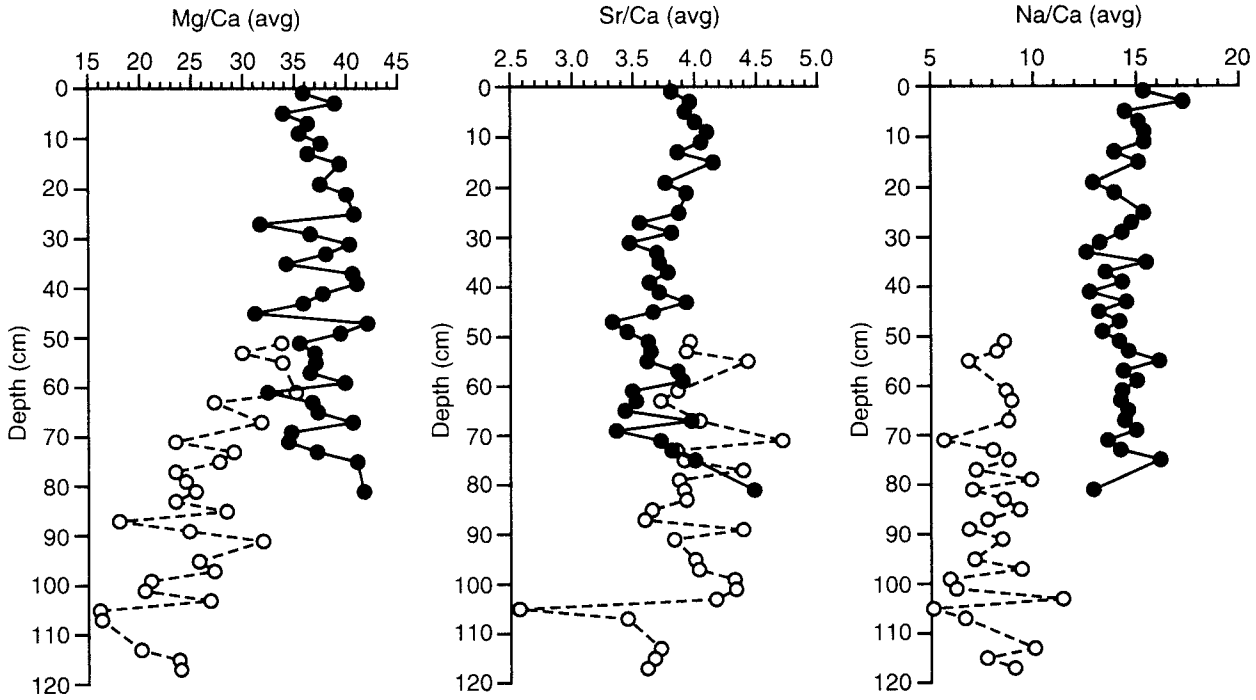
Table 3.—Continued.

| Depth (cm) | Year | Genus | Species | Molt | VPI | Mg/Ca | Sr/Ca | Na/Ca | Mg/Ca (avg.) | Sr/Ca (avg.) | Na/Ca (avg.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 1973.2 | *L.* | *matagord.* | A | — | 39.529 | 3.834 | 13.869 | | | |
| 17 | 1973.2 | *L.* | *matagord.* | A | — | 37.991 | 3.627 | 15.795 | | | |
| 19 | 1970.6 | *L.* | *matagord.* | A | — | 40.801 | 3.941 | 16.625 | 40.81 | 3.90 | 17.82 |
| 19 | 1970.6 | *L.* | *matagord.* | A | — | 46.646 | 3.505 | 17.558 | | | |
| 19 | 1970.6 | *L.* | *matagord.* | A | — | 34.976 | 4.248 | 19.266 | | | |
| 21 | 1968.1 | *L.* | *matagord.* | A | — | 43.454 | 3.955 | 18.219 | 37.96 | 3.90 | 17.42 |
| 21 | 1968.1 | *L.* | *matagord.* | A | — | 38.430 | 3.916 | 18.228 | | | |
| 21 | 1968.1 | *L.* | *matagord.* | A | — | 31.993 | 3.815 | 15.805 | | | |
| 23 | 1965.5 | *L.* | *matagord.* | A | — | 41.083 | 3.730 | 13.934 | 43.38 | 3.78 | 14.53 |
| 23 | 1965.5 | *L.* | *matagord.* | A | — | 44.853 | 3.805 | 17.531 | | | |
| 23 | 1965.5 | *L.* | *matagord.* | A | — | 44.190 | 3.815 | 12.135 | | | |
| 25 | 1962.9 | *L.* | *matagord.* | A | — | 43.813 | 3.832 | 14.306 | 35.44 | 3.47 | 12.49 |
| 25 | 1962.9 | *L.* | *matagord.* | A | — | 27.063 | 3.099 | 10.673 | | | |
| 27 | 1960.4 | *L.* | *matagord.* | A | — | 37.161 | 3.845 | 15.234 | 37.33 | 3.76 | 16.25 |
| 27 | 1960.4 | *L.* | *matagord.* | A | — | 35.081 | 3.762 | 14.894 | | | |
| 27 | 1960.4 | *L.* | *matagord.* | A | — | 39.754 | 3.661 | 18.617 | | | |
| 29 | 1957.8 | *L.* | *matagord.* | A | — | 42.313 | 4.079 | 14.168 | 38.62 | 4.05 | 14.65 |
| 29 | 1957.8 | *L.* | *matagord.* | A | — | 34.934 | 4.025 | 15.124 | | | |
| 31 | 1955.3 | *L.* | *matagord.* | A | — | 38.633 | 3.834 | 18.052 | 41.13 | 3.84 | 15.74 |
| 31 | 1955.3 | *L.* | *matagord.* | A | — | 36.882 | 3.639 | 15.555 | | | |
| 31 | 1955.3 | *L.* | *matagord.* | A | — | 47.863 | 4.055 | 13.613 | | | |
| 33 | 1952.7 | *L.* | *matagord.* | A | — | 38.465 | 3.572 | 18.343 | | | |
| 35 | 1950.1 | *L.* | *matagord.* | A | — | 32.028 | 3.720 | 14.424 | 37.74 | 3.73 | 15.14 |
| 35 | 1950.1 | *L.* | *matagord.* | A | — | 35.132 | 3.618 | 15.580 | | | |
| 35 | 1950.1 | *L.* | *matagord.* | A | — | 46.068 | 3.852 | 15.419 | | | |
| 37 | 1947.6 | *L.* | *matagord.* | A | — | 39.966 | 3.877 | 17.063 | 41.98 | 4.01 | 19.26 |
| 37 | 1947.6 | *L.* | *matagord.* | A | — | 36.811 | 3.928 | 17.330 | | | |
| 37 | 1947.6 | *L.* | *matagord.* | A | — | 49.168 | 4.240 | 23.390 | | | |
| 39 | 1945.0 | *L.* | *matagord.* | A | — | 37.609 | 3.710 | 16.161 | 37.61 | 3.71 | 16.16 |
| 41 | 1942.4 | *L.* | *matagord.* | A | — | 39.738 | 3.832 | 11.676 | 41.56 | 4.02 | 13.14 |
| 41 | 1942.4 | *L.* | *matagord.* | A | — | 43.387 | 4.214 | 14.597 | | | |
| 43 | 1939.9 | *L.* | *matagord.* | A | — | 36.224 | 3.436 | 14.897 | 36.85 | 3.81 | 16.27 |
| 43 | 1939.9 | *L.* | *matagord.* | A | — | 40.645 | 4.357 | 19.004 | | | |
| 43 | 1939.9 | *L.* | *matagord.* | A | — | 33.668 | 3.645 | 14.923 | | | |
| 45 | 1937.3 | *L.* | *matagord.* | A | — | 40.307 | 3.804 | 16.482 | 38.97 | 3.79 | 16.27 |
| 45 | 1937.3 | *L.* | *matagord.* | A | — | 38.335 | 3.540 | 16.605 | | | |
| 45 | 1937.3 | *L.* | *matagord.* | A | — | 38.279 | 4.019 | 15.730 | | | |
| 47 | 1934.7 | *L.* | *matagord.* | A | — | 37.157 | 3.935 | 16.233 | 35.59 | 3.59 | 15.40 |
| 47 | 1934.7 | *L.* | *matagord.* | A | — | 34.743 | 3.170 | 13.040 | | | |
| 47 | 1934.7 | *L.* | *matagord.* | A | — | 34.881 | 3.667 | 16.925 | | | |
| 49 | 1932.2 | *L.* | *matagord.* | A | — | 33.969 | 3.978 | 15.483 | 40.46 | 4.24 | 14.55 |
| 49 | 1932.2 | *L.* | *matagord.* | A | — | 46.949 | 4.500 | 13.614 | | | |
| 51 | 1929.6 | *L.* | *matagord.* | A | — | 34.572 | 3.568 | 14.314 | 35.26 | 3.80 | 16.18 |
| 51 | 1929.6 | *L.* | *matagord.* | A | — | 35.948 | 4.032 | 18.054 | | | |
| 53 | 1927.1 | *L.* | *matagord.* | A | — | 30.785 | 3.751 | 20.072 | 36.24 | 3.69 | 16.16 |
| 53 | 1927.1 | *L.* | *matagord.* | A | — | 46.299 | 3.431 | 14.939 | | | |
| 53 | 1927.1 | *L.* | *matagord.* | A | — | 31.636 | 3.900 | 13.483 | | | |
| 55 | 1924.5 | *L.* | *matagord.* | A | — | 40.095 | 4.165 | 16.014 | 38.61 | 4.01 | 16.57 |
| 55 | 1924.5 | *L.* | *matagord.* | A | — | 37.119 | 3.855 | 17.116 | | | |
| 57 | 1921.9 | *L.* | *matagord.* | A | — | 39.917 | 3.587 | 17.332 | 38.61 | 3.68 | 16.91 |
| 57 | 1921.9 | *L.* | *matagord.* | A | — | 37.298 | 3.763 | 16.494 | | | |
| 59 | 1919.4 | *L.* | *matagord.* | A | — | 44.702 | 3.725 | 13.998 | 43.47 | 3.79 | 15.44 |
| 59 | 1919.4 | *L.* | *matagord.* | A | — | 42.021 | 3.638 | 15.739 | | | |
| 59 | 1919.4 | *L.* | *matagord.* | A | — | 43.679 | 4.002 | 16.583 | | | |
| 61 | 1916.8 | *L.* | *matagord.* | A | — | 37.332 | 4.188 | 16.794 | 42.33 | 3.90 | 17.35 |
| 61 | 1916.8 | *L.* | *matagord.* | A | — | 47.322 | 3.608 | 17.898 | | | |
| 65 | 1911.7 | *L.* | *matagord.* | A | — | 32.995 | 3.757 | 19.137 | 33.00 | 3.76 | 19.14 |
| 69 | 1960.5 | *L.* | *matagord.* | A | — | 31.379 | 3.681 | 16.232 | 35.54 | 3.67 | 16.12 |

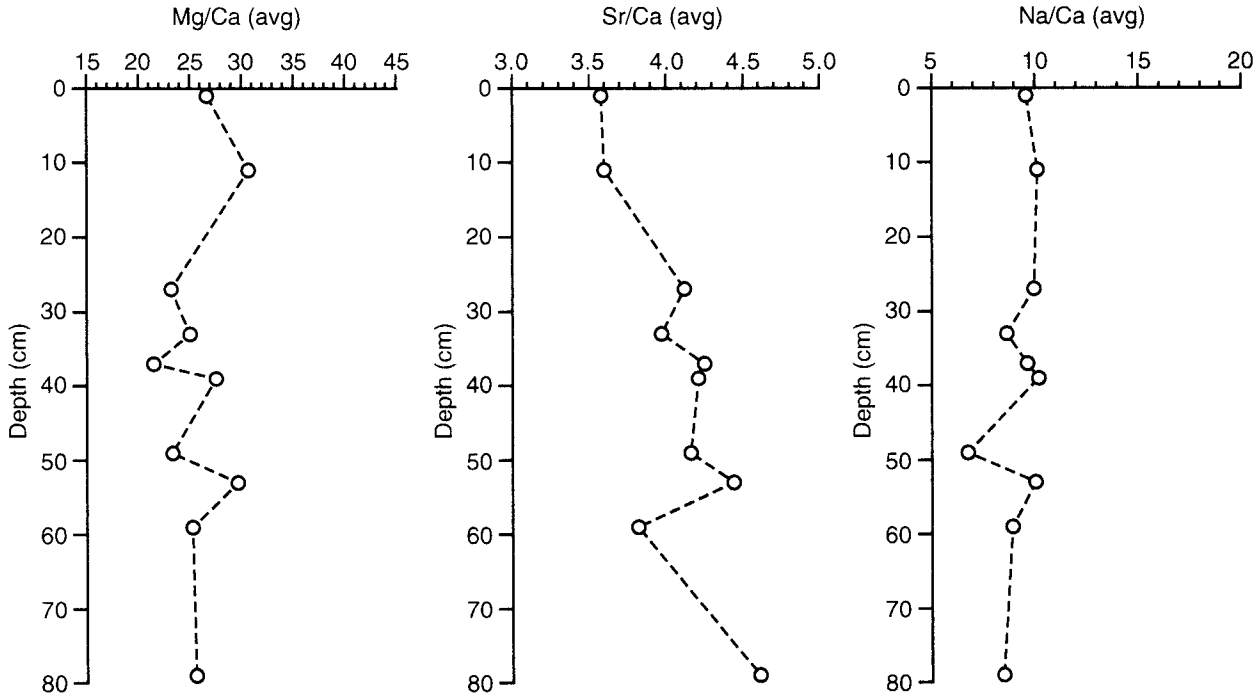



Text-figure 7.—Mg/Ca, Sr/Ca, and Na/Ca ratios of fossil ostracode shells versus depth from sediment cores collected from Russell Bank, Park Key, Bob Allen Keys, Little Madeira Bay, and Manatee Bay. *Loxoconcha matagordensis* (filled circles); *Pereatocytheridea setipunctata* (open circles).

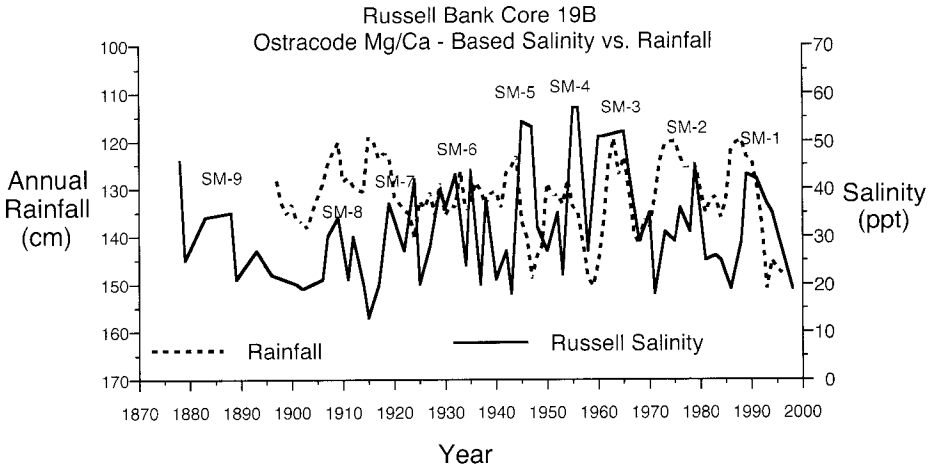
## *Manatee Bay Core MB1*




## *Little Madeira Bay Core T24*




Text-figure 7.—Continued.




Text-figure 9.—Ostracode Mg/Ca-based salinity estimates for Russell core 19B and 5-year running mean of annual rainfall. Salinity derivation discussed in text. SM designates intervals of relative salinity maximum.

A comparison of the Mg/Ca record from the Russell core to the rainfall record reveals many similarities (Text-figure 8). For example, the rainfall data indicate that since the late 1950's there have been 3 quasi-decadal oscillations in precipitation over southern Florida. While the amplitude correspondence varies, within the resolution of sediment chronology, the three rainfall oscillations are matched one-for-one by oscillations in ostracode Mg/Ca ratios. Over this time interval, peaks in Mg/Ca occur during dry intervals in the early 1960's, mid-to-late 1970's, and the late 1980's, all periods of known hypersalinity within Florida Bay.

The decadal-scale correlation between rainfall and Mg/Ca persists in the earlier part of the records as well. Based on the rainfall record, this was a period of low amplitude rainfall oscillations relative to the last 50 years, a pattern that also appears in the Mg/Ca record. Thus, Mg/Ca and rainfall show a correspondence over multi-decadal timescales.

In addition to the longer-term correlation, it also appears that single-year climate events may be recorded in the Mg/Ca record. For example, four of the extreme minima over the last century closely correspond with years when the El Nino southern oscillation index (SOI) was strongly negative (Text-fig. 8). Typically, south Florida receives unusually high dry-season rainfall under such climate conditions (Douglas and Englehart, 1981), presumably leading to significantly lower salinity in Florida Bay.

Mg/Ca records from the Park and Bob Allen cores also correspond with the rainfall record, though the similarities are not as strong as in the Russell core. This may be a result of the lower resolution sampling within these cores or in the case of Bob Allen, due to an ecological effect related to *Peratocytheridea*. Another possibility is that these sites have stronger local effects than Russell Bank. The Bob Allen and Park core sites appear to be located on the leeward side of complexes of islands and broad, shallow mudbanks which often experience wide temperature and salinity shifts relative to more open waters of Florida Bay. In contrast, the Russell Bank core site appears to be located in a much smaller lee on a narrow mudbank that extends out into open waters of the largest and deepest sub-bay within the eastern sector of Florida Bay. Thus, the Russell Bank site may be better situated to monitor large-scale changes in Florida Bay.

## A Paleosalinity Curve for Central Florida Bay

Using the down-core *Loxoconcha* Mg/Ca ratios and the provisional $K_{D\text{-}Mg}$ for *Loxoconcha*, we calculated estimates of past Mg/Ca ratios of Florida Bay water and converted them to estimates of past salinity based on the correlation between salinity and $Mg/Ca_{water}$ (Text-fig. 5). Text-figure 9 shows ostracode Mg/Ca-based salinity estimates derived for Russell Bank and the south Florida rainfall record. Two extreme values at intervals equivalent to 1963 (91 ppt) and 1897 (113 ppt) are excluded from this plot. Calculated salinity estimates range from 13 to over 50 ppt. The overall average is 32 ppt with around two thirds of the values falling between 20 and 43 ppt.

The salinity estimates are quite reasonable, strongly overlapping with the range of instrumental salinity measurements taken at or near this site over the last 50 years which range from 10 to 55 ppt (Swart *et al.*, 1996, Halley *et al.*, 1995). One notable example is the salinity during the late 1980's which has been widely discussed in the context of Florida Bay seagrass dieoffs. Another is the high salinity recorded during the mid 1970s (Swart *et al.*, 1996). It is important to note that calculated salinity estimates that are greater

than ~42 ppt lie outside the range of our modern calibration data set and thus are unconstrained. These estimates may be high because the slope of best-fit curve to the $Mg/Ca_{water}$ versus salinity data increases continuously above 42 ppt, even though it appears that water Mg/Ca ratios begin to plateau near the seawater value. Thus, we might expect that ostracode shell Mg/Ca ratios would also plateau at a value around 38 mmol/mol, a value that is actually exceeded in a number of intervals in the Russell core, perhaps suggesting that Mg/Ca ratios of Florida Bay water increases further with increasing salinity.

An alternative interpretation of the trends in shell Mg/Ca is that the signal may be all or partially related to temperature. Temperature and salinity measurements collected seasonally for the last few years (Brewster-Wingard *et al.*, 2001) near the Russell core site suggest that temperature and salinity covary at this site, more so than at Bob Allen and Park Key. Given the thermodependence on Mg uptake in *Loxoconcha* and other ostracode genera (Cadot and Kaesler, 1977; Dwyer *et al.*, 1995), the increased uptake of Mg resulting from higher water Mg/Ca ratios at higher salinity is likely further enhanced by an accompanying increase in water temperature. This may also help to explain the better correspondence between Mg/Ca and rainfall in the Russell core.

Until additional experiments in which adult ostracode shells are grown under controlled salinity and temperature conditions, the paleosalinity curve in Text-figure 9 must remain preliminary in nature. Still, the scale of variability in Mg/Ca ratios within all five cores and the estimated salinities are consistent with the hypothesis that salinity fluctuations occur over decadal timescales in Florida Bay. Moreover, the correspondence between interdecadal trends in rainfall and paleosalinity extremes indicates a strong climatic control on Florida Bay salinity. The shift to high amplitude oscillations in salinity after about 1950 seems to reflect a corresponding increase in rainfall extremes, but it may also reflect an alteration of the salinity regime due to human alteration of freshwater flow into Florida Bay.

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