
Diatom Paleoecology Pass Key Core 37, Everglades National Park, Florida Bay

by

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TABLE OF CONTENTS

Abstract	1
Introduction	2
Diatoms As Paleoecological Indicators	2
Acknowledgements	4
Methods	4
Collection and Dating of Core	4
Diatom methods	4
Data Analysis	4
Results	8
Diatom Flora and Species Abundances	8
Species Richness and Diversity	13
Centric to Pennate Ratio	13
Diatom Habitat Preferences	16
Marine Taxa	16
Brackish Taxa	18
Freshwater Taxa	18
Epiphytic and Epipelagic Taxa	18
Discussion	23
Summary	26
References cited	27
Appendix	30

FIGURES

1. Map of the core location	3
2. Concentration of diatom valves	9
3. Select digitized images of diatom valves from the Pass Key core 37	10
4. Select digitized images of diatom valves from the Pass Key core 37	11
5. Select digitized images of diatom valves from the Pass Key core 37	12
6. Diatom species richness	14
7. Diatom species diversity	14
8. Centric to pennate diatom ratios	15
9. Percent abundance of marine diatoms	17
10. Percent abundance of brackish species	19
11. Percent abundance of freshwater species	20
12. Percent abundance of epiphytic species	21
13. Percent abundance of epipelagic species	22
14. Percent abundance of planktonic taxa	25

TABLES

1. Percent abundances of diatom species in the Pass Key core 37	5-7
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ABSTRACT

During the 20th century, there have been large-scale anthropogenic modifications to the South Florida ecosystem. The effects of these changes on Florida Bay and its biological communities are currently of political and scientific interest. This study is part of a larger effort to reconstruct the history of environmental changes in the bay, using paleoecological techniques. We are using diatom indicators preserved in Florida Bay sediments to infer long-term water quality, productivity, nutrient, and salinity changes. We are also obtaining information concerning the natural variability of the ecosystem.

Diatoms are microscopic algae, the remains of which are generally well preserved in sediments, and their distributions are closely linked to water quality. Diatoms were extracted from a 70cm sediment core collected from the Pass Key mudbank of Florida Bay by the U.S. Geological Survey. Between 300-500 diatom valves from each of 15 core samples were identified and counted. Estimates of absolute abundance, species richness, Shannon-Wiener diversity, and centric:pennate ratios were calculated for each sample that was counted. Information on the ecology of the diatom species is presented, and changes in diatom community composition are evaluated.

Samples contained an average of four million diatom valves per gram of sediment. Major changes in the diatom community are evident down core. These include increases in the percent abundance of marine diatoms in the time period represented by the core, probably the result of increasing salinity at Pass Key. Benthic diatoms become less abundant in the top half of the core. This may be related to a number of factors including the die-off of sea grass beds or increased turbidity of the water column.

Once the chronology of the Pass Key core 37 is established, these down-core changes can be related to historical events and compared with other indicators in the sedimentary record that are currently being investigated by U.S Geological Survey researchers.

INTRODUCTION

Florida Bay is a large, shallow lagoonal estuary at the southernmost tip of Florida. The majority of freshwater flows into the bay are derived from the Everglades watershed, a region that has been greatly impacted by human activities during the last century (Davis and Ogden 1994). In 1994, the Everglades Forever Act was passed that mandates that the ecosystem should be returned to its “natural state”. However, without historical data on baseline conditions, restoration management decisions are difficult. Paleoecological techniques provide a powerful tool for obtaining such baseline data that is otherwise unavailable.

The goal of the “Ecosystem History of Florida Bay” project is to examine paleoecological indicators found within sediment cores taken from the bay that can be used to quantify the amount of natural variability in the estuary and to separate this from anthropogenic changes. Analyses of diatom communities will allow interpretations regarding both salinity and nutrient changes that may have occurred during the last few centuries in Florida Bay.

This report focuses on a short core (70 cm in length) taken from the mudbank south of Pass Key in eastern Florida Bay (Fig. 1). Sampling of modern diatom assemblages is currently underway in order to provide ecological information that can be used to refine paleoecological interpretations.

Diatoms As Paleoecological Indicators

Diatoms are microscopic algae that occur in both freshwater and marine environments. They have a siliceous shell, or frustule, consisting of two valves, that are generally preserved in sediments. They occur in a variety of habitats; for instance, there are planktonic diatoms that grow in open water, epiphytic diatoms that grow on plants and macroalgae, and epipelagic diatoms that grow on sediments.

Diatoms are particularly useful as environmental indicators because many species have a narrow range of environmental conditions that are optimal for growth and survival, and diatom populations respond rapidly to environmental change (e.g. Dixit *et al.* 1992). Diatoms have been used increasingly in studies concerning anthropogenic impacts on the environment (e.g. Cooper, 1995a and 1995b; Sweets *et al.* 1990), and in recent years, advances in statistical methods have allowed some researchers to develop “transfer functions” that allow quantitative reconstruction of past environmental characteristics. For example, Fritz *et al.* (1993) derived a diatom-based transfer function that allowed them to calculate total phosphorus levels in several Michigan lakes over the last 200 years. Similar functions have been developed for salinity in Great Plains lakes (Fritz *et al.* 1991), chlorophyll in Antarctic lakes (Jones and Juggins 1995), and salinity in the Thames estuary, England (Juggins 1992).

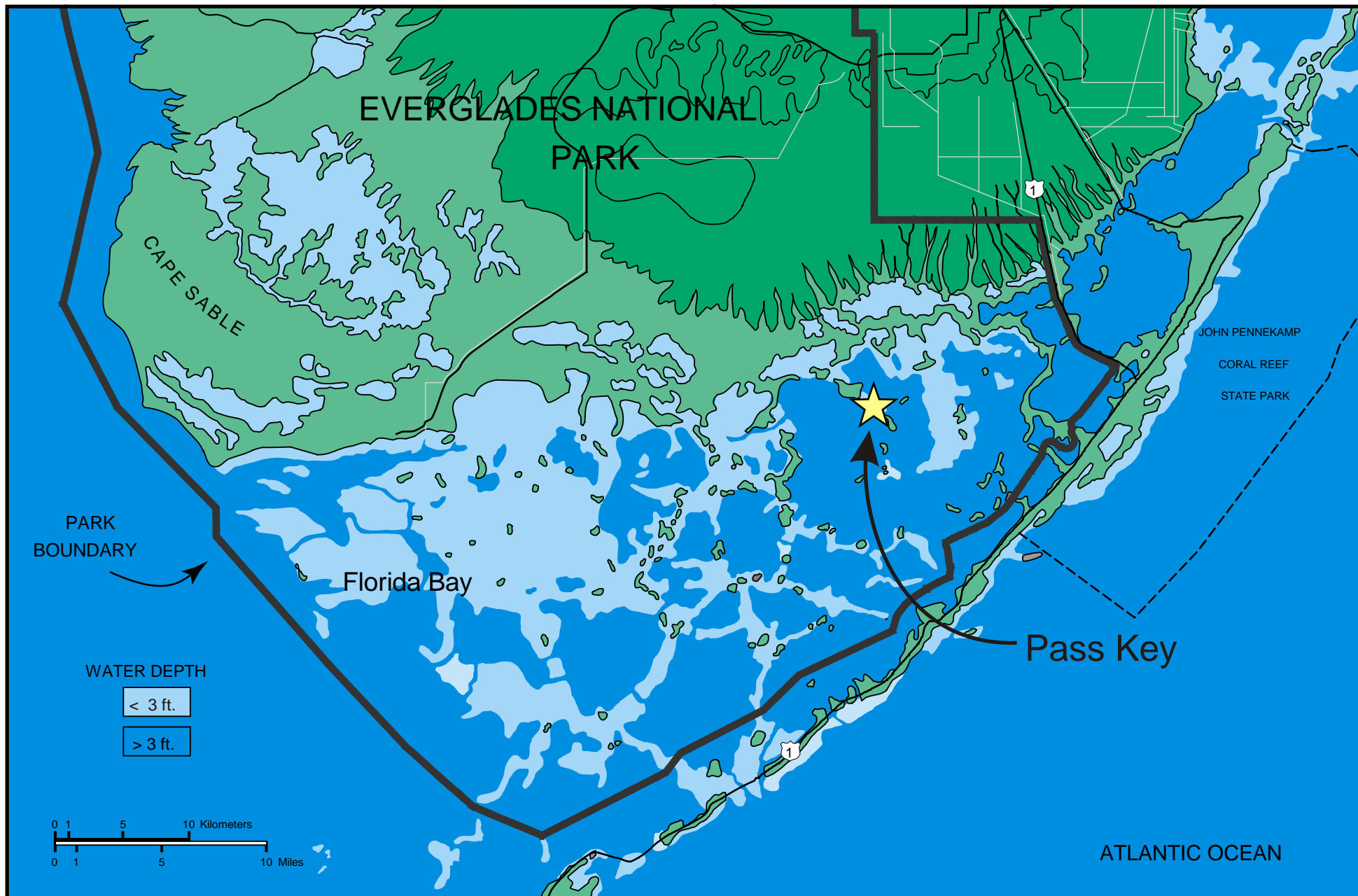


Figure 1. Location of Pass Key Core #37

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METHODS

Collection and Dating Of Cores

The Pass Key core 37 was collected by Gene Shinn and Marci Marot of the U.S. Geological Survey, St. Petersburg, Florida. Age models are being developed.

Diatoms Methods

The core was subsampled at 2 cm intervals. Diatoms were extracted from sediment using a modification of the method by [Funkhauser and Evitt \(1959\)](#), and permanently mounted on slides with Naphrax[®] for viewing with a light microscope. In each of 15 samples spaced throughout the core, 300-500 diatom valves were identified and counted. Counts were recorded as percent abundance within a sample ([Table 1](#)). An estimate of the total number of valves per gram of dry sediment also was made by relating the number of valves counted on a slide to the proportion of the area on the slide that was counted, taking into account dilution factors and the weight of sediment processed. No such estimate could be made for the sample at 30 cm, which boiled over during processing, resulting in the loss of part of the sample. The 10 cm, 34 cm, and 54 cm samples were processed as wet sediment, and these samples were not dried and reweighed. Therefore, only the number of valves per gram of wet sediment could be calculated, which would underestimate the number of valves per gram dry sediment. Light microscopic digital images were captured via CCD video camera and frame grabber of many of the species identified in the Pass Key core 37.

Data Analysis

Down-core changes in diatom assemblages can be analyzed by various methods, including the examination of changes seen in the relative abundance of dominant species. Species richness (total number of species seen in a sample) and Shannon-Wiener diversity (calculated as $-\sum p_i(\ln p_i)$, where p_i represents the proportion of the total number of individuals of a particular species ([Begon et al. 1996](#))) also were calculated for each depth interval. Long-term

Table 1: Percent abundance of diatom species in Pass Key core 37, and summary statistics for each depth interval. [0 cm refers to the 0-2 cm sample, etc.]

	0cm	4cm	10cm	14cm	20cm	24cm	30cm	34cm	40cm	44cm	50cm	54cm	60cm	64cm	70cm	Mean
Statistics:																
Number of valves counted	344	352	361	370	400	313	368	316	374	377	338	418	352	484	417	347
Species richness	48	54	48	62	47	49	54	47	50	52	37	53	40	50	52	49
Shannon-Wiener diversity	2.97	3.39	3.18	3.26	3.28	2.87	3.09	2.90	3.06	3.17	2.52	3.18	2.53	2.40	3.10	2.99
Centricpennate ratio	0.29	0.23	0.22	0.25	0.18	0.36	0.30	0.33	0.24	0.24	0.22	0.15	0.22	0.17	0.18	0.24
Valves per gram sediment (in millions of valves)	2.52	7.15	10.69	3.10	6.94	3.11	N/A	2.46	3.52	6.07	1.67	2.61	3.72	3.38	4.26	4.37
Species:																
<i>Achnanthesdelicatula</i> ssp. <i>hauckiana</i> (Grunow) Lange-Bertalot & Ruppel	1.74	0.28	1.94	0.00	2.00	0.00	0.00	0.00	0.00	0.53	0.00	0.24	0.00	0.00	0.24	0.47
<i>Amphora coffeaeformis</i> (Agardh) Kützing	3.78	3.69	7.20	5.14	9.00	1.92	3.80	1.27	2.14	1.86	0.59	2.15	0.28	1.65	2.64	3.14
<i>Amphora</i> cf. <i>Costata</i> Wm. Smith	0.58	1.14	1.11	0.54	2.00	1.28	3.53	6.33	1.60	1.86	1.48	1.67	0.00	0.62	0.72	1.63
<i>Amphora dubia</i> Gregory	0.00	0.00	0.28	0.54	0.00	0.32	0.27	0.00	0.00	0.27	0.00	0.24	0.00	0.00	0.24	0.14
<i>Amphora</i> aff. <i>Proboscidea</i> (Gregory) Cleve	0.58	1.42	0.83	1.08	4.50	0.00	0.82	0.00	0.53	0.53	0.00	1.20	0.28	0.21	2.16	0.94
<i>Amphora</i> cf. <i>Proteus</i> (Gregory)	1.16	0.85	1.94	0.54	1.00	1.92	2.99	2.53	1.07	1.06	1.48	1.91	2.56	0.62	0.72	1.49
<i>Amphora rhombica</i> Kitton	0.00	1.14	0.00	0.27	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	0.41	0.00	0.22
<i>Amphora ventricosa</i> Gregory	3.20	3.41	2.77	1.62	0.75	0.96	2.45	0.32	0.53	0.53	0.30	0.72	0.28	0.41	2.40	1.38
<i>Amphora</i> sp. 4	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
<i>Caloneis</i> cf. <i>Liber</i> (Wm. Smith) Cleve	0.29	0.00	0.00	0.00	0.25	0.64	0.27	0.95	0.27	0.53	1.18	0.48	0.28	2.27	0.24	0.51
<i>Campylodiscuss ubangularis</i> Grunow	0.00	0.57	0.28	0.54	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.16
<i>Climaconeis scopulorioides</i> Hustedt	0.58	1.99	6.09	2.70	2.25	0.32	2.17	0.00	1.87	0.53	0.00	1.20	0.85	0.62	3.60	1.65
<i>Cocconeis placentula</i> cf. var. <i>euglypta</i> (Ehrenberg) Cleve	2.91	3.98	6.93	7.03	4.00	3.19	4.35	0.32	4.81	8.22	0.59	7.66	9.38	3.31	6.71	4.89
<i>Cocconeis scutellum</i> Ehrenberg	0.00	0.00	0.83	0.54	0.00	0.32	0.27	0.00	1.07	1.33	1.18	1.44	1.42	1.03	0.24	0.64
<i>Coscinodiscus</i> sp. 1	0.29	0.85	0.28	0.00	0.25	0.00	0.27	0.32	0.00	0.27	0.30	0.00	0.00	0.21	0.24	0.22
<i>Cyclotella</i> cf. <i>litoralis</i> Lange & Syvertsen	28.20	20.17	20.50	22.43	16.75	32.91	29.62	29.75	24.06	21.22	16.57	12.92	17.61	14.67	17.03	21.63
<i>Cyclotella</i> cf. <i>meneghiniana</i> Kützing	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.09
<i>Cyclotellastrata</i> ? (Kützing) Grunow	0.29	0.29	0.00	0.27	0.25	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
<i>Cyclotella</i> cf. <i>stylorum</i> Brightwell	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.41	0.00	0.06
<i>Cyclotella</i> sp.	0.29	0.00	0.83	0.54	0.50	2.56	0.00	2.22	0.00	1.33	5.03	1.20	4.83	1.24	0.48	1.40
<i>Cyclotella</i> sp. 1	0.00	0.00	0.55	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.21	0.48	0.13
<i>Cymatosira lorenziana</i> Grunow	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
<i>Diploneis didyma</i> Ehrenberg	0.00	0.28	0.28	0.00	0.75	0.32	0.82	1.58	0.00	0.53	0.30	0.00	0.00	0.21	0.48	0.37
<i>Diploneis ovalis</i> (Hilse) Cleve	0.58	0.85	0.28	0.27	0.00	0.96	0.54	0.00	0.27	0.27	0.00	0.00	0.00	0.00	0.72	0.32
<i>Diploneis suborbicularis</i> var. <i>constricta</i> Hustedt	0.87	0.28	0.00	0.54	0.00	1.60	0.27	3.80	0.53	0.00	1.18	0.00	0.85	0.83	0.24	0.73

<i>Entomoneis alata</i> (Ehrenberg) Ehrenberg	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.03
<i>Epithemia cf. turgida</i> Kützing	0.00	0.57	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.48	0.00	0.21	1.92	0.26
<i>Fragilaria tabulata</i> var. <i>tabulata</i> (Agardh) Lange-Bertalot	1.16	1.42	1.94	2.97	6.00	5.75	4.35	6.96	6.42	4.24	3.25	3.59	1.70	3.10	2.88	3.72
<i>Frustulia interposita</i> (Lewis) de Toni	0.29	0.85	0.28	1.35	0.75	0.96	0.82	0.95	0.00	0.27	1.18	0.96	0.00	0.00	0.72	0.62
<i>Frustulia</i> sp. 2	1.16	1.14	0.28	0.27	1.50	0.32	0.54	0.63	0.27	0.00	0.00	0.48	0.28	0.21	0.00	0.47
<i>Grammatophora oceanica</i> var. <i>macilenta</i> (Wm. Smith) Grunow	0.87	0.85	0.00	0.54	0.50	1.28	0.27	2.22	0.53	0.00	1.78	0.72	1.14	1.65	0.96	0.89
<i>Gyrosigma balticum</i> (Ehrenberg) Cleve	1.74	1.14	1.94	1.35	0.50	0.32	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.48
<i>Mastogloia angulata</i> Lewis	0.29	0.00	0.00	0.00	1.00	0.00	0.00	1.58	0.27	0.53	0.30	0.00	0.00	0.00	0.00	0.26
<i>Mastogloia cf. angusta</i> Hustedt	0.29	0.28	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.27	0.00	0.72	0.28	0.21	0.00	0.19
<i>Mastogloia cf. apiculata</i> Wm. Smith	1.16	0.57	0.00	0.54	0.25	0.64	0.00	0.32	0.53	0.00	0.00	0.24	0.00	0.41	0.48	0.34
<i>Mastogloia barbadensis</i> (Grev.) Cleve	0.00	0.00	0.28	0.27	0.00	0.32	0.00	0.00	0.27	0.00	0.00	0.72	0.00	0.62	0.48	0.20
<i>Mastogloia binotata</i> (Grunow) Cleve	0.87	0.57	0.55	0.27	0.00	0.32	0.27	0.63	1.87	0.00	0.00	0.48	0.00	0.41	0.48	0.45
<i>Mastogloia biocellata</i> (Grunow) Novarino & Muftah	0.00	1.14	0.00	0.27	0.50	0.00	0.82	0.00	0.27	0.00	0.00	0.72	0.00	0.21	0.00	0.26
<i>Mastogloia braunii</i> Grunow	0.29	0.00	0.00	0.81	3.25	0.32	0.27	0.95	0.27	0.53	1.78	0.48	0.28	0.41	0.48	0.67
<i>Mastogloia corsicana</i> Grunow	0.29	0.57	1.66	0.27	4.00	2.56	2.17	0.95	4.81	2.92	1.18	1.67	1.70	1.03	1.20	1.80
<i>Mastogloia cribrosa</i> Grunow	0.29	0.57	0.55	0.54	0.25	0.64	0.27	0.63	0.80	0.27	1.78	0.24	0.28	0.62	0.48	0.55
<i>Mastogloia crucicula</i> Grunow	5.52	4.55	3.05	5.95	5.25	7.67	4.35	5.70	13.10	11.67	5.33	4.55	14.20	4.34	6.71	6.80
<i>Mastogloia cyclops</i> Voight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.02
<i>Mastogloia cf. decipiens</i> Hustedt	0.00	0.00	0.00	0.54	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.09
<i>Mastogloia discontinua</i> Paddock & Kemp	0.00	0.00	0.28	0.54	3.75	0.64	0.27	0.32	0.80	2.12	1.18	2.63	1.14	0.62	0.48	0.98
<i>Mastogloia elegans</i> Lewis	4.94	4.55	0.55	1.62	1.50	0.00	1.36	0.32	0.27	1.06	1.48	0.72	0.28	0.21	0.24	1.27
<i>Mastogloia erythrea</i> Grunow	4.94	4.55	1.66	1.35	4.00	0.96	3.26	1.58	3.74	3.18	0.30	5.98	0.57	1.24	3.84	2.74
<i>Mastogloia fimbriata</i> (Brightwell) Cleve	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.21	0.00	0.03
<i>Mastogloia cf. labuensis</i> Cleve	0.00	0.57	0.00	0.54	0.25	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.13
<i>Mastogloia cf. lanceolata</i> Thw.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
<i>Mastogloia ovalis</i> A. Schmidt	3.20	3.69	2.77	2.70	2.75	1.60	3.53	0.32	4.01	2.65	0.89	2.87	1.42	1.65	1.68	2.38
<i>Mastogloia ovulum</i> Hustedt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.02
<i>Mastogloia cf. pseudolaticostata</i> Yohn & Gibson	0.00	0.00	0.28	0.27	1.00	0.32	0.54	0.00	1.60	0.80	0.30	1.20	0.85	0.21	0.24	0.51
<i>Mastogloia punctifera</i> Brun.	0.29	0.28	1.11	1.35	0.75	0.64	1.90	0.95	0.80	1.06	1.18	0.96	0.28	0.62	0.24	0.83
<i>Mastogloia pusilla</i> Grunow	4.94	1.14	0.55	0.00	0.00	0.96	0.82	0.63	1.60	1.06	0.00	0.00	0.00	0.21	0.00	0.79
<i>Mastogloia rhombica</i> Cleve	0.00	0.28	0.00	0.27	0.00	0.96	1.36	2.53	0.27	1.33	2.66	0.24	0.28	0.00	0.24	0.69
<i>Mastogloia rimrosa</i> Cleve	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.32	0.00	0.00	0.30	0.48	0.28	0.00	0.00	0.11
<i>Mastogloia rostellata</i> Grunow	0.58	0.57	0.28	0.81	1.00	0.32	0.27	0.00	0.27	0.53	0.89	0.00	0.00	0.41	0.00	0.40
<i>Mastogloia cf. sturdyi</i> Paddock & Kemp	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.05
<i>Mastogloia subaffirmata</i> Hustedt	0.00	0.57	0.00	0.00	0.25	0.32	0.82	0.63	1.07	1.33	0.59	0.24	0.00	0.00	0.48	0.42

trends in several parameters, including species richness and diversity, were examined by fitting first order regressions to the data points using Sigma Plot[®] software.

RESULTS

Diatom Flora and Species Abundances

Diatom valves were generally well preserved and abundant in the Pass Key core 37, with estimates of the number of valves per gram of sediment ranging from just under 2 million to over 10 million (Fig. 2). Diatom concentration estimates are not constant with depth in the core; rather, these estimates fluctuate. The largest fluctuation is near the surface of the core, where estimates of around 3 million valves per gram in the 24-26 cm sample rise to over 10 million valves per gram in the 10-12 cm sample. Estimates return to just over 2 million valves per gram in the 0-2 cm sample. It appears that the diatom concentration has increased over time; a simple linear regression on these data results in a line with a slope that decreases toward the bottom of the core ($r^2=0.15$). This trend may reflect an increase in the productivity of the diatom community in the Pass Key area over the time period represented by the core. However, some or all of the changes could be due to other factors, such as a variable sedimentation rate or preservation of the valves. For example, a lower sedimentation rate may result in more diatom valves per unit of sediment given the same rate of diatom productivity, as there is less sediment to “dilute” the valves. A more precise estimate of sedimentation rate is necessary to assess diatom productivity. In addition, the diatom taxa in the Pass Key core 37 are of varying size and shape. Biovolumes would have to be determined in order to get a more accurate estimate of diatom productivity.

In general, the diatom flora represented in the Pass Key core 37 are similar to that of localities in the Caribbean and other tropical and subtropical areas for which taxonomic works have been completed, including Puerto Rico (Hagelstein 1938, Navarro *et al.* 1989), Cuba (Foged 1984), Greece (Foged 1986b), and Africa (Foged 1975, Foged 1986a). A complete list of all species counted in the core, along with the percent abundance per sample and mean percent abundance over all samples, can be found in Table 1. Ninety-five species and varieties were identified; genera with the most species were *Mastogloia* (34 species and varieties), *Amphora* (8 species), and *Navicula* (8 species). The ten species with the highest mean percent abundance were *Cyclotella cf. litoralis* (mean percent abundance=21.6), *Nitzschia granulata* (12.1%), *Mastogloia crucicula* (6.8%), *Cocconeis placentula cf. var. euglypta* (4.9%), *Fragilaria tabulata var. tabulata* (3.7%), *Amphora coffeaeformis* (3.1%), *Navicula cf. zostereti* (3.1%), *Mastogloia erythrea* (2.7%), *Mastogloia ovalis* (2.4%), and *Nitzschia maxima* (2.2%). Some of these species are shown in Figures 3-5.

The percent abundances of many of the more common species show changes throughout the time period represented by the Pass Key core 37 (Table 1). *Nitzschia granulata*, which is an epipelagic species, shows some of the largest changes in abundance. This species is much more common deeper in the core, with percent abundances as high as 45.3% and 36.4% in the 64-66 cm and 50-52 cm samples, respectively. Above the 44-46 cm sample, *N. granulata* is much less common, with percent abundances of 10% or less.

Concentration of diatom valves

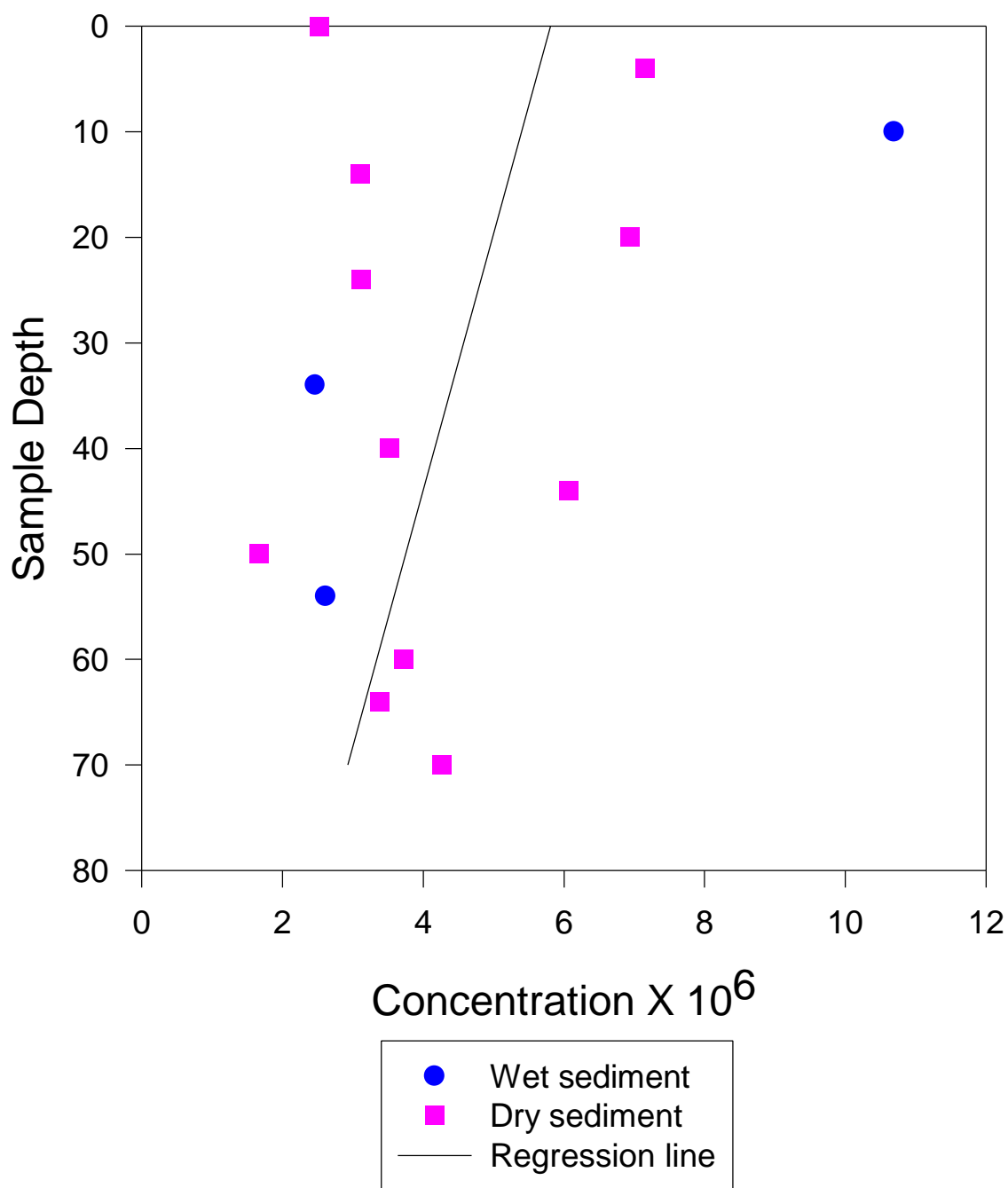


Figure 2. Concentration of diatom valves in the Pass Key core 37 ($r^2 = 0.15$).

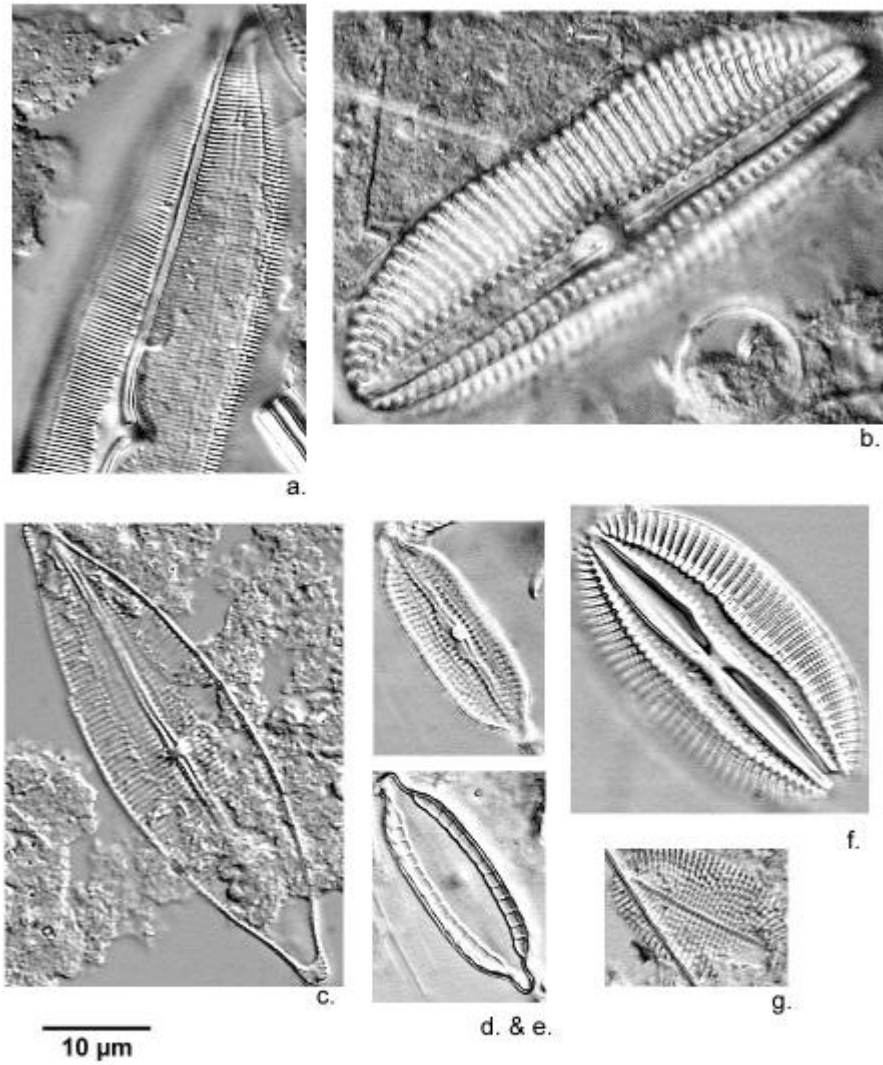


Figure 3. **a.** *Caloneis cf. liber* (Wm. Smith) Cleve. **b.** *Diploneis didyma* Ehrenberg.
c. *Mastogloia elegans* Lewis **d. & e.** *Mastogloia corsicana* Grunow. **f.** *Diploneis suborbicularis*
var. *constricta* Hustedt. **g.** *Cocconeis placentula cf. var. euglypta* Cleve.

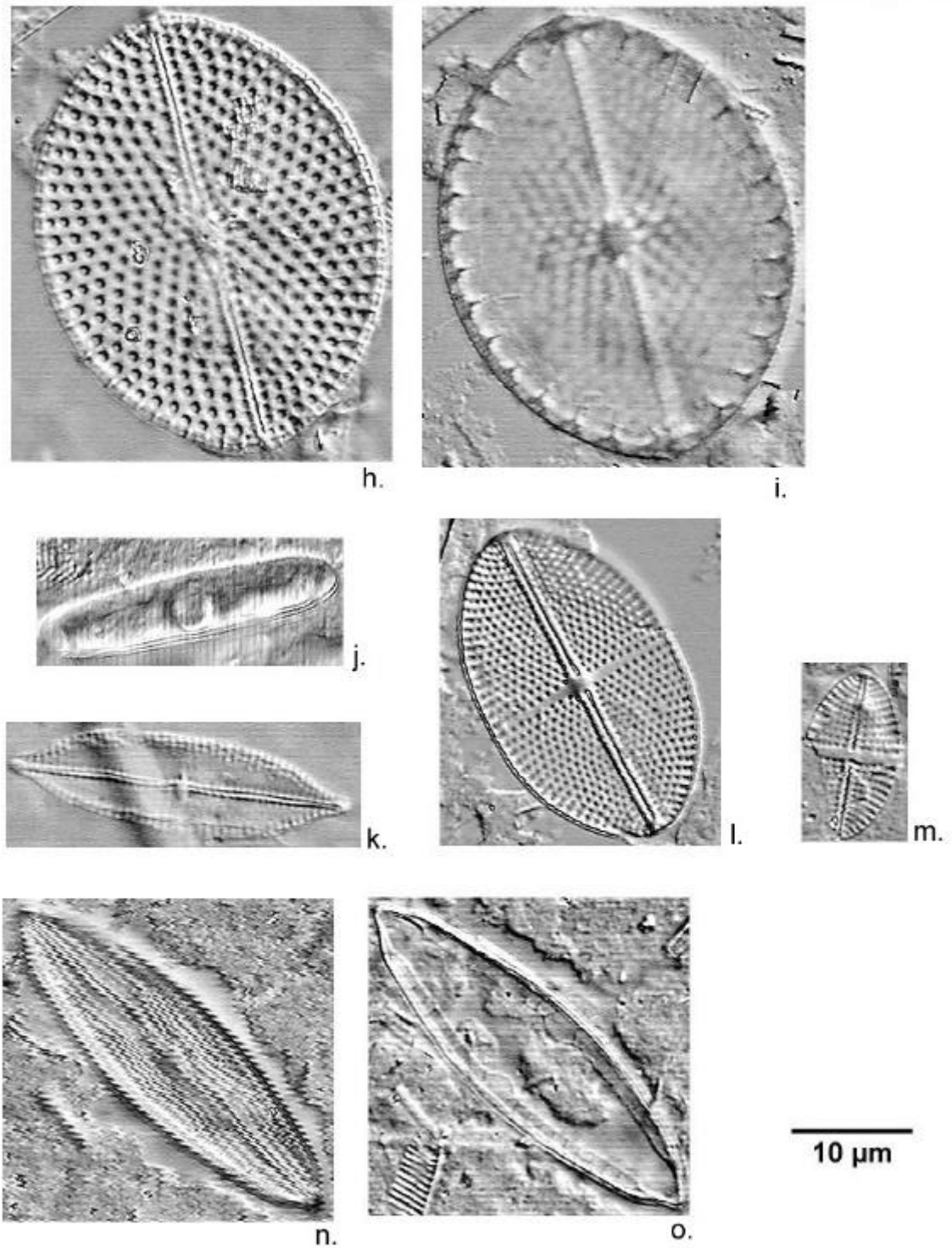


Figure 4. **h.** & **i.** *Mastogloia cribrosa* Grunow **j.** *Grammatophora oceanica* var. *macilenta* (Wm. Smith) Grunow. **k.** *Mastogloia discontinua* Paddock & Kemp. **l.** *Mastogloia binotata* (Grun.) Cleve. **m.** *Mastogloia crucicula* Grunow. **n.** & **o.** *Mastogloia biocellata* (Grun.) Novarino & Muftah.

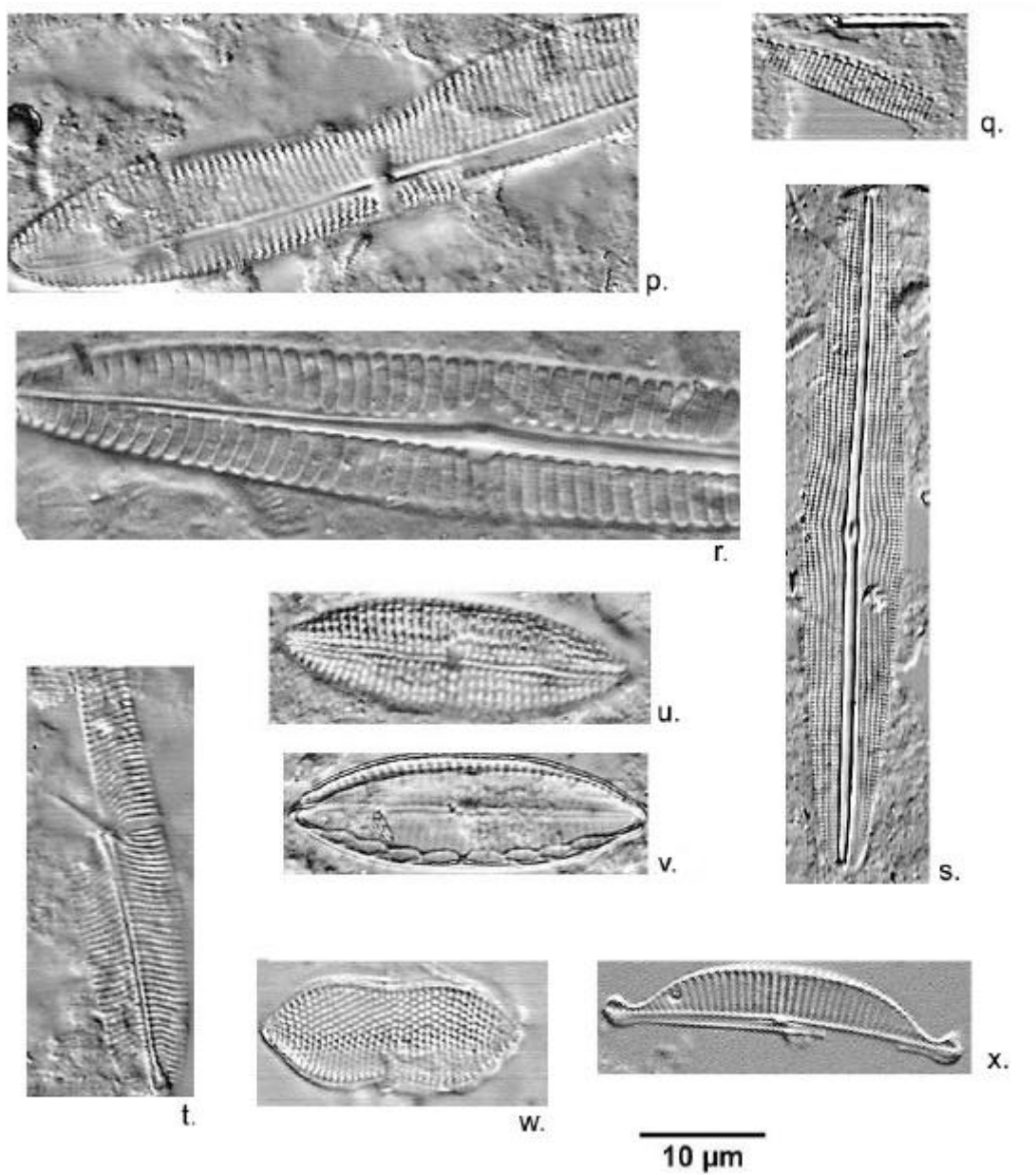


Figure 5. **p.** *Navicula cf. congenera* Hagelstein. **q.** *Nitzschia cf. frustulum* (Kutzing) Grunow
r. *Navicula zostereti* Grunow. **s.** *Frustulia interposita* (Lewis) de Toni. **t.** *Navicula* sp. 2.
u. & **v.** *Mastogloia* sp. 3. **w.** *Nitzschia panduriformis* Gregory. **x.** *Amphora coffeaeformis*
 (Agardh) Kutzing.

Cyclotella cf. litoralis, a planktonic marine species, also shows changes in abundance, ranging from 12-18% in the deeper samples, and increasing to over 20% above the 44-46 cm sample. The percent abundance of *C. litoralis* reaches a high of 32.9% in the 24-26 cm sample, decreases to 16.8% in the 20-22 cm sample, and resumes an increasing trend towards the surface of the core. *Mastogloia elegans*, a marine species common on the coast of North America, shows an increasing trend in abundance, with percent abundances <1% below the 50-52 cm sample, increasing to almost 5% at the top of the core. In contrast, *Nitzschia cf. frustulum*, a brackish-water benthic species, appears to have become less common through time. The percent abundance of *N. cf. frustulum* decreases from a high of 12.2% in the 70-72 cm sample to <1% in the 64-66 cm sample; its percent abundance remains <3% until the 10-12 cm sample, where it increases to 5%, decreasing again in the top sample of the core.

Many Florida Bay diatom species can be categorized by habitat and salinity preference. There is information in the literature describing species as planktonic, epiphytic, or epipelagic in growth form, and whether they are generally found in fresh water, estuaries, or the ocean. Some of the species identified from the Pass Key core 37 have only been recently described; for example, *Mastogloia discontinua*, which made up over 2% of the valves counted in some samples, was first described in 1990 (Kemp and Paddock 1990). It is not known whether the ecological information from the literature that is available from other geographical regions applies to the same species living in Florida Bay. Several species described by Hagelstein (1938) and Foged (1984) as marine in Puerto Rico and Cuba, respectively, are listed by DeFelice (1975) as occurring in upper Florida Bay (where salinities are normally <30 ppt) or in salinities ranging from 16-42 ppt by Stephens and Gibson (1979, 1980a, 1980b) in the Indian River Lagoon, Florida. The Appendix of this report contains ecological information for the species in the Pass Key core 37 that made up at least 1% of the valves in any sample; images of several of these species are shown in Figures 3-5.

Species Richness and Diversity

Species richness and Shannon-Wiener diversity of diatom communities in the core fluctuate together (Figs. 6 and 7), with deeper samples generally having lower species richness and diversity (especially the 50-52 cm, 60-62 cm, and 64-66 cm samples). Diversity is highest in the 4-6 cm, 14-16, and 20-22 cm samples, and species richness reaches its peak in the 14-16 cm sample. There appears to have been a gradual increasing trend in diatom community diversity with time; a regression on the diversity data results in a line with a slope that decreases toward the bottom of the core ($r^2=0.30$).

Centric to Pennate Ratio

Centric:pennate ratios (c:p ratios), which are ratios of the number of individuals of centric (in this case, planktonic) species to the number of individuals of pennate (usually benthic) species, can be useful as an indicator of the relative availability of planktonic and benthic habitats (Cooper 1995a & 1995b). An environmental change that causes a decrease in the availability of benthic habitat may be reflected in an increased c:p ratio as centric species gain a competitive advantage. C:p ratios increase in the Pass Key core 37 from between 0.12 and 0.22 in the deepest samples (Fig. 8) to over 0.35 in the 24-26 cm sample, decreasing to 0.18 in the 20-22 cm sample then resuming a gradually increasing trend toward the top of the core.

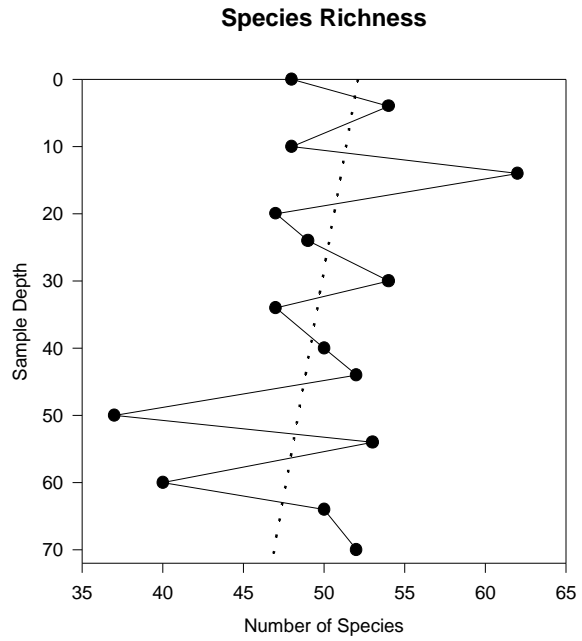


Figure 6. Diatom species richness (number of species per sample) with the fitted regression line ($r^2 = 0.08$).

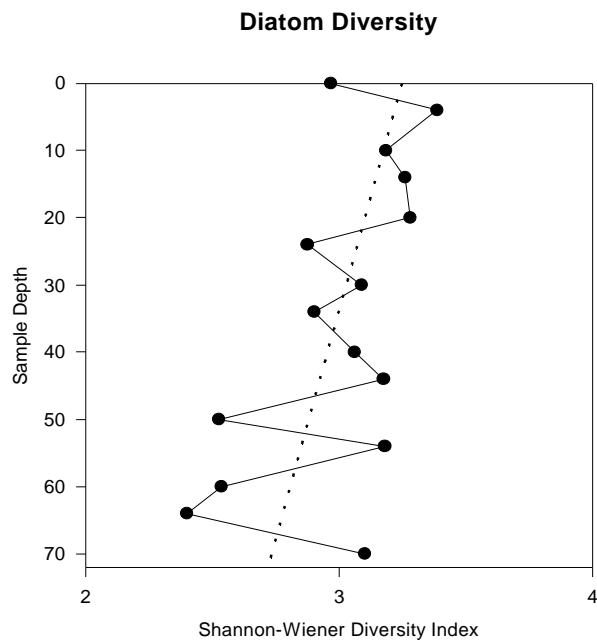


Figure 7. Shannon-Weiner diversity of diatom species with the fitted regression line ($r^2 = 0.30$).

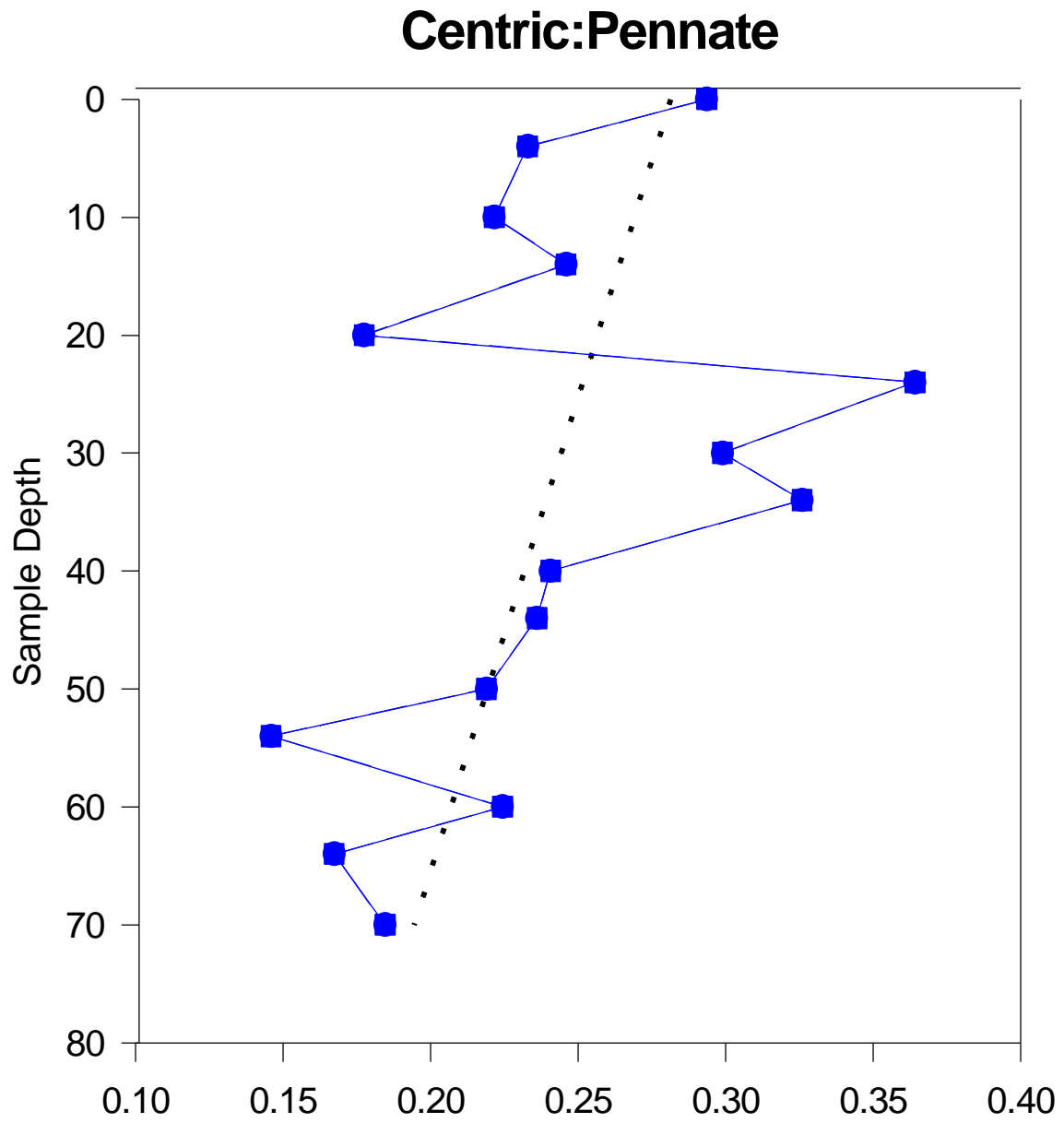


Figure 8. Centric:pennate diatom ratios with regression line ($r^2=0.21$).

A regression on these data results in a line with negative slope toward the bottom of the core ($r^2=0.21$), indicating a trend toward increased c:p ratios in the diatom communities near Pass Key over the time period represented by the core. Environmental changes that could act to increase c:p ratios include blooms of centric diatoms, larger populations or blooms of other planktonic algae (both possibly related to higher nutrient concentrations in the water column), or increased levels of suspended sediment, all of which would increase turbidity and reduce light availability to the benthic species. A reduction in the area covered by seagrass plants would also reduce habitat for benthic species, many of which are epiphytic. Increased water depth would also decrease the amount of light reaching the benthic diatom community and may result in a shift towards dominance of planktonic species.

Diatom Habitat Preferences

In order to examine potential changes in salinity, substrate availability, and the relative availability of benthic and planktonic habitats, species for which information on habitat preference was available were separated into several groups, and down-core changes in the abundance of these groups were evaluated. The “marine” group included 17 species for which all available ecological data clearly pointed to a preference for water of salinity >30 ppt (this group therefore excluded euryhaline species that have been reported growing in salinities as low as 16 ppt). However, since many of these marine species had very low percent abundances in the core and may have been allochthonous, a second group (referred to as “marine dominants”) was constructed that contained two species, *Mastogloia corsicana* and *Mastogloia elegans*. These two species are benthic and present in at least one sample at a percent abundance of >4% (and thus are less likely to be allochthonous), and exhibit a marine distribution. The “brackish” group included those species (*Achnanthes delicatula* ssp. *hauckiana*, *Amphora coffeaeformis*, and *Nitzschia* cf. *frustulum*) with a reported preference for brackish water, and the “freshwater” group included just two species (*Cocconeis placentula* and *Epithemia turgida*) that are distributed mainly in freshwater and brackish water of low salinity. Similarly, “epiphytes” included those (*Cocconeis* spp., *Grammatophora oceanica* var. *macilenta*, and several *Mastogloia* species) that occur predominantly on seagrasses and algae, “epipelics” included 7 species normally found growing on sediment, and the “planktonic” group included the centric species. Due to a lack of ecological information, some species were not included in any group; as a result, the patterns of changing abundance demonstrated by these ecological groupings do not reflect the responses of every member of the diatom assemblage.

Marine Taxa

Between 25-50% of the valves in the Pass Key core 37 (Fig. 9), are classified as “marine,” and it appears that these species generally have been increasing in abundance throughout the history of the core. A regression line fitted to these data has a slope that increases toward the top of the core ($r^2=0.48$). Similarly, the two species that comprise the “marine dominant” group increase from about 1% in the 70-72 cm sample to over 5% of the 0-2 cm sample (Fig. 9; $r^2=0.32$). The percent abundances of both the “marine” and “marine dominant” groups begin to increase at about the 44-46 cm sample, and reach near their highest levels between 24 and 40 cm. The percent of marine taxa decreases between 10 and 20 cm, and gradually resumes an increasing trend above 10 cm to the top of the core.

Marine Taxa

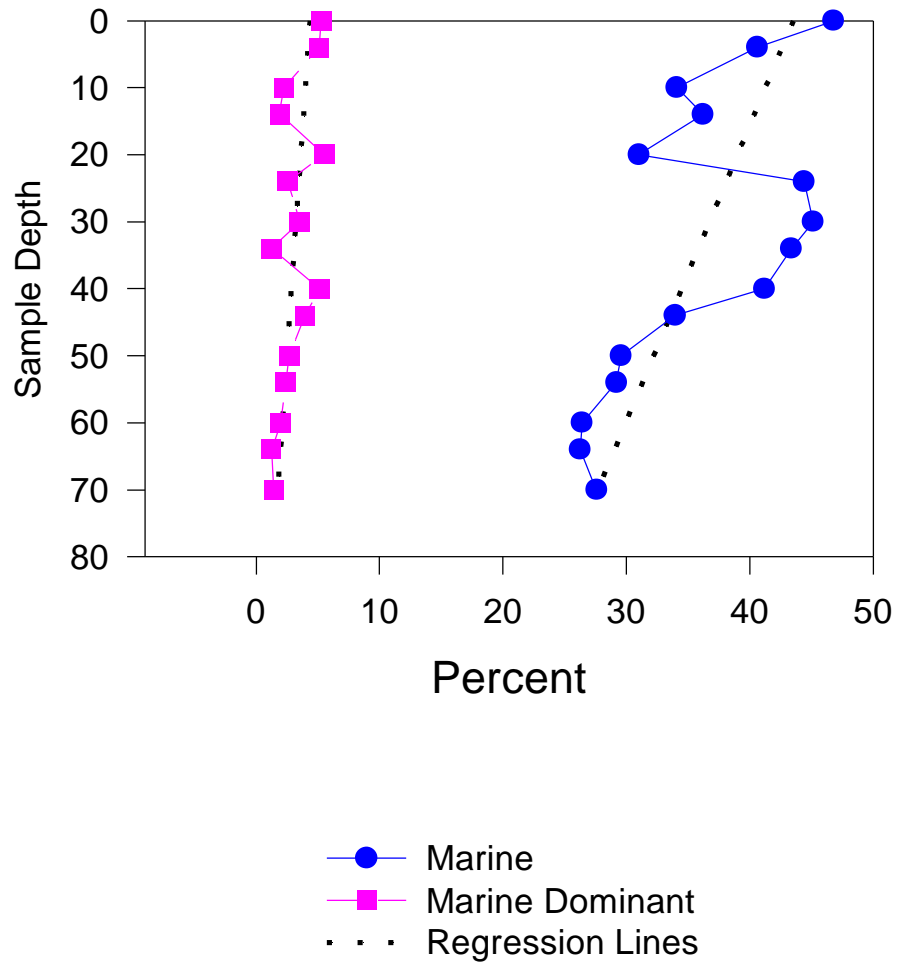


Figure 9. Percent abundance of marine and marine dominant groups, and their fitted regression lines (marine $r^2 = 0.48$ and marine dominant $r^2 = 0.32$)

Brackish Taxa

The “brackish” group has its highest percent abundance in the 70-72 cm sample (Fig. 10), mainly due to the large number of valves belonging to *Nitzschia cf. frustulum*, a brackish-water benthic species. The percent abundance of this group drops to below 4% between 50 and 64 cm, begins increasing at the 44-46 cm sample to almost 12% by the 20-22 cm sample. Abundance of brackish-water species remains high until the 4-6 cm sample, dropping below 7% at the top of the core. A regression line fitted to these data results in an increasing slope toward the top of the core, reflecting an increase in the percent abundance of brackish-water species over time, but the r^2 -value is low at 0.06.

Freshwater Taxa

The percent abundance of the species in the freshwater group shows a pattern that is an inverse of that shown by the marine and marine-dominant groups (Fig. 11). Freshwater species are more abundant in the deeper samples (although they make up <1% of the valves in the 50-52 cm sample), and show a decrease in abundance above the 44-46 cm sample. Percent abundance of freshwater species remains relatively low from 40 cm until 20 cm, increases in the 14-16 cm and 10-12 cm samples, and decreases again near the top of the core. The regression line fitted to these data has a negative slope toward the top of the core, reflecting a decrease in abundance of freshwater species over time ($r^2=0.08$).

Epiphytic and Epipellic Taxa

Like the freshwater group, the species in the “epiphyte” group appear to have decreased in abundance through time (Fig. 12, $r^2=0.04$). Below 40 cm, the percent abundance of epiphytic species such as *Cocconeis placentula* and *Mastogloia crucicula* fluctuates, reaching as high as 30% of valves counted. These fluctuations are consistent with DeFelice’s (1975) observation that these species, especially *C. placentula*, are “opportunistic,” forming “blooms” when conditions are favorable. Above 40 cm, the abundance of epiphytic species is much more constant, and remains below 20%. Epipellic diatoms also show a decreasing trend in abundance toward the top of the core (Fig. 13, $r^2=0.32$).

Brackish Taxa

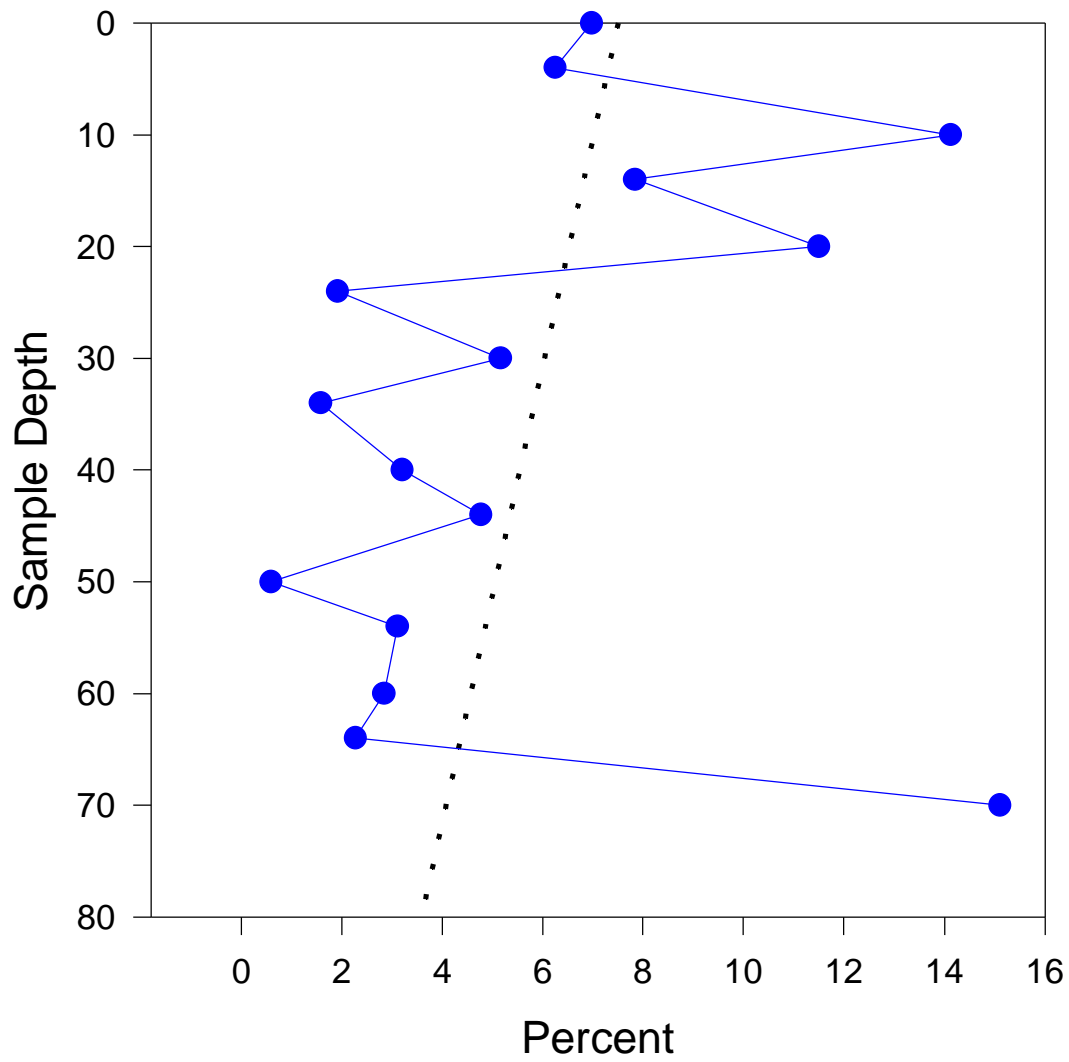


Figure 10. Percent abundance of brackish species with the fitted regression line ($r^2=0.06$).

Freshwater Taxa

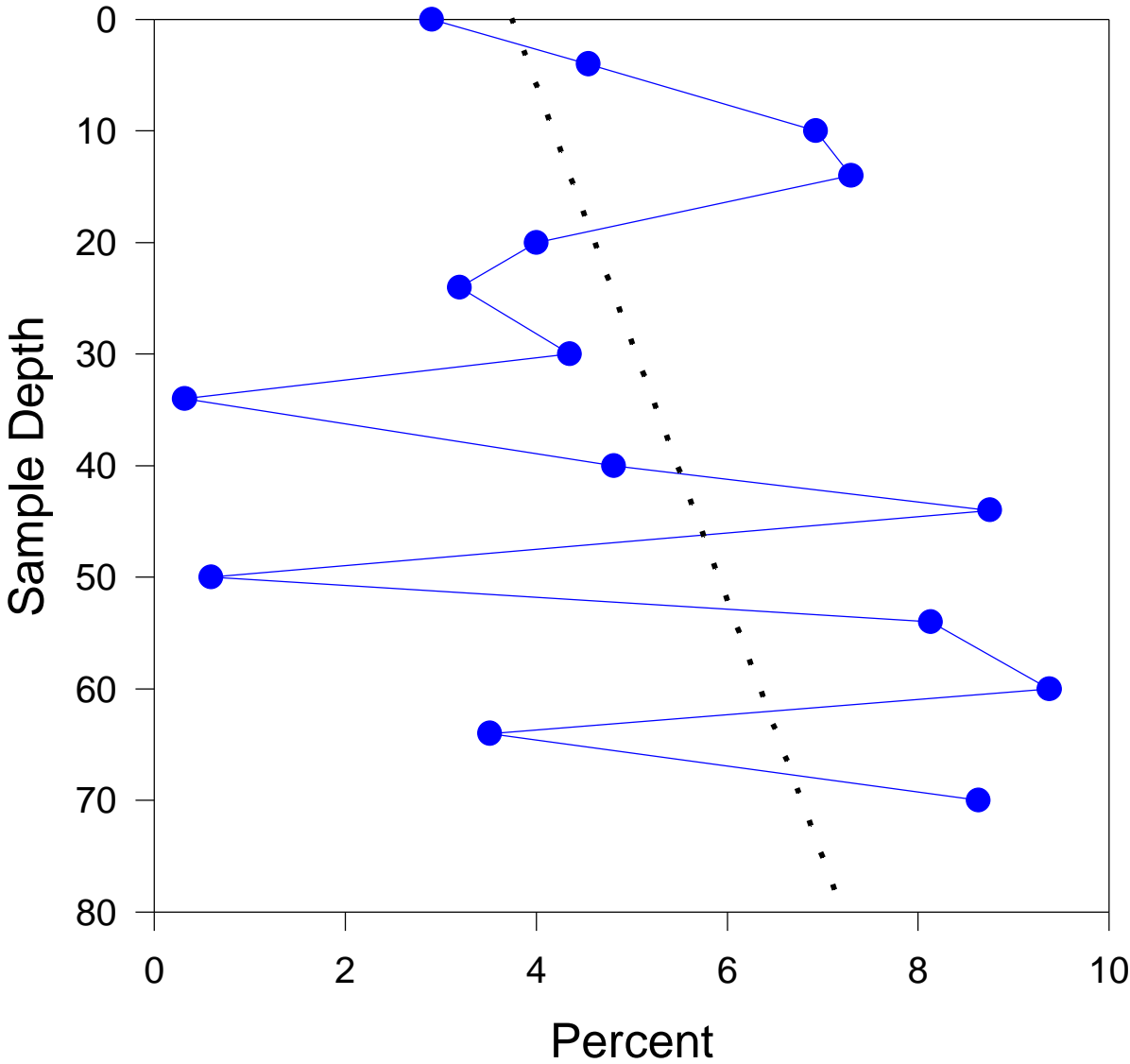


Figure 11. Percent abundance of freshwater species and the fitted regression line ($r^2=0.08$)

Epiphytic Taxa

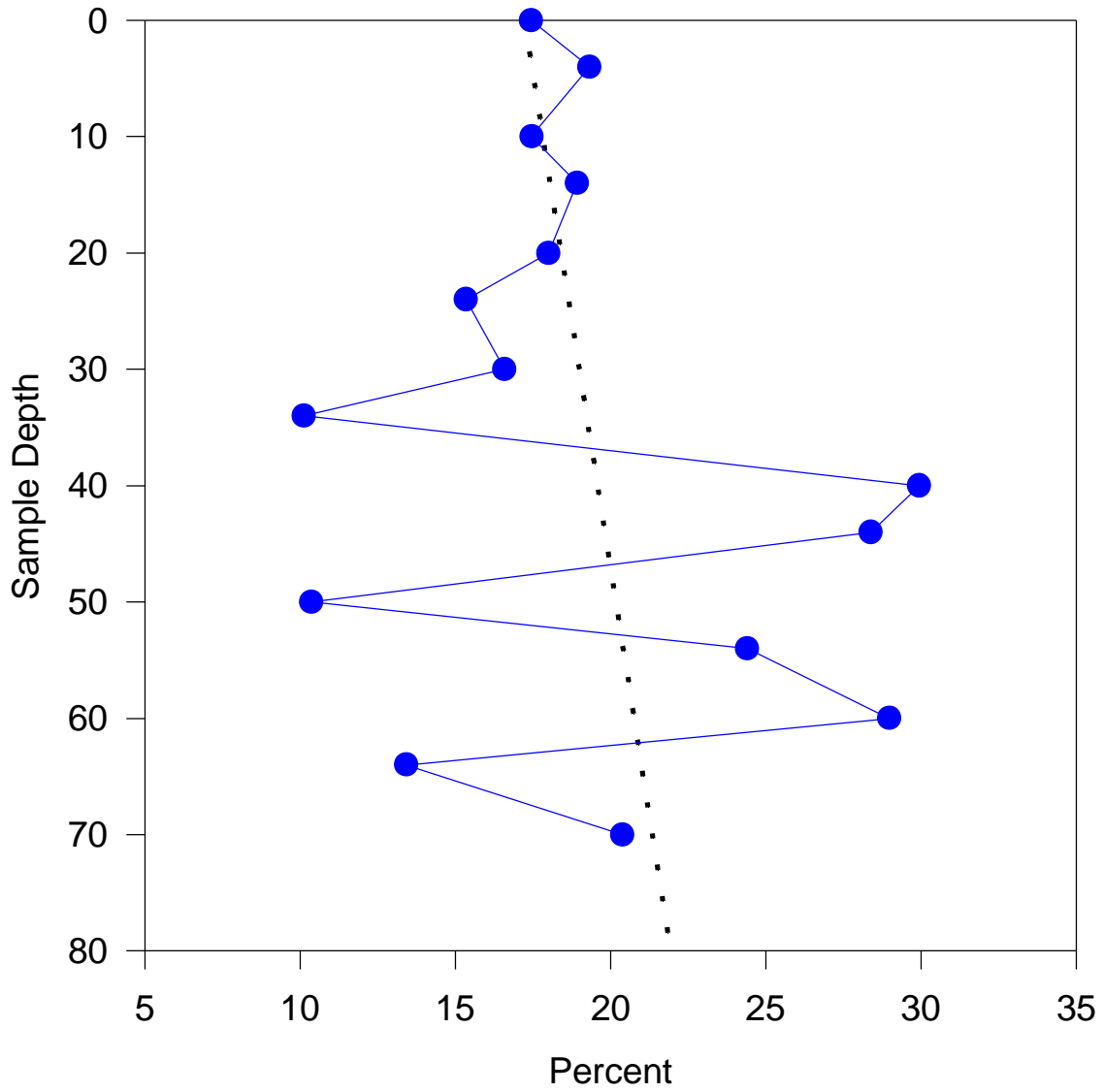


Figure 12. Percent abundance of epiphytic species ($r^2 = 0.04$).

Epipelagic Taxa

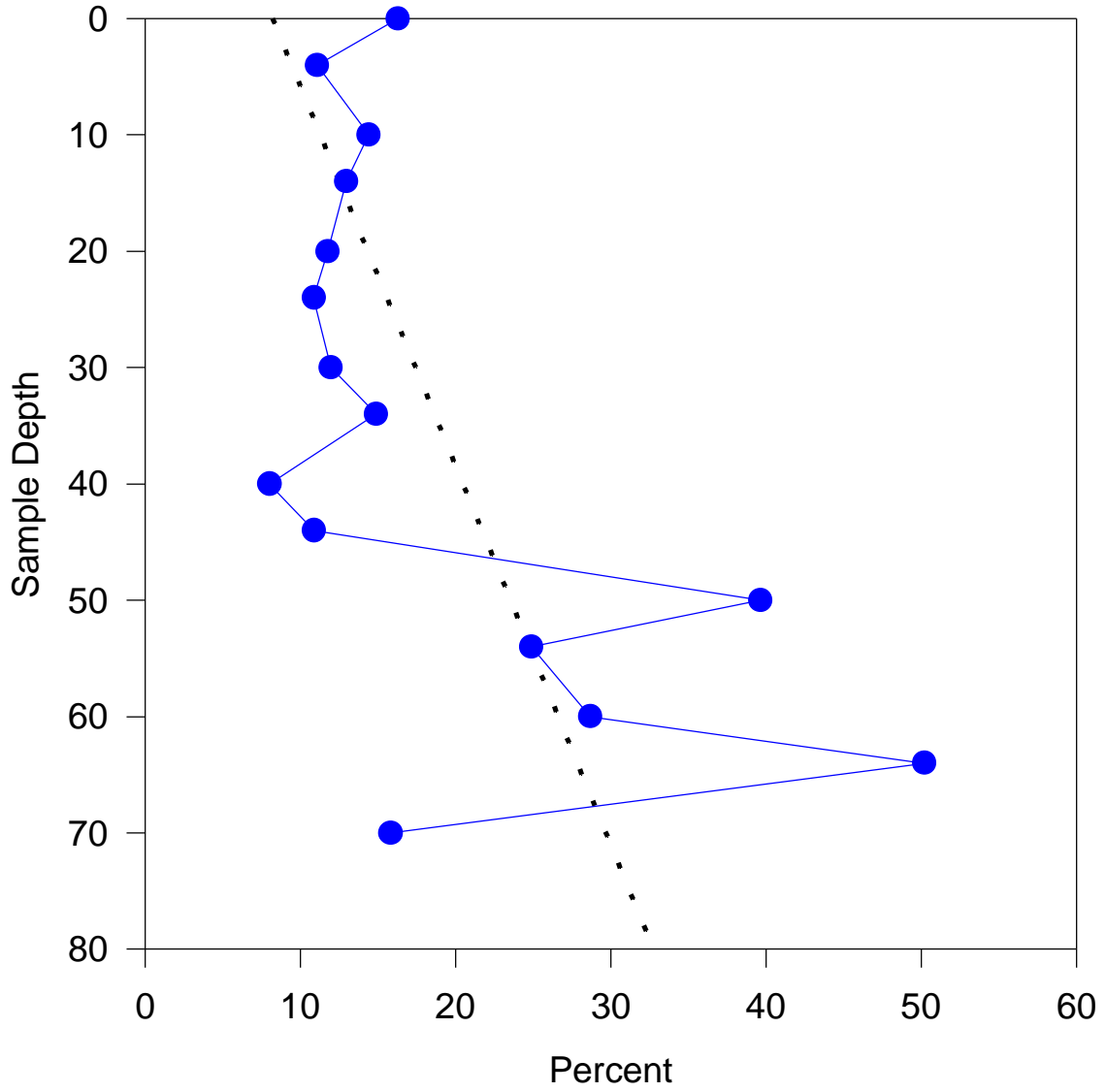


Figure 13. Percent abundance of epipelagic species and the fitted regression line ($r^2 = 0.32$).

DISCUSSION

The patterns of changing abundance shown by the groups of marine and freshwater species suggest that there has been an increase in salinity in the Pass Key area over the time period represented by the core. This effect becomes evident at about the 44-46 cm sample, above which marine species increase in abundance and freshwater species decrease in abundance. There appears to have been a time period represented by the portion of the core from 20 cm until 10 cm during which this pattern reversed itself. The trend toward increasing abundance of marine species is resumed above 10 cm towards the top of the core.

The benthic fauna record from the Pass Key core 37 shows similar fluctuations in both salinity and epiphytic species (Wingard *et al.* 1995). Studies of other Florida Bay cores have also indicated increasing salinity up-core. These include cores taken from the Little Madeira Bay (Ishman *et al.* 1996) and Russell Bank (Brewster-Wingard *et al.* 1997). A core taken from Bob Allen Key indicates fluctuations in salinity between 1930 and the present (Wingard *et al.*, 1995). These findings suggest that the diatom-inferred increase in salinity in the Pass Key core 37 is a widespread occurrence in Florida Bay.

Changing patterns of diatom assemblage diversity also support the hypothesis that salinity in the Pass Key area has increased to salinities nearer to that of seawater in more recent sediments. As salinity increases, more marine species may move into the Pass Key area, increasing the diversity of species found there. DeFelice (1975) found that diatom communities in Florida Bay showed increasing diversity along transects that ran from land toward open water; near-shore epipelagic and epiphytic samples tended to have lower diversity and equitability, and were more likely to be dominated by one or a few species. Similarly, there was also an increase in benthic faunal diversity in the upper 70 cm (since ca. 1931) of sediments from the Bob Allen core (Wingard *et al.* 1995).

The meaning of the patterns exhibited by the species classified as “brackish” is not clear at this time. The changes in abundance of this group appear to most closely track that of the freshwater group; this suggests that, at a time represented by the portion of the core between 24 and 40 cm, salinities near Pass Key increased to reach some level above the preference of most estuarine species. However, with the exception of the 70-72 cm sample, the brackish-water species are not particularly abundant in the deepest part of the core, and the regression line indicates an increasing abundance with time. It may be that one or more of these species is responding to an environmental factor other than salinity.

Several factors could cause the decreasing trend displayed in epiphytic species abundance. First, decreasing populations of seagrasses would reduce the habitat area for epiphytic species. Second, some other change (such as blooms of planktonic algae, increased levels of suspended sediment, or increased water depth) could have acted to reduce light availability. Third, the reported low salinity-tolerance of *Cocconeis placentula* (a dominant epiphyte in Florida Bay) suggests that the apparent increase in salinity, inferred from the increase in abundance of marine species, may underlie the decrease in abundance of epiphytic species. However, the other dominant epiphyte in Florida Bay, *Mastogloia crucicula* (DeFelice 1975), can live in salinities up

to 42 ppt (Stephens and Gibson 1979). Therefore, an increase in salinity is probably not the sole factor behind the decline in epiphytic diatoms.

The marked decline in abundance of epipelagic species that occurs above the 50 cm sample reinforces the pattern seen in the epiphytic species and in the planktonic species, which show an increasing trend in abundance towards the top of the core (Fig. 14; $r^2=0.21$). These changes appear to be relatively abrupt. Epipelagic species decreased from about 40% abundance in the 50-52 cm sample to about 10% in the 44-46 cm sample. Epiphytes declined from ~30% abundance in the 40-42 cm sample to ~10% by the 34-36 cm sample; planktonic species increased from <25% to ~33% during the same time period. The Pass Key core 37 has not yet been dated, but preliminary results suggest that this core is relatively young (Brewster-Wingard *et al.* 1998). These trends suggest that some factor may have acted to decrease the abundance of both epiphytic and epipelagic species, possibly by reducing the amount of light that penetrated the water column. Environmental changes that may reduce water clarity include increased nutrient concentrations (which could stimulate populations of planktonic algae) and increased levels of suspended sediments (either from terrestrial sources or re-suspension from the sediment surface). Increased water depth also may have acted to decrease the amount of light reaching the benthic species; however, this hypothesis is probably less likely than the others just discussed because of the relative rapidity of these changes. Perhaps these abrupt changes could be due to increased water depth if the cause was catastrophic (such as storms); the effects of rising sea-level would probably be more gradual, unless some threshold of water depth was reached, which the epiphytic and epipelagic species could not tolerate.

Inferred changes in substrate availability are more variable between cores taken from different sites in Florida Bay. The Pass Key core 37 provides some evidence that there were declines in sea grass communities (Brewster-Wingard *et al.* 1998). In contrast, the T-24 from Little Madeira Bay core shows increases in seagrass indicators in the upper 20 cm of the core (Ishman *et al.* 1996).

Many of the changes in species abundance and other indicators in the Pass Key core 37 occur between 40 and 50 cm. C:p ratios show an increasing trend starting at about 40 cm. As mentioned previously, the “marine” and “marine dominant” groups increase in abundance beginning with the 44-46 cm sample, and the percent abundance of the freshwater group decreases at about the same point. Epipelagic species and epiphytes decrease abruptly above 50 cm and 40 cm, respectively. Several of these trends are temporarily reversed from around 20 cm to about 10 cm depth in the core.

It appears that some event or combination of factors has greatly affected the diatom communities in the Pass Key region of Florida. The time period of greatest change is represented by the 50-52 cm sample, which also has the lowest estimate of absolute abundance of diatom valves of any sample in the core. This event probably had an effect on salinity, increasing the abundance of marine species and decreasing the abundance of freshwater species, and on the amount of light reaching the benthic species. The factors responsible for these changes appear to have reversed temporarily during the time period represented by the 10-20 cm portion of the core. A decrease in freshwater input from terrestrial sources and reduced flushing would have effects consistent with those seen in the core; however, without more information on the ecology of the

diatom species in Florida Bay and on the chronology of the core, it is premature to accept this hypothesis.

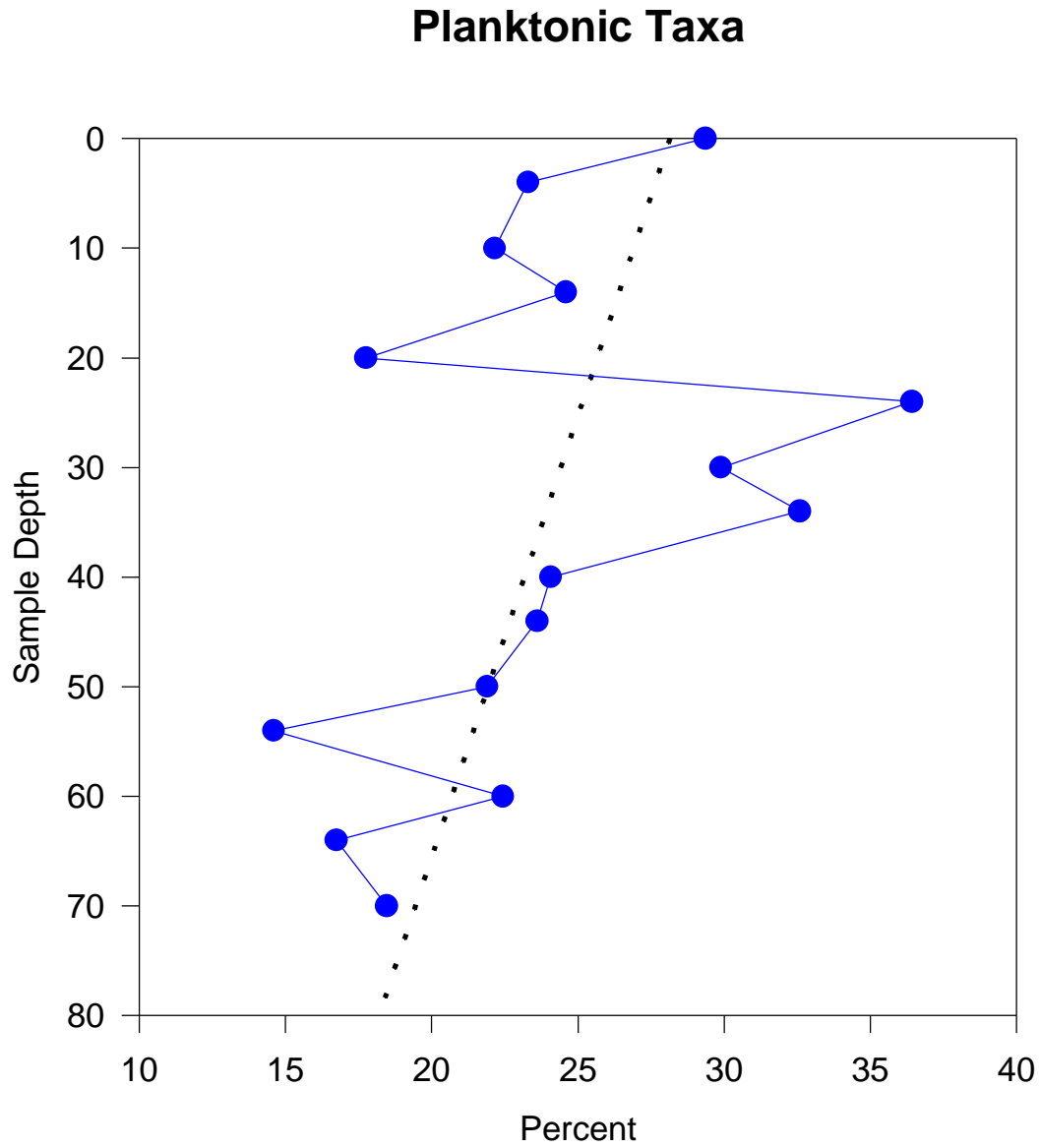


Figure 14. Percent abundance of planktonic taxa and the fitted regression line ($r^2=0.21$).

SUMMARY

- Diatom valves in the Pass Key core 37 were generally well-preserved and abundant, with estimates of the number of valves per gram of sediment ranging from just under 2 million to over 10 million, with the highest estimates and largest fluctuations in abundance near the surface of the core.
- 95 species and varieties of diatoms were identified in counts of 15 samples. Many of the dominant species show large changes in percent abundance down-core.
- Species richness and Shannon-Weiner diversity of diatom assemblages show relatively large fluctuations throughout the core, with highest values in the 4-6 cm, 14-16 cm, and 20-22 cm samples. Diversity appears to have increased during the time period represented by the core; this fact is consistent with a hypothesis of increased salinity in the Pass Key area.
- Centric:pennate diatom ratios range from just under 0.15 in the 54-56 cm sample to over 0.35 in the 24-26 cm sample, with a large drop in the c:p ratio occurring between the 24-26 cm and 20-22 cm samples. These ratios appear to have increased over time; factors that could cause an increase in the c:p ratio include increased nutrient concentrations (resulting in blooms of planktonic algae), increased levels of suspended sediment, or increased water depth.
- The percent abundance of the marine and “marine dominant” ecological diatom groups begins to increase at the 44-46 cm sample, reaches highest levels between 24 and 40 cm, decreases between 10 and 20 cm, and increases again toward the top of the core.
- The pattern of changing abundance for the freshwater ecological diatom group is almost the exact inverse of the marine and “marine dominant” groups, suggesting that there has been an increase in salinity over time, with highest salinities reached during the time period represented by the portion of the core between 24 and 40 cm.
- Epiphytic diatom species have become less abundant with time. Below 40 cm, the percent abundance of these species shows large fluctuations; above this point, the fluctuations dampen, and the percent abundance of these epiphytic species does not reach as high as it does in the deeper samples. Possible causes include reduced populations of seagrasses, increased levels of nutrients or suspended sediment in the water column, and increased water depth.
- Similarly, epipellic diatom species have become less common near the surface of the core, which suggests that the decline in benthic diatoms may be related to some factor that acted to decrease the amount of light reaching the benthic species.

- Many of the changes in diatom species abundance and other indicators occur between 40 and 50 cm; several of these trends are temporarily reversed between 10 and 20 cm. Information on the dating of the core will help to link these changes in diatom assemblages to known historical events that have affected Florida Bay.
- Studies on other Florida Bay cores indicate that a trend towards increasing salinity has occurred in other areas of the Bay. These studies, along with the Pass Key study, suggest that changes in macrophyte communities are variable from site to site.

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APPENDIX

Ecological information for diatoms with percent abundances greater than 1% in any sample.

The following summaries of ecological information were compiled from several publications dealing with diatom taxonomy and ecology.

***Achnanthes delicatula* ssp. *hauckiana* (Grunow) Lange-Bertalot and Ruppel**

Hendey (Hendey 1964) lists this as a common species found in brackish waters along the coasts of Britain. This species and other references for it are discussed in more detail in Cooper (1995b).

***Amphora coffeaeformis* (Agardh) Kützing**

According to Archibald and Schoeman (1984), this is a brackish-water species. Hustedt (1955) found it to be "frequent on mud from the beach as well as on piles from the harbor" near Beaufort, North Carolina. In a study of the Swan River estuary in Australia, John (1983) found it to be periphytic, and more common at upstream (lower salinity) stations than downstream. In the upper sounds of Florida Bay, DeFelice (1975) reported that it is a common epipelagic form, as did Hagelstein (1938) for Puerto Rico. Navarro (1982) listed it as a very rare, sub- and supra-littoral species on the mangroves of the Indian River Lagoon in Florida.

***Amphora* cf. *costata* Wm. Smith**

This species has been described as rare and sub-littoral on mangroves in Florida (Navarro 1982) and common on British coasts (Hendey 1964).

***Amphora* aff. *proboscidea* (Gregory) Cleve**

This species has two prominent convex "humps" on the dorsal side of the valve and 16 striae in 10 μm ; the identification was made with reference to drawings in Peragallo and Peragallo (1897-1908). According to Hendey (1964), it is occasional on British coasts.

***Amphora* cf. *proteus* (Gregory)**

Found on grass and sediment by DeFelice (1975) in upper Florida Bay, this species is a mesohalobe to polyhalobe in Cuba (Foged 1984). It also was reported from the Swan River estuary (John 1983) and Britain and the English Channel (Hendey 1964). It was found by Navarro (1982) to be common on the mangroves in Florida in all positions relative to the tides (sub-, supra-, and littoral). Miller *et al.* (1977) described it as a common species on the sand around Florida Keys coral reefs, and Hagelstein (1938) listed it as a common marine and brackish-water species in Puerto Rico.

***Amphora rhombica* Kitton**

A polyhalobe (Foged 1984).

***Amphora ventricosa* (Gregory)**

A polyhalobe in Cuba (Foged 1984), Hustedt (1955) found *A. ventricosa* "only on mud from the beach," and called it uncommon near Beaufort, N.C. It is common in all tidal positions on Florida mangroves (Navarro 1982), in the Swan River estuary (John 1983), and along British coasts (Hendey 1964).

***Caloneis cf. liber* (Wm. Smith) Cleve**

This is a marine species (Patrick and Reimer 1966, Foged 1984), common on sandy shores (Hendey 1964) and in San Juan Bay, Puerto Rico (Hagelstein 1938).

***Climaconeis scopulorioides* Hustedt**

This littoral species was originally described by Hustedt (1927-1964) from the Gulf of Mexico.

***Cocconeis placentula cf. var. euglypta* (Ehrenberg) Cleve**

Cocconeis placentula has been described variously as a brackish and freshwater species (Hagelstein 1938) and as an oligohalobe and salinity-indifferent (Foged 1984). DeFelice (1975) found it in "extremely large numbers" on *Thalassia* grass in upper Florida Bay, and Navarro (1982) stated that it was rare, and only found at the lower salinity station sampled in his study of diatoms on Florida mangroves. Patrick and Reimer (1966) called this species salt-indifferent, but said that it is "not observed in great numbers in slightly brackish waters." This species and other references for it are discussed in more detail in Cooper (1995b).

***Cocconeis scutellum* Ehrenberg**

This marine species has been reported as common in Cuba (Foged 1984), San Juan Bay (Hagelstein 1938), along British coasts (Hendey 1964), and on *Thalassia* and sediment in Florida Bay (DeFelice 1975). Navarro (1982) found it only at the higher salinity station in the Florida mangroves. This species and other references for it are discussed in more detail in Cooper (1995b).

***Cyclotella cf. litoralis* Lange & Syvertsen**

A planktonic species, it is probably "truly marine", according to Lange and Syvertsen (1989), but might be euryhaline. The original description of this morphologically variable species was published in 1990; under the light microscope *C. litoralis* is very similar to *C. stylorum*, somewhat similar to *C. striata*, and is often confused with the two (Lange and Syvertsen 1989). It is possible that a few of the valves identified as *C. litoralis* are actually *C. stylorum*, although such valves probably make up a small percentage of the total. Further SEM studies will help clarify the range of morphological variation in *C. litoralis* and help distinguish it from similar species.

***Diploneis didyma* Ehrenberg**

Patrick and Reimer (1966) described this species as euryhaline. According to DeFelice (1975), it is primarily epipelagic, but also epiphytic, in Florida Bay. It was rare at the lower stations in the Swan River estuary (John 1983) and is common on British coasts (Hendey 1964) and in San Juan Bay (Hagelstein 1938).

***Diploneis suborbicularis* var. *constricta* Hustedt**

A cosmopolitan species, more frequent on warmer coasts (Hustedt 1955). It is marine (Hagelstein 1938) and a polyhalobe (Foged 1984), and was collected from sub-littoral and littoral positions only at the higher salinity station in Navarro's (1982) study of diatom communities on mangrove prop roots in Florida. John (1983) collected this species at both upper and lower stations in the Swan River.

***Epithemia* cf. *turgida* Kützing**

Hagelstein (1938) reported this species as widely distributed in fresh and brackish waters in Puerto Rico. He also found it at a marine sampling station but attributed this to transport by tributary.

***Fragilaria tabulata* var. *tabulata* (Agardh) Lange-Bertalot**

A euryhaline species found in Cuba (Foged 1984), it is common in all positions on the Florida mangroves (Navarro 1982).

***Frustulia interposita* (Lewis) de Toni**

DeFelice (1975) found this species to be epipelagic and uncommon in upper Florida Bay. Patrick and Reimer (1966) reported that it prefers water of low mineral content. Hagelstein (1938) listed it as occurring in San Juan Bay and on the coast of North America.

***Frustulia* sp. 2**

This species has not yet been matched with a published description. Valves are usually between 40 and 70 μm long, and around 10 μm wide. There are 20-22 curved, radial striae in 10 μm .

***Grammatophora oceanica* var. *macilenta* (Wm. Smith) Grunow**

A marine (Foged 1984) epiphyte (John 1983), common on British coasts (Hendey 1964) and on Florida mangroves (Navarro 1982).

***Gyrosigma balticum* (Ehrenberg) Cleve**

This is a brackish-water and marine species (Hagelstein 1938, Patrick and Reimer 1966, Foged 1984). Hendey (1964) describes it as a littoral species that forms colonies on mud and sand. Navarro (1982) found it to be frequent in the sub-littoral and littoral positions on Florida mangroves, but Hustedt (1955) described it as scarce in Beaufort, North Carolina.

***Mastogloia angulata* Lewis**

According to Foged (1984) and Hagelstein (1938), this is a marine species; however, Stephens and Gibson (1980b) reported *M. angulata* as an epiphyte found in salinities ranging from 16-42 ppt. Navarro (1982) found it to be frequent on Florida mangroves, but it was rare in Beaufort, North Carolina (Hustedt 1955), the Swan River (John 1983), and in upper Florida Bay (DeFelice 1975).

***Mastogloia cf. apiculata* Wm. Smith**

This species is also listed as a polyhalobe (Foged 1984) and marine (Hagelstein 1938), yet was found in salinities from 16-42 ppt by Stephens and Gibson (1980a). It was found as an epiphyte on *Thalassia* and on sediment in Florida Bay (DeFelice 1975).

***Mastogloia binotata* (Grunow) Cleve**

Mastogloia binotata is a common epiphytic and epipelagic species on Florida mangroves (Navarro 1982) and in Florida Bay (DeFelice 1975). Hustedt (1955) found it to be scarce near Beaufort, North Carolina, but Hendey (1964) described it as frequent in the English Channel. It is a mesohalobe to polyhalobe (Hagelstein 1938, Foged 1984), found in salinities ranging from 16-42 ppt by Stephens and Gibson (1979).

***Mastogloia biocellata* (Grunow) Novarino & Muftah**

This species was originally regarded as a variety of *M. erythrea*, but was raised to species status by Novarino and Muftah (1991), who collected it in the Atlantic Ocean off the coast of Qatar.

***Mastogloia braunii* Grunow**

A mesohalobe to polyhalobe (Foged 1984), *M. braunii* is epiphytic and epipelagic in Florida Bay (DeFelice 1975). It is a common brackish water form on North Sea coasts (Hendey 1964), and is found in brackish water throughout North America (Patrick and Reimer 1966). Hagelstein (1938) found it at marine sampling stations in Puerto Rico and in the San Juan marshes.

***Mastogloia corsicana* Grunow**

Mastogloia corsicana is a polyhalobe collected in Cuba (Foged 1984), and by Yohn and Gibson (1982b) from the west end of Grand Bahama Island at 0-25 and 219 m depth.

***Mastogloia cribrosa* Grunow**

This species is described as marine (Hagelstein 1938) and a polyhalobe (Foged 1984), but has also been found throughout a range of salinities from 16-42 ppt (Stephens and Gibson 1979). Navarro (1982) reported it as frequent but only from the higher salinity station in his study of Florida mangroves. DeFelice also lists it as an epiphytic and epipelagic species in Florida Bay, and Hustedt (1955) reports it as scarce near Beaufort.

***Mastogloia crucicula* Grunow**

DeFelice (1975) described *M. crucicula* as a dominant epiphyte on *Thalassia* in upper Florida Bay. It was also a common epiphyte in the mangroves of Florida (Navarro 1982), but scarce off Beaufort, North Carolina (Hustedt 1955). According to Foged (1984) and Hagelstein (1938), this species is marine, but was collected in a range of salinities from 16-42 ppt by Stephens and Gibson (1979).

***Mastogloia discontinua* Kemp & Paddock**

This species, first described in 1990 (Kemp and Paddock 1990), was collected from St. James Reef off Bermuda.

***Mastogloia elegans* Lewis**

Mastogloia elegans may be a truly marine species. It was described by Foged (1984) as a polyhalobe, and Hagelstein (1938) found it at marine sampling stations (but also reported it from a freshwater spring). Yohn and Gibson (1982b) collected it off the west end of Grand Bahama Island, at depths of 25-50 m, and report that it is common on most of the Atlantic coast of North America.

***Mastogloia erythrea* Grunow**

Stephens and Gibson (1980b) found this species as an epiphyte on the seagrass *Halodule wrightii* in the Indian River Lagoon in Florida in salinities ranging from 16-42 ppt. DeFelice (1975) reported it as an epipelagic form in upper Florida Bay, and Navarro (1982) stated that it was rare, and only found at the higher salinity station, on coastal mangroves in Florida. Hustedt (1955) and John (1983) found it to be rare near Beaufort, North Carolina, and in the Swan River, Australia, respectively. It has also been described as marine (Hagelstein 1938) and a polyhalobe (Foged 1984).

***Mastogloia fimbriata* (Brightwell) Cleve**

Mastogloia fimbriata may be useful as an indicator of higher salinity; however, it was very rare in the Pass Key core 37. Hagelstein (1938) and Foged (1984) described it as marine, and Navarro (1982) found it only at the higher salinity sampling station in the Florida mangroves, where it was very rare. It was also a rare benthic and epiphytic form in the Swan River estuary (John 1983). Stephens and Gibson (1979) found this species only in salinities ranging from 28-35.5 ppt; it was absent in salinities <28 ppt.

***Mastogloia ovalis* A. Schmidt**

Stephens and Gibson (1979) found this species at salinities ranging from 16-42 ppt; however, Navarro (1982) and Foged (1984) reported it as a marine form.

***Mastogloia punctifera* Brun.**

Hustedt (1955) described *M. punctifera* as “not scarce” near Beaufort, and states that it is also known from the Mediterranean. Foged (1984) also reported it as a marine form from Cuba.

***Mastogloia pusilla* Grunow**

A meso- to polyhalobe (Foged 1984) collected by Stephens and Gibson (1980b) in water of 16-42 ppt, *M. pusilla* is common in all tidal positions in the mangroves of Florida (Navarro 1982).

***Mastogloia* cf. *pseudolatecostata* Yohn & Gibson**

This species, first described by Yohn and Gibson (1982a), was collected off the west end of Grand Bahama Island at depths of 61-300 m.

***Mastogloia rhombica* Cleve**

Probably a polyhalobe, *M. rhombica* was collected by Yohn and Gibson (1982b) off the west end of Grand Bahama Island at 50 m depth.

***Mastogloia rostellata* Grunow**

DeFelice (1975) listed this as an epipelagic form in Florida Bay. Described by Foged (1984) as a polyhalobe, it was also collected by Yohn and Gibson (1982a) from the west end of Grand Bahama Island at depths of 25-300 m.

***Mastogloia subaffirmata* Hustedt**

Found on *Thalassia* and sediment in Florida Bay (DeFelice 1975), this species is a polyhalobe also known from the East Indies and the Mediterranean (Foged 1984).

***Mastogloia varians* Hustedt**

A polyhalobe found in Cuba by Foged (1984), *M. varians* was reported as scarce off the coast of Beaufort, North Carolina by Hustedt (1955), who said it was known previously from Indomalaysian and Asian coasts. It was rare, and only at the higher salinity station, in Navarro's (1982) study of Florida mangroves.

***Mastogloia* #3**

This species or form has not yet been matched with a published description. Valves ranging in size from 20x8 μm to 60x12 μm have been counted, with 14-16 radial striae and 3 elongate, rounded locules in 10 μm . Valves are lanceolate, with rounded cuneate apices. Some valves appear to have a slightly constricted center; others do not.

***Navicula* cf. *congerana* Hagelstein**

This species appeared to be a good match to Plate 6, Figure 9 in Hagelstein (1938), described as a new species from a mangrove marsh in Miramar, Puerto Rico.

***Navicula cf. cancellata* Donkin**

According to Hendeby (1964), *N. cancellata* is a highly variable species that is adapted to large changes in salinity and environment; different morphologies may correspond to lower or higher salinities although not much more is known about polymorphism in this species. It is strongly euryhaline, common on sandy beaches in Britain, but less frequent on muddy shores (Hendeby 1964). John (1983) listed it as an epiphyte at the lower stations (higher salinity) in the Swan River. Hagelstein (1938) reported it from San Juan Bay, and Foged (1984) described it as a polyhalobe.

***Navicula cf. zostereti* Grunow**

A polyhalobe (Foged 1984), this species is common on sediment and grass in Florida Bay (DeFelice 1975).

***Navicula* sp. 3**

Valves are about 12 μm long and 3 μm wide, with 12 coarse, parallel striae in 10 μm ; the striae are shorter near the central area. Although quite different in size, this form resembles Plate 39, Figure 3 in Krammer and Lange-Bertalot (1986).

***Nitzschia cf. frustulum* (Kützing) Grunow**

Hendeby (1964) describes *N. frustulum* as a brackish-water species common in European estuaries, frequent on muddy shores. Navarro (1982) found it to be abundant in all positions (sub-, supra-, and littoral) on Florida mangroves. Foged (1984) and Hagelstein (1938) reported it as a common brackish-water species in the Caribbean.

***Nitzschia granulata* Grunow**

According to Krammer and Lange-Bertalot (1988), this is a cosmopolitan, littoral marine species, common on the "sandwatt" (which translates as a shallow place in sea covered only at high tide, or sandflat). Navarro (1982) described it as rare in his study of Florida mangroves. DeFelice (1975) described *N. granulata* as a sediment dweller in upper Florida Bay, and Hendeby (1964) said it is frequent on sandy shores. It is a common benthic form in the lower Swan River estuary and occasionally is found in the upper estuary (John 1983). Hagelstein (1938) reported it from marine, brackish, and fresh waters in Puerto Rico, although Foged (1984) described it as a polyhalobe.

***Nitzschia af. maxima* Grunow**

Valve lengths range from under 100 μm to several hundred μm ; the ends of the valves are slightly sigmoid. Striae are very fine, and there are 5 large, rectangular keel punctae in 10 μm . This species is common in the Pass Key core 37, and was identified by comparison to Plate 24, Figure 2 in Krammer and Lange-Bertalot (1988); no ecological information could be obtained.

***Nitzschia panduriformis* Gregory**

DeFelice (1975) found this species in the sediment of Florida Bay; it is common on European coasts (Hendey 1964). Foged (1984) listed it as a polyhalobe, and Navarro (1982) reported it only at the higher salinity station in the Florida mangroves, where it was very rare. It was a benthic form in the lower Swan River estuary (John 1983), and was also collected by Hagelstein (1938) in San Juan Bay, Puerto Rico.

***Pleurosigma cf. strigosum* Wm. Smith**

Found in marine and brackish water (Hagelstein 1938, Patrick and Reimer 1966), *P. strigosum* is common on muddy shores (Hendey 1964).

***Rhopalodia musculus* (Kützing) O. Möll.**

Hagelstein (1938) reported this species from both marine and freshwater, and Foged (1984) also described it as euryhaline. DeFelice (1975) found *R. musculus* on sediment and grass in upper Florida Bay. It is possible that some of these valves are really *R. operculata* or *R. gibberula*.

***Surirella fatuosa* (Ehrenberg) Kützing**

A polymorphic marine species (Foged 1984, Goldman *et al.* 1990), *S. fatuosa* is common in Puerto Rico (Hagelstein 1938), the Swan River (John 1983), European coastal waters (Hendey 1964), and Florida Bay (DeFelice 1975). Navarro (1982) reported it only from the higher salinity station in the Florida mangroves.

Unknown #1

This species is centric, and may be a member of the genus *Melosira*, although it was not matched to a species of this genus. To this point it has been seen only in valve view; valves are about 15 μm in diameter, and are composed of an outer, narrow ring and a larger, interior circular area. The valve surface has little ornamentation except for a granular-looking texture that covers the interior area.

