Ecosystem History of Southern and Central Biscayne Bay: Summary Report on Sediment Core Analyses – Year Two

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Table of Contents

Figures

Tables

Appendixes

Abstract/Executive Summary

The Comprehensive Everglades Restoration Plan (CERP) lists restoration of the timing, quantity, and quality of the natural flow of freshwater as one its primary goals. Before restoration can occur, however, the baseline conditions of the environment prior to significant human alteration must be established and the range of variation within the natural system must be determined. In addition, the response of the system to human alterations during the 20th century should be evaluated. Resource managers can use this information to establish targets and performance measures for restoration and to predict the system's response to changes invoked by restoration.

The objectives of the U.S. Geological Survey's Ecosystem History of Biscayne Bay research project are to examine historical changes in the Biscayne Bay ecosystem at selected sites on a decadal-centennial scale and to correlate these changes with natural events and anthropogenic alterations in the South Florida region. Specific emphasis is being placed on historical changes to (1) amount, timing, and sources of freshwater influx and the resulting effects on salinity and water quality; (2) shoreline and sub-aquatic vegetation; and (3) the relationship between sea-level change, onshore vegetation, and salinity.

This report compiles and summarizes results on analyses of cores from eleven sites in the Biscayne Bay ecosystem collected from 1996 to 2003. The following are the significant findings discussed:

- Southern Biscayne Bay, including Card Sound and Barnes Sound, has experienced distinctive changes over the last century. The four sites examined, Card Bank (northwest and southeast sides), Middle Key basin, and Manatee Bay, all show increasing salinity over the last 100 years.
    - Card Sound Bank has experienced relatively large swings in salinity, fluctuating between a more restricted upper estuarine environment and a more open estuarine environment, over multi-decadal and centennial timescales. The amplitude of change exceeds that seen in cores from central Biscayne Bay (No Name and Featherbed Bank). During the later part of the 20th century, the site has come under increasing marine influence. (Wingard and others, 2003, corroborated by new data in this report)
    - Middle Key basin has seen a steady increase in salinity that began prior to 1900. The earliest records from this site indicate a freshwater, limnetic environment, which began to shift toward brackish before the start of the 20th century. From the 1960s to the present, freshwater supply to Middle Key basin diminished, relative to the rise of estuarine conditions. Salinities in the basin ranged from mesohaline to polyhaline throughout the 20th century, and there is some evidence of increasingly fluctuating salinities over the past few decades at the site.
    - Manatee Bay also has undergone a change from a freshwater environment at the base of the core transitioning to an estuarine environment at the top (Ishman and others, 1998), similar to that seen in Middle Key basin. At

the Manatee Bay site, however, salinities in the upper part of the core reached upper polyhaline to euhaline levels.
    - Total carbon (TC), organic carbon (OC), total nitrogen (TN), and total phosphorus (TP) concentrations were all significantly high in the core from the Card Bank site, relative to the mudbank cores from central Biscayne Bay. However, the Middle Key site does not exhibit any significant increase in TP concentration in the upper 20-30 cm, as seen in the other cores examined.
- The mudbanks of central Biscayne Bay have become increasingly marine and have experienced lower amplitude decadal variability in salinity over the last one hundred years. (Wingard and others, 2003; corroborated by new data in this report)
    - The continental shelf and open marine influence has increased during the 20th century at Featherbed and No Name Banks.
    - No indications of inter-decadal salinity extremes have been found in cores from Featherbed and No Name Banks; salinities at these sites ranged from polyhaline to euhaline over the last three to four centuries.
    - The downcore total phosphorous (TP) profiles at No Name Bank represent a large increase in TP flux to the sediments, superimposed on the normal diagenetic recycling of P.
- The near-shore cores from north of Black Point and at Chicken Key record a period of fluctuating salinity during the last 50-100 years or more. Both sites show an increase in average salinity from mesohaline to polyhaline conditions, and possibly an increase in salinity fluctuations, in the last 10-30 years.
    - The direct influx of freshwater to the site north of Black Point appears to have fluctuated over the period of time represented by the core. From before 1900 to ~1970, direct freshwater influx to the site seems to have diminished, despite the lowering of salinities during this time period. The lowered salinities may have been caused by increases in groundwater upwelling, or dilution of the estuarine waters via runoff from other areas and/or by increased rainfall. In the late 20th century, the significant increase in freshwater gastropods indicates a direct influx of freshwater to the site.
    - At Chicken Key, no freshwater fauna were found in the core, suggesting that the site has not been influenced by a direct influx of freshwater during the time represented by the sediment accumulation.
    - Chicken Key and Black Point North cores exhibit a sharp increase in total phosphorous (TP) concentration above 20-30 cm. This increase appears to be above normal diagenetic trends, and may indicate an increase in TP load to the sediments in recent times.
- Pollen assemblages from all core sites reflect the long-term dominance of pinelands on the coastal ridge prior to the 20th century, followed by vegetational changes associated with various land-use activities.
    - Comparing the three near-shore cores, the greatest changes were noted at the two northernmost sites (Chicken Key and Black Point North). These

changes are roughly coincident with land clearance, initiation of extensive row-crop agriculture, and canal construction in the area.
- The two cores from Military Canal indicate that the southern site has always been relatively drier than the northern site, and that the vegetational differences between the two sites pre-date construction of the canal.
- At the Black Point North site, mangrove abundance peaked in the 1980's, but declines sharply at the top of core, reflecting the impact of Hurricane Andrew in 1992.

A general trend emerges from the multiproxy analyses of all the cores examined – increasing salinity during the 20th century. Although the timing and onset of increased salinity varies at the different core sites, there are no exceptions to this trend. In the nearshore sites, the increase in average salinity has been accompanied by an increase in variability of salinity. In contrast, the central Biscayne Bay sites have shown increasingly stable salinity over the last century, indicated in part by the influx of increasing numbers of marine species. These trends could be a result of a number of factors, including (1) rising sea level; (2) changes in the natural flow of freshwater into the bay either through surficial or groundwater processes; (3) changes in average rainfall or rates of evaporation; (4) changes in sedimentation rates; or (5) a combination of factors. The timing of changes at some of the near-shore sites suggests both anthropogenic and natural factors are involved.

In addition to the general salinity trend for Biscayne Bay, the near-shore sites at Middle Key and north of Black Point have illustrated distinct, but site specific, changes in freshwater influx over time. Our data suggest that sites we assumed had historic point-source inflow of freshwater may not have. The wetlands cores (near Military Canal) also illustrate that sites in very close proximity to each other have historically been affected by very localized hydrologic regimes.

These results have significant implications for restoration planning. First, the recognition that Biscayne Bay appears to be evolving toward a more marine environment due to both natural and anthropogenic factors must be factored into the planning process. Second, generalized performance measures and targets for the near-shore and wetlands areas may not reflect the natural variability seen at these sites. Third, the nearshore environments are dramatically different from the mid-bay mudbanks, and have been for hundreds of years. Influx of freshwater into the bay appears to have a subtle or indirect effect on the benthic fauna of the mudbanks. Changes in flow during restoration may have little effect on the central bay mudbanks.

Examining decadal-centennial trends in a variety of habitats within the Biscayne Bay ecosystem provides a realistic means to set performance measures, predict system response to changes invoked by restoration, and to enlighten the public on what the natural system of the bay looked like.

INTRODUCTION

Biscayne Bay is a large (428 square miles) subtropical estuarine ecosystem (Figure 1) that began forming approximately 3200 years ago as sea level rose and flooded southern Florida (Wanless and others, 1994). Throughout most of its history the pristine waters of the bay supported a rich and diverse marine fauna and flora and the bay waters served as a nursery for the adjacent coral reef ecosystem. In the 20th century, urbanization of the Miami-Dade area profoundly affected the environment of the bay. Construction of power plants, water treatment plants, solid waste sites, and large scale development along the shoreline stressed the ecosystem. Demands of the population for reliable freshwater supply and flood control led to the construction of extensive canal systems throughout south Florida, most notably the Central and Southern Florida Project.

The current massive effort to restore south Florida, guided by the Comprehensive Everglades Restoration Plan (CERP), lists restoration of the timing, quantity and quality of the natural flow of freshwater as one its primary goals. Before restoration can occur, however, the baseline conditions of the environment prior to significant human alteration must be established and the range of variation within the natural system must be determined. This information can then be used by resource managers to establish targets and performance measures for restoration.

The objectives of the U.S. Geological Survey's Ecosystem History of Biscayne Bay research project are to examine historical changes in the Biscayne Bay ecosystem at selected sites on a decadal-centennial scale, and to correlate these changes with natural events and anthropogenic alterations in the South Florida region. Specific emphasis is being placed on historical changes to (1) amount, timing, and sources of freshwater influx and the resulting effects on salinity and water quality; (2) shoreline and sub-aquatic vegetation; and (3) the relationship between sea-level change, onshore vegetation, and salinity.

The information generated by this research addresses the needs of the many entities involved in managing Biscayne Bay, primarily Biscayne National Park and South Florida Water Management District (SFWMD). SFWMD's Water Management Plan for south Florida includes the establishment of minimum flows and water levels for different bodies of water within the District, including Biscayne Bay (with an emphasis on central and southern Biscayne Bay) (www.sfwmd.gov/org/wsd/mfl/biscaynebay). The purpose of the Biscayne Bay Coastal Wetlands Project (BBCW) of the Comprehensive Everglades Restoration Plan (CERP) is "to rehydrate wetlands and reduce point source discharge to Biscayne Bay" (http://www.evergladesplan.org/pm/projects/proj_28_biscayne_bay.cfm) and the project identifies the need to "define target freshwater flows for Biscayne Bay and the wetlands." Biscayne National Park, like all National Parks, was charged by the Organic Act of 1916 with "conserving the scenery and the natural and historic objects, and the wildlife therein and to provide for the enjoyment of the same in such means as will leave them unimpaired for the enjoyment of future generations." One of the Park's management goals is to understand how the

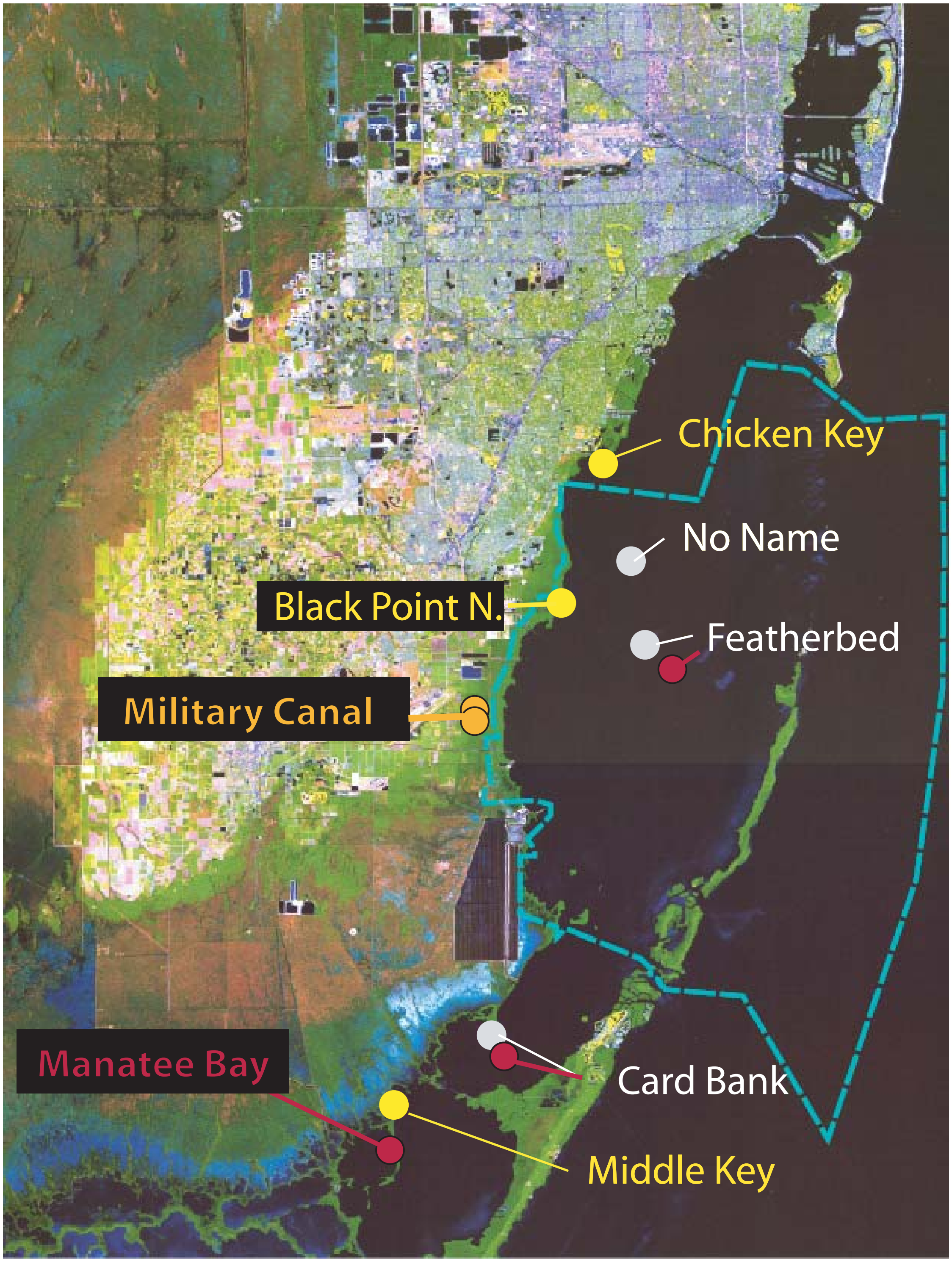

Figure 1. Satellite image map of Biscayne Bay, Florida, showing sites where USGS cores were collected and the boundary of Biscayne National Park (blue dashed line). Image cropped from John W. Jones and others (2001).

conditions of the resources have changed over time. Our research provides these agencies with long-term spatial and temporal data on changes to the ecosystem that allow them to establish minimum flow values, targets, and performance measures based on centuries of data and to understand how to conserve and protect the resource.

In order to achieve our project objectives, we have examined a total of eleven cores, six collected specifically for the current project. This report is divided into three sections to discuss three different categories of cores: (1) mudbank cores; (2) wetland cores; and (3) near-shore cores. Three of the eleven cores were collected from mudbanks in central and southern Biscayne Bay in 2002, and the bulk of these analyses were discussed in Wingard and others (2003); however, some additional analyses completed since the publication of that report are described here in the "Additional Analyses of Mudbank Cores" section. Two wetland cores were collected in order to examine changes to the wetland ecosystems bordering the bay; these are discussed in section entitled "Patterns of Change in the Wetlands at Military Canal." In order to determine more accurately the role of freshwater influx on the patterns seen in the mudbank cores, three additional cores were collected in 2003 at sites located in near-shore areas in close proximity to historical freshwater drainage; the preliminary results of these analyses are reported in the "Patterns of Change at Near-shore Sites" section.

The multiproxy, multicore approach utilized in this study has been successfully used in Florida Bay (Brewster-Wingard and others, 1998; Brewster-Wingard and Ishman, 1999; Nelsen and others, 2002; Wardlaw, 2001) and will be utilized to address issues in other areas of south Florida in the future. By understanding the past – the natural range of variation within an ecosystem – we can set realistic goals for restoration, and through the past we can potentially understand the future and how the system will respond to restoration efforts.

ACKNOWLEDGMENTS

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Radiocarbon analyses were conducted by Beta Analytic Radiocarbon Dating Laboratory, Miami, Florida. James Murray, Rob Stamm, and Joe Murray (U.S. Geological Survey) assisted with field work and the collection of the cores.

MATERIAL AND METHODS

Core Sites and Collection

This report discusses and/or includes results from three sets of cores collected between 1997 and 2003 (Table 1). The two wetland cores were collected in 1997 on either side of Military Canal (Figure 1) in collaboration with Dade County Department of Environmental Resources Management. Six cores were collected from three mudbanks located in a generally north-south transect through the Bay in 2002 (Figure 1; No Name Bank, Featherbed Bank, and Card Bank) (see Wingard and others, 2003 for complete description of cores and collecting methods). Three additional sites were selected in 2003 in areas within close proximity to historical freshwater outflow (Figure 1). Six cores were successfully collected from these three near-shore sites on June 19-20, 2003: 1) the basin west of Middle Key; 2) an inlet just north of Black Point; and 3) the southern end of Chicken Key. A and B cores were taken side by side at all three near-shore sites.

For the 2003 near-shore cores, the subset A cores were analyzed for 210-Pb, faunal remains (ostracodes, forams and mollusks), and sediment and shell geochemistry. Material from the A cores was archived for future diatom analyses. The subset B cores will be archived for any additional analyses that may be necessary. X-radiographs of the cores are shown in Figures 2-4 and descriptions are given in Appendix A.

In addition, this report will discuss results from cores collected between 1996 and 1997 by S.E. Ishman at Featherbed Bank (SEI297-FB1), Card Bank (SEI297-CB1) and Manatee Bay (SEI1196-MB1) (Table 1; Figure1). Detailed descriptions of these cores can be found in Ishman (1997). Ishman and others (1998) describe the faunal and floral patterns obtained from the SEI1196-MB1 core and Stone and others (2000) describe the faunal assemblages at SEI297-FB1. Mg/Ca data for SEI297-FB1 and ostracode data from SEI297-CB1 are reported in Wingard and others (2003). Interpretations and patterns in the 1996 and 1997 cores are discussed in light of the new findings reported here.

Faunal and Floral Analyses

Ostracodes, mollusks, foraminifers, and pollen were analyzed using the processing procedures described in Cronin and others (2001), Brewster-Wingard and others (2001), Ishman and others (1998), and Willard, Holmes, and Weimer (2001). All samples were taken in 2-cm segments for analyses. Sample spacing intervals for initial analyses varied from 2-cm to 16-cm depending on chronology, stratigraphy, and time constraints. Faunal

Table 1: List of cores discussed or analyzed in this report. See Figure 1 for location.

Core Location	Year Collected	Core ID	Latitude	Longitude	Core Length (cm)
Black Point North	2003	GLW603-BPNA	N 25° 32.781	W 80° 18.715	86.5
Card Bank	1997	SEI297-CB1	N 25° 18.37	W 80° 20.63	146
Card Bank	2002*	GLW402 -CBA	N 25° 19.295	W 80° 21.362	149
		GLW402 -CBB			148
Chicken Key	2003	GLW603-CKA	N 25° 37.214	W 80° 17.304	77.5
Featherbed Bank	1997	SEI2997-FB1	N 25° 31.31	W 80° 15.39	225
Featherbed Bank	2002*	GLW402 -FBA	N 25° 31.850	W 80° 15.575	188
		GLW402 -FBB			197
Manatee Bay	1996	SEI1196-MB1	N 25° 15.69	W 80° 24.06	120
Middle Key	2003	GLW603-MKA	N 25° 17.205	W 80° 24.170	114.5
Military Canal North	1997	SEI297-BW1	N 25° 29.55	W 80° 21.10	48
Military Canal South	1997	SEI297-BW2	N 25° 29.27	W 80° 21.00	47.5
No Name Bank	2002*	GLW402 -NNA	N 25° 34.484	W 80° 16.320	144
		GLW402 -NNB			153

* Note: for 2002 cores A cores were used for pollen, lead-210, and geochemical analyses and B cores were used for faunal analyses.

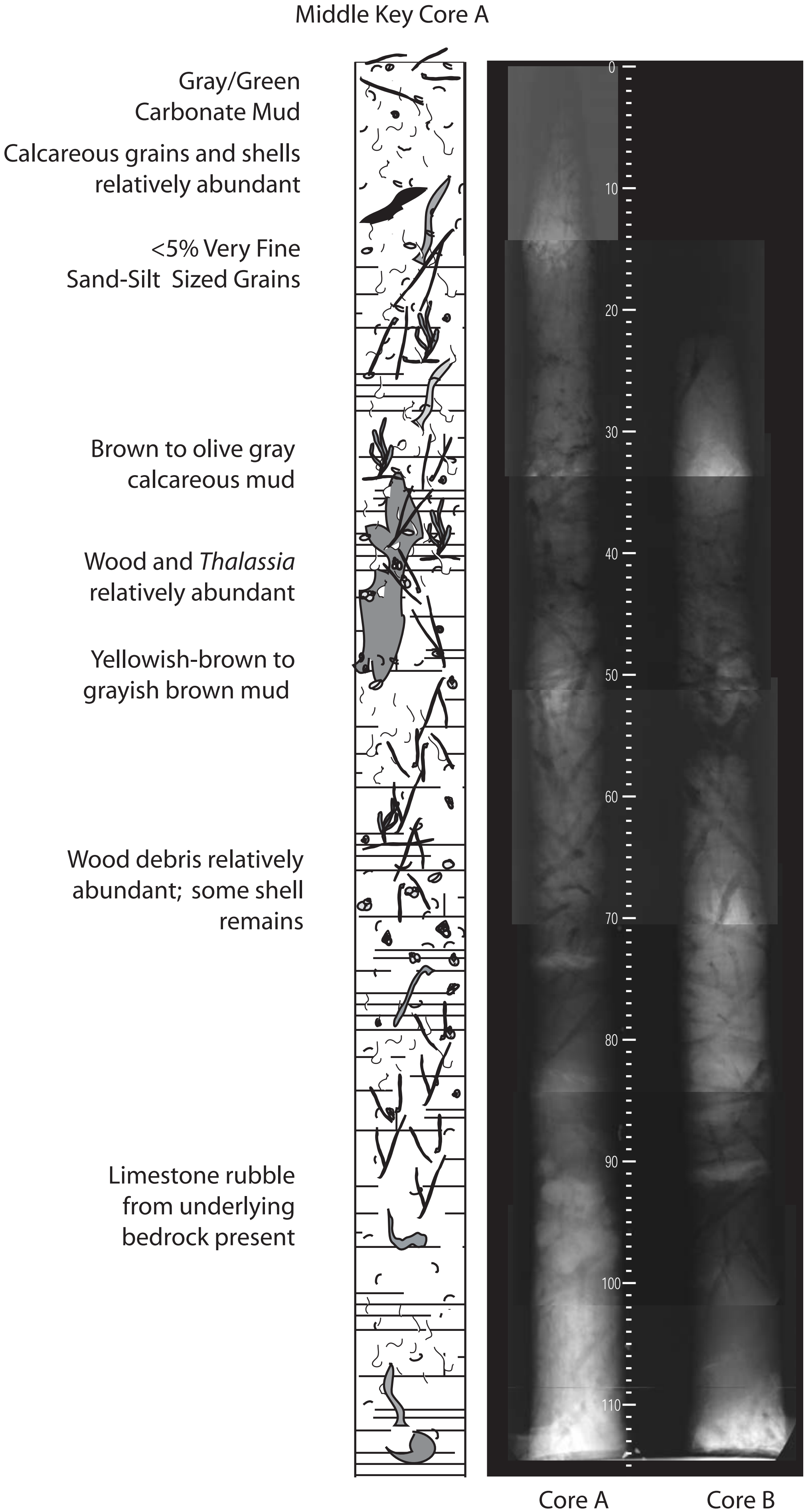


Figure 2. X-radiographs of A and B cores from Middle Key Basin (GLW603-MKA and MKB). Schematic diagram of A core only. B core has been archived. Scale is in cm.

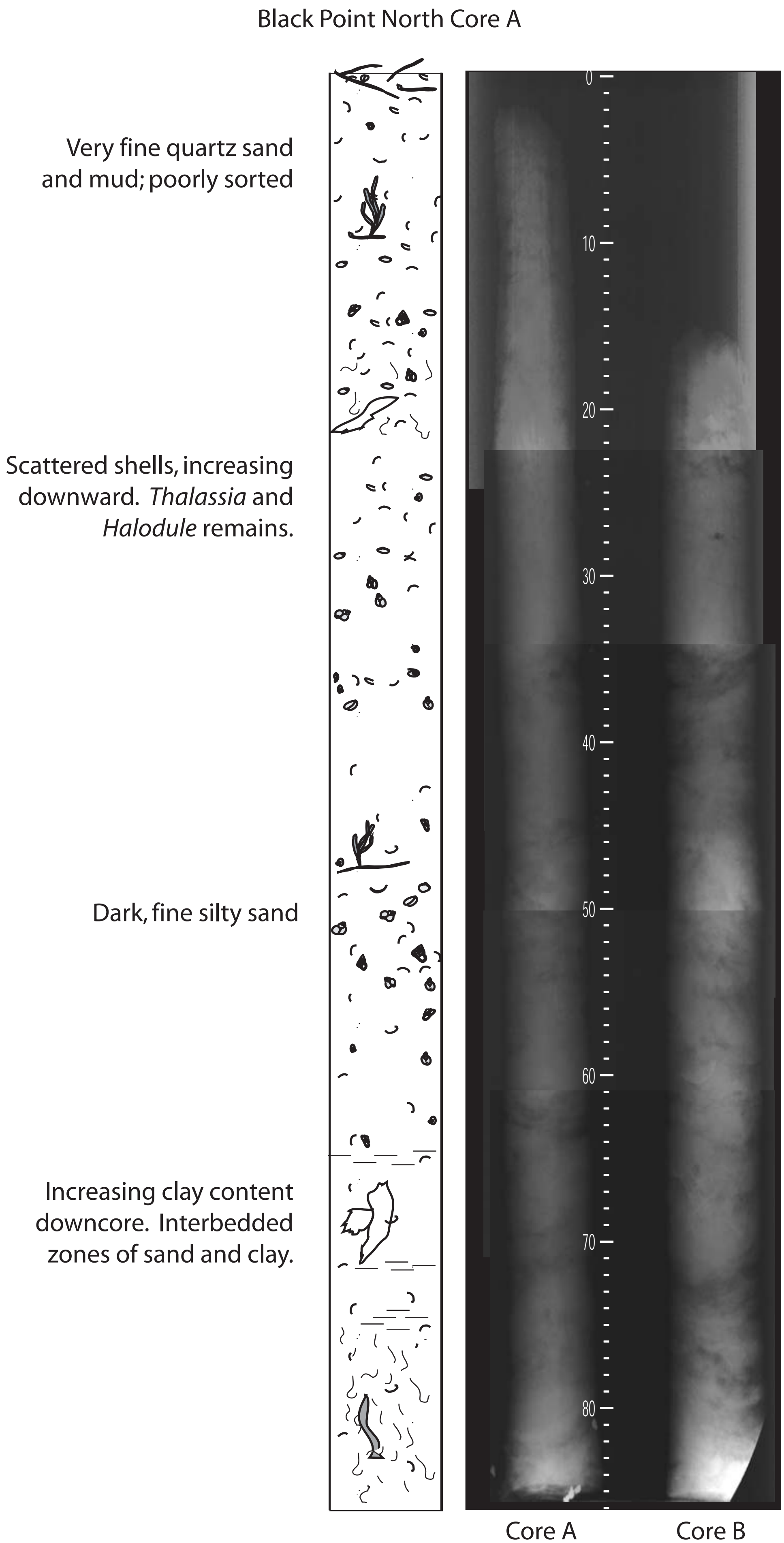


Figure 3. X-radiographs of A and B cores from inlet north of Black Point (GLW603-BPNA and BPNB). Schematic diagram of A core only. B core has been archived. Scale is in cm.

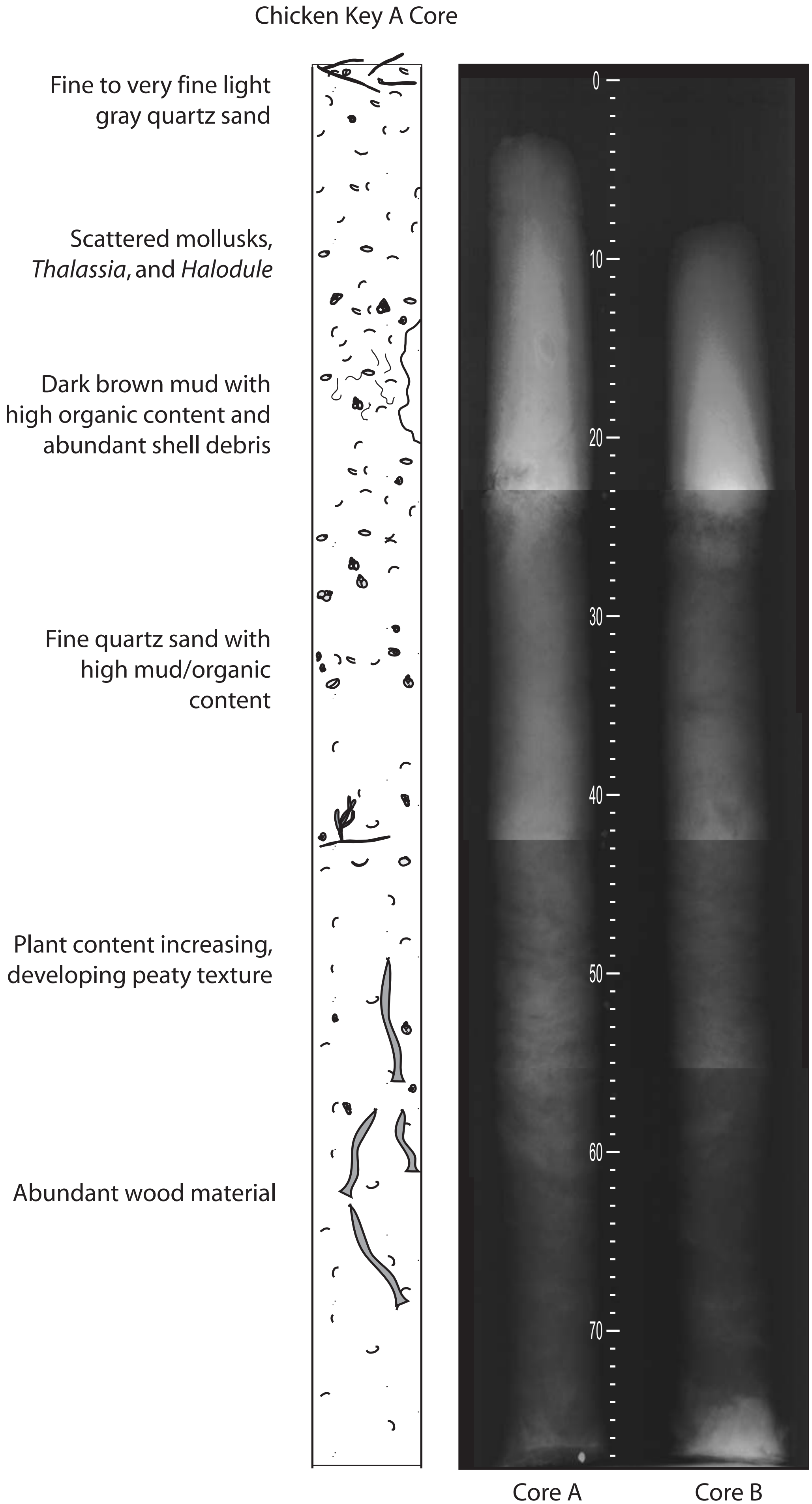


Figure 4. X-radiographs of A and B cores from Chicken Key (GLW603-CKA and CKB). Schematic diagram of A core only. B core has been archived. Scale is in cm.

and floral data were converted to percent abundance for analyses of faunal, floral, and ecosystem trends.

Ostracoda: One hundred ostracode specimens were picked, where possible, from the ≥150 and < 850 micron size fraction of the samples. If fewer than 100 ostracodes were present, all specimens were picked. Ostracode assemblages were examined from 55 samples (0-194 cm core depth) from 2002 Featherbed Bank core (GLW402-FBB) and from 6 samples (0-138 cm core depth) from 2002 Card Band core (GLW402-CBB). Eight samples were picked for ostracodes from the Middle Key core (GLW603-MKA) at 4-cm intervals (every other sample) down to 24 cm and separated into 16 taxonomic groups. Below 24 cm core depth the samples were essentially barren. Twenty two samples from Black Point North core (GLW603-BPN-A) were picked at 4-cm intervals and sorted into 18 taxonomic categories. Samples between 10 and 36 cm were barren. In Chicken Key core (GLW603-CKA) every sample was picked (2-cm intervals) down to 46 cm; below 38 cm core depth the samples were barren.

Mollusca: All mollusks ≥850 microns are picked and sorted into taxonomic groups and nine preservation categories. Samples containing extremely large quantities of mollusks are occasionally split and the size and number of splits are noted in the appendix data tables. The abundance data presented in this report exclude any worn mollusks and any fragments (defined as <50% of shell remaining) as these components are probably not indicative of the environment in which they are deposited. Worn and fragmented specimens do, however, provide important information about the depositional history of the sediments, so these data were utilized in interpretations.

Nineteen samples, at 8-cm intervals (every fourth sample), were analyzed for total molluscan faunal remains from the 1997 Card Bank Core (SEI297-CB1. Sixteen samples were picked for mollusks from Middle Key core (GLW603-MKA) at 8-cm intervals and were sorted into 41 taxonomic categories. Samples between 72 and 82 cm and from 96 cm to the bottom of the core were essentially barren. The lower most samples (below 112 cm) contained a mixed sample, contaminated by modern specimens and with recrystallized fossil material from the bedrock; these samples were not included in any analyses. Black Point North core (GLW603-BPNA) was examined at 8-cm intervals and the eleven samples yielded 54 taxonomic categories. No samples were barren in the Black Point North core, but the sample at 24-26 cm had very few mollusks in any preservation category. Ten samples were examined from Chicken Key core (GLW603-CKA), also at 8-cm intervals, but below 40 cm the samples essentially were barren.

Foraminifera: A total of 300 foraminifers were picked from the ≥63 and < 850 micron fraction of each sample where possible; otherwise all foraminifera present were picked. A number of barren samples were encountered in the near-shore cores as noted below. Twenty five samples were picked for foraminifera from the Featherbed Bank core (GLW402-FBB) at 8-cm intervals (every fourth sample) and separated into 69 taxonomic categories. Eight samples were examined from Middle Key core (GLW603-MKA) at 16-cm intervals (every eighth sample), but only two samples contained statistically significant numbers of foraminifera – 0-2 cm and 16-18 cm samples – the other samples were essentially barren. Black Point North core (GLW603-BPNA) contained 67 foraminiferal groups from twelve samples analyzed at 8-cm intervals. Eleven samples analyzed at 8-cm intervals from Chicken Key core (GLW603-CKA) contained 37 foraminiferal groups, but from 32 cm to the base of the core the samples contained twelve or fewer foraminifers total.

Pollen: Pollen samples were collected at 4, 6, or 10 cm intervals in the three near-shore cores (Middle Key core (GLW603-MKA), Black Point North core (GLW603-BPNA), and Chicken Key core (GLW603-CKA)) and at 2, 4, or 6 cm intervals in the two wetland cores (Military Canal cores SEI97-BW1 and SEI97-BW2) depending on depth in the core. No barren zones occurred but pollen concentrations did vary throughout the cores.

Ostracode Shell Chemistry Analyses

Geochemical analyses of metal/calcium ratios were conducted on ostracodes from the near-shore cores at Middle Key (GLW603-MKA), Black Point North (GLW603-BPNA), and Chicken Key (GLW603-CKA). Previous investigations have demonstrated that magnesium/calcium ratios can be effective proxies for estimating past salinity changes in Florida and Biscayne Bays (Dwyer and Cronin, 2001). The ostracodes utilized in the geochemical analyses were selected directly from samples also used in the analysis of ostracode faunal assemblages, and thus allowed for direct comparison of geochemical and faunal patterns.

Methods used on the near-shore cores collected in 2003 were identical to methods used on the 2002 mudbank cores, with the exception of the species used for shell chemistry analyses. The ostracode *Loxoconcha matagordensis* was analyzed in the 2002 cores, because of its abundance at sites in central Biscayne Bay. *Malzella floridana* shell chemistry is more suitable for analysis of the 2003 near-shore cores because this species is tolerant of a wide range of salinities and is common in cores from the Black Point, Chicken and Middle Key sites, where short term salinity variations are common. Wingard and others (2003) provided full details of the analytical procedures. Ideally a minimum of five adult valves of the ostracode species *Malzella floridana* were selected from each sample interval; however, in sparse intervals all valves available were used. These valves were processed and analyzed individually for Mg/Ca, Sr/Ca, and Na/Ca ratios by direct current plasma atomic emission spectrophotometry (DCP-AES) following procedures described in Dwyer and Cronin (2001, and references therein); results of analyses are presented in Appendix B. Precision on measurements is around two, four, and ten percent respectively. Some of the disparity in precision is because the instrument is optimized for Mg/Ca ratio analysis since Mg/Ca has proven to be the most useful paleoenvironmental indicator. While their usefulness is unclear, Sr/Ca and Na/Ca ratios were collected because with further study these data may provide additional paleoenvironmental information.

Conversion of the Mg/Ca ratios measured in the cores to a salinity value in ppt is based on analyses of the shell chemistry of living Biscayne Bay ostracodes. Live ostracodes were collected along with a water sample and the Mg/Ca of the shell was calibrated to the water chemistry (Cronin in Wingard, April 2003, unpublished report to SFWMD). Modern field collections were conducted in Biscayne Bay in 2002 and 2003 for the purpose of establishing the calibration index. However, it should be emphasized that sampling in low salinity waters was limited; fewer than ten samples were obtained in <10 ppt waters. Therefore, the Mg/Ca-based estimates of paleosalinity are most useful at salinities >10 ppt. Results of calibration of Mg/Ca values to actual salinity values are presented with the ostracode data results for each core in Appendix B.

Geochemical Analyses

Geochemical studies of sediments from dated cores collected in Biscayne Bay were conducted to examine historical changes in nutrient elements (C,N,P) and to correlate these changes with changes in faunal and floral indicators. Data on historical changes in nutrient elements in sediments reflect changes in nutrient load to the bay from natural and anthropogenic sources. For Biscayne Bay it is important to document the range of natural variability in nutrient load in order to evaluate the effects of recent anthropogenic activities (urbanization, canal discharge, agriculture).

Geochemical analyses were conducted on cores collected in 2002 from the mudbanks and cores collected in 2003 from the near-shore sites (Appendix C). Sub-samples of sediment for geochemistry were removed from the 2-cm core sample intervals, wet sieved (60 mesh) to remove coarse debris, dried, ground to a powder, and stored in clean glass vials prior to analysis. Total carbon (TC) and total nitrogen (TN) contents of sediments were determined using a Leco 932 CNS Analyzer (Leco Corporation, St. Joseph, MI, USA). Organic carbon (OC) was determined on the Leco analyzer after removal of inorganic carbon (IC, mostly carbonates) by an acid vapor method. Total phosphorus (TP) concentrations in sediments were determined by the method of Aspila and others (1976), slightly modified for work in Biscayne Bay sediments. Analytical precision (percentage relative standard deviation) was about 2% for TC, 4% for OC, and 3% for TN and TP. IC is reported as the calculated difference between TC and OC (for example (%TC) – (%OC)). TP analyses have been completed on both the mudbank and near-shore estuarine cores; TC, TN, and OC analyses have been completed on the mudbank cores and are pending on the near-shore cores.

Development of Age Model for Cores

Preliminary age models were developed for the near-shore cores using three methods of dating where possible: (1) lead-210 analyses of the sediments; (2) first stratigraphic appearance of *Casuarina* (Australian pine); and (3) radiocarbon analyses of shell or wood material. The chronology of the upper segments of the cores was established using the lead-210 and pollen data. Decay of lead-210 isotopes into its daughter products is a reliable method for dating 20th century sediments (see Holmes and others, 2001, for detailed explanation of the methodology). The first occurrence of *Casuarina* pollen (Australian Pine), an exotic introduced into south Florida around the beginning of the 20th century (Langeland, 1990), provides an excellent stratigraphic marker for the early 1900s.

In addition, disappearance of pine pollen and introduction of weedy species indicate land-clearing and agricultural practices, which can be correlated with historical records.

Carbon-14 analyses of individual shells or wood fragments were used in an attempt to establish ages for the lower portion of the cores (Table 2). Shell material was rare in these core segments, however, so we were unable to find well preserved specimens of the same species (the ideal situation) in the horizons we hoped to date. In addition, data are not currently available on the local carbon reservoir effect in Biscayne Bay. Conventional radiocarbon ages on marine shells must be corrected to account for the reservoir effect of ocean circulation on carbon. The global reservoir correction used in these analyses was 200-500 years, but local atmospheric and ocean processes can also affect the radiocarbon ages of marine and especially estuarine shells. The addition of terrestrial carbon into an estuary can produce older dates. The preliminary data presented here have not been corrected for these local effects.

The carbon-14 dates in the near-shore cores were calibrated using the procedure in Talma and Vogel (1993) and the INTCAL98 calibration dataset (Stuiver and others, 1998). Lead-210, carbon-14, and pollen stratigraphy also were utilized to establish the age models for the mudbank cores collected in 2002; details are presented in Wingard and others (2003). Radioisotopic analyses are in progress for the wetland cores; however, the first appearance of *Casuarina* and the decrease in pine pollen in the Military Canal cores provide a good estimate of the level at which 20th century sedimentation begins.

ADDITIONAL ANALYSES OF MUDBANK CORES

The following analyses have been completed on cores from No Name Bank, Featherbed Bank and Card Bank since the publication of Wingard and others (2003). These cores record the patterns of change in the more open-water areas, removed from the direct influence of freshwater inflow.

Featherbed Bank Foraminiferal Analyses

Relative abundances of key groups of foraminifers are shown in Figure 5 and the specific data are shown in Appendix D. *Cribroelphidium-Elphidium* and *Quinqueloculina* are the two most dominant foraminifer groups in the core, showing alternating patterns of dominance. In the uppermost portion of the core (above 32-34cm or since 1957) *Cribroelphidium-Elphidium* drop below 24% abundance, reaching a low of 3.48% in the top sample. These genera are typically more abundant in environments with greater freshwater mixing in which there are seasonal periods of reduced salinity. Fluctuations in relative abundance of *Rosalina* generally mimic the *Cribroelphidium-Elphidium* assemblage.

The relative sparseness of *Cribroelphidium-Elphidium* assemblage near the top of the core is the inverse of the trend seen in *Articulina* and *Archaias*. *Articulina* and *Archaias* are both marine species that are only present in minor amounts in the core, but their

Table 2. Summary of radiocarbon data on nearshore cores collected in 2003. Analyses were conducted by Beta Analytical Radiocarbon Dating Laboratory (Miami, FL). Conventional radiocarbon ages were converted to calendar years using the calibration for marine shells given in Stuiver and others (1998).

Core ID	*Depth (cm)*	*Beta ID*	*Sample Type* [>]	*Conventional Radiocarbon Age (yrs BP* [+] *)*	*Measured Radiocarbon Age (yrs BP* [+] *)*	*13C/12C ratio in 0/00*	*2 sigma calibrated age range (BP* [+] *)*	*Corrected Calendar Age* [#]
GLW603-CKA	32-34	184174	Shell (*Anomalocardia*)	112.93 +/-0.42 pMC*	117.6+/-0.42 pMC*	-5.0	Material living within last 50 years	
GLW603-CKA	32-34	184175	Shell (*Prunum*)	810 +/- 40	420 +/- 40	-1.2	400-510	1440-1540 AD
GLW603-NBPA	18-20	184176	Shell (*Prunum*)	120.93 +/- 0.44 pMC*	125.4+/-0.44 pMC*	-7.1	Material living within last 50 years	
GLW603-NBPA	38-40	184177	Shell (*Anomalocardia*)	790 +/-40	450 +/- 40	-4.4	320-500	1503-1683 AD
GLW603-NBPA	62-64	184178	Shell (ostreid, some borings)	840 +/- 40	510 +/-40	-5.0	420-520	1483-1583 AD
GLW603-NBPA	74-76	184179	Shell (*Anomalocardia*)	850 +/- 40 ^	520 +/- 40 ^	-5.0^	430-520	1483-1573 AD
GLW603-NBPA	74-76	184180	Wood (mangrove?)	390 +/-40	450 +/- 40	-28.9	420-520 & 320-400	1483-1583 & 1603-1683

[>]Shell samples were prepared by acid etch pretreatment. Wood samples by acid/alkali/acid pretreatment.

*pMC = percent modern Carbon; analyzed material less than 50 years old

^13C/12C estimated based on values typical of material type

+BP = Before Present (present for these calculations = 1950)

[#] Corrected Calendar age converts 2 sigma calibrated age, where 1950 is used as "present", to 2003 - the year the cores were collected.

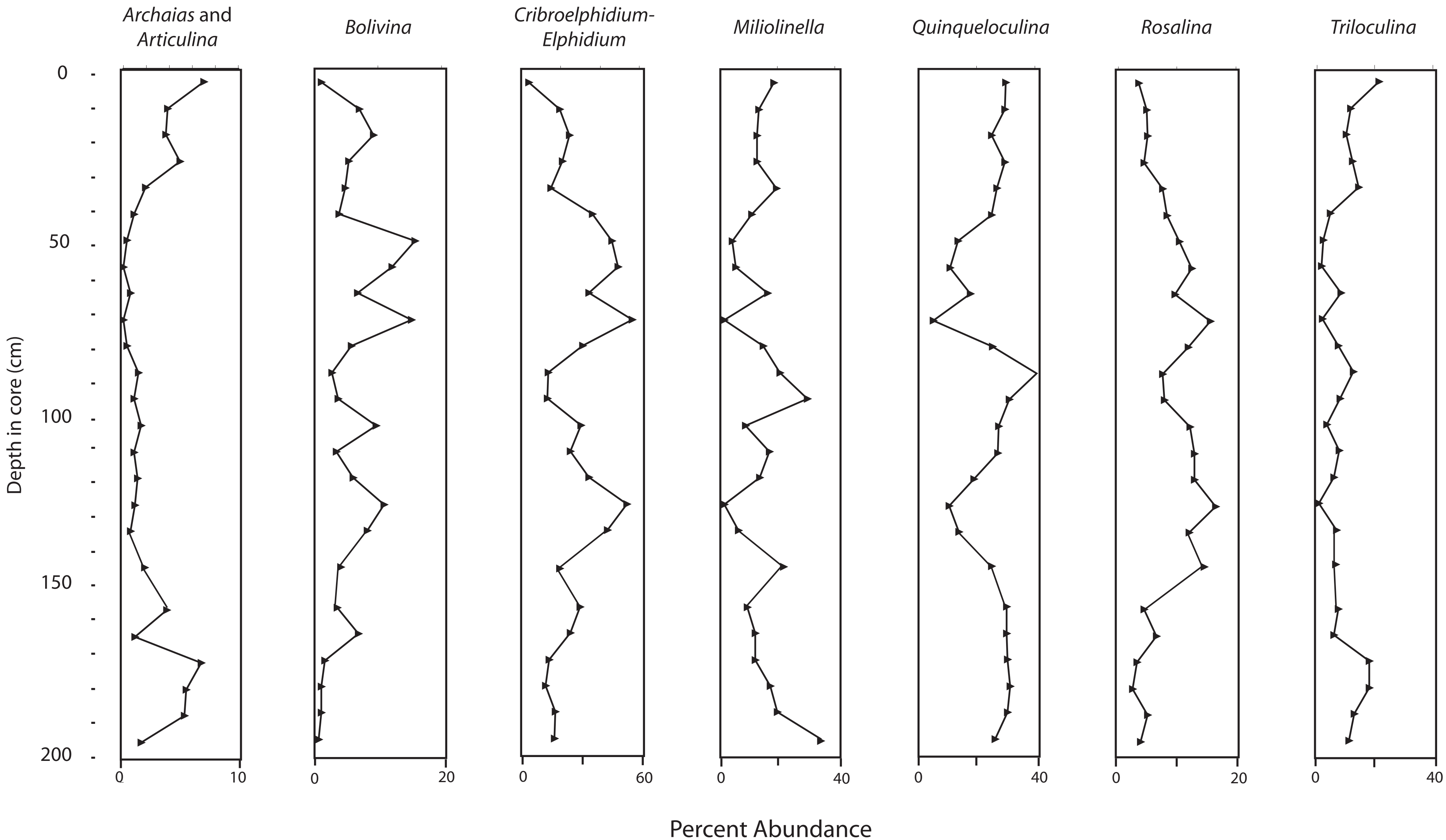


Figure 5. Percent abundance of key foraminifer taxonomic groups in 2002 Featherbed Bank (GLW402-FBB) core plotted against depth in centimeters. Note different percent abundance scales. Sample spacing changes between 138-156 cm. (See Appendix D for data.)

increases in abundance are indicative of increased oceanic influence and possibly more stable salinities at the site. *Archaias* is most abundant in the bottom of the core and *Articulina* in the top, both intervals where *Cribroelphidium-Elphidium* decreases in abundance.

In contrast, *Quinqueloculina* are relatively abundant (25-31%) and stable in the lower portion of the core (146-197 cm). *Quinqueloculina* reach their peak abundance (40%) in the sample from 88-90 cm (1885). A rapid decrease in abundance occurs between 1885 and 1903, reaching a low of 5% at 72-74 cm (1885). *Quinqueloculina* increase in abundance again beginning at 56-58 cm (1925) to >24% in the upper 40 cm (since 1947). *Miliolinella* also are relatively abundant in the Featherbed Bank core, occurring in every sample. Significant low abundances occur at 138-128cm (1835-1844), 72-74cm (1903), and between 58 and 48cm (1925-1936). The peak abundance of 35% occurs at the bottom of the core (194-197 cm). *Miliolinella* is an epiphytal species so the fluctuations in abundance are indicative of fluctuations in seagrass abundance.

Relative abundances of *Bolivina* fluctuate throughout the core, appearing to be almost cyclic with peaks ranging between 7 and 16% at approximately 16-18cm, 48-50cm, 72-74cm, 104-106cm, 128-130cm and 164-166cm; these alternate with periods of relatively low abundance (3-5%). *Bolivina* typically increase when nutrients and/or organics increase, thus indicating fluctuating nutrient supply at the site over the last 1783. *Triloculina* are most abundant in the lowermost and uppermost portions of the core. *Ammonia*, typically a low salinity genus, are present in very low amounts (<1%) throughout the core.

Featherbed Bank Ostracode Analyses

Ostracode assemblages were examined from 55 samples (0-194 cm core depth) from Featherbed Bank core FB-B (GLW402-FBB). Absolute abundance of these taxa are given in Appendix E. Figure 6 shows the relative proportions of the more indicative taxa plotted against core depth. These plots also show patterns for these taxa from the 1997 Featherbed Bank core (SEI297-FB1; data and results in Stone and others, 2000). The comparison between the two Featherbed cores indicates remarkably similar faunal patterns in the upper 2 meters of sediment from the two sites located about 1.6 km (1 mile) apart. Although one cannot assume similar sedimentation rates on the same bank, even for sites in close proximity to each other, comparison of the core depths for several distinct faunal markers, labeled 1-7 in Figure 6, indicates that sedimentation rates were generally similar if one assumes that no relative compaction or extension occurred during the two coring operations. For example, the sharp rise in *Loxoconcha matagordensis* (Figure 6, #1) occurs between 200 and 180 cm in FB-1, and 180 and 160 cm in FB-B. The recent decline in this species recorded in the uppermost section of the cores, attributed to increasingly marine salinity and decreases in seagrass abundance by Wingard and others (2003), occurs between 70 and 60 cm in FB-1 and 50 and 40 cm in FB-B (Figure 6, #2). Similar offsets of 10-20 cm are observed for the other faunal markers (Figure 6, #3-7). In sum, these results suggest that sedimentation rates at the FB-B site were approximately 10-20 % lower than at the site of FB-1 and provide a high

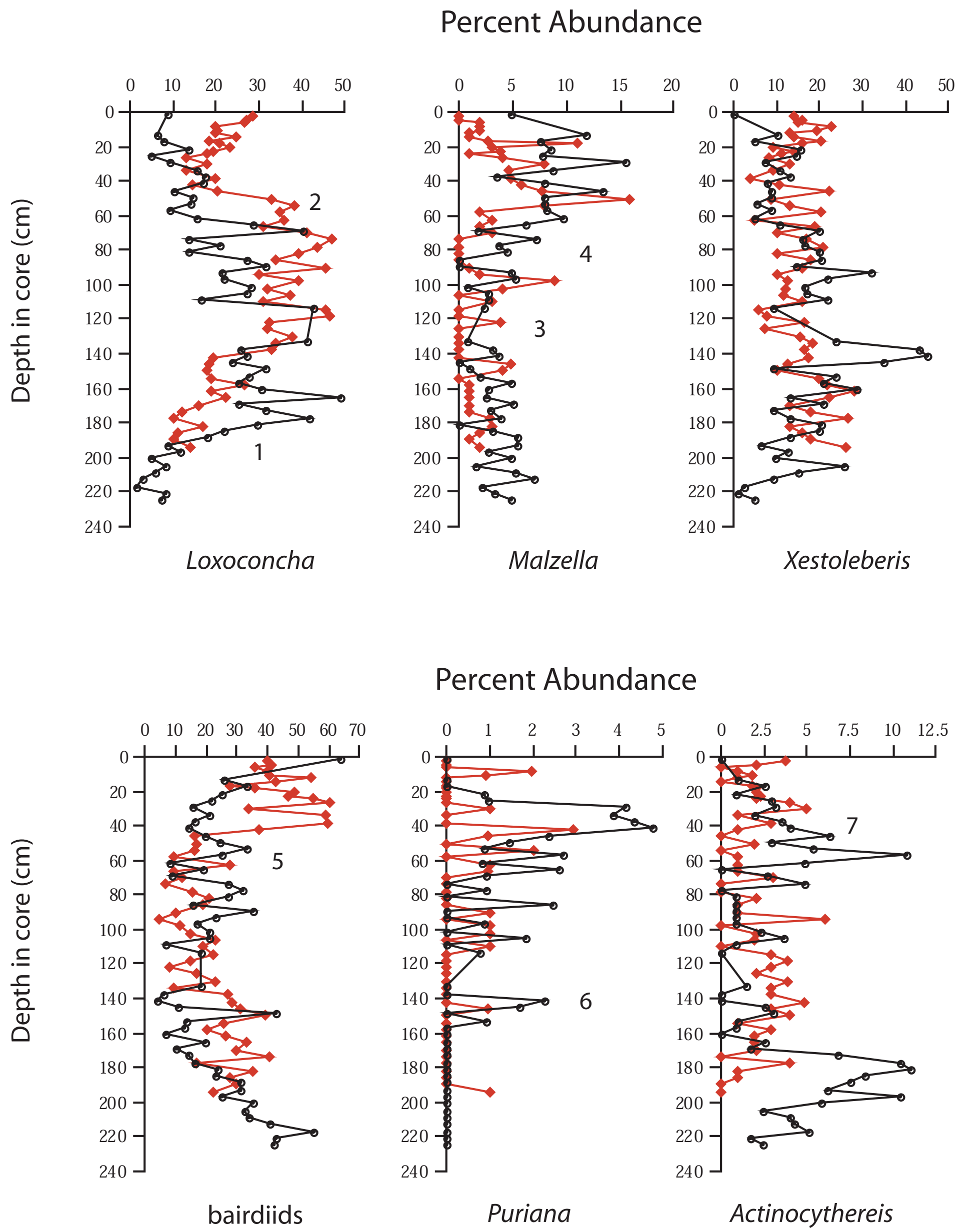


Figure 6. Percent abundance of key ostracode taxa at Featherbed Bank. Plots showing changes in 1997 Featherbed Bank core (SEI297-FB1 - black) and 2002 Featherbed Bank core (GLW402-FBB - red). Numbers 1-7 refer to distinct changes in key taxa that occur in both cores, slightly higher in the FB-B core. See text for discussion. Note different percent abundance scales. (See Appendix E for data.)

level of confidence that the temporal trends in ostracode faunas are representative of the ecological history of this part of Biscayne Bay.

Card Bank Ostracode Analyses

Six samples (0-138 cm depth) were examined from the Card Bank Core (GLW402-CBB). Appendix F gives the census counts of these taxa in the core and Figure 7 illustrates the relative proportions of the more indicative taxa plotted against core depth. These plots compare the patterns from the 2002 Card Bank core (GLW402-CBB) and the 1997 Card Bank core (SEI297-CB1) described in Wingard and others (2003), located approximately 2 km (1.3 miles) apart. The objective in studying a second core from Card Sound was to establish whether the patterns of decreasing *Malzella floridana* and *Peratocythereidea setipunctata*, and increases in *Loxoconcha matagordensis* and bairdiids, all identified at CB-1, also occurred at the CB-B site, located ~2.2 km away. Figure 7 indicates that this is the case, although there are slightly greater proportions of bairdiids and lower proportions of *L. matagordensis* at the CB-B site. These results suggest the CB-B core recovered sediments that can be useful in establishing the ecological history of Card Sound once more detailed analysis and dating of the CB-B site are carried out.

Card Bank Molluscan Analyses

Nineteen samples, at 8-cm intervals, were analyzed for total molluscan faunal remains from the Card Bank Core collected in 1997 (SEI297-CB1). The mollusks were classified into 63 faunal categories (excluding worn and fragmented specimens). The predominant species are *Bittiolum varium*, *Schwarziella catesbyana*, *Carditamera floridana*, *Laveicardium mortoni*, *Transennella* sp., and *Crepidula* spp. (Appendix G). The majority of these species live on some type of sub-aquatic vegetation. Figure 8 illustrates the distribution of epiphytal mollusks downcore. These data indicate that some type of sub-aquatic vegetation has been present at the CB1 site throughout the time of deposition. The sub-aquatic vegetation indicators only drop below 50% of the total molluscan fauna at three intervals in the core: 42-66 cm, 96 cm, and 138 cm. Fauna that live almost exclusively on *Thalassia* are present throughout most of the core (exceptions at 42-50 cm and 106 cm) at levels between 10-20 % of the total molluscan fauna (excluding worn and fragmented).

The distribution of the infaunal mollusks at CB1 follows the trend seen at the Featherbed Bank cores (GLW402-FBB and SEI297-FB1) and at No Name Bank (GLW402-NNB) (see Wingard and others, 2003, fig. 22 and discussion). As discussed in the earlier report, the decline in infaunal mollusks in the later half of the 20th century needs to be investigated more thoroughly. There is a possibility that this is an artifact of sedimentological and biological processes. However, the repetition of this trend in several cores lends support to the hypothesis that real declines have occurred in the infaunal mollusks and the occurrence of this pattern at Card Bank means it is not limited to central Biscayne Bay.

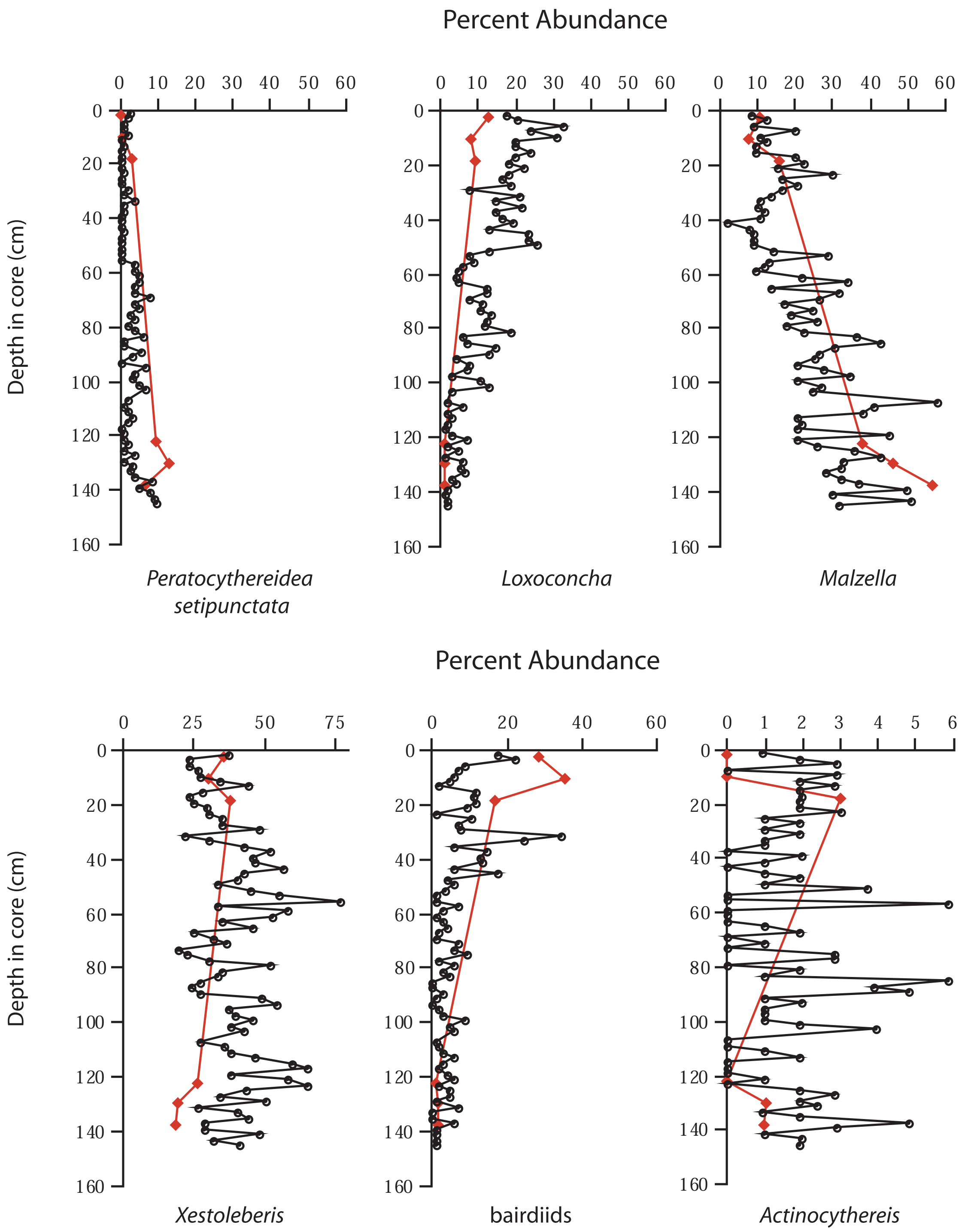


Figure 7. Percent abundance of key ostracode taxa at Card Bank. Plots showing changes in 1997 Card Bank core (SEI297-CB1 - black) and 2002 Card Bank core (GLW402-CBB - red). Note different percent abundance scales. (See Appendix F for data.)

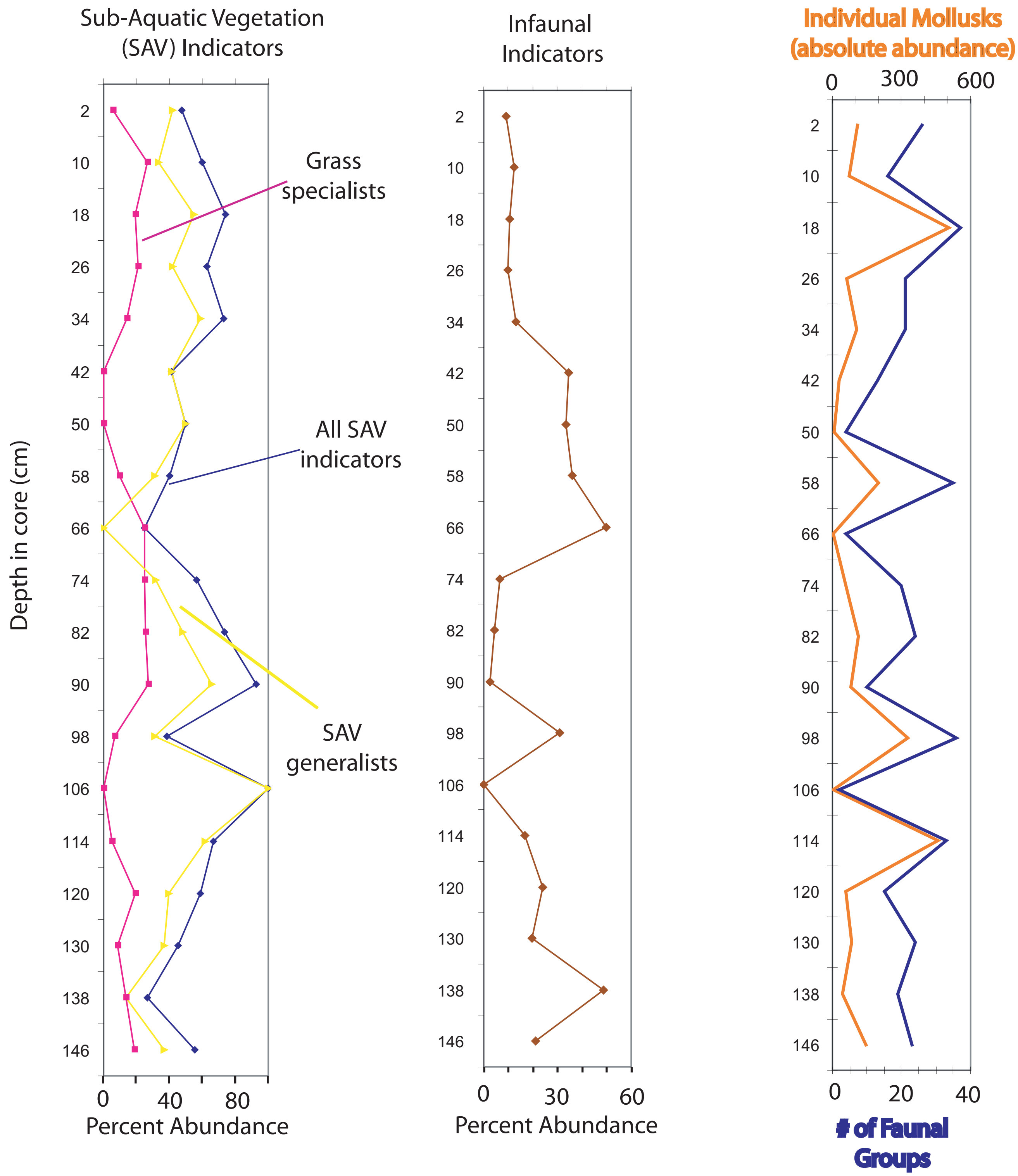


Figure 8. Changes in molluscan fauna in 1997 Card Bank Core (SEI297-CB1). Two left plots illustrate downcore changes in the percent abundance of molluscan environmental indicators. Right plot shows changes in molluscan absolute abundance and the number of faunal groups (a rough measure of diversity). Plots exclude worn and fragmented specimens. Note different scales on x-axes. (See Appendix G for data.)

The absolute abundance of mollusks and the number of faunal groups (a rough measure of diversity) (Figure 8) seem to have a higher frequency of change at Card Bank than the pattern seen in central Biscayne Bay (Wingard and others, 2003). Like the central Bay cores, the mollusks reach a peak in diversity and abundance in the upper 30 cm of the CB1 core.

Figure 9 illustrates the downcore distribution of some of the important molluscan indicator species present in the Card Bank core. *Bittiolum varium* is by far the dominant species in this core. *Bittiolum* is a minute (full grown adults can be <5mm) gastropod that can be found on any type of sub-aquatic vegetation. Its abundance in the upper part of the core is in contrast to the central Biscayne cores (No Name, and Featherbed; see Wingard and others, 2003) where *Bittiolum* decreases significantly and almost disappears in the upper portion of the cores. In Florida Bay, *Bittiolum* is common in the eastern and central portions of the Bay, in mesohaline to polyhaline salinities (Brewster-Wingard and others, 2001). *Carditamera floridana* is more commonly seen in the western portions of Florida Bay in polyhaline to euhaline salinities. The relative dominance of *Bittiolum* and *Carditamera* alternates, illustrating that Card Bank seems to be a transitional area between a more restricted upper estuarine environment and a more open estuarine environment. *Brachidontes* and *Anomalocardia* are both tolerant of wide fluctuations in salinity. The near absence of these two species in the upper part of the CB1 core is in agreement with results seen in the central Biscayne Bay cores (Wingard and others, 2003) – that salinity in Biscayne Bay is becoming increasingly stable and increasingly marine during the last century.

No Name, Featherbed Bank and Card Bank Geochemical Analyses

Results of geochemical analyses of sediments from these cores are shown in Appendix C, and the data are plotted in Figure 10. Total carbon (TC) contents ranged from 11.6-17.0% in these cores, inorganic carbon (IC) from 7.81-10.1%, and OC from 1.68-9.19%. Both TC and organic carbon (OC) concentrations were significantly higher in the core from the Card Bank site, and IC contents were lowest at Card Bank. The range of total nitrogen (TN) and total phosphorous (TP) contents in sediments from these cores are: 1.16% to 0.157%, and 0.030% to 0.0063%, respectively. As with OC, both TN and TP concentrations were higher at the Card Bank site. Significant downcore trends were observed at all sites, representing both diagenetic recycling of nutrient elements, as well as historical changes in the flux of nutrient elements to the sediments. Perhaps the most interesting historical trend is the large increase in TP concentrations in surface sediments at Card and No Name Banks, beginning in the 1970s. The downcore TP profiles at both sites represent a large increase in TP flux to the sediments, superimposed on the normal diagenetic recycling of phosphorous. Since the apparent increase in TP is largest in the south (Card Bank) and lowest in the north (Featherbed Bank), a source of the excess nutrients from the Miami urban area seems unlikely. It is possible the apparent increased TP flux to the sediments resulted from inputs from canal structures in the southern part of Biscayne Bay, especially the C-111 canal.

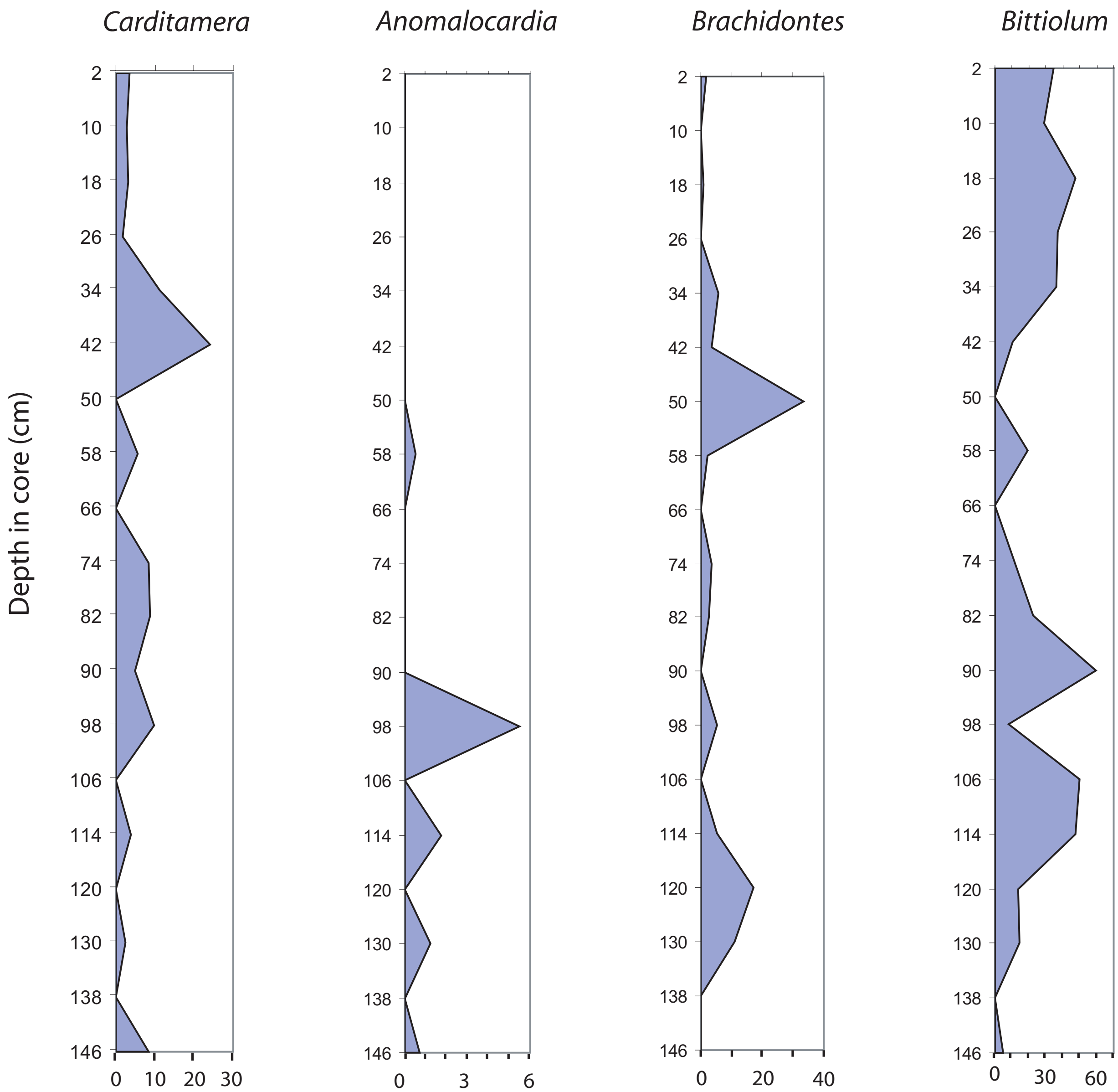


Figure 9. Percent abundance of key molluscan taxa from 1997 Card Bank core (SEI297-CB1). Data exclude worn specimens and fragments. Note different percent abundance scales. (See Appendix G for data.)

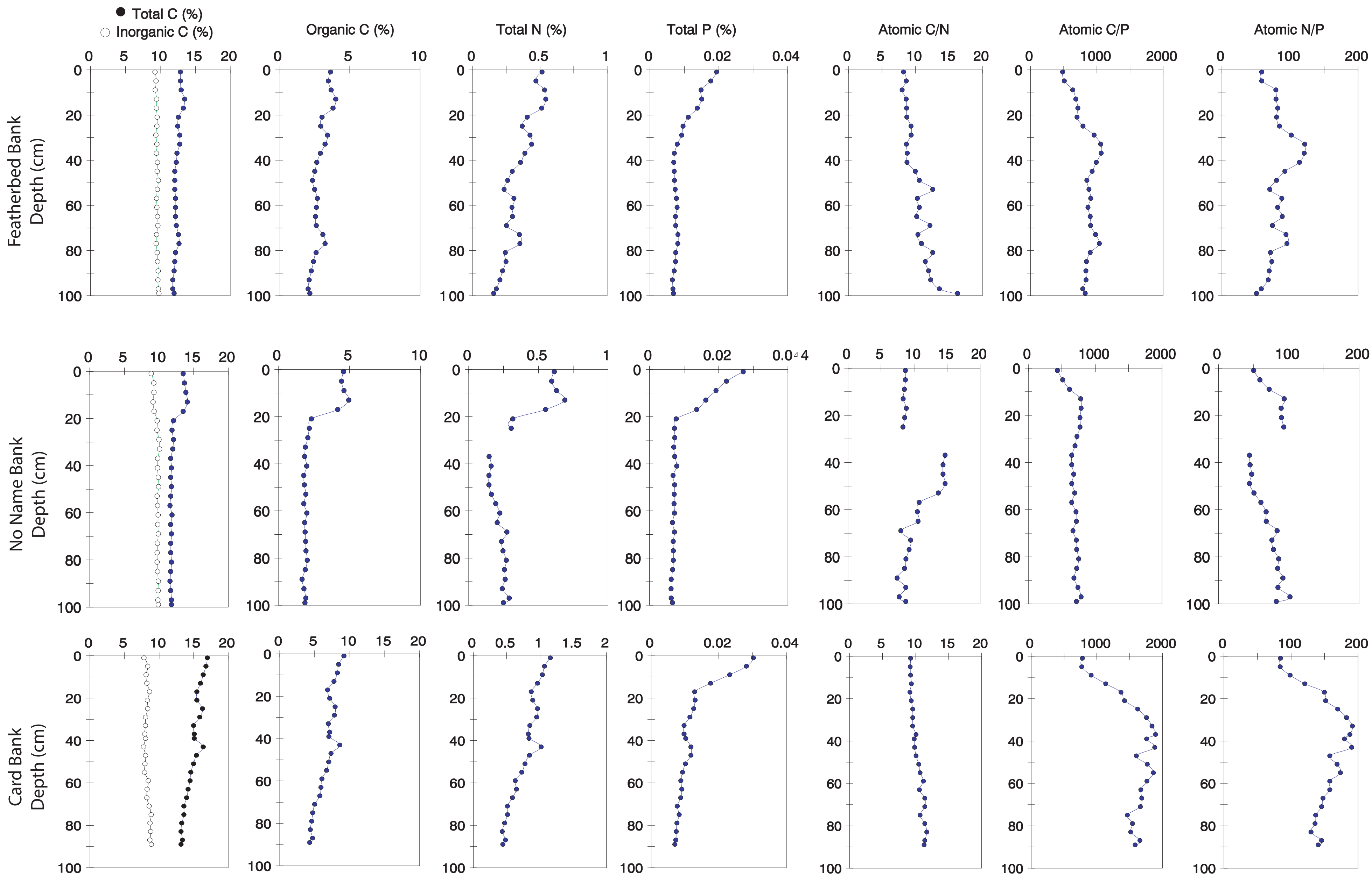


Figure 10. Plots of geochemical data (x-axis) versus core depth in cm (y-axis) for 2002 Featherbed Bank Core (GLW402-FBB), No Name Bank Core (GLW402-NNB) and 2002 Card Bank Core (GLW402-CBB). (See Appendix C for data.)

Discussion of Additional Analyses of No Name, Featherbed Bank and Card Bank Cores

The results reported here from additional analyses of the 1997 and 2002 cores are in agreement with the findings reported in Wingard and others (2003) and provide additional evidence that a bay-wide series of faunal events has occurred over the past 2 to 5 centuries. The addition of the geochemical data provides further insight to the system-wide changes taking place in Biscayne Bay.

Comparison of ostracode trends between the two Featherbed Bank cores (GLW402-FBB and SEI297-FB1), located 1.6 km (1 mile) apart, indicate remarkably similar faunal patterns in the upper two meters of sediment. Molluscan faunal trends at the two Featherbed Bank sites also are very similar (Wingard and others, 2003). The repetition of results provide a high level of confidence that the temporal trends in the faunas seen at the Featherbed sites are representative of the ecological history of this part of Biscayne Bay. Results of the foraminiferal analyses of the 2002 Featherbed Bank core are in agreement with the conclusions of the 2003 report and with ostracode and mollusk data. The foraminifers indicate a stronger marine influence in the upper portion of the core. Epiphytal indicators also are in agreement - there has likely been a natural variation of seagrass since at least 1814, and the most recent data from the top of the core suggest that the coverage at this location is somewhat near the average of the past two centuries.

Comparison of the ostracode trends between the two Card Bank cores (GLW402-CBB and SEI297-CB1) also indicates similar faunal patterns in the upper 2 meters of sediment from the two sites located about 2 km (1.3 miles) apart, and these trends also are very similar to the patterns seen at Featherbed Bank. Molluscan analyses of the 1997 Card Bank core illustrate that some type of sub-aquatic vegetation has been present at the site throughout the time of deposition. Card Bank has been a transitional area between a more restricted upper estuarine environment and a more open estuarine environment, fluctuating between these environments over time, but the site appears to have become increasingly stable and increasingly marine during the last century. These data are in agreement with the ostracode data from Card Bank, and with the conclusions of Wingard and others (2003) for Biscayne Bay as a whole.

Geochemically a shift appears to have occurred at Card Bank and No Name Bank around 1970, with a large increase in total phosphorus (TP) occurring. Since the apparent increase in TP is largest at Card Bank in the south and lowest at Featherbed Bank, a source of excess nutrients from the Miami urban area seems unlikely. It is possible that the apparent increased TP flux to the sediments resulted from inputs from canal structures in the southern part of Biscayne Bay, especially the C-111 canal.

PATTERNS OF CHANGE IN THE WETLANDS AT MILITARY CANAL

The wetland cores were collected to examine changes in the wetland ecosystems bordering the bay, and to identify changes in surficial water availability in the terrestrial near-shore portion of the ecosystem over time.

Military Canal North Core

Core SEI97-BW1, collected in a mangrove swamp on the north side of Military Canal, reveals sedimentological changes throughout the history of the site. A basal black peat (38-48 cm) is overlain by a peaty marl (24-38 cm), which grades into a tan marl (12-24 cm). A thin transitional peaty marl (10-12 cm) is overlain by an upper brown peat (0-10 cm). There is some correspondence of the three pollen assemblage zones with the lithologic changes. Zone I (24-48 cm) includes the basal peat and peaty marl and is dominated strongly by *Pinus* pollen, which comprises >75% of assemblages (Figure 11; Appendix H). *Myrica* and Cyperaceae pollen and fern spores also are common in this interval. Zone II (12-24 cm) consists of the tan marl and also is dominated by *Pinus* pollen (>80%), but *Casuarina* pollen is present, albeit in low percentages (<2%). Zone III includes the transitional peaty marl and uppermost peat and is characterized by *Casuarina* pollen abundance >5% and is divided into two subzones. Zone IIIa (8-12 cm), corresponding to the transitional peaty marl and basal peat, consists of a transitional pollen assemblage, with *Pinus* pollen and fern spores comprising 50-70% and up to 23% of assemblages, respectively. In Zone IIIb (0-8 cm), *Pinus* pollen is much less abundant (3-30%), and fern spores dominate the assemblages strongly (41-77%). Other taxa that reach their greatest abundances in Zone III are are *Quercus*, *Casuarina*, and the Chenopodiaceae/Amaranthaceae (Figure 11). Total pollen concentration fluctuates throughout the core.

Military Canal South Core

Core SEI97-BW2, collected in a mangrove swamp on the south side of Military Canal, includes a basal marl layer (40-44 cm), overlain by black peat (36-40 cm). This grades into a peaty marl (30-36 cm) then a tan marl (20-36 cm), which grades back into a brown peat in the upper 10 cm. There is less correspondence between pollen assemblages and lithology than in the BW1 core, and three pollen assemblage zones are present. The basal interval, Zone I (14-44 cm) is dominated strongly (76-98%) by *Pinus* pollen and members of the Asteraceae are common (Figure 12; Appendix H). The boundary between Zones I and II corresponds to a change from predominantly marl to peaty marl. Zones II (6-14 cm) and III (0-6cm) are distinguished primarily by differences in abundance of *Pinus* pollen, which comprises 33-52% of Zone II assemblages and <25% of Zone III assemblages. Otherwise, both zones are characterized by the presence of *Casuarina* pollen and greater abundances of pollen of the Euphorbiaceae, Solanaceae,

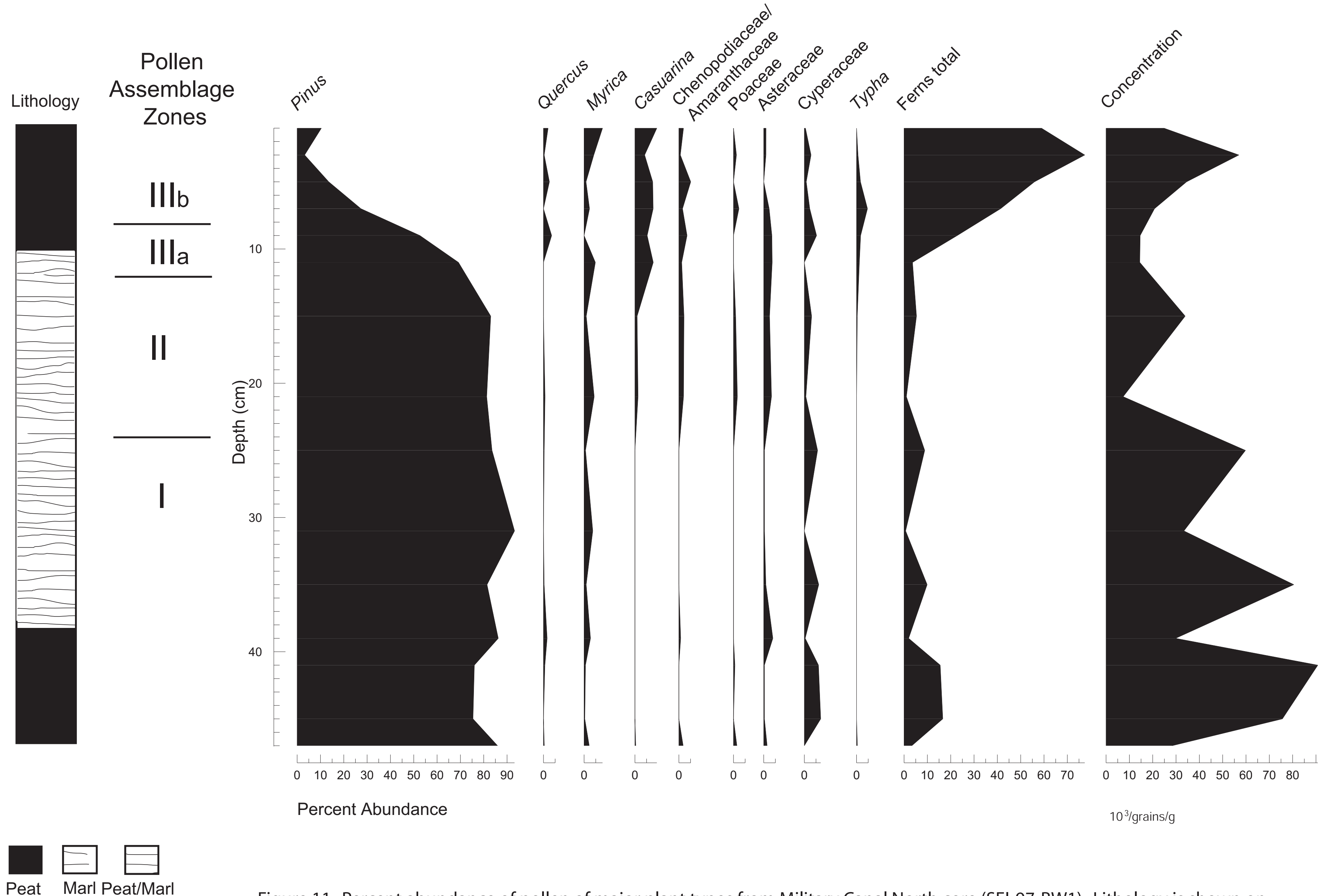


Figure 11. Percent abundance of pollen of major plant types from Military Canal North core (SEI-97-BW1). Lithology is shown on left; pollen concentration in grains/g/sample on the right. (Data in Appendix H.)

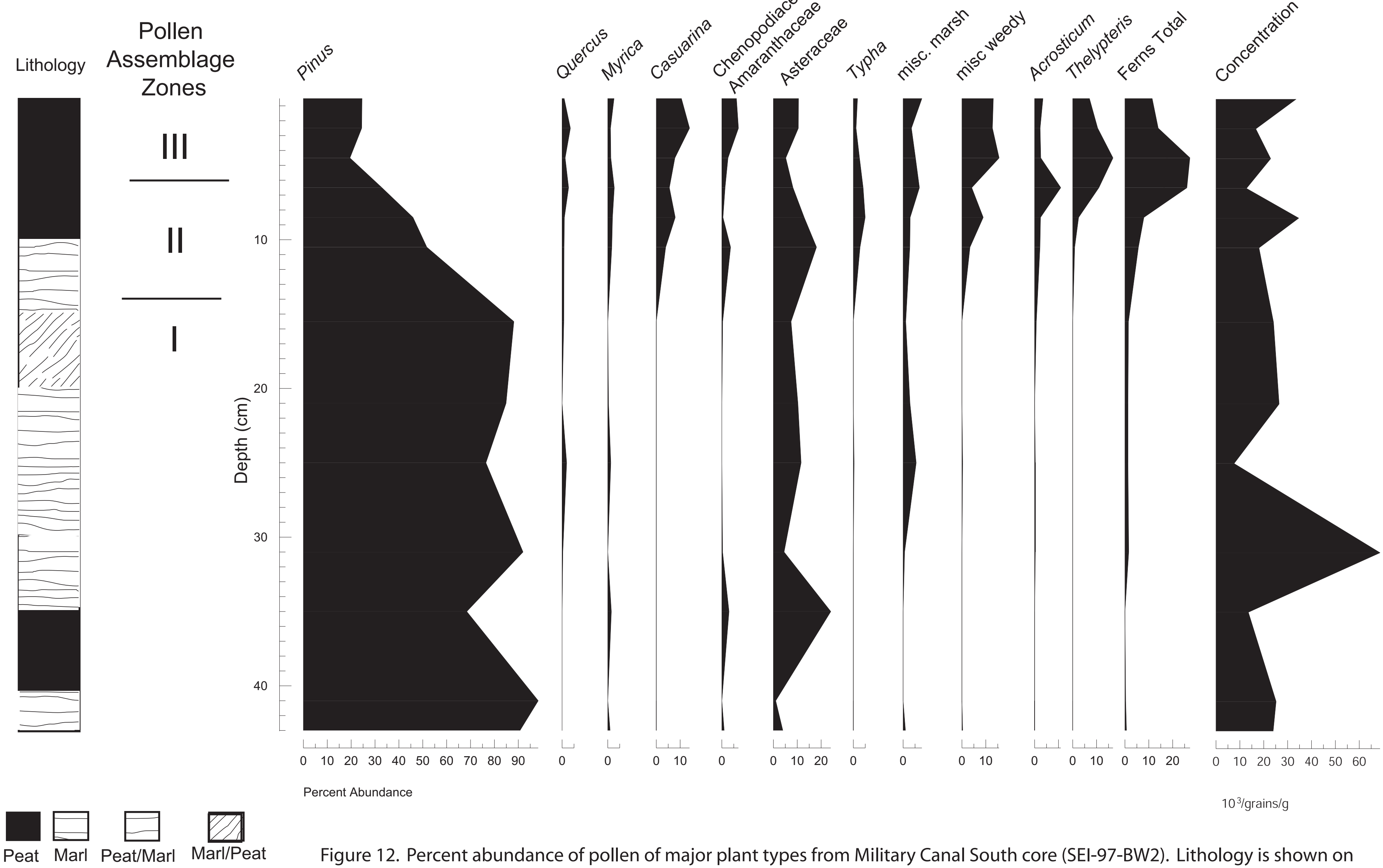


Figure 12. Percent abundance of pollen of major plant types from Military Canal South core (SEI-97-BW2). Lithology is shown on left; pollen concentration in grains/g/sample on the right. (Data in Appendix H.)

Typha, *Rhizophora*, *Ambrosia*, Chenopodiaceae/Amaranthaceae, and Apiaceae (Figure 12). Total pollen concentration fluctuates throughout the core.

Discussion of Military Canal Cores

Although both Military Canal cores were collected in modern mangrove forests, their pollen records indicate that this was the site of a complex history of vegetation and hydrology. Different understory species associated with different hydrologic regimes existed throughout the time of deposition at the sites. Recent assemblages from the site north of the canal (SEI97-BW1) are characterized by abundance of an unidentified fern species and poor representation of weedy taxa such as the Asteraceae or Chenopodicaeae/Amaranthaceae or marsh taxa (Cyperaceae, Poaceae). The site south of the canal, on the other hand, has abundant weedy and marsh taxa and ferns typical of drier conditions, similar to conditions found on tree-island heads (*Acrostichum*, *Thelypteris*). The greater abundance of weedy taxa, in particular the Asteraceae, is a long-term feature of the southern site, persisting throughout the entire core (Figure 12). We interpret these differences as indicative that the southern site has always been relatively drier than the northern site. Examination of aerial photographs from 1940 (Figure 13) shows a flow pattern discharging near the northern site; the distance between the two core sites apparently is great enough to result in hydrologic differences even before construction of Military Canal early in the 20th century. After its construction, the hydrology was further altered, increasing the abundance of ferns and other taxa characteristic of shorter hydroperiods (Willard, Weimer, and Riegel, 2001).

PATTERNS OF CHANGE AT NEAR-SHORE SITES

The near-shore cores were collected in 2003, in areas near historical freshwater drainage, in order to determine changes in freshwater influx to Biscayne Bay over time.

Middle Key Basin

Middle Key core (GLW603-MKA) is located southwest of the Card Sound Bridge in a relatively isolated shallow basin (Figures 1 and 14). No development has taken place in the basin or in the immediate drainage area west to US Route 1 and north to the Florida Sand and Gravel pits. Compared to other core locations, Middle Key represents a relatively undisturbed site.

An examination of the sediments in the core reveals primarily gradational transitions from a mixed matrix of carbonate mud and limestone rubble from the underlying bedrock in the lower portion of the core, to peaty material with very high organic content and few preserved shells in the middle of the core, to a carbonate mud with abundant shell material at the top of the core.

The lack of abundant, well-preserved shell material in the lower portion of the core prevented us from obtaining carbon-14 analyses in the initial phase of sampling (future

A

B

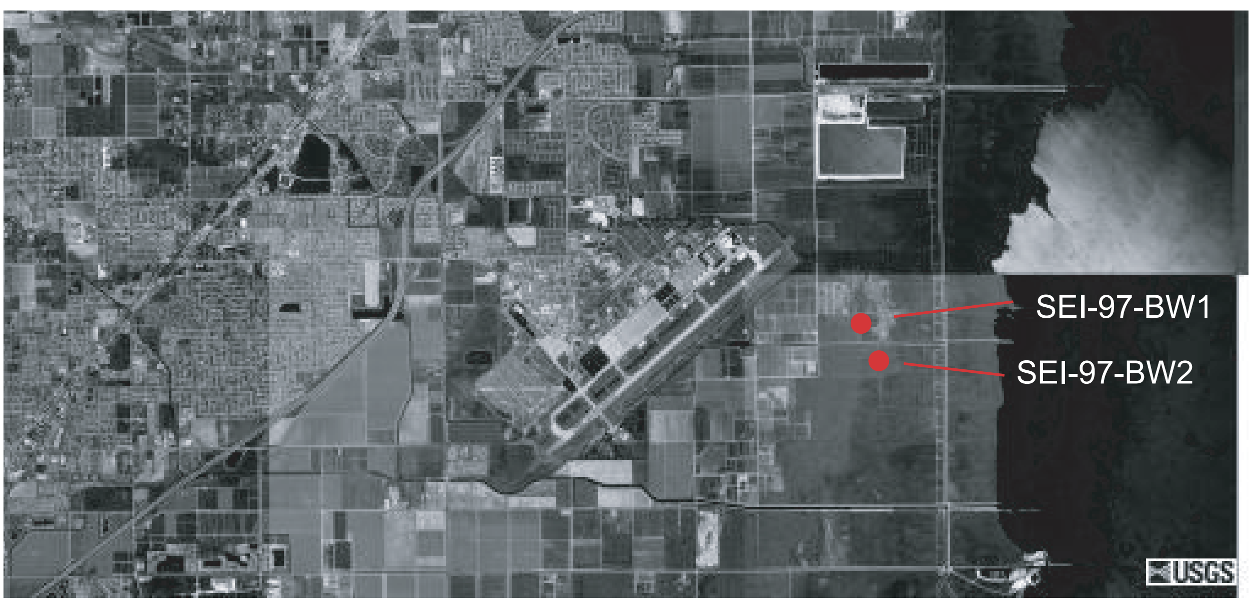
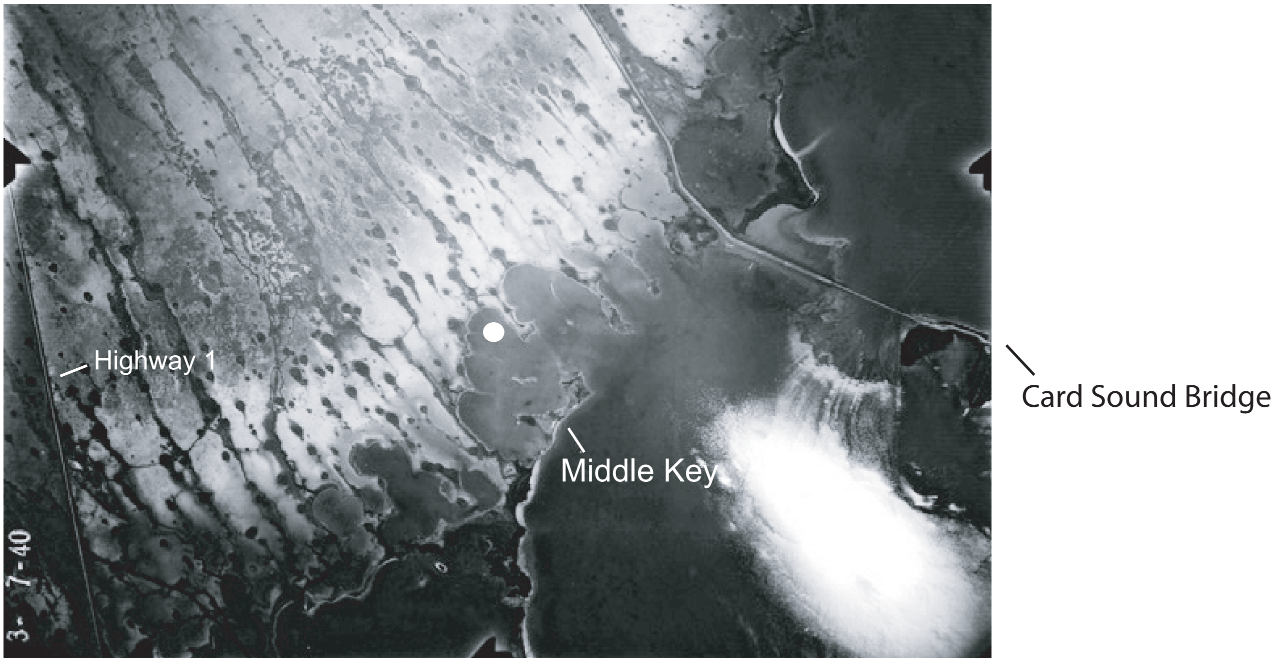


Figure 13. (A) Aerial photographs of Military Canal, 1940, from Smith (2002); and (B) digital orthophoto quadrangle, 1999, from EarthExplorer (http://edcsns17.cr.usgs.gov/EarthExplorer/). Red circles show core locations.

A



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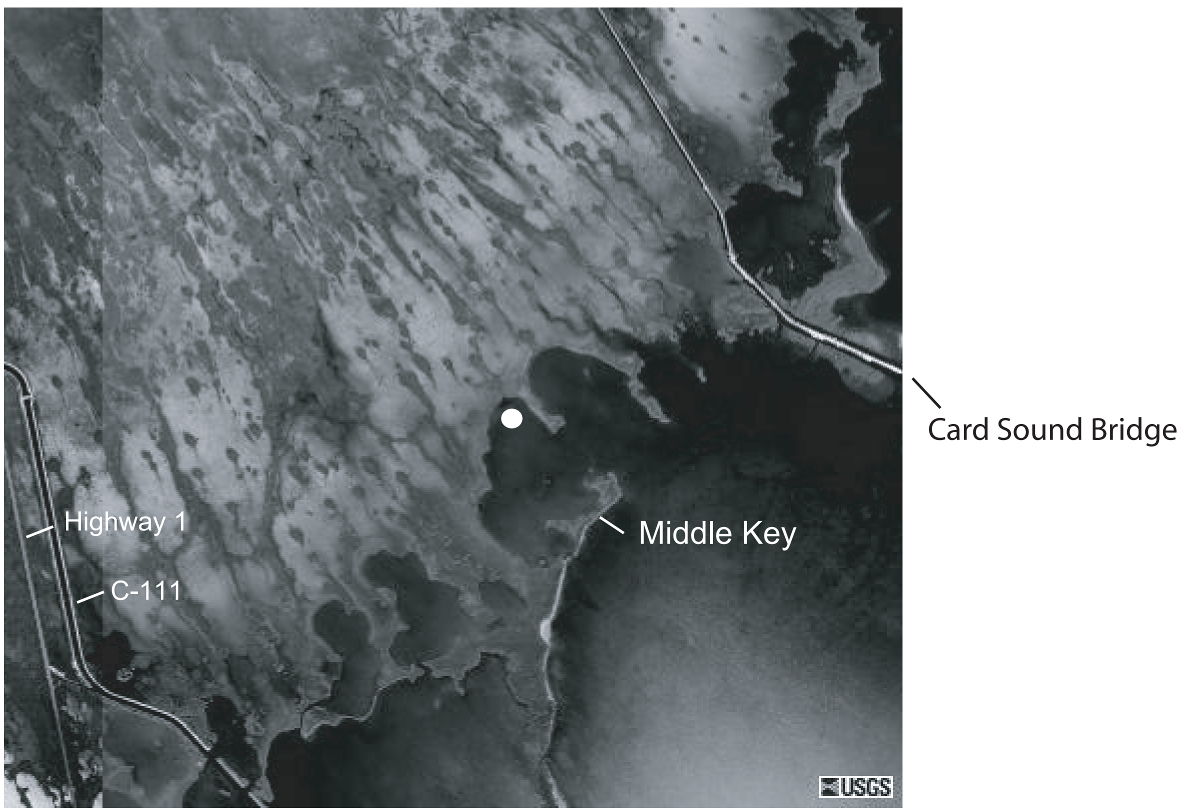

Figure 14. (A) Aerial photograph of Middle Key area, 1940, from Smith (2002); and (B) digital orthophoto quadrangle, 1999, from EarthExplorer (http://edcsns17.cr.usgs.gov/EarthExplorer/). Core site is indicated with white dot.

analyses are planned on wood and some shell material found during processing). The excess (or unsupported) lead-210 reaches background levels at 22-24 cm in depth (Figure 15). The first *Casuarina* pollen appears in the sample from 20-22 cm. As discussed in the Material and Methods section, lead-210 typically reaches background levels in the early 1900s and *Casuarina* was introduced in south Florida around the turn of the 20th century. The correlation of these two events in the core (Figure 16), the relatively good fit between the lead-210 data and the logarithmic decay curve (Figure 15D), and the lack of any obvious event horizons indicate that the age model for the 20th century is sound. The upper 20-25 cm of the core, therefore represent deposition in the 20th century; however, the relatively low sedimentation rate means each 2-cm core sample represents approximately seven years of sediment accumulation, preventing any precise correlations to anthropogenic or natural events.

The only method we currently have for estimating the age of the lower portion of the core is to extrapolate the sedimentation rate based on the lead-210 data backward. Using this approach, the base of the core may be around 1600, but it could be much older. Radiocarbon analyses corrected for the local reservoir effect should provide better data on the age of the lower portion of the core. The lower segment of Middle Key core, however, shows a distinct lead-210 anomaly beginning between 66 and 74 cm. This anomaly is similar to anomalies found in Florida Bay cores examined by the authors and is believed to be due to groundwater upwelling (Holmes, 2001).

Results

Ostracode assemblages in Middle Key core show distinctive changes occurring in the 20th century (Figure 17; Appendix I). The most significant change is the decline in non-marine species from about 20 to 10 cm core depth (~1934-1969). Sediments from the interval 27-13 cm core depth were deposited in close proximity to freshwater environments where non-marine taxa, such as *Candona*, *Heterocypris*, and cyprids, live. The disappearance of non-marine taxa near 10 cm core depth (mid-late 1960s) is accompanied by small increases in *Loxoconcha matagordensis* and *Malzella floridana*, as well as increases in Mg/Ca ratios of *M. floridana* shells from approximately 25-30 mmol/mol at 5 cm core depth (1980s) (Appendix B).

Three distinctive shifts occur in the molluscan assemblages in Middle Key core (Figure 18; Appendix J). First, from 90 cm to approximately 30 cm (pre-1900) the assemblage is predominantly freshwater fauna (hyrdrobiids, minute gastropods that can be found floating in freshwater currents, and Physidae and *Planorbella,* relatively large bottom dwelling freshwater gastropods). Besides the freshwater gastropods, the only other mollusks found below 42 cm are scattered terrestrial gastropods (*Polygyra* and Pupillidae). Portions of this lower section of the core do not contain statistically significant numbers of mollusks (from 82-72 cm > 5 individuals are present; from 56-70 cm >75 individuals are present), however, all the mollusks present are indicative of freshwater and terrestrial environments. The transition to the second assemblage is gradual, beginning with the sample at 42 cm (pre-1900), where *Cyrenoida floridana*, a clam that lives in very low salinity waters (<10 ppt and typically <5ppt; Brewster-

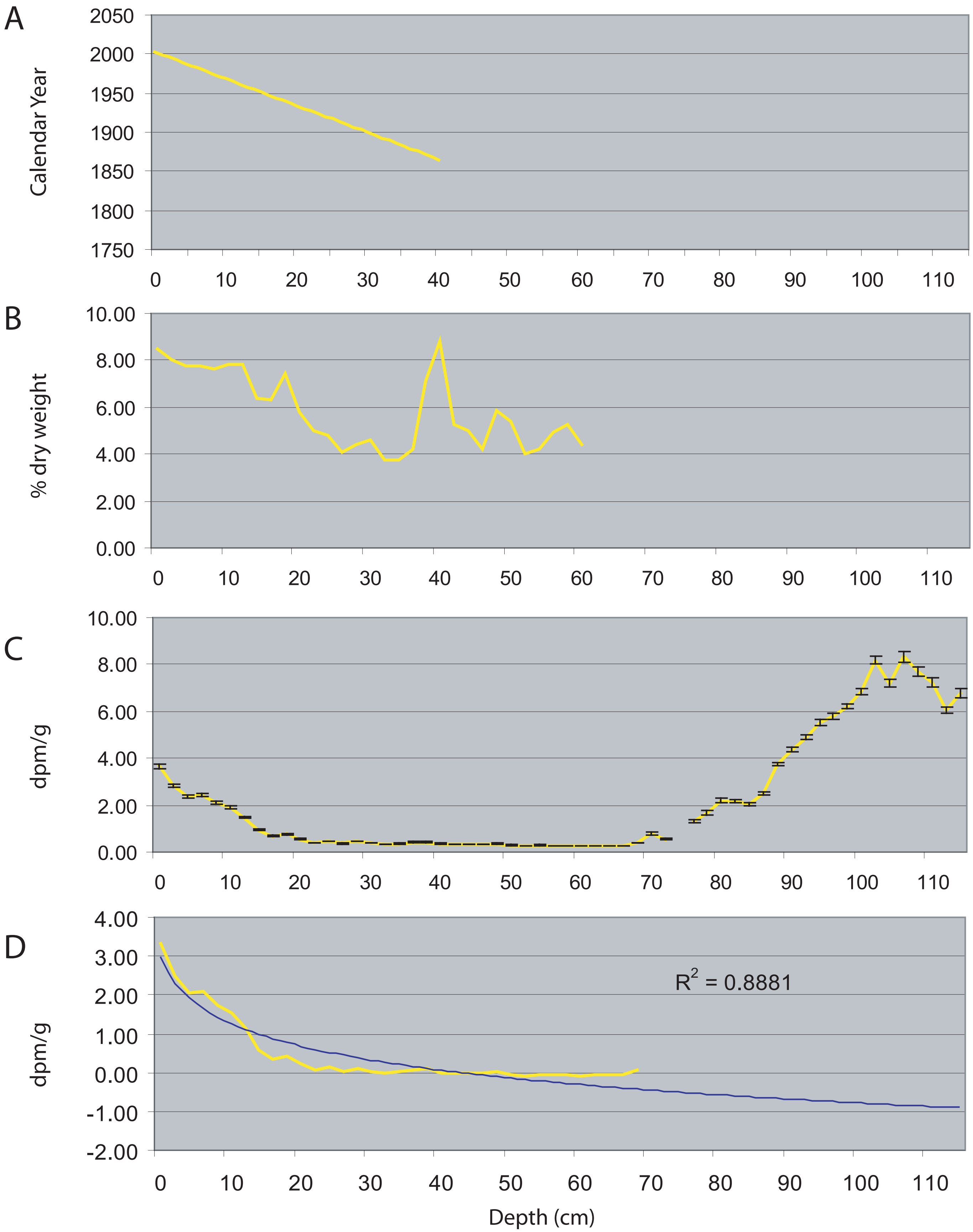

Figure 15. Lead-210 data for Middle Key core (GLW603-MKA). A. Projected calendar year at depth. B. Loss on ignition (% dry weight). C. Total lead-210 activity in decays per minute per gram (dpm/g), with error bars. D. Excess (or unsupported) lead-210 activity (dpm/g). Data in yellow, logarithmic decay curve in blue.

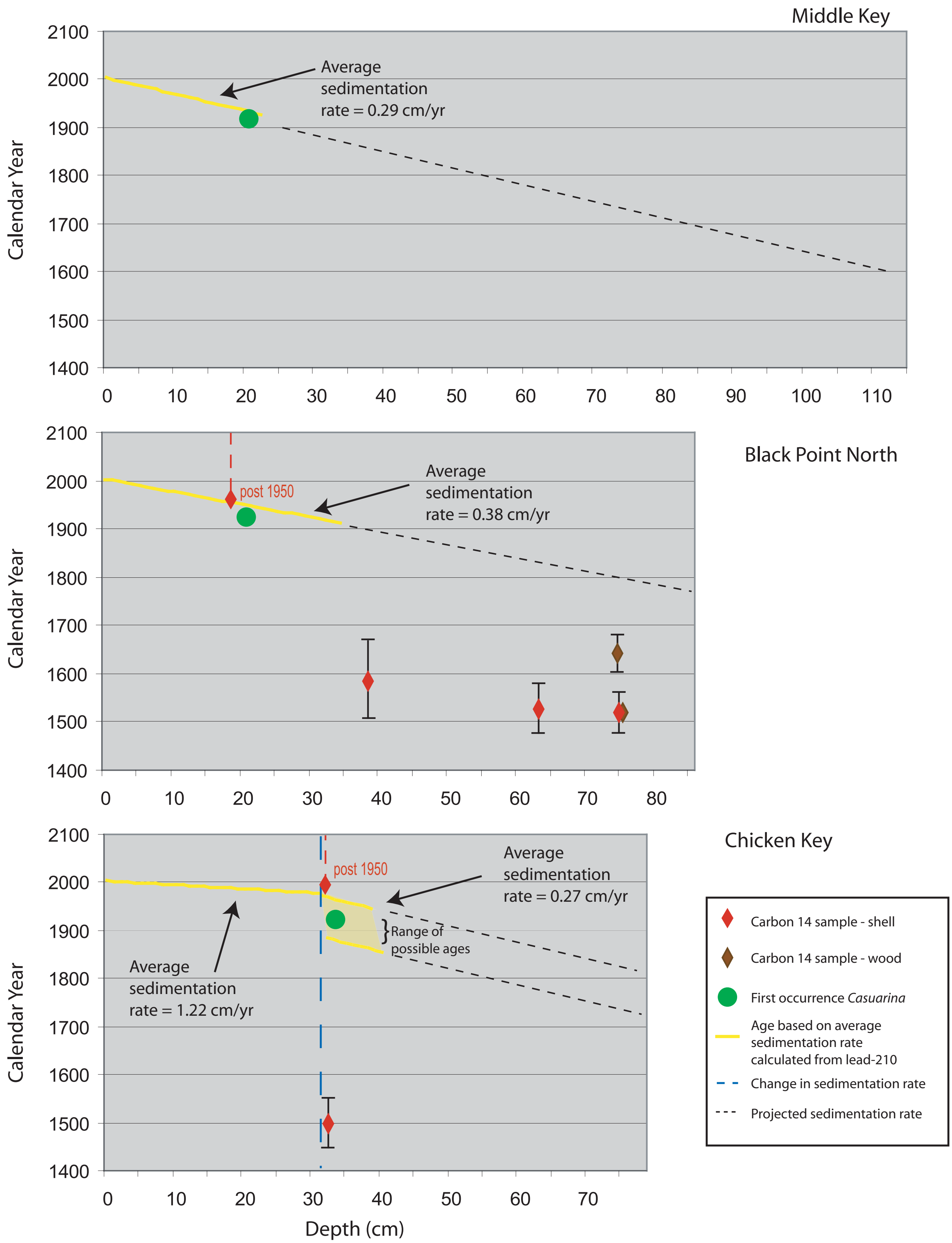

Figure 16 . Composite of age information for 2003 nearshore cores. Average sedimentation rate is based on lead-210 data (see Figures 15A, 24A, 32A); the lowest position of the yellow line in the core marks the point where lead-210 reaches background level - approximately 1900. Projected sedimentation rate assumes lowest measured sedimentation rate is constant to bottom of core. Chicken Key core has a change in sedimentation rate at 32 cm. Samples submitted for carbon-14 show position in core and estimated age without local correction factor (data from Table 2, see text for full explanation). Carbon-14 samples measured as having modern carbon indicate the shell grew after 1950. First occurrence of *Casuarina* shows position in core and assumes an age of ~1900-1925 (Langeland, 1990).

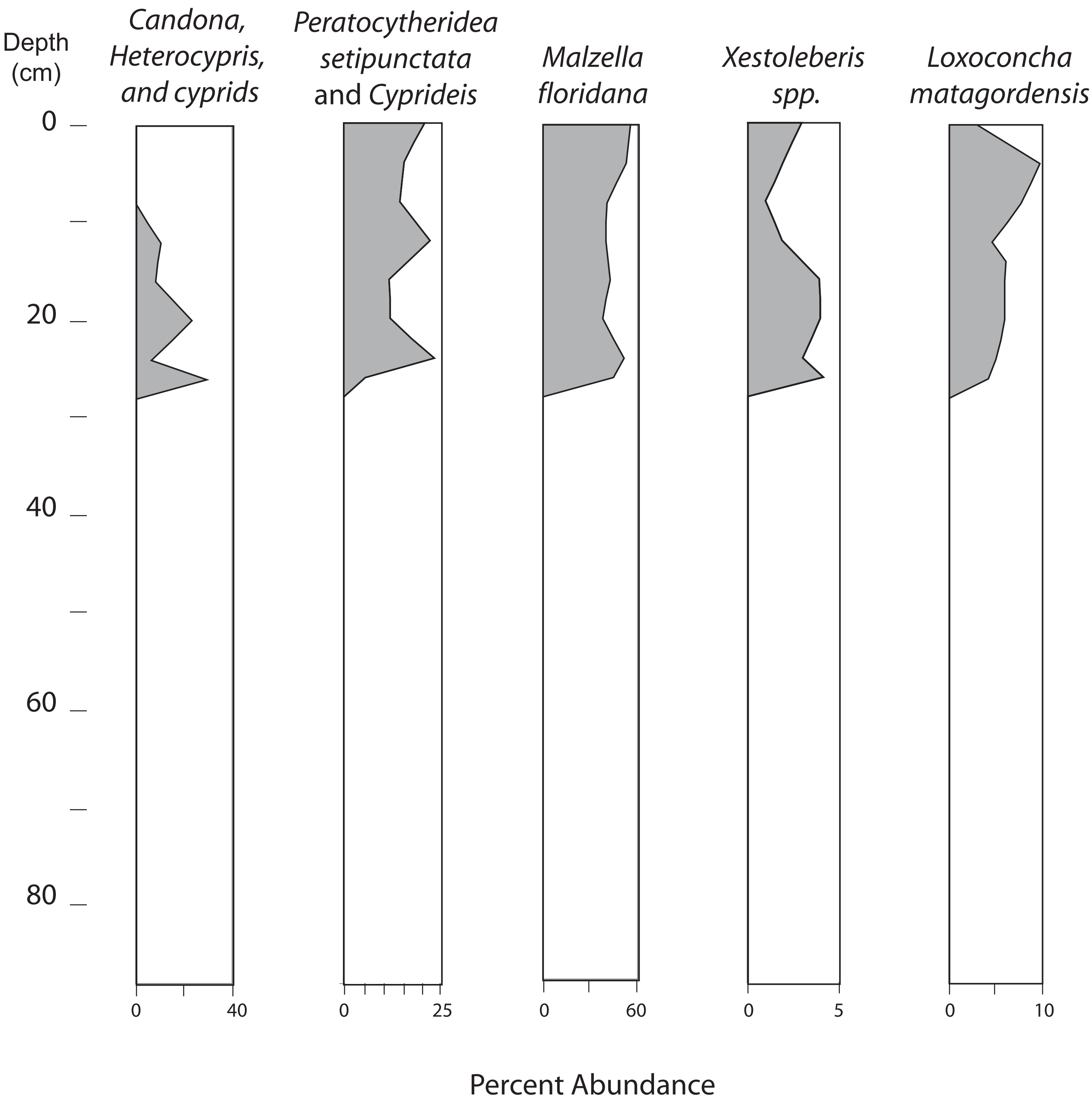

Figure 17. Percent abundance of key ostracode taxa in Middle Key core (GLW603-MKA) plotted against depth in cm. No ostracodes were recovered below 28 cm core depth. Note different percent abundance scales. (Data in Appendix I.)

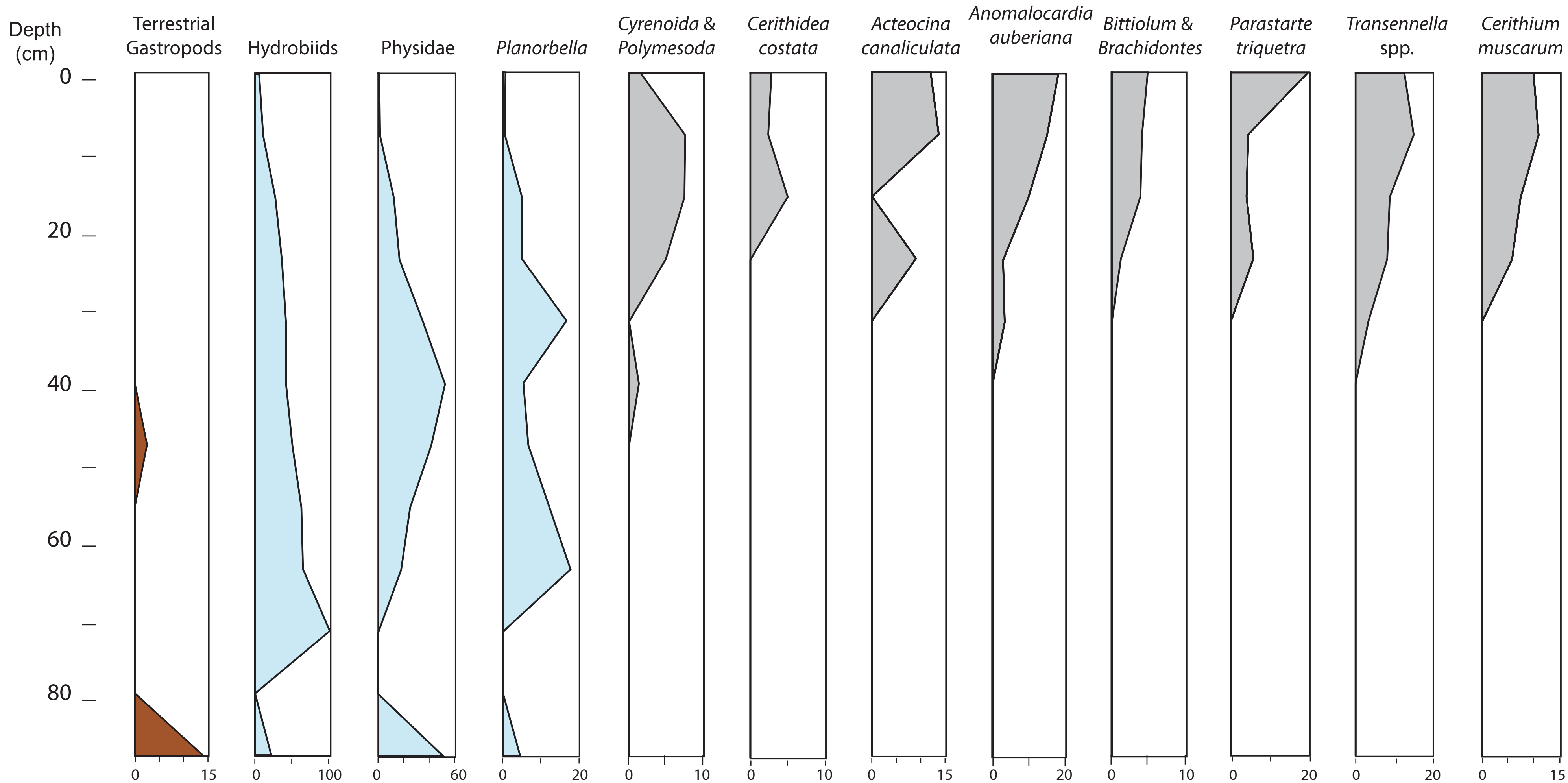

Figure 18. Percent abundance of key molluscan taxa (excluding worn and fragmented) in Middle Key core (GLW603-MKA) plotted against depth in cm. Brown shading are terrestrial species, blue freshwater, gray estuarine. Note different percent abundance scales. (Data in Appendix J.)

Wingard and others, 2001) makes a rare appearance. Above 40 cm core depth, the freshwater gastropods begin to decline steadily. At 24 cm (near the turn of the century to 1920s) typical near-shore estuarine species (*Acteocina canaliculata, Anomalocardia auberiana, Bittiolum varium,* and *Brachidontes exustus*) begin to increase. Diversity and absolute abundance also increase above 24 cm (data in Appendix J), consistent with a transition from freshwater to more estuarine or mixed salinities. The final shift occurs above 10 cm (late 1960s to mid-1970s) where freshwater gastropods drop to <13%, the oligohaline to low mesohaline species decline (*Cyrenoida* and *Polymesoda*), and species that can tolerate significant fluctuations in salinity increase (*Anomalocardia*, *Brachidontes, Bittiolum, Parastarte* and *Cerithium*). Also, the typically mesohaline to polyhaline clam, *Transennella* spp. increases in the upper 10 cm.

Two samples were quantified for foraminifers from Middle Key (0-2 cm, and 16-18 cm) (Figure 19; Appendix K); the six samples examined from the lower portion of the core were essentially barren. A comparison of the two samples indicates that the *Ammonia* and *Cribroelphidium- Elphidium* groups, which are more abundant in freshwater mixing zones, are relatively higher in abundance in the lower sample (16-18 cm; 1940s). The three groups more indicative of marine influence (*Miliolinella*, *Quinqueloculina,* and *Triloculina*) are higher in abundance in the upper sample (0-2 cm; ~1996-2003). The absence of foraminifers from the lower portion of the core is significant because they are indicative of estuarine and marine environments.

Only two pollen assemblage zones are found in the Middle Key core (Figure 20; Appendix L). In Zone I (22-114 cm), *Pinus* pollen comprises ≥90% of pollen assemblages, and pollen of *Myrica* and Chenopodiaceae/Amaranthaceae typically are present. In zone II (0-22 cm), *Casuarina* pollen is present; *Quercus*, *Myrica*, and Chenopodiaceae/Amaranthaceae pollen each are more abundant than in zone I, mangrove (*Laguncularia and Rhizophora*) pollen is present, and *Pinus* pollen comprises <90% of the assemblages. Pollen concentrations are reduced in Zone II.

Geochemical analyses of the total phosphorus (TP) concentrations in the Middle Key core are shown in Figure 21 (Appendix C). A significant TP anomaly occurs in the lower portion of this core from 100-70 cm (pre 1900), where TP levels reach 0.0588% in the 72-74 cm sample. In the upper 30-20 cm of the core TP levels exhibit a normal exponential decrease in TP with depth due to diagenetic recycling of P from sedimentary organic matter.

Discussion

Several anomalies occur in the lower portion of Middle Key core. Below 70 cm (pre-1900) total lead-210 concentration increases significantly and below 90 cm pollen concentrations are greatly reduced (Figures 15 and 20). Both of these factors may be related to the underlying bedrock. Upwelling of groundwater through the limestone allows radon to seep into the over-lying peat where is it adsorbed and then decays to lead-210, altering the total lead-210 concentrations for the bottom of the core. The occurrence of limestone rubble in the bottom of the core reduces the quantity of sediments and

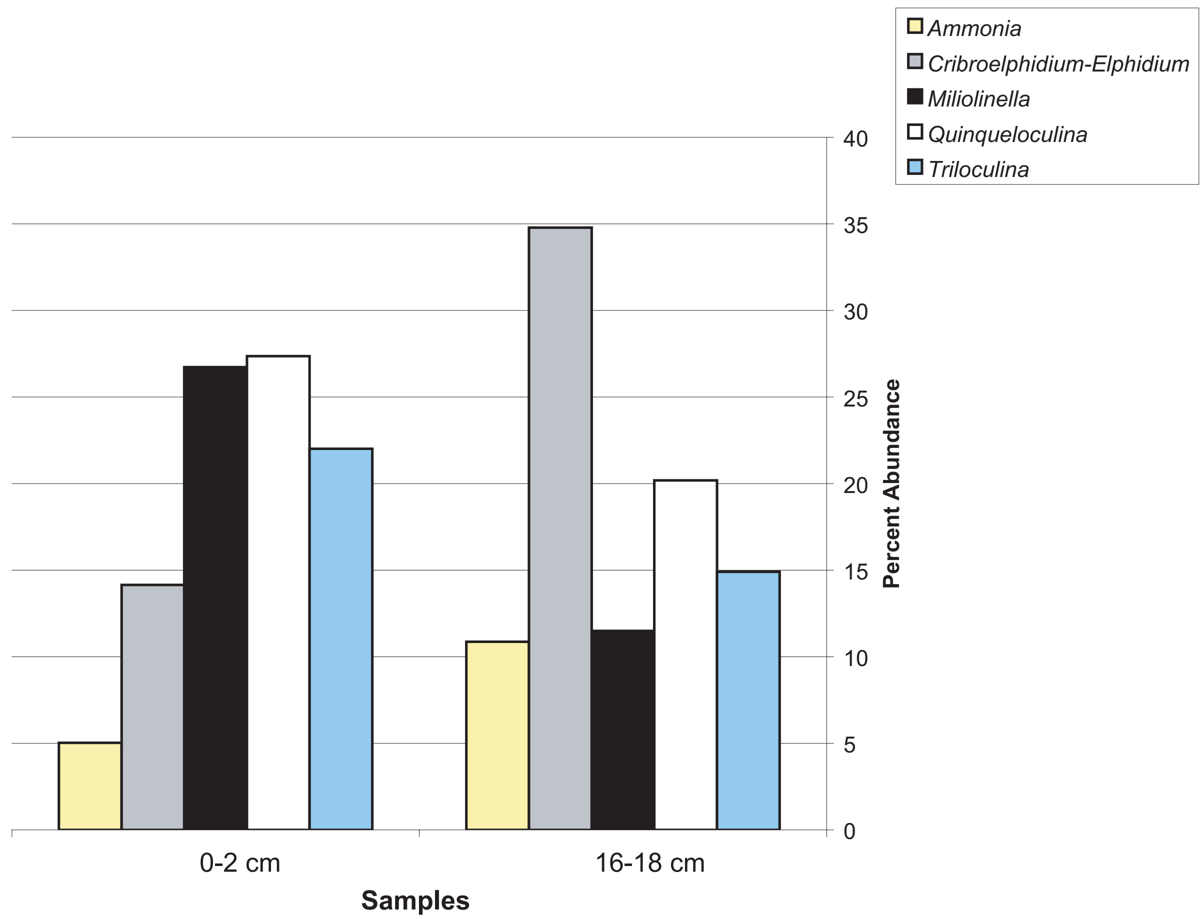

Figure 19. Bar graph of percent abundance of key foraminifers from two samples from Middle Key core (GLW603-MKA). (Data in Appendix K.)

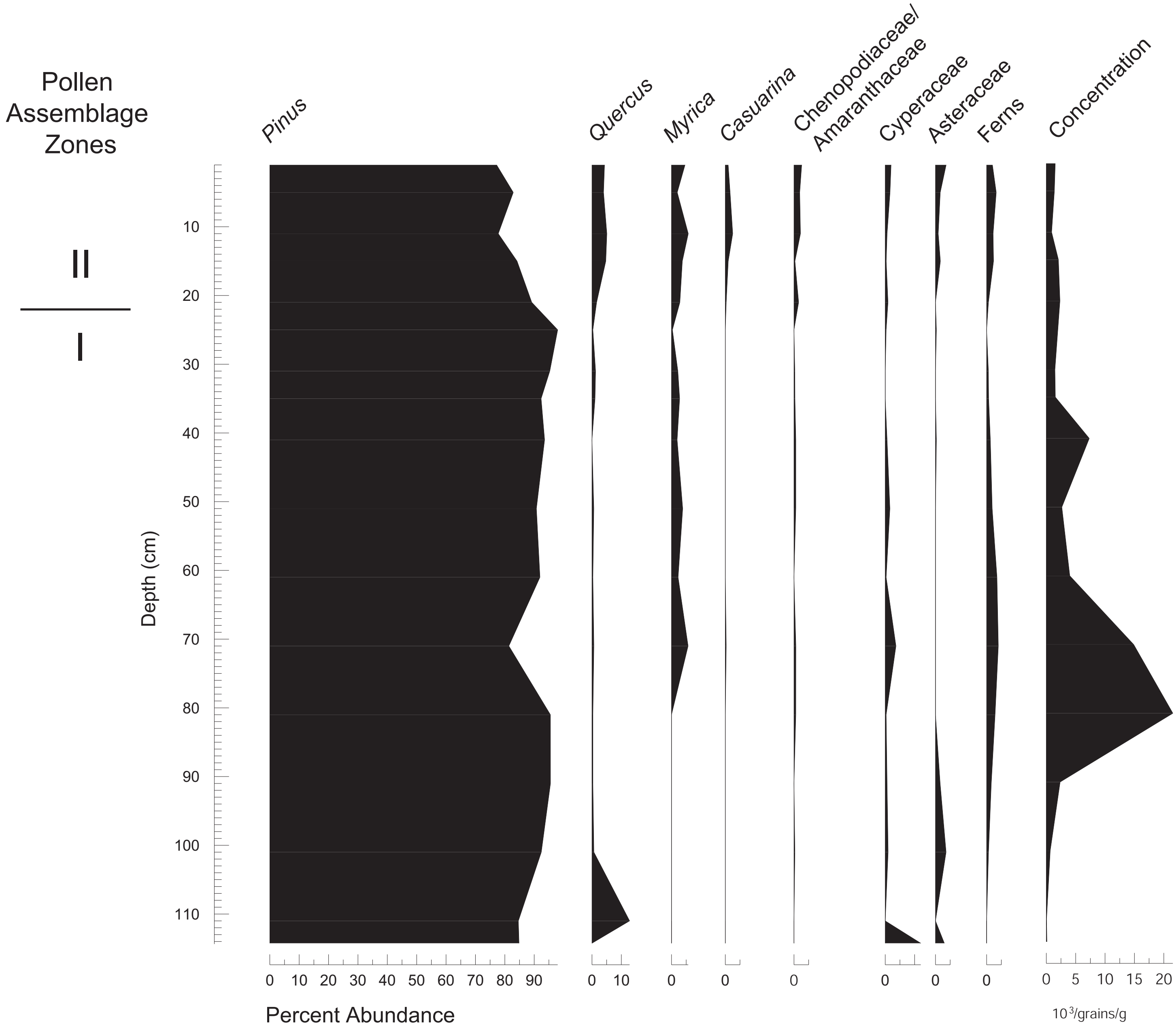

Figure 20. Percent abundance of pollen of major plant types from Middle Key core (GLW603-MKA) plotted against depth in cm. Right graph shows pollen concentration in grains/g/sample. (Data in Appendix L.)

therefore the quantity of pollen grains. The total phosphorus (TP) anomaly occurs from 100-70 cm (Figure 21) and may be related to the presence of the limestone and carbonate muds. Carbonates often seem to have somewhat higher TP values due to formation of calcium fluorapatite mineral phases that do not recycle very readily. Alternatively, the high TP values could represent a period of high aquatic productivity. The samples where TP is highest (72-74 and 80-82 cm) correspond to an essentially barren faunal zone. Whether these two factors are related is unknown.

The mollusk relative assemblage data illustrate a clear pattern of increasing salinity and shifting environments upcore (Figures 18 and 22). Below 40 cm (pre-1900) freshwater gastropods, with a few terrestrial mollusks are the only faunal component in the core (Figure 22, #1). The pollen data, the presence of large amounts of wood debris and organic material, and the peaty nature of segments of the lower core are consistent with a freshwater environment.

A gradual shift to more saline conditions occurs before the 20th century at approximately 42 cm core depth as indicated by the appearance of oligohaline to low-end mesohaline species (Figure 22, #2). A significant drop in pollen concentrations occurs at this point in the core, and the sediments shift to a carbonate mud. A steady decline in the relative abundance of all freshwater gastropods occurs above 30 cm (Figure 22, #3). Absolute abundance data of mollusks indicate significant pulses of freshwater influx above 30 cm, but the high numbers of estuarine species show an increasing influence of saline waters relative to freshwater at the site. Ostracodes typical of non-marine environments near freshwater influx are present in samples from 28-12 cm (late 1800s or early 1900s to ~1960) (Figure 22, #4). The Mg/Ca calibration developed for *Malzella* indicates the salinity for the sediments deposited between 28 and 12 cm (Figure 22, #5) was about 14-18 ppt.[1] Oligohaline and mesohaline mollusks continue to increase above 24 cm (1920s) (Figure 22, #6) and *Pinus* pollen decreases in abundance, while pollen of other trees and weedy species became more abundant. Foraminifers from the sample at 16-18 cm (1940s) are consistent with the mollusk and ostracode data; species typical of freshwater mixing environments are intermixed with species more indicative of higher salinities.

The upper 10-12 cm of the core, representing deposition from approximately the mid-late 1960s to the present, shows a significant decline in the relative abundance of all indicators of freshwater influx and an increase in more mesohaline to polyhaline fauna (Figure 22, #7). Several species of the mollusks and ostracodes present in this segment of the core can tolerate wide fluctuations in salinity from mesohaline to hypersaline. The Mg/Ca data also indicate increasing salinities in this segment of the core with values of 17-21.5 ppt[1]. The foraminifers from the top of the core are consistent with a shift toward increasing salinities. Mangrove pollen (*Laguncularia and Rhizophora*) appears above 12

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[1] As discussed in the Methods section, few modern calibration collections were made in salinities less than 10 ppt. *Malzella* Mg/Ca-salinity calibration was most evident at 12-30 ppt salinities. Below 12 ppt the data are currently useful for qualitative salinity estimates only. Moreover, Mg/Ca-based salinity estimates represent the salinity at the time of secretion of *Malzella* adult shells and may not capture seasonally low salinities.

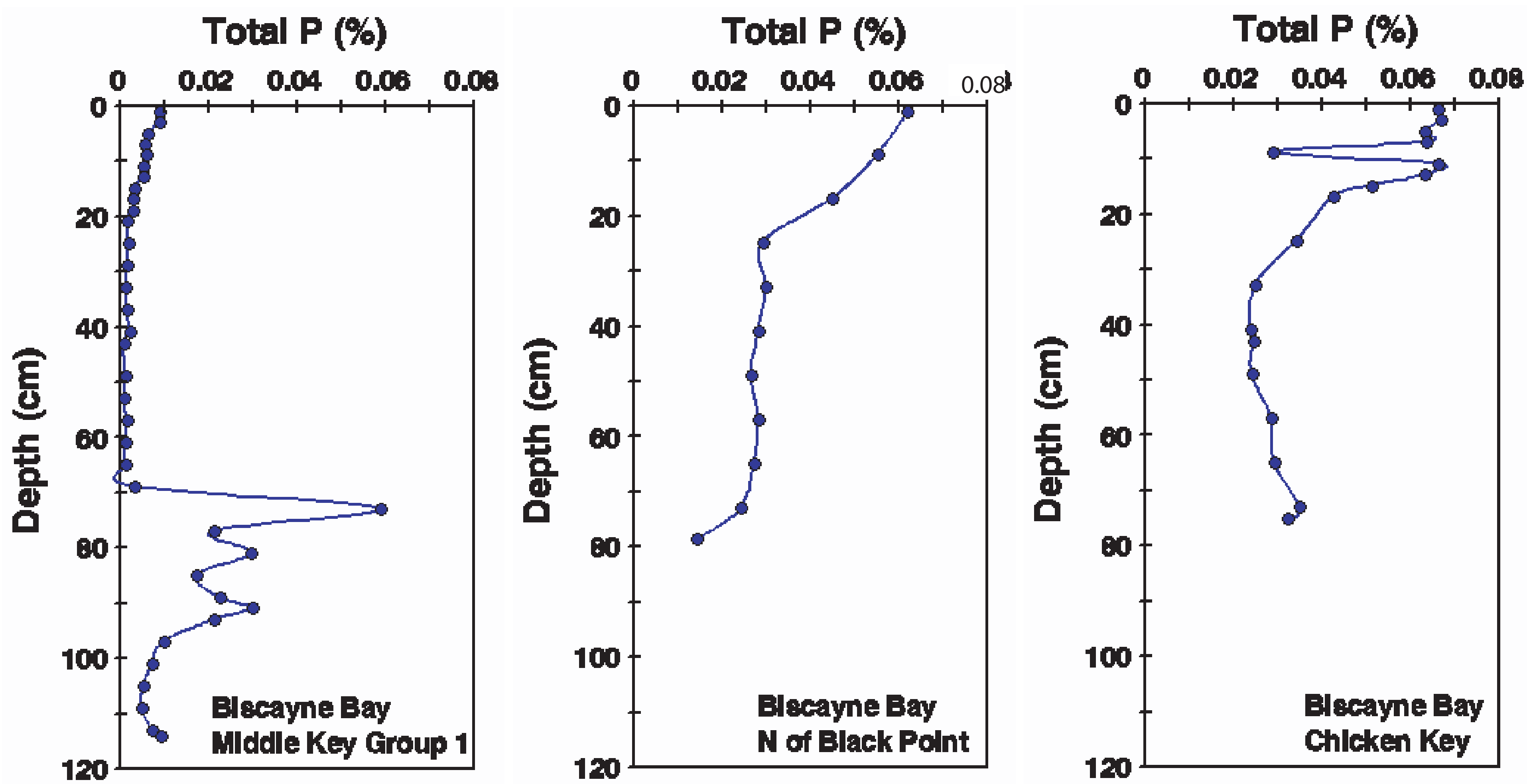


Figure 21. Total phosphorous analyses for 2003 near-shore cores. (Data are in Appendix C.)

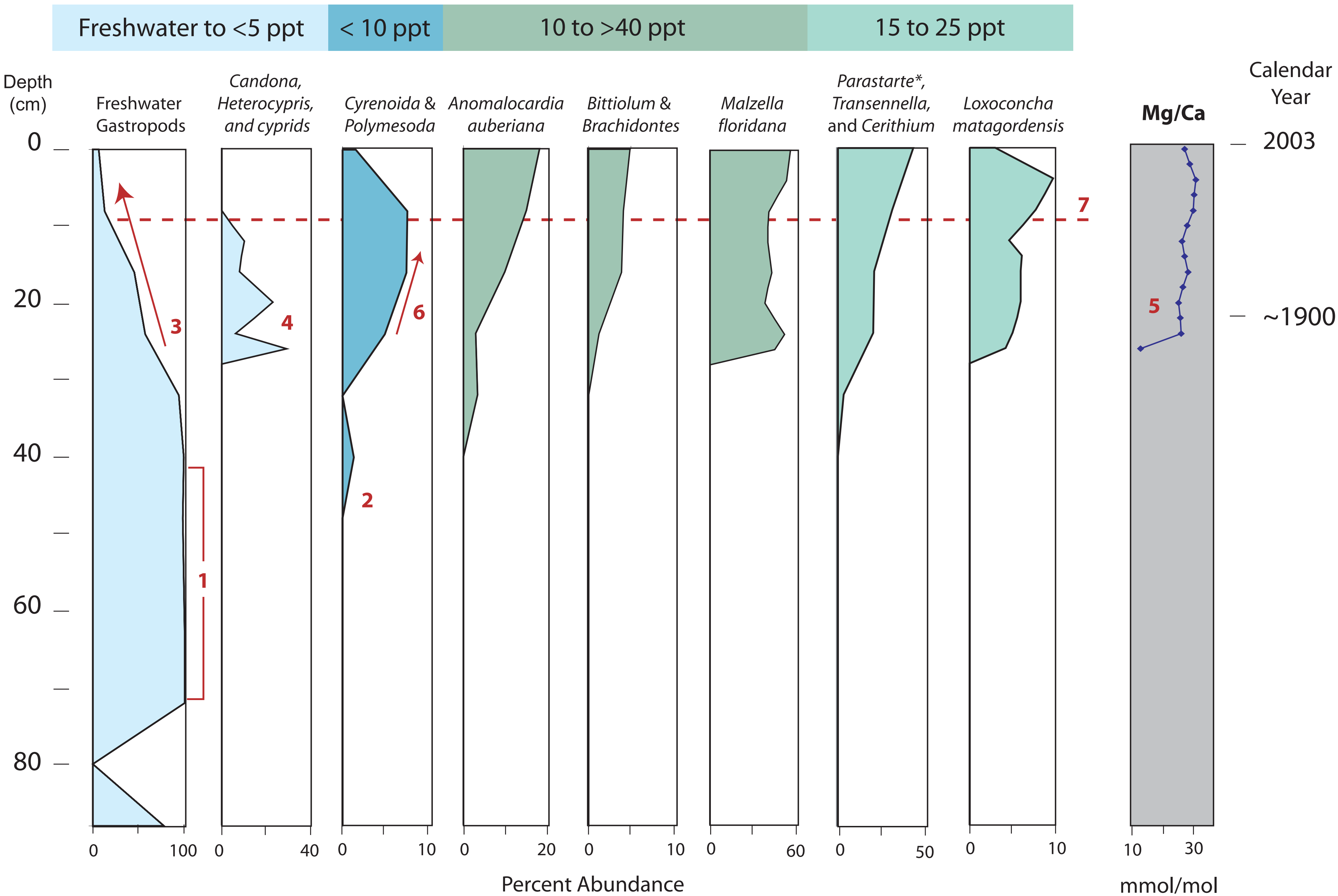


Figure 22. Changes in salinity in Middle Key Basin as indicated by percent abundance of key ostracode and mollusk indicators and Mg/Ca of ostracode shells (gray column on right) plotted against depth in cm, from Middle Key core (GLW603-MKA). Calendar year is indicated on right. Red numbers are referenced in text discussion. Note different percent abundance scales.

*Species is common to the northern transition zone of Florida Bay (Turney and Perkins, 1972), which typically experiences a wide range of salinities , but in our field work we have typcially found it in upper mesohaline-polyhaline salinities.

cm providing additional evidence of the increasingly brackish estuarine nature of the environment.

Taken together these patterns indicate increasing salinities and decreasing freshwater influence throughout the time of deposition of Middle Key core – a typical transgressive sequence. These changes could potentially be explained by rising sea level alone. Estimates of sea level rise in south Florida range from 2.27 mm/yr (http://co-ops.nos.noaa.gov/sltrends (FL: Key West Station Data); and Smith, 1997) to 3-4 mm/yr (Wanless, 1989; Wanless and others, 1994).

The pre-1900 shift towards increasing salinity at approximately 42 cm is most likely due to natural causes; however, the timing of some of the significant changes in the upper segment of the core indicates other factors may have influenced the changes seen at Middle Key. The decline in relative abundance of freshwater gastropods, the increase in brackish fauna, and the increase in trees and weedy species that occurs in the early 20th century could be explained by several events. The construction of the Flagler Railroad 4 km (2.5 miles) to the west of the site around 1906 may have reduced freshwater influx to Middle Key basin coming from the eastern Everglades. The first Card Sound bridge and a roadway leading to the bridge were constructed in the 1920s (http://www.keyshistory.org/osh.html); although this probably had less affect on the freshwater supply than the railroad construction, clearing for the road would account for a reduction in the pine and an increase in weedy species. Depending on the actual bridge construction, it could potentially have affected tidal flushing of the Middle Key basin. An unnamed category 4 hurricane in 1926 (Pielke and Landsea, 1998) also could explain changes in the flora. The increased salinity, the appearance of mangroves, and the sharp decline (both absolute and relative abundance) in freshwater fauna in the upper 12-10 cm of the core begin in approximately the 1960s and could be a response to the hydrologic changes of the Central and Southern Florida project (Light and Dineen, 1994).

The preliminary results from Middle Key can be compared to the Manatee Bay core collected in 1996 (SEI96-MB1), 2.8 km (1.7 miles) to the south. The age model for Manatee Bay (Ishman and others, 1998) is based on the first occurrence of *Casuarina;* lead-210 analyses were not done on the core so a direct comparison between the sites is difficult. The first occurrence of *Casuarina* in both cores, however, serves as a datum, indicating that the sedimentation rate at Manatee Bay is significantly higher than at Middle Key (*Casuarina* first appears at 65 cm in MB1 and at 22 cm in MKA). In general, a similar sequence is seen at both core sites of change from freshwater environments at the bottom of the core transitioning into increasingly estuarine environments in the upper portion of the core. The Manatee Bay site, however, records a change to a diverse polyhaline to nearly euhaline assemblage at the top of the core that is not seen at Middle Key.

Inlet North of Black Point

Black Point North core (GLW603-BPNA) was taken on a sand bar at the mouth of an inlet just north of Black Point (Figures 1 and 23). The Black Point area has undergone significant change in the 20^{th} century. Two canals, Goulds Canal and Black Creek Canal, enter the bay just south of Black Point and a long (>3000 m) channel leads into the canals. A water treatment and solid waste site (known as "Trash Mountain") are located near the mouth of the canals. The aerial photos (Figure 23) show that the area west of the shoreline north and south of Black Point already was cleared and partitioned for farming by 1940. Farming currently is still going on southwest of the site, but developments are rapidly taking over the farm land. The shoreline around Black Point, however, has actually become more forested since 1940, due in large part to its location inside Biscayne National Park.

The lower portion of the core has a high clay content, scattered wood and shell fragments and laminae of quartz sand interbedded with the clay. From 66-44 cm the clay content decreases upward and the dominant lithology is dark silty, fine sand with shell material (including an oyster) and wood fragments. The portion from 44-24 cm is poorly sorted very fine quartz sand, silt, and mud; shell content decreases upward and the sample from 24-26 contains relatively few shells; some burrows. The section from 24-14 cm is better sorted than below; a fine quartz sand with some mottling gradational to upper portion of the core. The top 14 cm consists of poorly sorted very fine quartz sand with relatively abundant shell material; *Thalassia* blades and rhizomes are present.

Five samples from Black Point North core were analyzed for carbon-14 (Figure 16; Table 2) and the results ranged from 1483 AD to post 1950 AD. Wood and shell pieces were both analyzed from the sample at 74-76 cm, giving ages ranging from 1483-1683 AD, and the shell sample from 38-40 cm yielded a possible age range of 1503-1683. As discussed in the methods section, these data have not been corrected for a local reservoir effect and the addition of terrestrial carbon can produce older dates. The excess lead-210 reaches background levels at 34 cm (Figure 24), indicating the sediments above this depth were deposited in the 20^{th} century. *Casuarina* makes its first appearance at 24 cm; based on the sedimentation rate of 0.38 cm/yr calculated from the lead-210 analyses, this occurs in the early 1940s. The carbon-14 sample from 18-20 cm yields a post 1950 age. These data are consistent; however, fluctuations in total and excess lead that correspond to changes in lithology indicate some disruption of sediments occurred in the upper portion of the core, therefore ages are only estimates.

Results

The ostracode assemblage data from Black Point North core indicate several distinct changes at the site (Figure 25; Appendix M). The most prominent ostracode faunal event in the Black Point North core is the large increase in *Peratocytheridea setipunctata* from ~ 65 cm to ~36 cm core depth (pre-1900). During this interval, *P. setipunctata* reaches peak abundances of up to ~90% whereas other species such as *Loxoconcha matagordensis* and *Malzella floridana* are rare to absent. The increase in *P. setipunctata* also coincides with decreases in Mg/Ca ratios, which are in the 20-25 mmol/mol range between 60 and 36 cm core depth. *Malzella floridana* is abundant in the lower and upper portions of the core where *Loxoconcha* also reaches its highest abundances. The 85-65 cm interval of the core has traces of non-marine fauna (*Candona*, *Heterocypris* and

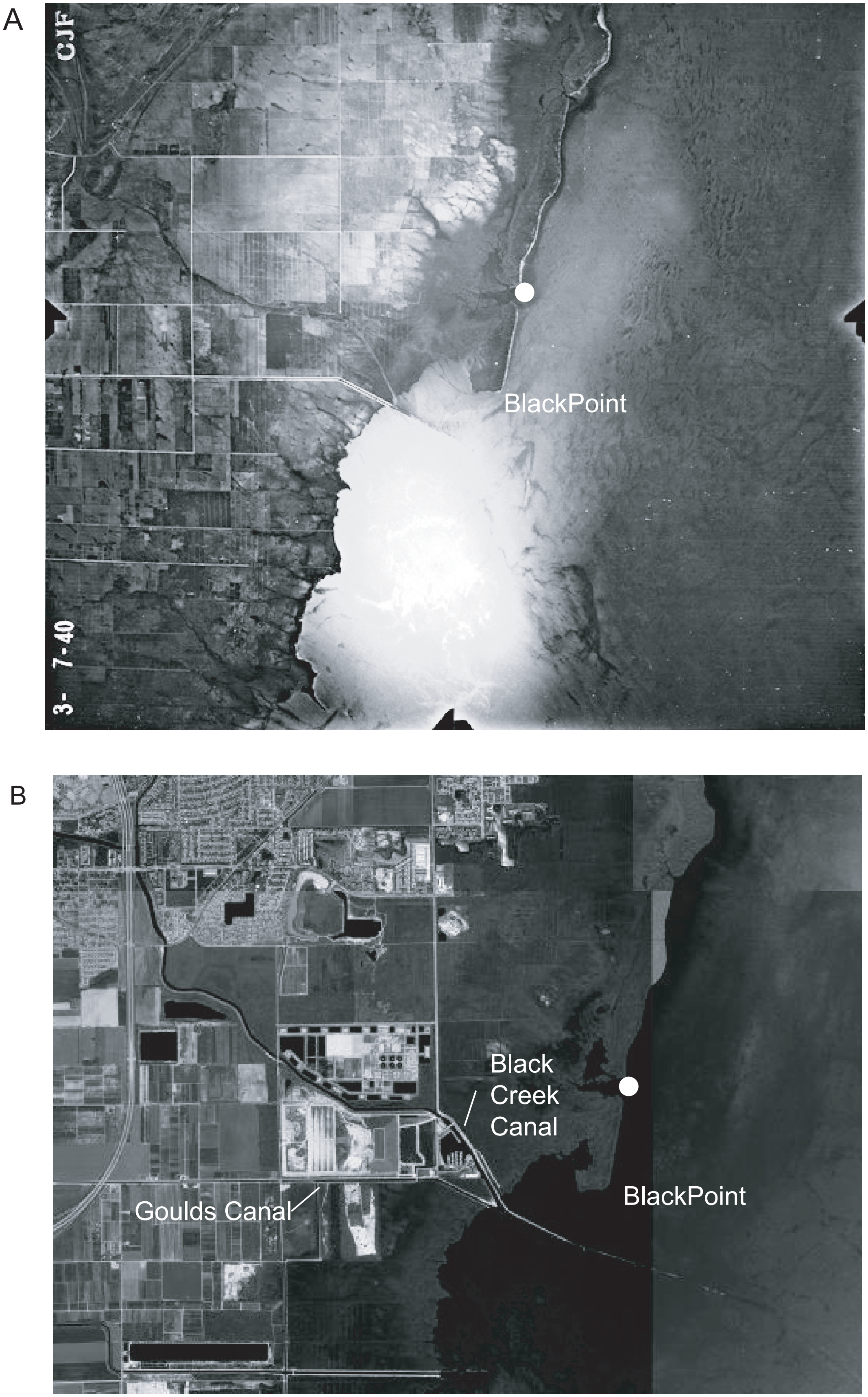


Figure 23. (A) Aerial photo of Black Point area, 1940, from Smith (2002); and (B) digital orthophoto quadrangle, 1999, from EarthExplorer (http://edcsns17.cr.usgs.gov/EarthExplorer/). Core site indicated by white dot.

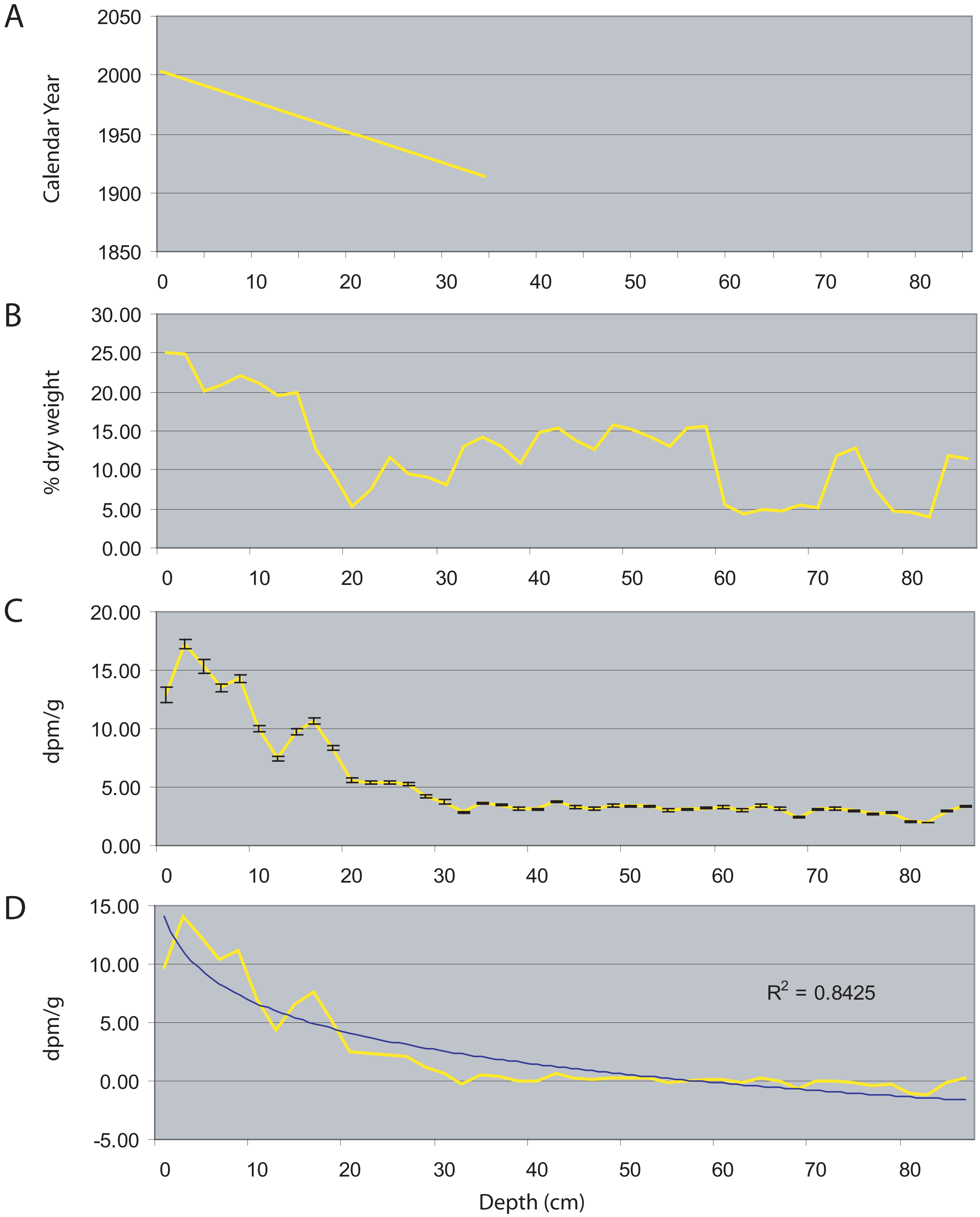


Figure 24. Lead-210 data for Black Point North core (GLW603-BPNA). A. Projected calendar year at depth. B. Loss on ignition (% dry weight). C. Total lead-210 activity in decays per minute per gram (dpm/g), with error bars. D. Excess (or unsupported) lead-210 activity (dpm/g). Data in yellow, logarithmic decay curve in blue.

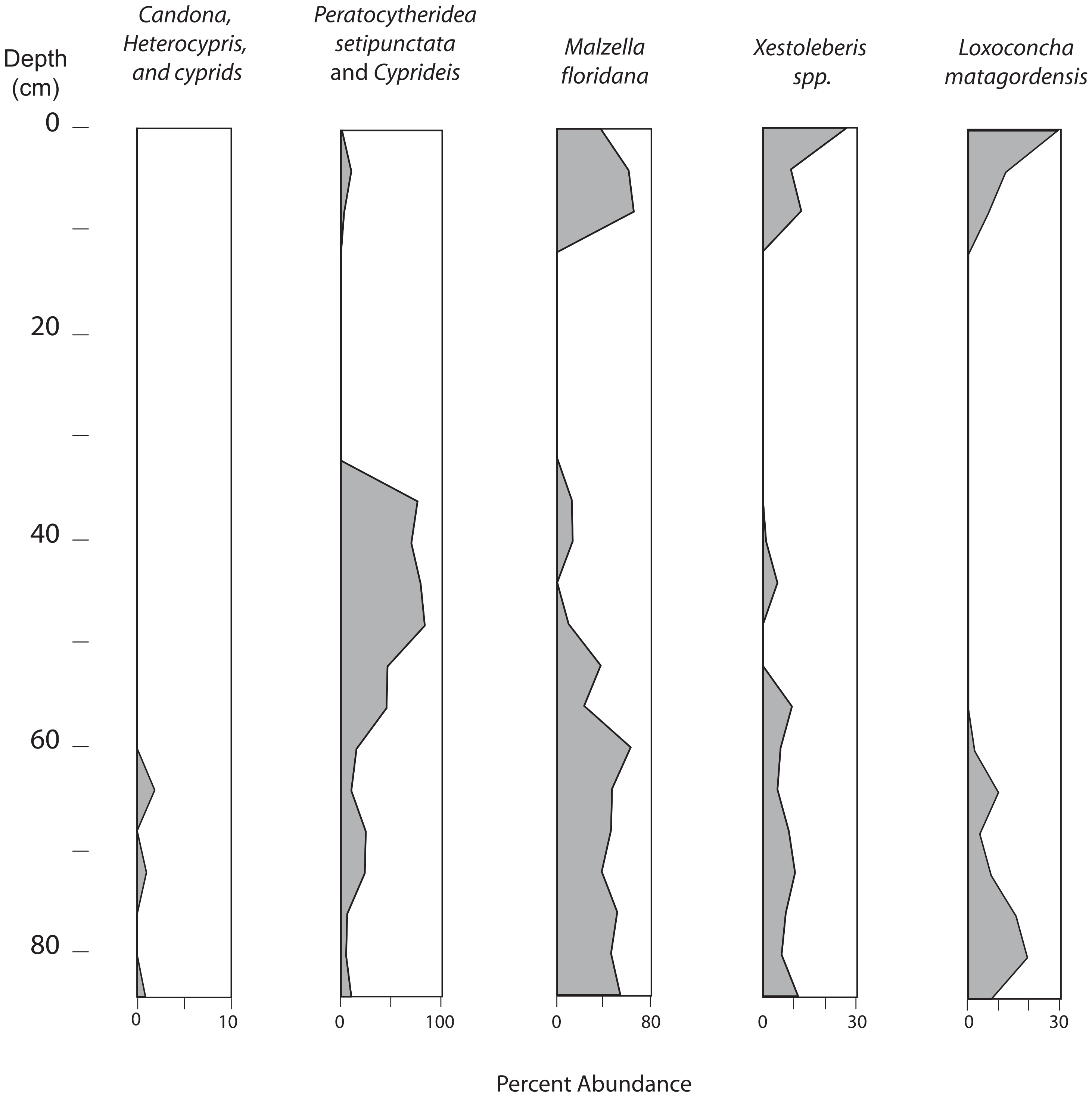


Figure 25. Percent abundance of key ostracode taxa in Black Point North core (GLW603-BPNA) plotted against depth in cm. Note different percent abundance scales. (Data in Appendix M.)

cyprids), and two other low-salinity taxa (3 to 9% *Perissocytheridea*; 1 to 8% *Reticulocythereis floridana).* Ostracodes are rare to absent in the sandy intervals from 10-34 cm.

The molluscan assemblage in Black Point North is dominated by *Bittiolum varium* from the base of the core to 14 cm (~mid-1960s) (Figure 26; Appendix N). A very subtle shift in the environment is indicated at ~60 cm (pre-1900) where a group of species (*Melampus, Melongena, Truncatella*) typical of very shallow near-shore mudflats drops below 2% abundance. The molluscan assemblages in the middle section of the core from 58-16 cm (pre-1900 to ~1960) show few fluctuations in abundance, with the exception of the sample at 24-26 cm (~1930s) where mollusks are very sparse and total abundance decreases dramatically. The common species in the middle section of the core (*Anomalocardia auberiana, Acteocina canaliculata, Bittiolum varium,* and *Cerithium muscarum*) are typical of environments near areas of freshwater influx, and can tolerate a wide range of salinities. The upper 10 cm (1970s to the present) of the core shows the most dramatic shifts in the molluscan assemblage. A group of minute freshwater gastropods, hydrobiids, which are extremely rare (<1%) below 18 cm, increase to 13% at the top of the core. *Brachidontes* and *Cerithium* rise from <7% to >20% at the top of the core; both species are tolerant of a wide range of salinities and rapid changes in salinity.

The foraminifers at Black Point North core site also show a significant change occurring near the bottom of the core (60-70 cm; pre-1900) and near the top (above 10 cm; 1970s to the present) (Figure 27; Appendix O). In the lowest sample at 80-82 cm, *Miliolinella, Quinqueloculina,* and *Triloculina* reach their highest relative abundances in the core (>75% combined), and *Ammonia* and *Cribroelphidium-Elphidium* their lowest (<20% combined). *Ammonia* and *Cribroelphidium-Elphidium* are indicative of low salinity freshwater mixing zones, whereas *Miliolinella, Quinqueloculina,* and *Triloculina* are indicative of higher salinities. The segment of the core from ~74-10 cm is dominanted by *Ammonia*, averaging >60% of the total foraminifers in these samples. The varieties of *Ammonia parkinsoniana* also provide information about the environment at the core site. *Ammonia parkinsoniana* var. *typica* is two to seven times more frequent than *Ammonia parkinsoniana* var. *tepida* in every sample. Poag (1978) notes from studies in San Antonio Bay, Texas that the *typica* ecophenotype is concentrated in areas of minimum salinity and temperature, whereas *tepida* is concentrated in areas of maximum salinity and temperature. *Cribroelphidium-Elphidium* also reach peak abundances in the middle section of the core. In the upper 10 cm (1970s to the present), *Ammonia* and *Cribroelphidium-Elphidium* decrease in abundance (although combined they are still >60% of the assemblage), and *Quinqueloculina* and *Triloculina* increase in abundance (> 30% combined).

The Black Point North core contains three pollen assemblage zones. Zone I (24-87 cm) is dominated strongly (>80%) by *Pinus* pollen with small amounts of *Quercus*, *Myrica*, and Asteraceae (Figure 28; Appendix P). Zone II (10-24 cm) is characterized by the first occurrence of *Casuarina* and increased abundance of pollen of the Chenopodiaceae/Amaranthaceae, Asteraceae, and mangroves (*Rhizophora* and *Laguncularia*). *Pinus* abundance is approximately halved in Zone II (41-61%), as is total

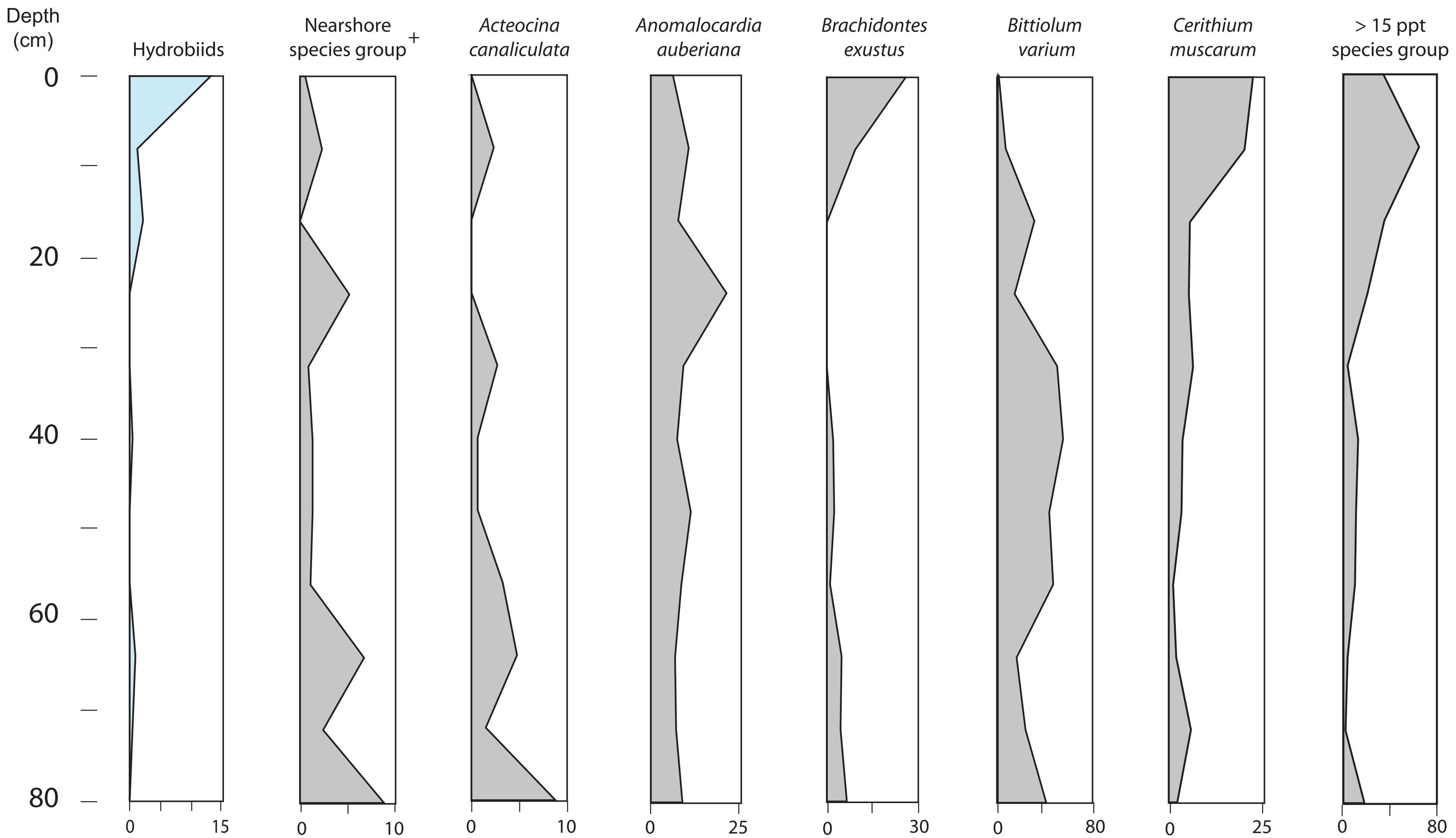


Figure 26. Percent abundance of key molluscan taxa (excluding worn and fragmented) in Black Point North core (GLW603-BPNA) plotted against depth in cm. Blue shading are freshwater species, gray estuarine. Note different percent abundance scales. (Data in Appendix N.)

+Near shore group is primarily represented by *Neritinea virginea, Cerithidea costata,* and *Truncatella* spp., with small numbers of *Melampus bidentatus, Melongena corona, Cyrenoida floridana* and *Polymesoda* sp.

^Group of species typical of >15 ppt salinity includes *Schwartziella catesyana, Acteocina candei, Marshallora nigrocincta, Modulus modulus, Carditimera floridana,* and *Turbo castaneus.*

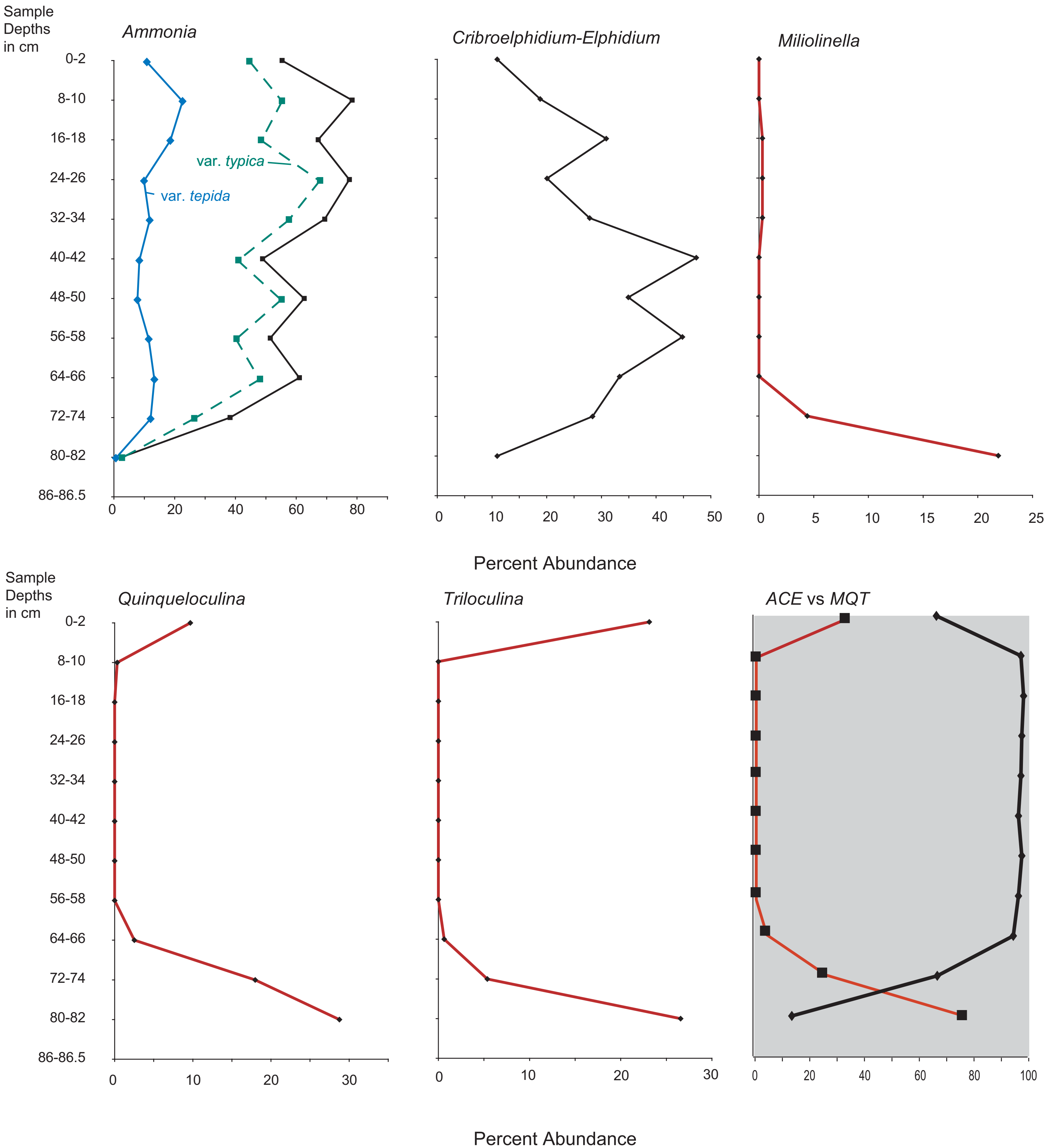


Figure 27. Percent abundance of key foraminifers from Black Point North core (GLW603-BPNA) plotted against sample depths. *Ammonia* plot shows percentage of *Ammonia parkinsoniana* var. *tepida* (blue) vs. var. *typica* (green); black line is sum of two subspecies. Gray box compares percent abundance of *Ammonia* and *Cribroelphidium-Elphidium* (black lines) to *Miliolinella, Quinqueloculina,* and *Triloculina* assemblage (red lines). Note different percent abundance scales. Lowermost data point not included, due to potential contamination. (Data in Appendix O.)

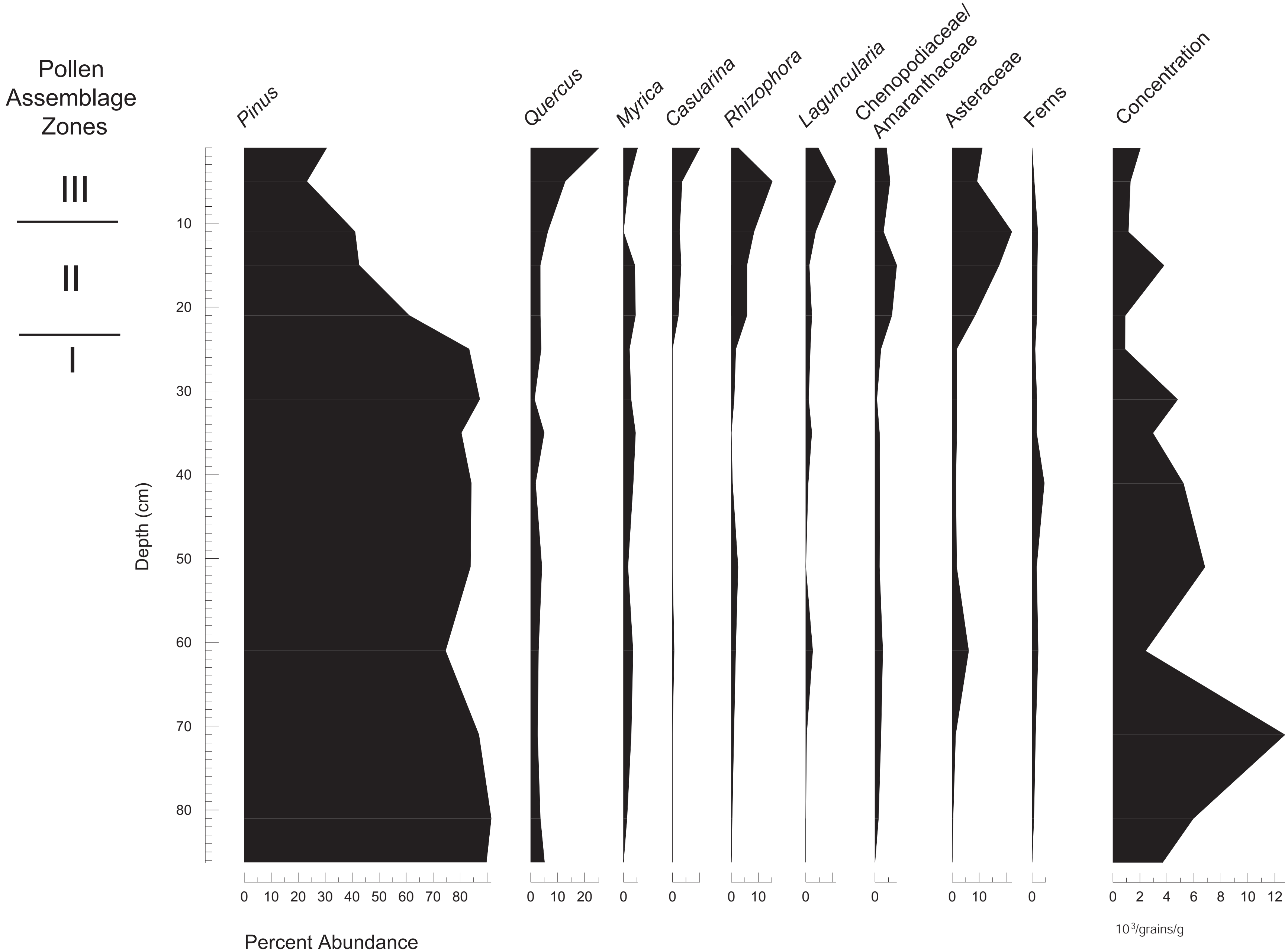


Figure 28. Percent abundance of pollen of major plant types in Black Point North core (GLW603-BPNA) plotted against depth. Right graph shows pollen concentration in grains/g/sample. (Data in Appendix P.)

pollen concentration. In the uppermost interval, zone III (0-10 cm), *Quercus* pollen is more abundant (13-25%), as is *Casuarina* pollen. Mangrove pollen abundance peaks at 5 cm (15% *Rhizophora* and 11% *Laguncularia*) but decreases to 3% and 5% of the assemblage, respectively, in the uppermost sample.

Geochemical analyses of the total phosphorus (TP) concentrations in the Black Point North core are shown in Figure 21 (Appendix C). A sharp increase in TP concentration is exhibited above 24cm (1930s to the present). This increase appears to be above normal diagenetic trends, and may indicate an increase in TP load to the sediments in recent times.

Discussion

The ostracodes, mollusks and foraminifers present in the lowest portion of Black Point North core (64-70 cm and below; pre-1900s) indicate higher salinities (upper mesohaline to polyhaline) relative to the overlying section (Figure 29). A small group of mollusks suggests this may have been a very shallow to possibly above low tide environment (Figure 29, #1). *Truncatella* spp. are typically found right at the shoreline beneath leaf litter in the swash zone; this is consistent with the fine laminae, wood debris, and root casts that occur in this section of the core. The average salinity estimate for the 76-86 cm portion of the core, based on *Malzella* Mg/Ca ratios is 17 ppt (Figure 29, #2). The traces of non-marine and low-salinity ostracode taxa and freshwater hydrobiid gastropods, however, suggest that there was a nearby source of freshwater habitats (Figure 29, #3).

A shift towards lower salinities occurs between 60 and 70 cm core depth (pre-1900s) signified by a decrease in the foraminfers *Miliolinella, Quinqueloculina,* and *Triloculina* and a concurrent increase in *Peratocytheridea setipunctata* and *Ammonia* and *Cribroelphidium-Elphidium* (Figure 29, #4A & B). *Peratocytheridea setipunctata* is indicative of low salinities (oligohaline to mesohaline) and its abundance in the segment of the core between 60 and 36 cm is significant, as is the decline in *Malzella* (Figure 29, #5-6). *Ammonia parkinsoniana* var. *typica* increases relative to *A. parkinsoniana* var. *tepida* in this middle segment, also indicative of lower salinities (Figure 29, #7). In general, the mollusks in the middle portion of the core do not show any significant changes in terms of salinity indicators, but they do reach their highest levels of abundance for this core between 56 and 40 cm. Minimum salinity estimated from *Malzella* Mg/Ca ratios occurred at 52-54 cm (pre-1900s), when it was about 8-9 ppt (Figure 29, #8), representing a decrease from mean conditions of 17 ppt in the lower part of the core. The average salinity value estimated from *Malzella* Mg/Ca in the 50-36 cm (pre-1900s to early 1900s) segment is 13ppt.

The faunal data as a whole for the core segment between 60 to 70 cm and ~35 cm indicate an environment of variable low salinity, brackish water (oligohaline to upper mesohaline) in a near-shore setting. The near absence of any freshwater gastropods, however, suggests that little direct influx of freshwater was occurring at the site. This area may have been influenced by mixing of freshwater from north or south with the more marine open-bay waters, or perhaps the source of freshwater at the site was

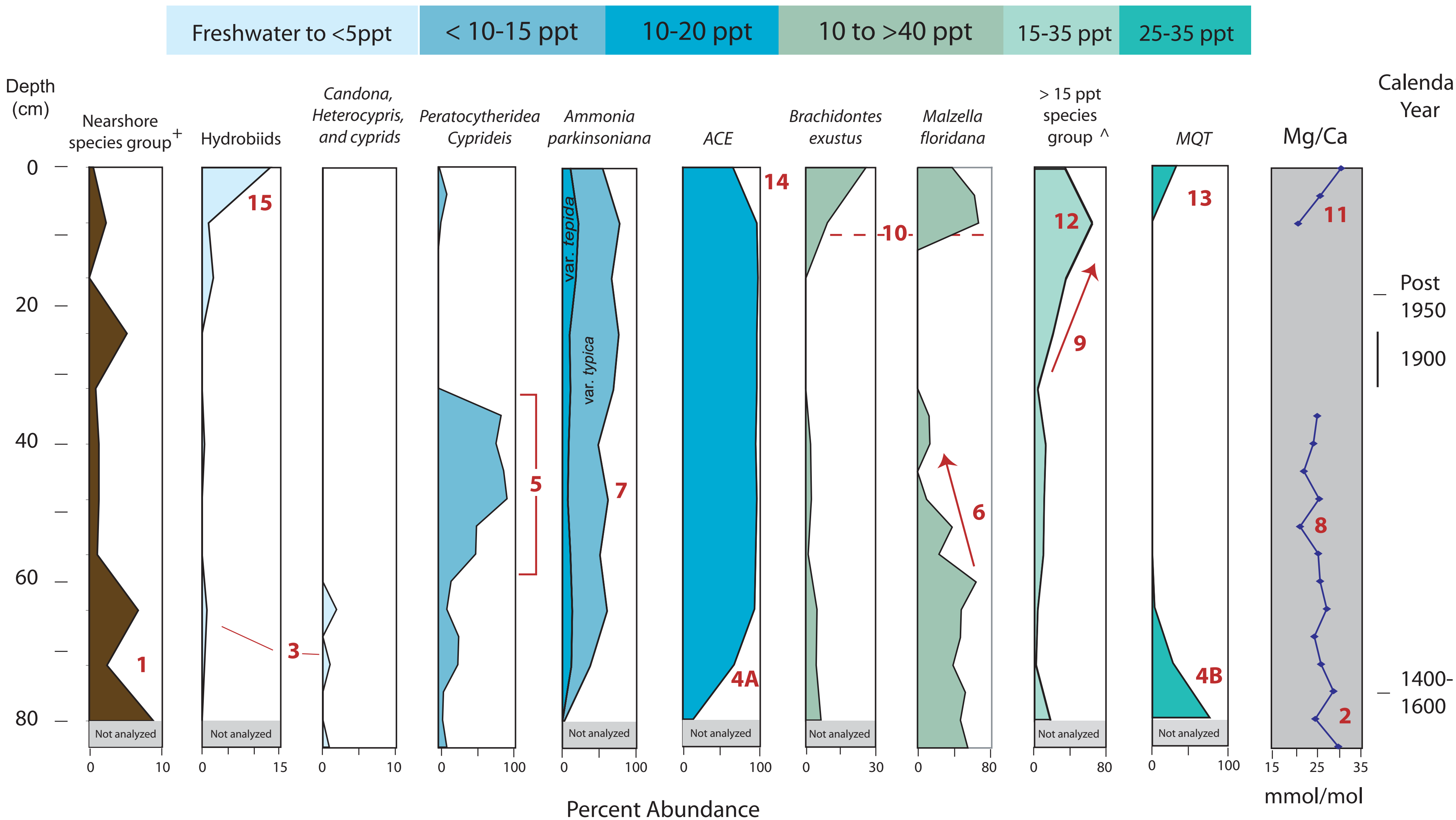


Figure 29. Changes in salinity and environment north of Black Point as indicated by percent abundance of key ostracode, mollusk, and foraminfer indicators and Mg/Ca of ostracode shells (gray column on right) plotted against depth in cm, from Black Point North core (GLW603-BPN-A). Calendar year is indicated on right. Red numbers are referenced in text discussion. Note different percent abundance scales.

ACE is *Ammonia* and *Cribroelphidium-Elphidium* foraminfer assemblage.
MQT is *Miliolinella, Quinqueloculina, and Triloculina* foraminfer assemblage.
+Near shore group is primarily represented by the mollusks *Neritinea virginea, Cerithidea costata,* and *Truncatella* spp., with small numbers of *Melampus bidentatus, Melongena corona, Cyrenoida floridana* and *Polymesoda* sp.
^Group of molluscan species typical of >15 ppt salinity includes *Schwartziella catesyana, Acteocina candei, Marshallora nigrocincta, Modulus modulus, Carditimera floridana,* and *Turbo castaneus.*

predominantly groundwater, which would explain the absence of the freshwater gastropods.

The segment from 35-30 cm to ~10 cm contains few indicative fauna, with the exception of the *Ammonia* and *Cribroelphidium-Elphidium* foraminiferal assemblage, indicating continued low salinities. A group of six molluscan species indicative of salinities >15 ppt begin to increase around 30 cm (Figure 29, #9). Ostracodes are absent in this segment and the mollusks reach very low absolute abundance levels at 24-26 cm, but the significance of these events is not understood. The first significant change in the pollen assemblage occurs at 24 cm (~1940) from a pine-dominated lower assemblage to a more diverse middle assemblage (Figure 28). The increased abundance of weedy species and mangroves after 1940 at the Black Point site are consistent both with the onset of drier conditions and with the agricultural activity indicated by 1940 aerial photographs (Smith and others, 2003). Mangrove abundance begins to increase between 24 and 10 cm, coinciding with gradual increases in higher salinity mollusks and ostracodes. The shift in total phosphorous (TP) also occurs above 24 cm and the phosphorous levels remain high to the top of the core (Figure 21).

The upper 10 cm (1970s to the present) of the core illustrate distinctive changes occurring in the later half of the 20th century. The ostracode, foraminifer, and mollusk assemblages indicate increasing average salinities, and the increases in *Malzella, Brachidontes,* and *Cerithium*, all species that tolerate variations in salinity from mesohaline to euhaline or hypersaline, suggest increasing variability of salinity (Figure 29, #10). Mg/Ca ratios in the upper 6 cm suggest salinity of 15-21 ppt at some times during the year and show a steady increase in average salinity at the site in the upper 10 cm (Figure 29, #11). The group of mollusks indicative of salinities greater than 15 ppt reach a peak abundance at 10 cm (Figure 29, #12) and *Miliolinella, Quinqueloculina,* and *Triloculina* are present (Figure 29, #13). *Ammonia parkinsoniana* var. *typica* decreases; however, the continued dominance of *Ammonia*, despite the slight decline, implies average salinities remained relatively low (Figure 29, #14). Additionally, the freshwater hydrobiid gastropods, present in very minor amounts in samples from lower in the core, reach 13% abundance at the top of the core (Figure 29, #15); their appearance implies a direct influence of freshwater flow to the site began sometime in the late 20th century.

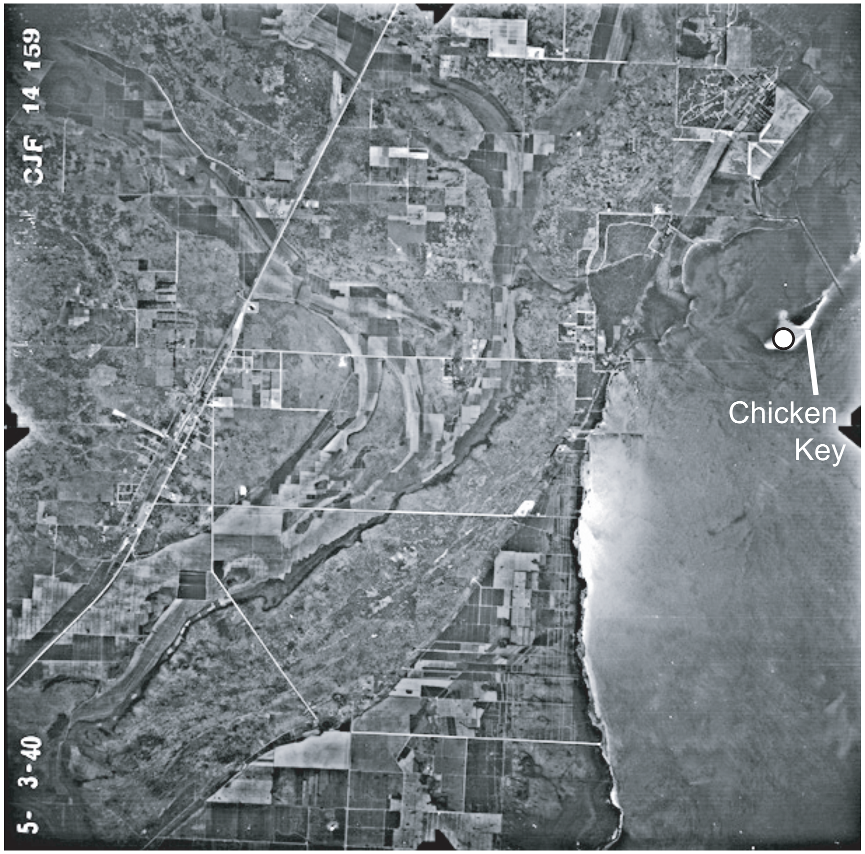
Mangrove abundance peaked in the 1980s (4-6 cm) (Figure 28), when forests of mangroves up to 20 meters tall occupied the area (Gwen Burzycki, pers. comm., 2004). The striking decrease in abundance of mangrove pollen between the sample at 4-6 cm and the surface sample represents the impact of Hurricane Andrew in 1992, which eliminated virtually every tree in the area. The poorly sorted nature of the sediments and the fluctuation in total and excess lead-210 (Figure 24) are consistent with storm impact on the sediments at this depth. The faunal, floral and biogeochemical indicators all suggest increased salinity during deposition of the most recent sediments at Black Point, with at least periodic influx of freshwater from some source.

Chicken Key

Chicken Key core (GLW603-CKA) was collected from the mudflat extending to the southwest of Chicken Key (Figures 1 and 30), just north of the Biscayne National Park boundary. Chicken Key is east of Cutler and Kings Bay, in an area that has undergone substantial change during the 20th century. A 2.4 km (1.5 mi) dredged channel, just north of Chicken Key, cuts into Kings Bay and Deering Bay. This channel was originally constructed in 1918 as part of the larger development of the Cutler Aerial Gunnery Field (later renamed the Chapman field) (McGuire)(Figure 31). In addition to the channel, the development of the airfield led to dredging of the bayside marshes to create landing fields, a lagoon for water landings, and clearing of palmettos and pines to create roads a mile inland. Three 20,000-100,000 gallon tanks were filled with groundwater for fire-fighting (McGuire). The Snapper Creek Canal to the north and the Cutler Canal to the south were constructed between 1912 and 1913 (Cantillo and others, 2000). The channel into Chapman field, just north of Chicken Key, was dredged again in the 1940s to allow military barges access to the facility. During this process, "most of the island's vegetation was destroyed" and "more than 30,000 cubic yards of fill were pumped onto the key and this material eventually eroded and reached the Bay" (Cantillo and others, 2000, p. 66). This fill probably explains the significant change in shape of the island, visible in a comparison of the 1940 aerial photo and the 1956 topographic map (Figure 30, A and B). By 1945 the area west and south of Chicken Key was partitioned for agriculture; today this area is almost entirely developed (Figure 30C). Chicken Key itself has benefited from a restoration effort in the 1990s, following the destruction of the exotic vegetation during hurricane Andrew (Milano, 1999).

The lower 10 cm of the core consist of a dark brown mud with scattered fine quartz grains and relatively high clay content; no obvious calcareous fragments or plant remains are present. The portion from 48-68 cm contains a high organic content, bordering on a peat near the bottom, grading into fine quartz sand. Wood material is present but calcareous grains are rare to absent. The fine quartz sand continues into the overlying segment (28-48 cm); scattered shells, other calcareous fragments, and wood occur; scattered small lenses (<1 cm) of pure white very fine quartz sand are present. From 18-28 cm the sediment is a dark brown mud with a high organic content and varying amounts of fine quartz sand, fining upwards; shell debris is abundant in this segment. The upper 18 cm consist of a white to light gray fine to very fine quartz sand with disseminated organics and shell material; a small area of the underlying sediment occurs, perhaps marking an erosional surface.

Due to the near absence of shell material below 34 cm, the lowest samples available for carbon-14 dating were from 32-34 cm. Two shells were analyzed from the same horizon and yielded dates ranging from post-1950 to 1440-1450 AD (Figure 16; Table 2). As discussed in the methods section, these results have not been corrected for a local reservoir effect; however, the considerable disparity between two specimens from the same sample suggests mixing occurred. The lead-210 data in this core show a change in



A)

B)

Figure 30. Changes in the Chicken Key area. (A) Aerial Photo, 1940, from Smith (2002); (B) reproduced and cropped from USGS 7 1/2" topographic map, 1956, Perrine quadrangle, Florida. (C) Digital orthophoto quadrangle, 1999, from EarthExplorer (http://edcsns17.cr.usgs.gov/EarthExplorer/). Core site indicated by white dot.

C)

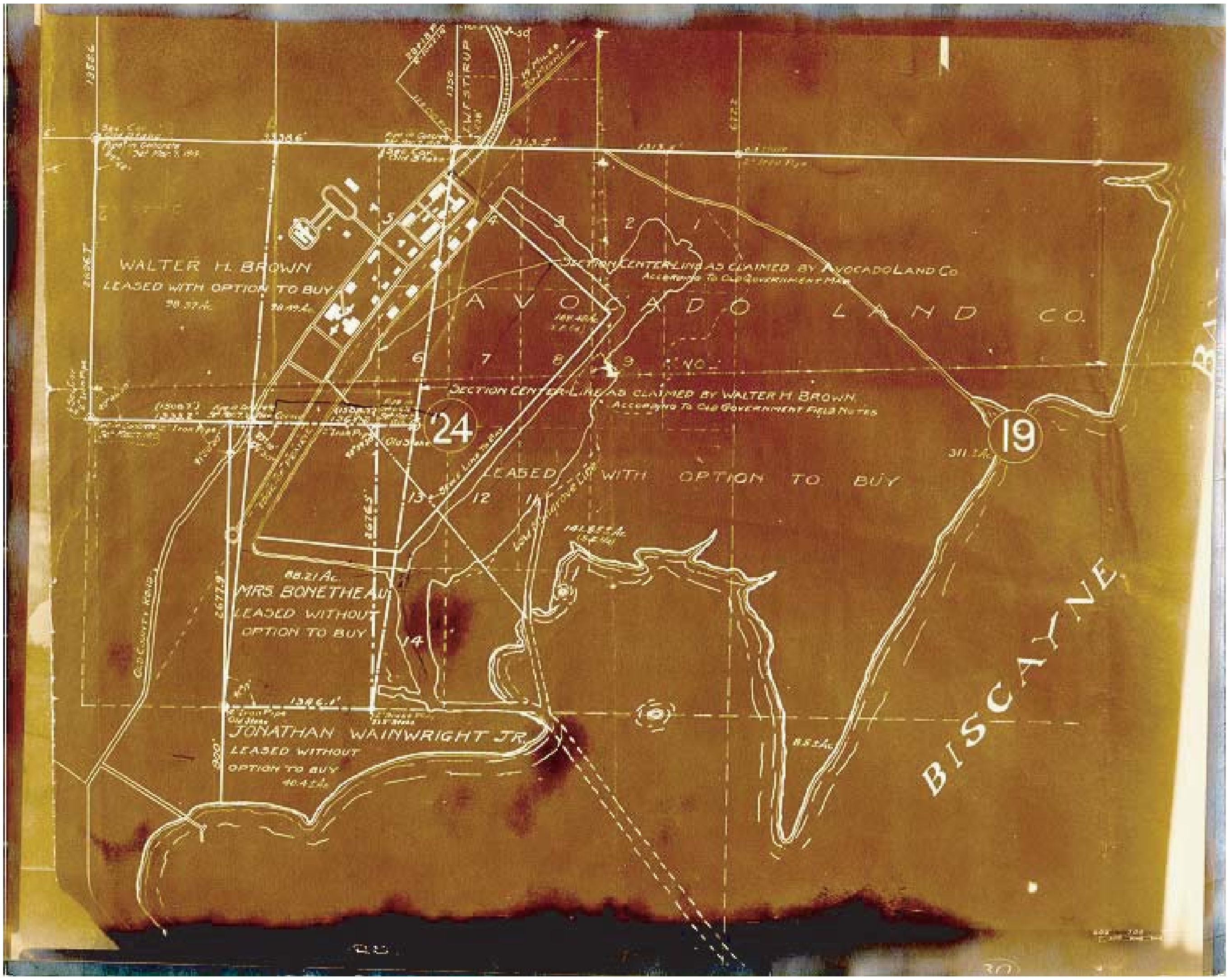


Figure 31. Survey diagram of the Cutler Aerial Gunnery Field, produced in 1918. Chicken Key is located just below the center of the diagram. (McGuire)

average sedimentation rate occurs at 32 cm, just above the sample where the carbon-14 dates were obtained, and excess lead-210 reaches background levels at 36-40 cm (Figure 32). The first *Casuarina* was noted in the sample from 34-36 cm. The position of *Casuarina* and the lower limits of excess lead-210 indicate that samples above 36 cm were deposited in the 20th century. Applying the high average sedimentation rate calculated for the upper segment of the core, the horizon at 32 cm may be as young as the late 1970s.

Results

The Chicken Key core shows a major change in ostracode assemblages between 15 and 20 cm core depth (late 1980s)(Figure 33; Appendix Q). This faunal shift is characterized by a decline in species preferring upper mesohaline to polyhaline, or higher salinities (*Loxoconcha matagordensis*, *Malzella floridana*, *Xestoleberis*) and a large increase in *Peratocytheridea setipunctata* (from 24% to >75%), which is predominant in oligohaline and mesohaline salinities. This faunal change corresponds to a shift in *Malzella* Mg/Ca ratios from an average of 29.5 mmol/mol in samples from 14-28 cm to an average of 22.4 mmol/mol in samples from 6-12 cm. Above 4 cm, *Xestoleberis* increases and *Peratocytheridea* declines slightly and Mg/Ca ratios increase (average 30.9 mmol/mol). No ostracodes were recovered below 36 cm.

The molluscan fauna undergo a shift between 24 and 18 cm (1980s) (Figure 34; Appendix R), from a *Bittiolum* dominated assemblage to a *Parastarte* dominated assemblage. *Parastarte* are small infaunal clams that have been found in salinities from 15-36 ppt, averaging 24 ppt; they increase from <3% below 24 cm to >30% above 18 cm. *Bittiolum* are found in a wide range of salinities, typically on macro-benthic algae or *Halodule*. The shift in assemblages may be due to a change in substrate. The uppermost sample shows a significant increase in *Brachidontes*, a species that can tolerate wide ranging and rapidly fluctuating salinities. Samples examined below 34 cm did not contain statistically significant numbers of mollusks.

The foraminifers in the upper 26 cm (1980s to the present) at Chicken Key show a relatively steady increase in *Miliolinella, Quinqueloculina,* and *Triloculina*, indicative of increasing salinities (Figure 35; Appendix S). Concurrently, *Cribroelphidium-Elphidium*, indicative of lower salinity freshwater mixing zones, decline. *Ammonia*, which are found in similar environments to *Cribroelphidium-Elphidium,* decline in the uppermost sample. Significantly, *Articulina* increase from <1% to 3% at the top of core, suggesting an increased marine influence. Below 32 cm the core is essentially barren of foraminifers.

Three pollen assemblage zones were identified in the Chicken Key core. Zone I (36-77 cm depth) is dominated strongly (>85%) by *Pinus* pollen with low abundances of *Quercus* and *Myrica* (Figure 36; Appendix T). The first occurrence of *Casuarina* is in zone II (26-36 cm), where it comprises up to 5% of the assemblage. Pollen of *Quercus*, Asteraceae, and Chenopodiaceae/Amaranthaceae are more abundant in Zone II, whereas *Pinus* pollen is less abundant (55-60%). Zone III (0-26 cm; 1980s to the present) is

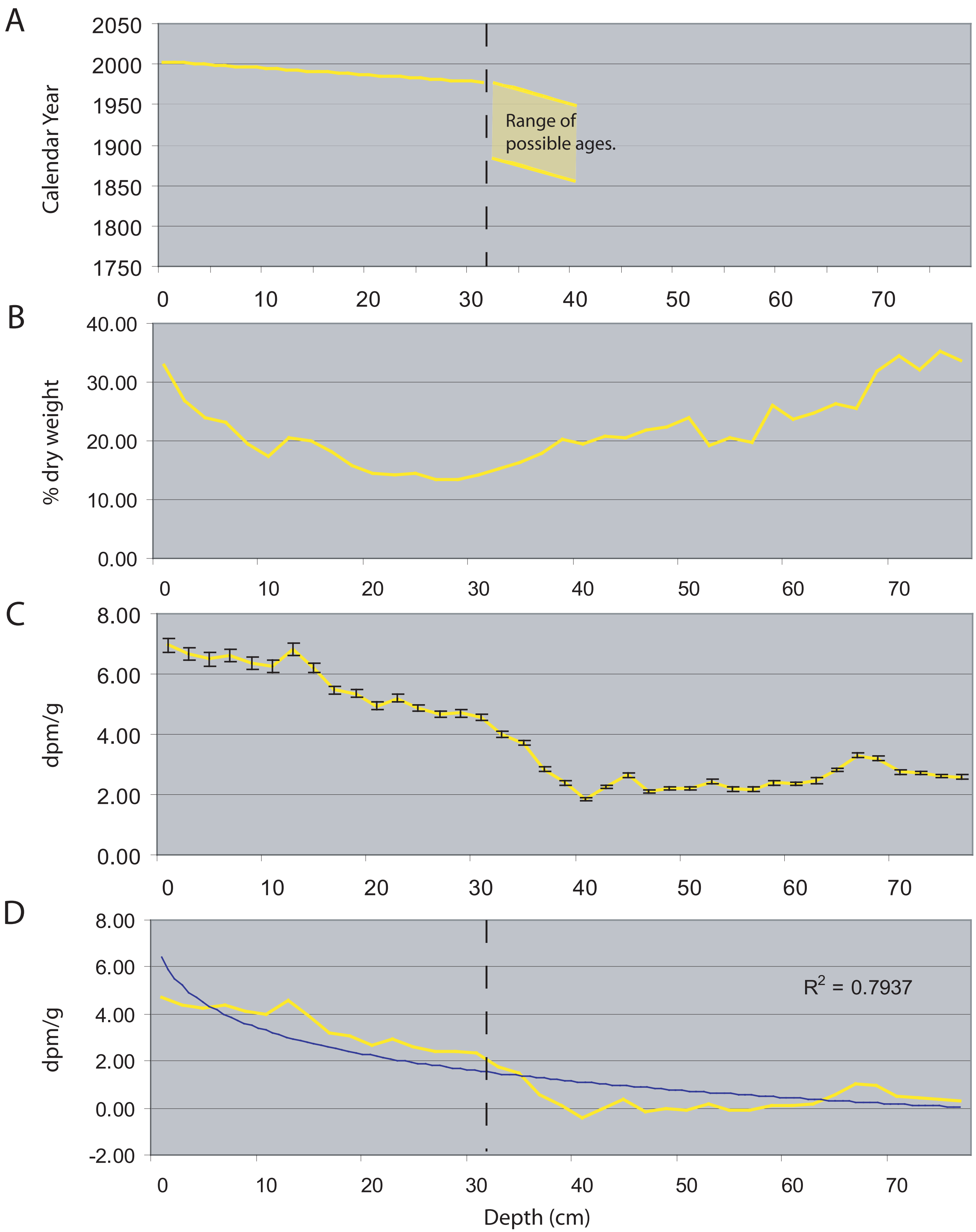


Figure 32. Lead-210 data for Chicken Key core (GLW603-CKA). Dashed line shows change in sedimentation rate. A. Projected calendar year at depth. Shaded area shows range of possible age following change in sedimentation rates. Upper line represents no sediment lost; lower line, maximum amount lost based on sedimentation rate calculated from lead-210 data. B. Loss on ignition (% dry weight). C. Total lead-210 activity in decays per minute per gram (dpm/g), with error bars. D. Excess (or unsupported) lead-210 activity (dpm/g). Data in yellow, logarithmic decay curve in blue.

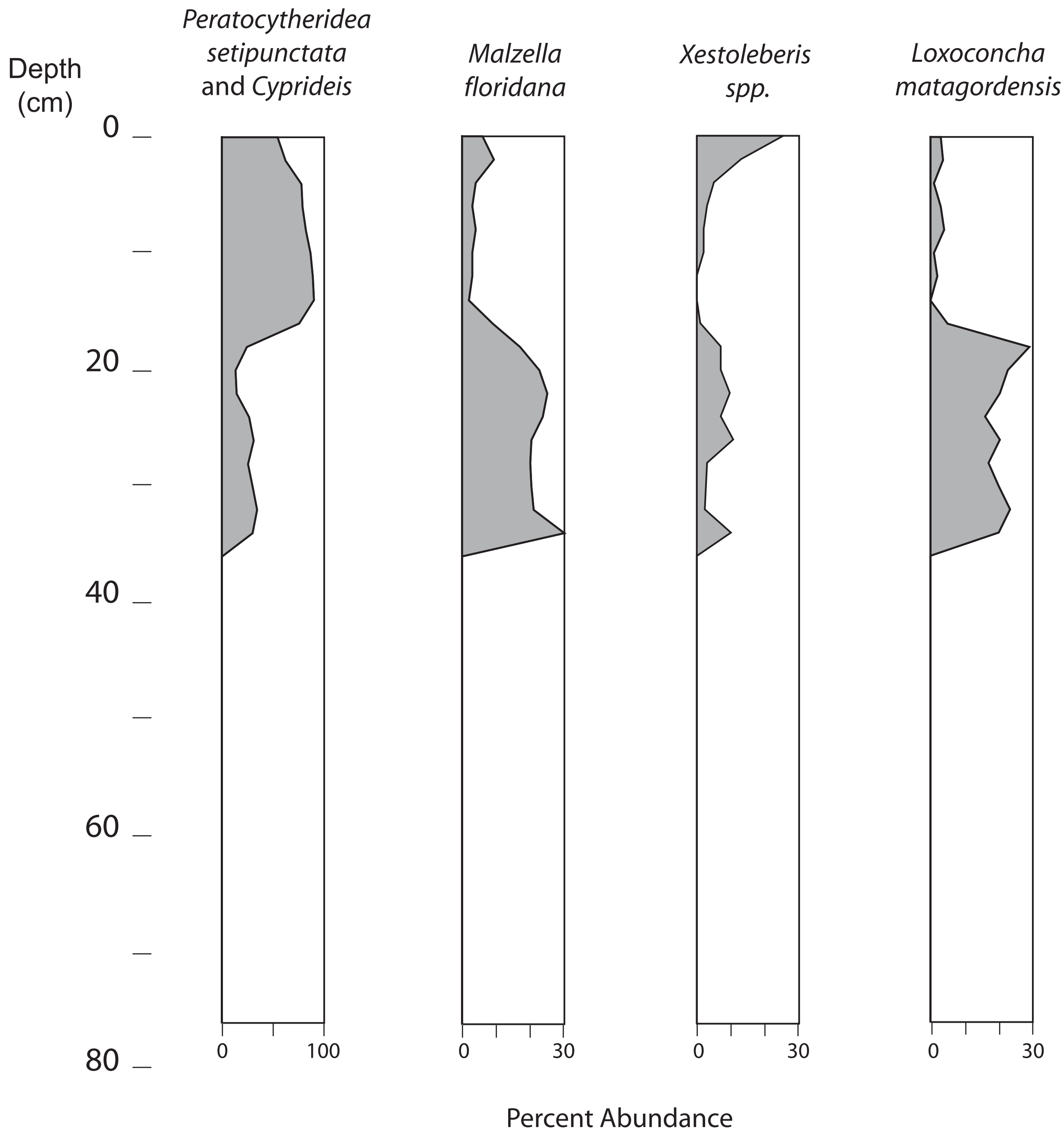


Figure 33. Percent abundance of key ostracode taxa in Chicken Key core (GLW603-CKA) plotted against depth in cm. No ostracodes were recovered below 36 cm core depth. Note different percent abundance scales. (Data in Appendix Q.)

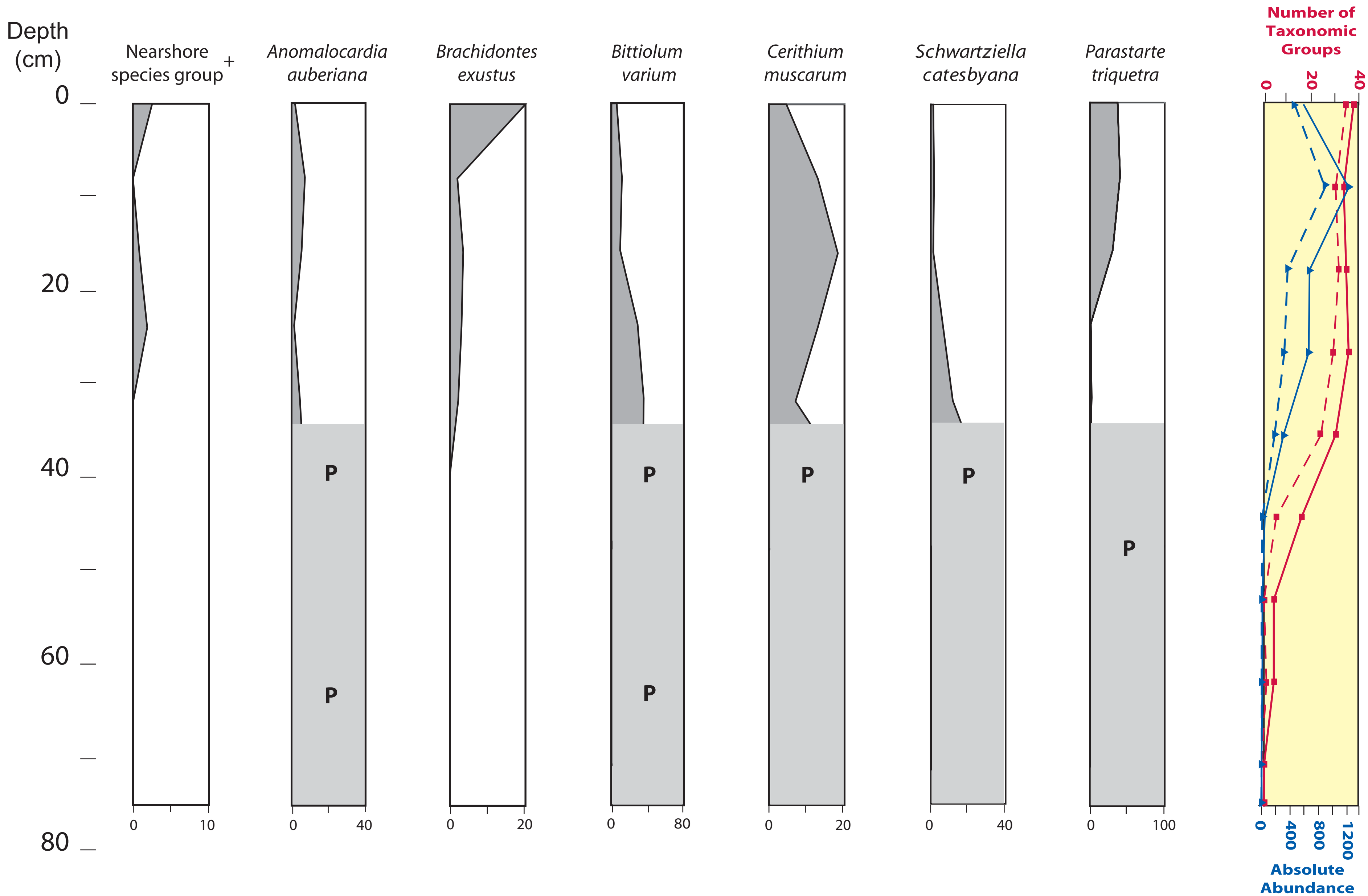


Figure 34. Percent abundance of key molluscan taxa (excluding worn and fragmented) in Chicken Key core (GLW603-CKA) plotted against depth in cm. Light gray blocks at bottom of core indicate low recovery, therefore data for percent abundance is not statistically signficant; P indicates where a species was present. Yellow column on right shows actual numbers recovered: red solid is number of total taxonmic groups in all preservation categories; red dashed is number of taxonomic groups, excluding worn and fragmented specimens; blue solid is total abundance of individual specimens in all preservation categories; blue dashed is total abundance of individual specimens, excluding worn and fragmented. Note different percent abundance scales. (Data in Appendix R.)

+Near shore group is represented by *Acteocina canaliculata, Truncatella caribaeensis,* and *Melampus coffeus.*

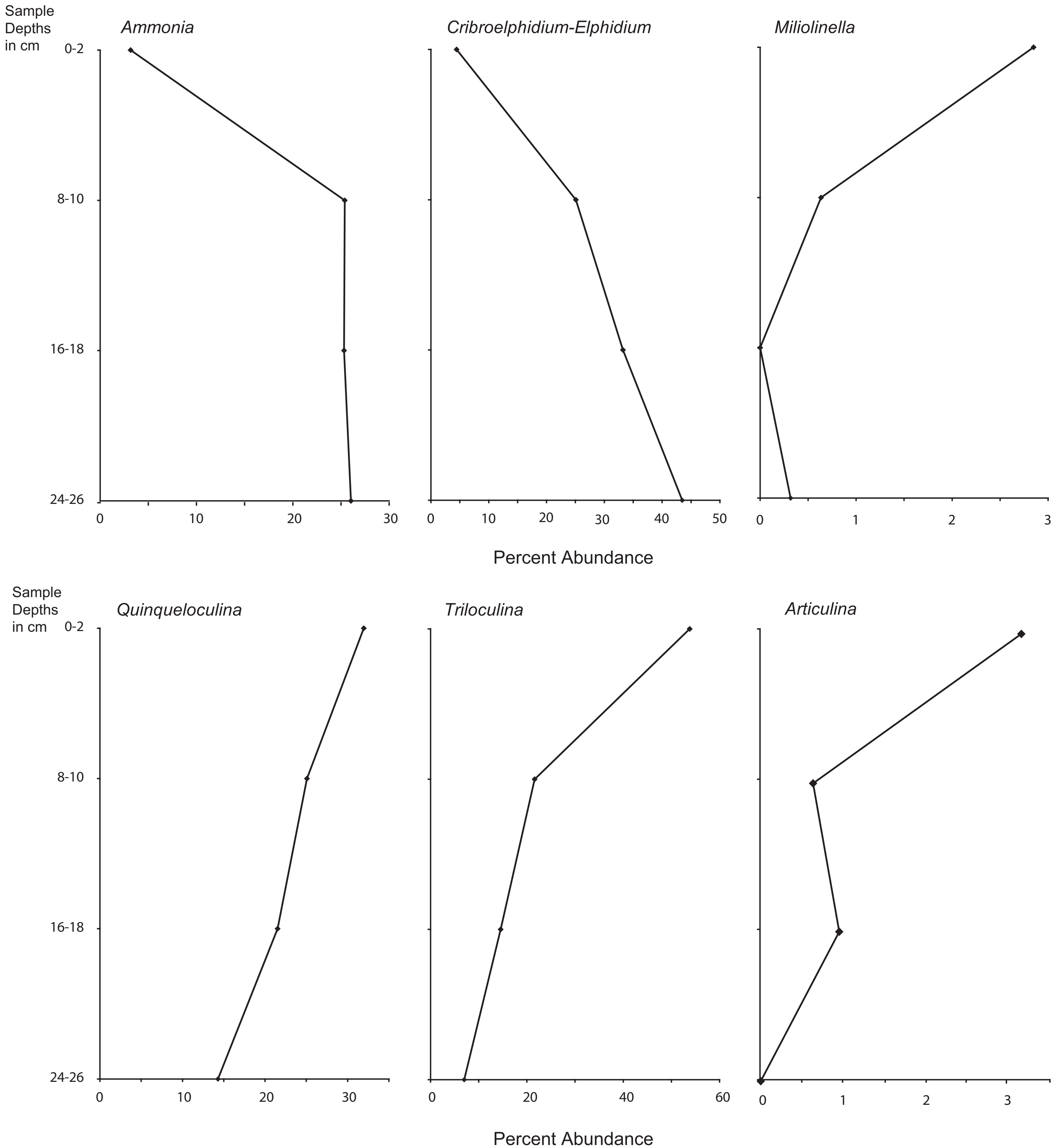


Figure 35. Percent abundance of key foraminifers from Chicken Key core (GLW603-CKA) plotted against sample depths. Note different percent abundance scales. (Data in Appendix S.)

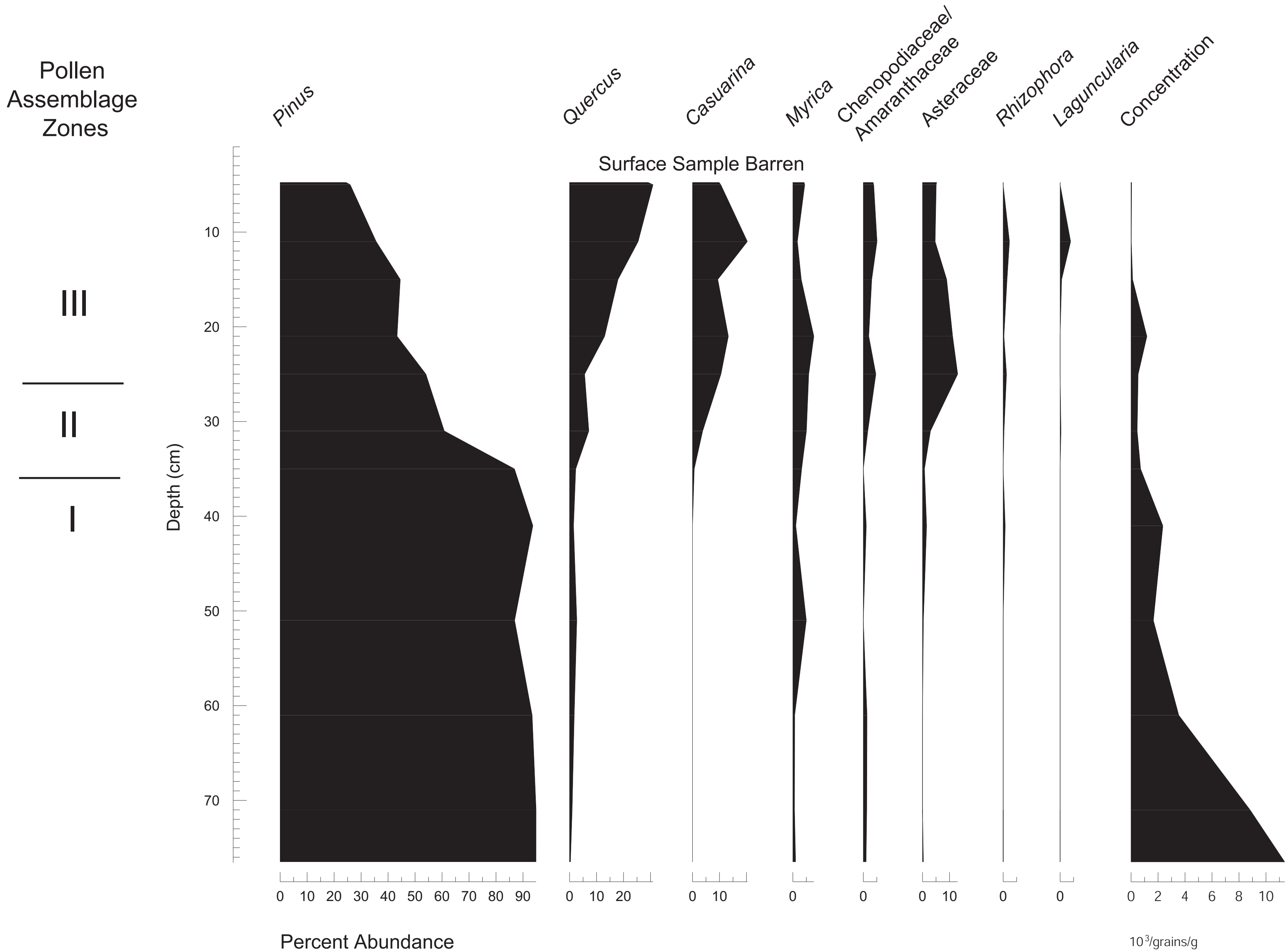


Figure 36. Percent abundance of pollen of major plant types in Chicken Key core (GLW603-CKA) plotted against depth.Right graph shows pollen concentration in grains/g/sample. (Data in Appendix T.)

distinguished by >10% each of *Quercus* and *Casuarina* pollen. Total pollen concentration is approximately halved in Zones II and III relative to Zone I.

Geochemical analyses of the total phosphorus (TP) concentrations in the Chicken Key core are shown in Figure 21 (Appendix C). A sharp increase in TP concentration is exhibited above 24cm (1930s to the present). This increase appears to be above normal diagenetic trends, and may indicate an increase in TP load to the sediments in recent times. However, a sudden and sharp drop in TP occurs at 8-10 cm to levels seen below 24 cm.

Discussion

The TP, lead-210, and pollen profiles of the lower portion of Chicken Key (below 34 cm) are similar to other cores in the region; however, this zone is essentially devoid of any faunal record. Altered sedimentation patterns at the site at approximately 32-34 cm are indicated by lead-210 profiles, reduced pollen concentration, increased faunal concentrations, and changes in pollen assemblage composition. The lower portion of this core, below the shift in sedimentation rates may represent erosion of spoil from the island dumped during the 1940s dredging of the channel to the north of the Key. The timing of the dredging is consistent with the age estimates from lead-210 analyses, and erosion of spoil would explain the mixed carbon-14 dates from the single sample at 32 cm. The upper portion of the core probably represents reestablishment of the benthic environment at Chicken Key in the latter half of the 20th century.

The faunal patterns seen in the upper 20-34 cm at the Chicken Key site are similar to those seen at the Black Point North site. From approximately 34 cm to 20 cm core depth, the assemblage contains indicators of salinities ranging from oligohaline to hypersaline (Figure 37) and the environment appears to have been relatively shallow (Figure 37, #1). Between 15 and 20 cm, a decline in salinity is indicated by the decline in *Loxoconcha matagordensis*, *Malzella floridana* and *Xestoleberis* (typically mesohaline to polyhaline) (Figure 37, #2), followed by the large increase in *Peratocytheridea* (oligohaline to mesohaline) (Figure 37, #3). *Bittiolum*, typically a mesohaline-polyhaline species (although it tolerates a wide range of salinities) also declines in abundance during this time period (Figure 37, #4), but *Parastarte triquetra*, similar to *Bittiolum* in salinity preferences, increases (Figure 37, #5). The shift in assemblages between 15 and 20 cm could be explained by a change in salinity, a change in substrate or a combination of factors. Most of the species that decline in this interval dwell on sub-aquatic vegetation, whereas those that increase are more common in muddy or sandy substrates. The average salinity value estimated from *Malzella* Mg/Ca fluctuates in this interval, but reaches a low of 11 ppt between 6 and 12 cm (Figure 37, #6).

In contrast to the ostracode patterns, the foraminifera show a steady trend of increasing salinities, from 26 cm to the top of the core, with declines occurring in the low-salinity *Ammonia* and *Cribroelphidium-Elphidium* assemblage (Figure 37, #7), and increases in the higher salinity *Miliolinella, Quinqueloculina,* and *Triloculina* assemblage (Figure 37,

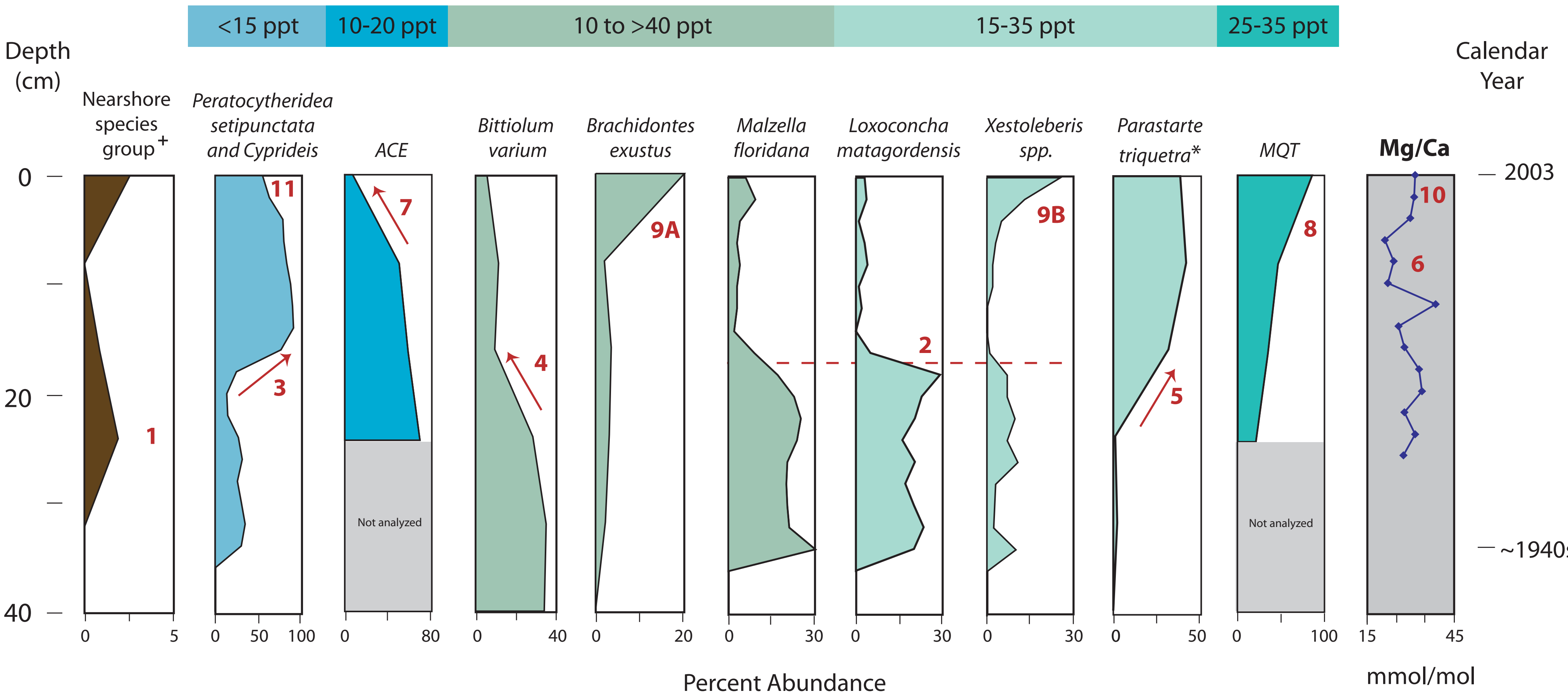


Figure 37. Changes in salinity and environment at Chicken Key as indicated by percent abundance of key ostracode, mollusk, and foraminfer indicators and Mg/Ca of ostracode shells (gray column on right) plotted against depth in cm, from Chicken Key core (GLW603-CK-A). Only the upper 40 cm of the core are shown; the lower portion of the core was essentially barren. Calendar year is indicated on right. Red numbers are referenced in text discussion.

ACE is *Ammonia* and *Cribroelphidium-Elphidium* foraminfer assemblage.
MQT is *Miliolinella, Quinqueloculina, and Triloculina* foraminfer assemblage.
+Near shore group is represented by the mollusks *Acteocina canaliculata*, *Truncatella caribaeensis*, and *Melampus coffeus*.

*Species is common to the northern transition zone of Florida Bay (Turney and Perkins, 1972), which typically experiences a wide range of salinities , but in our field work we have typcially found it in upper mesohaline-polyhaline salinities.

#8). Because the ostracodes were analyzed at a higher sample-spacing resolution, this apparent difference may be a function of sample spacing.

Changes in the pollen assemblages occur at 36 and 26 cm (Figure 36) representing shifts in the terrestrial environment not immediately reflected in the estuarine fauna. The vegetational changes recorded during the past 25 years at the site probably reflect both water diversion via canals and agricultural activity; these changes are indicated at Chicken Key by increased abundance of tree pollen (*Quercus, Casuarina*, mangroves) and weedy species (Chenopodiaceae/Amaranthaceae, Asteraceae).

The segment of the core above 6 cm, representing deposition since the late 1990s, indicates a return to higher salinities, possibly increasing fluctuations of salinity, and an increase in the marine influence at the site. The change in fauna around 6 cm also corresponds to an anomaly in the TP record; it is unknown if these events are related. *Brachidontes* and *Xestoleberis* (mesohaline to hypersaline indicators, and commonly found on macro-benthic algae) (Figure 37, #9A&B) and the *Miliolinella, Triloculina,* and *Quinqueloculina* assemblage (continuing a trend from the lower portion of the core(Figure 37, #8)), increase significantly in the top of the core. *Peratocytheridea* (Figure 37, #11) and *Ammonia*, both lower salinity indicators, decline. A simultaneous increase from 11 ppt to 22 ppt in average salinity value estimated from *Malzella* Mg/Ca occurs (Figure 37, #10). Mangrove pollen becomes slightly more abundant in the upper section of the core.

It is significant to note that no freshwater ostracodes and <1% freshwater gastropods were found in the entire core at Chicken Key, indicating direct mixing with freshwater has not occurred at this site. The lower salinity episodes do not indicate a point source for freshwater influx, but rather a mixing of lower salinity waters with the marine environment.

SUMMARY OF ENVIRONMENTAL CHANGES IN THE BISCAYNE BAY ECOSYSTEM

Compiling our multiproxy analyses of cores collected and analyzed for the current ecosystem history of Biscayne Bay Study (2002 and 2003) with cores collected previously (1996 and 1997) reveals some significant patterns and trends in the history of the Biscayne Bay ecosystem.

Southern Biscayne Bay salinity: Southern Biscayne Bay, including Card Sound and Barnes Sound, has been relatively isolated from direct marine influence for at least the last two centuries due to its enclosed configuration (Figure 1). Currently, this area is less influenced by the urbanization that has taken place to the north, and there are few developed areas along the shoreline. Despite this relative isolation, the area has undergone distinctive changes during the last century. Card Sound Bank has fluctuated between a more restricted upper estuarine environment and a more open estuarine environment over time. The relatively large swings in salinity at Card Sound Bank have occurred over multi-decadal and centennial timescales and the amplitude of change exceeds that seen in cores from central Biscayne Bay (No Name and Featherbed Bank). During the later part of the 20^{th} century, however, the site has come under increasing marine influence and fluctuations in salinity appear to have decreased in amplitude and frequency.

Middle Key basin has seen a steady increase in salinity that began prior to 1900. The earliest records from this site indicate a freshwater, limnetic environment, which began to shift toward brackish conditions before the start of the 20^{th} century. From the 1960s to the present, freshwater supply to Middle Key basin diminished, relative to the rise of estuarine conditions. The absolute abundance of freshwater gastropods indicate that significant pulses of freshwater entered the basin after 1900, but the dominance of estuarine species shows that the environment shifted from limnetic to estuarine prior to 1900. Salinities in the basin ranged from mesohaline to polyhaline range throughout the 20^{th} century and there is some evidence of increasingly fluctuating salinities over the past few decades at the site. Manatee Bay, located south of Middle Key basin, also has undergone a change from a freshwater environment at the base of the core to an estuarine environment at the top (Ishman and others, 1998), similar to that seen in Middle Key basin. At the Manatee Bay site, however, salinities in the upper part of the core reached upper polyhaline to euhaline levels.

Central Biscayne Bay salinity: The mudbanks of central Biscayne Bay have become increasingly marine and have experienced lower amplitude decadal variability in salinity over the last one hundred years. The data presented in this report have corroborated the earlier findings (Wingard and others, 2003) on cores from Featherbed Bank and No Name Bank. No indications of inter-decadal salinity extremes have been found during the 20^{th} century from Featherbed and No Name Banks, in contrast to the high variability seen at Card Bank to the south. Salinities at No Name and Featherbed have ranged between polyhaline and euhaline over the last three to four centuries, and there is no evidence of direct influence of freshwater or mesohaline environments seen in the nearshore cores out on the mudbanks.

Biscayne Bay nearshore salinity: The environments represented by the near-shore cores, located 3.4 to 4.8 km west (2.1 to 3.0 miles) of No Name and Featherbed Banks, bear little resemblance to the mudbank cores. The sediments, the sedimentation rates, and the faunal assemblages of the nearshore cores differ from the mudbank cores. The cores north of Black Point and at Chicken Key record a period of fluctuating environments over at least the last 50-100 years. At both sites the oldest sediments containing faunal remains were deposited under conditions of mesohaline to polyhaline salinities and these were succeeded by a period of lower mesohaline salinity. In the last 10-30 years, an increase in salinity occurs at the sites to polyhaline conditions and an apparent increase in amplitude of salinity fluctuations.

Based on the faunal indicators, the direct influx of freshwater near the Black Point North site appears to have fluctuated over the period of time represented by the core. The lowest segment of the core, deposited prior to 1900, appears to have had a nearby source of freshwater influx into the mesohaline to polyhaline estuarine environment; additionally, the site was very shallow and may have been above mean low tide part of the time. From before 1900 to ~1970, direct freshwater influx north of Black Point seems to have diminished, despite the lowering of salinities during this time period. The lowered salinities may have been caused by increases in groundwater upwelling, or dilution of the estuarine waters via runoff from other areas and/or by increased rainfall. In the late 20th century, the significant increase in freshwater gastropods indicates a direct influx of freshwater to the site. At Chicken Key, no freshwater fauna were found in the core, suggesting that the site has not been influenced by a direct influx of freshwater during the time represented by the sediment accumulation.

Terrestrial vegetation: Pollen assemblages from all the core sites reflect the long-term dominance of pinelands on the coastal ridge adjacent to Biscayne Bay prior to the 20th century, followed by vegetational changes associated with various land-use activities. Comparing the three near-shore cores, the greatest changes were noted at the two northernmost sites (Chicken Key and Black Point North). These changes are roughly coincident with land clearance, initiation of extensive row-crop agriculture, and canal construction in the area. The Military Canal cores indicate that distinct differences occurred in the wetlands, prior to canal construction; the southern site has always been relatively drier than the northern site. At Black Point, mangrove abundance peaked in the 1980's, but declines sharply at the top of core, representing the impact of Hurricane Andrew in 1992.

Geochemistry of sediments: Distinct differences occur in the geochemistry of the sites; however, a clear pattern is not evident. Total carbon (TC), organic carbon (OC), total nitrogen (TN), and total phosphorus (TP) concentrations were all significantly high in the core from the Card Bank site, relative to the mudbank cores from central Biscayne Bay, but the Middle Key site does not exhibit any significant increase in TP concentration in the upper 20-30 cm. No geochemical analyses were conducted on the Manatee Bay core to determine if C-111 might be the source of the high values seen at Card Bank. The downcore total phosphorous (TP) profiles at No Name Bank, Chicken Key and Black Point North cores represent large increases in TP flux to the sediments at those sites. These increases appear to be above typical diagenetic levels, and may indicate an increase in TP load to the sediments in recent times, superimposed on the normal diagenetic recycling of phosphorus, but nearby Featherbed Bank does not show this same pattern.

IMPLICATIONS FOR RESTORATION

A general trend emerges from the multiproxy analyses of all the cores examined – increasing salinity during the 20th century. Although the timing and onset of increased salinity varies at the different core sites, there are no exceptions to this trend. In the nearshore sites, the increase in average salinity has been accompanied by an increase in variability of salinity. In contrast, the central Biscayne Bay sites have shown increasingly stable salinity over the last century, indicated in part by the influx of increasing numbers of marine species. These trends could be a result of a number of factors, including (1) rising sea level; (2) changes in the flow of freshwater into the bay either through surficial or groundwater processes; (3) changes in average rainfall or rates of evaporation; (4) changes in sedimentation rates; or (5) a combination of factors. The timing of changes at some of the near-shore sites suggests that both anthropogenic and natural factors are involved.

In addition to the general salinity trend for Biscayne Bay, the near-shore sites at Middle Key and north of Black Point have illustrated distinct, but site specific, changes in freshwater influx over time. Our data suggest that some sites we assumed had historic point-source inflow of freshwater did not. The wetlands cores (near Military Canal) also illustrate that sites in very close proximity to each other have historically been affected by very localized hydrologic regimes.

These results have significant implications for restoration planning. First, the recognition that Biscayne Bay appears to be evolving toward a more marine environment due to both natural and anthropogenic factors must be factored into the planning process. Second, generalized performance measures and targets for the near-shore and wetlands areas may not reflect the natural variability seen at these sites. Third, the nearshore environments are dramatically different from the mid-bay mudbanks, and have been for hundreds of years. Influx of freshwater into the bay appears to have a subtle or indirect effect on the benthic fauna of the mudbanks. Changes in flow during restoration may have little effect on the central bay mudbanks.

Examining decadal-centennial trends in a variety of habitats within the Biscayne Bay ecosystem provides a realistic means to set performance measures, predict system response to changes invoked by restoration, and to enlighten the public on what the natural system of the bay looked like.

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APPENDIXES

Appendix A: Lithologic Description of Cores

Middle Key Core (GLW603-MKA)

Depth (cm)	**Description**
0-12	Light olive gray carbonate mud, with <5% silt sized grains. *Halodule* shoots in the upper part of segment; rootlets throughout. *Peneropolis* and small gastropods relatively abundant. Calcareous grains and shells.
12-30	Light olive gray to brownish gray carbonate mud, with very fine sand to silt sized grains. Increasing mud content in lower portion of segment. Scattered wood debris (*Rhizophora*?). *Thalassia* rhizomes throughout and interspersed *Halodule* rootlets. Scattered small burrows (< 4mm). Scattered small shells and calcareous debris.
30-44	Brownish gray to olive gray carbonate mud. In situ *Thalassia* rhizomes, wood debris (probably *Rhizophora*). Scattered *Halodule* rootlets. Calcareous grains and shell debris rare.
44-62	Dark to pale yellowish brown mud with increasing organic content downcore. Wood debris and *Thalassia* rhizomes relatively abundant. Fresh water gastropod at 50 cm. Visible calcareous grains relatively rare.
62-68	Dark yellowish brown mud. Shell debris content higher than overlying. Wood debris and relatively abundant. *Thalassia* rhizomes and *Halodule* rootlets present.
68-92	Dusky brown to grayish brown mud, with spongy texture. Scattered shell debris and calcareous grains; larger shell fragments are poorly preserved (increased acidity due to increased organics?). Wood material abundant. Scattered *Halodule* rootlets.
92-102	Transitional zone - gradational with overlying sediment but contains limestone rubble.
102-114.5 (bottom)	Dusky yellowish brown calcareous mud matrix with silt to very fine quartz sand. Scattered calcareous grains (primarily from LS rubble) and wood material (*Rhizophora*?) present. Some *Thalassia* rootlets. Mottled appearance - light areas seem to be decayed limestone rubble.

Black Point North Core (GLW603-BPNA)

Depth (cm)	**Description**
0-14	Very fine quartz sand and mud; poorly sorted. Relatively abundant shell debris and large whole mollusks. Upper portion has *Thalassia* blades and rhizomes, some live root material.
14-24	Gradational with overlying, somewhat better sorter than above. Sediment is very fine quartz sand, mottled dark brown sediment with light calcareous grains and whole shells. Scattered *Thalassia* rootlets.
24-44	Very fine quartz sand and silt, with mud; poorly sorted. Scattered black grains (phosphate?) and calcareous grains. Shell content increases

	downward in segment. Sediment very mottled throughout; possible burrows because lighter material contains increased shell fragments. Wood (probably *Rhizophora*) appears near bottom. Some surfaces near top of segment covered with small holes, probably *Halodule* root casts. Scattered bits of *Thalassia*.
44-64	Dark, fine silty sand; not mottled like overlying segment; increasing clay content downward. Scattered black grains, and shell material. Scattered wood fragments (probably *Rhizophora*). Large oyster attached to wood in lower portion of segment.
64-86.5 (bottom)	Gradational with overlying, increasing clay content, disseminated organics. Interbedded zones of higher sand vs. higher clay content. Scattered calcareous grains and shell fragments. Scattered wood fragments (probably *Rhizophora*) and *Rhizophora* leaf near bottom. Root casts near bottom of segment. Lowest sample contains fresh *Thalassia* - drag-down during coring process.

Chicken Key Core (GLW603-CKA)

Depth (cm)	Description
0-18	White to light gray, fine to very fine quartz sand, with disseminated organics, *Halodule* rootlets and some scattered *Thalassia*. Mollusk shells and fragments. Burrow from 14-18 cm. Small area of underlying mud - possible erosional surface?
18-28	Dark brown mud with high organic content, and varying amounts of fine quartz sand, coarsening downwards. Spongy texture. Abundant shell debris. Rare *Thalassia* rhizoids.
28-48	Fine quartz sand with high mud/organic content giving sediment dark brown color and sticky texture. Scattered shells and calcareous fragments. *Thalassia* root hairs, rare. Scattered small areas (<1 cm) of pure white very fine quartz sand. Scattered black grains (phosphate?) appear near bottom of segment.
48-68	General lithology same as overlying - fine quartz sand with high mud/organic content, but texture becomes spongy here, probably due to increased plant material. Spongy texture increases downward. Wood material (probably *Rhizophora*). Areas of pure white sand present as in overlying, but have swirled or marbled appearance. Calcareous fragments rare - no obvious SAV remains.
68-77.5 (bottom)	Dark brown mud with scattered fine quartz grains (most abundant at top of segment). Higher clay content makes texture slippery to sticky, crumbly in some sections. No obvious calcareous grains or plant remains.

Appendix B: Metal-Calcium Analyses of *Malzella floridana* in 2003 near-shore cores.

Core	Depth (cm)	Phase	Sample	# Specimens	Car	Valve	Mg/Ca (mmol/mol)	Sr/Ca (mmol/mol)	Na/Ca (mmol/mol)	Salinity Estimate*
MKA	0-2	50	1	7	7		26.91	3.99	13.38	16.85
MKA	4-6	50	2	7	7		30.56	3.89	12.69	21.38
MKA	8-10	50	3	5	5		29.70	3.96	13.50	20.31
MKA	12-14	50	4	5	5		26.10	3.94	13.17	15.84
MKA	16-18	50	5	5	5		27.93	3.91	12.64	18.11
MKA	20-22	50	6	5	5		25.10	3.93	12.56	14.60
MKA	24-26	50	7	5	5		25.78	3.80	12.65	15.44
BPNA	0-2	50	8	3	3		30.21	3.93	13.01	20.95
BPNA	4-6	50	9	3	3		25.42	4.03	10.76	14.99
BPNA	8-10	50	10	3	2	1	20.13	3.91	10.71	8.43
BPNA	20-22	50	11	1	1		12.14	3.87	11.65	14.10
BPNA	36-38	50	12	4	2	2	24.70	3.45	11.02	13.00
BPNA	40-42	50	13	5	5		23.81	3.67	9.58	10.13
BPNA	44-46	50	14	0	0		21.50	3.57	11.17	14.60
BPNA	48-50	50	15	1		1	25.10	3.69	10.02	8.96
BPNA	52-54	50	16	7	5	2	20.56	3.58	10.03	14.26
BPNA	56-58	50	17	5	5		24.82	3.67	10.57	14.96
BPNA	60-62	50	18	7	6	1	25.39	3.54	12.15	16.96
BPNA	64-66	50	19	7	7		27.00	3.90	11.88	13.16
BPNA	68-70	50	20	6	6		23.94	3.94	11.10	15.22
BPNA	72-74	50	21	5	5		25.60	3.65	10.44	18.77
BPNA	76-78	50	22	6	6		28.46	3.73	12.35	13.58
BPNA	80-82	50	23	6	4	2	24.28	3.61	10.99	20.06
BPNA	84-86	50	24	5	5		29.50	3.70	14.62	
CKA	0-2	50	25	3	2	1	31.62	3.79	16.27	22.69
CKA	2-4	50	26	0			31.13	3.61	13.14	22.08
CKA	4-6	50	27	1	1		29.85	3.79	11.47	20.50
CKA	6-8	50	28	2	2		21.17	3.56	12.05	9.72
CKA	8-10	50	29	1	1		24.02	3.64	13.40	13.26
CKA	10-12	50	30	1	1		22.07	4.14	15.44	10.84
CKA	12-14	50	31	1	1		38.47	3.39	12.79	31.19
CKA	14-16	50	32	1	1		25.64	3.47	14.11	15.26
CKA	16-18	50	33	2	2		27.72	3.53	13.08	17.85
CKA	18-20	50	34	2	2		32.99	3.74	13.12	24.39
CKA	20-22	50	35	4	4		34.01	3.70	12.82	25.65
CKA	22-24	50	36	5	5		27.70	3.70	11.60	17.83
CKA	24-26	50	37	3	3		31.38	3.76	12.37	22.39
CKA	26-28	50	38	2	1	1	27.40	3.65	13.51	17.45
CKA	28-30	50	39	2	2					
CKA	32-34	50	40	2	2					
CKA	34-36	50	41	0						
CKA	42-44	50	42	0						
CKA	44-46	50	43	0						
CKA	46-48	50	44	0						

* Salinity estimate based on Mg/Ca of shell, and calibration function calculated from analyses of modern ostracodes as described in text.

Appendix C, Part I. Elemental C, N, and P composition and atomic C/N, C/P, and N/P ratios of sediments from cores collected in 2002.

Sample Site	Depth (cm)	Total C (%)	Organic C (%)	Inorganic C (%)	Total N (%)	Total P (%)	Atomic C/N	Atomic C/P	Atomic N/P
No Name Bank	1	13.5	4.60	8.90	0.615	0.0271	8.72	438	50.2
Core: GLW402-NNA	5	13.7	4.45	9.25	0.596	0.0223	8.71	515	59.1
	9	13.9	4.62	9.28	0.631	0.0193	8.54	617	72.3
	13	14.1	4.96	9.14	0.691	0.0163	8.37	785	93.7
	17	13.5	4.19	9.31	0.553	0.0137	8.84	789	89.3
	21	12.1	2.34	9.76	0.317	0.00780	8.61	774	89.9
	25	11.9	2.18	9.72	0.306	0.00726	8.31	774	93.2
	29	12.1	2.08	10.0	0.195	0.00736	12.4	729	58.6
	33	12.0	1.92	10.1	0.188	0.00707	11.9	700	58.8
	37	11.7	1.87	9.83	0.148	0.00739	14.7	652	44.3
	41	11.8	2.00	9.80	0.162	0.00794	14.4	650	45.1
	45	11.7	1.80	9.90	0.146	0.00683	14.4	680	47.3
	49	11.8	1.84	9.96	0.146	0.00729	14.7	651	44.3
	53	11.7	1.94	9.76	0.165	0.00719	13.7	696	50.7
	57	11.6	1.80	9.80	0.195	0.00714	10.8	650	60.4
	61	11.9	2.02	9.88	0.224	0.00728	10.5	716	68.0
	65	11.7	1.87	9.83	0.206	0.00668	10.6	722	68.2
	69	11.8	1.89	9.91	0.275	0.00727	8.01	670	83.6
	73	11.7	1.93	9.77	0.237	0.00689	9.50	722	76.1
	77	11.7	1.96	9.74	0.247	0.00696	9.25	726	78.5
	81	11.8	2.04	9.76	0.271	0.00697	8.78	755	86.0
	85	11.7	1.90	9.80	0.258	0.00675	8.59	726	84.5
	89	11.6	1.68	9.92	0.263	0.00632	7.45	685	92.0
	93	11.7	1.82	9.88	0.242	0.00630	8.77	745	84.9
	97	11.8	1.94	9.86	0.291	0.00633	7.77	790	102
	99	11.8	1.88	9.92	0.250	0.00671	8.77	722	82.4

Appendix C, Part I. Elemental C, N, and P composition and atomic C/N, C/P, and N/P ratios of sediments from cores collected in 2002.

Sample Site	Depth (cm)	Total C (%)	Organic C (%)	Inorganic C (%)	Total N (%)	Total P (%)	Atomic C/N	Atomic C/P	Atomic N/P
Featherbed Bank	1	12.9	3.65	9.25	0.516	0.0194	8.25	485	58.8
Core: GLW402-FBA	5	12.9	3.50	9.40	0.471	0.0177	8.66	510	58.8
	9	13.0	3.69	9.31	0.536	0.0149	8.03	639	79.5
	13	13.5	4.02	9.48	0.544	0.0151	8.62	686	79.7
	17	13.3	3.83	9.47	0.513	0.0138	8.71	716	82.2
	21	12.6	3.05	9.55	0.407	0.0112	8.74	702	80.4
	25	12.5	2.96	9.54	0.369	0.00963	9.35	793	84.7
	29	12.8	3.43	9.37	0.427	0.00922	9.37	959	102
	33	12.8	3.27	9.53	0.439	0.00795	8.69	1061	122
	37	12.4	2.94	9.46	0.389	0.00711	8.81	1066	121
	41	12.3	2.68	9.62	0.357	0.00695	8.75	994	114
	45	12.1	2.54	9.56	0.295	0.00704	10.0	930	92.7
	49	12.1	2.37	9.73	0.261	0.00718	10.6	851	80.4
	53	12.1	2.52	9.58	0.234	0.00735	12.6	884	70.4
	57	12.2	2.72	9.48	0.307	0.00770	10.3	911	88.2
	61	12.2	2.66	9.54	0.294	0.00790	10.6	868	82.3
	65	12.2	2.59	9.61	0.297	0.00740	10.2	902	88.8
	69	12.3	2.64	9.66	0.252	0.00750	12.2	908	74.3
	73	12.6	3.11	9.49	0.349	0.00817	10.4	982	94.5
	77	12.7	3.27	9.43	0.351	0.00810	10.9	1041	95.8
	81	12.2	2.63	9.57	0.243	0.00753	12.6	901	71.4
	85	12.1	2.45	9.65	0.249	0.00749	11.5	844	73.5
	89	12.0	2.29	9.71	0.223	0.00706	12.0	836	69.8
	93	11.8	2.14	9.66	0.203	0.00658	12.3	839	68.2
	97	11.8	2.06	9.74	0.176	0.00672	13.6	790	57.9
	99	12.0	2.19	9.81	0.157	0.00684	16.3	826	50.8

Appendix C, Part I. Elemental C, N, and P composition and atomic C/N, C/P, and N/P ratios of sediments from cores collected in 2002.

Sample Site	Depth (cm)	Total C (%)	Organic C (%)	Inorganic C (%)	Total N (%)	Total P (%)	Atomic C/N	Atomic C/P	Atomic N/P
Card Bank	1	17.0	9.19	7.81	1.16	0.0303	9.24	782	84.6
Core: GLW402-CBA	5	16.8	8.44	8.36	1.07	0.0282	9.20	772	83.9
	9	16.4	8.26	8.14	1.04	0.0233	9.26	914	98.7
	13	16.0	7.77	8.23	0.966	0.0176	9.38	1138	121
	17	15.5	6.86	8.64	0.873	0.0129	9.16	1371	150
	21	15.5	7.18	8.32	0.895	0.0130	9.36	1424	152
	25	16.3	7.94	8.36	0.967	0.0126	9.58	1625	170
	29	15.9	7.84	8.06	0.953	0.0115	9.59	1758	183
	33	15.0	6.97	8.03	0.850	0.00976	9.56	1842	192
	37	15.1	7.17	7.93	0.827	0.00975	10.1	1896	188
	39	15.1	7.04	8.06	0.838	0.0103	9.80	1762	180
	43	16.4	8.62	7.78	1.02	0.0118	9.86	1884	191
	47	15.4	7.34	8.06	0.846	0.0118	10.1	1604	158
	51	15.0	7.01	7.99	0.778	0.0102	10.5	1772	169
	55	14.6	6.71	7.89	0.731	0.00929	10.7	1863	174
	59	14.5	6.05	8.45	0.632	0.00883	11.2	1767	158
	63	14.2	5.90	8.30	0.650	0.00909	10.6	1674	158
	67	14.0	5.75	8.25	0.590	0.00879	11.4	1687	148
	71	13.6	5.01	8.59	0.514	0.00776	11.4	1665	146
	75	13.6	4.74	8.86	0.517	0.00832	10.7	1469	137
	79	13.3	4.58	8.72	0.470	0.00764	11.4	1546	136
	83	13.2	4.39	8.81	0.438	0.00745	11.7	1520	130
	87	13.4	4.71	8.69	0.483	0.00733	11.4	1657	146
	89	13.2	4.31	8.89	0.446	0.00701	11.3	1586	141

Appendix C, Part II. Total P analyses for 2003 near-shore cores.

Middle Key Group 1 (GLW603-MKA)

Depth (cm)	Total P (ug/g)	Total P (%)
0-2	88.5	0.00885
2-4	88.8	0.00888
4-6	61.2	0.00612
6-8	57.1	0.00571
8-10	57.7	0.00577
10-12	52.5	0.00525
12-14	52.3	0.00523
14-16	31.4	0.00314
16-18	29.5	0.00295
18-20	29.6	0.00296
20-22	16.7	0.00167
24-26	19.4	0.00194
28-30	15.9	0.00159
32-34	13.9	0.00139
36-38	15.5	0.00155
40-42	22.2	0.00222
44-46	9.62	0.000962
48-50	14.3	0.00143
52-54	9.15	0.000915
56-58	15.4	0.00154
60-62	12.8	0.00128
64-66	14.1	0.00141
68-70	33.3	0.00333
72-74	588	0.0588
76-78	214	0.0214
80-82	296	0.0296
84-86	172	0.0172
88-90	225	0.0225
90-92	298	0.0298
92-94	213	0.0213
96-98	99.7	0.00997
100-102	73.6	0.00736
104-106	53.2	0.00532
108-110	48.7	0.00487
112-114	72.0	0.00720
114-114.5	91.1	0.00911

Black Point North (GLW603-BPNA)

Depth (cm)	Total P (ug/g)	Total P (%)
0-2	620	0.0620
8-10	554	0.0554
16-18	451	0.0451
24-26	294	0.0294
32-34	302	0.0302
40-42	285	0.0285
48-50	268	0.0268
56-58	285	0.0285
64-66	275	0.0275
72-74	244	0.0244
78-79	143	0.0143

Chicken Key (GLW603-CKA)

Depth (cm)	Total P (ug/g)	Total P (%)
0-2	663	0.0663
2-4	670	0.0670
4-6	636	0.0636
6-8	637	0.0637
8-10	291	0.0291
10-12	663	0.0663
12-14	634	0.0634
14-16	516	0.0516
16-18	428	0.0428
24-26	343	0.0343
32-34	251	0.0251
40-42	244	0.0244
48-50	243	0.0243
56-58	289	0.0289
64-66	294	0.0294
72-74	351	0.0351
74-76	323	0.0323

Appendix D: Foraminfer absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	0-2	8-10	16-18	24-26	32-34	40-42	48-50	56-58	64-66	72-74	80-82	88-90
Ammobaculites sp.	0	0	0	0	0	0	0	0	0	0	0	0
Ammonia beccarii var. *parkinsoniana*	3	1	3	2	2	2	2	1	1	2	1	1
Archaias angulatus	7	3	0	2	0	0	0	0	0	0	0	1
Archaias compressus	0	0	0	0	0	0	0	0	0	0	0	0
Articulina lineata	0	0	1	1	0	2	0	0	0	0	0	0
Articulina mexicana	1	1	2	1	2	1	0	0	0	0	0	0
Articulina mucronata	13	6	6	7	0	0	0	0	0	0	0	0
Articulina pacifica	0	1	2	1	1	0	1	0	0	0	1	0
Articulina sagra	1	1	1	4	3	0	0	0	2	0	0	3
Bolivina lanceolata	3	10	21	10	8	8	22	19	12	25	10	6
Bolivina lowmani	0	12	8	6	7	2	21	15	7	19	7	2
Bolivina striatula	0	0	1	1	0	0	4	1	0	1	1	0
Bolivina subspinescens	0	0	0	0	0	2	3	3	2	3	0	0
Cancris oblonga	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulinoides bradyi	2	2	1	1	3	1	4	2	1	3	0	0
Clavulina difformis	2	0	0	0	0	0	0	0	0	0	0	0
Clavulina tricarinata	0	1	0	1	1	0	0	0	0	0	0	0
Discorbis mira	6	5	4	7	9	5	1	3	3	0	1	0
Discorbis rosea	0	0	1	0	0	0	0	0	0	0	0	0
Elphidium advenum	0	2	2	1	0	0	0	3	1	1	3	0
E. discoidale/Cribroelphidium poeyanum	11	58	77	66	46	112	146	152	106	175	94	41
Elphidium sagrum	0	0	0	0	1	1	0	0	0	1	0	0
Fursenkoina compressa	2	0	0	0	0	0	3	5	0	0	0	0
Massilina protea	2	3	1	0	0	0	0	0	0	0	0	0
Massilina secans	0	0	0	0	1	0	0	0	1	0	0	0
Miliolinella circularis	21	34	36	39	57	34	14	16	51	5	43	58
Milionella fichteliana	3	0	0	1	0	0	0	0	0	0	0	0
Milionella labiosa	35	8	6	2	6	1	0	1	1	0	4	6
Nonion grateloupi	1	3	3	0	1	0	6	6	2	2	1	0
Peneroplis bradyi	0	0	0	0	0	0	0	0	0	0	0	0
Peneroplis carinatus	0	1	0	0	0	0	0	0	0	0	0	0
Peneroplis pertusus	1	1	0	0	0	0	0	0	0	0	0	0
Peneroplis proteus	1	0	0	0	0	0	0	0	0	0	0	0
Pyrgo denticulata	5	0	1	0	1	0	0	0	0	0	0	0
Pyrgo elongata	0	1	0	0	0	0	0	0	0	0	0	0
Pyrgo subsphaerica	4	0	4	1	2	0	0	0	0	0	0	0

Appendix D: Foraminfer absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	0-2	8-10	16-18	24-26	32-34	40-42	48-50	56-58	64-66	72-74	80-82	88-90
Quinqueloculina agglutinans	13	6	2	2	3	4	1	0	1	0	0	0
Quinqueloculina bicarinata	2	1	1	2	1	2	0	1	0	0	0	0
Quinqueloculina bicostata	4	2	0	0	0	0	0	1	0	0	1	0
Quinqueloculina bosciana	39	25	26	38	29	20	8	11	16	1	26	54
Quinqueloculina crassa var. *subcuneata*	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina lamarckiana	18	25	20	27	18	27	11	7	13	5	25	33
Quinqueloculina poeyana	19	28	28	20	33	25	22	12	23	9	26	36
Quinqueloculina wiesneri	0	5	4	7	1	0	1	2	2	0	1	1
Rosalina floridana	10	9	14	11	17	23	28	38	23	46	31	21
Rosalina floridensis	1	6	2	3	7	3	5	1	7	3	6	2
Rotaliids	5	11	9	12	6	19	5	6	10	5	5	2
Sorites marginalis	3	0	0	0	0	0	0	0	0	0	0	0
Spirillina obconica	0	0	0	0	0	0	0	2	1	0	0	0
Spiroloculina antillarum	4	1	1	1	0	0	0	0	0	0	2	0
Spiroloculina arenata	0	0	0	2	1	0	1	0	0	0	0	0
Spiroloculina caduca	0	0	1	0	0	0	0	1	0	0	0	0
Textularia agglutinans	1	0	0	0	0	0	0	0	0	0	0	0
Textularia conica	1	0	0	0	0	0	0	0	0	0	0	0
Tretomphalus atlanticus	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina bassensis	19	7	2	7	7	1	0	0	4	0	3	6
Triloculina bermudezi	36	14	15	11	25	6	5	2	8	1	8	22
Triloculina bicarinata	2	3	0	1	0	0	0	0	0	0	0	0
Triloculina carinata	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina fitterei var. *meningoi*	1	0	1	7	3	1	0	0	1	2	1	5
Triloculina linneiana	3	2	2	0	1	1	0	2	2	1	0	0
Triloculina oblonga	0	1	0	0	5	0	0	0	3	0	1	0
Triloculina planciana	3	2	6	9	4	1	1	1	2	0	1	0
Triloculina rotunda	2	2	1	2	1	3	0	0	3	1	4	1
Triloculina sidebottomi	0	1	0	0	0	0	0	0	0	0	0	1
Triloculina tricarinata	0	4	6	2	0	1	1	0	1	1	4	1
Triloculina trigonula	2	0	0	1	0	0	0	0	2	0	1	2
Uvigerina peregrina	0	0	0	2	0	0	0	0	0	2	1	1
Valvulina oviedoiana	4	3	3	3	5	5	1	0	1	0	0	0
SUM	316	312	325	324	318	313	317	314	313	314	313	306

Appendix D: Foraminfer absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	96-98	104-106	112-114	120-122	128-130	136-138	146-148	156-158	164-166	172-174	180-182	188-190	194-197
Ammobaculites sp.	0	1	0	0	0	0	0	1	0	0	0	0	0
Ammonia beccarii var. *parkinsoniana*	2	3	1	0	0	1	0	1	2	1	0	0	0
Archaias angulatus	0	2	3	1	0	0	2	10	1	20	14	15	2
Archaias compressus	0	0	0	0	0	0	0	0	0	0	0	2	1
Articulina lineata	1	0	0	0	0	0	0	0	0	0	0	0	1
Articulina mexicana	1	0	0	1	0	0	0	0	0	0	0	0	0
Articulina mucronata	1	0	0	0	3	0	0	1	0	0	4	0	0
Articulina pacifica	0	1	0	1	0	0	0	1	0	1	0	0	0
Articulina sagra	0	2	0	1	0	2	4	0	2	1	0	0	1
Bolivina lanceolata	6	13	6	6	22	14	8	9	13	0	2	3	1
Bolivina lowmani	5	16	4	12	7	11	5	2	4	4	1	0	1
Bolivina striatula	1	1	0	0	4	1	0	0	4	0	0	0	0
Bolivina subspinescens	0	1	1	1	0	0	0	0	0	1	0	0	0
Cancris oblonga	0	0	0	0	0	0	0	0	0	1	0	0	0
Cassidulinoides bradyi	0	0	0	0	0	0	0	0	0	0	0	0	1
Clavulina difformis	0	0	0	0	0	0	1	0	0	0	2	0	0
Clavulina tricarinata	2	0	0	0	0	0	0	2	0	6	2	2	0
Discorbis mira	0	3	3	10	4	7	3	5	5	5	11	4	5
Discorbis rosea	0	0	0	0	0	0	0	0	2	1	0	0	1
Elphidium advenum	0	1	2	1	4	2	1	2	2	2	4	1	2
E. discoidale/Cribroelphidium poeyanum	44	95	77	108	156	132	61	84	73	36	35	48	50
Elphidium sagrum	0	1	1	0	3	3	0	8	1	8	1	5	1
Fursenkoina compressa	2	0	1	1	1	4	3	2	2	0	0	0	0
Massilina protea	0	0	0	0	0	0	0	0	0	0	0	0	0
Massilina secans	0	0	0	0	0	0	0	0	0	2	0	0	0
Miliolinella circularis	99	29	52	44	5	19	68	28	37	35	53	57	107
Milionella fichteliana	0	0	0	0	0	0	0	1	0	0	0	0	0
Milionella labiosa	2	0	4	0	0	1	3	1	1	5	5	7	6
Nonion grateloupi	2	2	0	3	2	5	1	1	4	1	0	1	0
Peneroplis bradyi	0	0	0	0	0	0	0	0	0	1	2	3	0
Peneroplis carinatus	0	0	0	0	0	0	0	0	0	0	0	1	0
Peneroplis pertusus	0	0	0	0	0	0	1	0	0	0	0	0	0
Peneroplis proteus	0	0	0	0	0	0	0	0	0	2	1	1	0
Pyrgo denticulata	0	0	0	0	0	0	0	0	0	0	1	0	1
Pyrgo elongata	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo subsphaerica	0	0	0	0	0	0	0	1	0	2	2	0	0

Appendix D: Foraminfer absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	96-98	104-106	112-114	120-122	128-130	136-138	146-148	156-158	164-166	172-174	180-182	188-190	194-197
Quinqueloculina agglutinans	1	3	1	1	2	1	0	6	4	20	17	12	1
Quinqueloculina bicarinata	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina bicostata	0	0	0	0	0	0	0	0	0	1	0	0	0
Quinqueloculina bosciana	30	26	30	11	12	10	36	18	31	21	25	30	34
Quinqueloculina crassa var. *subcuneata*	0	0	0	0	0	0	0	0	0	1	0	0	0
Quinqueloculina lamarckiana	43	27	28	31	13	15	31	48	30	35	35	33	19
Quinqueloculina poeyana	28	32	27	15	2	14	11	23	24	17	26	22	30
Quinqueloculina wiesneri	1	0	2	2	2	3	3	1	4	4	0	0	0
Rosalina floridana	20	37	33	28	44	34	40	12	15	10	7	14	11
Rosalina floridensis	6	2	9	13	6	4	7	2	5	0	1	2	1
Rotaliids	2	7	7	5	4	5	5	18	17	10	3	5	4
Sorites marginalis	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirillina obconica	0	0	0	0	0	0	0	2	0	0	2	1	2
Spiroloculina antillarum	1	0	1	2	0	1	0	0	1	0	0	0	0
Spiroloculina arenata	0	0	0	0	0	0	0	0	0	0	1	0	0
Spiroloculina caduca	1	0	1	1	0	0	2	0	0	0	0	0	0
Textularia agglutinans	0	0	0	0	0	0	0	0	0	0	0	0	0
Textularia conica	0	0	0	0	0	0	0	0	1	0	1	0	0
Tretomphalus atlanticus	0	0	0	0	0	1	0	0	0	0	0	0	0
Triloculina bassensis	3	3	3	3	0	3	2	2	1	9	13	4	4
Triloculina bermudezi	9	2	10	5	0	6	9	6	5	9	5	16	16
Triloculina bicarinata	0	0	1	0	0	0	0	0	0	3	0	0	0
Triloculina carinata	0	0	0	0	0	0	0	0	0	0	3	0	2
Triloculina fitterei var. *meningoi*	7	3	1	3	2	3	2	2	3	8	3	2	4
Triloculina linneiana	2	0	1	1	0	1	1	2	1	3	3	0	0
Triloculina oblonga	0	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina planciana	3	3	5	2	0	4	3	3	3	6	3	4	1
Triloculina rotunda	1	0	1	1	0	2	2	5	0	7	5	3	3
Triloculina sidebottomi	0	0	0	0	0	0	0	0	0	0	0	0	0
Triloculina tricarinata	1	0	2	3	0	2	2	3	2	9	19	5	0
Triloculina trigonula	0	0	1	0	0	0	0	0	3	4	5	7	5
Uvigerina peregrina	4	2	1	1	4	2	5	0	2	0	2	1	0
Valvulina oviedoiana	1	2	3	0	1	1	0	4	3	12	10	7	3
SUM	332	320	323	318	303	314	322	317	308	324	329	318	321

Appendix E: Ostracode absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	0	2	4	6	8	10	12	14	16	18	20	22
Actinocythereis	1	3	0	1	2	1	0	2	2	2	3	2
Acuticythereis lacvissima (Juveniles)	0	0	0	0	0	0	0	2	0	0	0	0
Bairdiids	42	38	36	41	44	53	43	30	36	49	60	55
Caudites/ Neocaudites	0	0	0	0	0	2	0	0	1	0	0	0
Cytherellids	0	0	14	10	6	6	9	11	3	6	3	4
Cytheromorpha	0	0	0	0	0	0	0	0	0	0	0	0
Cytherura	1	0	0	0	4	0	0	1	0	0	0	0
Loxoconcha matagordensis	29	27	27	19	22	19	25	20	21	23	25	18
Malzella floridana	0	0	1	2	2	2	4	4	11	3	5	5
Megacythere johnsoni	0	0	0	0	0	0	0	2	0	0	0	0
Paracytheridea	0	0	0	0	0	0	0	0	0	0	0	0
Peratocytheridea setipunctata	0	0	0	1	2	0	0	1	0	0	0	0
Puriana convoluta	4	0	0	2	1	0	0	0	0	0	0	0
Quadracythere	0	0	0	0	0	0	0	2	2	0	1	0
Radimella/ Jugosocythereis/Hermanites	0	0	0	1	4	2	0	1	2	1	1	0
Reticulocithereis floridana	0	0	0	0	0	0	0	0	0	0	0	0
Thalassocypris	0	2	0	1	5	3	6	11	3	6	9	3
Xestoleberis spp.	14	14	15	23	21	12	14	22	16	9	18	11
OTHER	9	17	15	1	0	0	4	0	3	1	4	2
TOTAL	100	101	108	102	113	100	105	109	100	100	129	100

Appendix E: Ostracode absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	24	28	32	36	40	44	48	52	56	60	64	68
Actinocythereis	4	7	1	3	1	0	2	0	1	1	0	3
Acuticythereis lacvissima (Juveniles)	0	0	1	0	0	6	1	0	2	1	3	2
Bairdiids	60	34	63	61	38	17	17	16	10	28	10	12
Caudites/ Neocaudites	0	0	0	0	0	0	0	0	1	0	1	0
Cytherellids	6	5	4	4	5	3	5	11	1	5	9	6
Cytheromorpha	0	0	0	0	0	0	0	0	4	0	0	6
Cytherura	0	0	0	0	2	2	0	0	0	0	0	1
Loxoconcha matagordensis	13	18	14	20	15	21	33	38	36	36	33	41
Malzella floridana	4	9	5	5	6	8	16	8	2	3	2	3
Megacythere johnsoni	0	1	0	0	2	3	1	1	0	1	3	2
Paracytheridea	0	0	0	0	0	0	0	0	0	0	1	0
Peratocytheridea setipunctata	0	0	1	0	0	0	0	0	0	0	0	0
Puriana convoluta	0	1	1	0	3	1	0	2	0	1	2	0
Quadracythere	3	2	5	0	9	6	2	0	0	0	0	0
Radimella/ Jugosocythereis/Hermanites	1	0	0	4	0	2	3	5	13	13	18	6
Reticulocithereis floridana	0	0	0	0	0	0	0	1	0	0	0	3
Thalassocypris	0	10	1	1	5	5	0	5	10	6	4	5
Xestoleberis spp.	8	13	10	4	11	23	9	13	21	5	20	10
OTHER	1	1	1	0	6	6	12	0	2	0	0	0
TOTAL	100	101	107	102	103	103	101	100	103	100	106	100

Appendix E: Ostracode absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	72	76	80	84	88	92	96	100	104	108	112	116
Actinocythereis	0	0	2	1	1	6	0	2	2	0	3	4
Acuticythereis lacvissima (Juveniles)	0	1	0	0	0	0	0	2	3	1	0	1
Bairdiids	7	16	21	19	10	5	12	15	24	19	23	15
Caudites/ Neocaudites	4	1	0	1	0	0	1	0	2	1	1	0
Cytherellids	3	3	8	13	11	9	4	1	5	6	7	7
Cytheromorpha	1	1	0	0	2	1	2	3	0	0	0	1
Cytherura	0	0	0	0	1	2	0	1	3	4	1	0
Loxoconcha matagordensis	47	44	39	34	46	30	40	32	39	31	47	48
Malzella floridana	0	0	0	0	1	2	9	4		3	0	0
Megacythere johnsoni	0	1	0	1	0	4	3	2	2	0	3	0
Paracytheridea	0	0	0	0	0	0	0	0	0	1	0	0
Peratocytheridea setipunctata	0	0	0	0	0	1	1	0	0	0	0	0
Puriana convoluta	0	0	0	0	1	0	1	1	0	1	0	0
Quadracythere	0	0	1	0	0	0	0	1	0	0	0	0
Radimella/ Jugosocythereis/Hermanites	14	10	10	6	2	3	13	16	11	12	7	13
Reticulocithereis floridana	2	0	0	0	2	0	0	2	0	0	0	2
Thalassocypris	3	3	8	7	8	27	3	6	2	5	5	4
Xestoleberis spp.	17	21	10	18	16	10	13	12	12	16	6	8
OTHER	2	0	1	1	0	0	0	0	0	0	0	0
TOTAL	100	101	100	101	101	100	102	100	105	100	103	103

Appendix E: Ostracode absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	120	124	128	132	136	140	144	148	152	156	160	164
Actinocythereis	3	2	4	3	3	5	3	4	1	3	2	2
Acuticythereis lacvissima (Juveniles)	2	3	1	1	1	2	0	1	1	1	2	1
Bairdiids	8	17	24	10	28	29	32	39	26	21	28	34
Caudites/ Neocaudites	0	0	0	1	1	1	1	1	0	1	0	1
Cytherellids	10	5	4	3	3	2	6	5	12	6	5	4
Cytheromorpha	2	2	1	1	3	2	0	0	1	1	1	0
Cytherura	2	0	0	2	1	1	1	1	0	1	0	1
Loxoconcha matagordensis	33	32	39	35	34	20	19	18	19	27	20	23
Malzella floridana	4	0	0	0	0	0	5	4	0	1	1	1
Megacythere johnsoni	4	1	0	4	2	2	1	0	1	2	0	0
Paracytheridea	0	1	0	1	0	1	2	1	0	0	0	0
Peratocytheridea setipunctata	0	0	0	0	0	0	0	1	0	0	0	0
Puriana convoluta	0	0	0	0	0	0	1	0	0	0	0	0
Quadracythere	0	0	0	0	0	0	1	0	0	1	0	0
Radimella/ Jugosocythereis/Hermanites	16	25	10	20	9	15	11	8	14	13	10	8
Reticulocithereis floridana	0	1	0	0	0	2	3	1	4	1	0	1
Thalassocypris	1	3	3	2	2	3	3	4	0	1	6	4
Xestoleberis spp.	17	7	16	19	17	18	13	10	20	22	30	23
OTHER	0	1	1	1	0	0	1	2	3	0	2	0
TOTAL	102	100	103	103	104	103	103	100	102	102	107	103

Appendix E: Ostracode absolute abundance data for 2002 Featherbed Bank core (GLW402-FBB).

Sample depth in cm	168	172	176	180	184	188	192
Actinocythereis	2	0	4	1	1	0	0
Acuticythereis lacvissima (Juveniles)	4	5	5	3	6	9	7
Bairdiids	30	41	17	35	28	30	22
Caudites/ Neocaudites	0	0	1	1	1	0	0
Cytherellids	5	2	9	4	5	7	5
Cytheromorpha	1	1	3	1	2	0	1
Cytherura	2	2	2	3	4	2	2
Loxoconcha matagordensis	16	12	10	17	11	10	14
Malzella floridana	1	1	3	3	2	1	2
Megacythere johnsoni	0	2	3	1	3	6	0
Paracytheridea	0	0	0	0	0	0	0
Peratocytheridea setipunctata	0	0	0	0	0	0	1
Puriana convoluta	0	0	0	0	0	0	1
Quadracythere	2	0	1	0	1	0	0
Radimella/ Jugosocythereis/Hermanites	11	8	3	10	15	9	9
Reticulocithereis floridana	5	3	3	1	1	4	2
Thalassocypris	8	6	9	7	5	3	8
Xestoleberis spp.	13	18	27	13	16	18	26
OTHER	0	0	1	0	0	2	0
TOTAL	100	101	101	100	101	101	100

Appendix F: Ostracode absolute abundance data from 2002 Card Bank core (GLW402-CBB).

Sample depth (cm)	0	8	16		120	128	136
Bairdiids	29	36	17	NO SAMPLE COUNTS MADE	1	2	2
Actinocythereis	0	0	3		0	1	1
Acuticythereis lacvissima (Juveniles)	1	0	0		4	0	0
Caudites/ Neocaudites	0	2	0		0	4	0
Cytherellids	2	5	2		0	0	0
Cytheromorpha	0	0	1		0	0	0
Cytherura	0	1	1		3	3	4
Loxoconcha matagordensis	13	8	9		1	1	1
Malzella floridana	11	8	16		39	46	57
Megacythere johnsoni	0	1	0		8	0	4
Paracytheridea	0	0	0		0	1	1
Peratocytheridea setipunctata	0	1	3		10	13	7
Puriana convoluta	0	0	0		6	4	5
Quadracythere	1	4	2		0	0	0
Radimella/ Jugosocythereis/ Hermanites	0	0	0		1	0	0
Reticulocithereis floridana	0	0	2		3	3	0
Thalassocypris	8	5	5		0	3	0
Xestoleberis spp.	36	31	38		27	19	19
OTHER	1	0	1		0	0	0
TOTAL	102	102	100		103	100	101

Appendix G: Molluscan absolute abundance data, excluding worn and fragmented specimens, for 1997 Card Bank core (SEI297-CB1).

	Sample depth in cm																		
	0	8	16	24	32	40	48	56	64	72	80	88	96	104	112	118	128	136	144
Acteocina sp.	0	1	4	0	0	0	0	1	0	1	0	1	15	0	9	0	3	1	1
Anomalocardia auberiana	0	0	0	0	0	0	0	1	0	0	0	0	18	0	8	0	1	0	1
Anomia sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arcopsis adamsi	1	0	2	0	0	0	0	3	0	1	0	0	6	0	2	0	1	0	3
Argopecten irradians	0	0	3	0	0	1	0	2	0	3	2	0	3	0	3	1	4	1	3
Bailya intricata?	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bittiolum varium	38	21	241	23	38	3	0	39	0	7	26	48	26	2	219	8	12	0	7
Brachidontes exustus	2	0	4	0	6	1	2	4	0	2	3	0	17	0	24	10	9	0	0
Bulla striata	0	1	2	0	3	1	1	5	0	4	11	0	19	0	17	4	5	0	6
Caecum cornucopiae	7	0	2	0	0	0	0	2	0	0	1	0	0	0	3	0	0	0	0
Caecum pulchellum	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carditamera floridana	4	2	16	1	12	7	0	11	0	5	10	4	32	0	18	0	2	0	12
Cerithiopsis emersoni	0	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cerithiopsis greenii	0	0	3	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Cerithium muscarum	2	0	11	2	2	0	0	3	0	1	3	1	8	2	5	1	2	6	29
Chione cancellata	2	2	5	2	0	3	0	5	0	0	1	1	11	0	7	4	4	3	11
Codakia spp	1	0	1	0	0	0	0	1	0	0	1	0	7	0	0	0	1	1	0
Collumbella rusticoides	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Columbellid juv?	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Costanachis sp. A	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Crassispira tampaensis	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0
Crepidula spp.	1	4	29	4	0	0	0	6	0	4	8	19	6	0	10	5	1	1	18
Cumingia tellinoides	1	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	2	1	0
Cyclostremiscus suppressus	3	1	13	3	6	0	0	1	0	5	8	0	17	0	4	0	5	3	1
Dentimargo ? sp.	1	0	3	2	0	0	0	0	0	2	0	1	1	0	2	0	0	0	0
Diodora sp.	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Epitonium echinocostatum ?	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Eulima/Melanella sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Fasciolaria sp	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finella dubia ?	1	0	1	0	0	0	0	0	0	0	0	0	4	0	3	0	1	0	0
Granulina hadria	0	0	0	1	0	1	0	4	0	3	2	0	7	0	6	2	1	0	0
Laesidae?	0	0	2	1	0	0	0	1	0	0	0	1	1	0	1	0	1	0	0

Appendix G: Molluscan absolute abundance data, excluding worn and fragmented specimens, for 1997 Card Bank core (SEI297-CB1).

	0	8	16	24	32	40	48	56	64	72	80	88	96	104	112	118	128	136	144
Laevicardium mortoni	3	7	17	5	1	1	1	17	0	1	1	2	25	0	26	3	6	2	14
Limaria sp. cf *L. pellucida*	1	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Lucinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Marshallora nigrocincta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Mitra nodulosa	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Modulus modulus	1	4	14	1	3	0	0	1	1	2	6	0	5	0	3	1	1	2	6
Nassarius sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Nucula proxima	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0
Odostomia laevigata	1	0	2	0	0	0	0	2	0	0	2	0	1	0	0	0	0	0	0
Olivella pusilla	0	0	1	0	0	0	0	0	0	0	0	0	3	0	6	0	4	0	0
Turbo opercula	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parastarte triquetra	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Parvilucina multilineata	4	2	23	2	9	3	2	29	0	2	0	0	0	0	1	0	0	0	0
Pilsbryspira leucocyma	0	0	2	1	2	0	0	0	0	0	2	0	3	0	0	0	0	0	0
Pitar simpsoni	1	0	4	0	4	2	0	14	1	0	0	0	0	0	21	6	0	8	4
Prunum sp.	2	0	3	0	1	3	0	4	0	2	2	0	3	0	5	3	4	1	3
Rictaxis punctostriatus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Rissoina cancellata	0	0	6	1	0	1	0	1	0	0	0	0	4	0	0	0	0	1	3
Schwartziella catesbyana	4	10	55	7	10	0	0	12	0	9	15	3	8	0	10	5	5	3	3
Seila adamsi	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stellatoma stellata?	0	0	3	1	0	0	0	0	0	3	0	0	2	0	2	0	0	0	2
Tellina spp.	0	5	9	0	1	2	0	3	0	2	1	0	15	0	7	0	3	2	7
Transennella sp.	1	0	10	1	0	0	0	16	1	0	2	0	46	0	30	4	4	6	8
Triptychus niveus	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Turbo castanea	0	1	0	1	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Turbo opercula	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Turbonilla spp.	0	3	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0
Vermicularia sp.	3	5	5	1	2	0	0	3	0	0	2	0	0	0	0	0	0	0	1
Vitrinella floridana	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0
Unidentified Gastropods	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Total taxonomic groups present (excluding fragments & worn)	26	16	37	21	21	13	4	35	4	20	24	10	36	2	33	15	24	19	23
Total abundance/sample (excluding fragments & worn)	110	72	506	62	106	29	6	201	4	60	114	81	327	4	459	58	82	45	146

Appendix H. Pollen absolute abundance counts for Military Canal wetlands cores (SEI97-BW1 and BW2).

SEI-97-BWI

	Sample depth in cm														
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	20-22	24-26	30-32	34-36	36-38	40-42	44-46	46-48
Alnus	1	0	2	0	0	0	0	0	1	1	0	1	0	0	0
Carya	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Cephalanthus	0	3	4	3	0	2	1	2	0	0	0	0	0	0	0
Casuarina	19	13	9	10	3	13	3	4	0	0	0	0	0	0	1
Ilex	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0
Myrica	16	13	1	3	0	8	3	13	2	11	3	7	2	1	6
Nyssa	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
Pinus	21	10	16	35	30	114.5	264	243	264	274.5	263	219.5	250	236	232.5
Quercus	4	1	3	0	2	0	0	2	1	0	1	4	2	0	1
Ambrosia	0	0	0	2	1	0	4	0	0	0	0	0	0	1	0
Aster Indeterminate	2	3	0	1	1	6	4	10	1	1	3	10	1	0	4
Cheno-Ams	4	2	6	2	2	2	7	6	0	0	0	2	0	0	5
Cladium	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Cyperaceae	0	9	1	3	3	0	10	2	18	0	20	0	20	22	0
Poaceae	0	4	0	3	0	0	3	5	0	0	0	0	2	0	4
Sagittaria	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Typha	0	2	2	6	1	2	1	0	0	0	0	0	0	0	1
Umbelliferea	1	2	0	0	0	0	0	2	0	0	0	1	0	0	0
Waltheria	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
SAO	112	210	66	51	13	4	15	3	28	1	32	5	50	52	7
SCO	7	2	0	0	0	1	1	0	0	0	0	0	1	0	1
Osmunda	0	28	0	2	0	1	1	0	0	1	0	0	0	0	1
PO3	13	7	7	7	1	9	1	5	0	0	0	1	1	1	3
PC3	1	0	0	0	0	2	0	1	0	1	0	0	0	0	1
Total	202	310	118	128	57	164.5	318	299	316	294.5	323	251.5	329	313	267.5
Crumpled	5	2	0	2	0	2	4	0	0	0	4	0	3	2	0
Exotics	155	110	73	153	73	185	70	286	68	157	68	134	53	85	179
Sample Weight (g)	0.56	0.53	0.5	0.43	0.57	0.66	1.43	1.52	0.83	0.6	0.63	0.68	0.73	0.52	0.57

Appendix H. Pollen absolute abundance counts for Military Canal wetlands cores (SEI97-BW1 and BW2).

SEI97-BW2

	Sample depth in cm												
	0.5	2.5	4.5	6.5	8.5	10.5	15.5	21	25	31	35	41	43
Alnus	0	0	0	0	0	1	0	0	0	0	0	0	0
Brassicaceae	0	0	2	0	0	0	0	0	0	0	0	0	0
Carya	0	0	0	0	0	0	0	1	2	0	0	0	0
Casuarina	12	12	6	4	16	14	0	0	0	0	0	0	0
Myrica	3	1	1	2	4	6	0	1	4	0	1	0	3
Pinus	28	21	15	24	92.5	183	238	264	237	287	45.5	299	274
Quercus	1	3	1	2	2	3	2	0	6	1	0	0	0
Rhizophora	1	0	2	0	1	1	0	0	0	0	0	0	1
Ambrosia	1	4	1	0	0	6	0	0	0	0	0	0	0
Aster Indet.	11	5	3	6	26	58	20	32	36	14	16	3	12
Brassicaceae	0	0	2	0	0	0	0	0	0	0	0	0	0
Cheno-Ams	7	6	2	1	1	13	1	0	0	1	2	0	3
Cladium	1	0	0	0	0	0	0	0	4	0	0	0	0
Cyperaceae	0	0	0	2	2	1	1	0	0	0	0	0	0
Euphorbiaceae	8	4	6	2	7	0	0	0	0	0	0	0	0
Ericaceae	0	0	0	0	0	0	1	0	2	1	0	0	0
Nymphaea	0	0	0	0	0	0	0	0	0	0	0	0	0
Onagraceae	0	0	0	0	0	1	0	0	2	0	0	0	0
Poaceae	1	1	0	1	0	8	0	6	4	1	0	0	2
Pteris	1	0	1	1	2	2	1	1	3	1	0	0	0
Sagittaria	0	0	0	0	0	0	0	0	1	0	0	0	0
Solanaceae	7	7	6	1	11	12	0	0	1	0	0	0	1
Thelypteris	8	9	13	8	5	3	0	0	0	0	0	0	0
Typha	2	1	2	3	10	10	0	0	1	0	0	0	0
Umbelliferea	7	2	4	2	4	0	1	3	4	0	0	0	1
Waltheria	0	0	0	0	0	0	0	0	0	1	0	1	0
SAO	0	1	5	1	3	4	1	3	0	2	0	0	0
SCO	0	0	0	1	0	3	0	0	0	0	0	0	2
Osmunda	0	0	0	0	1	0	0	0	0	1	0	1	0
PO3	5	2	2	2	4	8	1	0	2	1	2	0	3
PC3	4	2	2	1	1	5	1	0	0	0	0	0	0
Total	108	81	76	64	192.5	342	268	311	309	311	66.5	304	302
Crumpled	2	2	7	1	1	2	1	1	0	1	0	0	0
Exotics	19	27	19	33	32	105	30	31	103	12	13	32	33

Appendix I: Ostracode absolute abundance data from Middle Key core (GLW60
3-MKA).

Sample depth (cm)	0	4	8	12	16	20	24	26	28	30	34	38	42	46	50	54
Actinocythereis	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Candona	0	0	0	8	7	23	5	19	0	0	0	0	0	0	0	0
Caudites/ Neocaudites	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprid	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0
Cytherelliids	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Cytheromorpha	3	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0
Cytherura	4	2	2	4	9	1	1	2	0	0	0	0	0	0	0	0
Heterocyprid	0	0	0	1	1	0	0	2	0	0	0	0	0	0	0	0
Loxoconcha levis	3	3	7	5	2	0	1	1	0	0	0	0	0	0	0	0
Loxoconcha matagordensis	3	10	8	5	6	6	5	3	0	0	0	0	0	0	0	0
Malzella floridana	56	54	42	43	43	38	51	32	0	0	0	0	0	0	0	0
Megacythere johnsoni	3	5	5	2	3	6	3	2	0	0	0	0	0	0	0	0
Peratocytheridea setipunctata	21	16	15	24	12	12	23	4	0	0	0	0	0	0	0	0
Reticulocithereis	4	8	14	7	12	7	6	4	0	0	0	0	0	0	0	0
Thalassocypria	1	0	4	5	1	1	0	0	0	0	0	0	0	0	0	0
Xestoleberis spp.	3	2	1	2	4	4	3	3	0	0	0	0	0	0	0	0
TOTAL	101	103	104	108	102	100	99	72	0	0	0	0	0	0	0	0

Appendix I: Ostracode absolute abundance data from Middle Key core (GLW603-MKA).

Sample depth (cm)	58	62	66	70	74	78	82
Actinocythereis	0	0	0	0	0	0	0
Candona	0	0	0	0	0	0	0
Caudites/ Neocaudites	0	0	0	0	0	0	0
Cyprid	0	0	0	0	0	0	0
Cytherelliids	0	0	0	0	0	0	0
Cytheromorpha	0	0	0	0	0	0	0
Cytherura	0	0	0	0	0	0	0
Heterocyprid	0	0	0	0	0	0	0
Loxoconcha levis	0	0	0	0	0	0	0
Loxoconcha matagordensis	0	0	0	0	0	0	0
Malzella floridana	0	0	0	0	0	0	0
Megacythere johnsoni	0	0	0	0	0	0	0
Peratocytheridea setipunctata	0	0	0	0	0	0	0
Reticulocithereis	0	0	0	0	0	0	0
Thalassocypria	0	0	0	0	0	0	0
Xestoleberis spp.	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	0

Appendix J: Molluscan absolute abundance data, excluding worn and fragmented specimens, from Middle Key core (GLW603-MKA).

	Sample depth in cm															
	0	8^	16	24	32	40	48	56	64	72	80	88	96#	104#	112#	114#
Acteocina canaliculata	55	70	0	22	0	0	0	0	0	0	0	0	0	0	0	0
Anomalocardia auberiana	82	76	51	7	2	*	0	0	0	0	0	0	0	0	0	0
Astyris lunulata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bittiolum varium	12	18	17	3	0	0	0	0	0	0	0	0	0	0	0	0
Brachidontes exustus	10	3	3	*	0	0	0	0	0	0	0	0	0	0	0	0
Bulla striata	9	22	6	2	0	0	0	0	0	0	0	0	0	0	*	0
Caecum pulchellum	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerithidea costata	13	12	26	*	0	0	0	0	0	0	0	0	0	0	0	0
Cerithium muscarum	45	56	39	14	0	0	0	0	0	0	0	0	0	0	0	0
Chione cancellata	1	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Codakia spp.	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Crepidula spp.	15	18	11	3	0	0	0	0	0	0	0	0	0	0	0	0
Cyclostremiscus suppressus	0	*	0	*	0	0	0	0	0	0	0	0	0	0	0	0
Cyrenoida floridana	*	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0
Epitomium sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Granulina hadria	3	1	2	1	0	0	0	0	0	0	0	0	*	0	0	0
Haminoea elegans	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobiids	27	56	145	87	25	61	59	40	36	1	0	34	0	0	0	0
Laevicardium mortoni	2	2	*	0	0	0	0	0	0	0	0	0	0	0	0	0
Longchaeus crenulatus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lucina multilineata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lyonsia sp.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melongena corona	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Modulus modulus	3	6	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Odostomia laevigata	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0
Odostomia producta	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Olivella pusilla	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Parastarte triquetra	91	23	21	14	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	2	7	63	40	21	77	49	16	10	0	0	81	0	0	0	0
Pitar simpsoni	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planorbella sp.	3	2	26	12	10	8	8	8	10	0	0	7	0	0	0	0
Pleuromeris tridenta?	0	0	0	0	0	0	0	0	0	0	0	0	*	0	0	0
Polygyra sp.	0	0	*	0	0	0	3	*	0	0	0	16	*	0	0	0
Polymesoda sp.	7	39	37	12	0	0	0	0	0	0	0	0	0	0	0	0
Prunum apicinum	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Indicates taxonomic group is present in sample as a worn or fragmented specimen (or specimens), but is not included in counts for analytical purposes.

Appendix J: Molluscan absolute abundance data, excluding worn and fragmented specimens, from Middle Key core (GLW603-MKA).

	Sample depth in cm															
	0	8^	16	24	32	40	48	56	64	72	80	88	96#	104#	112#	114#
Prunum sp	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0
Pteria longisquamosa	0	0	*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pupillidae	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Sinum? sp.	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0
Stellatoma stellata	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Tagelus sp.	0	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tellina spp.	9	12	9	3	0	0	0	0	0	0	0	0	0	0	0	0
Transennella sp	58	77	47	20	2	0	0	0	0	0	0	0	*	0	*	3
Vitrinella floridana	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER Gastropods	1	*	0	0	*	0	0	1	0	0	0	11	*	*	*	0
OTHER Pelecypods	0	0	0	0	0	0	0	0	0	0	0	0	*	*	*	0
Total taxonomic groups present including fragments & worn	26	32	30	20	6	5	4	5	3	1	0	7	6	2	4	1
Total taxonomic groups present excluding fragments and worn	25	28	27	17	5	4	4	4	3	1	0	7	0	0	0	1
Total abundance/sample (excluding fragments & worn)	458	513^	524	244	60	148	119	65	56	1	0	158	0	0	0	3

^ Sample too large to pick entire fraction >850 microns so sample was split. Picked fraction = 52% of the weight of the entire sample, so counts do not represent total sample counts but ~ 52% of sample. Total abundance shows total of counted specimens. Estimate for total number of specimens in sample (excluding worn and fragmented) is 987.

Samples below 90 cm depth were excluded from the analyses because they contained mixed assemblages of fossil specimens from the underlying limestone rubble and the lowermost samples had some "drag-down" contamination from the modern environment.

* Indicates taxonomic group is present in sample as a worn or fragmented specimen (or specimens), but is not included in counts for analytical purposes.

Appendix K: Foraminifer absolute abundance data from Middle Key core (GLW603-MKA).

	Sample depth in cm							
	0-2	16-18	32-34	48-50	64-66	88-90	104-106	114-114.5
Ammonia parkinsoniana var. *tepida*	2	10	0	0	0	0	0	0
Ammonia parkinsoniana var. *typica*	14	25	9	1	0	0	0	0
Archaias angulatus	5	7	1	0	0	0	0	0
Astrononion stelligerum	2	4	0	0	0	0	0	0
Bolivina lanceolata	1	1	0	0	0	0	0	0
Cassidulinoides bradyi	1	1	0	0	0	0	0	0
Clavulina difformis	0	1	0	0	0	0	0	0
poeyanum	45	112	2	2	0	0	0	2
Miliolinella circularis	74	34	1	0	0	0	0	0
Milionella labiosa	11	3	0	0	0	0	0	0
Peneroplis proteus	1	5	0	0	0	0	0	0
Quinqueloculina bicarinata	1	0	0	0	0	0	0	0
Quinqueloculina bicostata	2	1	0	0	0	0	0	0
Quinqueloculina bosciana	41	17	0	0	0	0	0	0
Quinqueloculina lamarckiana	21	14	0	0	0	0	0	0
Quinqueloculina poeyana	17	29	0	0	0	0	0	0
Quinqueloculina wiesneri	5	4	0	0	0	0	0	0
Rosalina floridana	0	1	0	0	0	0	0	0
Triloculina bassensis	0	1	0	0	0	0	0	0
Triloculina bermudezi	47	20	0	0	0	0	0	0
Triloculina fitterei var. *meningoi*	5	4	0	0	0	0	0	0
Triloculina linneiana	6	6	0	0	0	0	0	0
Triloculina planciana	4	7	1	0	0	0	0	0
Triloculina rotunda	3	5	0	0	0	0	0	0
Triloculina tricarinata	0	3	0	0	0	0	0	0
Triloculina trigonula	5	2	0	0	0	0	0	0
Rotaliids	5	5	0	0	0	0	0	0
TOTAL	318	322	14	3	0	0	0	2

Appendix L: Pollen absolute abundance data from Middle Key core (GLW603-MKA).

	Sample depth in cm																
	0-2	4-6	10-12	14-16	20-22	24-26	30-32	34-36	40-42	50-52	60-62	70-72	80-72	90-97	100-102	110-112	114-114.5
Acer	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0
Alnus	0	0	2	0	0	1	0	0	0	0	1	0	0	1	0	0	0
Cephalanthus	3	0	0	1	2	0	1	1	1	0	0	2	0	0	0	0	0
Casuarina	3	5	8	3	1	0	0	0	0	0	0	1	0	0	0	0	0
Ilex	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Laguncularia	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liquidambar	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Myrica	14	6	18	11	9	1	7	8	6	12	7	17	0	0	0	0	0
Nyssa	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Pinus	234	252	245	250	280	295	306	266	290	285	286	245	299	301	281	33	28
Quercus	13	12	16	14	5	1	4	3	0	2	1	2	1	1	2	5	0
Rhizophora	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulmus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ambrosia	8	4	1	5	0	0	0	0	1	0	0	0	0	0	3	0	0
Aster Indet.	3	1	2	0	0	1	0	0	0	0	0	0	0	5	8	0	1
Cheno-Ams	8	6	7	1	5	0	1	1	2	2	0	2	2	0	1	0	0
Cyperaceae	6	5	2	1	3	1	0	0	2	5	1	11	1	2	3	0	4
Fabaceae	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0
Nymphaea	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0
Poaceae	3	1	1	0	1	0	0	1	1	0	0	0	0	0	2	1	0
Sagittaria	0	0	0	0	2	1	0	0	0	0	0	6	0	1	0	0	0
Typha	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
SCO	2	3	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0
SAO	4	5	6	6	2	0	2	2	3	3	8	11	9	4	1	0	0
PO3	2	1	3	3	2	1	0	2	1	0	1	2	1	0	2	0	0
PC3	0	0	2	0	1	0	0	2	0	0	0	0	0	0	0	0	0
Osmunda	0	2	0	1	0	0	0	0	0	3	3	1	0	0	1	0	0
Total	307	308	318	300	314	302	322	288	308	316	312	301	313	316	304	39	33
Crumpled	1	2	2	1	2	0	0	0	0	0	0	0	1	0	0	0	0
Exotic	275	310	330	264	225	0	186	130	58	82	50	60	33	125	240	400	230

Appendix M: Ostracode absolute abundance data from Black Point North core (GLW603-BPNA).

Sample depth (cm)	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
Actinocythereis	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acuticythereis lacvissima (Juv.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bairdiids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Candona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Caudites/ Neocaudites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cytherelliids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cytheromorpha	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Cytherura	4	5	3	0	0	0	0	0	0	1	2	0	0	2	1	2	10
Heterocyprid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Loxoconcha levis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Loxoconcha matagordensis	29	12	2	0	0	0	0	0	0	0	0	0	0	0	0	2	10
Malzella floridana	37	61	21	0	0	0	0	0	0	12	13	0	1	20	10	66	49
Megacythere johnsoni	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Peratocytheridea setipunctata & *Cyprideis*	1	11	1	0	0	0	0	0	0	80	76	18	9	27	21	17	12
Paracytheridea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perissocytheridea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	5
Puriana convoluta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quadracythere	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radimella/ Jugosocythereis/Hermanites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulocithereis	0	0	0	0	0	0	0	0	0	0	1	0	0	2		1	7
Thalassocypria	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Xestoleberis spp.	27	9	4	0	0	0	0	0	0	0	1	1	0	0	4	6	5
OTHER	0	0	0	0	0	0	0	0	0	4	2	2	0	3	7	0	0
TOTAL	100	100	32	0	0	0	0	0	0	97	100	21	10	54	43	104	104

Appendix M: Ostracode absolute abundance data from Black Point North core (GLW603-BPNA).

Sample depth (cm)	68	72	76	80	84
Actinocythereis	0	0	0	1	0
Acuticythereis lacvissima (Juv.)	0	0	0	1	0
Bairdiids	0	0	0	0	0
Candona	0	0	0	0	0
Caudites/ Neocaudites	0	0	0	0	0
Cyprid	0	0	0	0	1
Cytherelliids	0	0	0	1	0
Cytheromorpha	0	0	0	0	0
Cytherura	11	7	4	5	9
Heterocyprid	0	1	0	0	0
Loxoconcha levis	0	0	0	0	0
Loxoconcha matagordensis	4	7	15	19	8
Malzella floridana	50	37	50	46	58
Megacythere johnsoni	0	0	1	0	0
Peratocytheridea setipunctata & *Cyprideis*	29	25	7	6	12
Paracytheridea	0	0	0	0	0
Perissocytheridea	6	5	3	0	3
Puriana convoluta	0	0	0	0	0
Quadracythere	0	0	0	0	0
Radimella/ Jugosocythereis/Hermanites	0	0	0	0	0
Reticulocithereis	0	4	8	7	3
Thalassocypria	0	0	0	3	1
Xestoleberis spp.	9	10	7	6	12
OTHER	0	0	2	4	0
TOTAL	109	96	97	99	107

Appendix N: Molluscan absolute abundance data, excluding worn and fragmented specimens, from Black Point North core (GLW603-BPNA).

	Sample depth in cm										
	0	8	16	24	32	40	48	56	64	72	80
Acteocina canaliculata	0	2	0	0	3	4	2	9	5	3	4
Acteocina candei	7	0	1	0	0	6	0	2	0	0	1
Amygdalium?	0	*	0	0	0	0	0	0	0	0	0
Anomalocardia auberiana	12	9	7	4	10	45	34	23	7	14	4
Anomia simplex?	0	0	0	0	0	0	0	0	0	2	0
Arcopsis adamsi	0	0	0	0	0	0	0	0	2	0	0
Astyris lunulata	0	0	3	0	0	3	*	1	*	*	1
Batillaria minima	0	0	*	0	0	0	0	0	0	0	0
Bittiolum varium	2	6	31	3	61	360	142	138	18	52	20
Brachidontes exustus	52	8	*	*	*	13	7	3	5	9	3
Brachidontes modiolus?	0	*	0	0	0	0	0	0	0	0	0
Bulla striata	5	1	*	*	0	*	*	1	*	*	1
Caecum cornucopiae	0	0	0	0	0	0	0	*	2	0	0
Caecum pulchellum	1	0	0	0	1	6	1	4	0	*	0
Carditamera floridana	*	6	0	0	0	0	0	0	0	0	0
Cerithidea costata	0	0	*	0	*	1	*	2	4	4	1
Cerithiopsis greeni	0	0	0	0	0	3	0	0	0	0	0
Cerithium muscarum	44	17	5	1	7	21	10	3	2	12	1
Chione cancellata	0	*	1	0	0	0	0	0	0	0	0
Columbellids	0	0	0	0	*	0	0	0	0	0	0
Crepidula spp.	5	5	4	*	0	5	1	2	*	0	0
Cyclostremiscus suppressus	0	*	4	0	1	13	3	5	2	*	1
Cyrenoida floridana	0	0	0	1	0	0	0	0	0	0	0
Epitomium sp.	0	0	0	0	0	0	0	*	0	0	0
Eulithidium affine	*	1	*	*	0	0	0	0	0	0	0
Geukenesia demissa	0	*	0	0	0	0	0	1	0	0	0
Granulina hadria	6	2	*	*	*	0	1	*	0	0	0
Haminoea sp.	0	0	0	0	0	0	0	0	0	1	0
Hydrobiids	26	1	2	0	*	3	0	0	1	1	0
Laevicardium mortoni	0	*	0	*	*	1	1	2	0	1	0
Limaria sp. cf *L. pellucida*	0	0	0	0	0	0	*	*	*	0	0
Longchaeus crenulatus	0	0	1	0	0	0	0	0	0	0	0
Lyonsia ? sp.	0	0	0	0	0	0	0	0	1	0	0
Macoma sp.	1	0	0	0	0	0	0	0	0	0	0
Marshallora nigrocincta	3	1	0	0	*	2	1	0	1	1	1
Melampus bidentatus	0	0	0	0	0	1	0	0	0	0	0

* Indicates taxonomic group is present in sample as a worn or fragmented specimen (or specimens), but is not included in counts for analytical purposes.

Appendix N: Molluscan absolute abundance data, excluding worn and fragmented specimens, from Black Point North core (GLW603-BPNA).

	Sample depth in cm										
	0	8	16	24	32	40	48	56	64	72	80
Melongena corona	0	0	0	0	0	1	0	0	0	0	0
Modulus modulus	5	1	2	0	0	0	0	0	0	*	0
Mytilid	1	0	0	0	0	0	0	0	0	0	0
Nassarius sp.	0	0	0	0	*	*	*	1	0	0	*
Nassarius sp. cf. *N. scissuratus*	0	0	*	0	0	0	0	0	0	0	0
Neritina virginea	1	2	*	0	1	4	2	1	*	*	1
Nucula proxima	0	0	0	0	0	0	0	1	0	0	0
Odostomia laevigata	2	0	*	0	*	1	*	1	0	0	*
Odostomia producta	0	0	0	0	0	1	0	1	*	1	0
Olivella pusilla	0	1	0	0	0	1	0	0	1	0	0
Parastarte triquetra	1	4	13	7	14	30	16	8	11	32	0
Polymesoda sp.	0	0	0	0	0	0	0	0	2	1	0
Prunum sp. (aff *P. apicinum*)	3	5	2	0	*	*	0	0	0	0	0
Rictaxis punctostriatus	0	0	0	0	0	1	0	2	0	1	0
Schwartziella catesbyana	2	4	5	1	1	11	7	5	*	0	*
Stellatoma stellata?	0	0	2	0	1	2	0	*	*	0	0
Tagelus sp.	*	0	*	0	0	*	*	0	0	0	0
Teinostoma biscaynense	0	0	0	0	0	0	0	1	0	0	0
Tellinidae	13	4	4	1	6	45	49	29	21	52	2
Teredinidae cf. *Teredo bartschi*	0	*	0	0	0	0	0	0	6	2	0
Transennella sp	1	2	2	1	3	11	15	17	7	6	2
Truncatella caribaeensis	0	0	0	0	0	1	1	0	1	0	2
Truncatella sp. cf. *T. scalaris*	0	0	0	0	0	0	1	0	*	0	0
Turbo castaneus	0	2	0	0	0	0	0	0	0	0	0
Turbonilla sp.	0	0	0	0	0	0	0	*	0	*	0
Vitrinella floridana	1	*	2	0	2	6	9	7	3	7	0
OTHER Gastropods	4	1	0	0	0	*	*	0	1	0	0
OTHER Pelecypods	*	*	*	*	0	0	*	0	*	0	0
Total taxonomic groups present including fragments & worn	27	31	30	15	23	34	28	32	31	26	18
Total taxonomic groups present excluding fragments and worn	23	22	18	8	13	29	19	26	21	19	15
Total abundance/sample (excluding fragments & worn)	198	85	91	19	111	602	303	270	103	202	45

* Indicates taxonomic group is present in sample as a worn or fragmented specimen (or specimens), but is not included in counts for analytical purposes.

Appendix O: Foraminifer absolute abundance data from Black Point North core (GLW603-BPNA).

	Sample depth in cm											
	0-2	8-10	16-18	24-26	32-34	40-42	48-50	56-58	64-66	72-74	80-82	86-86.5#
Ammonia parkinsoniana var. *tepida*	34	72	59	31	37	26	24	36	42	38	1	46
Ammonia parkinsoniana var. *typica*	143	174	152	216	182	130	175	127	152	83	7	113
Archaias angulatus	0	0	0	0	0	0	0	0	0	0	1	0
Astrononion stelligerum?	0	0	0	7	6	9	7	9	3	5	0	3
Bolivina lanceolata	0	0	1	0	0	0	0	0	0	0	0	0
Bolivina lowmani	0	1	1	0	0	1	0	0	0	0	0	0
Cassidulinoides bradyi	0	0	0	0	0	0	0	0	0	0	1	0
Discorbis mira	0	0	0	0	0	0	0	0	0	1	7	0
Discorbis rosea	0	0	0	0	0	0	0	1	0	0	0	0
Elphidium advenum	0	0	0	0	0	0	0	0	1	0	0	0
Elphidium discoidale/ Cribroelphidium poeyanum	35	55	93	56	87	147	106	142	105	89	35	120
Elphidium sagrum	0	4	4	8	1	4	5	0	0	1	0	1
Fursenkoina compressa	0	0	0	0	0	0	0	0	0	0	1	0
Miliolinella circularis	0	0	1	1	1	0	0	0	0	14	66	3
Milionella labiosa	0	0	0	0	0	0	0	0	0	0	4	0
Nonion grateloupi	0	0	0	0	0	0	0	0	0	0	1	0
Quinqueloculina agglutinans	0	0	0	0	0	0	0	0	0	0	1	0
Quinqueloculina bosciana	2	1	0	0	0	0	0	0	0	3	30	0
Quinqueloculina lamarckiana	19	0	0	0	0	0	0	0	1	16	26	2
Quinqueloculina poeyana	10	0	0	0	0	0	0	0	7	38	32	2
Quinqueloculina wiesneri	0	0	0	0	0	0	0	0	0	0	3	0
Rosalina floridana	1	0	0	0	0	0	0	0	0	0	1	0
Rosalina floridensis	0	1	0	0	0	1	0	0	1	0	1	0
Triloculina bassensis	0	0	0	0	0	0	0	0	0	0	10	0
Triloculina bermudezi	12	0	0	0	0	0	0	0	0	5	47	2
Triloculina fitterei var. *meningoi*	1	0	0	0	0	0	0	0	0	2	11	0
Triloculina linneiana	0	0	0	0	0	0	0	0	0	0	1	0
Triloculina planciana	0	0	0	0	0	0	0	0	0	2	1	1
Triloculina rotunda	53	0	0	0	0	0	0	0	2	6	7	1
Triloculina sidebottomi	3	0	0	0	0	0	0	0	0	0	0	0
Triloculina tricarinata	4	0	0	0	0	0	0	0	0	0	1	0
Triloculina trigonula	1	0	0	0	0	0	0	0	0	2	7	1
Trochammina japonica	0	0	0	0	1	1	0	2	0	0	0	2
Valvulina oviedoiana	0	0	0	0	0	0	0	0	0	1	0	0
Rotaliids	2	6	3	0	1	0	1	0	4	11	17	8
SUM	320	314	314	319	316	319	318	317	318	317	320	305

Lowermost sample excluded from the analyses because it was contaminated with modern material during the coring process.

Appendix P: Pollen absolute abundance data for Black Point North core (GLW603-BPNA).

	Sample depth in cm													
	0-2	4-6	10-12	14-16	20-22	24-26	30-32	34-36	40-42	50-52	60-62	70-72	80-82	86-86.5
Acer	7	7	5	3	2	0	0	0	0	0	0	0	0	0
Alnus	0	3	0	1	0	0	1	0	0	1	0	0	1	0
Carya	1	0	0	1	0	0	0	0	0	0	1	0	0	1
Cephalanthus	3	4	1	1	0	0	1	0	1	0	0	0	0	1
Casuarina	31	9	5	10	5	0	0	0	0	0	2	0	0	0
Conocarpus	0	1	0	0	0	0	0	0	0	2	0	0	0	0
Ilex	0	0	0	0	2	0	2	1	1	0	1	1	0	0
Laguncularia	14	28	7	4	5	3	3	4	2	0	8	1	0	0
Liquidambar	0	1	1	2	0	0	1	0	0	0	0	0	0	0
Magnolia	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Myrica	16	5	7	13	10	4	8	8	8	4	11	9	4	0
Nyssa	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Pinus	93	58	78	132	137	150	247	144	186	202	232	273	281	35
Quercus	77	32	12	11	8	7	4	9	4	10	9	8	11	2
Rhizophora	8	38	16	18	13	3	3	0	1	6	5	3	1	0
Ulmus	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ambrosia	27	13	31	26	18	2	1	2	2	1	9	2	0	0
Aster Indet.	7	10	11	28	1	1	4	1	1	3	10	2	1	0
Brassicaceae	2	0	0	12	0	0	0	0	0	2	2	0	0	0
Cheno-Ams	13	14	6	25	14	4	2	3	4	4	9	7	4	0
Cyperaceae	1	2	1	2	0	0	1	1	0	0	1	1	0	0
Fabaceae	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hibiscus	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Nymphaea	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Poaceae	5	3	2	6	4	3	0	1	1	0	0	0	0	0
Sagittaria	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Typha	0	9	0	0	0	0	0	1	0	0	0	0	1	0
Vitis	3	0	0	0	0	0	0	0	0	0	0	0	1	0
SCO	0	1	1	2	1	0	1	1	7	0	0	1	0	0
SAO	0	1	2	2	2	2	4	2	2	2	6	2	2	0
Osmunda	0	0	1	2	1	0	0	0	1	2	1	1	0	0
PO3	3	10	8	5	1	0	0	0	0	0	3	1	0	0
PC3	1	1	0	0	0	0	0	1	0	2	0	2	0	0
Total	314	250	196	310	224	180	283	179	221	241	311	314	307	39
Crumpled	0	5	2	0	0	0	0	0	0	0	2	0	0	0
Exotic	1154	1093	732	590	1117	912	440	768	386	242	781	289	568	177

Appendix Q: Ostracode absolute abundance data from Chicken Key core (GLW603-CKA).

Sample depth in cm	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	32
Actinocythereis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Acuticythereis lacvissima	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Bairdiids	2	0	0	1	1	0	0	1	1	0	1	4	1	3	7	3
Candona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caudites/ Neocaudites	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Cyprid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cytherelliids	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Cytheromorpha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cytherura	5	3	0	4	4	1	3	3	6	18	23	20	14	4	7	1
Heterocyprid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Loxoconcha levis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Loxoconcha matagordensis	3	4	1	3	4	1	2	0	5	29	23	21	16	21	17	10
Malzella floridana	6	10	4	3	4	3	3	2	9	17	23	26	24	21	20	9
Megacythere johnsoni	1	5	5	4	1	0	0	3	0	5	6	5	9	5	14	3
Paracytheridea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peratocytheridea setipunctata	55	68	78	80	83	87	89	91	76	24	13	15	27	32	26	15
Puriana convoluta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quadracythere	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radimella/ Jugosocythereis/ Hermanites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulocithereis	4	5	5	3	2	4	3	0	2	0	2	1	0	1	0	0
Thalassocypria	0	0	0	0	0	0	0	0	1	0	1	2	1	2	1	0
Xestoleberis spp.	26	14	5	3	2	2	0	0	1	7	7	10	7	11	3	1
OTHER	0	0	0	0	0	1	0	0	0	0	0	0	2	3	5	1
TOTAL	102	109	100	101	101	100	100	101	101	100	101	104	101	103	100	43

Appendix Q: Ostracode absolute abundance data from Chicken Key core (GLW603-CKA).

Sample depth in cm	34	36	38	40	42	44
Actinocythereis	0	0	0	0	0	0
Acuticythereis lacvissima	0	0	0	0	0	0
Bairdiids	0	0	0	0	0	0
Candona	0	0	0	0	0	0
Caudites/ Neocaudites	0	0	0	0	0	0
Cyprid	0	0	0	0	0	0
Cytherelliids	0	0	0	0	0	0
Cytheromorpha	0	0	0	0	0	0
Cytherura	0	0	0	0	0	0
Heterocyprid	0	0	0	0	0	0
Loxoconcha levis	0	0	0	0	0	0
Loxoconcha matagordensis	2	0	0	0	0	0
Malzella floridana	3	0	0	0	0	0
Megacythere johnsoni	1	0	0	0	0	0
Paracytheridea	0	0	0	0	0	0
Peratocytheridea setipunctata	3	0	0	0	0	0
Puriana convoluta	0	0	0	0	0	0
Quadracythere	0	0	0	0	0	0
Radimella/ Jugosocythereis/ Hermanites	0	0	0	0	0	0
Reticulocithereis	0	0	0	0	0	0
Thalassocypria	0	0	0	0	0	0
Xestoleberis spp.	1	0	0	0	0	0
OTHER	0	1	0	0	0	0
TOTAL	10	0	0	0	0	0

SAMPLES BELOW 46 CM SCANNED FOR OSTRACODES - NONE FOUND

Appendix R: Molluscan absolute abundance data, excluding worn and fragmented specimens, from Chicken Key core (GLW603-CKA).

	Sample depth in cm									
	0	8	16^	24	32	40	48	64	72	76
Acteocina canaliculata	8	0	1	6	*	*	0	0	0	0
Anomalocardia auberiana	9	64	20	5	8	1	*	1	0	0
Arcopsis adamsi	0	0	0	0	0	*	0	0	0	0
Astyris lunulata	*	3	*	5	2	0	0	0	0	0
Batillaria minima	11	46	12	1	1	0	0	0	0	0
Bittiolum varium	25	97	35	91	62	5	0	2	0	0
Brachidontes exustus	94	17	13	10	4	*	0	*	0	*
Bulla striata	5	*	11	1	1	0	0	0	0	0
Caecum cornucopiae	1	1	1	2	2	0	0	0	0	0
Caecum pulchellum	23	18	3	20	10	0	0	0	0	0
Carditamera floridana	8	32	5	10	5	0	0	0	0	0
Cerithiopsis greeni	1	0	0	1	0	0	0	0	0	0
Cerithium muscarum	22	115	67	42	13	3	0	0	0	0
Chione cancellata	0	1	2	1	0	0	0	0	0	0
Codakia spp.	0	2	0	0	0	0	0	0	0	0
Crepidula spp.	6	22	17	37	16	1	0	0	0	0
Cyclostremiscus suppressus	2	0	3	11	13	0	0	0	0	0
Eulithidium affine	*	1	0	0	0	0	0	0	0	0
Granulina hadria	8	2	2	1	0	0	0	0	0	0
Haminoea elegans?	1	1	0	0	0	0	0	0	0	0
Hydrobiids	0	0	3	0	0	0	0	0	0	0
Laevicardium mortoni	3	4	2	1	1	*	0	0	0	0
Limaria sp. cf. *L pellucida*	0	0	0	*	*	*	0	0	0	0
Marshallora nigrocincta	1	0	1	0	0	0	0	0	0	0
Melampus coffeus	1	0	1	0	0	0	0	0	0	0
Modiolus sp.?	0	0	0	*	0	0	0	0	0	0
Modulus modulus	0	0	4	1	3	0	0	0	0	0
Mysella sp.?	0	0	0	0	1	0	0	0	0	0
Nassarius albus	2	1	1	1	*	0	0	0	0	0
Odostomia laevigata	8	11	8	9	1	0	0	0	0	0
Odostomia producta	*	1	0	1	0	0	0	0	0	0
Olivella pusilla	0	0	1	*	*	0	0	0	0	0
Parastarte triquetra	175	363	113	4	5	*	1	0	0	0
Parvilucina multilineata	0	1	0	0	1	0	0	0	0	0
Prunum apicinum	4	0	0	0	0	0	0	0	0	0
Prunum sp.	0	20	18	18	2	*	0	*	0	0
Prunum sp. A	8	0	0	0	0	0	0	0	0	0
Prunum sp. B	17	0	0	0	3	0	0	0	0	0
Pteria longisquamosa	0	0	0	*	0	0	0	0	0	0
Puberella intrapurpurea	0	0	0	0	1	0	0	0	0	0
Rictaxis punctostriatus	0	2	0	1	0	0	0	0	0	0
Ringicula semistriata	0	2	0	0	0	0	0	0	0	0

*Indicates taxonomic group is present in sample as a worn or fragmented specimen (or specimens), but is not included in counts for analytical purposes.

Appendix R: Molluscan absolute abundance data, excluding worn and fragmented specimens, from Chicken Key core (GLW603-CKA).

	Sample depth in cm									
	0	8	16^	24	32	40	48	64	72	76
Schwartziella catesbyana	6	15	5	21	22	4	0	0	0	0
Stellatoma stellata	1	3	*	0	*	0	0	0	0	0
Teinostoma biscaynense	1	2	0	0	0	0	0	0	0	0
Tellina spp.	6	40	12	19	1	*	*	0	0	0
Teredinidae	0	0	1	0	0	0	0	0	0	0
Transennella sp.	3	4	1	2	5	1	0	0	0	0
Truncatella caribaeensis	3	0	1	*	0	0	0	0	0	0
Truncatella sp.	0	*	0	0	0	0	0	0	0	0
Turbonilla spp.	1	2	*	*	*	*	*	*	*	*
Vitrinella floridana	2	0	0	2	0	0	0	0	0	0
OTHER Gastropods	2	*	2	1	0	0	0	0	0	0
OTHER Pelecypods	0	0	1	0	0	*	*	0	0	0
Total taxonomic groups present including fragments & worn	36	33	34	35	30	16	5	5	1	2
Total taxonomic groups present excluding fragments and worn	33	30	31	29	24	6	1	2	0	0
Total abundance/sample (excluding fragments & worn)	468	893	367^	325	183	15	1	3	0	0

^Sample too large to pick entire fraction >850 microns so sample was split. Picked fraction = 46% of the weight of the entire sample, so counts do not represent total samples counts but ~46% of sample. Total abundance shows total of counted specimens. Estimate for total number of specimens in sample (excluding worn and fragmented) is 798.

*Indicates taxonomic group is present in sample as a worn or fragmented specimen (or specimens), but is not included in counts for analytical purposes.

Appendix S: Foraminfer absolute abundance data from Chicken Key core (GLW603-CKA).

	Sample depth in cm										
	0-2	8-10	16-18	24-26	32-34	40-42	48-50	56-58	64-66	72-74	76-77.5
Ammonia parkinsoniana var. *tepida*	4	40	40	40	0	0	0	0	0	0	0
Ammonia parkinsoniana var. *typica*	6	40	40	42	1	4	10	0	1	0	0
Articulina mucronata	8	1	1	0	0	0	0	0	0	0	0
Articulina pacifica	0	0	1	0	0	0	0	0	0	0	0
Articulina sagra	2	1	1	0	0	0	0	0	0	0	0
Bolivina lanceolata	0	0	0	8	0	0	0	0	0	0	0
Bolivina lowmani	0	1	0	0	0	0	0	0	0	0	0
Bolivina striatula	0	0	0	2	0	0	0	0	0	0	0
Discorbis mira	0	0	0	1	0	0	0	0	0	0	0
Elphidium discoidale/ Cribroelphidium poeyanum	14	78	105	137	5	3	2	0	0	0	0
Elphidium sagrum	0	1	0	0	0	0	0	0	0	0	0
Miliolinella circularis	6	2	0	1	0	0	0	0	0	0	0
Milionella fichteliana	1	0	0	0	0	0	0	0	0	0	0
Milionella labiosa	2	0	0	0	0	0	0	0	0	0	0
Nonion grateloupi	0	0	0	2	0	0	0	0	0	0	0
Quinqueloculina agglutinans	0	1	0	0	0	0	0	0	0	0	0
Quinqueloculina bicarinata	0	0	0	1	0	0	0	0	0	0	0
Quinqueloculina bosciana	16	26	24	16	0	0	0	0	0	0	0
Quinqueloculina lamarckiana	7	24	23	16	0	0	0	0	0	0	0
Quinqueloculina poeyana	78	27	21	12	0	0	0	0	0	0	0
Quinqueloculina wiesneri	0	1	0	0	0	0	0	0	0	0	0
Robertinoides bradyi	0	0	1	0	0	0	0	0	0	0	0
Rosalina floridana	0	1	0	0	0	0	0	0	0	0	0
Rosalina floridensis	0	0	1	0	0	0	0	0	0	0	0
Spiroloculina antillarum	1	0	0	0	0	0	0	0	0	0	0
Tretomphalus atlanticus	0	0	1	0	0	0	0	0	0	0	0
Triloculina bassensis	26	0	0	2	0	0	0	0	0	0	0
Triloculina bermudezi	13	2	2	2	0	0	0	0	0	0	0
Triloculina fitterei var. *meningoi*	18	10	4	2	0	0	0	0	0	0	0
Triloculina linneiana	44	28	8	6	0	0	0	0	0	0	0
Triloculina planciana	26	19	17	5	0	0	0	0	0	0	0
Triloculina rotunda	16	5	9	3	0	0	0	0	0	0	0
Triloculina sidebottomi	6	0	1	0	0	0	0	0	0	0	0
Triloculina tricarinata	8	1	1	1	0	0	0	0	0	0	0
Triloculina trigonula	13	3	4	1	0	0	0	0	0	0	0
Trochammina japonica	0	0	0	1	0	0	0	0	0	0	0
Rotaliids	1	3	11	14	0	0	0	0	0	0	0
SUM	316	315	316	315	6	7	12	0	1	0	0

Appendix T: Pollen absolute abundance data from Chicken Key core (GLW603-CKA).

	Sample depth in cm												
	0-2	4-6	10-12	14-16	20-22	24-26	30-32	34-36	40-40	50-52	60-60	70-70	76.75
Acer	0	0	0	0	1	0	0	0	0	0	0	0	0
Alnus	1	0	0	0	2	0	0	0	0	0	0	0	0
Carya	0	0	0	0	1	0	1	0	0	0	0	1	0
Casuarina	1	19	12	12	46	34	9	2	0	0	0	0	0
Ilex	0	0	0	0	0	1	0	0	0	1	0	0	0
Laguncularia	0	2	0	5	2	0	0	1	0	0	0	0	0
Liquidambar	0	0	0	0	0	1	0	0	0	1	0	0	0
Myrica	0	8	1	4	27	19	12	10	3	13	2	2	3
Pinus	8.5	47	21	57	150	174	144.5	264	251.5	225.5	269.5	296	276
Quercus	6	56	15	23	45	18	17	7	4	7	5	3	1
Rhizophora	0	0	0	3	5	1	3	1	0	2	0	0	0
Ambrosia	0	7	2	5	26	26	24	7	1	1	0	0	1
Aster Indet.	1	7	1	1	5	10	7	2	1	3	1	0	0
Callicarpa	0	0	0	0	0	2	2	0	0	1	0	0	1
Cheno-Ams	0	7	3	4	7	15	4	0	3	0	4	4	3
Cyperaceae	0	1	0	0	0	0	0	0	0	0	0	0	0
Descurainia	0	2	0	0	0	2	0	0	0	0	0	0	0
Plantago	0	0	0	1	0	0	0	0	0	0	0	0	0
Poaceae	0	2	0	4	0	4	2	4	0	1	0	0	0
Sagittaria	0	0	0	0	0	0	0	1	0	0	0	0	0
Sapindaceae	0	0	0	0	1	0	0	0	0	0	0	0	0
Solanaceae	0	7	0	0	0	1	1	1	0	0	0	0	0
Typha	0	1	0	0	0	0	0	0	0	1	0	0	0
Vitis	0	0	0	0	1	3	0	0	0	0	2	0	0
Waltheria	0	1	0	0	0	0	0	0	0	0	0	0	0
SCO	0	1	0	0	0	1	0	0	1	0	0	0	2
SAO	0	2	1	2	3	2	2	0	0	0	3	3	1
PO3	0	2	1	6	15	3	4	0	0	0	0	0	0
PC3	0	3	1	1	4	2	0	1	0	0	0	1	2
Total	17.5	175	58	128	341	319	232.5	301	264.5	256.5	286.5	310	290
Crumpled	0	2	0	1	6	0	1	0	0	0	0	0	0
Exotic	392	1696	1320	648	234	431	685	380	71	161	136	51	58