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Cover photograph – "Little Ricky" - juvenile dolphin, San Salvador, Bahamas (courtesy of Sandra Voegeli, 2003)

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# THE GROWTH RATE OF THE RED MANGROVE (*RHIZOPHORA MANGLE*), N ANDROS ISLAND BAHAMAS.

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## ABSTRACT

For many years texts on the accretion of sediments, and ultimately island expansion in the carbonate environment of the Bahamas Platform, have cited the importance of the red mangroves (*Rhizophora mangle*) as a sediment trapping agent. Little has been done to investigate the speed at which individual plants affect this process. The growth rate of the red mangrove was investigated in three different locations and environments to look for variations and patterns that could be applied to other carbonate islands of the Bahamian Platform. The study sites were located on "Henderson's Island," Saddleback Cay, and a bay north of Forfar Field Station on Andros Island, Bahamas.

Tiffany Albertson began the project in 1994-1998, it was continued in 1999 by Brandy Wallace, and in 2001/2002 and 2003 by Amber Whipp. Some of the original trees in the Albertson Stage were "lost." Some have been relocated and included in the subsequent efforts. One hundred and one trees are being monitored. Fifty one new sites were added this field season. Mangroves have been selected from land and leeward environments (those mentioned most frequently as areas of island accretion). Young as well as established trees are included. The measurements include height, prop root system perimeter, and number and length of new prop roots. The data revealed variation in growth rates from 0-tens cm growth per year of individual prop roots and effected prop root circumferences exceeding meters per year.

## INTRODUCTION

*Rhizophora mangle* is an important component of island accretion, which is in turn, important to the growth of the calcium carbonate islands. The red mangrove grows in tidal areas and mangrove swamps ranging from Western Africa to the Pacific side of Central America. Tiffany Albertson began studying *Rhizophora mangle* in 1994 and this project is a continuation of her study in the hopes of obtaining more data in order to accurately pick out the trends and variations of the growth rates. The goal is to figure out the speed at which the trees trap sediment, how the filtration fan created by the roots is related to prop root perimeter, and what factors affect the growth of the trees in each location and environment.

The red mangrove belongs to family Rhizophoraceae and reproduces viviparously. The seedlings, called propagules begin growing up to 30 centimeters while still on the tree and eventually drop off and float to another location. They can float for up to a year and an end up miles away from the parent tree (Egler, 1948). A study was done on the establishment and growth of the seedlings by Frank E. Egler (1948) and it was noted that the hypocotyls were curved when the propagule started to root. It was also mentioned that it can take as few as two days for rooting to occur and the propagule will be pulled upright. It will continue to grow until a strong storm comes through. This is significant because Hurricane Michelle came through the Bahamas and hit the Androsian study areas in November, 2001. Storms that strong can destroy trees that are just starting out a new community (Egler, 1948).

Once the tree is upright, it goes through a nonbranching phase followed be a branching phase. The canopy branches in a tiered fashion according to Attim's architectural model, however, the canopy can develop differently depending on the environmental factors influencing the tree, or if the tree gets damaged (Ellison & Farnsworth, 1996).

The prop roots of the red mangrove are aerial roots that loop above the substrate and anchor to it at the end of each loop. They can grow from the main stem or a lower branch from the canopy and new roots can grow a millimeter a day until they reach the substrate (Ellison & Farnsworth, 1996). New roots grow when an injury to the apex occurs. The prop roots are necessary because the sediment is anaerobic and the tree must somehow obtain gas exchange. The prop roots become very dense and intertwine in thickets of mangroves and they slow down water and sediment flow through the filtration fan formed. According to a study by A.P. Spenceley (1987), in Victoria Australia, the sediment in mangrove swamps has a layer that is bound by the roots as well as a layer of loose sediment. Low energy conditions can result in deposition and high-energy conditions can still result in erosion. The mangroves may affect sedimentation, but the local sedimentation also seems to affect the mangroves.

A study was done that showed some other factors that influence the growth of mangroves. The effects of hormones, light and salinity on the growth rates of mangroves were investigated (Smith, Yang, Kamiya, and Snedaker, 1996). It was deduced that lower salinity resulted in enhanced root and shoot growth. The trees in the study were grown in three different salinity treatments that included 0%, 3.5%, and 7%. The trees in the 0% salinity treatment showed more rapid root and shoot growth. Although *R. mangle* lives in salt-water conditions, it does not use the salt. It is a salt excluder, but some salt still enters, this is excreted through the surface of a leaf (Tomlinson, 1986).

Water level change is another factor that was shown to influence the growth *of R. mangle.* An experiment was done by Ellison and Farnsworth (1997) that included growing trees under different water level conditions in a greenhouse to see how sea level changes due to potential global warming could affect the growth of *R. mangle.* Trees were grown under current conditions, and under a 16 cm decrease and a 16 cm increase in sea level. The trees grown under current conditions were larger. The other two were shorter and narrower.

Another factor that influences the growth of *R. mangle* is the association of certain fauna with the prop roots. Two important ones are the boring isopod, *Sphaeroma peruvianum*, and encrusting barnacles of the *Balonus* species. A study was done in Costa Rica (Perry, 1988) in which prop roots of *R. mangle* were tagged and monitored for isopods and barnacles. The barnacles were shown to cause a 30% decrease in root growth (lateral) and a 52% decrease in net root production when 75% of the tree is covered. The isopods caused an even bigger reduction in root growth and production because they bore into the root tips where growth occurs. These interactions are significant to the Andros study because many mangroves from each study site were encrusted with large amounts of barnacles.

Another creature, *Littoraria*, a gastropod, is common on the red mangrove but it is not documented to have an effect on the growth. It grazes on the leaves and it is mentioned here because it was also observed in the field.

## MATERIALS AND METHODS

The study was conducted from Forfar Field Station (International Field Studies) located on Andros Island, Bahamas near Stafford Creek. This year's field season ran from Jan. 3 – Jan. 11, 2003. The study site includes three areas in order to observe variety and patterns. The areas are Saddleback Cay, a small island off the northeast side of Andros, Henderson's island (walking distance from Forfar during low tide), and a bay on the north side of Forfar. Saddleback contained *R. mangle* on the shores of two sides, the leeward and the South side, both were sampled.

A hand held GPS was used to obtain accurate locations for each tree and data sheets were made prior to the trip. Separate data sheets were assigned to each tree as in past years. The main trunks of the trees were tagged with yellow plastic cow tags from TSC farm supply and they were held on by clear plastic zip ties. The new trees were tagged with orange cow tags and they are designated O-1 through O-50. The zip ties were loosely placed around the trunk to prevent damage from the tree outgrowing the zip tie. No damage from rubbing caused by earlier tagging has been noted. Prop roots on some trees were marked with neon zip ties in order to keep track of them. This method should make it easier to locate the study trees. The colored zip ties used by Albertson and later by Wallace (1999, 2000) faded and some became obscure. Many of the trees not found in the Wallace study were found in the 2002 study, but there were not many additional trees found from the Wallace study during this year's field season.

The trees were all photo documented with a digital camera and placed on file on a CD (see figure 1 for some photos). The tree number was written along with photo orientation, on a small wipe off board that was placed in front of the tree for the picture. This was repeated for every tree. The photos were taken in order to photo document the growth, help match new data to the previous data, and to help locate trees again in the future. A variety of young trees were chosen in each study area in order to observe the patterns of growth from no prop roots or a low amount. It will allow the prop root development patterns in each area to be compared annually.

The measurements that were taken include height (from the ground to the highest point on the tree), diameter around the prop root system of each individual tree, length and number of new prop roots. The prop roots were considered to be new if they had not yet anchored to the substrate. Prop roots that appeared damaged and not anchored to the substrate were also not included. They were left out of the perimeter measurements. The water level at high tide on Saddleback Cay was not measured during this study. The condition of the trees was noted if they were in poor condition. Fifty and 100-foot fiberglass tape measures were used to obtain the measurements.

Data collection began on January 3, 2003 on Henderson's Island. Data collection continued on Henderson's each morning or afternoon during low tide when the sand bar was exposed. Eighteen new trees were added to study at the Henderson's site. There were previously nineteen trees, of which 11 were in Albertson and Wallace's original studies.

The first set of Saddleback trees were measured on January 7, 2003 and the rest were measured on January 9. Nineteen trees were added to the nineteen from 2001/2002 study. Five of the trees from last year were in Albertson and Wallace's studies. The trees in the bay next to Forfar were measured on January 6 and January 10, 2003. Nineteen new trees were also added to the study from the Forfar site. There were eight trees included last year. See the results section for the complete tables of data form each site.

The next step included compiling the measurements from the data sheets with the data from previous years. The data was recorded into an excel spreadsheet with each site being designated a sheet. A prop root perimeter comparison graph was made that included the new trees. A height comparison graph was also made (see figure 2 for graphs). The rest of the graphs from 2001/2002 were updated. The graphs included Henderson's trees 12, 15, 20, 25, 26, 27, 29, and Saddleback tree 6.

## RESULTS AND DISCUSSION

The data revealed a large amount of variation in the growth patterns and physical characteristics of *R. mangle* between the study sites and even within each site. The eight graphs of individual tree prop root perimeters that were updated from last year differed drastically, but some of the trees followed their individual trends. Tree 15 decreased as it has been since 1998 and tree 20 slightly increased and followed its trend (see figure 3). Tree 12 increased since last year but it had decreased in the previous years of the project. Tree 25 did not have any perimeter growth since last year. Tree 29 had a decrease in growth and its growth has been up and down throughout the project. Tree 26 had a big decrease since last year, but it had been growing a larger perimeter from 1997 to last year.. Data was not charted due to human error for tree 6 on Saddleback. Decreases in growth can be due to burial of prop roots by sand, death, or breakage of prop roots

Of the eight trees, three had a decrease in perimeter growth, three increased, one had no data, and one did not change. Of the trees that had an increase in perimeter growth, 12 and 20 are larger than all but 29, and 27 is further on the island and sheltered behind some of the other trees. The large perimeters of 12 and 20 and the location of 27 could account for the increase.

Tree 29, one of the trees that had a decrease in perimeter growth is located by the shoreline across from Henderson's Island and it does not have any other large mangroves near it. There were some small saplings growing near it. The isolation could have left it open to damage. Tree 26 was near tree 27, but it had a big decrease. The decrease could have been do to the death of one of the large prop roots. Tree 25 had most of its prop roots in the crevices of the rock, which may help keep them anchored and make it difficult for new prop roots to get a good start. That could be the reason why it did not have any growth.

The overall perimeter growth of the mangroves on each island changed slightly. Last year, Saddleback had three trees with very large perimeters. Henderson's had one tree that had a perimeter that was about as large, but most of the perimeters were smaller compared to Saddleback. In the 2003 study, Henderson's had more trees with large perimeters. Some of the trees from last year grew new prop roots that made them have a larger perimeter. Tree nineteen had eleven new prop roots and its perimeter increased by almost meters. Tree 20 gained one new prop root and its perimeter increased by one and a half meters. Both of those trees are low to the ground with large canopies and long prop roots.

The amounts of barnacle coverage also differed like last year. Although a vast number of differences were discovered, there were also some similarities, such as the amount of prop root production and the number of saplings in the three sites. Some trees in each area also confirmed to the ideal Attim's model. The large number of trees included in the study also showed that there could be an ideal or common height. *Rhizophora mangle* can grow up to two feet in the first year (Greenberg, 2000). The graph of the tree heights shows that many of the trees are near that height (2 ft = 0.61 m). Many of the trees range from 0.61 meters to a little over a meter.

It is not certain whether the heights change from sediment buildup of growth of the tree. An example of a height change due to sediment occurred on January 7. The winds were strong out of the Northeast and blew water in when tide was supposed to be out. Tree 13 on Henderson's Island was buried in sediment on January 8. The height of the tree changed from 2'5" to 1'8" indicating an accumulation of 7 inches of sediment in that area. The trees appeared to have been acting as filtration fans for the large amounts of sediment that were blown in.

There were more saplings at each site. Two of the saplings from last year were deceased this year. One was Forfar tree 38, which was located almost up against another mangrove. It still had a trunk left but no leaves. The other tree, 37, could have out-competed it. The other tree that was deceased was Henderson's tree 40. It was completely missing. It was out away from the other trees last year and it had its trunk completely encrusted with barnacles.

The trees that were included in all three study areas were in a variety of shapes, sizes, and ages. The addition of 51 new trees gave a better sample size. The trees on Henderson's that were covered up with more water during high tide had longer prop roots and were taller than the trees closer to dry land and on rock in most cases. A good example is a comparison between trees # 12 and # 19. Tree 12 is located further out on the sandbar and it has a larger canopy, longer prop roots, and is taller than tree 19. Tree 19 is located further in near the rock and it is low to the ground with short prop roots and a large canopy. That trend was not as apparent in the other two study sites. The trees in the rock on Henderson's do not have as extensive prop root systems.

The Forfar site contained a variety of ages of trees from saplings to older trees offshore on rocks with massive prop root systems. The Forfar site also contained a variety of saplings and young trees that were up high on shore and underneath the White mangrove branches in the shade. A number of those were included in this study in order to observe how the shade and other plants in the vicinity effect there growth.

The Saddleback trees differed immensely from the leeward side of the island to the trees just around the corner (see figure 1, a & b). The back contained trees that were sparse and some were taller than a person. The large size could be due to the low energy conditions of the back of the island. The sparseness could be due to the same thing because low energy waters may keep propagules from being carried to the back of the island as easily as the other sides. The tallest tree was the furthest out from shore, but it was still on the rocky area of the shoreline. The trees around the corner were more abundant and grew much further out into the sandbar. There were many young trees and saplings growing close to the shoreline. There were dense thickets of mangroves further in shore and the sediment was loose and soft there. Many of the trees that were located further out were growing on rock. Tree 13 and tree 8 both appeared to be unhealthy; they didn't have many leaves and what was left appeared wilted.

## CONCLUSION

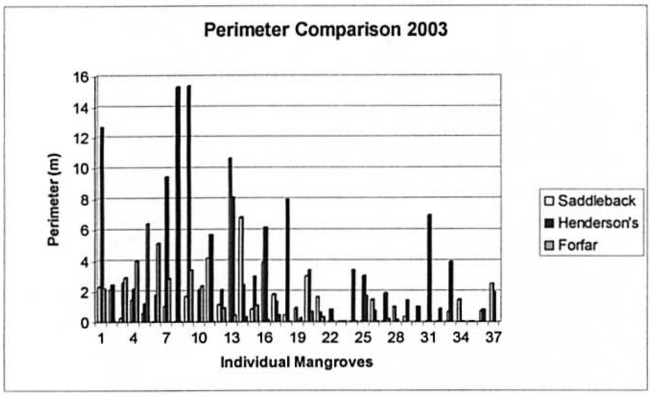
The continuation of the *Rhizophora mangle* growth rate project revealed more about the patterns of growth of the trees. An ideal height was seen because of the larger sample size, and a change in overall perimeter growth could be seen. *Rhizophora mangle* did pretty much conform to Attim's model although there was much diversity The new trees that were added to the study could reveal much more if the project is continued. The project will be continued next year in order to obtain another set of data for each tree. Each tree needs about four or more sets of data so that graphs can be made of all of them. Trends may become more obvious with a larger set of graphs.

The sedimentation rates also have to be monitored, perhaps by placing a rod into the ground at each site in certain areas and marking the sediment level during each data collection day. This may help figure out if tree height changes are caused by sedimentation buildup. It also might be helpful to test salinity since that also affects the growth of the trees. The rate at which the trees trap sediment and its relationship to perimeter need to be determined. It is the goal of the study to include as many trees from the three study areas and obtain as many sets of data for them as time permits.

*Figure 1. a. tree 3, Saddleback, 2002 (leeward side). This and the following photos illustrate the variation between the trees.*

*Figure 1. b. Tree 11, Saddleback, 2003 (South side)*

*Figure 1. c. Tree 20, Hendersons, 2003*



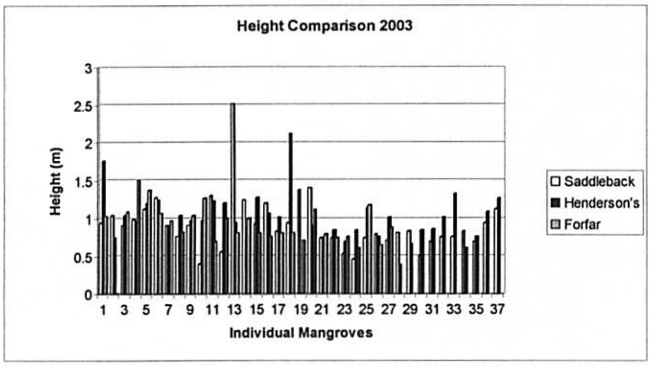


*Figure 2. Perimeter and height comparison graphs for all of the trees.*

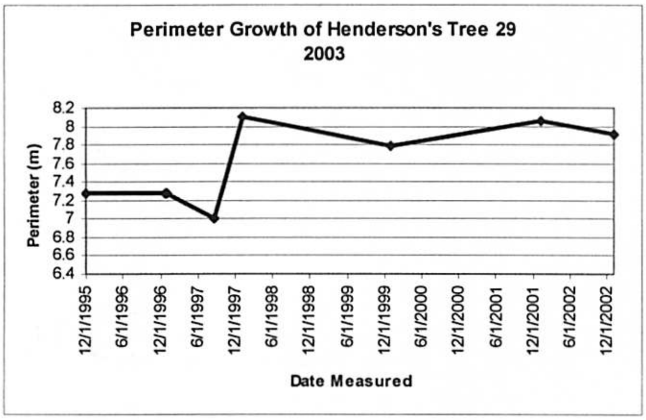


*Figure 3. c. a prop root perimeter growth chart for tree 20, Hendersons, 2003*

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