

Benthic Foraminiferal Census Data from Louisiana Continental Shelf Cores, Gulf of Mexico

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By Lisa E. Osterman, Wendy S. Kelly, and John P. Ricardo

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Contents

Introduction.....	1
Methods and Materials.....	1
Faunal Analysis	15
Acknowledgments	15
References Cited.....	15
Faunal Reference List.....	16

Figure

1. Map showing location of the hypoxia zone	2
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Tables

1. Longitude and latitude of Louisiana Shelf cores, Gulf of Mexico	2
2-11. Benthic foraminiferal data from core:	
2. MRJ03-2BC, Louisiana Shelf, Gulf of Mexico	3
3. MRJ03-3BC, Louisiana Shelf, Gulf of Mexico.....	4
4. MRD05-6BC, Louisiana Shelf, Gulf of Mexico.....	5
5. MRD05-6GC, Louisiana Shelf, Gulf of Mexico.....	6-8
6. PE0609BC, Louisiana Shelf, Gulf of Mexico	9
7. MCH-11BC, Louisiana Shelf, Gulf of Mexico.....	10
8. MCH-33BC, Louisiana Shelf, Gulf of Mexico.....	11
9. PE07-1BC, Louisiana Shelf, Gulf of Mexico.....	12
10. PE07-7BC, Louisiana Shelf, Gulf of Mexico.....	13
11. PE07-8BC, Louisiana Shelf, Gulf of Mexico	14

Conversion Factors, Acronyms, and Abbreviations

Multiply	By	To obtain
micrometer (μm)	0.0000394	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
liter (L)	33.82	ounce, fluid (fl. oz)
milliliter (mL)	0.03382	ounce, fluid (fl. oz)
cubic centimeter (cm^3)	0.06102	cubic inch (in^3)
gram (g)	0.03527	ounce, avoirdupois (oz)
Celsius ($^{\circ}\text{C}$)	$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$	Fahrenheit ($^{\circ}\text{F}$)

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Introduction

An area of oxygen-depleted bottom- and subsurface-water (hypoxia = dissolved oxygen $< 2 \text{ mg/L}^{-1}$) occurs seasonally on the Louisiana Shelf near the Mississippi River (fig. 1). The area of hypoxia, also known as the “dead zone,” forms when spring and early summer freshwater flow from the Mississippi River supplies a large amount of nutrients to the shelf while creating a freshwater lens, or cap, above the shelf water. The excess nutrients cause phytoplankton blooms in the shallow shelf water. After the bloom ceases, the organic material sinks in the water column and uses up oxygen during decomposition. Thus, the subsurface waters become oxygen depleted. The seasonal dead zone exists until a reduction in freshwater flow, or overturning by storms, allows mixing of the water column to restore normal oxygen conditions (Rabalais and others, 1994, 1996; Rabalais, 2002).

Since systematic measurement of the extent of the dead zone began in 1985, the overall pattern indicates that the area of the dead zone is increasing (Rabalais and Turner, 2001; Turner and others, 2005). Several studies have concluded that the expansion of the Louisiana Shelf dead zone is related to increased nutrients (primarily nitrogen, but possibly also phosphorous) in the Mississippi River drainage basin and is responsible for the degradation of Gulf of Mexico marine habitats (Goolsby and others, 2001). This paper presents the benthic foraminiferal data from 10 sediment cores collected from the Continental Shelf of Louisiana (table 1), obtained as part of an initiative to investigate the geographic and temporal extent of hypoxia prior to 1985 in the Gulf of Mexico (fig. 1).

Benthic foraminifers provide a method to track the development of hypoxia prior to 1985 (Blackwelder and others, 1996; Sen Gupta and others, 1996). Previous work (Osterman, 2003) has shown statistically that the relative occurrence of three low-oxygen-tolerant species represents the modern seasonal Louisiana hypoxia zone (fig. 1). The cumulative percentage of these three species (% *Pseudonion atlanticum* + % *Epistominella vitrea*, + % *Buliminella morgani* = PEB index of hypoxia) provides a way to investigate fluctuation in paleohypoxia. Interpretation of some of these cores is provided in Osterman and others (2005), Osterman and others (2008a,b), and Swarzenski and others (2008). Our hypothesis is that the increased relative abundance of PEB species in dated sediment cores accurately tracks past seasonal low-oxygen conditions on the Louisiana Shelf.

Methods and Materials

The cores were collected between 20 and 231 m water depth (mwd) during five cruises (table 1). Gravity and box cores were collected on the Louisiana Continental Shelf and Slope on the R/V *Pelican* cruises MRD05 (May 2005), PE06 (July 2006), MCH (April 2007), and PE07 (April 2007). Two box cores were collected on the R/V *Longhorn* cruise MRJ03 (July 2003). In all cases, the box cores were subsampled using push cores that were extruded and sampled within 1 day. Gravity core MRD05-06 was sectioned and capped after collection. The gravity-core and box-core samples were refrigerated and transported to the U.S. Geological Survey (USGS),

2 Benthic Foraminiferal Census Data from Louisiana Continental Shelf Cores, Gulf of Mexico

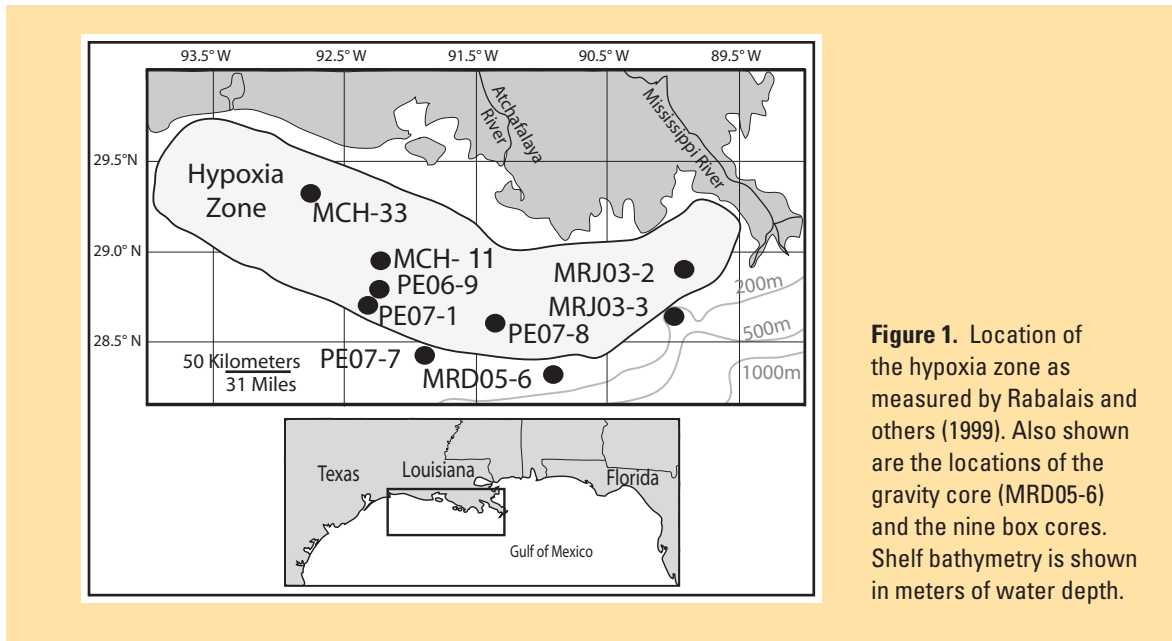


Figure 1. Location of the hypoxia zone as measured by Rabalais and others (1999). Also shown are the locations of the gravity core (MRD05-6) and the nine box cores. Shelf bathymetry is shown in meters of water depth.

Table 1. Longitude and latitude of Louisiana Shelf cores, Gulf of Mexico.

Core	Latitude "decimal degrees"	Longitude "decimal degrees"	Water depth (m)	Core length (cm)
MRJ03-2BC	28.89033	89.89300	43	52
MRJ03-3BC	28.62580	90.00090	231	58
MRD05-6BC	28.27910	90.90950	65	42
MRD05-6GC	28.27990	90.91120	65	153
PE06-09BC	28.77500	92.38330	33	18
MCH-11BC	28.68060	92.20960	30	36
MCH-33BC	29.19840	92.70110	20	36
PE07-1BC	28.69972	92.39110	33	38
PE07-7BC	29.49528	91.99722	47	31.5
PE07-8BC	28.58300	91.36670	32	37

in St. Petersburg, FL, where the gravity-core sediments in plastic core liners were extruded and sampled within weeks of collection. Each 1-cm slice, of either box- or gravity-core sediment, was divided into three subsamples and stored either frozen in precombusted glass jars (organics), or refrigerated in pre-weighed plastic cups (trace elements and radionuclides) or in plastic bags (foraminifers) for further processing.

The foraminiferal samples were processed at the USGS Foraminiferal Research Laboratory in Reston, VA, before October 2005 and in St. Petersburg, FL, after that date. Each 1-cm sediment sample for faunal analyses was soaked in water with 10 mL of percent Calgon solution, slowly agitated for up

to 1 hour to aid disaggregation, then washed over a stainless steel 63- μ m sieve. In most cases, the top 8 to 10 samples in each box core were additionally treated with 10 mL of 8 percent hydrogen peroxide solution to disaggregate organic material. After sieving, the remaining sample was oven dried at ≤ 60 °C, then dry sieved at 125 μ m. The samples were not dried prior to the wet-sieving process; the calculated dry weights were obtained by measuring the moisture content of a small subsample of each sample. More recently, we have measured the wet volume (cubic centimeter) of each sample prior to wet sieving. The calculated dry sample weight, or wet sample volume, is used to calculate the number of forams per gram or cc, respectively (tables 2-11).

Table 2. Benthic foraminiferal data from core MFJ03-2BC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.5	1.56	197	99	50	101	447	2047.96	77.40	3.88
1.5	1.56	150	125	45	99	419	1743.92	76.37	4.07
2.5	3.13	197	211	105	119	632	1523.00	81.17	3.05
3.5	3.13	201	187	67	81	536	1251.86	84.89	3.03
4.5	3.13	158	93	35	102	388	1114.63	73.71	4.38
5.5	6.25	247	141	52	106	546	548.53	80.59	3.32
6.5	3.13	220	153	41	114	528	1221.25	78.41	3.51
7.5	6.25	225	129	46	120	520	673.59	76.92	3.62
8.5	6.25	130	164	35	95	424	532.93	77.59	3.97
9.5	6.25	216	77	15	175	483	514.18	63.77	4.29
10.5	6.25	173	55	13	110	351	351.59	68.66	4.85
11.5	6.25	304	136	31	157	628	599.79	75.00	3.39
12.5	6.25	196	50	11	111	368	410.37	69.84	4.69
13.5	6.25	233	59	7	116	415	367.31	72.05	4.32
14.5	6.25	330	147	42	196	715	630.56	72.59	3.27
15.5	6.25	247	63	18	246	574	559.01	57.14	4.05
16.5	12.50	137	37	7	167	348	182.63	52.01	5.25
17.5	12.50	155	36	9	265	465	179.42	43.01	4.50
18.5	12.50	119	32	1	295	447	180.91	34.00	4.39
19.5	12.50	62	15	6	254	337	144.11	24.63	4.60
20.5	6.25	108	69	23	234	434	395.73	46.08	4.69
21.5	12.50	82	26	10	349	467	184.79	25.27	3.94
22.5	12.50	55	15	1	338	409	168.97	17.36	3.67
23.5	12.50	107	21	10	319	457	192.61	30.20	4.21
24.5	12.50	71	19	13	290	393	148.96	26.21	4.35
25.5	12.50	45	14	4	490	553	215.23	11.39	2.65
26.5	12.50	61	11	2	391	465	183.22	15.91	3.32
27.5	6.25	27	15	1	283	326	244.36	13.19	3.67
28.5	12.50	32	8	3	354	397	148.66	10.83	3.06
29.5	6.25	39	9	1	256	305	221.80	16.07	4.12
30.5	6.25	23	6	5	263	297	180.30	11.45	3.62
31.5	12.50	37	6	1	357	401	149.59	10.97	3.06
32.5	12.50	42	7	1	310	360	116.73	13.89	3.57
33.5	12.50	44	13	1	261	319	117.52	18.18	4.23
34.5	12.50	32	28	5	290	355	147.18	18.31	4.02
35.5	12.50	27	17	6	251	301	129.56	16.61	4.20
36.5	25.00	45	1	1	421	468	79.43	10.04	2.72
37.5	18.75	37	16	2	336	391	103.50	14.07	3.45
38.5	12.50	58	72	20	397	547	203.08	27.42	3.74
39.5	25.00	46	9	2	399	456	98.10	12.50	3.04
40.5	25.00	33	19	3	599	654	106.28	8.41	2.13
41.5	25.00	41	13	1	442	497	108.74	11.07	2.76
42.5	25.00	40	11	0	586	637	101.54	8.01	2.11
43.5	25.00	21	10	1	247	279	55.41	11.47	3.74
44.5	25.00	14	11	2	298	325	67.72	8.31	3.00
45.5	25.00	32	15	1	493	541	113.93	8.87	2.40
46.5	50.00	20	4	1	519	544	44.67	4.60	1.76
47.5	37.50	8	4	0	323	335	46.27	3.58	1.99
48.5	50.00	9	6	0	359	374	38.55	4.01	1.99
49.5	66.67	28	18	3	377	426	30.03	11.50	3.03

4 Benthic Foraminiferal Census Data from Louisiana Continental Shelf Cores, Gulf of Mexico

Table 3. Benthic foraminiferal data from core MRJ03-3BC, Louisiana Shelf, Gulf of Mexico.

[See text (Introduction) for definition of PEB; due to extremely rapid sedimentation rate (1.24 cm/yr), not all samples were counted]

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
1.5	25.00	25	0	0	360	385	134.27	8.57	2.80
14.5	12.50	24	1	0	334	359	174.58	6.96	2.63
22.5	12.50	14	2	0	408	424	289.23	3.77	1.81
30.5	25.00	46	1	0	732	779	178.59	6.03	1.67
44.5	25.00	22	1	0	413	436	121.25	5.28	2.10
50.5	25.00	22	1	0	509	532	99.18	6.58	2.11

Table 4. Benthic foraminiferal data from core MRD05-6BC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.5	40.63	45	4	3	303	355	130.33	14.65	3.68
1.5	12.50	68	8	1	272	349	416.42	22.06	4.35
2.5	75.00	53	4	2	281	340	67.61	17.35	4.03
3.5	50.00	64	5	2	325	396	118.12	17.93	3.78
4.5	20.00	53	10	2	364	429	319.92	15.15	3.39
5.5	100.00	48	2	3	294	347	51.75	15.27	3.79
6.5	20.00	59	17	4	292	372	277.41	21.51	4.18
7.5	25.00	72	13	2	338	425	253.55	20.47	3.84
8.5	12.50	60	18	5	280	363	433.12	22.87	4.32
9.5	18.75	49	11	3	338	401	318.97	15.71	3.56
10.5	6.25	47	5	0	261	313	746.92	16.61	4.12
11.5	12.50	47	6	2	285	340	405.68	16.18	3.91
12.5	16.67	39	20	6	347	412	368.69	15.78	3.52
13.5	25.00	45	10	2	270	327	195.08	17.43	4.11
14.5	12.50	29	12	3	289	333	397.32	13.21	3.64
15.5	15.63	36	5	3	325	369	352.22	11.92	3.31
16.5	6.25	24	12	5	272	313	746.92	13.10	3.74
17.5	12.50	30	11	3	309	353	421.19	12.46	3.45
18.5	12.50	12	6	0	295	313	373.46	5.75	2.58
19.5	12.50	15	13	2	302	332	396.13	9.04	3.08
20.5	12.50	22	15	1	356	394	470.11	9.64	2.91
21.5	18.75	20	5	1	345	371	295.11	7.01	2.60
22.5	25.00	18	0	0	326	344	205.22	5.23	2.35
23.5	12.50	17	4	0	306	327	390.17	6.42	2.66
24.5	12.50	34	2	1	344	381	454.60	9.71	2.97
25.5	12.50	19	5	1	286	311	371.08	8.04	3.02
26.5	12.50	11	6	3	291	311	371.08	6.43	2.73
27.5	18.75	31	3	1	351	386	307.04	9.07	2.86
28.5	12.50	23	11	2	337	373	445.05	9.65	3.00
29.5	18.75	26	3	2	354	385	306.25	8.05	2.72
30.5	9.38	32	9	1	395	437	695.22	9.61	2.76
31.5	6.25	16	7	1	338	362	863.85	6.63	2.56
32.5	8.33	11	3	2	349	365	653.26	4.38	2.10
33.5	6.25	12	4	3	314	333	794.65	5.71	2.49
34.5	12.50	14	2	5	364	385	459.37	5.45	2.27
35.5	25.00	64	40	4	698	806	480.85	13.40	2.35
36.5	25.00	25	4	3	473	505	301.27	6.34	2.12
37.5	9.38	10	8	1	292	311	494.77	6.11	2.66
38.5	6.25	20	21	0	281	322	768.40	12.73	3.64
39.5	9.38	12	6	2	312	332	528.18	6.02	2.56
40.5	25.00	46	7	0	757	810	483.23	6.54	1.70
41.5	37.50	47	16	1	701	765	304.26	8.37	1.96

6 Benthic Foraminiferal Census Data from Louisiana Continental Shelf Cores, Gulf of Mexico

Table 5. Benthic foraminiferal data from core MRD05-6GC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.5	25.00	33	9	2	548	592	239.33	7.76	2.15
1.5	16.67	21	0	0	318	339	341.90	7.08	2.61
2.5	25.00	31	0	0	472	503	320.91	7.10	2.13
3.5	50.00	11	0	0	293	304	100.71	4.95	2.13
4.5	50.00	19	1	0	339	359	80.06	7.23	2.41
5.5	50.00	9	1	0	327	337	109.99	4.74	1.84
6.5	50.00	10	0	1	395	406	105.41	4.18	1.60
7.5	33.33	6	0	0	323	329	127.20	4.18	1.47
8.5	50.00	10	0	0	293	303	88.86	6.31	2.04
9.5	25.00	11	0	0	332	343	150.35	6.17	1.89
10.5	66.67	9	0	0	324	333	69.82	6.02	1.77
11.5	27.78	7	0	0	347	354	118.30	5.33	1.47
12.5	20.83	13	0	2	418	433	193.12	6.10	1.75
13.5	50.00	17	0	1	401	419	104.36	7.61	1.97
14.5	50.00	9	0	2	316	327	77.67	7.44	1.98
15.5	100.00	14	3	1	357	375	48.76	9.10	2.20
16.5	100.00	14	1	1	440	456	64.61	7.16	1.71
17.5	100.00	17	1	0	446	464	53.04	7.96	1.78
18.5	50.00	19	2	1	291	313	62.77	13.57	2.88
19.5	100.00	30	5	3	576	614	75.39	9.46	1.94
20.5	100.00	18	2	2	464	486	58.79	8.73	1.88
21.5	58.33	17	0	1	303	321	64.55	12.71	2.56
22.5	50.00	16	3	0	331	350	78.01	12.54	2.41
23.5	25.00	13	1	1	303	318	126.61	12.38	2.37
24.5	27.78	11	0	2	325	338	134.81	10.92	2.08
25.5	25.00	13	1	0	320	334	140.40	12.34	2.18
26.5	25.00	14	0	1	309	324	130.50	13.11	2.32
27.5	18.75	15	1	1	325	342	171.29	13.38	2.34
28.5	25.00	7	0	1	317	325	146.03	11.20	1.71
29.5	25.00	16	0	0	418	434	204.06	10.89	1.80
30.5	16.67	7	0	0	317	324	224.61	11.83	1.61
31.5	25.00	16	1	0	399	416	184.66	12.16	1.93
32.5	12.50	13	0	0	311	324	216.73	14.63	2.17
33.5	25.00	13	1	0	322	336	161.13	14.75	2.17
34.5	50.00	13	0	1	395	409	97.56	12.03	1.79
35.5	50.00	15	0	1	334	350	80.17	15.12	2.22
36.5	26.67	7	3	0	355	365	123.09	13.10	1.70
37.5	44.44	4	0	0	332	336	98.47	12.50	1.18
38.5	46.67	8	4	2	327	341	91.98	15.44	2.14
39.5	22.22	10	0	1	313	324	142.08	15.81	2.00
40.5	60.00	14	0	0	342	356	71.43	15.94	2.05
41.5	55.56	15	0	0	324	339	73.96	17.44	2.22
42.5	20.00	6	1	1	375	383	163.68	13.20	1.45
43.5	26.67	10	0	0	327	337	161.63	16.36	1.84
45	26.67	6	0	0	337	343	86.58	15.13	1.41
46.5	35.56	12	0	0	347	359	121.21	16.86	1.89
47.5	26.67	7	0	0	352	359	175.05	15.48	1.45
48.5	35.56	15	0	0	324	339	119.76	19.60	2.22
49.5	26.67	9	0	0	334	343	135.96	17.51	1.72

Table 5. (Continued) Benthic foraminiferal data from core MRD05-6GC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
50.5	20.00	10	1	0	346	357	188.47	17.77	1.82
51.5	20.00	10	1	0	340	351	153.42	18.38	1.85
52.5	22.22	11	0	1	340	352	131.91	18.68	1.92
53.5	26.67	16	0	0	343	359	110.94	20.26	2.17
54.5	26.67	8	3	0	318	329	114.66	20.60	1.97
55.5	20.00	7	1	0	344	352	144.69	18.46	1.58
56.5	26.67	13	0	1	330	344	131.18	21.06	2.12
57.5	28.89	10	0	0	326	336	103.87	20.71	1.84
59	11.11	10	0	0	318	328	175.13	21.70	1.89
60.5	25.00	8	0	0	307	315	124.28	22.31	1.76
61.5	25.00	10	0	1	364	375	147.80	19.64	1.73
62.5	25.00	2	0	1	309	312	135.73	20.87	1.10
63.5	50.00	10	0	0	319	329	73.23	23.04	1.88
64.5	25.00	8	0	0	347	355	141.09	20.89	1.57
65.5	25.00	12	0	0	309	321	150.02	25.08	2.11
66.5	18.75	9	0	0	341	350	176.44	22.14	1.68
67.5	12.50	6	0	0	356	362	251.18	20.65	1.34
68.5	9.38	11	0	0	302	313	271.55	26.32	2.07
69.5	18.75	10	0	0	366	376	210.19	21.72	1.65
70.5	50.00	14	0	1	428	443	91.55	19.74	1.71
71.5	100.00	4	1	0	141	146	29.46	54.26	3.00
72.5	100.00	2	0	0	221	223	31.56	33.71	1.26
73.5	100.00	8	0	0	220	228	30.60	37.05	2.42
74.5	66.67	15	0	0	310	325	66.62	28.87	2.32
75.5	25.00	23	0	0	370	393	162.32	26.62	2.36
76.5	50.00	17	0	0	301	318	66.05	31.06	2.51
77.5	40.00	7	0	0	379	386	98.80	22.30	1.35
78.5	31.25	7	1	0	318	326	101.14	27.20	1.71
79.5	50.00	14	0	0	327	341	74.10	28.59	2.14
80.5	41.67	12	0	0	370	382	84.94	25.00	1.78
81.5	35.71	6	0	0	314	320	93.91	27.87	1.51
82.5	33.33	14	0	0	311	325	89.57	31.03	2.24
83.5	50.00	7	0	0	327	334	78.09	27.68	1.56
84.5	33.33	19	0	0	302	321	105.90	34.27	2.62
85.5	50.00	26	0	0	322	348	83.38	34.63	2.80
86.5	50.00	27	0	0	302	329	84.54	37.58	3.01
87.5	50.00	23	0	0	356	379	84.24	31.04	2.44
88.5	33.33	34	0	0	362	396	127.19	33.84	2.80
89.5	25.00	27	0	1	302	330	143.52	38.58	3.05
90.5	27.27	20	0	3	302	325	112.59	36.59	2.83
91.5	35.00	11	0	0	301	312	107.43	34.05	2.08
92.5	20.00	20	1	1	347	369	152.31	32.71	2.45
93.5	15.00	16	0	0	333	349	184.72	32.88	2.23
94.5	25.00	12	0	0	300	312	142.62	35.50	2.17
95.5	18.75	15	0	0	350	365	174.14	31.57	2.07
96.5	25.00	15	2	1	324	342	127.77	35.03	2.40
97.5	25.00	17	1	1	287	306	141.22	40.24	2.75
98.5	31.25	21	1	1	301	324	100.96	40.03	2.84

8 Benthic Foraminiferal Census Data from Louisiana Continental Shelf Cores, Gulf of Mexico

Table 5. (Continued) Benthic foraminiferal data from core MRD05-6GC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
99.5	50.00	16	0	0	304	320	75.52	37.99	2.42
100.5	40.00	17	0	0	334	351	102.80	35.18	2.28
101.5	31.11	16	0	0	321	337	101.60	36.60	2.31
102.5	60.00	18	0	0	363	381	71.51	33.20	2.16
103.5	48.89	10	0	0	331	341	75.83	34.29	1.82
104.5	35.56	14	0	0	324	338	82.64	36.57	2.16
105.5	40.00	20	0	1	390	411	102.80	32.18	2.16
106.5	60.00	20	0	0	319	339	67.26	39.66	2.55
107.5	60.00	13	0	2	323	338	69.01	37.31	2.23
108.5	40.00	13	0	0	329	342	91.30	36.93	2.06
109.5	80.00	14	0	0	315	329	48.06	39.21	2.21
110.5	37.78	18	0	0	326	344	75.00	39.42	2.39
111.5	42.22	15	0	0	318	333	78.24	39.78	2.26
112.5	100.00	17	1	0	345	363	42.75	37.83	2.27
113.5	84.44	22	0	0	308	330	46.95	43.99	2.73
114.5	64.44	16	1	0	313	330	53.31	42.01	2.42
115.5	64.44	11	0	0	349	360	61.44	36.25	1.81
116.5	40.00	19	0	0	314	333	86.96	43.15	2.53
117.5	40.00	11	2	0	337	350	95.18	38.72	2.01
118.5	53.33	17	1	1	328	347	72.33	41.62	2.43
119.5	20.00	14	2	1	348	365	172.33	38.94	2.19
120.5	42.22	20	1	1	369	391	94.14	38.35	2.32
121.5	28.89	12	0	0	338	350	100.90	39.50	1.94
122.5	46.67	13	0	1	314	328	85.27	43.15	2.22
123.5	24.44	19	0	0	320	339	123.16	44.53	2.49
124.5	31.11	19	0	1	307	327	108.25	46.74	2.64
125.5	31.11	33	0	0	312	345	113.21	50.80	3.15
126.5	22.22	22	0	0	312	334	139.11	47.60	2.70
127.5	48.89	17	1	0	332	350	83.90	43.83	2.35
128.5	31.11	34	2	1	313	350	102.04	52.56	3.27
129.5	42.22	31	2	0	310	343	80.63	52.42	3.17
130.5	31.11	29	1	0	307	337	119.14	52.28	3.09
131.5	28.89	12	0	0	318	330	126.16	45.13	2.05
132.5	31.11	21	0	1	329	351	103.55	46.66	2.57
133.5	22.22	14	0	0	354	368	174.29	41.67	1.98
134.5	8.89	15	5	1	310	331	317.62	49.84	2.67
135.5	20.00	22	0	0	326	348	197.61	48.31	2.60
136.5	100.00	159	28	4	1506	1697	156.69	21.48	1.53
137.5	15.56	23	2	0	318	343	204.91	51.10	2.79
138.5	20.00	26	1	1	324	352	173.95	51.08	2.87
139.5	20.00	18	1	0	375	394	197.41	42.27	2.15
140.5	28.89	23	1	0	330	354	118.91	49.85	2.66
141.5	48.89	23	0	0	324	347	79.69	50.77	2.66
142.5	40.00	13	0	0	313	326	80.65	49.68	2.16
143.5	40.00	23	0	1	371	395	88.15	44.88	2.39
144.5	40.00	17	0	1	337	355	103.02	47.92	2.32

Table 6. Benthic foraminiferal data from core PE0609BC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.5	25.00	46	10	3	403	462	194.83	12.77	3.04
1.5	3.13	50	33	14	237	334	1126.80	29.04	4.87
2.5	3.13	46	25	15	328	414	1396.69	20.77	3.91
3.5	6.25	47	21	7	272	347	585.33	21.61	4.33
4.5	18.75	48	17	12	294	371	208.60	20.75	4.13
5.5	3.13	55	23	15	278	371	1251.62	25.07	4.41
6.5	4.69	45	22	7	261	335	753.45	22.09	4.44
7.5	6.25	28	4	2	316	350	590.39	9.71	3.10
8.5	1.56	22	0	1	503	526	3549.07	4.37	1.75
9.5	1.95	13	3	1	388	405	2186.12	4.20	1.95
10.5	3.88	27	1	3	339	370	1004.89	8.38	2.82
11.5	4.69	19	4	2	328	353	793.93	7.08	2.68
12.5	3.91	24	1	0	360	385	1039.08	6.49	2.46
13.5	7.81	30	2	3	360	395	533.04	8.86	2.80
14.5	6.25	21	0	1	382	404	681.48	5.45	2.21
15.5	6.25	25	0	0	360	385	649.43	6.49	2.46
16.5	12.50	17	2	0	421	440	371.10	4.32	1.90
17.5	7.81	26	0	1	323	350	472.31	7.71	2.80

10 Benthic Foraminiferal Census Data from Louisiana Continental Shelf Cores, Gulf of Mexico

Table 7. Benthic foraminiferal data from core MCH-11BC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.25	75.00	85	19	25	302	431	95.78	29.93	4.32
1.25	75.00	67	8	8	280	363	48.40	22.87	4.32
2.25	100.00	47	9	15	170	241	24.10	29.46	5.76
3.5	100.00	55	5	2	121	183	18.30	33.88	6.86
4.5	100.00	90	7	4	218	319	31.90	31.66	5.10
5.5	100.00	41	1	6	69	117	11.70	41.03	8.91
6.5	100.00	25	3	2	43	73	7.30	41.10	11.29
7.5	100.00	63	6	7	66	142	14.20	53.52	8.20
8.5	100.00	143	22	17	81	263	26.30	69.20	5.58
9.25	100.00	97	24	5	48	174	17.40	72.41	6.64
9.75	100.00	184	90	68	199	541	54.10	63.22	4.06
10.25	100.00	130	49	26	87	292	29.20	70.21	5.25
10.75	75.00	177	44	36	91	348	46.40	73.85	4.62
11.25	75.00	115	53	63	117	348	46.40	66.38	4.96
11.75	75.00	149	65	37	134	385	51.33	65.19	4.76
12.25	75.00	156	56	42	117	371	49.47	68.46	4.73
12.75	100.00	190	34	28	114	366	36.60	68.85	4.74
13.25	100.00	211	42	39	151	443	44.30	65.91	4.41
13.75	50.00	142	49	21	118	330	66.00	64.24	5.17
14.25	50.00	138	52	41	112	343	68.60	67.35	4.96
14.75	50.00	191	59	49	169	468	93.60	63.89	4.35
15.25	25.00	102	44	41	140	327	118.91	57.19	5.36
16.25	25.00	135	58	59	205	457	166.18	55.14	4.56
17.25	6.25	70	46	46	157	319	464.00	50.78	5.49
18.25	6.25	46	40	40	250	376	601.60	33.51	4.77
19.25	18.75	19	4	12	296	331	176.53	10.57	3.31
20.25	25.00	40	1	3	276	320	128.00	13.75	3.77
21.25	12.50	9	0	1	323	333	266.40	3.00	1.83
22.25	3.13	10	1	2	301	314	1004.80	4.14	2.20
23.25	6.25	12	0	4	307	323	516.80	4.95	2.37
24.25	7.81	15	1	7	333	356	455.68	6.46	2.55
25.25	6.25	18	0	6	429	453	724.80	5.30	2.06
26.25	7.81	24	2	3	334	363	464.64	7.99	2.79
27.25	6.25	13	0	2	368	383	612.80	3.92	1.94
28.25	6.25	21	1	1	304	327	523.20	7.03	2.77
29.25	12.50	12	2	2	311	327	261.60	4.89	2.34
30.25	6.25	25	1	2	354	382	611.20	7.33	2.61
31.25	6.25	16	1	1	352	370	592.00	4.86	2.19
32.25	12.50	13	0	0	318	331	264.80	3.93	2.09
33.25	15.63	16	3	1	333	353	225.92	5.67	2.41
34.25	12.50	24	1	0	290	315	252.00	7.94	2.99
35.25	12.50	22	2	1	350	375	300.00	6.67	2.52

Table 8. Benthic foraminiferal data from core MCH-33BC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.25	6.25	73	10	4	315	402	643.20	21.64	4.03
0.75	12.50	67	21	5	345	438	350.40	21.23	3.83
1.25	12.50	112	21	1	464	598	478.40	22.41	3.34
1.75	9.38	71	7	5	376	459	489.60	18.08	3.52
2.75	6.25	70	8	0	256	334	534.40	23.35	4.54
3.25	6.25	106	18	10	354	488	780.80	27.46	3.96
3.75	12.50	171	34	9	637	851	680.80	25.15	2.91
4.25	3.13	46	5	0	278	329	1052.80	15.50	3.91
4.75	3.13	40	4	0	347	391	1251.20	11.25	3.13
5.25	3.13	42	6	3	355	406	1299.20	12.56	3.22
5.75	3.13	64	11	4	329	408	1305.60	19.36	3.83
6.25	3.13	33	1	2	331	367	1468.00	9.81	3.04
6.75	6.25	62	4	3	431	500	888.89	13.80	3.02
7.25	3.13	44	2	0	286	332	1328.00	13.86	3.72
7.75	3.13	38	1	0	370	409	1454.22	9.54	2.85
8.25	3.13	34	3	1	328	366	1673.14	10.38	3.13
8.75	3.13	28	5	0	285	318	1017.60	10.38	3.35
9.25	4.69	39	1	1	367	408	870.40	10.05	2.92
9.75	3.13	42	5	1	369	417	1334.40	11.51	3.06
10.75	4.69	30	3	1	437	471	1004.80	7.22	2.34
11.75	4.69	46	4	1	354	405	864.00	12.59	3.23
12.75	3.13	41	0	2	337	380	1216.00	11.32	3.19
13.75	3.13	41	0	0	377	418	1337.60	9.81	2.85
14.75	3.13	31	1	1	340	373	1193.60	8.85	2.88
15.75	3.13	22	0	2	348	372	1190.40	6.45	2.50
16.75	3.13	34	2	2	315	353	1129.60	10.76	3.23
17.75	4.69	32	0	2	346	380	810.67	8.95	2.87
18.75	3.13	30	1	0	383	414	1324.80	7.49	2.54
19.75	4.69	40	0	1	410	451	962.13	9.09	2.65
20.75	4.69	45	1	2	357	405	864.00	11.85	3.15
21.75	6.25	50	2	0	445	497	795.20	10.46	2.69
22.75	6.25	34	3	0	384	421	673.60	8.79	2.70
23.75	4.69	27	2	0	345	374	797.87	7.75	2.71
24.75	3.13	31	1	2	324	358	1145.60	9.50	3.04
25.75	4.69	29	4	1	287	321	684.80	10.59	3.37

12 Benthic Foraminiferal Census Data from Louisiana Continental Shelf Cores, Gulf of Mexico

Table 9. Benthic foraminiferal data from core PE07-1BC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.25	75.00	44	2	0	372	418	222.93	11.00	3.00
1.25	12.50	65	1	0	386	452	361.60	14.60	3.26
2.25	12.50	90	4	2	341	437	349.60	21.97	3.88
3.25	12.50	55	6	1	374	436	436.00	14.22	3.28
4.25	7.81	45	7	8	299	359	459.52	16.71	3.86
5.25	12.50	50	12	4	295	361	361.00	18.28	3.99
6.25	31.25	47	6	4	324	381	121.92	14.96	3.58
7.25	37.50	40	6	4	338	388	147.81	12.89	3.33
8.25	25.00	64	11	14	277	366	146.40	24.32	4.40
9.25	25.00	35	4	6	260	305	122.00	14.75	3.98
10.25	31.25	44	6	12	289	351	112.32	17.66	3.99
11.25	31.25	57	4	8	247	316	101.12	21.84	4.56
12.25	9.38	21	2	3	303	329	350.93	7.90	2.92
13.25	4.69	30	0	0	320	350	746.67	8.57	2.93
14.25	6.25	35	0	1	336	372	595.20	9.68	3.00
15.25	1.95	9	1	0	314	324	1658.88	3.09	1.88
16.25	3.13	28	2	0	303	333	1065.60	9.01	3.08
17.25	3.13	24	2	0	287	313	1001.60	8.31	3.06
18.25	3.91	28	1	0	313	342	972.80	8.48	2.95
19.25	3.13	20	1	1	315	337	1078.40	6.53	2.64
20.25	3.91	25	1	2	326	354	906.24	7.91	2.81
21.25	3.13	16	1	2	301	320	1024.00	5.94	2.59
22.25	2.34	16	0	1	290	307	1309.87	5.54	2.56
23.25	3.13	23	3	1	323	350	1120.00	7.71	2.80
24.25	3.13	16	0	0	272	288	921.60	5.56	2.65
25.25	3.13	18	0	0	319	337	1078.40	5.34	2.40
26.25	3.13	19	1	1	329	350	1493.33	6.00	2.49
27.25	3.13	27	0	0	352	379	1617.07	7.12	2.59
28.25	3.13	23	0	0	388	411	1315.20	5.60	2.22
29.25	3.13	27	0	1	318	346	1107.20	8.09	2.87
30.25	4.69	19	0	0	392	411	974.22	4.62	2.03
31.25	3.13	34	0	0	326	360	1152.00	9.44	3.02
32.25	1.56	17	1	2	250	270	1728.00	7.41	3.12
33.25	3.13	26	1	0	403	430	1376.00	6.28	2.29
34.25	3.13	30	0	1	343	374	1196.80	8.29	2.79
35.25	3.13	24	0	1	276	301	963.20	8.31	3.12
36.25	1.56	26	2	0	288	316	2022.40	8.86	3.13
37.25	1.56	37	1	0	299	337	2156.80	11.28	3.38

Table 10. Benthic foraminiferal data from core PE07-7BC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.25	37.50	24	0	1	357	382	509.33	6.54	2.48
1.25	15.63	30	0	0	323	353	451.70	8.50	2.91
2.25	18.75	17	3	0	333	353	188.27	5.67	2.41
3.25	4.69	17	3	0	376	396	844.35	5.05	2.16
4.25	7.81	19	1	0	349	369	787.45	5.42	2.31
5.25	9.38	27	0	0	350	377	502.40	7.16	2.60
6.25	9.38	35	0	1	360	396	422.17	9.09	2.83
7.25	9.38	12	2	0	341	355	420.52	3.94	2.02
8.25	9.38	26	2	0	334	362	385.93	7.73	2.75
9.25	9.38	38	0	0	416	454	484.01	8.37	2.55
10.25	6.25	24	1	1	329	355	568.00	7.32	2.71
11.25	12.50	32	2	0	466	500	400.00	6.80	2.21
12.25	6.25	15	0	0	316	331	529.60	4.53	2.24
13.25	12.50	21	0	1	302	324	370.29	6.79	2.74
14.25	6.25	32	1	3	332	368	588.80	9.78	3.04
15.25	12.50	17	0	0	345	362	289.60	4.70	2.18
16.25	12.50	21	0	1	417	439	351.20	5.01	2.04
17.25	6.25	18	1	0	289	308	492.80	6.17	2.69
18.25	12.50	29	2	0	494	525	420.00	5.90	2.02
19.25	4.69	15	0	1	302	318	678.04	5.03	2.40
20.25	3.13	16	0	0	296	312	996.81	5.13	2.45
21.25	9.38	17	0	0	312	329	350.75	5.17	2.39
22.25	12.50	22	0	0	411	433	346.40	5.08	2.07
23.25	9.38	24	2	0	391	417	444.56	6.24	2.32
24.25	18.75	21	2	0	335	358	272.76	6.42	2.54
25.25	9.38	18	0	0	334	352	375.27	5.11	2.30
26.25	9.38	15	0	0	334	349	372.07	4.30	2.13
27.25	9.38	17	1	0	327	345	367.80	5.22	2.35
28.25	9.38	9	0	0	307	316	336.89	2.85	1.83
29.25	21.88	22	0	1	294	317	144.88	7.26	2.86
30.25	21.88	20	1	0	296	317	144.88	6.62	2.74
31.25	12.50	14	0	0	307	321	256.80	4.36	2.23

14 Benthic Foraminiferal Census Data from Louisiana Continental Shelf Cores, Gulf of Mexico

Table 11. Benthic foraminiferal data from core PE07-8BC, Louisiana Shelf, Gulf of Mexico.

Sample depth midpoint (cm)	Percentage of sample examined	Number of <i>P. atlanticum</i>	Number of <i>E. vitrea</i>	Number of <i>B. morgani</i>	Number of other foraminifers	Total number of foraminifers (N)	Number of foraminifers per gram	Percentage of PEB species	Confidence interval of PEB
0.25	50.00	197	15	1	368	581	232.40	36.66	3.92
1.25	25.00	148	10	6	167	331	132.40	49.55	5.39
2.25	18.75	171	9	5	266	451	240.53	41.02	4.54
3.25	25.00	108	19	7	210	344	137.60	38.95	5.15
4.25	25.00	107	18	8	188	321	128.40	41.43	5.39
5.25	25.00	150	18	4	209	381	152.40	45.14	5.00
6.25	12.50	97	39	29	217	382	305.60	43.19	4.97
7.25	12.50	108	40	35	333	516	412.80	35.47	4.13
8.25	18.75	112	36	36	258	442	235.73	41.63	4.60
9.25	6.25	115	31	33	264	443	708.80	40.41	4.57
10.25	12.50	96	16	24	217	353	282.40	38.53	5.08
11.25	12.50	95	22	27	242	386	308.80	37.31	4.82
11.75	6.25	74	16	19	197	306	489.60	35.62	5.37
12.25	9.38	75	22	22	255	374	398.72	31.82	4.72
12.75	12.50	132	26	30	303	491	392.80	38.29	4.30
13.25	5.66	96	24	18	265	403	712.01	34.24	4.63
13.75	12.50	129	45	31	337	542	433.60	37.82	4.08
14.25	11.52	99	32	19	293	443	384.55	33.86	4.41
14.75	9.38	93	21	20	277	411	438.40	32.60	4.53
15.25	6.25	74	21	15	236	346	553.60	31.79	4.91
16.25	6.25	78	15	16	275	384	614.40	28.39	4.51
16.75	9.38	65	6	7	259	337	359.47	23.15	4.50
17.25	6.25	74	5	5	261	345	552.00	24.35	4.53
17.75	9.38	75	10	16	286	387	412.80	26.10	4.38
18.25	9.38	82	11	10	289	392	417.91	26.28	4.36
18.75	6.25	81	9	15	220	325	520.00	32.31	5.08
19.25	6.25	92	13	20	326	451	721.60	27.72	4.13
19.75	6.25	69	8	10	203	290	464.00	30.00	5.27
20.25	15.63	95	10	13	247	365	233.53	32.33	4.80
20.75	6.25	129	12	17	270	428	684.80	36.92	4.57
21.25	4.69	87	15	12	202	316	674.13	36.08	5.29
22.25	3.13	127	24	15	324	490	1568.00	33.88	4.19
23.25	12.50	154	10	15	374	553	491.56	32.37	3.90
24.25	6.25	98	19	20	339	476	1088.00	28.78	4.07
25.25	3.13	50	23	13	244	330	1320.00	26.06	4.74
26.25	3.13	51	14	11	280	356	1139.20	21.35	4.26
27.25	3.13	52	8	13	370	443	1417.60	16.48	3.45
28.25	6.25	38	10	9	322	379	606.40	15.04	3.60
29.25	4.69	42	9	10	314	375	800.00	16.27	3.74
30.25	4.69	30	2	5	278	315	672.00	11.75	3.56
31.25	4.69	51	6	4	345	406	866.13	15.02	3.48
32.25	3.13	29	2	5	280	316	1011.20	11.39	3.50
33.25	3.13	33	3	8	293	337	1078.40	13.06	3.60
34.25	6.25	37	2	6	320	365	584.00	12.33	3.37
35.25	9.38	50	1	4	256	311	473.90	17.68	4.24
36.25	6.25	39	0	2	278	319	510.40	12.85	3.67
37.25	6.25	46	4	10	362	422	675.20	14.22	3.33
38.25	4.69	22	2	10	276	310	661.33	10.97	3.48
39.25	4.69	38	1	7	329	375	800.00	12.27	3.32
40.25	6.25	27	2	9	269	307	491.20	12.38	3.68
41.25	6.25	36	6	5	340	387	619.20	12.14	3.25

Faunal Analysis

Osterman (2003) determined that in the benthic foraminiferal assemblages found in the Gulf of Mexico, the relative abundance of three low-oxygen-tolerant species was highest in the Louisiana hypoxic zone. Therefore, in this research, only these three species were identified and counted as described herein. Processed samples contained few to abundant benthic foraminifera (30 – 2,186 foraminifers/g or 7 – 1,658 foraminifers/cm³). When required, a representative subsample of approximately 300 specimens was obtained for faunal analysis using a microsplitter. Benthic foraminifera were picked from the >125- μ m faunal split spread across a 45 square, hole-punched tray and viewed through a binocular stereo microscope. When an individual foraminifer was encountered in the picking process, it was identified and counted as one of four categories (*P. atlanticum*, *E. vitrea*, *B. morgani*, and others). This allowed for the calculation of the cumulative percentage of these three species in each sample. After identification and counting, each specimen was dropped through a hole in the punched tray onto a stationary 60-square micropaleontological slide placed in a cardboard cutout. All faunal slides will be curated at the Natural History Museum, Smithsonian Institution, at the conclusion of the study. Identifications of benthic foraminiferal species were based on the use of classic and modern literature, including the taxonomy of Phleger and Parker (1951), Bandy (1954), Parker (1954), Anderson (1961), Bock and others (1971), Murray (1971, 2000), Poag (1981), Morkhoven and others (1986), and Loeblich and Tappan (1988, 1994). Tables 2-11 display sample interval, percentage of sample examined, benthic foraminiferal counts, relative percentage of the PEB species (Osterman, 2003), and confidence-interval data (Patterson and Fishbein, 1989) for gravity- and box-core samples.

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