A biogeochemical analysis of restored and natural mangrove forest substrates, Southwestern, Florida

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INTRODUCTION

Southwestern Florida has the greatest abundance of mangrove forest in the United States. In recent years, much work has been done to preserve these forests and to restore once forested sites to their former state. Historically, little research made use of coherent geochemical trends to determine the functioning of these restoration projects. Moreover, there has been almost no research done concerning the long term growth and development of these mangrove forests.

In southwestern Florida, there exist three species of true mangrove: the red mangrove (*Rhizophoria mangle*), the black mangrove *(Avecennia germinans*), and the white mangrove (*Laguncularia racemosa*). Typically, the red mangroves exist closest to shore, black further back, and white mangroves in the upper swamp (Barbel, 1985). White mangroves are also found in well-exposed patches, often formed by lightning strikes, and in this study, dominate the restoration areas whose adjacent forests are largely red (Jeffery, 1987).

It is possible to gauge the success of a mangrove forest restoration site through analysis of the major elements contained in the underlying substrate. A distinct geochemical difference between natural and restored substrates of various ages is a function of the maturity of the mangroves, addition of fill, and compaction of historic peat. This paper will explore the biogeochemical variations found between these restoration sites and the surrounding mature forest.

LOCATION

Three study sites, located in Collier County, Florida, were chosen for this analysis (Figure 1). The Henderson Creek Restoration Site consists of a mature mangrove forest at least 67 years old, and an adjacent mitigation area of approximately 5 acres. This mitigation site was cleared and filled in 1972, and during restoration some of the dredge spoil was removed down to a 1.4’ NGVD elevation; flushing cuts were emplaced to compensate for the artificial lake dug in the site’s center. This site was restored in two phases, the first completed in December 1991 and the second in January 1992. Both in the first phase and once again at the Phase II site in February 1992, red mangrove seedlings were planted (Staff, 1993; Staff, 1992). Cores were taken in both the old growth and mitigation forests.

The second field site is located at the Winstar Resort, a golf course community located on the eastern shore of Naples Bay. It consists of three separate restoration areas, totaling 15.4 acres, that were restored in August and September of 1982. The mitigation process also involved the removal of fill, exposure of the old peat at a 0.8-1.9' NGVD elevation, and the planting of red mangrove seedlings (Proffitt et. al., 1990; McKee et. al., 1999). Like Henderson, white mangroves now dominate this mitigation area. Cores were taken at one of these restoration sites and at an adjacent old growth forest.

The final field site is adjacent to the Faka Union Canal and consists of an old growth white mangrove forest and a time transgressive, natural white mangrove forest. The more mature forest is about 50 years old while the latter is about 10 years old (Matt Finn, 1999, personal communication). This time trangressive site was once a seagrass community which, through the process of succession, is naturally turning into a mangrove forest (e.g. Dawes, 1998).

METHODS

Field Work

A minimum of two cores were collected at each of the three sampling sites; one at each mature forest and another at the adjacent regrowth forests. Two cores were collected at the Henderson Creek mediation site; because the first core was unable to penetrate the fill layer, a second core was collected in a flushing cut. By using a stake with a 5m long string attached to it, the mangrove forest was characterized by noting the various species, their abundance, and circumference at breast height (CBH).

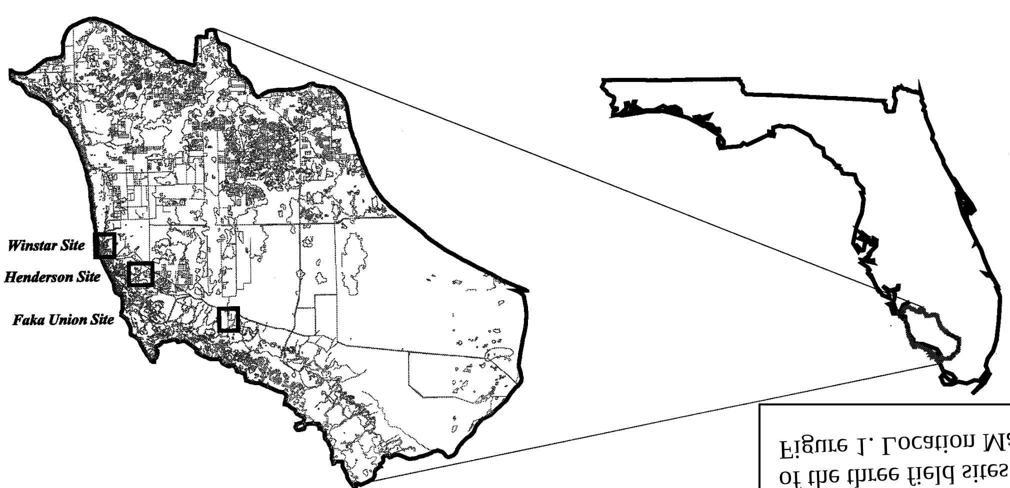

Figure 1. Location Map of the three field sites in Southwestern Florida.

Laboratory Methods

Samples were collected from these cores, every five centimeters, with depth. These samples were subsequently dried and split into 0.5g triplicate samples. Each triplicate was treated with 10mL Aqua Regia solution (100mL HCl, 300mL NaCl and 600mL deionized water), and placed on a shaker table for a minimum of 24hours, to ensure complete digestion. Then, the acid solution was filtered through a .45 μm filter. Samples were diluted and run on an

Ion Chromatograph (IC) for the major base cations: Potassium (K), Magnesium (Mg), and Calcium (Ca) and then on a Flame Atomic Absorption Spectrometer (AA) for Iron. Concentration values were converted for dilution and they were converted into gram per gram units, which is gram of cation per gram of sediment.

GEOCHEMISTRY

Henderson Site

The first organic-rich core, taken from the mature forest located adjacent to Henderson Creek, shows Mg, Ca, and K coherently trending together while Fe does not follow this trend (Figure 2). While the cation levels stayed relatively consistent (ranging from .5144g/g to 3.555g/g), the amount of Fe increased with depth. At 75cm there begins a notably sharp increase in Fe (from 1.041g/g at 65cm to 12.62g/g at 75cm) which continues until the end of the core, at 100cm.

The core taken from on top of the fill shows high amounts of Ca (ranging from 61.32g/g at 2cm to 25.67g/g at 16cm), and elevated Mg within the top 10cm, in comparison to the previous core. The smallest amounts of all four elements are found in the bottom 2cm of the core. This bottom (from 11-16cm) consists of extremely hard, dense fill material which was made up of shell fragments and hard, grey carbonate clasts of up to 3cm in diameter. This fill layer was impenetrable by both our coring tube and the surrounding mangrove prop roots, physically observed as distortion within the roots themselves and with trees twisted and bent over. Similarly, the core collected in the flushing cut, which also shows elevated levels of Ca in the first 25cm of the core, contained mussels (between 0-12cm) and a shelly, sandy spoil mixture between 12 and 19cm. As in the first core, K, Mg, and Ca trend down together from 30cm to the end of the core, at 80cm. The compacted organic rich sediment (from 19-60cm) is both dense and abundant in dead roots and linearly compacted burrows. The bottom 60-80cm is very sandy with lessening quantities of roots and elevated levels of Fe.

Winstar Site

The first core, taken in the mature forest, has K, Mg, and Ca trending similarly with depth, particularly from 20cm down to the core bottom, at 100cm. At 15cm there is an elevated amount of both Fe and Ca, which occurs directly above a silty sediment layer (18 to 28cm). The core segment, from 28-75cm, is black, organic rich, contains living roots, and has cation values ranging from 5.204g/g to .5595g/g. In contrast to this, the bottom 25cm of core is also primarily organic matter, with some sandy mottling and all cation values ranging in tenths of a g/g.

As with the Henderson restoration cores, the Winstar Restoration core has elevated levels of Ca (up to 40.63g/g) and Fe for the first 45 cm. The following 47-100cm of dense, highly compacted organic rich sediment contains very little Fe, and similarly trending K, Mg, and Ca. There is very little K and Mg (in the tenths of g/g's) between 4 and 42cm, a sandy section of core with thin shelly layers of about 1mm thickness. The highest levels of Fe and Ca occur between 42 and 47cm, an area consisting of thinly alternating laminations of white, grey and black silty mud.

Faka Union Site

The core taken from the older white mangrove forest has a very dark, reddish black organic rich parent material for the first 50cm of substrate. There are also high and greatly varying amounts of K, Mg, Ca, and Fe. At 50cm the substrate becomes a mottled mixture of sand and organics, and root abundance decreases with depth. Directly above this boundary (at ~40-45cm), K, Mg, Ca and Fe sharply increase and then decline to tenths of a g/g. It is not until below 80cm that abundance of Fe elevates and a sharp peak of Ca occurs.

Appearing similar to the middle of the aforementioned core (between 50 and 80 cm), the Transgressive Forest substrate contains very little and remarkably similar amounts of Fe, K, Ca, Mg.

DISCUSSION

The most apparent variations in cation behavior is dependent primarily on the parent material. There is an obvious correlation between the abundance of these elements and the type of substrate present. The increased iron, particularly at the bottom of the two of the Henderson cores and the Mature Faka Union core, may indicate a heavy metal sink, which is common in mangrove forests. The iron is indicative of higher sorpitive capacity for organics and possibly heavy metal concentrations as well (Ramanathan, 1997, Piascik et al., 1997).

The levels of Mg, K, and Ca all generally follow one another with depth in the cores. The only exceptions are the elevated Ca levels when shells or other forms of carbonates are present in the parent material. In both the Henderson and Winstar Restoration, cores have both high amounts of Ca and shelly materials present, as seen in Figure 2. In all three natural cores there are lower amounts of these three cations present, but the restoration cores have high amounts of Ca, and increased cation levels in the compacted organic rich substrate, under the fill. This may be a function of the mangrove plants' inability to penetrate the fill and absorb these cations or perhaps is a reflection of the compaction of the substrate.

Aside from the obvious physical evidence that mangrove roots are unable to penetrate the compacted and fill sediments, this biogeochemical analysis serves to further illustrate the differences between natural and restored mangrove forests. While the major chemical difference between these two depends primarily on the variations in parent material, the importance of this should not be overlooked. Mangrove plants in the restoration sites have different cation availabilities than do those in mature forests, although this may, in part, be attributed to their relative youth.

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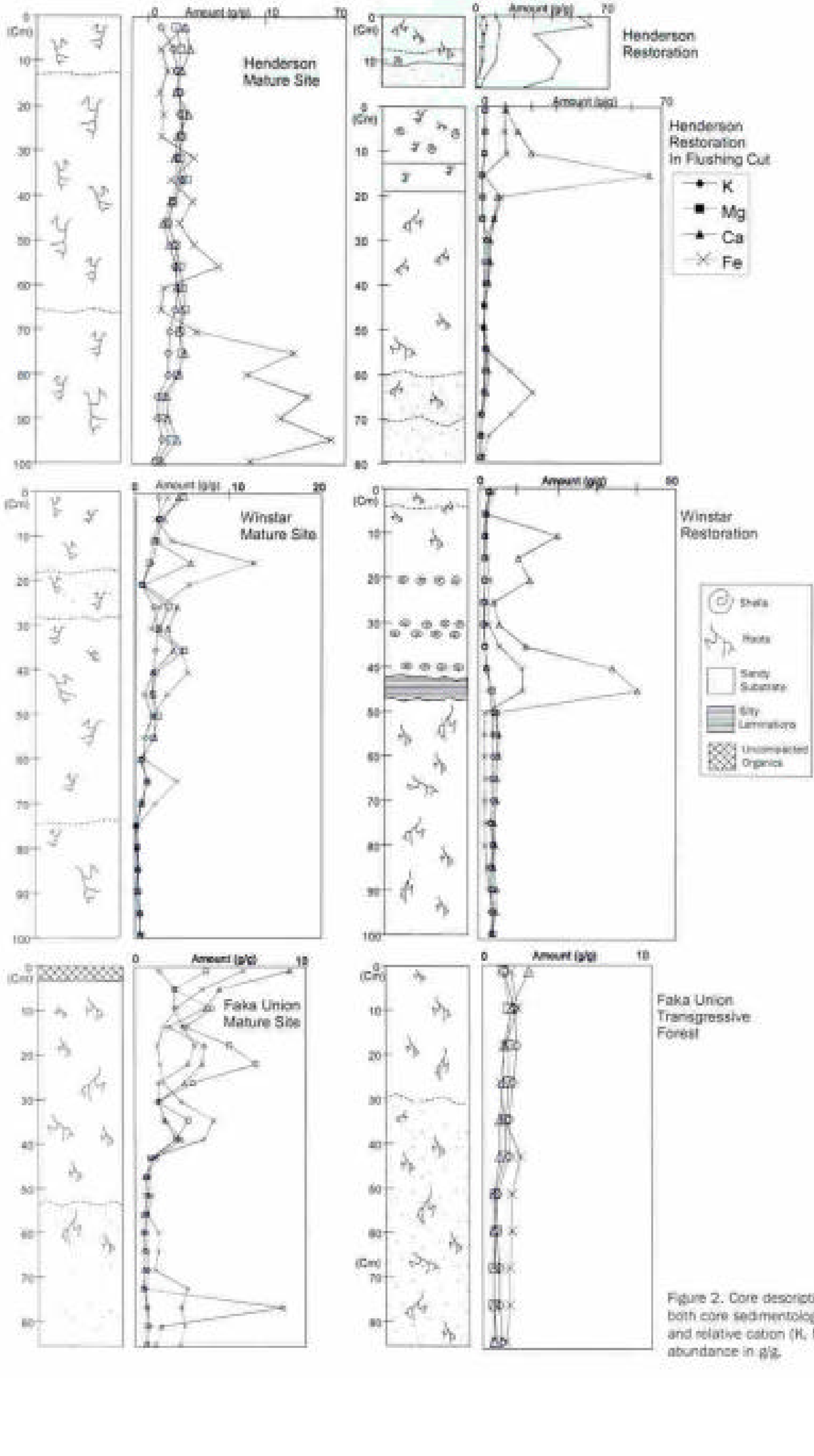

Figure 2. Core descriptions depicting both core sedimentology and morphology and relative cation (K, Mg, Ca, Fe) abundance in g/g.