RECENT AND ABRUPT ENVIRONMENTAL CHANGE IN THE FLORIDA EVERGLADES INDICATED FROM SILICEOUS MICROFOSSILS

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Abstract: We used paleoecological methods to infer environmental conditions in Water Conservation Area 2A (WCA-2A) of the Everglades before impoundment in 1961, and we compared pre-impoundment environmental conditions to present conditions. Abundances of siliceous microfossils (diatoms, chrysophyte cysts, sponge gemmoscleres, and plant phytoliths) were analyzed in two sediment cores from nutrient-enriched northern WCA-2A and in two sediment cores from unenriched southern WCA-2A. Nutrient enrichment in northern WCA-2A after 1961 was associated with an increase in relative abundance of eutrophic diatoms. A pH increase in much of WCA-2A after 1961 was indicated by a decrease in relative abundance of acidic indicators (Eunotia diatoms and the sponge Anheteromeyenia ryderi) and a decrease in richness of chrysophyte cysts. An increase in anoxia in nutrient-enriched northern WCA-2A, during about 1961–1980 when high water depth was maintained, was suggested by an increase in visible dissolution of siliceous microfossils. A decrease in palm phytolith abundance after 1961 and lack of recovery after water depth was lowered suggest either that water depth is still maintained high enough to adversely affect vegetation or that there has been insufficient time for recovery. Numbers of sponge gemmoscleres decreased to less than 1% of pre-impoundment numbers, suggesting that there has been a dramatic decrease in sponge abundance. The environmental changes discovered in this study suggest directions for future management of the Everglades.

Key Words: Everglades, paleoecology, eutrophication, pH, water depth, diatoms, chrysophytes, sponges, phytoliths

INTRODUCTION

The Florida Everglades, one of the largest freshwater wetlands in the world, has been modified greatly in recent years. Although limited drainage and agriculture occurred in the Everglades between 1880 and 1950, efforts intensified in the 1950s and early 1960s. Canals draining the Everglades were deepened, and levees were built that impounded the water, creating Water Conservation Areas. Water flow in and out of the Water Conservation Areas is controlled by pumping stations and gates in the levees, disrupting natural hydrologic cycles (Light and Dineen 1994).

The drainage and impoundment projects of the 1950s and early 1960s particularly affected Water Conservation Area 2A (WCA-2A). Agricultural production increased 10-fold, which increased input of agricultural runoff enriched with nutrients (Snyder and Davidson 1994). Although background concentrations of total phosphorus in Everglades water were <10 μg/L, concentrations in northern WCA-2A are now as high as 150 μg/L (McCormick et al. 1996). Input of calcium carbonate also increased due to the erosion of limestone bedrock through which canals were deepened (Gleason and Spackman 1974). Water depth was increased in order to use WCA-2A as a reservoir, but because tree islands were drowned and vegetation characteristic of deep-water sloughs developed, water depth was permanently lowered in 1980 (SFWMD 1992, Light and Dineen 1994).
Unfortunately, systematic monitoring to assess the environmental effects of drainage and impoundment was not emphasized until the 1980s (SFWMD 1992). Therefore, we inferred pre-impoundment environmental conditions by using paleoecological techniques and compared pre-impoundment conditions to present conditions. Diatoms, sponge gemmoscleres, chrysophyte cysts, and plant phytoliths were analyzed in four WCA-2A sediment cores to determine whether changes in nutrient enrichment, pH, and water depth occurred and to examine the effects of these changes on the ecosystem. Diatoms, sponge gemmoscleres, and chrysophyte cysts have been used in paleoecological studies in other ecosystems to infer changes in nutrient enrichment, pH, and water depth (e.g., Harrison et al. 1979, Carney and Sandgren 1983, Smol 1985, Harrison and Warner 1986, Battarbee et al. 1990, Facher and Schmidt 1996, Hall et al. 1997, Gaiser et al. 1998). In addition, plant phytoliths have provided information on vegetation shifts (reviewed in Piperno 1988). Comparison of pre-impoundment environmental conditions to present conditions will help determine effectiveness of current restoration efforts.

MATERIALS AND METHODS

Core Collection and Description

Water Conservation Area 2A (WCA-2A) borders the Everglades Agricultural Area and receives nutrient-enriched agricultural runoff from the Hillsboro Canal (Figure 1). Water and sediments in northern WCA-2A are enriched with nutrients, and as water flows south through WCA-2A, nutrient concentrations decrease (Craft and Richardson 1993, McCormick et al. 1996). Two sediment cores (N1 and S1) were collected in nutrient-enriched northern WCA-2A, and two cores (S1 and S2) were collected in unenriched southern WCA-2A. The cores were collected in deep-water sloughs. Cattail (Typha domingensis Pers.), which invades the Everglades in areas of nutrient enrichment (Wu et al. 1997), surrounded the sloughs at sites N1 and N2, and sawgrass (Cladium jamaicense Crantz) surrounded the sloughs at sites S1 and S2. The cores were collected with a piston corer with a clear tube of 4-cm diameter in February 1995. The cores were sectioned horizontally in increments of 0.5 cm for the first 10 cm (except for core N1, which was sectioned in increments of 0.5 cm for the first 20 cm), and the rest of the cores were sectioned in 1-cm increments. Watery flocculent sediment occurred from 0- to 8-cm depth. Peat soil with rootlets and other pieces of plant material occurred below 8 cm. The amount of water in the cores gradually decreased from 0 to 15 cm. At about 15 cm in each core, the peat soil became noticeably drier and blacker and remained so to the bottom of the cores.

\[ ^{137}\text{Cs} \text{Dating} \]

The portions of core sections not used for siliceous microfossil analysis were analyzed for \(^{137}\text{Cs} \) activity. Some core sections were combined, usually into 2-cm increments, to provide enough sediment to measure \(^{137}\text{Cs} \) activity. After air drying, the sediment was ground with a mortar and pestle. \(^{137}\text{Cs} \) activity was measured for 8 hours by counting gamma emissions at 661.62 kV with a gamma spectrometer with a planar configuration (Canberra Nuclear Instruments, Meriden, Connecticut, USA). The midpoint of the depth increment with the highest \(^{137}\text{Cs} \) activity was assumed to correspond to 1963, the year of highest \(^{137}\text{Cs} \) emissions (Olsson 1986). The sediment surface corresponded to 1995, and remaining dates were estimated by linear interpolation.

Siliceous Microfossil Analysis

To reveal distinguishing characteristics of siliceous microfossils, organic material was digested by heating in concentrated nitric acid and potassium dichromate. A known volume of digested sediment was dried onto a circular cover slip. Cover slips were mounted onto glass slides with Naphrax \(^{\text{R}} \) (Northern Biological Supplies Ltd., 3 Betts Avenue, Martlesham Heath, Ipswich, IP5 7RH, England). Microfossils were counted from the center to the edge of the cover slip to account for uneven distribution. Although the cores were 29- to 50-cm depth, siliceous microfossils were only abundant above 25 cm, so the first 25 cm (after about 1945) were analyzed.

Siliceous microfossils were counted at least every 3 cm in cores N1 and S1. Cores N2 and S2 served as replicate cores to provide additional replicates for statistical analysis. Five core sections were counted in each replicate core. Counting was done with a research quality Nikon microscope (numerical aperture = 1.35) at 1000x. Diatoms were identified to species using the following primary references: Patrick and Reimer (1966, 1967), Foged (1984), Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), and Lange-Bertalot (1993). Images of diatom species, with taxonomical notes, are in Slate (1998). Five hundred diatom valves per core section were counted except when diatom concentrations were very low. Sponge gemmoscleres were identified to species using Penney and Racek (1968), Porrier (1974, 1976, 1977), and Frost (1991). When abundance of sponge gemmoscleres was >100/cm\(^2\), 40 gemmoscleres were counted. Because identifications of chrysophyte cysts have primarily been published for