FORAMINIFERA AS INDICATORS OF HYPOXIA OFF SOUTHWEST PASS, MISSISSIPPI DELTA, GULF OF MEXICO?

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The continental shelf west of the Mississippi River Delta (the Louisiana Bight) experiences seasonal hypoxia that has been increasing in frequency since the second half of the 20th century due to anthropogenic influence. To address the impact of hypoxia in the easternmost Lousiana Bight, this study looks at benthic foraminiferal assemblages from four ~2 m kasten cores taken southwest of Southwest Pass of the Mississippi River Delta. The PEB index, a proxy for hypoxia, is composed of the combined percentages of *Protononion atlanticum (= Nonionella atlantica* of this study), *Nonionella opima*, *Epistominella vitrea* and *Buliminella morgani*. Little variation in the PEB index occurred throughout the assemblages of the shallowest core, KC4, from 59 m water depth. Assemblages were strongly dominated by PEB index taxa giving an average value of 95%. This high PEB index value is due mainly to *E. vitrea* dominating the assemblages with a core average of 76% for this taxon. Core KC3 from 75 m was also dominated by *E. vitrea,* which averaged 61% and contributed to an average PEB index value of 84%. The PEB index of core KC3 changed with core depth and was consistently higher in the top 90 cm. The shift to increased PEB index occurred between 1946 and 1951 according to ^{210}Pb-derived age estimates, and could be due to an increased influence of hypoxia or a change in environment

associated with Mississippi delta progradation. A similar trend can be seen in core KC2 from 87 m. The PEB index is approximately 18% from 240 cm, core bottom, to 140 cm, where it begins to increase due almost entirely to an increase in *E. vitrea*. This trend is also interpreted as reflecting an increasing influence from the Mississippi River. The top 30 cm of the core shows an increase in the other PEB taxa, *B. morgani* and *N. opima;* this shift is interpreted as reflecting increasing hypoxia that occured between 1930 and 1945 according to ^{210}Pb-derived age estimates. Core KC1 from within the Mississippi Canyon, at 473m, had high diversity assemblages with *Bolivina lowmani, Cassidulina neocarinata*, and *Bolivina ordinaria* each comprising ~15% of assemblages. The PEB index taxa comprised only a minor part of the assemblage except for a 30 cm interval where PEB index values increased from an average of 5% to 19%, likely representing an interval of increased off-shelf transport. In summary, PEB index values reflect increasing hypoxia in the study area over the past 60 to 80 years but are also probably affected by sedimentological factors related to Mississippi River discharge.

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TABLE OF CONTENTS

LIST OF FIGURES....x

LIST OF TABLES....xi

INTRODUCTION....1

PREVIOUS WORKS....2

Foraminiferal Distriubtion....2

Hypoxia....6

Proxies for Hypoxia....8

Foraminiferal Adaptation to Hypoxia....9

History of Hypoxia in the Louisiana Bight....12

METHODS....14

Sample Collection....14

^{210}Pb Analysis....14

Numerical Analysis....15

RESULTS....16

Sedimentology and Sedimentation Rates....16

Foraminiferal Assemblages....18

PEB index....21

Cluster Analyses....22

DISCUSSION....28

Species Richness and Percent of planktonics....28

High PEB Index Values and Sieve Size....28

Effect of the Mississippi Delta on Abundance of *Epistominella vitrea*....30

Temporal Trends in *Epistominella vitrea*.... 32

Record of Hypoxia....32

CONCLUSIONS....34

REFERENCES....36

APPENDIX 1: Taxonomic reference list....48

APPENDIX 2: X-radiographs of cores 51

APPENDIX 3: Core metadata....52

APPENDIX 4: Foraminiferal census data....53

APPENDIX 5: Foraminiferal relative abundance data....59

APPENDIX 6: Arcsine square-root transformed foraminiferal census data for cluster analysis .65

LIST OF FIGURES

Figure 1: Map of the study area showing locations of the cores of this study (KC1 to KC4) as well as core and sample sites from other related studies (Blackwelder, 1996; Nelson, 1996; Chen et al., 2001; Platon et al., 2005; Osterman et al., 2009). The outline of the area in the Lousianan Bight affected by hypoxia is taken from CENR (2000) ……………….…………………………3

Figure 2: Map of the frequency of occurance of hypoxia across the Louisiana shelf, averaged from the years 1985 to 1999. Modified from CENR, 2000………………...…………………....8

Figure 3: The line represents the accumulation rate determined for KC2 using excess ^{210}Pb activity below the shift at ~10 cm due to a hurricane deposit above this depth (Rabien, 2013). Box core data are from Rabien (2012)…………………………………………………….……17

Figure 4: Plots of (A) Species richness and (B) percent planktonics for cores KC1–KC4….…19

Figure 5: The PEB index of each sample from the four cores is shown together with the percent abundance of the four taxa comprising the index. Note the legend in the bottom right………..20

Figure 6: The combined percentage of *Buliminella morgani, Nonionella opima* and *N. atlantica* in core KC2, with dates drived from ^{210}Pb age estimates. The dates start at 1990 due to the loss of sediment during retrvial of the core…………………………………………………………22

Figure 7: Dendrograms showing the results of cluster analysis of each core………………….24

Figure 8: Dendrogram showing the results of cluster analysis of all cores combined………... 24

LIST OF TABLES

Table 1: Mean percent abundance of taxa in groups defined by cluster analysis of the foraminiferal assemblage data in core KC3……………………………………………………26

Table 2: Mean percent abundance of taxa in groups defined by cluster analysis of the foraminiferal assemblage data in core KC2……………………………………………………27

INTRODUCTION

Hypoxia, commonly defined as dissolved oxygen levels of < 2 mg/L (2.8 ml/L), is the condition in which oxygen concentrations in water are low enough to have a negative effect on aquatic life. Where rivers enter marine water they can create conditions conducive to hypoxia as their fresh water outflow causes water column stratification and carries nutrients that promote eutrophication. The eutrophication causes algal blooms which sink to the seafloor and undergo decay that depletes the water of oxygen. The stratified water column does not allow replenishment of oxygen to the sea floor thus leaving a hypoxic environment.

Extensive studies of coastal hypoxia began in the 1980s (Nixon, 1997). Marine hypoxic events were becoming more prevalent as the result of anthropogenic effects such as fertilizer-related nutrient loading from rivers (Gooday et al., 2009). But records of hypoxia for any given area are limited to when field observations began, with some of the longest records only reaching back to 1985 (CENR, 2000). Fortunately, multiple proxies exist that can be used to provide a longer history of hypoxia. One of these proxies is foraminifera. They are a useful proxy because they respond to changes in the benthic environment and are abundant in the sediment record. Foraminiferal assemblages have been shown to be useful as hypoxia proxies at many locations: North Adriatic Sea (Barmawidjaja et al., 1995); Mississippi Delta, U.S.A. (Blackwelder et al., 1996); Chesapeake Bay, U.S.A. (Karlsen et al., 2000); Drammensfjord, Norway (Alve, 2000); Long Island Sound, U.S.A. (Thomas et al., 2000); St. Lawrence Estuary, Canada (Thibodeau et al., 2006); Gulf of Tehuantepec, Mexico (Vásquez-Bedoya et al., 2008); Osaka Bay, Japan (Tsujimoto et al., 2008). The hypoxic area to the west of the Mississippi Delta is one of the most extensively studied (e.g., Denne and Sen Gupta, 1993; Blackwelder et al., 1996; Sen Gupta et al., 1996; Platon and Sen Gupta, 2001; Osterman, 2003).

The Mississippi River is the sixth largest river in the world in terms of discharge and third largest in terms of drainage basin area at 3,203km^2 (Milliman and Meade, 1983). The Mississippi Bight (Fig. 1) has the second largest coastal anthropogenic hypoxia zone in the world (Rabalais et al., 2007a) with a recorded maximum of 22,000 km^2 and an average of 13,500 km^2 between 1985 and 2009 (Rabalais et al., 2010). Field measurements since 1985 have shown the hypoxic zone is increasing in size, from 8,200 km^2 in 1985–1992 to 10,500 km^2 in 2003–2007 (CENR, 2000; Rabalais et al., 2007a). Proxies representing hypoxia also show hypoxia was increasing before field measurements were taken in the Mississippi Bight; the timing of the increase in hypoxia has been reviewed by Rabalais et al. (2007b) and Osterman and others (2009). Despite numerous works on the history of hypoxia in the Mississippi Bight, the area directly southwest of Southwest Pass of the Mississippi Delta has gone unstudied. Based on foraminiferal data, Osterman and others (2009), however, suggested the general area near the Mississippi River Delta experienced hypoxia as far back as the early 1900s and noted that more hypoxia occurred farther west by the mid-1900s.

The purpose of this study is to investigate the history of hypoxia in the high sediment input area southwest of Southwest Pass, providing a record southeast of the region sampled by the Nutrient Enhanced Coastal Ocean Productivity program (Rabalais et al., 1991). Foraminiferal assemblages from four ~2m cores taken along a transect from near Southwest Pass across the shelf to the Mississippi Canyon are investigated for their utility as indicators of hypoxia in this region.

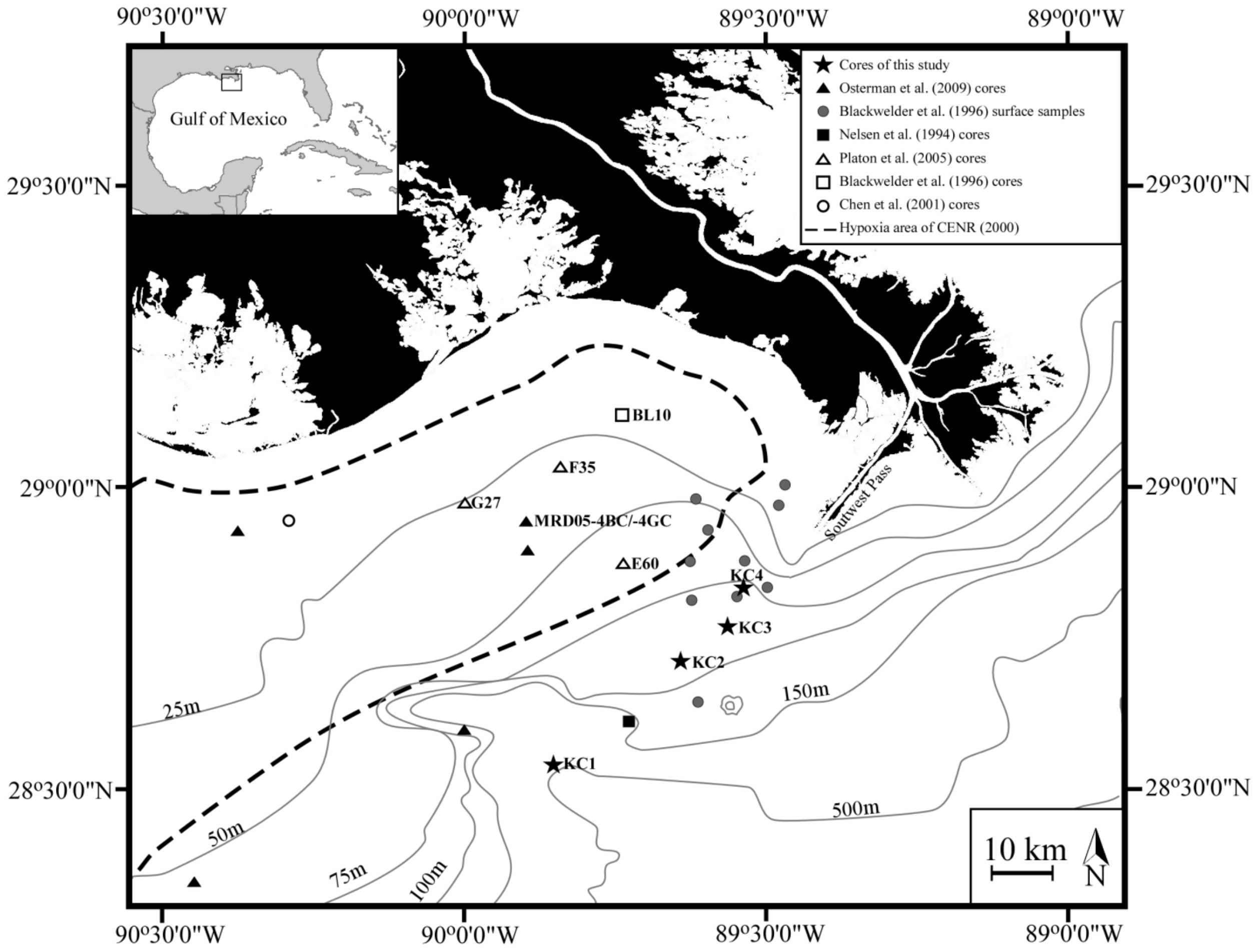

FIGURE 1. Map of the study area showing locations of the cores of this study (KC1 to KC4), as well as core and sample sites from other related studies (Blackwelder, 1996; Nelson, 1996; Chen et al., 2001; Platon et al., 2005; Osterman et al., 2009). The outline of the area in the Lousianan Bight affected by hypoxia is taken from CENR (2000).

PREVIOUS WORK

FORAMINIFERAL DISTRIBUTION

The distribution of foraminifera in the Gulf of Mexico began to be extensively studied in the 1950's (e.g., Lowman, 1949; Phleger and Parker, 1951; Parker, 1954; Phleger, 1954; Bandy, 1954, 1956; Lankford, 1959). In two early companion studies, Phleger and Parker (1951) and

Parker (1954) examined foraminifera in the west and east Gulf of Mexico, respectively, recognizing indicator species and defining a bathymetric zonation. Parker (1954) sampled 11 transects from the Mississippi River Delta to southern Florida. Using these data, she defined six depth facies and noted her shallowest facies, 12 to 80–100 m, was characterized by lower salinity immediately offshore of the subaerial Mississippi Delta. Albers (1966), with a committee of Gulf Coast paleontologists, defined biofacies within eight bathymetric zones ranging from brackish water to abyssal (>2000 m). Using the same eight bathymetric zones Tipsword et al. (1966) defined very similar biofacies for work in the recent as well as a different set of biofacies for paleontological work. Pielou (1979) used precedence analysis to reanalyze Parker's (1954) data and determined four indicator groups (bathymetric zones).

In the early 1980s several synthesis works on benthic foraminiferal distribution were published. Culver and Buzas (1981) compiled all published benthic foraminifera distribution data from the Gulf of Mexico before 1980, standardized the taxonomy and documented the distribution of 848 species. Culver and Buzas (1983) used cluster analysis of the data from Culver and Buzas, (1981) to define four zoogeographic provinces, the Inner Shelf Province, Outer Shelf Province, Slope and Abyssal Plain Province as well as a separate biofacies for the Mississippi River mouth. Poag (1981) used unsynonymized published data along with new samples to define predominance facies focusing on the most abundant genus in a sample, and defined 21 facies in the Gulf of Mexico. Culver (1988) used Phleger and Parker's (1951) and Parkers's (1954) data to define 14 *a priori* bathymetric intervals, six in the neritic zone, seven in the bathyal zone and one at abyssal depths. Buzas and Hayek (1998) used SHEBI (SHE analysis for Biozone Identification) analyses on transect six of Parker (1954), to determine seven biofacies between 20 m to 2697 m. These various studies demonstrate the robust nature of the foraminiferal depth zonations in the northern Gulf of Mexico, and show that no matter the type of analytical approach, whether generic or species level data were used, or whether full or partial datasets were employed, meaningful depth assemblages could be defined.

Some authors (van der Zwaan, 1990; Osterman, 2003) have pointed out a possible problem with the Parker (1954) dataset. In Parker's (1954) transect located off Southwest Pass of the Mississippi Delta, she found a unique assemblage that was dominated by the agglutinated taxa *Goesella mississippiensis* and *Textularia earlandi.* Calcareous benthic foraminifera comprised ≤ 3% of the assemblage in nine of the 11 samples. Her transect near Southwest Pass samples extended to 430 m, but planktonic foraminifera occurred in only one sample at 93 m. She attributed the composition of this assemblage to the Mississippi River and its effects on turbidity, food supply and chemistry.

Parker (1954) herself mentioned that there was evidence of decalcification of tests in some samples from her transects around the Mississippi Delta. Van der Zwann (1990) and Osterman (2003) later suggested post-collection dissolution had altered Parker's assemblages in the Mississippi River Delta area. These assemblages, however, had already been utilized in Albers et al. (1966), Culver (1988), Culver and Buzas (1981a), (1981b), (1983), Pielou (1979), Poag (1981), Buzas and Hayek (1998) and may have led to partially distorted interpretations of foraminiferal assemblages around the outflow of the Mississippi River. Greiner (1970) described the area immediately west of the Mississippi River mouth as dominated by agglutinated taxa (Greiner, 1970). Similarly, in the Mississippi River mouth biofacies, defined by Culver and Buzas (1983), *Texularia earlandi* and *Ammoscalaria pseudospiralis* were the diagnostic species due to the influence of the samples from Parker (1954). The biofacies, however, contained many calcareous taxas from several other studies such as *Ammonia beccarii*, *Epistominella exigua* (=

Epistominella vitrea of this study) and *Buliminella bassendorfensis* (= *Buliminella morgani* of this study) (Culver and Buzas 1983). Poag (1981) defined a *Nouria* and *Goesella* generic predominance facies southwest of the Mississippi River mouth using samples from Parker (1954). Poag (1981) also described assemblages near the delta and inshore of the *Nouria* and *Goesella* predominance facies as almost completely composed of *Epistominella* and *Nonionella.* In more recent studies of samples taken near the mouth of the Mississippi River, a calcareous, low diversity assemblage with high dominance of *Epistominella vitrea, Nonionella,* and *Buliminella morgani* has been described and could be related to the seasonal hypoxia that characterizes this area (e.g., Denne and Sen Gupta, 1993; Blackwelder et al., 1996; Sen Gupta et al., 1996; Platon and Sen Gupta, 2001; Osterman, 2003).

HYPOXIA

When the oxygen concentration of a system becomes low enough to affect the health of organisms, the system is said to be hypoxic. Hypoxia is defined as dissolved oxygen levels of < 2 mg/L (2.8 ml/L) (Pavela et al., 1983; Leming and Stuntz, 1984; Renaud, 1986). This definition was adopted by the Nutrient Enhanced Coastal Ocean Productivity program (Rabalais et al., 1991) and by most studies of northern Gulf of Mexico foraminifera (e.g., Blackwelder et al., 1996; Osterman, 2003; Platon and Sen Gupta, 2005; Brunner et al., 2006). Hypoxia in the northern Gulf of Mexico has been shown to be the result of two main factors: the stratification of the water column created by freshwater input from rivers, and decomposition on the seafloor of organic matter from phytoplankton blooms (CENR, 2000). The outflow of the Mississippi and Atchafalaya River creates a layer of warmer, fresher water on top of the seawater of the Gulf of Mexico. This stratification creates a halocline that prevents oxygen transport through dispersion or vertical mixing (Wiseman et al., 1997). The stratification is most prominent during the summer months (i.e., mid-May through mid-September) and is broken up by winter storms; thus, hypoxia occurs seasonally (Rabalais and Turner, 2001). The size and persistence of seasonal hypoxic events are controlled in part by the amount of Mississippi and Atchafalaya River discharge, increasing in size and lasting longer with increasing amounts of discharge (Wiseman et al., 1997; CENR, 2000). The outflow of the rivers brings nutrients (e.g., nitrogen, phosphorus, and silica) that facilitate the growth of phytoplankton. The phytoplankton eventually sink to the seabed and provide carbon for decomposition (Turner, 2002). Decomposition at the seafloor uses the poorly replenished dissolved oxygen of the bottom water leading to oxygen depletion (Rabalais et al., 1991; Turner and Rabalais 1994a; Eadie et al., 1994).

Hypoxia occurs west of the Mississippi Delta, offshore of the Louisiana coast (Fig. 2). The affected area can be as large as 22,000 km^2, averaging 16,500 km^2 in 2001–2006 (Rabalais et al., 2007). Recorded hypoxic conditions vary from 4–60 m water depth and are found in as much as two-thirds of the water column (CENR, 2000). The size and dimensions of hypoxic waters have been measured since 1985. Hypoxia does not necessarily occur every year in a particular area, but certain areas have more frequent occurrence of hypoxia (Fig. 2) (Rabalais et al., 1999; CENR, 2000). To get a better understanding of the complex history of the extent of hypoxia in the northern Gulf of Mexico since 1985, records have been developed across the shelf using proxies coupled with measurements of oxygen concentration (e.g., Turner et al., 1991, 1994, 2004; Eadie et al., 1994; Rabalais et al., 1996, 2000, 2004, 2007b; Sen Gupta et al., 1996; Chen et al., 2001; Platon et al., 2001, 2005; Osterman, 2003; Osterman et al., 2005, 2008, 2009; Brunner et al., 2006).

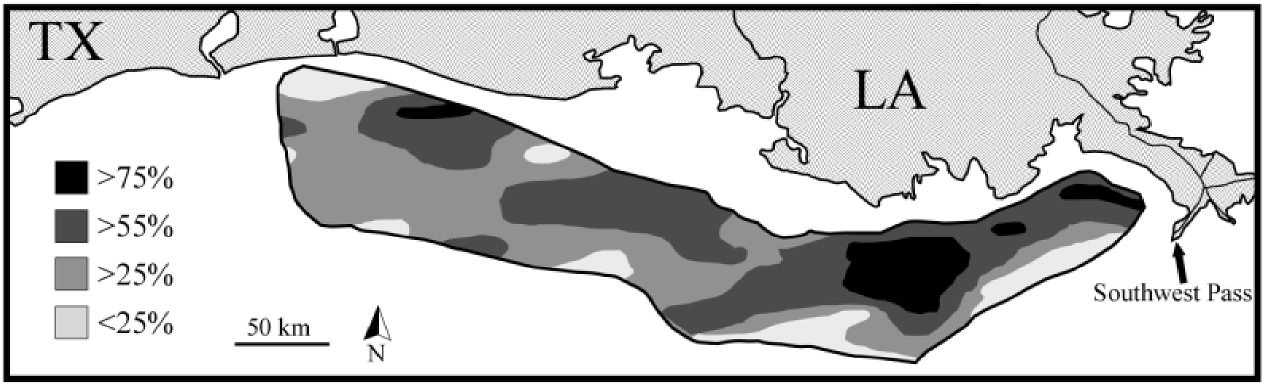

Figure 2. Map of the frequency of occurence of hypoxia across the Louisiana shelf, averaged for the years 1985 to 1999. Modified from CENR (2000).

PROXIES FOR HYPOXIA

Some proxies reflect the eutrophication that is an integral part of the creation of hypoxia. For example, diatoms increase in abundance and change relative abundances of taxa with eutrophication (Turner and Rabalais, 1994a; Parsons et al., 2002). Further, the amount of pigments from phytoplankton in sediment can serve as a reflection of phytoplankton biomass and thus a reflection of eutrophication (Rabalais et al., 2002, 2004). The concentrations of total marine organic carbon in cores indicate changes of past accumulation of organic matter, so increases in total marine organic carbon have been shown to reflect increasing phytoplankton blooms (Eadie et al., 1994, Turner and Rabalais, 1994b).

Other proxies are controlled by the low oxygen concentration in the water. Glauconite forms more rapidly in oxygen-stressed environments and its abundance in a core can reflect the history of hypoxia occurring in an area (Nelson et al., 1994). Also, assemblages of ostracods (Zarikian et al., 2000) and foraminifera (Blackwelder et al., 1996; Sen Gupta et al., 1996; Osterman, 2003; Platon and Sen Gupta, 2005; Brunner et al., 2006) change as certain taxa are better able to survive the oxygen-stressed environment. Foraminifera are considered to be particularly useful as they are abundant in sediment, easily preserved and affected but not killed by seasonal hypoxia (e.g., Moodley and Hess, 1992). Recurring seasonal hypoxia has been shown to alter species richness and evenness leaving a record of decreasing diversity with the increasing influence of hypoxia (Rabalais et al., 2007a).

FORAMINIFERAL ADAPTATION TO HYPOXIA

Foraminifera have the ability to survive hypoxia better than most meiofauna (Josefson and Widbom, 1988, Moodley et al., 1998), and some species are known to survive complete anoxia (e.g., Moodley and Hess, 1992; Bernhard, 1993; Alve and Bernhard, 1995; Moodley et al., 1997, 1998; Jannink et al., 1998) for as long as 86 days (Pina-Ochoa, 2010a). Foraminifera can do this by slowing metabolism, respiring through nitrate through denitrification, adapting unique cell ultrastructures, using symbiotic bacteria, or simply moving into the sediment. Bernhard and Alve (1996) used ATP measurements to show that under low oxygen conditions foraminifera can go into a dormant state; this state of dormancy may include development of a cyst that allows foraminifera to survive anoxia (Linke and Lutze 1993). Foraminifera are the only known eukaryote that respire through denitrification in environments lacking oxygen (Risgaard-Petersen et al., 2006, Høgslund et al., 2008, Pina-Ochoa et al., 2010b). Foraminifera have made many cell ultrastructural adaptations that help them survive low oxygen conditions such as retention of chloroplasts (Cedhagen, 1991) and amassing mitochondria near pores (Bernhard and Bowser, 2008).

FORAMINIFERAL PROXIES FOR HYPOXIA

Seasonal hypoxia leaves a detectable mark on foraminiferal assemblages in the Gulf of Mexico. Foraminiferal assemblages in the areas of seasonal hypoxia have lower species richness, lower abundances, lower amounts of agglutinated and porcelaneous foraminifera, and increases in species tolerant of oxygen stresses (e.g., Nelson et al., 1994; Blackwelder et al., 1996; Sen Gupta et al., 1996, Platon and Sen Gupta, 2001; Osterman, 2003; Brunner et al., 2006; Rabalais et al., 2007b). To understand these conditions, three taxa-based proxies have been established: the *Ammonia-Elphidium* (A-E) index (Sen Gupta et al., 1996), the agglutinated–porcelaneous (A-P) index (Platon and Gupta, 1995) and the *Protononion atlanticum*, *Epistominella vitrea*, and *Buliminella morgani* (PEB) index (Osterman, 2003).

The A-E index is calculated by $[N_A/(N_A + N_E)]*100$, where N_A is the amount of *Ammonia parkinsoniana* and the N_E is the amount of *Elphidium excavatum*. Increasing abundances of the stress-tolerant *Ammonia parkinsoniana*, and decreasing abundances of *Elphidium excavatum*, results in an increase in the A-E index, indicate increasing hypoxia. The A/E index is suggested for use in waters shallower than 30 m as the percentages of *Ammonia parkinsoniana* and *Elphidium excavatum* drop below useful levels in deeper waters (Platon and Sen Gupta, 2001). The reliability of this proxy has been questioned as it appears to rely more on the conditions changing in association with hypoxia, such as benthic trophic levels (Brunner et al., 2006).

Platon and Sen Gupta (2005) suggested the A-P index, which utilizes the percentages of all agglutinated and porcelaneous taxa. Agglutinated and porcelaneous taxa have been shown to become less abundant relative to calcareous hyaline taxa as hypoxia increases, sometimes disappearing from the assemblage completely (Rabalais et al.; 1996, 2000; Sen Gupta; 1996; Platon et al., 2005). The index reflects the decreasing diversity common in hypoxia-influenced samples and was found to correlate well with other proxies namely glauconite abundance and the concentration of biogenic silica (Platon et al., 2005).

Osterman (2003) developed the PEB index, calculated as the combined relative abundance of *Protononion atlanticum*, *Epistominella vitrea,* and *Buliminella morgani*. Osterman (2003) performed principal component analysis and cluster analysis on the assemblages of 74 surface samples taken within and outside areas of known hypoxia. She found *P. atlanticum, E. vitrea*, and *B. morgani* were the taxa that most strongly associated with the zones of hypoxia. Nelson et al. (1994) and Blackwelder et al. (1996) also found *B. morgani, Nonionella opima,* and *E. vitrea* to be associated with hypoxia. In a study of box cores from within the 1995 hypoxic zone, Platon et al. (2001) found that living (stained) *B. morgani, Brizalina lowmani* and *Nonionella basiloba* (=*Protononion atlanticum*) were associated with an infaunal microhabitat characterized by diminished oxygen concentration. *Epistominella vitrea* dominated their total (live plus dead) assemblages in samples from the hypoxic zone, but this taxon was assumed to have been transported into the study area by the Mississippi River plume (Platon et al., 2001). Blackwelder et al. (1996) had previously pointed out that high densities of *E. vitrea* are correlated with the Mississippi River plume as well as low oxygen environments.

Ernst et al. (2005) found that *Epistominella vitrea* migrated to shallower sediment and increased in abundance in the presence of organic matter. In the same experiment, *E. vitrea* did not respond to oxygen depletion. However, in a different laboratory observation *E. vitrea* migrated upward in the sediment in response to hypoxia (Alve and Bernhard, 1995). In field observations *E. vitrea* has been described as migrating up in the sediment seasonally, suggesting high infaunal mobility (Barmawidjaja et al., 1992). Near the mouth of the Rhone and Adour rivers *E. vitrea* has been found in areas with high inputs of food in the form of phytodetritus deposits (Duchemin et al., 2007; Mojtahid et al., 2008). Similarly *E. vitrea* are even seen to increase in abundance due to algal blooms (Gooday and Hughes, 2002; Langezaal et al., 2006).

Epistominella vitrea was also shown to be negatively affected by increasing frequencies of hypoxia, but less so than most other species (Duijnstee et al., 2004). In summary, evidence suggests that *E. vitrea* is resilient to hypoxia, but its changes in abundance could be responding other environmental variables associated with hypoxia such as food input associated with phytoplankton blooms.

History of Hypoxia in the Louisiana Bight

Proxies for oxygen stress and eutrophication have been used to understand the temporal and spatial history of hypoxia in the northern Gulf of Mexico. Foraminiferal proxies for hypoxia have shown change in the Louisiana Bight during the 1900s with a sharp increase around the 1950s–1960s (Blackwelder et al., 1996; Rabalais et al., 1996, 2000, 2007b; Sen Gupta et al., 1996; Platon et al., 2001, 2005; Osterman et al., 2005, 2008, 2009). This trend is seen in other proxies for low oxygen, including glauconite grain abundance (Nelson et al., 1994) and pigments from anoxygenic bacteria (Chen et al., 2001). Proxy records for eutrophication, such as phytoplankton pigments (Rabalais et al., 2004), frequency of biologically bound silica (Turner et al., 1994, 2004), and organic carbon accumulation (Eadie et al., 1994), show similar patterns. The exact timing of the changes in the stratigraphic record varies with proxy type and position on the shelf.

Periods of hypoxia occurred before anthropogenic influnce in the Louisiana Bight (Osterman et al., 2008), but have increased in the past century due to the impact of increased use of fertilizers in farming (CENR, 2000). Variations of the PEB index from within the hypoxic zone indicate at least five periods of hypoxic events between 1100 BP and the 1900s (Osterman et al., 2008). These events are attributed to natural increases in river flow which brings more intense stratification and increased nutrients (Osterman et al., 2008).

The beginning of anthropogenically enhanced expansion and frequency of modern hypoxia conditions occurred around the turn of the 20th century. Sen Gupta et al. (1996) documented one of the earliest signs for anthropogenic hypoxia in core G27 (Fig. 1) from the center of the modern day hypoxic zone. The core, which dates to ~1700 AD showed an A/E index that increased since the 1800s with a higher rate of increase in the 1900s. This environmental shift at the turn of the 20th century is seen in several proxies, such as the 1870s disappearance of the hypoxia-sensitive *Quinqueloculina* in core G27 (Fig. 1), taken inside the hypoxic zone in the Louisiana Bight (Rabalais et al.; 1996, 2000; Sen Gupta; 1996; Platon et al., 2005). This increase in hypoxia is also seen in the pigment concentration in sediment derived from two anoxygenic bacteria, which first appear in the 1900s (Chen et al., 2001). The foraminiferal assemblage of core BL10 (Fig. 1), of Nelson et al. (1994) and Blackwelder et al. (1996), from within the hypoxic zone shows a trend of decreasing species richness and a stronger influence of the low-oxygen adapted *Buliminella morgani* starting as early as the 1910s. Total pheopigment concentration, a proxy for eutrophication, from core D50 of Rabalais et al. (2004) shows an increase starting ~1930.

A much more pronounced change in proxies occurring during the late 1940s to the early 1960s has been well documented throughout the Louisiana Bight (Eadie et al., 1994; Turner et al., 1991, 1994, 2004; Rabalais et al., 1996, 2000, 2004, 2007b; Sen Gupta et al., 1996; Chen et al., 2001; Platon et al., 2001, 2005; Osterman et al., 2005, 2009). This increase in the area and temporal length of hypoxia since the 1950s has been attributed largely to the increased amount of the nutrients, primarily nitrogen in the form of nitrate, coming out of the Mississippi and Atchafalaya Rivers facilitating eutrophication of the Mississippi River basin (Rabalais et al., 1994, 1996, 1999; Rabalais and Turner 2001, 2006; Goolsby et al., 2001; Stow et al., 2005).

METHODS

SAMPLE COLLECTION

Sample material was collected during September 2007 aboard the R/V Pelican. Four ~2 m kasten-type gravity cores were collected along a transect southwest of Southwest Pass and into the Mississippi canyon (Fig. 1; Appendix 3); the cores were taken at water depths of 59 m, 75 m, 87 m, and 473 m. Immediately after collection, the cores were X-radiographed and wrapped in polyvinylidene chloride film. On return to the laboratory at East Carolina University, the cores were subsampled at 10 cm intervals; each sample comprised 1cm of the core. Samples were dried overnight in a low humidity oven at ~35°C. The samples were weighed to an accuracy of the nearest centigram, and then disaggregated in a beaker of tap water for 12–24 hours. Approximately 0.13 g of sodium hydroxide (NaOH) was added to aid disaggregation. Samples were washed over 710 μm and 63 μm sieves to remove coarse material and mud, and the >63 μm material was picked for foraminifera. Samples were split into aliquots, when necessary, with a riffle microsplitter. Splits were evenly spread on a gridded picking tray and a random number generator was used to select the squares to be picked. Approximately 200 specimens of benthic foraminifera were picked from each sample. Foraminifera were identified to the species level using classic references (e.g., Phleger and Parker, 1951; Parker, 1954). Identifications were confirmed via comparison with type and figured specimens, when available, at the Smithsonian Institution, Washington, D.C.

^{210}PB ANALYSIS

^{210}Pb levels were obtained via alpha spectroscopy following a modified method of Nittrouer et al. (1979). Samples were ground to a fine power and 1.0–1.5 g were spiked with a ^{209}Po tracer to act as a yield determinant. Samples were then digested for >12 hours in 8 N

HNO3 prior to a high temperature, high pressure, acid-leach in a CEM microwave reaction system (MARS 5). $^{210, 209}Po$ were electrodeposited on to nickel disc from the acidic solution following a modified version of the method from Flynn (1968). Supported levels of ^{210}Pb from decaying ^{226}Ra were obtained from samples where ^{210}Pb had reached a stable level deep in the core. Supported ^{210}Pb was subtracted from total ^{210}Pb activities to obtain excess ^{210}Pb activities. Linear sediment accumulation rates were determined by assuming:

$$A_x = A_0 e^{-\lambda x/S}$$

where A_x represents the excess ^{210}Pb activity at depth x (cm); A_0 represents the excess ^{210}Pb activity at the bottom boundary of the mixed layer; λ is the day constant of ^{210}Pb (0.031 yr^{-1}); and S is a linear sediment accumulation rate (cm yr^{-1}) (Appleby and Oldfield, 1992).

NUMERICAL ANALYSIS

The PEB index was used as a proxy for hypoxia as it is more applicable at the depths of the cores and the PEB taxa were present in all cores. *Nonionella atlantica* (= *Protononion atlanticum* of Osterman, 2003) was rare, and was grouped with *Nonionella opima,* a morphologically similar species, to obtain PEB values (analogous to the methodology of Osterman, 2006). Samples contained too few *Ammonia* and *Elphidium* for the A-E index to be of practical use as well as too few agglutinated and porcelaneous foraminifera for the A-P index.

Cluster analysis (Mello and Buzas, 1968) was performed on each core. Foraminiferal abundance data were transformed using an arcsine square-root transformation on the relative abundances of all species (Bartlett, 1947). The Q-mode cluster analyses used Ward linkage and Euclidean distance and was done on Paleontological Statistics (PAST) version 2.17.

RESULTS

SEDIMENTOLOGY AND SEDIMENTATION RATES

The sediment comprising the entirety of the four cores was dark green-gray mud. The >63 µm fraction of each sample was composed primarily of foraminiferal tests. X-radiographs of the four cores demonstrated the presence of a few slightly sandier intervals. In particular, the top ~5cm of Core KC2 is sandier and represents a bioturbated hurricane unit (Rabien, 2013) (Appendix 2). A single sample was taken from the top of this section (0–1 cm).

The down-core profile of ^{210}Pb activity from core KC2 and the ^{210}Pb activity of a box core taken from the same site at the same time are shown in Figure 3. This core was chosen for ^{210}Pb analysis because it contained two distinct core depth-related cluster groups. Comparison of the ^{210}Pb activity in kasten core KC2 to a box core collected at the same site (Rabien, 2012) gives an estimated loss of 8 cm of sediment from the top of the core during kasten coring. A sediment accumulation rate of 0.62 ± 0.03 cm/y was determined from the KC2 excess ^{210}Pb data. The ^{210}Pb activity of KC3 was not analyzed due to instrument failure, but a sediment accumulation rate of 1.99 ± 0.45 cm/y (Corbett et al., 2006) from another core at the same site was determined using excess ^{210}Pb and core top loss of 32 cm KC3 was estimated when the core was collected. Activities values of ^{210}Pb for KC1 and KC4 were not determined as their foraminiferal assemblages showed no significant trends over time.

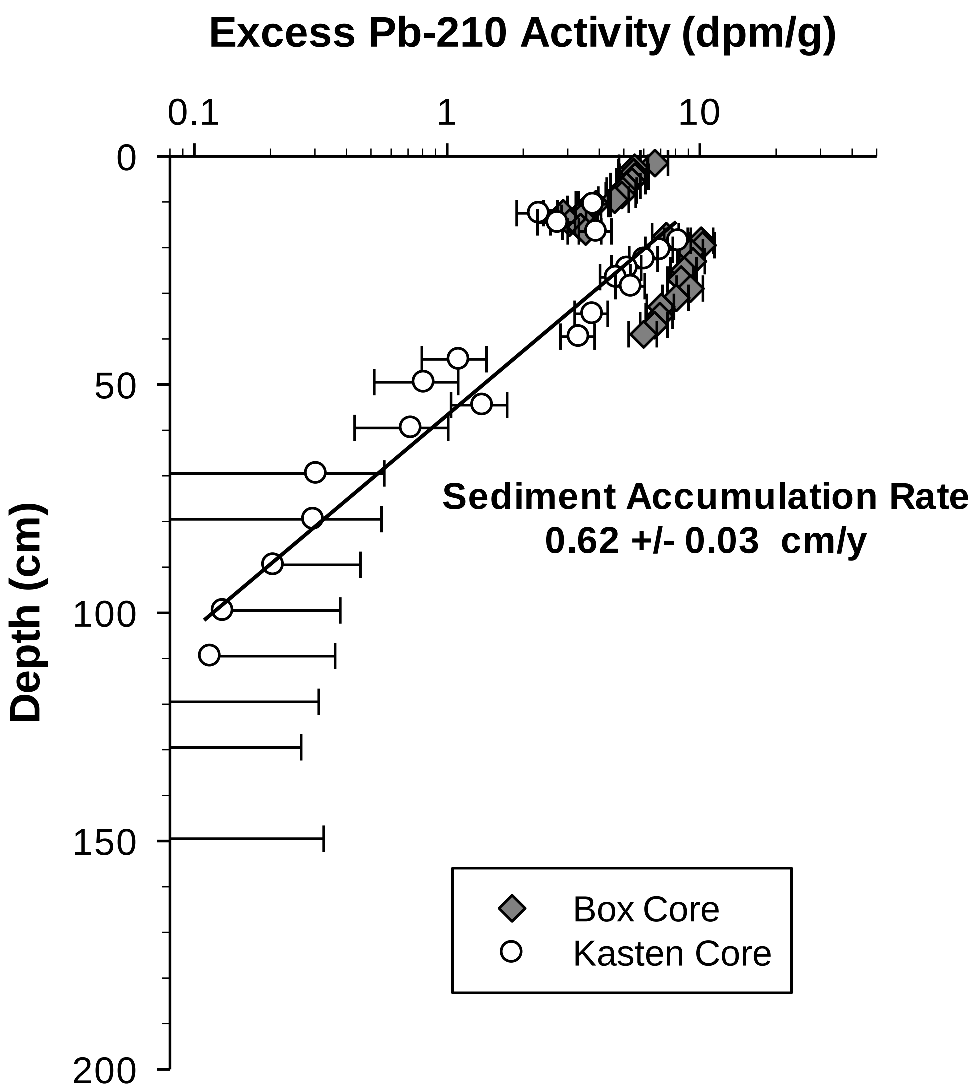

Figure 3.The line represents the accumulation rate determined for KC2 using excess ^{210}Pb activity below the shift at ~10 cm due to a hurricane deposit above this depth (Rabien, 2013). Box core data are from Rabien (2012).

Foraminiferal assemblages

Twenty five samples from the shallowest core (59 m water depth), KC4, contained 32 species (Appendix 3). The average percent planktonics was 1.2% (Standard Error (SE) = 0.2) and average species richness (S) was 8 (SE = 0.5) (Fig. 4) *Epistominella vitrea* was the most dominant species in all the samples of the core and comprised an average of 76% (SE = 2.0) of assemblages (Fig. 4). *Buliminella morgani* and *Nonionella opima* were also common, averaging 11% (SE = 1.0) and 8% (SE = 1.4) respectively.

Twenty samples from core KC3 (75 m water depth) contained 35 species (Appendix 3). The core had an average percent planktonics of 4.0% (SE = 0.5) and an average species richness (S) of 12 (SE = 0.2), both higher than in KC4 (Fig. 4). *Epistominella vitrea* was the most dominant species, averaging 61% (SE = 2.37) of the assemblages in the core (Appendix 4). *Buliminella morgani* was the second most common and averaged 18% (SE = 1.52); all other taxa averaged less than 5% of the total core assemblage.

Twenty samples from core KC2 (87 m water depth) contained 60 species (Appendix 3). The average percent planktonics of 18.6% (SE = 2.4) and the average species richness (S) of 23 (SE = 0.8) were both greater than in KC3 (Fig. 4). The percent planktonics showed a trend of decreasing steadily up-core above 130 cm (Fig. 4). *Epistominella vitrea* was again the most abundant taxa averaging 31% (SE = 3.28), much less than in KC4 and KC3 (Appendix 4). Species evenness is higher than in the other two shelf cores, KC3 and KC4, with *Bolivina lowmani*, *Uvigerina peregrina*, *Bulimina marginata*, and *Bolivina barbata* each comprising greater than 5% of the averaged assemblage for the core (Appendix 4).

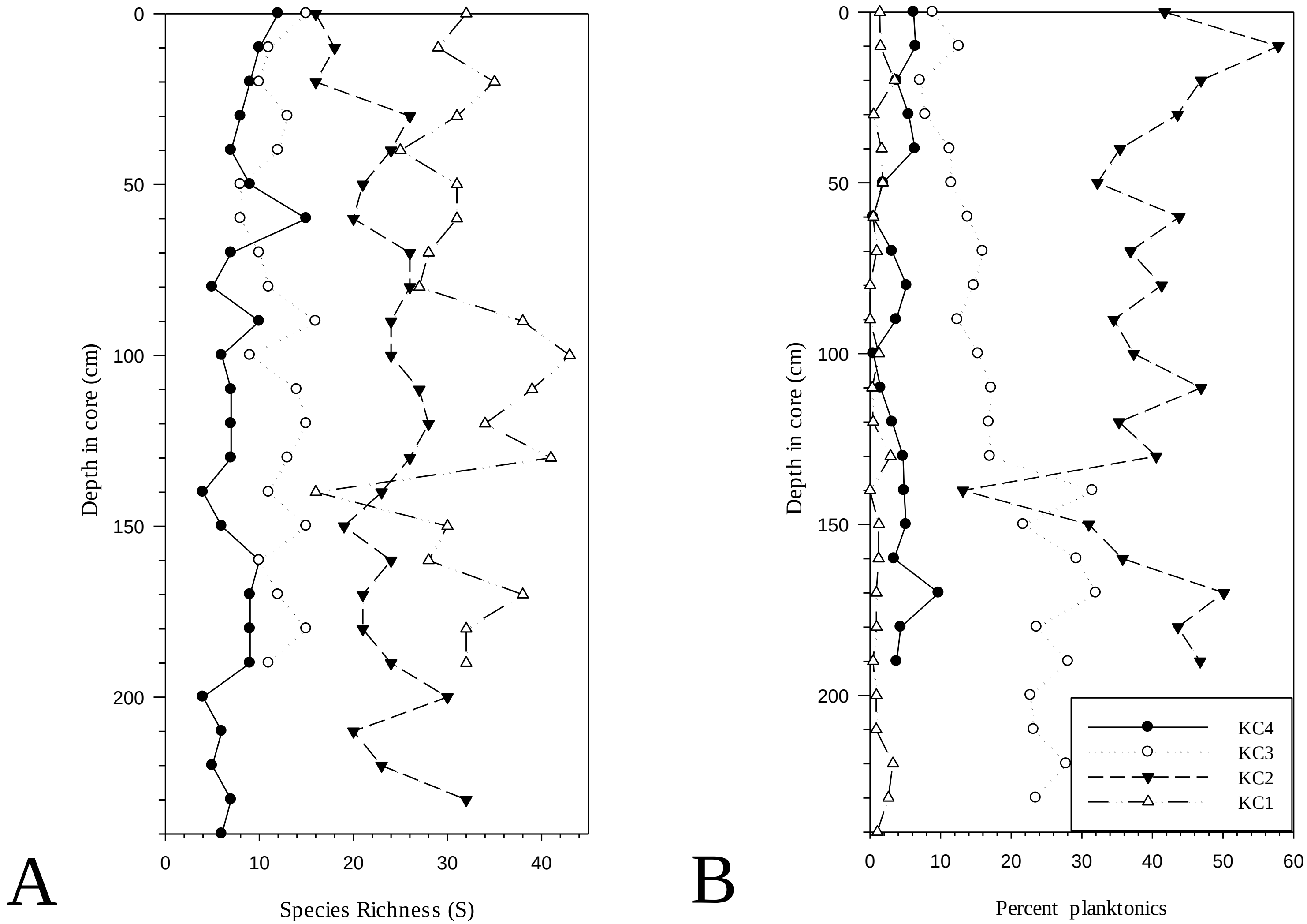

Figure 4. Plots of (A) Species richness and (B) percent planktonics for cores KC1–KC4.

Shallow Deep

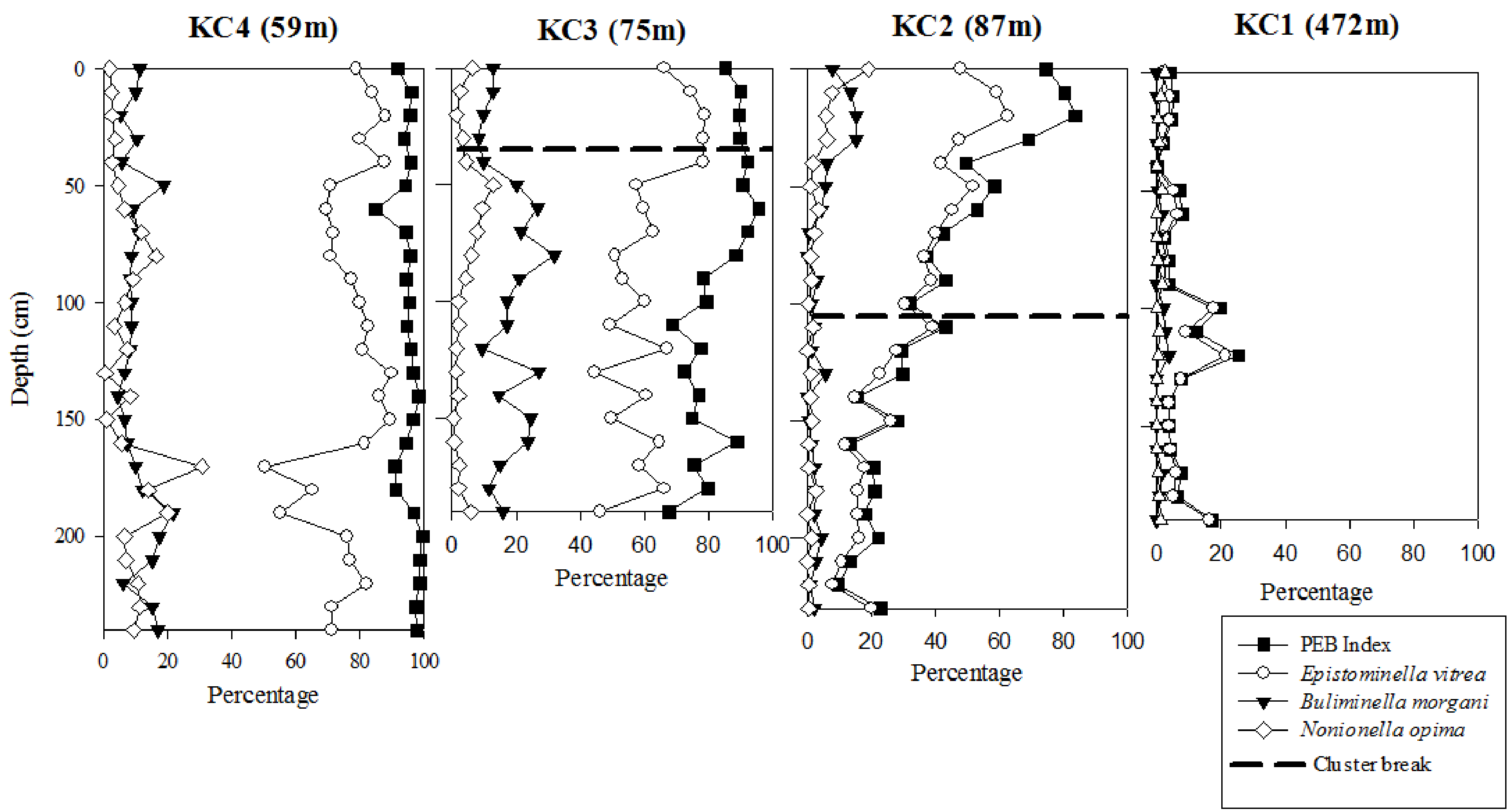

Figure 5. The PEB index of each sample from the four cores is shown together with the percent abundance of the four taxa comprising the index. Note the legend in the bottom right.

Twenty samples from core KC1, from within the Mississippi Canyon (473 m water depth), contained 78 species, 27 of which did not occur in any of the shelf cores (Appendix 3). The core had an average percent planktonics of 39.7% (SE = 3.4) and an average species richness (S) of 32 (SE = 1.3) (Fig. 4). *Bolivina lowmani*, common in the shelf assemblages, and deeper water taxa *Cassidulina necoarinata* and *Bolivina ordinaria* are the most abundant taxa with average relative abundances of 15% (SE = 3.0), 15% (SE = 3.8) and 13% (SE = 2.4), respectively.

PEB INDEX

Epistominella vitrea is the main contributor to the PEB index in every sample of each core (Fig. 5). The PEB index decreases with increasing water depth. In the shallowest core (KC4), the index averages 95% (SE = 0.6) but ranges as high as 99.6% (Fig.4). The PEB taxa comprise nearly the entire assemblage of each sample and exhibit little change in abundance throughout KC4 except from 170 to 190 cm where *E. vitrea* exhibits a slight decrease in relative abundance. Core KC3 has a lower average PEB index of 83% (SE = 1.9). PEB index values are higher for the upper portion of KC3 with an average of 90% (SE = 1.0) above 80 cm and 76% (SE = 1.7) lower in the core (Fig. 5). The relative abundance of *E. vitrea* increases in the top 40 cm of KC3 while the relative abundance of *Buliminella morgani* decreases in the same interval. The average PEB index for KC2 is less than half of KC3 at 38% (SE = 4.5). The PEB index from the core bottom to 140 cm averages 19% (SE = 1.8). It then increases to the top of KC2 with a peak value of 84% (Fig. 5). The PEB index in KC2 increases up-core almost entirely due to an increase in the percentage of *E. vitrea* until the upper 30 cm of the core. The top 30 cm also show an increase in *B. morgani* and *Nonionella opima*, which together average 22.7% (SE = 1.4) of the assemblage compared to 3.7% (SE = 0.5) in the rest of the core (Fig. 6). PEB taxa are rare in

KC1, averaging only 7% (SE = 1.4) of the assemblage. However, between 100 cm and 120 cm the PEB index averages 19%.

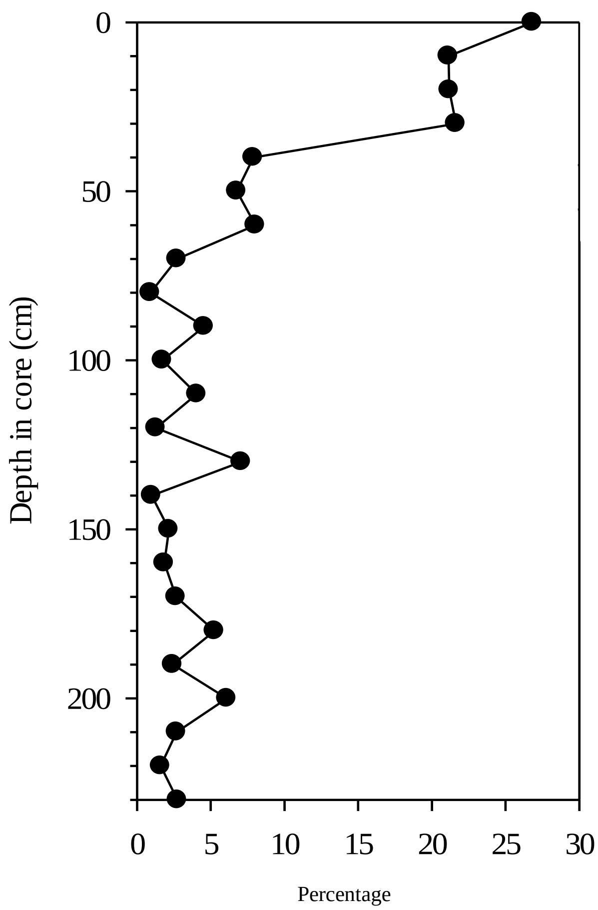

Figure 6. The combined percentage of *Buliminella morgani, Nonionella opima* and *N. atlantica* in core KC2.

Cluster analyses

Cluster analyses did not group samples by depth in core KC4 (59 m) or KC1 (473 m) (Fig. 6) because, as indicated in Figure 5, the assemblages change very little throughout the length of these cores. Cluster analysis of core KC3 (75 m) (Fig. 7) distinguished the top 40 cm (group 1) from the rest of the core (group 2). Although group 2 as a whole contains more taxa than group 1 (Table 1), both groups have a similar mean species richness (S) of 12. The assemblage of group 1 is dominated by the PEB taxon, *Epistominella vitrea*, with an average of 75% (SE = 2.4) of the assemblage. *Epistominella vitrea* represents 56% (SE = 2.4) of the assemblage in group 2 (Table 1). *Buliminella morgani* is twice as abundant in group 2 than in group 1 (Table 1)

Cluster analyses of the foraminiferal assemblages of core KC2 (87 m) distinguished the top 110 cm of the core (group 1) from the rest (group 2) (Fig. 7). Both groups have similar mean species richness values of 22 and 24 for groups 1 and 2, respectively. The groups differ in evenness and dominant taxa. Group 1 is dominated by *E. vitrea* with a mean percent abundance of 45% (SE = 3.9) (Table 2). Group 2 has a more even distribution with *E. vitrea* decreasing to 17% (SE = 1.6). *Bolivina lowmani* is the most common taxon with a mean percent abundance of 16% (SE = 1.2). The other PEB taxa, *Nonionella opima* and *Buliminella morgani,* do not vary much between the two groups and have a combined average for both taxa of ~10% in each group (Table 2).

Cluster analyses of all samples from the four cores defined four groups, each composed primarily of samples from a single core (Fig. 8). Group 1 represents the diverse assemblages of core KC1 and is distinguished from the rest of the cores. Most samples of KC2 are in group 4 but three samples, where *N. opima* and *B. morgani* are more abundant, are clustered in group 3 with the bottom portion of KC3. In core KC3 the lower samples clustered in group 3 and the upper samples, characterized by higher PEB index values, clustered with the high PEB index samples of core KC4 in group 2.

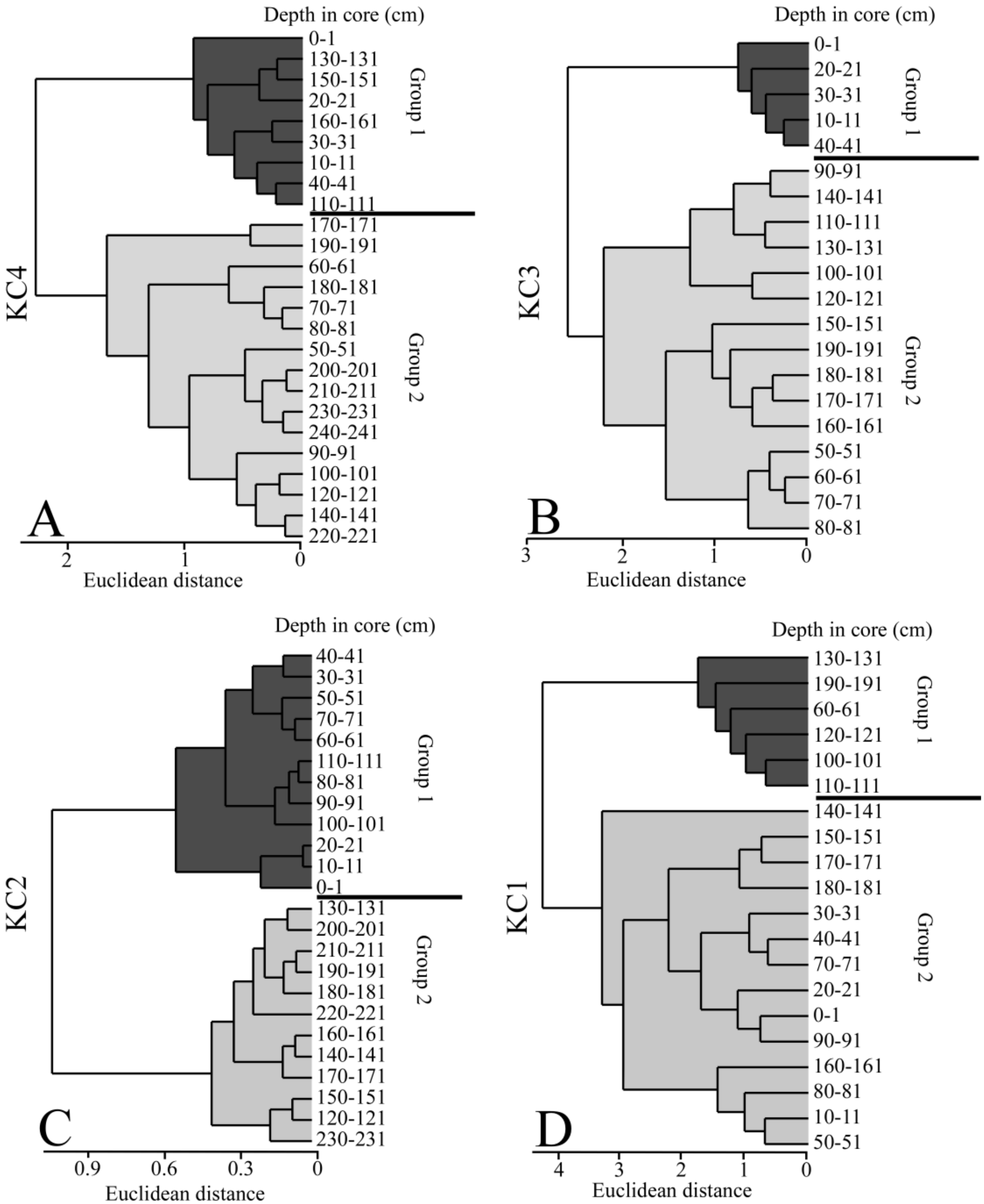

Fig. 7. Dendrograms showing the results of cluster analysis of each core.

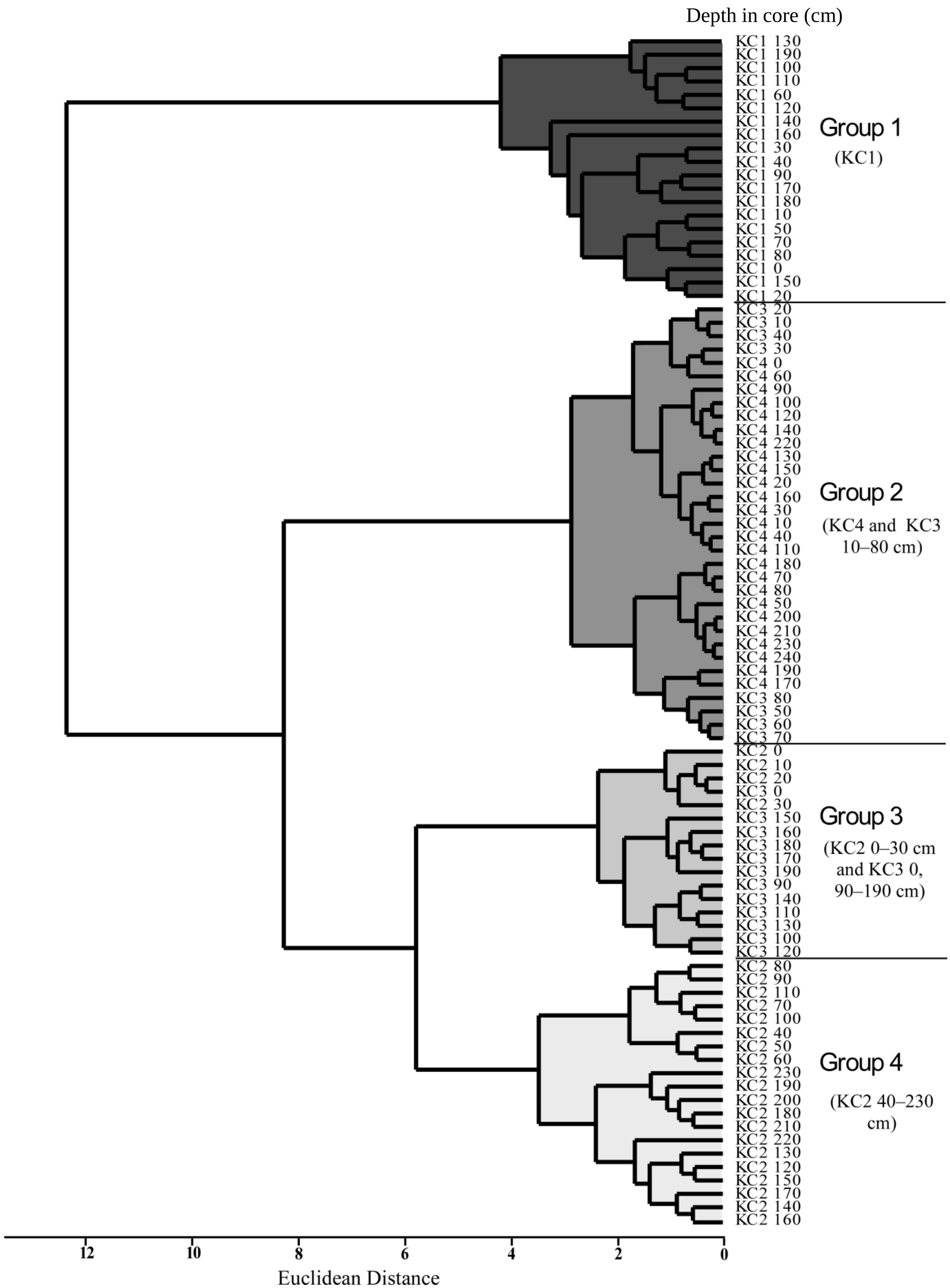

Figure 8. Dendrogram showing the results of cluster analysis of all cores combined.

Table 1. Mean percent abundance of taxa in groups defined by cluster analysis of the foraminiferal assemblage data in core KC3

Group 1 (0-40 cm) 5 samples, 21 taxa	Mean %	**Group 2 (50-190 cm)** 15 samples, 32 taxa	Mean %
Epistominella vitrea	75.11	*Epistominella vitrea*	56.35
Buliminella morgani	10.68	*Buliminella morgani*	19.85
Bolivina lowmani	4.12	*Bolivina lowmani*	5.01
Nonionella opima	3.62	*Uvigerina peregrina*	4.77
Bolivina cf. *B. daggarius*	1.35	*Nonionella opima*	3.98
Uvigerina peregrina	1.35	*Bolivina* cf. *B. daggarius*	3.51
Bulimina marginata	0.67	*Texularia earlandi*	1.32
Indeterminate rotaliids	0.67	*Bulimina marginata*	1.11
Bolivina striatula spinata	0.59	*Bolivina striatula spinata*	0.76
Bolivina translucens	0.25	*Islandiella* cf. *I. subglobosa*	0.59
Lenticulina cf. *L. peregrina*	0.25	*Bolivina barbata*	0.41
Quinqueloculina sp. C	0.25	*Ammotium salsum*	0.32
Buliminella elegantissima	0.17	*Quinqueloculina* spp.	0.32
Elphidium excavatum	0.17	*Globobulimina miss.*	0.23
Fursenkoina pontoni	0.17	Indeterminate rotaliids	0.23
Quinqueloculina sp. B	0.17	Indeterminate textulariids	0.23
Bolivina barbata	0.08	*Pyrgo nasutus*	0.20
Islandiella cf. *I. subglobosa*	0.08	*Bolivina daggarius*	0.15
Lagena spp.	0.08	*Bolivina subaenariensis mex.*	0.09
Quinqueloculina spp.	0.08	*Quinqueloculina* sp. D	0.09
Indeterminate textulariids	0.08	*Elphidium excavatum*	0.06
		Elphidium gunteri	0.06
		Fursenkoina pontoni	0.06
		Quinqueloculina sp. A	0.06
		Ammonia parkinsoniana	0.03
		Ammonia tepida	0.03
		Bolivina goesii	0.03
		Bulimina gibba	0.03
		Elphidium mexicanum	0.03
		Lagena spp.	0.03
		Lenticulina cf. *L. peregrina*	0.03
		Quinqueloculina sp. C	0.03

TABLE 2. Mean percent abundance of taxa in groups defined by cluster analysis of the foraminiferal assemblage data in core KC2

Group 1 (0–110 cm) 12 samples, 50 taxa	Mean %	**Group 2 (120–230 cm)** 12 samples, 54 taxa	Mean %
Epistominella vitrea	45.31	*Epistominella vitrea*	16.52
Uvigerina peregrina	12.20	*Bolivina lowmani*	16.28
Bolivina lowmani	7.47	*Uvigerina peregrina*	10.54
Bulimina marginata	6.37	*Bolivina barbata*	10.26
Buliminella morgani	6.37	*Bulimina marginata*	9.11
Nonionella opima	4.22	*Buliminella morgani*	9.11
Bolivina barbata	3.97	*Eponides turgidus*	4.44
Bolivina striatula spinata	1.29	*Eponides repandus*	3.17
Bolivina subaenariensis mex.	1.25	*Bolivina subaenariensis mex.*	2.58
Indeterminate rotaliids	1.22	Indeterminate rotaliids	2.34
Eponides turgidus	0.97	*Islandiella* cf. *I. subglobosa*	1.94
Islandiella cf. *I. subglobosa*	0.82	*Cibicides* spp.	1.82
Indeterminate miliolids	0.72	*Valvulineria mexicana*	1.23
Lenticulina cf. *L. peregrina*	0.68	*Bolivina striatula spinata*	0.87
Bolivina cf. *B. daggarius*	0.64	*Gavelinopsis praegeri*	0.87
Gavelinopsis praegeri	0.64	*Elphidium excavatum*	0.75
Elphidium excavatum	0.50	*Lagena* spp.	0.75
Indeterminate textulariids	0.43	*Nonionella opima*	0.75
Hanzawaia strattoni	0.39	*Cibicides robertsonianus*	0.71
Cibicides spp.	0.36	*Hanzawaia strattoni*	0.48
Lagena spp.	0.36	*Fissurina* spp.	0.44
Ammonia tepida	0.32	*Uvigerina auberiana*	0.40
Eponides repandus	0.32	*Ammonia tepida*	0.36
Valvulineria mexicana	0.29	Indeterminate miliolids	0.36
Cibicides robertsonianus	0.25	*Lenticulina* cf. *L. peregrina*	0.32
Quinqueloculina spp.	0.25	*Buliminella elegantissima*	0.28
Quinqueloculina sp. C	0.21	*Eponides regularis*	0.28
Ammotium salsum	0.18	*Lenticulina calcar*	0.28
Bulimina aculeata	0.18	*Sagrina pulchella primitiva*	0.28
Buliminella elegantissima	0.18	*Quinqueloculina* spp.	0.24
Globobulimina mississippiensis	0.18	*Globobulimina mississippiensis*	0.20
Pyrgo nasutus	0.18	*Quinqueloculina* sp. B	0.20
Bolivina translucens	0.14	*Islandiella norcrossi australis*	0.16
Bolivina daggarius	0.11	*Pyrgo nasutus*	0.16
Cassidulina neocarinata	0.11	Indeterminate textulariids	0.16
Fursenkoina complanata	0.11	*Bolivina* cf. *B. daggarius*	0.12
Fursenkoina pontoni	0.11	*Islandiella* sp. A	0.12
Bolivina fragilis	0.07	*Quinqueloculina* sp. C	0.12
Fursenkoina mexicana	0.07	*Quinqueloculina* sp. D	0.12
Gaudryina spp.	0.07	*Sigmoilina* spp.	0.12
Islandiella norcrossi australis	0.07	*Ammonia parkinsoniana*	0.08
Lenticulina calcar	0.07	*Bolivina daggarius*	0.08
Nonionella atlantica	0.07	*Fursenkoina mexicana*	0.08
Textularia earlandi	0.07	*Fursenkoina pontoni*	0.08
Ammonia parkinsoniana	0.04	*Quinqueloculina* sp. A	0.08
Bolivina goesii	0.04	*Textularia candeiana*	0.08
Fissurina spp.	0.04	*Ammotium salsum*	0.04
Marginulina marginulinoides	0.04	*Bolivina fragilis*	0.04
Quinqueloculina sp. D	0.04	*Cassidulina neocarinata*	0.04
Sigmoilina spp.	0.04	*Elphidium mexicanum*	0.04
		Fursenkoina complanata	0.04
		Gaudryina spp.	0.04
		Hoeglundina elegans	0.04
		Marginulina marginulinoides	0.04

DISCUSSION

Species Richness and Percent of planktonics

The average species richness and percent planktonics in the cores increases with water depth (Fig. 4). Cores KC4 and KC3, from shallower water, higher sedimentation rate areas, and have consistently low values of percent planktonics (>6%). In the deeper shelf core, KC2, planktonics average 26% (SE = 1.2) below 130 cm and then decrease in abundance steadily towards the core top where they are as low as 7% (Fig. 4B). This trend is not seen in species richness of KC2 although *Epistominella vitrea* increases in abundance at the same depth (Fig. 4), possibly resulting in a lower relative percent planktonics rather than an actual decrease in the density of planktonics. Core KC1 from the Mississippi Canyon has much higher values for percent planktonics and species richness with the exception of the sample at 140 cm which contained anomalously abundant *Bulimina striata mexicana* (Appendix 3). *Bulimina striata mexicana* occurs in water as shallow as 100 m (Phleger and Parker, 1951) but is typical of bathyal water deeper than 600 m (Pflum and Frerichs, 1976).

High PEB index values and sieve size

The PEB taxa *Nonionella opima* (plus *Nonionella atlantica* = *Protononion atlanticum* of Osterman, 2003), *Epistominella vitrea*, and *Buliminella morgani* comprise 85% to 100% of foraminiferal assemblages in core KC4 (Fig. 5). This results in an average PEB index for KC4 of 95% (SE = 0.1). Every sample but one in KC4 has a higher PEB index than all samples investigated by Osterman et al. (2009) who reported a high PEB index value of 89%. Osterman et al. (2009) used a core (MRD05-4GC; Fig. 1) from the within the hypoxia zone (Rabalais et al., 1999) to define a long-term background level for the PEB index of 12%. In a separate core (BL-10; Fig. 1) they described values over 50% as very high (Osterman et al., 2009). Thus, the average PEB index of 95% in KC4 is extremely high, despite not being collected in an area recognized for hypoxia.

In the Buzas et al. (2007) review of foraminiferal communities in the Gulf of Mexico, they showed sieve size does not affect diversity of foraminifera. However, since *E. vitrea* is generally smaller than the other PEB taxa, the size fraction of foraminifera picked can affect the PEB index in areas where *E. vitrea* is very abundant. Osterman et al. (2009) used the >125 µm fraction to facilitate picking foraminifera, whereas the current study used >63 µm. Picking a fraction larger than 63 µm could obscure some details of the environmental record garnered from foraminiferal proxies based on particular species. Small outer-shelf to abyssal foraminiferal species have been suggested to be opportunistic and to likely change in abundance during eutrophication and thus are important in determining past environmental conditions (Gooday, 1988, 1993; Kitazato et al., 2000; Duchemin et al., 2007). Duchemin et al. (2007) pointed out, however, that some smaller opportunistic taxa, including *Epistominella* spp. and *Nonionella* spp., are more sensitive to taphonomic destruction than larger foraminifera, so this can lead to incorrect estimates and possibly misleading trends. However, species of *E. vitrea* and *N. opima* in this study are delicate but well preserved and show no sign of dissolution or physical breakage. Mojtahid et al. (2009) found that cluster groups in the 63–125 µm and >150 µm size fractions of their Rhône prodelta study were similar, but noted that the smaller size fraction contained more abundant smaller species including *E. vitrea.*

Moodley et al. (1997) showed that using the >38 µm size fraction resulted in different trends in foraminiferal assemblages than when using the > 63 µm size fraction. They found that the larger sieve size tended to overestimate the abundance of certain foraminifera, including the genus *Nonionella*, and suggested the use of smaller sieve sizes (38 µm or 45 µm) in certain environments such as those experiencing anoxia. However, a standard sieve size of 63 μm has been suggested (Schröder et al., 1987; Sen Gupta et al., 1987) and this measurement boundary has been utilized in most recent foraminferal assemblage studies including those of several authors when working on foraminiferal proxies for hypoxia in the Gulf of Mexico (e.g., Blackwelder et al., 1996; Sen Gupta et al., 1996; Platon and Sen Gupta, 2005; Brunner et al., 2006). Picking at this 63 μm level allows for a compromise between the time it takes to pick samples and completeness of the assemblages and enables comparison with most of the previous work on foraminifera in the Gulf of Mexico such as Platon and Sen Gupta (2005) and Blackwelder (1996). The PEB index values of Platon and Sen Gupta (2005) range up to 90+ percent, similar to values in the current study. Blackwelder (1996) had high PEB index values around 70%. This suggests that sieve size may contribute to the higher PEB index in KC4 compared to the Osterman et al. (2007) work, but it is likely not the only factor.

EFFECT OF THE MISSISSIPPI RIVER ON ABUNDANCE OF *EPISTOMINELLA VITREA*

Comparison of the percent contribution of each species to the PEB index determined for the cores in this study to other studies in the Louisania Bight reveals a strong difference. In core MRD05-04BC (Fig. 1) of Osterman et al. (2007), taken from an area where hypoxia is known to occur frequently (Rabalais et al., 1999), *Epistominella vitrea* averages 35% of the PEB index taxa. In contrast, *E. vitrea* averages 80% of the PEB taxa in KC4, only ~35 km east-southeast of MRD15-04BC (Fig. 1). In other work in the hypoxia zone, *E. vitrea* yielded similar percentages for the PEB index to those in Osterman et al. (2009) although the >63 μm size fraction was used. For example, in core 10 of Blackwelder et al. (1996) (BL10 in Platon et al., 2005; Osterman 2008, 2009) (Fig. 1), *E. vitrea* comprised an average of 31% of the PEB index and in Platon and Sen Gupta's (2005) core F35 (Fig. 1), *E. vitrea* comprised an average of 33% of the PEB index.

The similar values of *E. vitrea* as a percentage of the PEB index in other work in the Louisiana Bight suggests that environmental conditions near Southwest Pass related to Mississippi River influnce may be the main factor contributing to the high abundance of *E. vitrea* in KC4 rather than sieve size. Delta progradation involving high sedimentation rates (Corbett et al., 2006) and mudflows (Walsh et al., 2006) are likely related to the great abundance of *E. vitrea.* This is supported by Platon and Sen Gupta's (2005) core E60 (Fig. 1), taken only ~20 km west of KC4, which has a higher average relative abundance of *E. vitrea* at 44% of the PEB index. In surface samples near the mouth of Southwest Pass (Blackwelder et al., 1996), as close as 2 km from KC4 (Fig.1), the average PEB index was 78% with *E. vitrea* comprising an average of 60% of the PEB index. In the surface samples of Blackwelder et al. (1996) from the center of the Louisiana Bight, farther away from Southwest Pass, *E. vitrea* comprised an average of 26% of the PEB index in samples with a PEB index value of greater than 12%, the minimum value for areas of lower-oxygen values determined by Osterman et al. (2008, 2009).

The location of the very high abundance of *Epistominella vitrea* near the mouth of Southwest Pass suggests that this high abundance is not solely related to hypoxia. Ecological controls on the abundance of *E. vitrea* are, however, complex. Blackwelder et al. (1996) attributed the high abundance of *E. vitrea* near Southwest Pass to the higher sedimentation rates of this area. This is supported by the fact that the sites of KC4 and KC3 were shown by Corbett et al. (2006) to exhibit the highest sedimentation rates in the Louisiana Bight. In some laboratory studies, *E. vitrea* has been observed migrating within sediment in response to hypoxia (Alve and Bernhard, 1995), but in other studies *E. vitrea* showed no response to hypoxia (Ernst et al., 2005). *Epistominella vitrea* has also been recorded as increasing in abundance in response to the presence of organic matter and to algal blooms (Gooday and Hughes, 2002; Langezaal et al., 2006). Thus, hypoxia and abundant organic matter, which are related conditions, can affect the abundance of *E. vitrea,* but the main controlling factors in areas near the outflow Mississippi River are likely the sedimentary processes involved in delta progradation.

TEMPORAL TRENDS IN *EPISTOMINELLA VITREA*

The interpretation that *Epistominella vitrea* has changed in abundance due to environmental variation other than hypoxia explains why this species shows temporal trends that differ from those for other PEB taxa in the current study. In the lower part of core KC2, *E. vitrea* shows little variation in abundance (~23%) until above 140 cm core-depth where it increases upwards to 83% at 20 cm (Fig. 5). The other PEB taxa, *Nonionella opima* and *Buliminella morgani*, have a combined average of 3.7% (SE = 0.5) below 40 cm and 23% (SE = 1.4) above 40 cm (Fig. 5), suggesting *N. opima* and *B. morgani* are responding to different environmental variables or the same variables at a different threshold. The trend in *E. vitrea* is paralleled by the trend of decreasing percent planktonics above 140 cm and up to 20 cm (Fig. 4B). The decrease in percent planktonics suggests the trend up-core from 140 cm represents an increasing density of *E. vitrea* in the sediment. This trend in KC2 represents an up-core shift to an assemblage more typical of shallower water cores in this study, suggesting delta progradation as a causative factor.

RECORD OF HYPOXIA

If *Epistominella vitrea* is not considered in the PEB index for KC2, a different trend is seen that may indicate the increased influence of hypoxia on the foraminiferal assemblage near the top of this core. *Nonionella opima* and *Buliminella morgani* increase in combined abundances between 40 cm and 30 cm (from 8% to 22%; Fig. 5), this likely represents anthropogenically increased hypoxia. Using the ^{210}Pb age estimates, this change occurred between 1950 and 1966. Core KC3 shows an increase in PEB taxa above 80 cm (Fig. 5), but not as strong as the three-fold increase of *N. opima* and *B. morgani* seen in the top 30 cm of KC2. In KC3 the PEB index is higher in the upper part of the core with an average index of 90% (SE = 0.10) above 80 cm and 76% (SE = 1.74) below (Fig. 5). Above 50 cm the abundance of *E. vitrea* increases while the abundance of *N. opima* and *B. morgani* decreases. This shift in the relative abundance of taxa that comprise the PEB index does not change the value of the index as a whole, but suggests a shift in environmental conditions, possibly a stronger influence from the Mississippi River. The increase in the PEB index in KC3 takes place between 90 cm and 80 cm. The ^{210}Pb data indicate this shift occurred between 1946 and 1951. This timing agrees quite well with the change in relative abundance of *N. opima* and *B. morgani* in KC2. These dates also agree well with the evidence of increasing PEB index in the Louisiana Bight in the mid-20th century (Osterman et al., 2008, 2009). Other studies of foraminiferal assemblages in this region have shown an increasing influence from hypoxia from the late 1940s to the early 1960s (Sen Gupta et al., 1996; Platon et al., 2001, 2005; Osterman, 2009) as well as some other indicators of hypoxia (e.g., total marine organic matter, percent biologically bound silica, phytoplankton assemblages, pigments concentrations from anoxygenic bacteria; Turner et al., 1991, 1994, 2004; Eadie et al., 1994; Rabalais et al., 1996, 2000, 2004, 2007b; Chen et al., 2001).

In addition to PEB taxa, several other species in KC2 and KC3 are found in low-oxygen settings and contribute to the indication of a hypoxic environment. *Bolivina lowmani* is the second most abundant species in KC2 and the third most abundant in KC3 and did not change in abundance in a core that showed an increasing influence of hypoxia (Blackwelder et al., 1996). Three additional common species in core KC3 and KC2, *Uvigerina peregrina*, *Bulimina marginata*, and *Bolivina subaenariensis*, have been shown to be able to undergo nitrate storage, which is associated with the ability of foraminifera to respire nitrate thus making them more resistant to periods to hypoxia (Pina-Ochoa et al., 2010b).

CENR (2000) revealed hypoxia as deep as 60 m water depth to the west of the Mississippi delta. Foraminiferal data from core KC3, at 75m, and core KC2, at 87 m, suggest hypoxia is occurring unusually deep in the study area or that PEB taxa in these cores have been transported down-slope. Storm-driven sediment mudflows of the prograding deltaic system have been reported in this region (Walsh et al., 2006). However, the tiny, delicate PEB taxa could be transported downslope primarily in suspension avoiding taphonomic alteration. This is supported by their pristine condition and the several deeper water taxa occurring with PEB taxa in KC2. However, *Uvigerina peregrina* and *Bulimina marginata* comprise an average of 11% and 8% percent of the assemblages in KC2. The genera *Uvigerina* and *Bulimina* have been described as characteristic of 101–150 m water depth in the northwestern Gulf of Mexico (Culver et al., 1988), suggesting that at least a portion of the assemblages is autochthonous. In the Mississippi Bight, Blackwelder et al. (1996) pointed out that *Uvigerina peregrina* was found in water deeper than 50 m. The PEB index in the Mississippi Canyon core (KC1) averages 5%, but from 100 to 130 cm the PEB index increases to ~15%. This is most likely indicative of an episode of off-shelf sediment transport.

CONCLUSIONS

PEB index values off Southwest Pass, very high compared to samples from other studies in the Louisiana Bight, could be interpreted as indicating that the study area is experiencing extensive and strong seasonal hypoxia. However, the increase in abundance of *Epistominella vitrea* towards Southwest Pass suggests that this species is responding to the sedimentological processes (e.g., high sedimentation rates and mudflows) related to Mississippi River discharge. The increased abundance of *E. vitrea* toward the top of cores KC2 and KC3 is interpreted to be a reflection of delta progradation in this region. *Buliminella morgani, Nonionella opima* and *Nonionella atlantica,* however, show different trends than *E. vitrea* in cores KC2 and KC3 and began increasing in the 1950s. This date agrees temporally with other records of hypoxia in the Louisiana Bight, and suggest that these taxa do indicate hypoxia influencing the area. Thus, the use of the PEB index as a simple indicator of hypoxia in the area near Southwest Pass is somewhat problematic. *B. morgani, N. opima,* and *N. atlantica* are indicators of hypoxia but *E. vitrea* is indicative of Mississippi River-related sedimentary processes.

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APPENDIX 1: TAXONOMIC REFERENCE LIST

Ammonia parkinsoniana (d’Orbigny) = *Rosalina parkinsoniana* d’Orbigny, 1839, p. 99, pl. 4, figs. 25–27.

Ammonia tepida (Cushman) = *Rotalia beccarii* (Linné) var. *tepida* Cushman, 1926, p. 79, pl. 1, figs. 8a–c.

Ammotium salsum Cushman and Brönnimann, 1948, p. 39, pl. 7, fig. 9.

Anomalinoides mexicana Parker, 1954, p. 539, pl. 11, figs. 21–23.

Bolivina alata (Seguenza) = *Vulvulina alata* Seguenza, 1862, p. 115, pl. 2, figs. 5.

Bolivina albatrossi Cushman, 1922, pt. 3, p. 31, pl. 6, fig. 4.

Bolivina barbata Phleger and Parker, 1951, p. 13, pl. 6, figs. 12a, b, 13.

Bolivina daggarius (Parker) = *Bolivina lanceolata* Parker, 1954, p. 514, pl. 7, figs. 17–20.

Bolivina fragilis Phleger and Parker, 1951, p. 13, pl. 6, figs. 14, 23, 24a, b.

Bolivina goesii Cushman, 1922, pt. 3, p. 34, pl. 6., fig. 5.

Bolivina lowmani Phleger and Parker, 1951, p. 13, pl. 6, figs. 20a, b, 21.

Bolivina minima Phleger and Parker, 1951, p. 14, pl. 6, figs. 22a, b, 25; pl. 7, figs. 1, 2.

Bolivina ordinaria (Phleger and Parker) = *Bolivina simplex* Phleger and Parker 1951, p. 14, pl. 7, figs. 4–6.

Bolivina striatula spinata (Cushman) = *Bolivina striatula* var. *spinata* Cushman, 1936, p. 59, pl.8, figs. 9a, b.

Bolivina subaenariensis mexicana (Cushman) = *Bolivina subaenariensis* var. *mexicana* Cushman, 1922, pt. 3, p. 47, pl. 8, fig. 1.

Bolivina subspinescens Cushman, 1922, pt. 3, p. 48, pl. 7, fig. 5.

Bolivina translucens Phleger and Parker, 1951, p. 15, pl. 7, figs. 13, 14a, b.

Bulimina aculeata d'Orbigny, 1826, p. 269, n. 7.

Bulimina alazanensis Cushman, 1927, p. 161, pl. 25, fig. 4.

Bulimina marginata d’Orbigny, 1826, p. 269, pl. 12, figs. 10–12.

Bulimina striata mexicana (Cushman) = *Bulimina striata* var. *mexicana* Cushman, 1922, pt. 3, p. 95, pl. 21, fig. 2.

Buliminella elegantissima (d'Orbigny) = *Bulimina elegantissima* d'Orbigny, 1839, p. 51, pl. 7, figs. 13, 14.

Buliminella morgani Andersen, 1961, p. 87, pl. 19, fig. 10.

Cassidulina carinata (Cushman) = *Cassidulina laevigata* var. *carinata* Cushman, 1922, pt. 3, p. 124, pl. 25, figs. 6,7.

Cassidulina crassa d'Orbigny, 1839, p. 56, pl. 7, figs. 18–20

Cassidulina tenuis Phleger and Parker, 1951, p. 27, pl. 14, figs. 14–17

Chilostomella oolina Schwager, 1878, p. 527, pl. 1, fig. 16.

Cibicides robertsoniana (Brady) = *Truncatulina robertsonianus*, Brady, 1881, v. 21, p. 65.

Cibicides umbonatus Phleger and Parker, 1951, p. 31, pl. 17, figs 7–9.

Elphidium excavatum (Terquem) = *Polystomella excavata* Terquem, 1876, p. 469, pl. 2, figs. 2a–d.

Elphidium gunteri Cole, 1931, p. 34, pl. 4, figs. 9, 10.

Epistominella vitrea Parker, Phleger and Pierson, 1953, p. 9, pl. 4, figs. 34–36, 40, 41.

Eponides antillarum (d'Orbigny) = *Rotalina antillarum* d'Orbigny, 1839, p. 75, pl. 5, figs. 4–6.

Eponides regularis Phleger and Parker, 1951, p. 21, pl. 11, figs. 3a, b, 4a–c.

Eponides repandus (Fichtel and Moll) = *Nautilus repandus* Fichtel and Moll, 1803, p. 35, pl. 3, figs. a–d.

Eponides turgidus Phleger and Parker, 1951, p. 22, pl. 11, figs. 9a, b.

Fursenkoina complanata (Egger) = *Virgulina complantata* Egger, 1893, p. 292, pl. 8, figs. 91, 92.

Fursenkoina mexicana (Cushman) = *Virgulina mexicana* Cushman, 1922, pt. 3, p. 120, pl. 23, fig. 8.

Fursenkoina pontoni (Cushman) = *Virgulina pontoni* Cushman, 1932, p. 17, pl. 3, fig. 7.

Fursenkoina tessellata Phleger and Parker, 1951, p. 19, pl. 9, figs 15, 16.

Gavelinopsis translucens (Phleger and Parker) = *"Rotalia" transluscens* Phleger and Parker, 1951, p. 24, pl. 12, figs. 11a, b, 12a, b.

Globobulimina mississippiensis Parker, 1954, p. 511, pl. 7, figs. 3, 4, 10.

Gyroidina altiformis Stewart and Stewart, 1930, p. 67, pl. 9, fig. 2a–c.

Gyroidina orbicularis d'Orbigny, 1826, p. 278, n. 13.

Hanzawaia strattoni (Applin) = *Truncatulina americana* var. *strattoni* Applin et al., 1925, p. 99, pl. 3, fig. 8.

Hoeglundina elegans (d'Orbigny) = *Rotalia elegans* d'Orbigny, 1826, p. 276, n. 54.

Hopkinsina atlantica (Cushman) = *Hopkinsina pacifica* var. *atlantica* Cushman, 1944

Islandiella nocrossi australis Phleger and Parker, 1951, p. 27, pl. 14, figs. 8a, b, 9, 10.

Lenticulina calcar (Linné) = *Nautilus calcar* Linné, 1767, p. 1162, n. 272.

Lenticulina peregrina Schwager, 1866, p. 245, pl. 7, fig. 89.

Lenticulina thalmanni Hessland, 1943, pl. 1, 2

Marginulina marginulinoides (Göes) = *Cristellaria aculeata* var. *marginulinoides* Göes, 1896, p. 56, pl. 5, figs. 15, 16.

Nonionella atlantica Cushman, 1947, p. 90, pl. 20, figs. 4,5.

Nonionella opima Cushman, 1947, p. 90, pl. 20, figs. 1–3.

Nonionoides turgida (Williamson) = *Rotalina turgida* Williamson, 1858, p. 50, figs. 95–97

Oridorsalis umbonatus (Reuss) = *Rotalina umbonatus* Reuss, 1851, p. 75, pl. 5, figs. 35a–c.

Pseudononion atlanticum (Cushman) = *Nonionella atlantica* Cushman, 1947, p. 11, pl. 5, figs. 21–23.

Pyrgo nasutus Cushman, 1935, p. 7, pl. 3, figs. 1–4.

Sagrina pulchella (Cushman) = *Bolivina pulchella* var. *primitiva* Cushman, 1930, p. 47, pl. 8, figs. 12a, b.

Sigmoilina distorta Phleger and Parker, 1951, p. 8, pl. 4, figs. 3–5.

Siphonina pulchra Cushman, 1919, p. 42, pl. 14, figs. 7a–c.

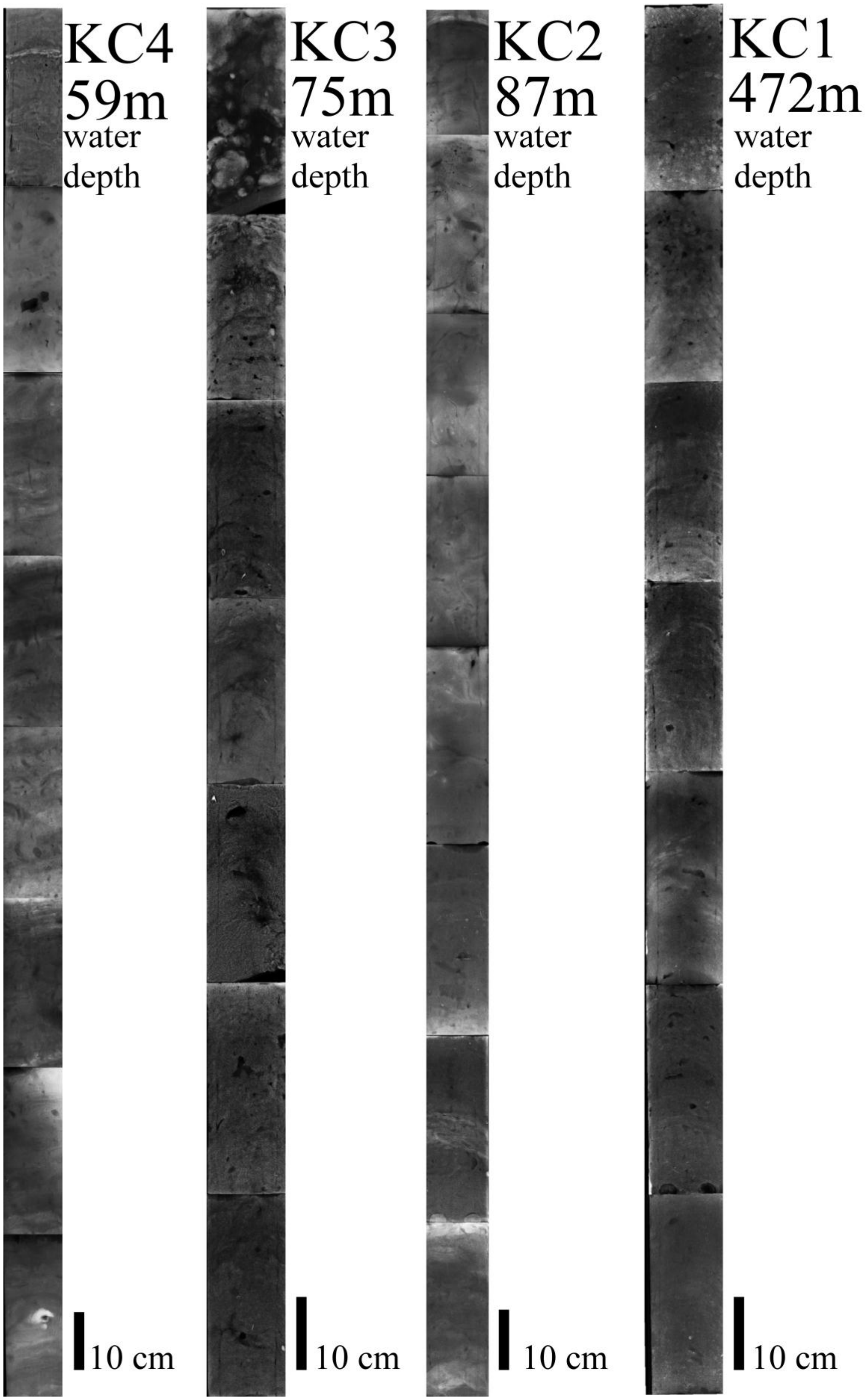
Texularia candeiana d'Orbigny, 1839, p. 143, pl. 1, figs. 19, 20.

Textularia earlandi Parker, 1952, p. 458.

Uvigerina laevis (Goës) = *Uvigerina auberiana* (d'Orbigny) var. *laevis* Goës, 1896, p. 51.

Uvigerina peregrina Cushman, 1923, p. 166, pl. 42, figs. 7–10.

APPENDIX 2: X-RADIOGRAPHS OF CORES



APPENDIX 3: CORE METADATA

Core name	Date Taken	Latitude	Longitude	Water Depth (m)	Core length (cm)
PEL0907KC4	9/19/2007	28°51.867 N	89°31.638 W	59	240
PEL0907KC3	9/19/2007	28°48.382 N	89°33.002 W	75	190
PEL0907KC2	9/19/2007	28°45.545 N	89°37.918W	87	230
PEL0907KC1	9/19/2007	28°34.728 N	89°49.176 W	473	190

APPENDIX 4: FORAMINIFERAL CENSUS DATA

	KC4 (59 m)																								
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**	**200–201**	**210–211**	**220–221**	**230–231**	**240–241**
Ammonia parkinsoniana	1						1																	1	1
Ammonia tepida			1			1	4	1	1	1	3		1	1					5						
Bolivina cf. *B. daggarius*	1		3	1							2					1	1								
Bolivina daggarius																						1			
Bolivina fragilis																		1		1					
Bolivina goesii			1																						
Bolivina lowmani	7	3	3	7	8	8	10	9	9	2	6	14	6	4	3	6	9	15	10	2	1	1	2	3	5
Bolivina striatula spinata					1	1				2		1		1			1	1		1		1		1	
Bolivina translucens					1	1																			
Bulimina aculeata																	1								
Bulimina gibba							1																		
Bulimina marginata	2	1					1					1				1	3		1						1
Buliminella elegantissima							1																		
Buliminella morgani	24	20	12	20	14	42	20	23	20	16	21	27	18	13	8	15	25	22	26	48	38	35	13	35	49
Elphidium excavatum	1						3											1							
Epistominella vitrea	170	171	201	154	213	158	151	151	165	152	191	253	178	185	156	211	269	112	140	122	167	177	177	164	205
Fursenkoina mexicana		1																							
Fursenkoina pontoni						1	1	1					1						1	1					
Gavelinopsis praegeri												1													
Hopkinsina pacifica atl.	4	1					2			3									1						
Islandiella cf. *I. subglobosa*		1	1	2				1		1							3							1	
Islandiella sp. A																		1							
Lenticulina cf. *L. peregrina*										1								1							
Nonionella atlantica	1	1			1																				
Nonionella opima	3	4	6	7	5	10	14	25	38	18	16	10	16	1	15	2	18	68	30	44	14	16	23	26	27
Quinqueloculina sp. A				1																					
Quinqueloculina sp. B	1						3						1												
Quinqueloculina sp. C	1						2																		
Trochammina sp. A				1																					
Uvigerina peregrina										1				1						1					
Indeterminate miliolids							4										1			1					
Indeterminate rotaliids		1	1																1				1		
Indeterminate textulariids						1																			
Total benthics (N)	216	204	229	193	243	223	218	211	233	197	239	307	221	206	182	236	331	222	215	221	220	231	216	231	288
Total planktonics	3	3	8	1	4	4	1	2	0	0	3	1	1	6	0	3	4	2	2	1	2	2	7	6	3

KC3 (75 m)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–101**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Ammonia parkinsoniana									1											
Ammonia tepida										1										
Ammotium salsum												1				8	1		1	
Bolivina barbata				1				1		2			1	3			2	3	1	1
Bolivina cf. *B. daggarius*	5	5	1	4	1	12	2	4	4	13	2	21		11	13	5	2	11	3	17
Bolivina daggarius													5							
Bolivina goesii										1										
Bolivina lowmani	12	8	16	6	7	2	2	9	8	7	9	10	5	10	8	14	12	26	24	25
Bolivina striatula spinata	1	1		1	4	2	1	2	1	3		8	1	2	4			1	1	
Bolivina subaenariensis mexicana									1			2								
Bolivina translucens	1				2															
Bulimina gibba															1					
Bulimina marginata	1	3		3	1	2			6			5	2	5	2	3	2		1	10
Buliminella elegantissima	1		1																	
Buliminella morgani	31	30	22	17	27	43	60	60	64	49	35	57	20	66	32	55	47	35	23	32
Elphidium excavatum			2													1			1	
Elphidium gunteri											2									
Elphidium mexicanum											1									
Epistominella vitrea	161	172	180	162	218	122	135	175	102	124	122	163	144	108	131	111	128	135	131	94
Fursenkoina pontoni		1			1					1					1					
Globobulimina mississippiensis													1			5		2		
Islandiella cf. *I. subglobosa*	1									3		1	1	4		5		4	1	1
Lagena spp.					1														1	
Lenticulina cf. *L. peregrina*	1		1	1						1										
Nonionella opima	15	6	3	7	12	27	21	22	12	10	4	7	3	3	4	1	1	5	4	12
Pyrgo nasutus							1					2	1	1	1		1			
Quinqueloculina sp. A									1				1							
Quinqueloculina sp. B	1			1																
Quinqueloculina sp. C	1			2						1										
Quinqueloculina sp. D										1			1			1				
Quinqueloculina spp.				1				1	1					3		1		4		1
Texularia earlandi											21	17	3	1		3				
Uvigerina peregrina	10	2	1		3	2	4	3		16	7	30	26	27	20	9	2	5	4	8
Valvulinaria mexicana																				
Indeterminate rotaliids	1	2	2	1	2			2								1		1	1	3
Indeterminate textulariids		1								1		6							1	
Total benthics (N)	243	231	229	207	279	212	226	279	201	234	203	330	215	244	217	223	198	232	198	204
Total planktonics	16	16	9	12	19	4	1	9	11	9	1	5	7	12	11	12	7	25	9	8

	KC2 (87 m)																							
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**	**200–201**	**210–211**	**220–221**	**230–231**
Ammonia parkinsoniana	1																					1		1
Ammonia tepida	5							1		1		2	1	1		1				1	3			2
Ammotium salsum								1	1	2		1									1			
Bolivina barbata	1		1	3	12	13	7	11	20	20	9	14	21	39	36	15	24	17	12	25	17	22	18	13
Bolivina cf. *B. daggarius*	1	1	3	1	1	3	1	3	1		2	1		1	2									
Bolivina daggarius	1	1							1															2
Bolivina fragilis					2																		1	
Bolivina goesii				1																				
Bolivina lowmani	12	8	15	6	12	25	30	36	14	23	17	11	44	34	47	34	38	47	20	33	22	24	32	36
Bolivina striatula spinata	8	3	3	5	6	1	2	1	2	4	1		3	2	1		3	3	1	5	3		1	
Bolivina subaenariensis mex.		1		1	1	4	5	6	5		8	4	10	10	5	3	6	5	4	2	3	3	12	2
Bolivina translucens	1	1	2																					
Bulimina aculeata										5														
Bulimina marginata	3	5	8	10	10	6	12	18	24	20	40	22	20	20	16	33	18	12	17	19	25	15	24	11
Buliminella elegantissima							1	1			1	2	1						2		1	1		2
Buliminella morgani	16	26	44	47	14	12	10	1	0	7	3	5	3	15	0	1	2	4	4	5	9	4	2	5
Cassidulina neocarinata								1	2														1	
Cibicides robertsonianus		1		1					2	3			1	5		1			5	2				4
Cibicides spp.				1		1	4		1	1	1	1		2	1		7	1	3	9	2	6	12	3
Elphidium excavatum	2					1	1	1	3	4		2	1		1				8		6	3		
Elphidium mexicanum																								1
Epistominella vitrea	98	115	180	145	95	107	101	103	80	85	71	87	65	58	30	48	19	34	24	32	32	16	15	44
Eponides regularis																				2			4	1
Eponides repandus					1			4		2	2		6	3	5	3	5	6	7	7	3	8		27
Eponides turgidus		1		1		2		2	5	1	10	5	11	11	16	10	7	8	9	6	5	9	9	11
Fissurina spp.				1									1	1	1	2		3			1			2
Fursenkoina complanata									1	2														1
Fursenkoina mexicana				2									1											1
Fursenkoina pontoni	1				1		1										1				1			
Gaudryina spp.					1							1	1											
Gavelinopsis praegeri				1		1		4	3	4	5		2	2	1	1	1	5	4	2	1	3		
Globobulimina mississippiensis		1		2	1						1			1	1		2						1	
Hanzawaia strattoni					2	2			4	1		2	1		1		3			4			1	2
Hoeglundina elegans																							1	
Islandiella cf. *I. subglobosa*	3	1	1			1		5	3	2	4	3	4	2	5	3	1	9	7	6	4	3		5
Islandiella norcrossi australis											1	1		1			1		1	1				
Islandiella sp. A															1									2
Lagena spp.		1	2	3		1	1				1	1	1		8	1	1	1	1		1		3	2
Lenticulina calcar									2				1					1		2	1	1	1	
Lenticulina cf. *L. peregrina*				1		1	9	3			1	4	1	1	1	2				1	1	1		

KC2 (87 m) (cont.)																								
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**	**200–201**	**210–211**	**220–221**	**230–231**
Nonionella atlantica					2																			
Nonionella opima	39	15	17	19	2	2	8	6	2	3	1	4		3	2	3	1	1	4		3		1	1
Pyrgo nasutus					1		1			1		2						4						
Quinqueloculina sp. A																								2
Quinqueloculina sp. B																								5
Quinqueloculina sp. C			1	2	1					2			1				1				1			
Quinqueloculina sp. D							1						1	1			1							
Quinqueloculina spp.		2		2			2	1								3					1			2
Sagrina pulchella primitiva													1				1	3				1		1
Sigmoilina spp.							1						1	1			1							
Textularia candeiana																							2	
Textularia earlandi				1					1															
Uvigerina auberiana																		1		5	1			3
Uvigerina peregrina	13	8	9	47	53	19	26	32	32	24	43	35	28	33	20	18	17	20	10	24	33	17	36	10
Valvulineria mexicana			1	2				1	1		1	2	1		1		2		3	8	3	3	5	5
Indeterminate miliolids					3			6	3		4	4		3	1			4			1			
Indeterminate rotaliids		3	1	1	3	2	1	9	7	1	5	1		3		2	2		9	11	11	8	4	9
Indeterminate textulariids			1		2	2		1				6	1	1						1	1			
Total benthics (N)	192	173	253	269	222	200	227	275	244	231	269	241	251	260	219	216	181	197	168	227	213	160	208	224
Total planktonics	2	28	22	26	29	27	36	49	38	31	42	46	47	52	93	51	67	89	47	8	58	45	72	67

KC1 (473 m)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Ammobaculites spp.			1													1				
Ammonia tepida																		2		
Anomalinoides mexicana	2	1					7			3	7	3	4	8					2	1
Bolivina alata		2		1	1	4	1	2	5	1	4	2	5	3		7	5	3	7	2
Bolivina albatrossi			2	7	4	1	3	1		4	1	1	3	7		2	1		2	1
Bolivina barbata	2	4	2	1		6	11	1	1		7	4	9	4	2	3		2	2	10
Bolivina cf. *B. daggarius*											1									
Bolivina daggarius													4			2	2	1		1
Bolivina fragilis			1				1	1	1		2	3	3			2				3
Bolivina lowmani	35	35	43	20	29	40	36	24	54	9	20	27	30	11	4	35	54	20	28	26
Bolivina minima										1										
Bolivina simplex	26	28	37	29	43	19	22	41	24	39	22	30	11	23	9	45	10	21	17	31
Bolivina striatula spinata										2	3								1	1
Bolivina subaenariensis mex.	2	2	2	2		2	5	1	1	2	7	5	4	2	5		6	1	2	2
Bolivina subspinescens	1							1		1	1			1			1	2		
Bolivina translucens	3	2	3		4	10	7	4	12	4	4	4	3	2		3	4	1		3
Bulimina aculeata	4		13	11	11		1	3		8			3	1		4	1	13	4	
Bulimina alazanensis			1						1		1	1								
Bulimina marginata	1	5	2		1		13			2	7	3	10	12		2	2	5	3	9
Bulimina striata mexicana	4	8	4		4	3	4	3	2	4	1	2	5	8	48	6	3	12		3
Buliminella morgani			1			1	3	1	2		4	5	8					3	1	
Cassidulina carinata			2			2	2					1		3	1				2	1
Cassidulina crassa	4		4		1						1	1		2		1		1		
Cassidulina neocarinata	19	33	13	45	23	22	12	50	47	38	13	20	9	20	72	23	31	46	36	7
Cassidulina tenuis							1				1			2			1			1
Chilostomella oolina	2	1	1		1	3	2	4	6	1	1			2		4	6	1	1	
Cibicides spp.			1	1	1		2	2		1	2									
Cibicides umbonatus	1	2	2			2				2	1	4		3		1	1	1		
Cibicides robertsonianus					2		1	2		2	2	1				1	2		1	
Elphidium excavatum	2									1	3	1					2	1		
Epistominella vitrea	3	8	8	3		10	12	4	6	5	34	17	46	13	7	7	7	12	8	31
Eponides antillarum				1																
Eponides regularis	24	19	22	21	38	14	6	27	9	18	8	7	10	13	14	10	0	13	20	2
Eponides turgidus	2		4	3	2	4	6	3	1	4	7	11	12	6		6		3	9	9
Fissurina spp.				1			1				2			2						
Fursenkoina complanata		2				2														
Fursenkoina tessellata			2																	
Fursenkoina mexicana			2	2		1	2		1	1	1					1	7		2	
Gavelinopsis praegeri	9	6	8	14	14	21		6	7	9	2	2	1	7		7	4	15	4	1
Globobulimina mississippiensis												1								
Gyroidina altiformis	3			1					1	1			1	1	3		1			

KC1 (473 m) (cont.)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Gyroidina orbicularis											1			1						
Hanzawaia strattoni				1	1	3		3		1			1		2		1	2	1	
Haplophragmoides spp.	1																			
Hoeglundina elegans																		1		
Hopkinsina pacifica atl.										1	1									
Islandiella cf. *I. subglobosa*		6	12	4	4	7	15		3	5	9	12	17	6		2		3	4	13
Islandiella norcrossi australis	18	27	26	10	7	21	10	28	41	40	6	13	11	11	27	12	24	12	5	3
Lagena spp.	1			2	1		2			1	1		1	2				1		
Lenticulina cf. *L. peregrina*														1						
Lenticulina sp. A				1			1					1								
Lenticulina thalmanni								1	1					1						
Nodosaria spp.						1					1									
Nonionella atlantica		2	1	1		3													1	
Nonionella opima	5								1	3		1	1					1		2
Nonionella turgida		2											1				2			
Oolina spp.												1						1		
Oridorsalis umbonatus			1	1				1		1	1			1	1		1	1	1	1
Pullenia spp.						1														
Pyrgo nasutus				1					2			1				1	1	2	1	1
Pyrgo spp.										1		1	2							
Quinqueloculina sp. A																				1
Quinqueloculina sp. D	1								1											
Quinqueloculina sp. E						1														
Quinqueloculina spp.	1	1					3				1	2	3	2	1			1		
Rosalina spp.				1		2					1	1		1				1		1
Sagrina pulchella primitiva	1											1	1	2					1	
Sigmoilina spp.					1									1					1	1
Siphonina pulchra		1																		
Sphaeroidina bulloides	4	2	2	1				1		1				1	1	1	2			
Textularia candeiana																			1	
Trochammina sp. A			1																	
Uvigerina peregrina	4	6	12	14	9	5	11	7	5	9	11	4	5	19		2		6	4	21
Uvigerina laevis		2	1	1	1		1			1	1	5	2	1	1		1	2		2
Valvulineria minuta	7	3		9	10	9		8	0	11		1	2	6		11		5	7	7
Indeterminate miliolids		1							1	1	1	3	1			1		2	2	
Indeterminate rotaliids	1	1	1	5	4	2		6	7		8	3	4	2		4		2		8
Indeterminate textulariids	1	1	1			1														
Total benthics (N)	194	213	239	215	217	223	204	236	243	239	213	206	233	214	198	207	183	222	181	206
Total planktonics	139	292	211	166	119	106	159	138	171	126	127	182	127	146	30	93	102	223	140	181

APPENDIX 5: FORAMINIFERAL RELATIVE ABUNDANCE DATA

	KC4 (59 m)																								
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**	**200–201**	**210–211**	**220–221**	**230–231**	**240–241**
Ammonia parkinsoniana	0.5						0.5																	0.4	0.3
Ammonia tepida			0.4			0.4	1.8	0.5	0.4	0.5	1.3		0.5	0.5					2.3						
Bolivina cf. *B. daggarius*	0.5		1.3	0.5							0.8					0.4	0.3								
Bolivina daggarius																						0.4			
Bolivina fragilis																		0.5		0.5					
Bolivina goesii			0.4																						
Bolivina lowmani	3.2	1.5	1.3	3.6	3.3	3.6	4.6	4.3	3.9	1.0	2.5	4.6	2.7	1.9	1.6	2.5	2.7	6.8	4.7	0.9	0.5	0.4	0.9	1.3	1.7
Bolivina striatula spinata					0.4	0.4				1.0		0.3		0.5			0.3	0.5		0.5		0.4		0.4	
Bolivina translucens					0.4	0.4																			
Bulimina aculeata																	0.3								
Bulimina gibba							0.5																		
Bulimina marginata	0.9	0.5					0.5					0.3				0.4	0.9		0.5						0.3
Buliminella elegantissima							0.5																		
Buliminella morgani	11.1	9.8	5.2	10.4	5.8	18.8	9.2	10.9	8.6	8.1	8.8	8.8	8.1	6.3	4.4	6.4	7.6	9.9	12.1	21.7	17.3	15.2	6.0	15.2	17.0
Elphidium excavatum	0.5						1.4											0.5							
Epistominella vitrea	78.7	83.8	87.8	79.8	87.7	70.9	69.3	71.6	70.8	77.2	79.9	82.4	80.5	89.8	85.7	89.4	81.3	50.5	65.1	55.2	75.9	76.6	81.9	71.0	71.2
Fursenkoina mexicana		0.5																							
Fursenkoina pontoni						0.4	0.5	0.5					0.5						0.5	0.5					
Gavelinopsis praegeri												0.3													
Hopkinsina pacifica atl.	1.9	0.5					0.9			1.5									0.5						
Islandiella cf. *I. subglobosa*		0.5	0.4	1.0				0.5		0.5							0.9							0.4	
Islandiella sp. A																		0.5							
Lenticulina cf. *L. peregrina*										0.5								0.5							
Nonionella atlantica	0.5	0.5			0.4																				
Nonionella opima	1.4	2.0	2.6	3.6	2.1	4.5	6.4	11.8	16.3	9.1	6.7	3.3	7.2	0.5	8.2	0.8	5.4	30.6	14.0	19.9	6.4	6.9	10.6	11.3	9.4
Quinqueloculina sp. A				0.5																					
Quinqueloculina sp. B	0.5						1.4						0.5												
Quinqueloculina sp. C	0.5						0.9																		
Trochammina sp. A				0.5																					
Uvigerina peregrina										0.5				0.5						0.5					
Indeterminate miliolids							1.8										0.3			0.5					
Indeterminate rotaliids		0.5	0.4																0.5				0.5		
Indeterminate textulariids						0.4																			
Cumulative percentage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

KC3 (75 m)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Ammonia parkinsoniana									0.5											
Ammonia tepida										0.4										
Ammotium salsum												0.3				3.6	0.5		0.5	
Bolivina barbata				0.5				0.4		0.9			0.5	1.2			1.0	1.3	0.5	0.5
Bolivina cf. *B. daggarius*	2.1	2.2	0.4	1.9	0.4	5.7	0.9	1.4	2.0	5.6	1.0	6.4		4.5	6.0	2.2	1.0	4.7	1.5	8.3
Bolivina daggarius													2.3							
Bolivina goesii										0.4										
Bolivina lowmani	4.9	3.5	7.0	2.9	2.5	0.9	0.9	3.2	4.0	3.0	4.4	3.0	2.3	4.1	3.7	6.3	6.1	11.2	12.1	12.3
Bolivina striatula spinata	0.4	0.4		0.5	1.4	0.9	0.4	0.7	0.5	1.3		2.4	0.5	0.8	1.8			0.4	0.5	
Bolivina subaenariensis mexicana									0.5			0.6								
Bolivina translucens	0.4				0.7															
Bulimina gibba															0.5					
Bulimina marginata	0.4	1.3		1.4	0.4	0.9			3.0			1.5	0.9	2.0	0.9	1.3	1.0		0.5	4.9
Buliminella elegantissima	0.4		0.4																	
Buliminella morgani	12.8	13.0	9.6	8.2	9.7	20.3	26.5	21.5	31.8	20.9	17.2	17.3	9.3	27.0	14.7	24.7	23.7	15.1	11.6	15.7
Elphidium excavatum			0.9													0.4			0.5	
Elphidium gunteri											1.0									
Elphidium mexicanum											0.5									
Epistominella vitrea	66.3	74.5	78.6	78.3	78.1	57.5	59.7	62.7	50.7	53.0	60.1	49.4	67.0	44.3	60.4	49.8	64.6	58.2	66.2	46.1
Fursenkoina pontoni		0.4			0.4					0.4					0.5					
Globobulimina mississippiensis													0.5			2.2		0.9		
Islandiella cf. *I. subglobosa*	0.4									1.3		0.3	0.5	1.6		2.2		1.7	0.5	0.5
Lagena spp.					0.4														0.5	
Lenticulina cf. *L. peregrina*	0.4		0.4	0.5						0.4										
Nonionella opima	6.2	2.6	1.3	3.4	4.3	12.7	9.3	7.9	6.0	4.3	2.0	2.1	1.4	1.2	1.8	0.4	0.5	2.2	2.0	5.9
Pyrgo nasutus							0.4					0.6	0.5	0.4	0.5		0.5			
Quinqueloculina sp. A									0.5				0.5							
Quinqueloculina sp. B	0.4			0.5																
Quinqueloculina sp. C	0.4			1.0						0.4										
Quinqueloculina sp. D										0.4			0.5			0.4				
Quinqueloculina spp.				0.5				0.4	0.5					1.2		0.4		1.7		0.5
Texularia earlandi											10.3	5.2	1.4	0.4		1.3				
Uvigerina peregrina	4.1	0.9	0.4		1.1	0.9	1.8	1.1		6.8	3.4	9.1	12.1	11.1	9.2	4.0	1.0	2.2	2.0	3.9
Valvulinaria mexicana																				
Indeterminate rotaliids	0.4	0.9	0.9	0.5	0.7			0.7								0.4		0.4	0.5	1.5
Indeterminate textulariids		0.4								0.4		1.8							0.5	
Cumulative percentage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

KC2 (87 m)																								
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**	**200–201**	**210–211**	**220–221**	**230–231**
Ammonia parkinsoniana	0.5																					0.7		0.5
Ammonia tepida	2.4							0.4		0.5		0.9	0.4	0.4		0.5				0.5	1.5			0.9
Ammotium salsum								0.4	0.5	0.9		0.4									0.5			
Bolivina barbata	0.5	0.0	0.3	1.0	5.3	6.3	3.1	4.2	9.1	9.2	3.9	6.3	9.0	15.4	17.7	8.2	14.6	9.0	7.7	11.7	8.6	14.8	9.6	6.0
Bolivina cf. *B. daggarius*	0.5	0.5							0.5															0.9
Bolivina daggarius	0.5	0.5	1.0	0.3	0.4	1.4	0.4	1.2	0.5		0.9	0.4		0.4	1.0									
Bolivina fragilis					0.9																		0.5	
Bolivina goesii				0.3																				
Bolivina lowmani	5.9	4.1	5.2	2.0	5.3	12.1	13.4	13.9	6.4	10.6	7.3	4.9	18.9	13.4	23.2	18.5	23.2	24.9	12.9	15.5	11.2	16.1	17.1	16.5
Bolivina striatula spinata	3.9	1.5	1.0	1.6	2.6	0.5	0.9	0.4	0.9	1.8	0.4		1.3	0.8	0.5		1.8	1.6	0.6	2.3	1.5		0.5	
Bolivina subaenariensis mex.		0.5		0.3	0.4	1.9	2.2	2.3	2.3		3.4	1.8	4.3	3.9	2.5	1.6	3.7	2.6	2.6	0.9	1.5	2.0	6.4	0.9
Bolivina translucens	0.5	0.5	0.7																					
Bulimina aculeata										2.3														
Bulimina marginata	1.5	2.6	2.8	3.3	4.4	2.9	5.4	6.9	10.9	9.2	17.2	9.8	8.6	7.9	7.9	17.9	11.0	6.3	11.0	8.9	12.7	10.1	12.8	5.0
Buliminella elegantissima							0.4	0.4			0.4	0.9	0.4						1.3		0.5	0.7		0.9
Buliminella morgani	7.8	13.4	15.2	15.4	6.2	5.8	4.5	0.4	0.0	3.2	1.3	2.2	1.3	5.9	0.0	0.5	1.2	2.1	2.6	2.3	4.6	2.7	1.1	2.3
Cassidulina neocarinata								0.4	0.9														0.5	
Cibicides robertsonianus		0.5		0.3					0.9	1.4			0.4	2.0		0.5			3.2	0.9				1.8
Cibicides spp.				0.3		0.5	1.8		0.5	0.5	0.4	0.4		0.8	0.5		4.3	0.5	1.9	4.2	1.0	4.0	6.4	1.4
Elphidium excavatum	1.0					0.5	0.4	0.4	1.4	1.8		0.9	0.4		0.5				5.2		3.0	2.0		
Elphidium mexicanum																								0.5
Epistominella vitrea	47.8	59.3	62.3	47.4	41.9	51.7	45.1	39.8	36.4	39.0	30.6	38.8	27.9	22.8	14.8	26.1	11.6	18.0	15.5	15.0	16.2	10.7	8.0	20.2
Eponides regularis																				1.0			2.1	0.5
Eponides repandus					0.4			1.5		0.9	0.9		2.6	1.2	2.5	1.6	3.0	3.2	4.5	3.3	1.5	5.4		12.4
Eponides turgidus		0.5		0.3		1.0		0.8	2.3	0.5	4.3	2.2	4.7	4.3	7.9	5.4	4.3	4.2	5.8	2.8	2.5	6.0	4.8	5.0
Fissurina spp.				0.3									0.4	0.4	0.5	1.1		1.6			0.5			0.9
Fursenkoina complanata									0.5	0.9														0.5
Fursenkoina mexicana				0.7									0.4											0.5
Fursenkoina pontoni	0.5				0.4		0.4										0.6				0.5			
Gaudryina spp.					0.4							0.4	0.4											
Gavelinopsis praegeri				0.3		0.5		1.5	1.4	1.8	2.2		0.9	0.8	0.5	0.5	0.6	2.6	2.6	0.9	0.5	2.0		
Globobulimina mississippiensis		0.5		0.7	0.4						0.4			0.4	0.5		1.2						0.5	
Hanzawaia strattoni					0.9	1.0			1.8	0.5		0.9	0.4		0.5		1.8			1.9			0.5	0.9
Hoeglundina elegans																							0.5	
Islandiella cf. *I. subglobosa*	1.5	0.5	0.3			0.5		1.9	1.4	0.9	1.7	1.3	1.7	0.8	2.5	1.6	0.6	4.8	4.5	2.8	2.0	2.0		2.3
Islandiella norcrossi australis											0.4	0.4		0.4			0.6		0.6	0.5				
Islandiella sp. A															0.5									0.9
Lagena spp.		0.5	0.7	1.0		0.5	0.4				0.4	0.4	0.4		3.9	0.5	0.6	0.5	0.6		0.5		1.6	0.9
Lenticulina calcar									0.9				0.4					0.5		1.0	0.5	0.7	0.5	
Lenticulina cf. *L. peregrina*				0.3		0.5	4.0	1.2			0.4	1.8	0.4	0.4	0.5	1.1				0.5	0.5	0.7		
Marginulina marginulinoides												0.5		0.4										

KC2 (87 m) (cont.)																								
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**	**200–201**	**210–211**	**220–221**	**230–231**
Nonionella atlantica					0.9																			
Nonionella opima	19.0	7.7	5.9	6.2	0.9	1.0	3.6	2.3	0.9	1.4	0.4	1.8		1.2	1.0	1.6	0.6	0.5	2.6		1.5		0.5	0.5
Pyrgo nasutus					0.4		0.4			0.5		0.9						2.1						
Quinqueloculina sp. A																								0.9
Quinqueloculina sp. B																								2.3
Quinqueloculina sp. C			0.3	0.7	0.4					0.9			0.4				0.6				0.5			
Quinqueloculina sp. D							0.4						0.4	0.4			0.6							
Quinqueloculina spp.		1.0		0.7			0.9	0.4								1.6					0.5			0.9
Sagrina pulchella primitiva													0.4				0.6	1.6				0.7		0.5
Sigmoilina spp.					0.4	0.5		0.4															0.5	
Textularia candeiana																							1.7	
Textularia earlandi				0.3					0.5															
Uvigerina auberiana																		0.5		2.3	0.5			1.4
Uvigerina peregrina	6.3	4.1	3.1	15.4	23.3	9.2	11.6	12.4	14.5	11.0	18.5	15.6	12.0	13.0	9.9	9.8	10.4	10.6	6.5	11.3	16.8	11.4	19.3	4.6
Valvulineria mexicana			0.3	0.7				0.4	0.5		0.4	0.9	0.4		0.5		1.2		1.9	3.8	1.5	2.0	2.7	2.3
Indeterminate miliolids					1.3			2.3	1.4		1.7	1.8		1.2	0.5			2.1			0.5			
Indeterminate rotaliids		1.5	0.3	0.3	1.3	1.0	0.4	3.5	3.2	0.5	2.2	0.4		1.2		1.1	1.2		5.8	5.2	5.6	5.4	2.1	4.1
Indeterminate textulariids			0.3		0.9	1.0		0.4				2.7	0.4	0.4						0.5	0.5			
Cumulative percentage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

KC1 (473 m)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Ammobaculites spp.			0.4													0.5				
Ammonia tepida																		0.9		
Anomalinoides mexicana	1.0	0.5					3.4			1.3	3.3	1.5	1.7	3.7					1.1	0.5
Bolivina alata		0.9		0.5	0.5	1.8	0.5	0.8	2.1	0.4	1.9	1.0	2.1	1.4		3.4	2.7	1.4	3.9	1.0
Bolivina albatrossi			0.8	3.3	1.8	0.4	1.5	0.4		1.7	0.5	0.5	1.3	3.3		1.0	0.5		1.1	0.5
Bolivina barbata	1.0	1.9	0.8	0.5		2.7	5.4	0.4	0.4		3.3	1.9	3.9	1.9	1.0	1.4		0.9	1.1	4.9
Bolivina cf. *B. daggarius*											0.5									
Bolivina daggarius													1.7			1.0	1.1	0.5		0.5
Bolivina fragilis			0.4				0.5	0.4	0.4		0.9	1.5	1.3			1.0				1.5
Bolivina lowmani	18.0	16.4	18.0	9.3	13.4	17.9	17.6	10.2	22.2	3.8	9.4	13.1	12.9	5.1	2.0	16.9	29.5	9.0	15.5	12.6
Bolivina minima										0.4										
Bolivina simplex	13.4	13.1	15.5	13.5	19.8	8.5	10.8	17.4	9.9	16.3	10.3	14.6	4.7	10.7	4.5	21.7	5.5	9.5	9.4	15.0
Bolivina striatula spinata										0.8	1.4								0.6	0.5
Bolivina subaenariensis mex.	1.0	0.9	0.8	0.9		0.9	2.5	0.4	0.4	0.8	3.3	2.4	1.7	0.9	2.5		3.3	0.5	1.1	1.0
Bolivina subspinescens	0.5							0.4		0.4	0.5			0.5			0.5	0.9		
Bolivina translucens	1.5	0.9	1.3		1.8	4.5	3.4	1.7	4.9	1.7	1.9	1.9	1.3	0.9		1.4	2.2	0.5		1.5
Bulimina aculeata	2.1		5.4	5.1	5.1		0.5	1.3		3.3			1.3	0.5		1.9	0.5	5.9	2.2	
Bulimina alazanensis			0.4						0.4		0.5	0.5								
Bulimina marginata	0.5	2.3	0.8		0.5		6.4			0.8	3.3	1.5	4.3	5.6		1.0	1.1	2.3	1.7	4.4
Bulimina striata mexicana	2.1	3.8	1.7		1.8	1.3	2.0	1.3	0.8	1.7	0.5	1.0	2.1	3.7	24.2	2.9	1.6	5.4		1.5
Buliminella morgani			0.4			0.4	1.5	0.4	0.8		1.9	2.4	3.4					1.4	0.6	
Cassidulina carinata			0.8			0.9	1.0					0.5		1.4	0.5				1.1	0.5
Cassidulina crassa	2.1		1.7		0.5						0.5	0.5		0.9		0.5		0.5		
Cassidulina neocarinata	9.8	15.5	5.4	20.9	10.6	9.9	5.9	21.2	19.3	15.9	6.1	9.7	3.9	9.3	36.4	11.1	16.9	20.7	19.9	3.4
Cassidulina tenuis							0.5				0.5			0.9			0.5			0.5
Chilostomella oolina	1.0	0.5	0.4		0.5	1.3	1.0	1.7	2.5	0.4	0.5			0.9		1.9	3.3	0.5	0.6	
Cibicides robertsonianus					0.9		0.5	0.8		0.8	0.9	0.5				0.5	1.1		0.6	
Cibicides spp.			0.4	0.5	0.5		1.0	0.8		0.4	0.9									
Cibicides umbonatus	0.5	0.9	0.8			0.9				0.8	0.5	1.9		1.4		0.5	0.5	0.5		
Elphidium excavatum	1.0									0.4	1.4	0.5					1.1	0.5		
Epistominella vitrea	1.5	3.8	3.3	1.4		4.5	5.9	1.7	2.5	2.1	16.0	8.3	19.7	6.1	3.5	3.4	3.8	5.4	4.4	15.0
Eponides antillarum				0.5																
Eponides regularis	12.4	8.9	9.2	9.8	17.5	6.3	2.9	11.4	3.7	7.5	3.8	3.4	4.3	6.1	7.1	4.8	0.0	5.9	11.0	1.0
Eponides turgidus	1.0		1.7	1.4	0.9	1.8	2.9	1.3	0.4	1.7	3.3	5.3	5.2	2.8		2.9		1.4	5.0	4.4
Fissurina spp.				0.5			0.5				0.9			0.9						
Fursenkoina complanata		0.9				0.9														
Fursenkoina mexicana			0.8	0.9		0.4	1.0		0.4	0.4	0.5					0.5	3.8		1.1	
Fursenkoina tessellata			0.8																	
Gavelinopsis praegeri	4.6	2.8	3.3	6.5	6.5	9.4		2.5	2.9	3.8	0.9	1.0	0.4	3.3		3.4	2.2	6.8	2.2	0.5
Globobulimina mississippiensis												0.5								
Gyroidina altiformis	1.5			0.5					0.4	0.4			0.4	0.5	1.5		0.5			

KC1 (473 m) (cont.)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Gyroidina orbicularis											0.5			0.5						
Hanzawaia strattoni				0.5	0.5	1.3		1.3		0.4			0.4		1.0		0.5	0.9	0.6	
Haplophragmoides spp.	0.5																			
Hoeglundina elegans																		0.5		
Hopkinsina pacifica atl.										0.4	0.5									
Islandiella cf. *I. subglobosa*		2.8	5.0	1.9	1.8	3.1	7.4		1.2	2.1	4.2	5.8	7.3	2.8		1.0		1.4	2.2	6.3
Islandiella norcrossi australis	9.3	12.7	10.9	4.7	3.2	9.4	4.9	11.9	16.9	16.7	2.8	6.3	4.7	5.1	13.6	5.8	13.1	5.4	2.8	1.5
Lagena spp.	0.5			0.9	0.5		1.0			0.4	0.5		0.4	0.9				0.5		
Lenticulina cf. *L. peregrina*														0.5						
Lenticulina sp. A				0.5			0.5					0.5								
Lenticulina thalmanni								0.4	0.4					0.5						
Nodosaria spp.						0.4					0.5									
Nonionella atlantica		0.9	0.4	0.5		1.3													0.6	
Nonionella opima	2.6								0.4	1.3		0.5	0.4					0.5		1.0
Nonionella turgida		0.9											0.4				1.1			
Oolina spp.												0.5						0.5		
Oridorsalis umbonatus			0.4	0.5				0.4		0.4	0.5			0.5	0.5		0.5	0.5	0.6	0.5
Pullenia spp.						0.4														
Pyrgo nasutus				0.5					0.8			0.5				0.5	0.5	0.9	0.6	0.5
Pyrgo spp.										0.4		0.5	0.9							
Quinqueloculina sp. A																				0.5
Quinqueloculina sp. D	0.5								0.4											
Quinqueloculina sp. E						0.4														
Quinqueloculina spp.	0.5	0.5					1.5				0.5	1.0	1.3	0.9	0.5			0.5		
Rosalina spp.				0.5		0.9					0.5	0.5		0.5				0.5		0.5
Sagrina pulchella primitiva	0.5											0.5	0.4	0.9					0.6	
Sigmoilina spp.					0.5									0.5					0.6	0.5
Siphonina pulchra		0.5																		
Sphaeroidina bulloides	2.1	0.9	0.8	0.5				0.4		0.4				0.5	0.5	0.5	1.1			
Textularia candeiana																			0.6	
Trochammina sp. A			0.4																	
Uvigerina laevis		0.9	0.4	0.5	0.5		0.5			0.4	0.5	2.4	0.9	0.5	0.5		0.5	0.9		1.0
Uvigerina peregrina	2.1	2.8	5.0	6.5	4.1	2.2	5.4	3.0	2.1	3.8	5.2	1.9	2.1	8.9		1.0		2.7	2.2	10.2
Valvulineria minuta	3.6	1.4		4.2	4.6	4.0		3.4	0.0	4.6		0.5	0.9	2.8		5.3		2.3	3.9	3.4
Indeterminate miliolids		0.5							0.4	0.4	0.5	1.5	0.4			0.5		0.9	1.1	
Indeterminate rotaliids	0.5	0.5	0.4	2.3	1.8	0.9		2.5	2.9		3.8	1.5	1.7	0.9		1.9		0.9		3.9
Indeterminate textulariids	0.5	0.5	0.4			0.4														
Cumulative percentage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

APPENDIX 6: ARCSINE SQUARE-ROOT TRANSFORMED FORAMINIFERAL CENSUS DATA FOR CLUSTER ANALYSIS

	KC4 (59 m)																								
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**	**200–201**	**210–211**	**220–221**	**230–231**	**240–241**
Ammonia parkinsoniana	0.14						0.14																	0.13	0.12
Ammonia tepida			0.13			0.13	0.27	0.14	0.13	0.14	0.22		0.13	0.14					0.31						
Bolivina cf. B. daggarius	0.14		0.23	0.14							0.18					0.13	0.11								
Bolivina daggarius																						0.13			
Bolivina fragilis																		0.13		0.13					
Bolivina goesii			0.13																						
Bolivina lowmani	0.36	0.24	0.23	0.38	0.36	0.38	0.43	0.42	0.40	0.20	0.32	0.43	0.33	0.28	0.26	0.32	0.33	0.53	0.43	0.19	0.13	0.13	0.19	0.23	0.26
Bolivina striatula spinata					0.13	0.13				0.20		0.11		0.14			0.11	0.13		0.13		0.13		0.13	
Bolivina translucens					0.13	0.13																			
Bulimina aculeata																	0.11								
Bulimina gibba							0.14																		
Bulimina marginata	0.19	0.14					0.14					0.11				0.13	0.19		0.14						0.12
Buliminella elegantissima							0.14																		
Buliminella morgani	0.68	0.64	0.46	0.66	0.48	0.90	0.62	0.67	0.59	0.58	0.60	0.60	0.58	0.51	0.42	0.51	0.56	0.64	0.71	0.97	0.86	0.80	0.50	0.80	0.85
Elphidium excavatum	0.14						0.24											0.13							
Epistominella vitrea	2.18	2.31	2.43	2.21	2.42	2.00	1.97	2.02	2.00	2.14	2.21	2.28	2.23	2.49	2.37	2.48	2.25	1.58	1.88	1.68	2.12	2.13	2.26	2.00	2.01
Fursenkoina mexicana		0.14																							
Fursenkoina pontoni						0.13	0.14	0.14					0.13						0.14	0.13					
Gavelinopsis praegeri												0.11													
Hopkinsina pacifica atl.	0.27	0.14					0.19			0.25									0.14						
Islandiella cf. *I. subglobosa*		0.14	0.13	0.20				0.14		0.14							0.19							0.13	
Islandiella sp. A																		0.13							
Lenticulina cf. *L. peregrina*										0.14								0.13							
Nonionella atlantica	0.14	0.14			0.13																				
Nonionella opima	0.24	0.28	0.33	0.38	0.29	0.43	0.51	0.70	0.83	0.61	0.52	0.36	0.54	0.14	0.58	0.18	0.47	1.17	0.77	0.93	0.51	0.53	0.66	0.68	0.62
Quinqueloculina sp. A				0.14																					
Quinqueloculina sp. B	0.14						0.24						0.13												
Quinqueloculina sp. C	0.14						0.19																		
Trochammina sp. A				0.14																					
Uvigerina peregrina										0.14				0.14						0.13					
Indeterminate miliolids							0.27										0.11			0.13					
Indeterminate rotaliids		0.14	0.13																0.14				0.14		
Indeterminate textulariids						0.13																			

KC3 (75 m)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Ammonia parkinsoniana									0.14											
Ammonia tepida										0.13										
Ammotium salsum												0.11				0.38	0.14		0.14	
Bolivina barbata				0.14				0.12		0.19			0.14	0.22			0.20	0.23	0.14	0.14
Bolivina cf. *B. daggarius*	0.29	0.30	0.13	0.28	0.12	0.48	0.19	0.24	0.28	0.48	0.20	0.51		0.43	0.49	0.30	0.20	0.44	0.25	0.59
Bolivina daggarius													0.31							
Bolivina goesii										0.13										
Bolivina lowmani	0.45	0.37	0.54	0.34	0.32	0.19	0.19	0.36	0.40	0.35	0.42	0.35	0.31	0.41	0.39	0.51	0.50	0.68	0.71	0.72
Bolivina striatula spinata	0.13	0.13		0.14	0.24	0.19	0.13	0.17	0.14	0.23		0.31	0.14	0.18	0.27			0.13	0.14	
Bolivina subaenariensis mexicana									0.14			0.16								
Bolivina translucens	0.13				0.17															
Bulimina gibba															0.14					
Bulimina marginata	0.13	0.23		0.24	0.12	0.19			0.35			0.25	0.19	0.29	0.19	0.23	0.20		0.14	0.45
Buliminella elegantissima	0.13		0.13																	
Buliminella morgani	0.73	0.74	0.63	0.58	0.63	0.93	1.08	0.96	1.20	0.95	0.86	0.86	0.62	1.09	0.79	1.04	1.02	0.80	0.70	0.81
Elphidium excavatum			0.19													0.13			0.14	
Elphidium gunteri											0.20									
Elphidium mexicanum											0.14									
Epistominella vitrea	1.90	2.08	2.18	2.17	2.17	1.72	1.77	1.83	1.59	1.63	1.77	1.56	1.92	1.46	1.78	1.57	1.87	1.74	1.90	1.49
Fursenkoina pontoni		0.13			0.12					0.13					0.14					
Globobulimina mississippiensis													0.14			0.30		0.19		
Islandiella cf. *I. subglobosa*	0.13									0.23		0.11	0.14	0.26		0.30		0.26	0.14	0.14
Lagena spp.					0.12														0.14	
Lenticulina cf. *L. peregrina*	0.13		0.13	0.14						0.13										
Nonionella opima	0.50	0.32	0.23	0.37	0.42	0.73	0.62	0.57	0.49	0.42	0.28	0.29	0.24	0.22	0.27	0.13	0.14	0.29	0.29	0.49
Pyrgo nasutus							0.13					0.16	0.14	0.13	0.14		0.14			
Quinqueloculina sp. A									0.14				0.14							
Quinqueloculina sp. B	0.13			0.14																
Quinqueloculina sp. C	0.13			0.20						0.13										
Quinqueloculina sp. D										0.13			0.14			0.13				
Quinqueloculina spp.				0.14				0.12	0.14					0.22		0.13		0.26		0.14
Texularia earlandi											0.65	0.46	0.24	0.13		0.23				
Uvigerina peregrina	0.41	0.19	0.13		0.21	0.19	0.27	0.21		0.53	0.37	0.61	0.71	0.68	0.62	0.40	0.20	0.29	0.29	0.40
Valvulinaria mexicana																				
Indeterminate rotaliids	0.13	0.19	0.19	0.14	0.17			0.17								0.13		0.13	0.14	0.24
Indeterminate textulariids		0.13								0.13		0.27							0.14	

Depth in Core (cm)→ Taxon↓	KC2 (87 m)																							
	0-1	**10-11**	**20-21**	**30-31**	**40-41**	**50-51**	**60-61**	**70-71**	**80-81**	**90-91**	**100-111**	**110-111**	**120-121**	**130-131**	**140-141**	**150-151**	**160-161**	**170-171**	**180-181**	**190-191**	**200-201**	**210-211**	**220-221**	**230-231**
Ammonia parkinsoniana	0.14																					0.17		0.14
Ammonia tepida	0.31							0.13		0.14		0.19	0.13	0.13		0.14				0.14	0.25			0.19
Ammotium salsum								0.13	0.14	0.19		0.13									0.14			
Bolivina barbata	0.14		0.11	0.20	0.46	0.51	0.35	0.41	0.61	0.62	0.40	0.51	0.61	0.81	0.87	0.58	0.78	0.61	0.56	0.70	0.60	0.79	0.63	0.49
Bolivina cf. *B. daggarius*	0.14	0.14							0.14															0.19
Bolivina daggarius	0.14	0.14	0.20	0.11	0.13	0.24	0.13	0.22	0.14		0.19	0.13		0.13	0.20									
Bolivina fragilis					0.19																		0.14	
Bolivina goesii				0.11																				
Bolivina lowmani	0.49	0.41	0.46	0.28	0.46	0.71	0.75	0.76	0.51	0.66	0.55	0.45	0.90	0.75	1.01	0.89	1.01	1.04	0.73	0.81	0.68	0.83	0.85	0.84
Bolivina striatula spinata	0.40	0.25	0.20	0.25	0.32	0.14	0.19	0.13	0.19	0.27	0.13		0.23	0.18	0.14		0.27	0.25	0.16	0.30	0.25		0.14	
Bolivina subaenariensis mex.		0.14		0.11	0.13	0.28	0.30	0.30	0.30		0.37	0.27	0.42	0.40	0.32	0.25	0.39	0.32	0.32	0.19	0.25	0.28	0.51	0.19
Bolivina translucens	0.14	0.14	0.17																					
Bulimina aculeata										0.30														
Bulimina marginata	0.25	0.32	0.34	0.37	0.42	0.34	0.47	0.53	0.67	0.62	0.86	0.64	0.60	0.57	0.57	0.87	0.68	0.51	0.68	0.61	0.73	0.65	0.73	0.45
Buliminella elegantissima							0.13	0.13			0.13	0.19	0.13						0.23		0.14	0.17		0.19
Buliminella morgani	0.57	0.75	0.80	0.81	0.50	0.49	0.43	0.13		0.36	0.23	0.30	0.23	0.49		0.14	0.22	0.29	0.32	0.30	0.43	0.33	0.21	0.30
Cassidulina neocarinata								0.13	0.19														0.14	
Cibicides robertsonianus		0.14		0.11					0.19	0.24			0.13	0.28		0.14			0.36	0.19				0.27
Cibicides spp.				0.11		0.14	0.27		0.14	0.14	0.13	0.13		0.18	0.14		0.42	0.14	0.28	0.41	0.20	0.40	0.51	0.24
Elphidium excavatum	0.20					0.14	0.13	0.13	0.24	0.27		0.19	0.13		0.14				0.46		0.35	0.28		
Elphidium mexicanum																								0.14
Epistominella vitrea	1.53	1.76	1.82	1.52	1.41	1.60	1.47	1.37	1.30	1.35	1.17	1.34	1.11	1.00	0.79	1.07	0.70	0.88	0.81	0.80	0.83	0.67	0.57	0.93
Eponides regularis																				0.20			0.29	0.14
Eponides repandus					0.13			0.25		0.19	0.19		0.32	0.22	0.32	0.25	0.35	0.36	0.43	0.37	0.25	0.47		0.72
Eponides turgidus		0.14		0.11		0.20		0.18	0.30	0.14	0.42	0.30	0.44	0.42	0.57	0.47	0.42	0.41	0.49	0.34	0.32	0.49	0.44	0.45
Fissurina spp.				0.11									0.13	0.13	0.14	0.21		0.25			0.14			0.19
Fursenkoina complanata									0.14	0.19														0.14
Fursenkoina mexicana				0.17									0.13											0.14
Fursenkoina pontoni	0.14				0.13		0.13										0.16				0.14			
Gaudryina spp.					0.13							0.13	0.13											
Gavelinopsis praegeri				0.11		0.14		0.25	0.24	0.27	0.30		0.19	0.18	0.14	0.14	0.16	0.32	0.32	0.19	0.14	0.28		
Globobulimina mississippiensis		0.14		0.17	0.13						0.13			0.13	0.14		0.22						0.14	
Hanzawaia strattoni					0.19	0.20			0.27	0.14		0.19	0.13		0.14		0.27			0.28			0.14	0.19
Hoeglundina elegans																							0.14	
Islandiella cf. *I. subglobosa*	0.25	0.14	0.11			0.14		0.28	0.24	0.19	0.26	0.23	0.26	0.18	0.32	0.25	0.16	0.44	0.43	0.34	0.28	0.28		0.30
Islandiella norcrossi australis											0.13	0.13		0.13			0.16		0.16	0.14				
Islandiella sp. A															0.14									0.19
Lagena spp.		0.14	0.17	0.20		0.14	0.13				0.13	0.13	0.13		0.40	0.14	0.16	0.14	0.16		0.14		0.25	0.19
Lenticulina calcar									0.19				0.13					0.14		0.20	0.14	0.17	0.14	
Lenticulina cf. *L. peregrina*				0.11		0.14	0.40	0.22			0.13	0.27	0.13	0.13	0.14	0.21				0.14	0.14	0.17		
Marginulina marginulinoides												0.14		0.13										

KC2 (87 m)																								
Depth in Core (cm)→ Taxon↓	**0-1**	**10-11**	**20-21**	**30-31**	**40-41**	**50-51**	**60-61**	**70-71**	**80-81**	**90-91**	**100-111**	**110-111**	**120-121**	**130-131**	**140-141**	**150-151**	**160-161**	**170-171**	**180-181**	**190-191**	**200-201**	**210-211**	**220-221**	**230-231**
Nonionella atlantica					0.19																			
Nonionella opima	0.90	0.56	0.49	0.50	0.19	0.20	0.38	0.30	0.19	0.24	0.13	0.27		0.22	0.20	0.25	0.16	0.14	0.32		0.25		0.14	0.14
Pyrgo nasutus					0.13		0.13			0.14		0.19						0.29						
Quinqueloculina sp. A																								0.19
Quinqueloculina sp. B																								0.30
Quinqueloculina sp. C			0.11	0.17	0.13					0.19			0.13				0.16				0.14			
Quinqueloculina sp. D							0.13						0.13	0.13			0.16							
Quinqueloculina spp.		0.20		0.17			0.19	0.13								0.25					0.14			0.19
Sagrina pulchella primitiva													0.13				0.16	0.25				0.17		0.14
Sigmoilina spp.					0.13	0.14		0.13															0.14	
Textularia candeiana																							0.26	
Textularia earlandi				0.11					0.14															
Uvigerina auberiana																		0.14		0.30	0.14			0.24
Uvigerina peregrina	0.51	0.41	0.35	0.81	1.01	0.62	0.70	0.72	0.78	0.68	0.89	0.81	0.71	0.74	0.64	0.64	0.66	0.66	0.52	0.69	0.84	0.69	0.91	0.43
Valvulineria mexicana			0.11	0.17				0.13	0.14		0.13	0.19	0.13		0.14		0.22		0.28	0.39	0.25	0.28	0.33	0.30
Indeterminate miliolids			0.00		0.23			0.30	0.24		0.26	0.27		0.22	0.14			0.29			0.14			
Indeterminate rotaliids		0.25	0.11	0.11	0.23	0.20	0.13	0.38	0.36	0.14	0.30	0.13		0.22		0.21	0.22		0.49	0.46	0.48	0.47	0.29	0.41
Indeterminate textulariids			0.11		0.19	0.20		0.13				0.33	0.13	0.13						0.14	0.14			

KC1 (473 m)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Ammobaculites spp.			0.13													0.14				
Ammonia tepida																		0.19		
Anomalinoides mexicana	0.20	0.14					0.37			0.22	0.36	0.24	0.26	0.39					0.21	0.14
Bolivina alata		0.19		0.14	0.14	0.27	0.14	0.18	0.29	0.13	0.27	0.20	0.29	0.24		0.37	0.33	0.23	0.40	0.20
Bolivina albatrossi			0.18	0.36	0.27	0.13	0.24	0.13		0.26	0.14	0.14	0.23	0.36		0.20	0.15		0.21	0.14
Bolivina barbata	0.20	0.27	0.18	0.14		0.33	0.47	0.13	0.13		0.36	0.28	0.40	0.27	0.20	0.24		0.19	0.21	0.44
Bolivina cf. *B daggarius*											0.14									
Bolivina daggarius													0.26			0.20	0.21	0.13		0.14
Bolivina fragilis			0.13				0.14	0.13	0.13		0.19	0.24	0.23			0.20				0.24
Bolivina lowmani	0.88	0.83	0.88	0.62	0.75	0.87	0.87	0.65	0.98	0.39	0.62	0.74	0.73	0.46	0.29	0.85	1.15	0.61	0.81	0.73
Bolivina minima										0.13										
Bolivina simplex	0.75	0.74	0.81	0.75	0.92	0.59	0.67	0.86	0.64	0.83	0.65	0.78	0.44	0.67	0.43	0.97	0.47	0.63	0.62	0.80
Bolivina striatula spinata										0.18	0.24								0.15	0.14
Bolivina subaenariensis mex.	0.20	0.19	0.18	0.19		0.19	0.31	0.13	0.13	0.18	0.36	0.31	0.26	0.19	0.32		0.36	0.13	0.21	0.20
Bolivina subspinescens	0.14							0.13		0.13	0.14			0.14			0.15	0.19		
Bolivina translucens	0.25	0.19	0.22		0.27	0.43	0.37	0.26	0.45	0.26	0.27	0.28	0.23	0.19		0.24	0.30	0.13		0.24
Bulimina aculeata	0.29		0.47	0.46	0.45		0.14	0.23		0.37			0.23	0.14		0.28	0.15	0.49	0.30	
Bulimina alazanensis			0.13						0.13		0.14	0.14								
Bulimina marginata	0.14	0.31	0.18		0.14		0.51			0.18	0.36	0.24	0.42	0.48		0.20	0.21	0.30	0.26	0.42
Bulimina striata mexicana	0.29	0.39	0.26		0.27	0.23	0.28	0.23	0.18	0.26	0.14	0.20	0.29	0.39	1.03	0.34	0.26	0.47		0.24
Buliminella morgani			0.13			0.13	0.24	0.13	0.18		0.27	0.31	0.37					0.23	0.15	
Cassidulina carinata			0.18			0.19	0.20					0.14		0.24	0.14				0.21	0.14
Cassidulina crassa	0.29		0.26		0.14						0.14	0.14		0.19		0.14		0.13		
Cassidulina neocarinata	0.64	0.81	0.47	0.95	0.66	0.64	0.49	0.96	0.91	0.82	0.50	0.63	0.40	0.62	1.29	0.68	0.85	0.95	0.92	0.37
Cassidulina tenuis							0.14				0.14			0.19			0.15			0.14
Chilostomella oolina	0.20	0.14	0.13		0.14	0.23	0.20	0.26	0.32	0.13	0.14			0.19		0.28	0.36	0.13	0.15	
Cibicides robertsonianus					0.19		0.14	0.18		0.18	0.19	0.14				0.14	0.21		0.15	
Cibicides spp.			0.13	0.14	0.14		0.20	0.18		0.13	0.19									
Cibicides umbonatus	0.14	0.19	0.18			0.19				0.18	0.14	0.28		0.24		0.14	0.15	0.13		
Elphidium excavatum	0.20									0.13	0.24	0.14					0.21	0.13		
Epistominella vitrea	0.25	0.39	0.37	0.24		0.43	0.49	0.26	0.32	0.29	0.82	0.58	0.92	0.50	0.38	0.37	0.39	0.47	0.42	0.80
Eponides antillarum				0.14																
Eponides regularis	0.72	0.61	0.62	0.64	0.86	0.51	0.34	0.69	0.39	0.56	0.39	0.37	0.42	0.50	0.54	0.44	0.00	0.49	0.68	0.20
Eponides turgidus	0.20		0.26	0.24	0.19	0.27	0.34	0.23	0.13	0.26	0.36	0.47	0.46	0.34		0.34		0.23	0.45	0.42
Fissurina spp.				0.14			0.14				0.19			0.19						
Fursenkoina complanata		0.19				0.19														
Fursenkoina mexicana			0.18	0.19		0.13	0.20		0.13	0.13	0.14					0.14	0.39		0.21	
Fursenkoina tessellata			0.18																	
Gavelinopsis praegeri	0.43	0.34	0.37	0.52	0.51	0.62		0.32	0.34	0.39	0.19	0.20	0.13	0.36		0.37	0.30	0.53	0.30	0.14
Globobulimina mississippiensis												0.14								
Gyroidina altiformis	0.25			0.14					0.13	0.13			0.13	0.14	0.25		0.15			

KC1 (473 m) (cont.)																				
Depth in Core (cm)→ Taxon↓	**0–1**	**10–11**	**20–21**	**30–31**	**40–41**	**50–51**	**60–61**	**70–71**	**80–81**	**90–91**	**100–111**	**110–111**	**120–121**	**130–131**	**140–141**	**150–151**	**160–161**	**170–171**	**180–181**	**190–191**
Gyroidina orbicularis											0.14			0.14						
Hanzawaia strattoni				0.14	0.14	0.23		0.23		0.13			0.13		0.20		0.15	0.19	0.15	
Haplophragmoides spp.	0.14																			
Hoeglundina elegans																		0.13		
Hopkinsina pacifica atl.										0.13	0.14									
Islandiella cf. I. *subglobosa*		0.34	0.45	0.27	0.27	0.36	0.55		0.22	0.29	0.41	0.49	0.55	0.34		0.20		0.23	0.30	0.51
Islandiella norcrossi australis	0.62	0.73	0.67	0.43	0.36	0.62	0.45	0.70	0.85	0.84	0.34	0.51	0.44	0.46	0.76	0.49	0.74	0.47	0.33	0.24
Lagena spp.	0.14			0.19	0.14		0.20			0.13	0.14		0.13	0.19				0.13		
Lenticulina cf. *L. peregrina*														0.14						
Lenticulina sp. A				0.14			0.14					0.14								
Lenticulina thalmanni								0.13	0.13					0.14						
Nodosaria spp.						0.13					0.14									
Nonionella atlantica		0.19	0.13	0.14		0.23													0.15	
Nonionella opima	0.32								0.13	0.22		0.14	0.13					0.13		0.20
Nonionella turgida		0.19											0.13				0.21			
Oolina spp.												0.14						0.13		
Oridorsalis umbonatus						0.13														
Pullenia spp.				0.14					0.18			0.14				0.14	0.15	0.19	0.15	0.14
Pyrgo nasutus										0.13		0.14	0.19							
Pyrgo spp.																				0.14
Quinqueloculina sp. A	0.14								0.13											
Quinqueloculina sp. D						0.13														
Quinqueloculina sp. E	0.14	0.14					0.24				0.14	0.20	0.23	0.19	0.14			0.13		
Quinqueloculina spp.				0.14		0.19					0.14	0.14		0.14				0.13		0.14
Rosalina spp.	0.14											0.14	0.13	0.19					0.15	
Sagrina pulchella primitiva					0.14									0.14					0.15	0.14
Sigmoilina spp.		0.14																		
Siphonina pulchra	0.29	0.19	0.18	0.14				0.13		0.13				0.14	0.14	0.14	0.21			
Sphaeroidina bulloides																			0.15	
Textularia candeiana			0.13																	
Trochammina sp. A	0.29	0.34	0.45	0.52	0.41	0.30	0.47	0.35	0.29	0.39	0.46	0.28	0.29	0.61		0.20		0.33	0.30	0.65
Uvigerina laevis	0.38	0.24		0.41	0.43	0.40		0.37	0.00	0.43		0.14	0.19	0.34		0.47		0.30	0.40	0.37
Uvigerina peregrina		0.19	0.13	0.14	0.14		0.14			0.13	0.14	0.31	0.19	0.14	0.14		0.15	0.19		0.20
Valvulineria minuta		0.14							0.13	0.13	0.14	0.24	0.13			0.14		0.19	0.21	
Indeterminate miliolids	0.14	0.14	0.13	0.31	0.27	0.19		0.32	0.34		0.39	0.24	0.26	0.19		0.28		0.19		0.40
Indeterminate rotaliids	0.14	0.14	0.13			0.13														
Indeterminate textulariids																				