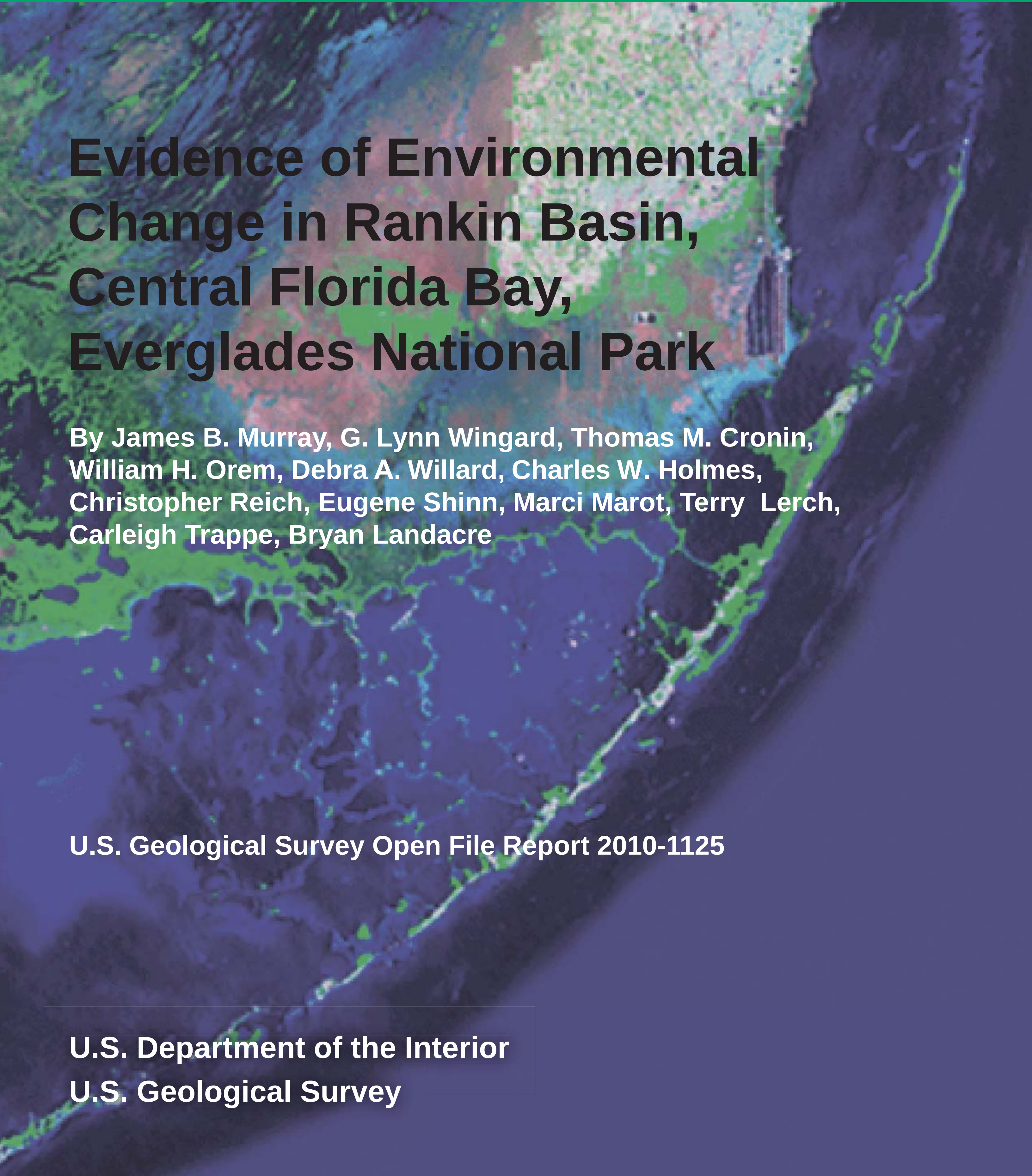

Evidence of Environmental Change in Rankin Basin, Central Florida Bay, Everglades National Park

By James B. Murray, G. Lynn Wingard, Thomas M. Cronin, William H. Orem, Debra A. Willard, Charles W. Holmes, Christopher Reich, Eugene Shinn, Marci Marot, Terry Lerch, Carleigh Trappe, Bryan Landacre

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U.S. Department of the Interior
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Abstract

Analyses of core GLBW601 RL1 collected in Rankin Basin (see fig.1), Florida Bay, Everglades National Park, in June 2001 indicate that significant environmental changes occurred at the site over the last two centuries. The core was collected at a site of documented seagrass die-off in 1987-1988. The purpose of this study was to document the long-term sequences of events leading up to the die-off event. Analyses have been conducted to examine (1) faunal changes in the ostracodes and mollusks, (2) biochemistry of the ostracode shells, (3) floral changes in the pollen assemblages, and (4) geochemical and elemental changes in the sediment. The faunal assemblage analyses provide information on the salinity and benthic habitat at the site. The biochemical and geochemical data provide information about the water chemistry and sedimentation rates. The floral assemblage provides data about the nearby terrestrial environment and the first occurrence of pollen of the Australian pine, *Casuarina equisetifolia,* serves as a biostratigraphic marker for the beginning of the 20th century. These data provide clues to the cause and effect of the seagrass die-off and changes in salinity patterns and also illustrate decadal-scale patterns of change.

The analyses of GLBW601 RL1 show two important results. First, prior to 1900, Rankin Basin tended to be oligohaline to mesohaline on the basis of faunal data showing the assemblage to be similar to that of the lowest portions of a core from Taylor Creek. Second, prior to the documented seagrass die-off, the faunal assemblages indicate an increase in the amplitude of salinity fluctuations; a significant increase occurs in the mollusks *Brachidontes exustus* and *Anomalocardia auberiana*, two species that tolerate fluctuations in salinity.

Acknowledgments

We thank our colleagues at a number of other agencies, including South Florida Water Management District and Everglades National Park, who have collaborated and cooperated on this research. This work was conducted under NPS Permit # EVER-2001-SCI-0048 (Study # EVER-00048). We would especially like to thank the staff of Keys Marine Laboratory, who provided field support and facilities. The collection and initial research of the Rankin Basin core (GLBW601 RL1) was funded by the U.S. Geological Survey, Eastern Region Venture Capital Fund (2001). Subsequent analyses and the writing of this report have been generously supported by the Greater Everglades Priority Ecosystem program, coordinated by G. Ronnie Best (USGS).

Introduction

The South Florida ecosystem has been the focus of national attention following the passage of the Everglades Forever Act in 1994, which mandates the return of the Everglades to its "natural state." The massive ongoing restoration efforts are governed by the Comprehensive Everglades Restoration Plan (CERP) initiated in the late 1990s (www.evergladesplan.org). Everglades National Park (ENP) encompasses Florida Bay, a downstream recipient of terrestrial runoff from South Florida. One goal of U.S. Geological Survey (USGS) research on the history of South Florida's estuaries is to determine the nature and timing of changes to the South Florida ecosystem and the agents responsible for those changes. In developing goals for management and restoration of the ecosystem, it is essential to separate human-induced changes from natural changes.

Changes in the environment, whether natural or anthropogenic, ultimately change the biological makeup of an ecosystem. Different organisms prefer different salinities and substrates (biohabitats). Reconstruction of past environmental conditions is possible by analyzing the abundance and distribution of remains of organisms preserved in shallow sediment cores, collected throughout the region.

The USGS is conducting ecosystem history research in the estuaries of South Florida to determine changes in the environment, with particular emphasis on changes in salinity patterns. Rankin Basin, located in north-central Florida Bay, was the site of a seagrass (*Thalassia testudinum*) die-off event that occurred in 1987-1988 (Robblee and others, 1991). This site was selected to examine the long term sequence of changes leading up to the die-off and the role that salinity may have played. We conducted analyses on the Rankin Basin core (GLBW601 RL1) to examine faunal changes in the ostracodes and mollusks and geochemical changes in the sediment. Faunal analyses yield information on the salinity and benthic habitat at the site. Floral analyses provide information about the surrounding terrestrial environment and the first appearance of *Casuarina equisetifolia* (Australian pine) an exotic introduced around 1900 (Morton, 1980). This report presents the results of these analyses. These data provide a means to test hypotheses concerning cause and effect in seagrass die-off and salinity changes and illustrate decadal-scale patterns of change in environmental conditions, whether natural (sea-level or climate changes) or anthropogenic.

Setting

Florida Bay is an integral part of the greater Everglades ecosystem, which forms the boundary between the terrestrial Everglades and the Atlantic and Gulf of Mexico marine systems. It constitutes 2,201 square kilometers (km^2) of water within Everglades National Park (McPherson and Halley, 1996) and has been the subject of much concern in recent decades. In Florida Bay sea-grass die-offs, algal blooms and declining numbers of fish, shellfish, and sponges are issues of public concern (Lodge, 2005, p. 182-185). An important question concerns the degree to which these changes represent natural variation within the ecosystem versus human-induced change. A series of sediment cores from Florida Bay have been analyzed to determine the changes that have occurred over the last 150-200 years. This report presents the data from the Rankin Basin core (GLBW601 RL1), taken in June of 2001 from a location near an ENP water monitoring station (fig. 1) at a site of documented seagrass die-off in 1987-1988 (P. Carlson,

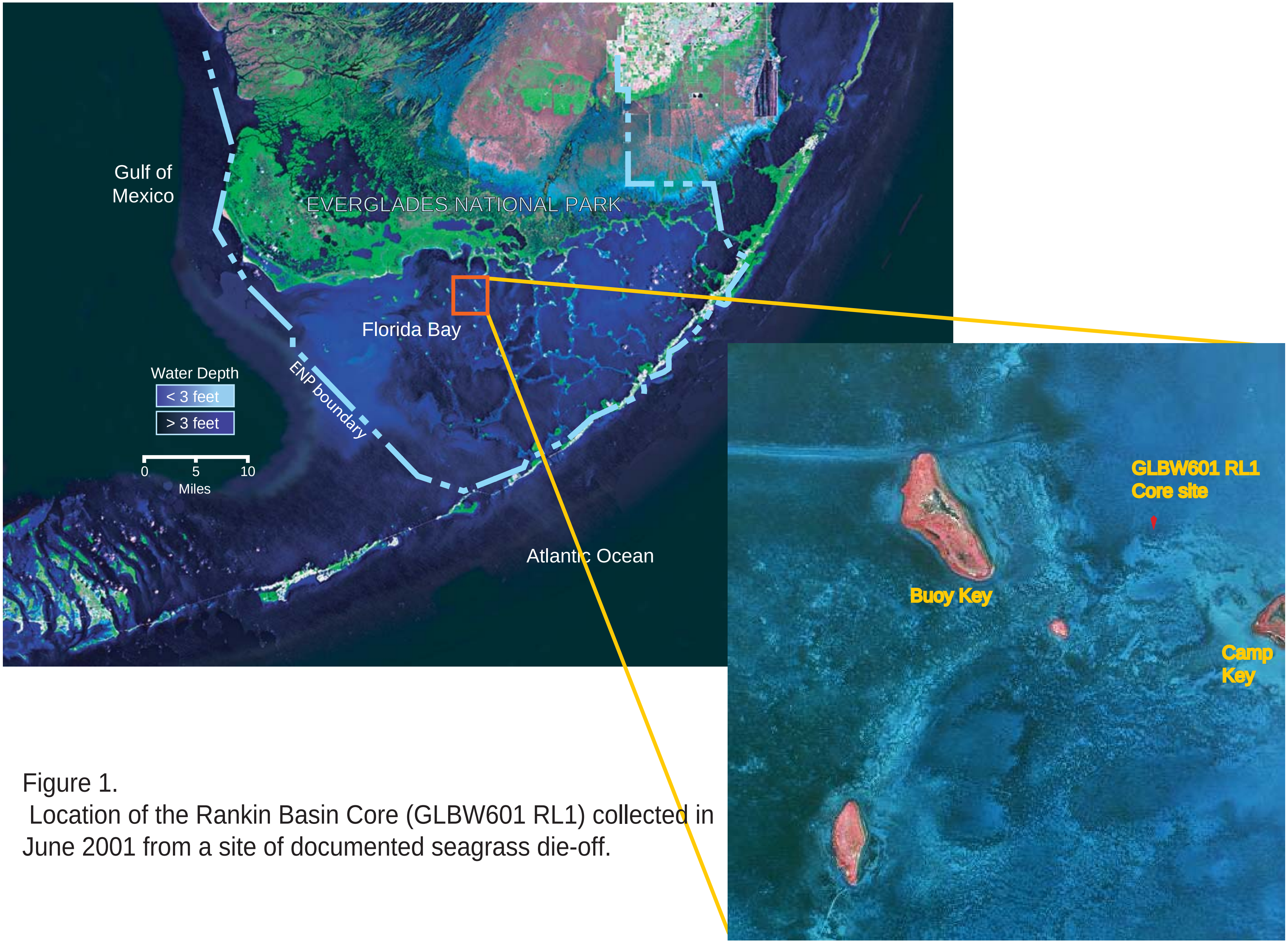


Figure 1.
Location of the Rankin Basin Core (GLBW601 RL1) collected in June 2001 from a site of documented seagrass die-off.

pers. comm.). These monitoring stations, located throughout Florida Bay, provide data on recent intra-annual to annual cycles of change in water quality (salinity, temperature, pH, and so on) and weather (precipitation and air temperature). These recent measurements provide insight for interpreting environmental changes recorded in the cores.

Rankin Basin, approximately 10.2 km^2, consists of shallow carbonate mud banks surrounded by mangrove islands at the southernmost margin of the terrestrial Everglades (fig. 1). The position and configuration of the basin restricts tidal mixing and reduces the influence of tides and currents (Boyer and others, 1999), which can lead to hypersaline conditions and increased concentrations of organic material (McIvor and others, 1994; Fourqurean and others, 1992). Very high salinities (> 50 parts per thousand (ppt)) were recorded in Rankin Basin from 1989-90 during a drought (Fourqurean and others, 1992). Rankin Basin and other areas in west central and western Florida Bay were the sites of a massive seagrass die-off that began in 1987 and eventually led to the loss of more than 40,000 hectares (ha) of seagrass (Robblee and others, 1991; McIvor and others, 1994).

Methods

Core Collection and Sampling

The Rankin Basin core (GLBW601 RL1), located on a mudbank between Buoy Key and Camp Key, at N 25º 06’. 969, W 80º 49’.176 (fig. 1), was collected June 19, 2001. The 12.2 centimeter (cm) (4 inch) diameter piston core apparatus recovered 143-cm of calcareous mud but did not reach the underlying limestone bedrock. The core was collected in approximately 75 cm of water from an area of dense *Thalassia testudinum*, with sparsely dispersed *Halodule wrightii* seagrasses and intermittent “blowout” areas. Bare areas surrounded by dense grass beds with a very sharp transition zone are commonly referred to as "blowouts" in Florida Bay. The cause of these blowouts is unknown, but some researchers have speculated that they could be caused by seagrass die-off or by animals such as rays in the process of foraging for food (Brewster-Wingard and others, 2001). Basic sediment lithology was described at the time of sectioning for processing (fig. 2). Sectioning was done within 24 hours after core collection in order to preserve sample integrity.

The GLBW601 RL1 core was sectioned into 2-cm increments throughout its 143- cm length and processed for faunal, floral, and chemical analyses. Each interval was washed through two sieves of 850 micrometer (µm) and 63 µm size, using hyper-filtered (distilled and twice deionized) water. The sediment fraction smaller than 63 µm remaining was dried at 50° C and weighed for ^{210}Pb, and elemental analysis. Any components larger than 63-µm were dried at 50° C and separated for faunal analyses. Several mollusk specimens were removed for ^{14}C radiometric dating. All mollusks were picked from every fourth 2-cm sample interval, identified, characterized for preservation state (taphonomic condition), and counted. Ostracodes were picked, identified, and counted from every other 2-cm sample interval, with selected specimens chosen for shell chemical analysis. In order to standardize the counts, data for each sample were converted to percent abundance data. Palynomorphs were processed using standard palynological techniques (Willard and others 2003). At least 300 palynomorphs were counted per sample, and results are presented as percent abundance.

Rankin Basin Core Description
(GLBW-601 RL1)

Fine shell hash in a gelatinous micritic mud.

Abundant shell debris and plant material mostly root mass in brown/gray mud.

Sediment firmer, shell visible with plant material throughout. Light gray slightly mottled fine mud.

92-94 cm Very firm grass shoots and root material in gray mottled mud with whole shells present.

Sharp change at 125 cm to darker brown mud with intermingled gray muds.

Change to peat/mud mixture at 140 cm grading to entirely peat at the base of the core.

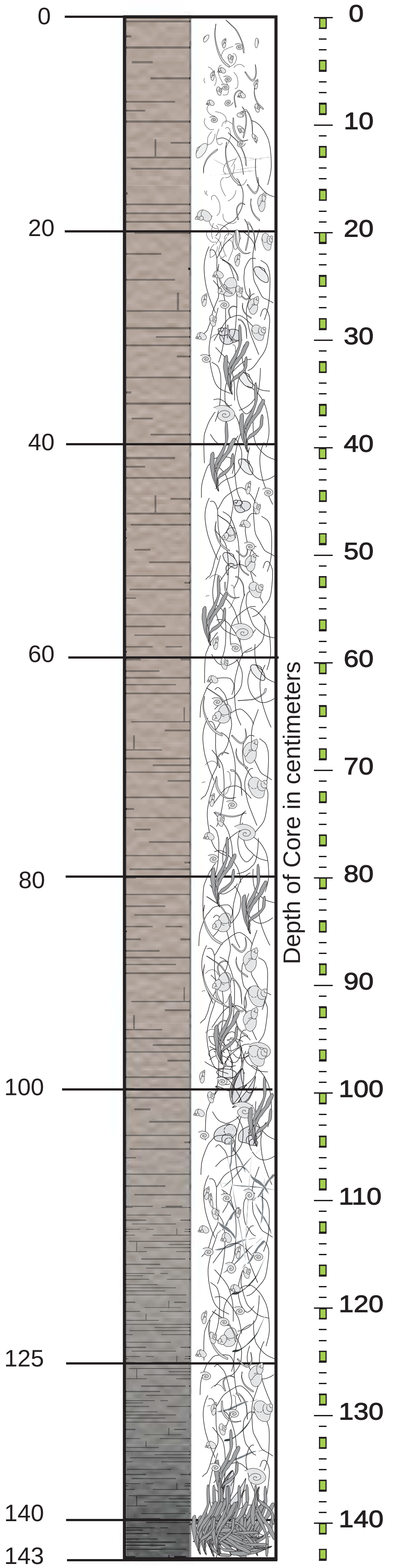


Figure 2
Basic lithology of the Rankin Basin Core GLBW601 RL1

🟩 Indicates interval analyzed

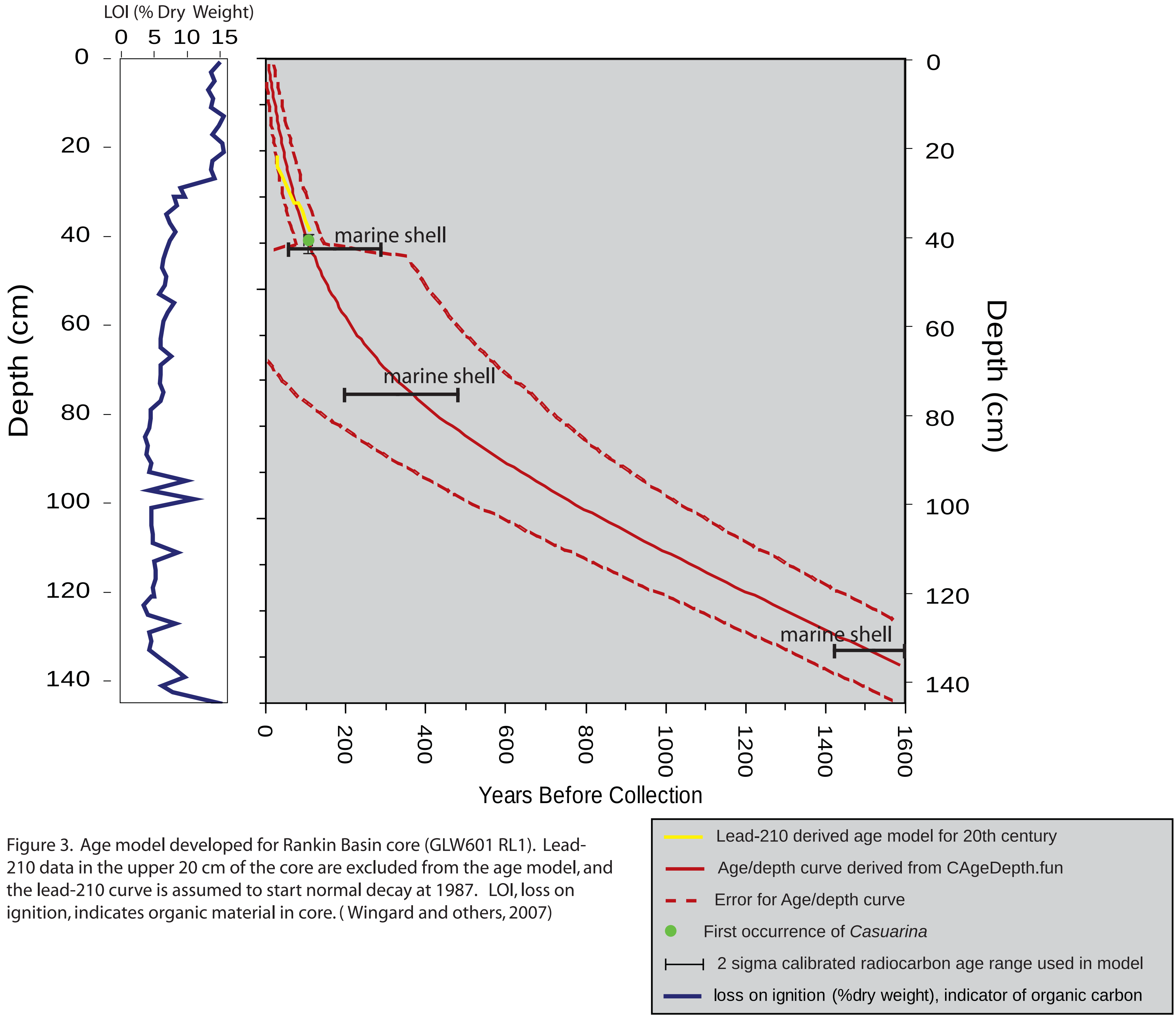


Figure 3. Age model developed for Rankin Basin core (GLW601 RL1). Lead-210 data in the upper 20 cm of the core are excluded from the age model, and the lead-210 curve is assumed to start normal decay at 1987. LOI, loss on ignition, indicates organic material in core. (Wingard and others, 2007)

Geochronology

The age model (fig. 3) for the Rankin Basin core (GLBW601 RL1) is based on three methods of dating: 1) ^{210}Pb analyses from the less than 63-µm sediment fraction of the core samples; 2) ^{14}C analysis of mollusk shells chosen from selected intervals; and 3) first appearance of *Casuarina* pollen. The ^{210}Pb analysis has been used to establish a chronology of the shallow portion of the core as the isotope provides reliable models for ages less than 100 years old (see Holmes and others, 2001 for details on methodology). The ^{14}C analyses provide a model for ages greater than 100 years. (See http://sofia.usgs.gov/publications/ofr/2007-1203/ (Wingard and others 2007) for more details). *Casuarina* was introduced to Florida in 1898 as an ornamental tree and also for use as a windbreak to border agricultural groves (Morton, 1980). Its first occurrence in other Florida Bay and Biscayne Bay cores is at ~1900 A.D., and its pollen occurs commonly in sediments after 1900 AD.

Faunal and Floral Analyses

Ostracodes: Specimens from the > 63-µm size fraction of core GLBW601 RL1 were picked and sorted into eleven taxonomic categories representing indicator species and genera or groups having similar ecological preferences. The ecology of Florida Bay ostracodes and the methodology used in faunal analyses are discussed in detail in Cronin and others (2001). In the present study, intervals from the Rankin Basin core were analyzed for 100 individuals, a number that usually gives statistically meaningful faunal trends in situations where there are large oscillations in the relative proportions of taxa. To assure reproducibility of results, we augmented the 100 individuals by picking another 200 individuals for the critical interval of the core between 20 and 80-cm. Ostracode assemblages were identified using the taxonomy of Teeter (1975), Keyser (1975, 1976, and 1977) and Garbett and Maddocks (1978).

Molluscs: Molluscan faunal assemblages from core GLBW601 RL1 were picked from the ≥850 µm size fraction every 8-cm and then sorted and classified into nine preservation categories and 79 taxonomic categories (Brewster-Wingard and others, 2001). The data presented here represent all specimens counted, excluding worn specimens and fragments, which may be more indicative of transport rather than *in situ* conditions (Wingard and others, 2004). Mollusk identification was primarily determined using the taxonomy and descriptions of Abbott (1974), Warmke and Abbott (1961), Lyons (1996), and Perry and Schwengel (1955). All updated taxonomic nomenclature was based on Turgeon and others (1998).

Pollen: Pollen was isolated from the < 63-µm sediment fraction of core GLBW601 RL1 using standard procedures summarized in Willard and others (2003). At least 300 grains per sample were identified and counted, with identifications based primarily on comparison with USGS pollen reference collections and descriptions in Willard and others (2004). Pollen data were used to reconstruct vegetation changes in the region and for biostratigraphic control, based on whether *Casuarina equisetifolia* (Australian pine) was present or not.

Chemical Analyses

***Ostracode Shell Chemistry*:** In addition to other types of faunal analyses, metal/calcium ratios (primarily Mg/Ca) were determined for selected ostracodes from core GLBW601 RL1. The Mg/Ca ratios provide a useful proxy for estimating salinities that were present when the organism secreted its shell (Dwyer and Cronin, 2001). Ostracodes selected for this process were taken from intervals within the core that had been processed, sieved and picked for the faunal assemblage analyses. Direct comparison could then be made between the shell chemistry and the assemblage data for that interval. These samples were analyzed for Mg/Ca, Na/Ca, and Sr/Ca ratios using a direct coupled plasma atomic emission spectrophotometer (DCP-AES), following procedures referenced in Dwyer and Cronin (2001). Each specimen used for this analytical method was examined and assigned a preservation index (optical clarity-based dissolution index).

***Total C, P, N, and Organic C*:** The fine fraction (<63-µm) of the sieved material from coreGLBW601 RL1 was used for chemical analysis of organic carbon and nutrients (total nitrogen and phosphorus). The sample from each interval of the core was lyophilized (cryodessicated,a specific method of freeze drying), ground to a powder in a mill, and stored in clean glass containers. Samples were dried in an oven at 60° C to remove adsorbed water prior to chemical analysis. Total carbon (TC) and total nitrogen (TN) were determined on the dry/powdered samples using a Leco model 932 CHNS Analyzer $^{\text{TM}}$ (Leco Corp., St. Joseph, MI). Several different certified standards were used to calibrate the instrument daily, and appropriate blanks were run. Organic carbon (OC) was determined using the Leco analyzer after removal of inorganic carbon (carbonates) using an acid fuming procedure (Orem and others, 1999). Total phosphorus (TP) was determined using a slight modification of the method of Aspila and others (1976). This method involves baking approximately 0.5 gram (g) of dried sediment at 550°C, extracting the residue in 1M HCl, and analyzing the extracted total P using the standard phospho-molybdate method (Strickland and Parsons, 1973). Analytical precision (percentage relative standard deviation or %RSD) for these methods based on replicate analysis is approximately ±3% for TC and TN, and ±5% for OC and TP.

***Elemental Analyses*:** For elemental analysis, a 0.5 g portion of the sample is digested with aqua regia (0.5 milliliters (ml) H_2O, 0.6 ml concentrated HNO_3 and 1.8 ml concentrated HCl) for 2 hours at 95°C. The sample was cooled, diluted to 10 ml with deionized water, homogenized, and then analyzed using a Perkin Elmer OPTIMA 3000 Radial ICP for the 30-element suite. A matrix standard and blank was run every 13 samples. For vegetation a 0.25 g sample was used. A series of USGS geochemical standards were used as controls. This digestion is near total for base metals; however, it is only partial for silicates and oxides.

For mercury (Hg) analyses, a 0.5 g portion of the sample is digested with aqua regia at 90º C. The Hg in the resulting solution was then oxidized to the stable divalent form. Because the concentration of Hg is determined via the absorption of light at 253.7 nanometers (nm) by Hg vapour, Hg (II) is reduced to the volatile-free atomic state using stannous chloride. Argon is bubbled through the mixture of sample and reductant solutions to liberate and to transport the Hg atoms into an absorption cell. The cell is placed in the light path of an Atomic Absorption Spectrophotometer. The maximum amount absorbed (peak height) is directly proportional to the concentration of mercury atoms in the light path. Measurement can be performed manually or automatically using a flow injection technique (FIMS). Mercury (Hg) analysis is performed on a Perkin Elmer FIMS 100 cold vapor Hg analyzer, with a detection limit of 5 parts per billion (ppb) and an upper limit of 100,000 ppb.

RESULTS

Age Model

The ^{210}Pb results yielded an average sedimentation rate of 0.4 centimeters per year (cm/yr) for the Rankin Basin core (GLBW601 RL1). The bottom of the GLBW601 RL1 core is 143 cm, and dates to approximately 1600 years before present (ybp) (fig. 3). The 36-42-cm depth of GLBW601 RL1 represents the beginning of the 1900s. The upper 20 cm of the core appears to have been deposited after the 1987-1988 die-off. See http://sofia.usgs.gov/publications/ofr/2007-1203/synth.html#fig23 (Wingard, and others, 2007) for a detailed discussion of the age model.

Mollusks

A cluster analysis of the molluscan faunal data (app. A; fig. 4) illustrates that significant changes have occurred in the assemblage at the Rankin core site. First, a freshwater to oligohaline assemblage is present near the bottom of the core (143-130-cm) (fig. 4, cluster 1). Figures 4 and 5 show freshwater mollusks present in the lowest 20 cm of the core, reaching a high of 24 percent of the molluscan fauna at 138 cm. Small percentages of terrestrial gastropods (Polygyridae) and a clam, *Polymesoda maritima,* also are present in this segment of the core. *Polymesoda maritima* is found in oligohaline to lower mesohaline waters (5-12 ppt), so it is an indicator of reduced salinities. This assemblage is similar to that seen in the lowest portions of a core (FB594 24) from Taylor Creek (located E/NE of Rankin Basin) (Ishman, and others, 1996). The lowest assemblage is overlain by a mesohaline grading into a polyhaline assemblage between 122 and 42-cm (fig. 4, cluster 2). Several molluscan species, including *Cerithium muscarum*, *Brachidontes exustus* and *Modulus modulus*, indicate an increase in *Thalassia testudinum* habitat between the early 1600s and the early 1900s (75 cm to 38 cm respectively).

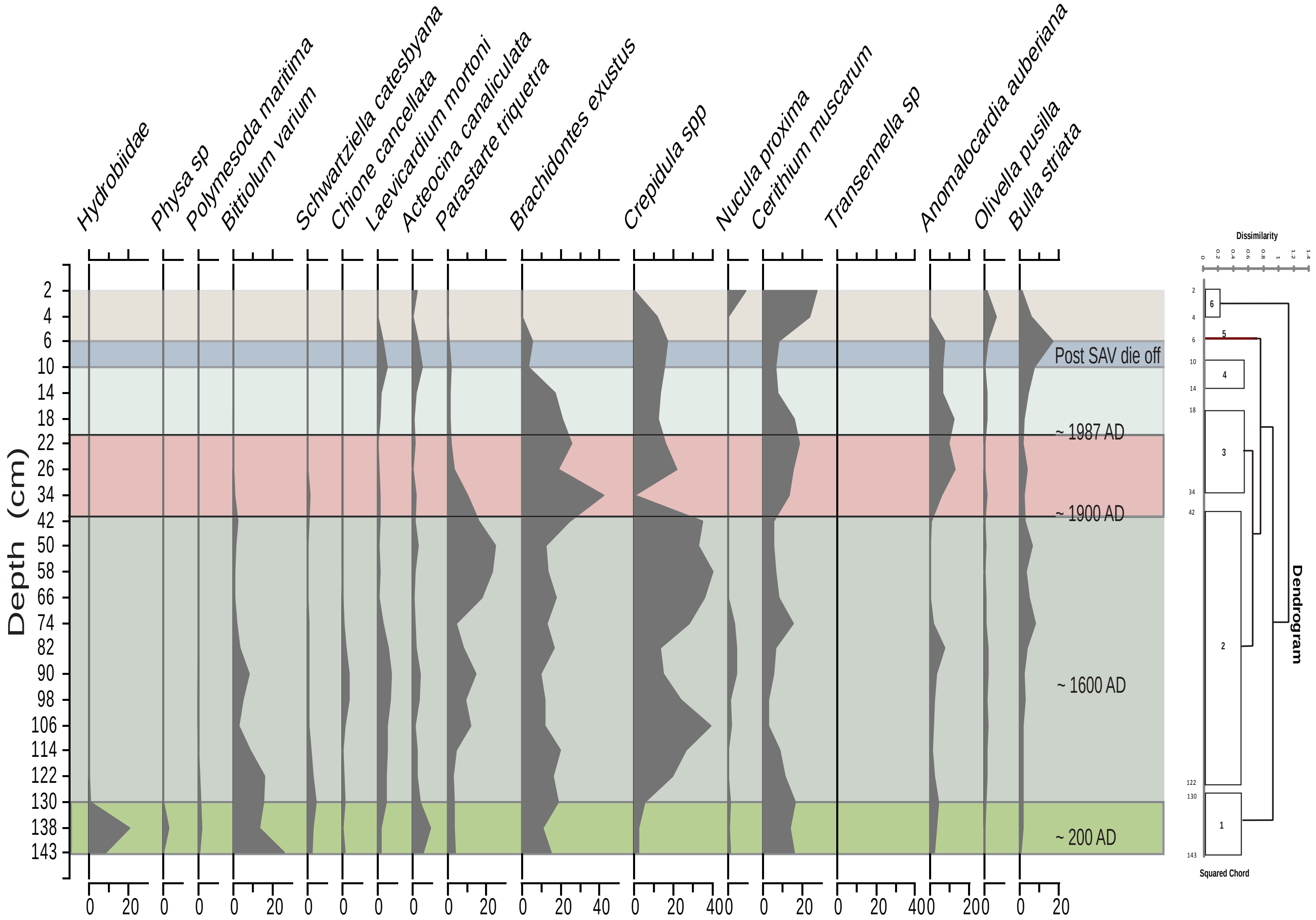


Figure 4. Percent abundance of molluscan indicator species for Rankin Basin core (GLBW601 RL1), plotted against core depth. Note, freshwater mollusks, terrestrial gastropods (Polygyridae) and a clam, *Polymesoda maritima*, are only present in the lowest 20 cm of core. The cluster was generated using XLSTAT 2009.4.02 - Agglomerative Hierarchical Clustering,unweighted pair-group average method, squared chord distance.

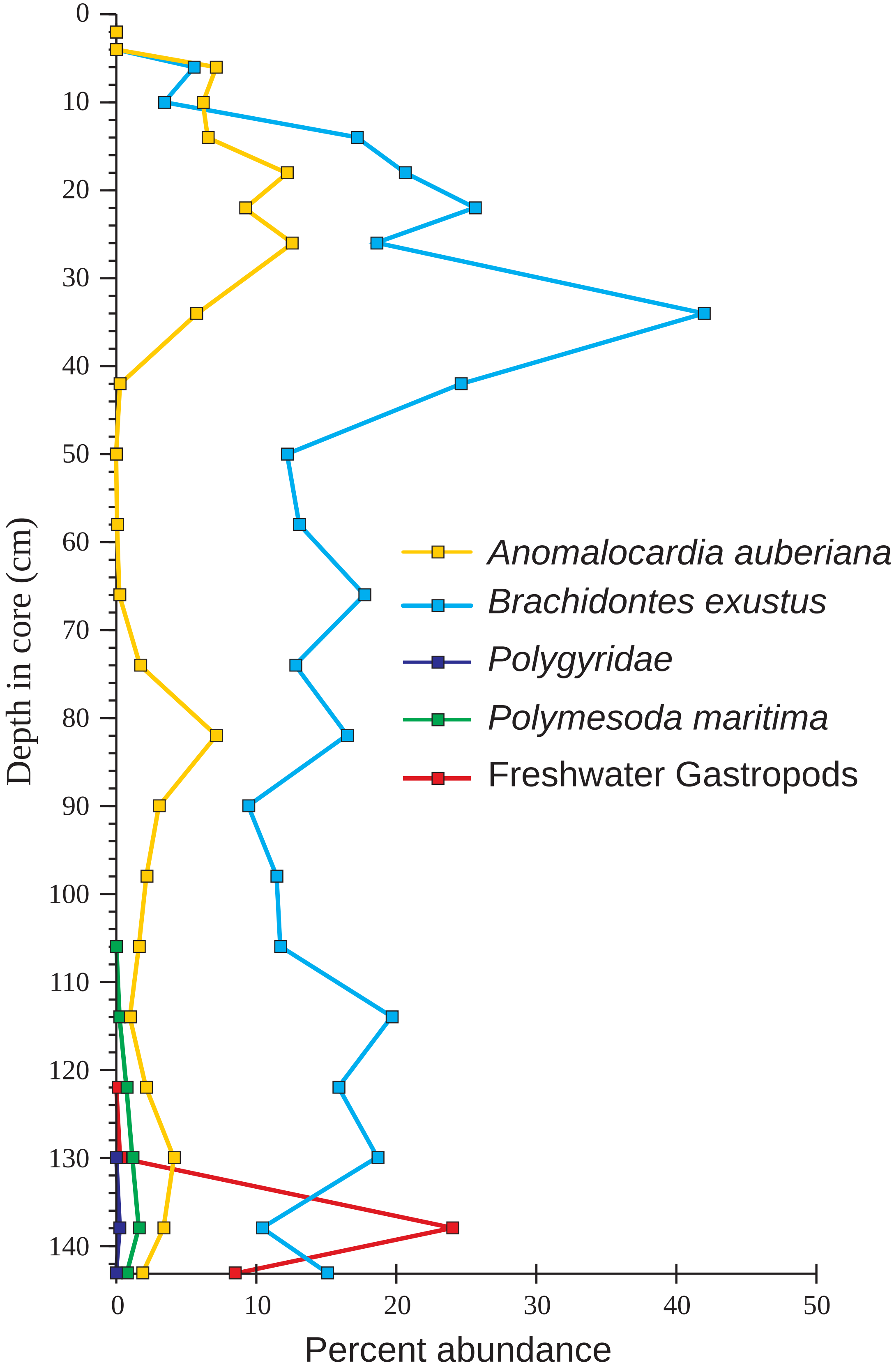


Figure 5
Presence of freshwater mollusks in the
lowest 20cm of the Rankin Basin core.

At approximately 50-cm a significant increase occurs in *Brachidontes exustus* and *Anomalocardia auberiana*, two species that tolerate fluctuations in salinity; today these species are typical of the Northern Transition Zone of Florida. The third cluster (34 and 18-cm) represents the assemblage present between the early 1900s and the seagrass die-off event in 1987. The predominant species in cluster 3 are indicative of rapid salinity changes and are tolerant of wide ranging salinities, but overall abundance and diversity (number of genera and species) of the mollusks decline through this interval. Three small clusters comprise the post die-off portion of the core; these clusters are dominated by species that live in or on mud surfaces or macro-benthic algae; overall molluscan diversity and abundance are significantly reduced in these samples.

Ostracodes

The ostracode assemblage data for the Rankin Basin core (GLBW601 RL1) are shown in app. B. Each of these taxa has distinct ecological requirements. Figure 6 shows the distribution in the Rankin basin core of the relative proportions of the four most common taxa found in Florida Bay, each of which has distinct ecological requirements.

The faunal patterns reflect a large degree of temporal variability in the ostracode assemblages, which also has been documented at other sites in central Florida Bay. Most notable are the following trends:

- Progressive rise in *Loxoconcha matagordensis* from a low of 10 percent at 125 cm to a peak near 50 percent at 51 cm
- Near absence of *Xestoleberis* (except for minor peak near 80 cm) until a large increase beginning near 25-30 cm

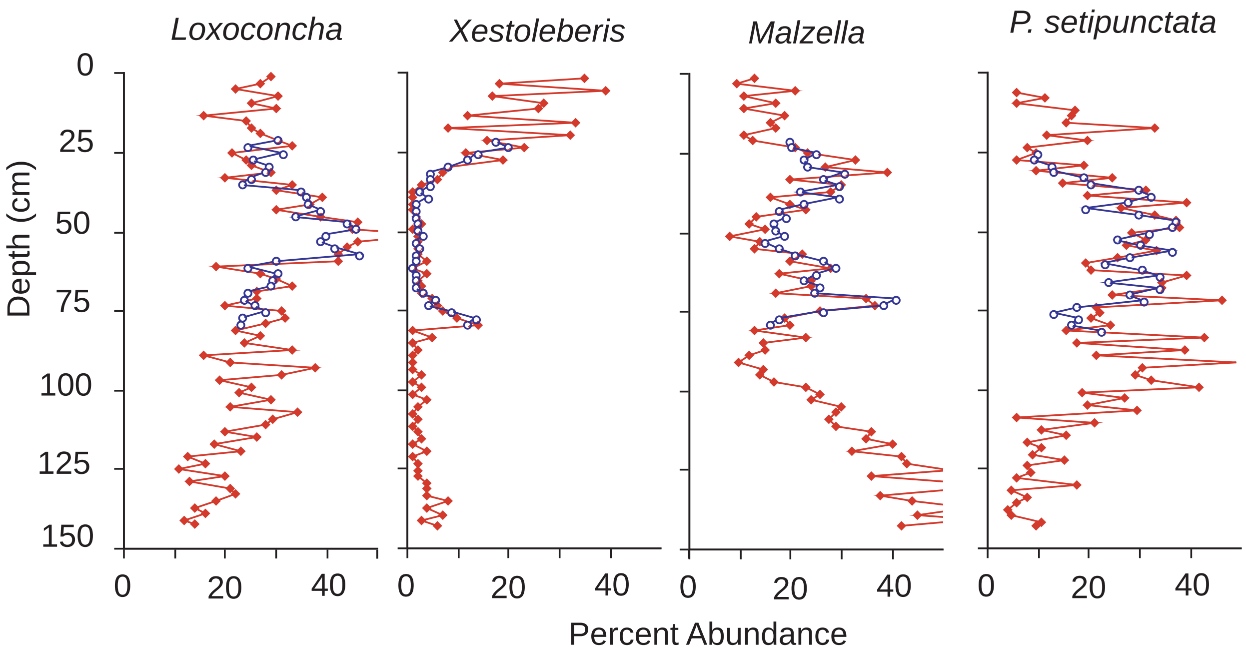


Figure 6.
The relative proportions of the four most common ostracod taxa in the Rankin Basin core (GLBW601 RL1) based on 100 individuals (red) and 200 individuals for the interval 20-80 cm (blue).

- Oscillating numbers of *Malzella floridana*, with proportions inversely related to *L. matagordensis*
- Low proportions of *Peratocytheridea setipunctata* in the lowermost 30 cm and uppermost 20 cm of the core, with higher proportions between 30 and 110-cm core depth.

Trends in other species also are significant. Between 142 and ~ 100 cm core depth there is progressive decline and even disappearance in several upper polyhaline – euhaline species that do not tolerate hypersalinity and large-scale salinity variability. These species include *Actinocyterheis subquadrata*; *Reticulocythereis floridana*, *Puriana* sp. *Paracytheroma stephensoni,* and *Cytheromorpha* cf. *C. warneri*.

Pollen

Pinus pollen is strongly dominant throughout the core, comprising from 49-87% of pollen assemblages (fig. 7, app. C). *Quercus*, *Myrica*, and Amaranthaceae pollen are common throughout the core, as are fern spores. The assemblages are separable into two pollen zones. Pollen zone I (40-143-cm) lacks *Casuarina* pollen, and *Typha* and Asteraceae pollen are rare. In pollen zone II (0-40-cm), *Casuarina* is present, and Asteraceae, Amaranthaceae, and *Typha* pollen are slightly more common.

Ostracode Shell Chemistry

The results of the metal/Ca ratio analyses performed on selected ostracodes from core GLBW601 RL1 show frequent fluctuations in the milli-mole to mole (mmol/mol) ratio of Mg/Ca between the bottom of the core and approximately 38 cm (fig. 8). The upper 35 cm show a decrease in the both the Mg/Ca ratio and the fluctuations in the ratio. Based on modern

Percent Abundance of Pollen of Major Plant Taxa, Core GLBW601 RL1, Rankin Basin, Florida Bay

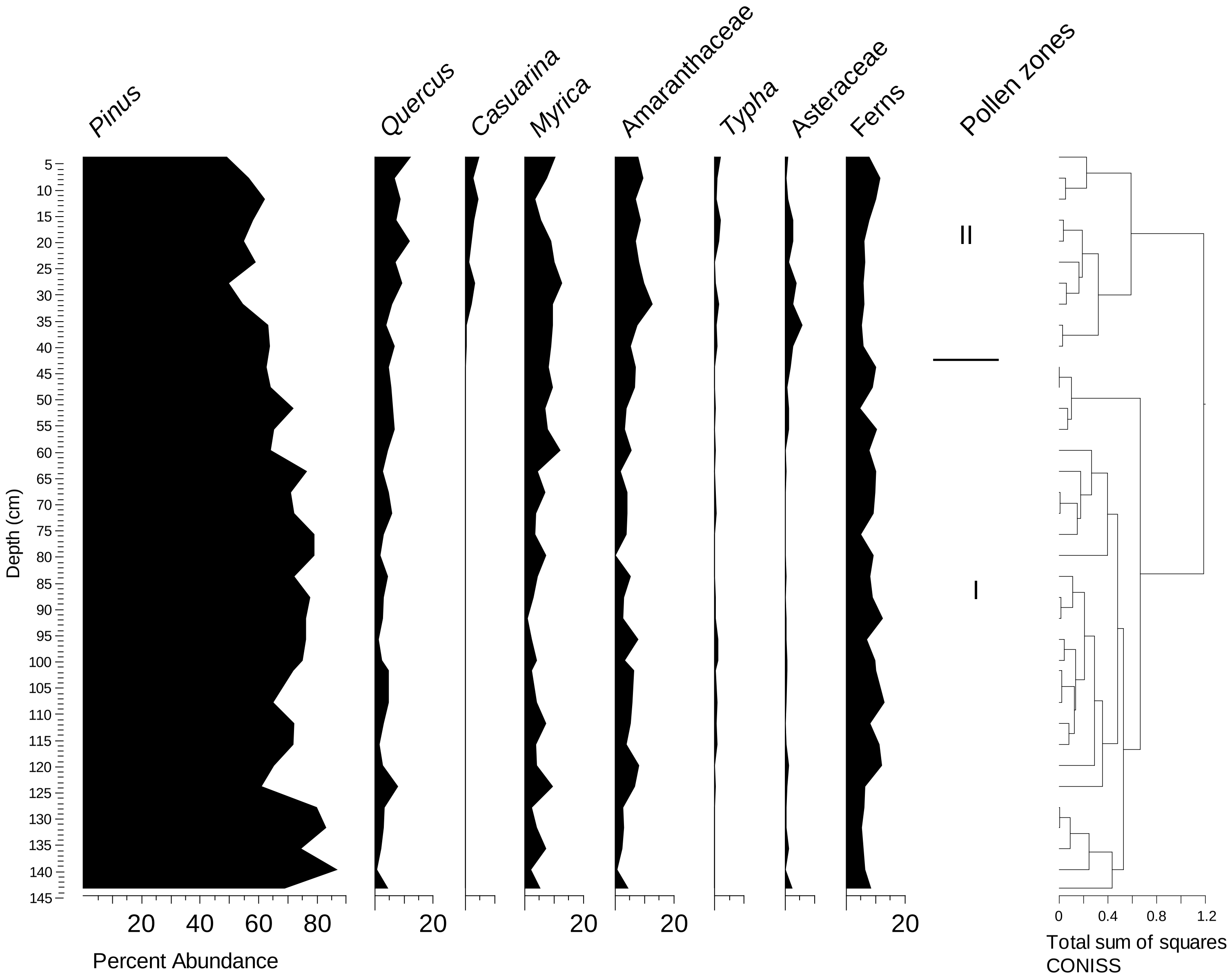
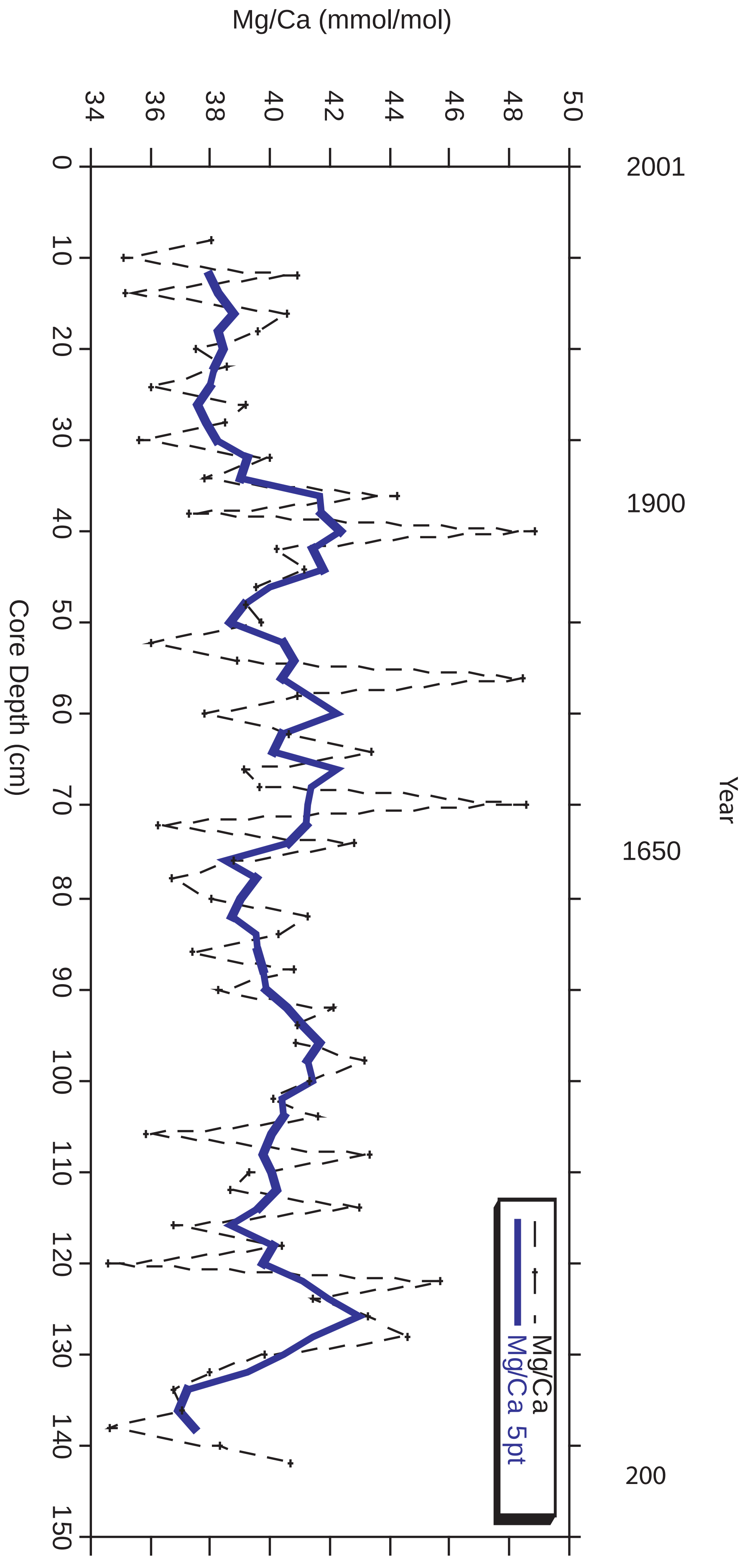


Figure 7. Pollen indicator species assemblages for the Rankin Basin Core (GLBW601 RL1). Also shown is the cluster analysis (CONISS- Constrained Incremental Sums of Squares cluster analysis) for this core.



Rankin Basin
Ostracode Mg/Ca

Figure 8.
Mg/Ca ratios of selected ostracode specimens, in the Rankin Basin core GLBW601 RL1.
Blue line in plot is the 5 point moving average.

calibration studies (Dwyer and Cronin, 2001), all of the ratios recorded from this core represent high salinities, but these data indicate that higher salinities were more stable after 1900 AD.

Geochemical Results

Results of the chemical analyses of total carbon (TC) organic carbon (OC), total nitrogen (TN), and total phosphorus (TP) concentrations are presented in app. D. TC, OC, and TN are presented as percent of sediment, and TP is presented as μg/g of sediment for convenience of presentation. All concentrations are on a sediment dry weight basis. TC contents of the sediments ranged from 13.9 to 10.6 percent. OC contents ranged from 5.41 to 1.06 percent and TN contents ranged from 0.660 to 0.105 percent. These values are somewhat higher than OC and TN contents of sediments in eastern Florida Bay, but similar to OC and TN contents in Whipray Basin (Orem and others, 1999). TP content ranged from 332 to 101 μg/g.

The TC, OC, TN, and TP results are plotted versus depth in fig. 9. TC contents are relatively constant (13.0-13.9 percent) in the upper 25 cm, then decline from 25 to 35 cm to relatively constant values (10.6-11.3 percent) below 35 cm. The peak in TC content (13.9 percent) occurs at 20-22 cm, corresponding to similar peaks in OC and TN. The vertical profiles of OC and TN are virtually identical. Peak concentrations for both OC and TN (and for TC) occur at about 21 cm, but the bulge in OC and TN actually covers the range from about 12 to 23 cm depth. Below about 23 cm, concentrations generally decrease with depth as a consequence of microbial recycling of organic matter. Small secondary peaks in TC and TN are apparent at about 53 and 77 cm, and may represent small increases in organic productivity in Florida Bay. The TP downcore profile differs from that of OC and TN. The downcore plot of TP shows an overall

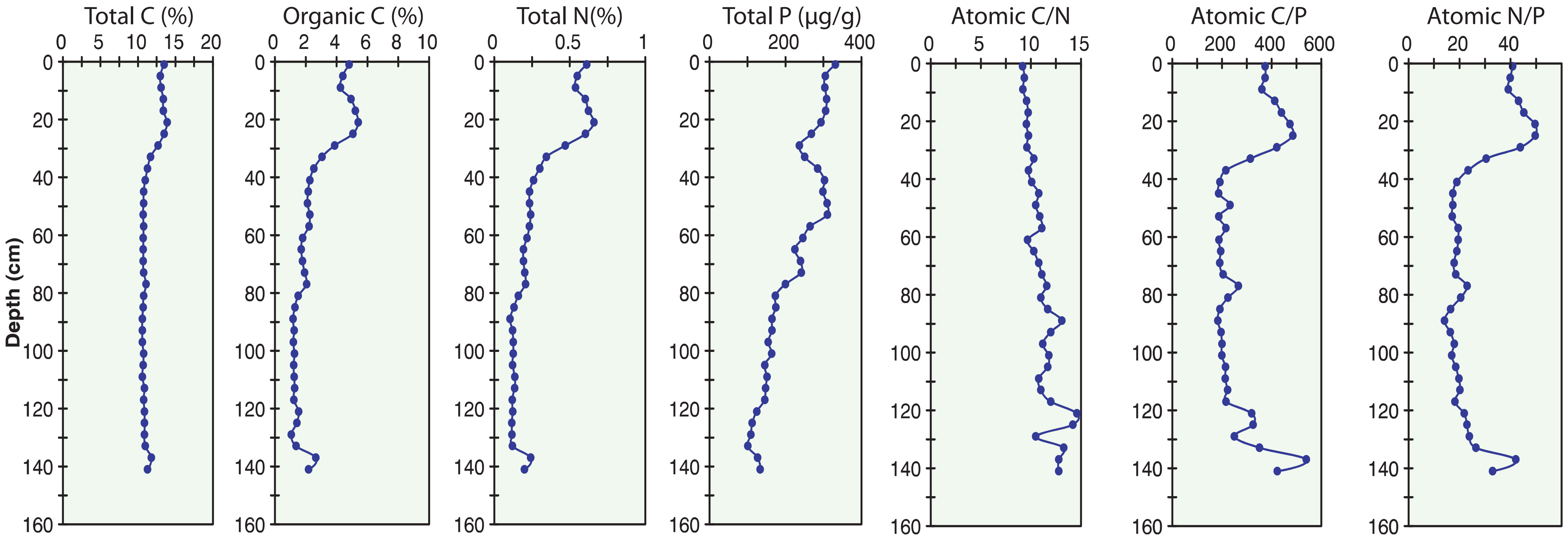


Figure 9.
Rankin Basin core GLBW601 RL1
Organic elemental composition of sediments
and atomic ratios.

decline from the top to the bottom of the core, presumably due to biodegradation and recycling of the TP in organic matter. Superimposed on this overall decline in TP are subsurface peaks, notably in the 10-20 cm and 40-75 cm depth intervals.

Atomic C/N, C/P, and N/P ratios also are presented in app. D. These ratios are shown plotted with depth in fig. 9. Atomic C/N ratios range from 9.1 to 14.6. This is within the range of values typical for nearshore marine sediments and suggests mostly marine influence with some influx of terrestrial material. The atomic C/N ratio gradually increases with depth in the core, reflecting preferential recycling of N-containing organic matter.

The atomic C/P ratios range from values of 184 to 540, again typical of nearshore marine sediments. The large bulge in the C/P ratio from the surface to about 35 cm reflects the large amounts of organic C deposited during a peak in productivity, as discussed earlier. Atomic C/P values gradually increase with depth below 40 cm, reflecting preferential decomposition on P-containing organic matter. The large jump near the base of the core reflects the effects of approach to the limestone bedrock. Atomic N/P values range from 14.1 µg/g to 49.7 µg/g in this core.

Elemental Results

All of the elemental analyses of the insoluble residue conducted on samples from core GLBW601 RL1 show noticeable changes between 56 and 36 cm, which correspond to the beginning of the floral and faunal changes. Individual elements are plotted in figures 10 and 11, and elemental ratios are shown in figures 12 and 13.

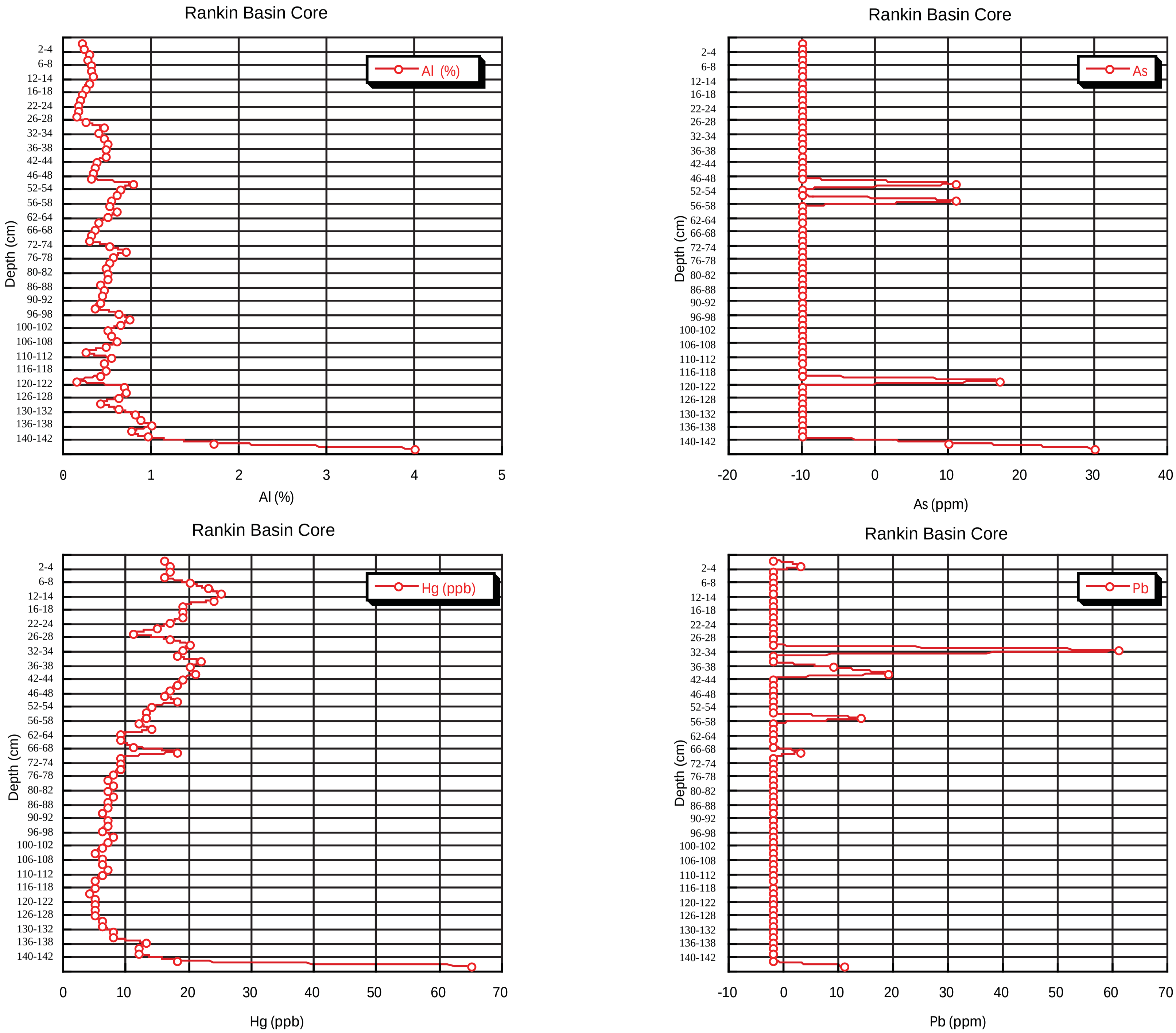


Figure 10. The elemental analyses of the insoluble residue conducted on intervals from the Rankin Basin core (GLBW601 RL1).

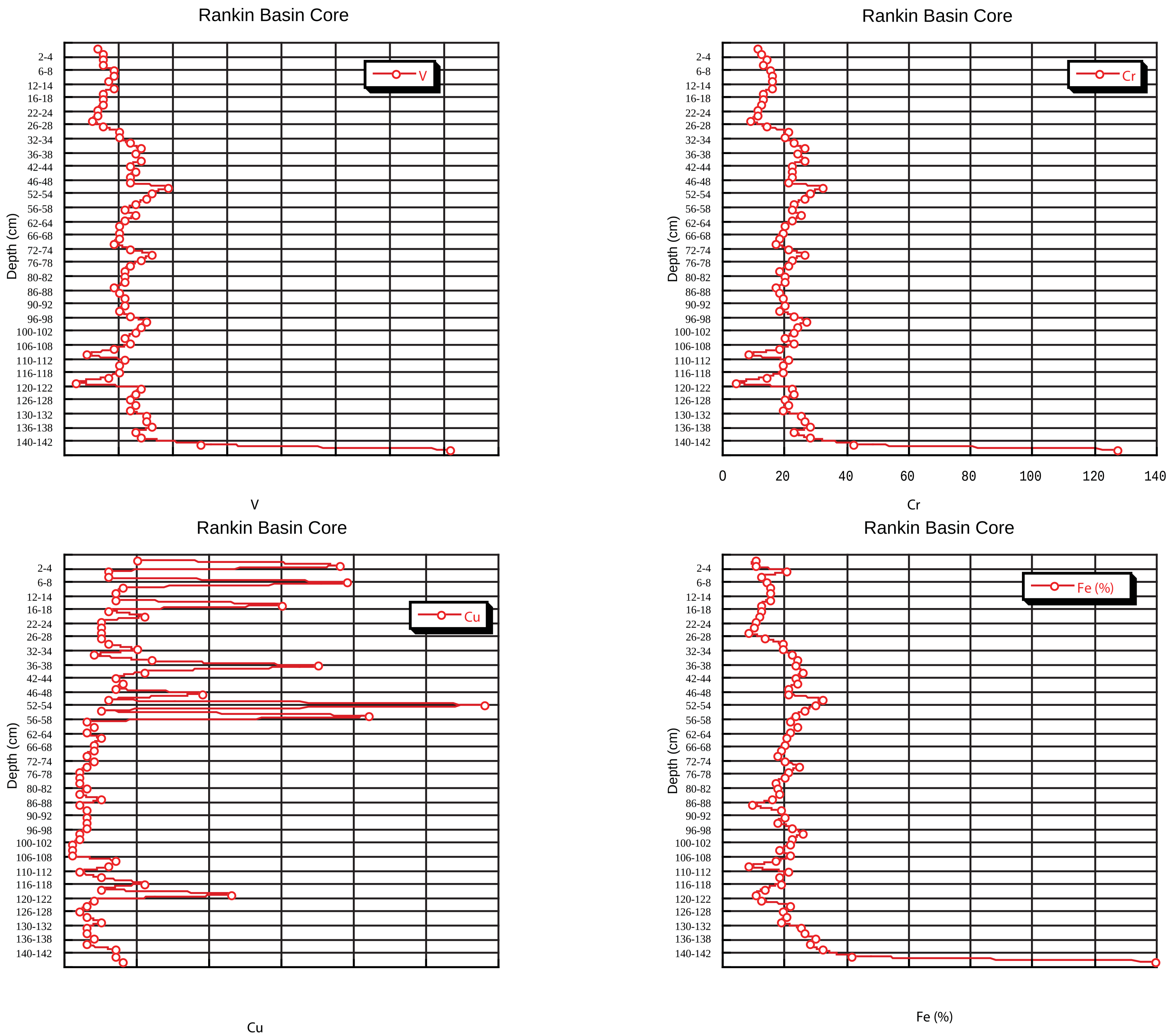


Figure 11. The elemental analyses of the insoluble residue conducted on intervals from the GLBW601 RL1 core.

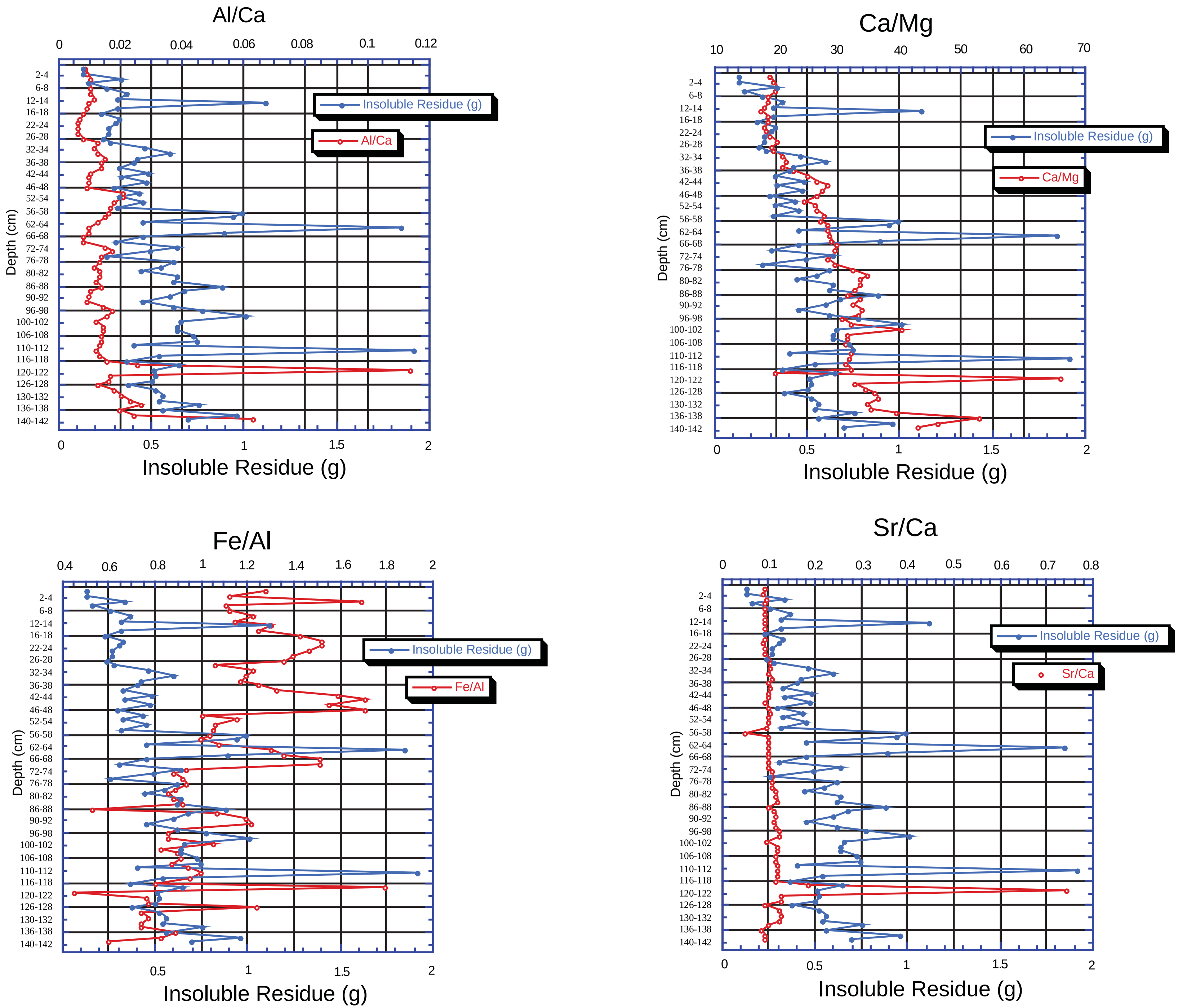


Figure 12. The elemental ratios of the insoluble residue conducted on intervals from the Rankin Basin core GLBW601 RL1.

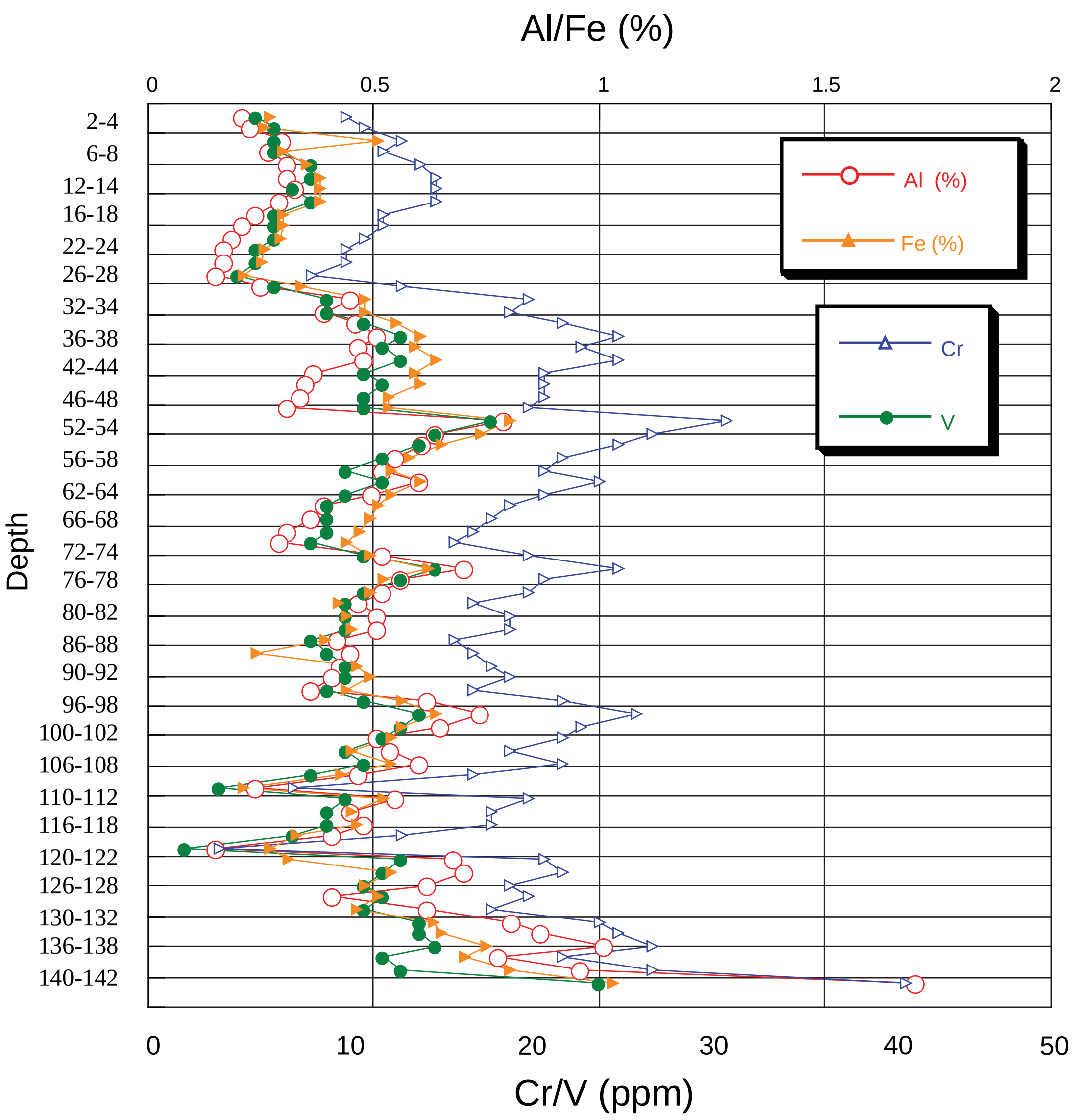


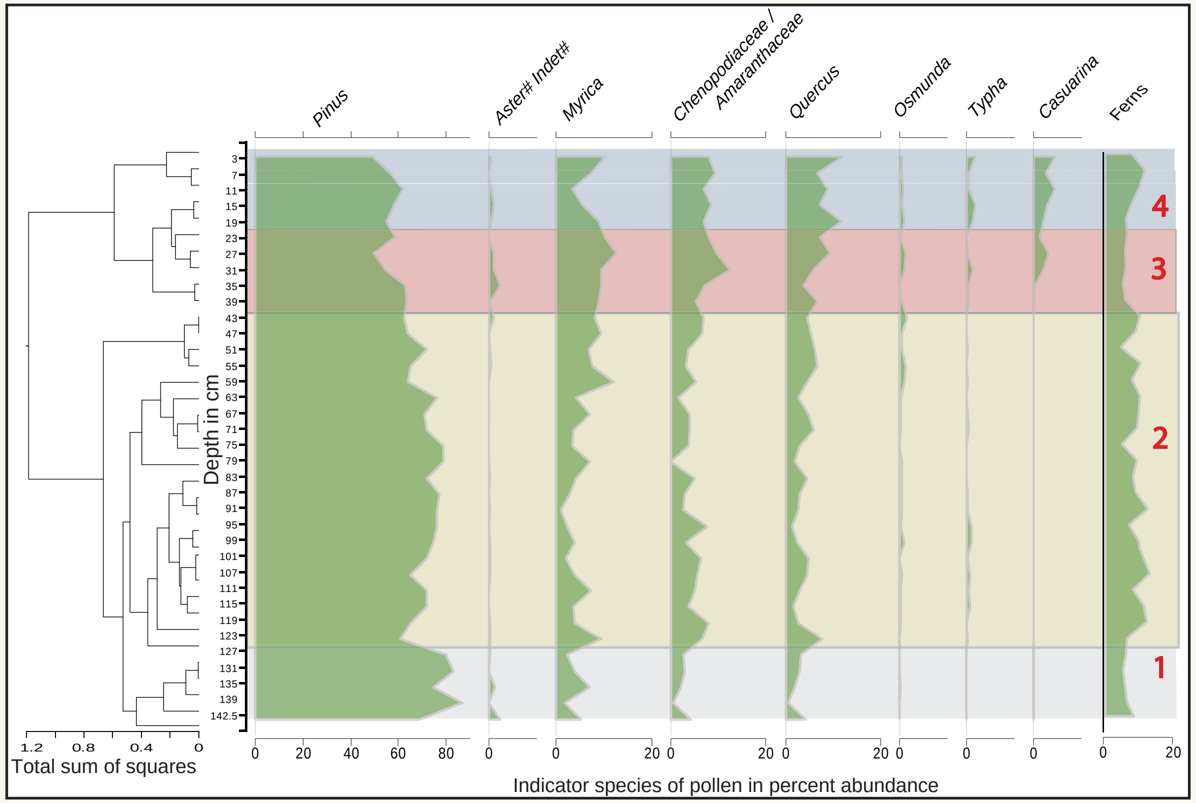
Figure 13 The elemental analyses comparison of Al and Fe percentages to Cr and V for each interval downcore in the Rankin Basin Core GLBW601 RL1.

Discussion

Although multiple environmental factors (including climate and sea-level) control the presence and abundance of any species or group, certain factors such as salinity fluctuations and the presence or absence of abundant seagrass or other requisite substrate often play an important role in the success or failure of a species to colonize and reproduce into larger populations. The patterns in species diversity and abundance that are preserved in sediment cores are therefore an indicator of what the environment may have looked like. The fossil assemblages in the Rankin Basin core (GLBW601 RL1) show strong correlations between terrestrial and benthic aquatic environmental changes. These correlations are illustrated in figure 14 and are represented by the same color bands across (highlighting these similarities) both terrestrial and aquatic assemblages; note the cluster analyses also correlate well across assemblages.

In the lowest segment of the core, Zone 1 (fig. 14), a trend from a mesohaline environment toward a polyhaline system is indicated by the decline of oligohaline and mesohaline molluscan species and in the overall decline in dominance of the ostracode *Malzella floridana*. The molluscan species Polymesoda and others appear only in the lower sections, 143 cm up to 120 cm (200 to 700 A.D.) of the Rankin Basin core and are not observed again.

The interval between 120 cm and 42 cm (fig. 14, Zone 2) indicates an increasingly saline environment, shifting from mesohaline to polyhaline. A progressive increase in sea-grass, *Thalassia testudinum*, occurs between the late 1600s and the early 1900s (114 cm to 38 cm respectively) as indicated by the ostracode *Loxoconcha matagordensis* and multiple species of



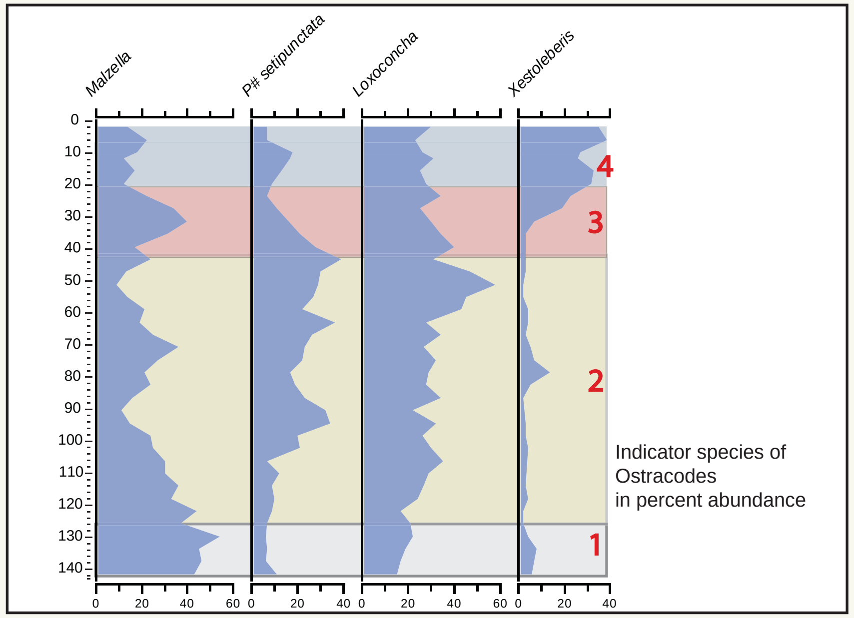
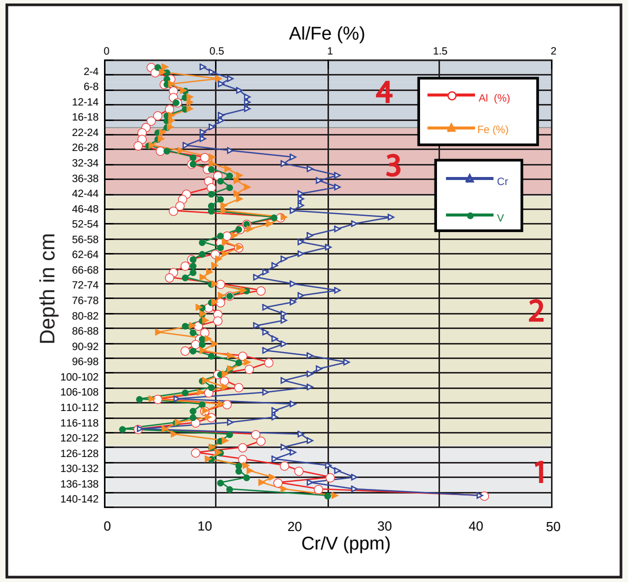
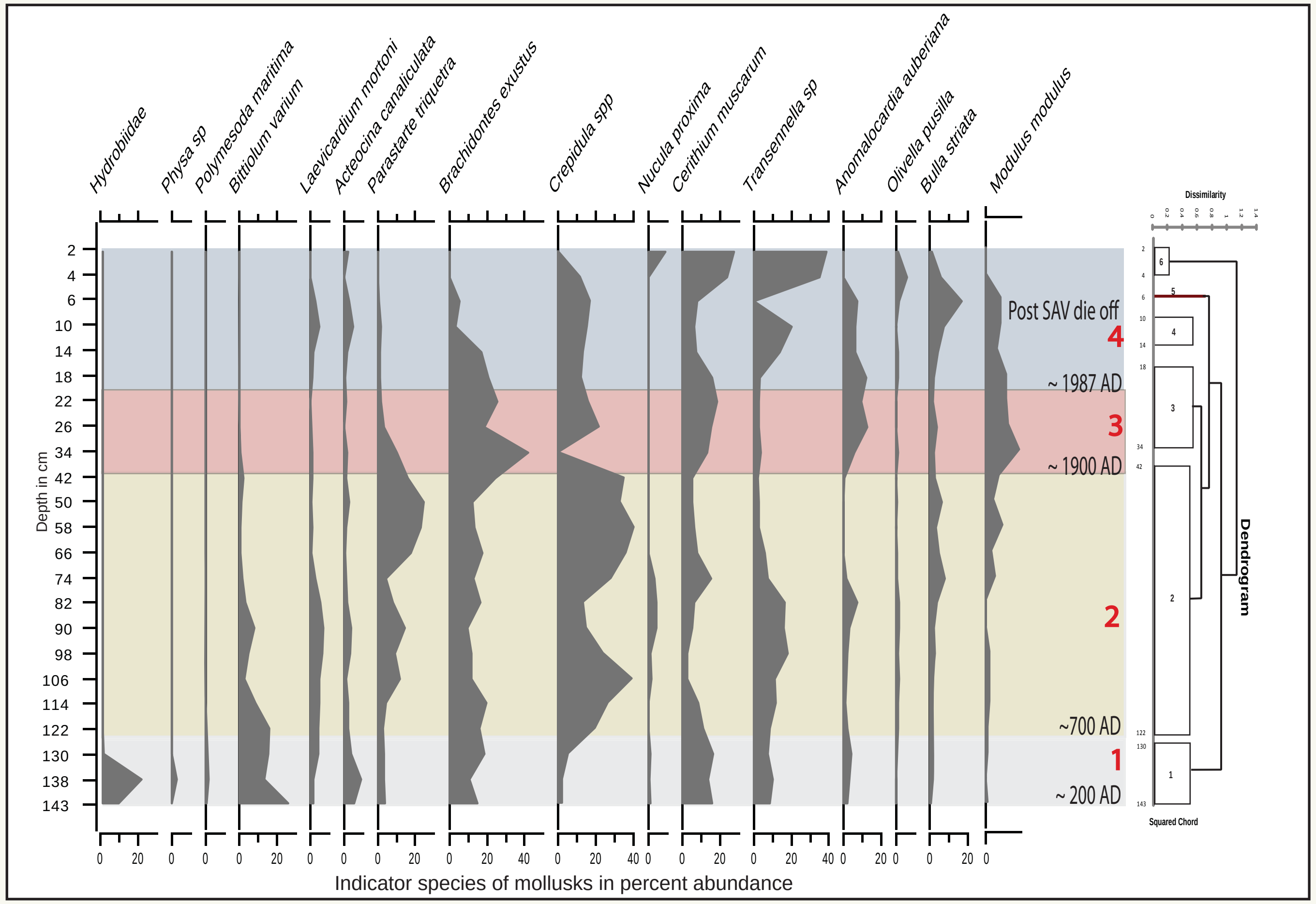


Figure 14.
Summary plot showing pollen, ostracode, and molluscan key species, trends, associated cluster analyses, and insoluble residue elemental analyses.





mollusks, (*Modulus modulus*, *Brachidontes exustus,* and *Crepidula* sp.). The observed ostracode and mollusk species indicate sub-aquatic vegetation was present in the area of the core between 120 cm and 42 cm (molluscan submerged aquatic vegetation (SAV) indicators range between 40-75percent of the total molluscan fauna.) Oscillations in *Malzella floridana* abundance suggest swings in mean salinity in Rankin Basin, including periods of relatively high salinity. These observations are supported by the large fluctuations in Mg/Ca ratios (from 35 to 49 mmol\mol, fig 8) from the ostracode shells. The highest molluscan diversity in the Rankin Basin core occurs between 90 cm and 50 cm.

The beginning of Zone 3 (42-20 cm) corresponds to the approximate beginning of the 20th century, and a number of significant changes occur right around the beginning of this interval. The first appearance of *Casuarina equisetifolia* pollen at ~43 cm marks the turn of the 20th century. A steep decline in the molluscan diversity starts at approximately 42 cm and continues to the top of the core. The elemental analyses of the insoluble residue show significant changes as well between 50 and 30 cm marked by elevated levels of Cu, Fe, Cr, Pb, As, and Hg (figs. 10-13). The significance of these elemental geochemical changes is not well understood but appears to correspond to the beginning of widespread floral and faunal changes. The increases of pollen from *Casuarina, Typha*, and *Asteraceae* in the core indicate the nearby terrestrial environment also was undergoing changes.

Beginning in Zone 3 and continuing to the top of the core, the total phosphorus (TP) values are the highest observed in any of the Florida Bay cores examined by the USGS to date (up to 332 µg/g). These values may indicate input from the terrestrial regions (Orem and others, 1999).

Values in sediments from eastern Florida Bay cores do not exceed 150 µg/g, and TP values from Whipray Basin just to the southeast of Rankin Basin are <250 µg/g.

Zone 4 represents the post-seagrass die-off (1987) segment of the core (20-0 cm). A decline in abundance of *L. matagordensis, B. exustus, M. modulus, Crepidula* sp., and others occurs between 20 cm and 10 cm in the core. There is an unprecedented increase in macro benthic algal habitats, preferred by many species of *Xestoleberis* and *Cerithium*. Pure algal material produce an atomic N/P of approximately 16.0 µg/g, so values approaching this number are indicative of a primary algal source. Atomic N/P in the Rankin Basin core ranges from 14.1 µg/g to 49.7 µg/g, suggesting a large amount of algal material was present.

Summary

The fauna, flora, and sediments preserved in the Rankin Basin core record four distinct periods of environmental change. The gradual increase in salinity from Zones 1 to 2 is consistent with changes associated with rising sea level, and the associated terrestrial vegetation suggests drier conditions. Near the beginning of Zone 3, dramatic changes occur in virtually all indicators measured within the core, including the terrestrial vegetation and geochemistry, which imply that region-wide events were affecting Rankin Basin. The turn of the 20th century marks the beginning of the time period when significant alteration of the South Florida landscape began to occur, as roads, canals, and agricultural areas were developed. The building of the Flagler Railway has been associated with large-scale change in Florida Bay circulation (Swart and others, 1996) and may be a primary factor in explaining these early 20th century patterns. Zone 4 records the seagrass die-off event, but the changes observed in all the environmental indicators in the decades preceding the 1987 die-off imply this "event" was triggered by a long sequence of ongoing and cumulative environmental changes.

Together these patterns, first observed in other sediment cores form Florida Bay and now reproduced at Rankin Basin, suggest that dynamic salinity variations and associated seagrass fluctuations have been influenced by climate, sea level, rainfall variability, and changes in salinity patterns over the past 300 years, exacerbated by altered freshwater flow patterns and (or) water exchange (especially during the 1900s). It appears that these environmental fluctuations were anomalous relative to fluctuation patterns prior to the 20th century, which implies that altered water circulation changed boundary conditions sufficiently to create a bay increasingly susceptible to climate, sea level, and land-use changes.

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Appendix A. Mollusk species total excluding worn and fragmented specimens for core GLBW601 RL1, Rankin Basin, Florida Bay.

	Sample depth (centimeters)																						
Species	2	4	6	10	14	18	22	26	34	42	50	58	66	74	82	90	98	106	114	122	130	138	143	Total # of particular specimens
Acteocina canaliculata	2		3	7	2	2	4	0	5	21	22	12	5	7	9	15	20	5	8	13	12	72	33	279
Anomalocardia auberiana			9	9	8	42	40	56	19	5		1	2	13	39	13	13	7	4	14	14	27	12	347
Arcopsis adamsi																		1		5	3			9
Argopecten irradians										0	0						2							2
Bittiolum varium							1		1	37	9	7	4	12	16	33	27	11	33	101	52	103	165	612
Brachidontes exustus			7	5	21	71	111	83	139	462	111	147	142	96	90	40	68	50	78	103	63	83	96	2066
Bulla striata	1	1	21	11	5	8	7	17	7	47	59	38	39	60	19	8	17	7	7	11	6	13	2	411
Busycotypus sp.												2												2
Calliostoma sp.										1														1
Carditamera floridana			1	2					1	2	3	1		2	3	1								16
Cerithidea sp.																								1
Cerithiopsis greeni														4										4
Cerithium eburneum ?							1				1			2					1	1				6
Cerithium muscarum	24	4	10	9	9	55	79	67	44	102	50	73	62	113	35	22	15	12	33	72	55	107	101	1153
Cerithium sp.	1	1																						1
Cerithium sp cf muscarum						2																		2
Cerodrillia sp.																								0

	Sample depth (centimeters)																							
Species	2	4	6	10	14	18	22	26	34	42	50	58	66	74	82	90	98	106	114	122	130	138	143	Total # of particular specimens
Chione cancellata											1			5	8	14	19	5	1	4	4	0	6	67
Codakia sp.																			1	1			1	3
Columbella rusticoides											2	3												5
Columbellid													2		2									4
Conidae juv										1														1
coppery muscle-like sp.													1											1
Corbula swiftiana																							1	1
Crepidula sp.																								17
Crepidula sp.		2	21	22	16	41	68	97		653	297	448	285	210	71	62	140	167	105	125	17	18	13	2878
Cumingia tellinoides							1		1	4				2	1		2				1	1	1	14
Cyclostremiscus suppressus							1		1		1						1		1	3			5	13
Dentimargo sp cf aureocinctus									2			2			1									5
Fasciolaria sp						1						1	0										1	3
Granulina hadria		1	3	2	1	2	2	1	1	2	2		1	2	4			1	1	3		2		31
Haminoea elegans				3			6	5									2							16
Haminoea succinea				12	10	10	9	9		15	16	7	5	0	5		2							100
Hydrobiidae																					1	162	54	217
Lasaeidae											2	1			3			1	3					10

	Sample depth (centimeters)																						
Species	2	4	6	10	14	18	22	26	34	42	50	58	66	74	82	90	98	106	114	122	130	138	143	Total # of particular specimens
Laevicardium mortoni			3	7	2	3	1	3	4	17	6	11	4	19	28	29	39	21	18	27	14	12	11	279
Latirus cariniferus									2															2
Limaria sp. cf. L. pellucida									1															1
Longchaeus crenulatus																					1			1
Lucinisca nassula													2	3	2	7	7	2	0	4	1		2	30
Lyonsia sp.	4		7	3	1	2	2	1	1	0		3	1	2	2									29
Marginellid													0	0	0	0				1				1
Marshallora nigrocincta							2		0	11	4	1	5	1		1	2	2	0	3			4	36
Melanella sp.																		1						1
Mitrella argus												0												0
Mitrella argus					1																			1
Mitrella ocellata			1		2	4	2	3	1	6	2		3	3										27
Modulus modulus			5	6	4	20	26	29	31	67	21	56	13	20	1	0	5	5	5	5	2	2	2	325
Murex cf Poiriera stimpsoni											1													1
Muricidae												1												1
Musculus lateralis											1													1
Nassarius albus																	2					2		4
Nucula proxima	8											1	1	22	22	18	7	6	1	0	4	4	8	102

	Sample depth (centimeters)																						
Species	2	4	6	10	14	18	22	26	34	42	50	58	66	74	82	90	98	106	114	122	130	138	143	Total # of particular specimens
Nuculana acuta																			2	6				8
Odostomia laevigata	3	1	7	1	2	1	1	3	0	3	1	5	2	4	5	7	4	4	3	15	12	2	10	96
Olivella pusilla	1	1	2		1	3	1		3	2	5	1	5	4	10	6	7	7	5	7	2	2		75
Parastarte triquetra			1	2	1	3	6	15	34	303	226	261	141	34	45	61	55	51	17	17	10	25	25	1333
Parvanachis obesa	1																							1
Pectinid										0														0
Physa sp.																				1		23		24
Pilsbryspira leucocyma						1		1			1	1	1	1				1					0	7
Pitar simpsoni																1				5	5			11
Planorbella duryi																						6		6
Polygyridae																						2		2
Polymesoda maritima																			1	5	4	13	5	28
Prunum apicinum	2																							2
Prunum sp. cf. apicinum													6					0	3	2	7			18
Prunum sp. cf. apicinum			3	4	3	24	26	12	9	29	10			18	8		6							152
Pseudosuccinea columella?																						2		2
Pteria longisquamosa						0	0	1	0	0	0	0	0	0	0		0	0	0	0	0	0	0	1
Rictaxis punctostriatus			4	1	1	2					1				2	1								12

	Sample depth (centimeters)																						
Species	2	4	6	10	14	18	22	26	34	42	50	58	66	74	82	90	98	106	114	122	130	138	143	Total # of particular specimens
Rissoina cancellata														1	1	1	0	1	6	6	1		1	18
Schwartziella catesbyana									4	11	1	2	1	4	2	3	4	3	6	18	14	21	13	107
Stellatoma stellata							2	2	1	7		1	2	2	5		8	2		2	1		1	36
Tellina mera	2																							2
Tellina sp.			18	9	14	28	21	22	6	15	11	7	10	20	12	11	9	5	0	9	2	6	4	239
Tellina tampaensis																			1		1			2
Tellina texana	4																		3	0	2			9
Transennella sp.	34	6		29	17	11	11	12	12	43	26	28	46	54	90	67	107	48	47	56	25	81	53	903
Turbonilla sp.										2					3	0	1					1	2	9
Turrid								2		0	3		1						2	0		1		9
Unidentified Gastropods			0		0	4	0	1	0	2	11	0	3	7	1	2	0	0	0	3	0	1	0	35
Unidentified Pelecypods					0				0	0	0	0	4										0	4
Vitrinella floridana				1		3	2	4	1	3		2	1	2							1	1	4	25
Volvarina sp. cf avena					1	1				3	1						2							8
Total number of specimens in this interval	87	17	126	145	122	344	433	446	331	1876	908	1124	800	749	545	423	593	426	396	648	337	795	636	12324

Appendix B Ostracod counts for GLBW601 RL1

Depth	Actinocythereis	Cytheromorpha	Loxoconcha	Malzella	P stephensoni	P. setipunctata	Perissocytheridea	Xestoleberis	Puriana	Reticulocythereis	Other	Total ostracodes	Comments
1	0		29	13	1	6		34			17	100	
3												0	
5	0	2	22	21	1	6		38		2	8	100	
7												0	
9	1		25	17		17		26			14	100	
11	0	0	30	11	0	16		25		5	13	100	
13												0	
15	1	1	24	16	0	12		32		4	10	100	
17												0	
19	1	0	27	11	0	8		31		6	16	100	
21												0	
23	1	0	33	21	1	6		22		3	13	100	
25												0	
27	0	0	24	33	0	10		18		3	12	100	
29												0	
31	2		29	39	2	15		6		3	4	100	
33												0	
35	1	1	33	30	4	20		2		1	8	100	
37												0	
39	4		39	16	3	27				1	10	100	
41												0	
43	0	0	30	23	2	38					7	100	
45												0	
47	0	0	46	12	1	29		2			10	100	
49												0	
51	0	1	57	8	2	28		1			3	100	
53												0	
55	0	1	44	13	5	26		1			10	100	
57												0	
59	0	2	42	20	2	21		3			10	100	
61												0	
63	0	2	27	18	7	35		3			8	100	
65												0	
67	1	3	33	24	8	25		2		1	3	100	
69												0	
71	1	2	26	35	6	22		4			4	100	
73												0	
75	2	4	31	26	2	21		6			8	100	
77												0	
79	2	3	28	20	8	16		13			10	100	
81												0	
83	1	6	27	23	8	18		4			13	100	
85												0	
87	1	6	33	15	7	22		1			15	100	
89												0	
91	9	5	21	10	4	31					20	100	
93												0	
95	1		31	14	4	33		2			15	100	
97												0	
99	6	4	25	23	4	19		2	2	1	14	100	
101												0	
103	5	4	29	24	3	20	1	3			11	100	
105												0	
107	5	5	34	29	9	6				2	10	100	
109												0	
111	6	6	28	29	4	11	2		2		12	100	
113												0	
115	5	3	26	35	8	8	1	2			12	100	
117												0	
119	12	7	23	32	1	9	1	3	0	1	11	100	
121												0	
123	16	4	16	43	2	8		1		1	9	100	
125												0	
127	10	8	20	36	3	6	1	1	1		14	100	
129												0	
131	5	2	21	53		5	3	3			8	100	
133												0	
135	2	8	18	44	1	6	4	7		3	7	100	
137												0	
139	4	9	16	45		5	7	6	1		7	100	
141												0	
142.5	6	7	14	42	2	10	1	5	13			100	

Appendix C Total pollen counts GLBW601 RL1

Depth	*Pinus*	*Quercus*	*Casuarina*	*Cephalanthus*	*Myrica*	*Bursera*	*Nyssa*	*Ilex*	Euphorbiaceae	Cheno-Ams	*Ambrosia*	Aster. Indet.	TCT	Poaceae
3	162	40	15	0	34	0	0	1	0	26	1	2	0	2
7	175	21	8	0	23	1	0	0	2	29	1	0	0	1
11	213	30	15	0	12	0	0	0	0	24	1	2	0	0
15	178	22	9	0	17	0	0	0	0	26	5	3	0	1
19	176	38	7	0	29	2	0	0	1	22	7	2	0	0
23	191	23	4	0	33	0	0	1	1	26	4	0	0	2
27	160	30	10	1	41	0	0	0	1	31	9	3	0	1
31	166	18	6	2	29	2	1	0	2	38	5	3	0	0
35	207	12	1	0	31	0	0	0	1	24	11	8	0	2
39	194	20	1	0	27	0	0	0	0	16	7	1	0	3
43	202	15	0	0	26	1	0	0	0	22	3	3	0	1
47	202	17	0	0	30	1	0	0	0	21	2	0	0	3
51	233	20	0	0	22	0	0	0	0	12	3	1	0	0
55	205	21	0	0	24	0	0	0	1	10	2	2	0	1
59	203	14	0	0	38	1	0	0	0	17	0	0	0	4
63	236	8	0	0	13	0	0	0	3	5	1	0	0	0
67	223	15	0	0	22	0	0	0	0	13	0	0	0	2
71	234	19	0	0	12	2	0	0	0	13	0	0	0	1
75	209	8	0	0	9	0	0	0	0	10	0	0	0	2
79	246	6	0	0	22	0	0	0	0	0	0	0	0	0
83	225	14	0	0	13	0	1	0	0	16	0	1	3	0
87	244	9	0	0	9	0	0	1	1	9	0	0	1	1
91	238	8	0	0	3	0	0	0	3	8	0	1	0	0
95	228	4	0	1	7	0	1	0	0	23	1	0	0	0
99	229	7	0	1	12	0	0	0	1	10	1	1	0	1
101	228	15	0	0	7	0	0	0	0	20	1	1	0	1
107	239	17	0	0	15	0	0	0	0	21	0	1	0	3
111	238	10	0	0	24	0	0	0	2	17	0	0	0	1
115	239	5	0	0	12	0	0	0	2	12	1	0	0	0
119	201	8	0	0	12	0	0	0	0	25	3	1	0	1
123	195	25	0	0	30	0	0	0	1	21	1	1	0	0
127	247	10	0	0	7	0	1	0	0	8	0	1	0	0
131	253	9	0	0	12	0	0	0	0	9	1	0	0	0
135	231	6	0	0	22	0	0	0	0	7	0	4	0	5
139	268	2	0	0	6	0	0	0	0	2	0	0	0	1
142.5	208	13	0	0	16	1	0	0	1	13	0	7	0	1

Nymphaea	**Ericaceae**	**Cyperacea**	***Cladium***	***Typha***	***Schinus***	***Rhus***	***Rhizophor***	***Laguncula***	***Conocarp***	***Callicarpa***	***Carica***	***Sabal***	***Batis***	***Sambucus***	***Hydrocotyle***
0	0	0	0	6	0	1	0	0	0	2	1	0	1	0	0
0	0	2	0	2	0	0	0	0	0	1	0	0	0	0	0
0	0	2	1	2	0	1	0	0	0	0	0	0	0	0	0
0	0	3	1	6	0	1	2	1	1	0	2	1	1	0	0
0	0	1	1	4	0	0	0	1	0	1	0	0	0	0	0
0	0	1	3	0	0	1	1	0	0	2	0	1	0	1	0
0	0	2	0	1	0	1	0	0	0	2	0	0	0	0	0
0	1	0	0	4	0	0	0	0	0	1	0	0	0	0	0
0	0	1	0	2	0	0	0	0	0	0	0	0	4	1	0
0	1	2	0	2	0	2	2	0	0	0	0	0	0	0	0
0	2	1	1	0	0	2	0	1	1	3	0	1	1	0	1
0	0	1	2	0	0	0	0	0	0	2	0	0	1	0	0
0	0	1	1	1	1	3	1	0	0	0	0	2	0	0	0
0	1	5	0	0	1	0	0	0	0	0	1	0	0	0	0
0	1	0	0	1	2	1	0	0	0	2	0	2	0	0	0
0	0	0	2	0	0	0	0	0	0	0	2	1	0	0	0
0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0
0	0	0	0	2	0	1	2	1	0	1	0	0	0	0	0
0	1	1	1	0	1	2	0	2	0	0	0	1	0	0	0
0	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	1	2	2	0	0	0	0	2	0	0
0	2	2	1	1	1	0	1	0	0	0	1	0	0	0	0
0	1	1	1	1	0	2	0	1	0	0	1	0	0	0	0
0	2	0	1	3	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0
1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	3	1	0	1	0	0	0	1	2	0	0	0
0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
1	0	1	0	3	1	3	0	0	0	1	1	0	0	0	0
0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0
0	1	0	0	1	0	1	0	4	0	2	1	0	1	0	2
0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	1
1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	2	4	0	1	0	1	1	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	2	1	0	0	1	0	1	1	0	0	0	0	0	0

Carya	***Liquidamb***	***Ulmus***	***Alnus***	***Juglans***	***Plantago***	***Fraxinus***	***Alternanth***	**Faboideae**	**Fabaceae**	***Pontederi***	***Fagus***	***Morus***	**Solanacea**	***Heliotropi***	***Bacopa***
1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
1	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	3	1	0	0	0	0	0	0	0	0	0	0	0
0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0
1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
0	1	0	2	1	0	0	0	0	1	0	0	0	1	0	0
2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	1	0	0	0	1	0	0	0	0	2	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0
0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
0	1	0	1	0	0	0	0	0	0	0	0	0	2	0	0
1	1	1	1	0	1	0	0	2	0	0	0	1	2	0	0
0	1	0	2	1	0	0	0	0	2	0	0	0	0	0	0
0	3	0	3	0	0	0	0	0	0	0	0	0	4	1	0
2	1	0	2	2	0	0	0	0	0	0	0	0	3	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	1
0	1	0	0	0	0	0	0	0	1	0	0	2	3	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
0	1	1	0	1	0	0	0	0	0	0	0	1	1	0	0
1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0

Sagittaria	***Proserpina***	***Vitis***	***Polygala***	**PC0**	**PC3**	**PO3**	**PD4**	**SCO**	**SAO**	***Osmunda***
0	0	0	0	1	0	4	0	4	20	2
0	0	0	0	1	1	2	0	15	19	2
0	0	0	0	0	1	2	0	11	21	3
0	0	0	0	0	0	1	0	11	11	2
0	0	0	0	0	1	4	0	2	14	3
0	0	0	0	1	1	4	0	7	13	1
0	0	0	0	1	2	1	0	5	10	4
0	0	0	0	2	0	3	0	3	12	3
0	0	0	0	0	0	1	0	5	12	0
0	0	0	0	0	1	1	0	3	13	2
0	0	0	0	0	0	1	0	10	18	5
0	0	0	0	3	0	1	0	14	12	2
0	0	0	0	1	3	1	0	8	5	2
0	0	0	0	1	2	0	1	21	8	4
0	0	0	0	1	0	0	0	12	10	3
0	0	0	0	1	0	0	0	18	12	1
0	0	0	0	1	1	0	0	18	12	1
0	0	0	0	0	1	0	0	16	13	1
0	0	0	0	0	0	1	0	10	3	0
0	0	0	0	0	1	0	0	19	8	2
0	0	0	0	0	1	1	0	18	5	2
0	0	0	0	1	2	0	0	23	3	2
0	0	0	0	0	1	0	0	26	11	2
0	0	0	0	1	2	1	0	13	7	1
0	0	0	0	1	3	1	0	15	12	3
0	0	0	0	3	2	0	0	22	10	0
0	0	0	0	1	5	0	0	32	14	2
0	0	0	0	0	1	0	0	17	9	1
0	0	0	0	0	3	0	0	29	7	1
0	0	0	0	3	4	0	0	22	14	1
3	0	0	0	1	5	0	0	13	7	0
1	0	0	0	1	3	0	0	12	7	0
0	0	0	0	0	2	0	0	11	5	0
0	0	0	0	1	2	1	0	6	11	1
0	1	1	0	1	1	0	0	13	7	0
0	0	1	6	1	0	0	0	14	11	0

Appendix D

Total C, Organic C, Total N, Total P and Atomic C/N, C/P, and N/P ratios of sediments from Florida Bay, Rankin Basin core GLBW601 RL1.
The Total C, Organic C, Total N, and Total P results are reported on a dry weight basis.

Depth (cm)	Total C (%)	Organic C (%)	Total N (%)	Total P (ug/g)	Atomic C/N	Atomic C/P	Atomic N/P
0-2	13.5	4.82	0.613	332	9.17	374	40.8
4-6	13.0	4.42	0.551	305	9.35	374	39.9
8-10	13.1	4.26	0.539	304	9.22	361	39.2
12-14	13.4	4.95	0.603	309	9.57	413	43.2
16-18	13.4	5.22	0.625	306	9.74	440	45.2
20-22	13.9	5.41	0.660	294	9.56	474	49.6
24-26	13.5	5.07	0.605	269	9.77	486	49.7
28-30	12.7	3.88	0.471	237	9.61	422	43.9
32-34	11.7	3.07	0.346	251	10.3	315	30.5
36-38	11.3	2.53	0.302	285	9.77	216	23.4
40-42	11.0	2.27	0.261	303	10.1	193	19.0
44-46	10.8	2.17	0.235	299	10.8	187	17.4
48-50	10.8	2.12	0.235	310	10.5	233	17.4
52-54	10.7	2.27	0.242	311	10.9	188	17.2
56-58	10.8	2.22	0.234	265	11.1	216	19.5
60-62	10.7	1.80	0.217	246	9.67	189	19.5
64-66	10.7	1.71	0.193	225	10.3	196	19.0
68-70	10.7	1.79	0.194	240	10.8	192	17.9
72-74	10.8	1.93	0.203	242	11.1	206	18.5
76-78	11.1	2.07	0.208	200	11.6	267	23.0
80-82	10.8	1.52	0.161	174	11.0	225	20.5
84-86	10.7	1.31	0.131	175	11.7	193	16.6
88-90	10.6	1.18	0.105	165	13.1	184	14.1
92-94	10.6	1.26	0.122	165	12.0	197	16.4
96-98	10.6	1.21	0.126	155	11.2	201	18.0
100-102	10.8	1.27	0.126	164	11.8	200	17.0
104-106	10.7	1.22	0.122	146	11.7	215	18.5
108-110	10.6	1.26	0.136	152	10.8	214	19.8
112-114	10.9	1.28	0.135	148	11.0	223	20.2
116-118	10.8	1.23	0.120	146	12.0	217	18.2
120-122	10.9	1.55	0.124	125	14.6	320	21.9
124-126	10.9	1.43	0.117	113	14.2	326	22.9
128-130	10.9	1.06	0.118	109	10.5	251	23.9
132-134	11.0	1.38	0.121	101	13.3	352	26.5
136-138	11.8	2.66	0.242	127	12.8	540	42.1
140-142	11.3	2.20	0.200	134	12.8	423	33.0