PROCEEDINGS

OF THE

ELEVENTH SYMPOSIUM

ON THE

NATURAL HISTORY OF THE BAHAMAS

Edited by
Beverly J. Rathcke
and
William K. Hayes

Conference Organizer
Vincent J. Voegeli

Gerace Research Center, Ltd.
San Salvador, Bahamas
2007

Cover photograph – Courtesy of Sandra Voegeli

Printed at the Gerace Research Center.

ISBN 0-935909-81-8

DISTRIBUTION OF THE BRAZILIAN PEPPER TREE (*SCHINUS TEREBINTHIFOLIUS* RADDI, ANACARDIACEAE) ON SAN SALVADOR ISLAND, BAHAMAS

Jonathan A. Slusher[1] and R. Laurence Davis
Department of Biology and Environmental Science, University of New Haven, 300 Boston Post Road, West Haven, Connecticut 06516 USA

Lee B. Kass
L. H. Bailey Hortorium, Department of Plant Biology 228 Plant Science Building, Cornell University, Ithaca, New York 14853 USA

[1]*Current address: 23 Warwickshire Dr., Killingworth, Connecticut 06419 USA*

ABSTRACT

This study considers the location and condition of the Brazilian Pepper Tree (*Schinus terebinthifolius* Raddi, Anacardiaceae), an introduced invasive species, on San Salvador Island, Bahamas. Five sites were examined and environmental data were recorded, including depth to bedrock, proximity to wetlands, soil moisture, as well as soil nutrient concentrations. In addition, at one of these sites, tree positions were recorded using global positioning and heights and diameters were recorded. These data were also recorded in areas currently without Brazilian Peppers in order to assess factors limiting to tree growth and distribution and to identify areas that might be at risk for invasion. Results show that, at present, invasive growth of the trees is limited to areas with at least seasonal freshwater and disturbance. Soil moisture and proximity to wetlands are statistically significant limiting factors in tree growth and distribution. As large tracts of the island have yet to be explored, the tree may also be present elsewhere. A Brazilian Pepper Tree GIS geodatabase has been created to store current records and help future investigators who might wish to track the tree's spread on the island.

INTRODUCTION

Native biodiversity, agriculture, and human infrastructure are highly sensitive to invasive exotic species. The total costs of controlling all non-indigenous species of plants, animals, and microorganisms causing damage in the United States has been estimated at over $138 billion dollars per year (BEST, 2003:12). Invasive plants are a particular problem in Florida. The Florida Exotic Pest Plant Council (FLEPPC, 1999) concluded that 31% of the state's plant species outside of cultivation were non-natives. The council's 2003 "plant pests" included 123 species, 67 of which were designated as Category 1 plants, "species that are invading and disrupting native plant communities in Florida."

The Brazilian Pepper Tree ("Pepper Tree"; *Schinus terebinthifoius* Raddi, Anacardiaceae), also called "Christmas-berry Tree", is one of these Category 1 species. A native of South America, the tree was intentionally brought in 1926 to Punta Gorda on Florida's west coast by plant enthusiast, Dr. George Stone, for use as an ornamental (Morton, 1978).

By 1969, biologists at Everglades National Park noticed that the plant was spreading at an alarming rate and determined that it had the potential to destroy many natural areas throughout the southern portion of the state (Morton, 1978). The tree is currently the most widespread exotic plant in the state, covering more than 400,000 ha in central and southern Florida (Ferriter, 1997).

Although its presence on San Salvador Island has been known for some time, the overall extent of Pepper Tree spread has not been examined pre-

viously. This study identifies some of the localities invaded by the Pepper Tree and attempts to define the factors that limit its growth on the island. The proximity and climactic similarities of the island to Florida suggest that extensive invasive growth poses a serious problem. However, the lack of well-developed soils, extensive karstification, inland saline lakes, and other environmental considerations on San Salvador may ameliorate some of the threat.

BACKGROUND

The Brazilian Pepper Tree.

The Brazilian Pepper Tree, a relative of Poison Wood (*Metopium toxiferum* (L.) Krug & Urb Anacardiaceae; see Kass, 2005:134), has been referred to by a variety of names in the past, including *Schinus mucronulata* Mart., and *Schinus antiarthriticus* Mart. (due to a supposed anti-arthritic effect from its resin; Ferriter, 1997). Like Poison Wood (and close cousins: Poison Ivy, Poison Oak, and Poison Sumac), direct contact with Pepper Tree's sap can cause severe and persistent skin irritation (Morton, 1978).

The tree is an evergreen that is 3-7 m tall. In its native environment, Pepper Tree is found from sea level to elevations of over 700 m (Ferriter, 1997).

The tree has alternate compound leaves (Figure 1). In the winter months, female trees have pea-sized red fruit, which remain for up to eight months (Ewel *et al.*, 1982; Figure 2). Birds and other animals disperse the seeds. The success of the Pepper Tree in south Florida can possibly be attributed to its fruits being one of the few winter fruit available (Ewel *et al.*, 1982; Ewel, 1986).

Pepper Tree has a shallow root system. Root suckers can produce new individuals. Tree seedlings are shade tolerant over a wide range of growing conditions, and reproduce quickly (Ewel, 1979). It thrives in disturbed soils created by human activities and hurricanes. It quickly invades abandoned farmlands, roadsides, and canal banks (Ewel, 1986).

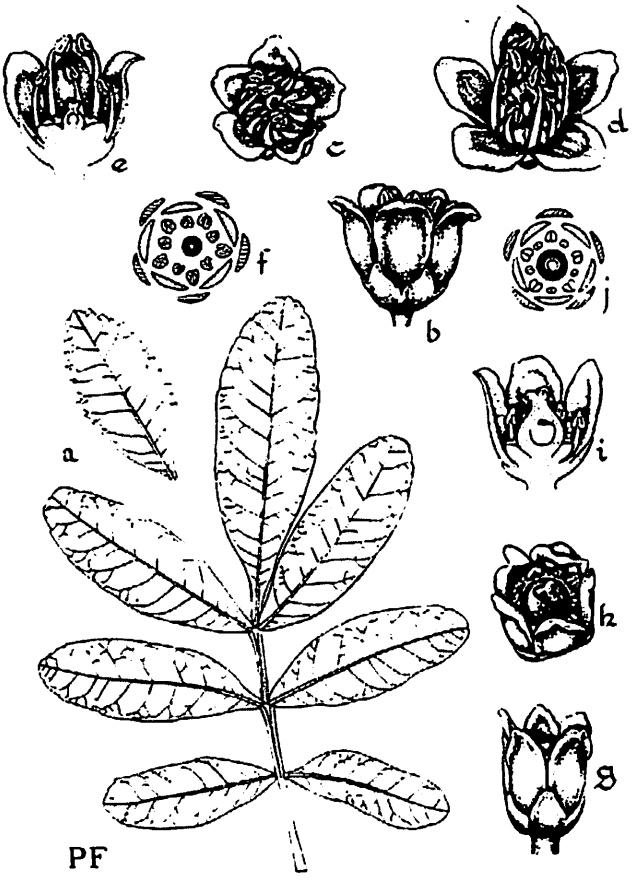

Figure 1. Schinus terebinthifolius *leaf and flowers.* **a.** *Leaf outline; toothed leaflet above;* **b-f.** *male flower:* **b.** *from the side,* **c.** *from above, early stage,* **d.** *from above, late stage,* **e.** *in longitudinal section,* **f.** *floral diagram;* **g-i.** *female flower:* **g.** *from the side,* **h.** *from above,* **i.** *in longitudinal section;* **j.** *floral diagram (used with permission, Tomlinson, 1980; note that this illustration of a Florida specimen is also used in Correll & Correll, 1982:855; see Kass & Miller, 2006).*

In some locations, this tree has not only threatened to out-compete native plants, but it has also been harmful to other organisms. Curnutt (1989) found that avian species diversity was lower in Pepper Tree stands in Florida than in the native pinelands that the Pepper Trees replaced.

In the United States, the Pepper Tree is also found in Louisiana, Texas, California, and Hawaii. However, besides Florida, Hawaii is the only other state in which the tree is an aggressive colonizer. In Southern California, it is still used in ornamental plantings (Ferriter, 1997).

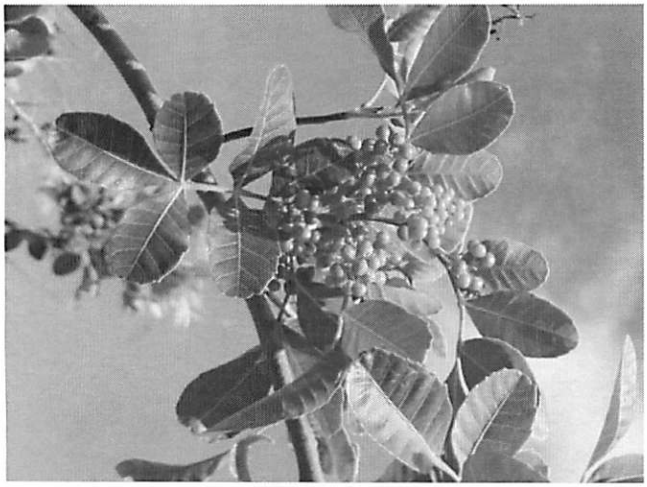

*Figure 2. Brazilian Pepper Tree (*Schinus terebinthifolius*) with bright red fruits (about 6 mm in diameter), North Victoria Hill (Figure 7).*

Nilson & Muller (1980) attribute its non-aggressive growth in California to the short time period there when soil moisture is sufficient for germination and root establishment. Other factors may also influence patterns of success and mortality of Pepper Tree seedlings (Ferriter, 1997). The Pepper Tree does not become established in deep water wetlands communities and rarely grows on sites inundated longer than three to six months. In Everglades National Park, it is absent from marshes and prairies with hydroperiods exceeding six months as well as from tree islands with closed canopies (LaRosa *et al.*, 1992). Seed germination of transplanted seedlings did not succeed at salinities >5 ppt (Mytinger & Williamson, 1987). This lack of salinity tolerance excludes the tree from invasive growth in mangrove-dominated ecosystems.

Despite being a pest in many areas, the tree is still cultivated in some places. The dried fruits of the Pepper Tree are used as a spice and sold in the United States as "pink peppercorn" (Ferriter, 1997). It is valued as an important nectar and pollen source by the bee industry in Hawaii (Yoshioka & Marken, 1991). In parts of South America (where it is native), the plant is considered a tonic and astringent (Uphof, 1968).

San Salvador Island, Bahamas

San Salvador is the easternmost Bahamian island, located approximately 640 km east-southeast of Miami, Florida. It has a surface area of 94.9 km^2, one third of which is of saline inland lakes. Annual rainfall averages about 1200 mm. There are distinct rainy (June-December) and dry (January-May) seasons. Similar to the neighboring islands, San Salvador has beautiful white sand beaches and stunningly clear sea water. Despite a picture postcard-worthy setting, the island's remote location and lack of freshwater have kept it largely undeveloped.

Christopher Columbus is believed to have made his first landfall on San Salvador. The island's landscape, wildlife, and human populations have undergone many changes since 1492 (Gillis, 1970), although the greatest impacts did not come until the American Revolution. Americans who remained loyal to Britain were forced to emigrate and many ended up in the Bahamas. Beginning in 1783, they built extensive farming estates and operated them using African slaves. They cleared the native Mahogany forest to make room for agriculture and livestock. Soon, however, the nutrient-poor soils were exhausted and most of the loyalists departed, leaving the island to the former slaves. Farming does continue today on small slash-and-burn garden plots (Meyer *et al.*, 2003).

San Salvador Soils and Native Plant Communities

There are three distinct soil groups on San Salvador. Sandy soils dominate the coastal areas. Rich, black loam is found in crevices and pockets in the limestone bedrock. Finally, pineapple loam, a red-orange colored soil, is the most fertile on the island. Smith (1993) names Pineapple loam as the preferred soil for farming.

Location, topography, and soil type are the main factors determining where the majority of native and naturalized species grow on San Salvador. Moisture and exposure are secondary (Correll, 1979). These factors combine to yield seven plant communities in the Bahamas: Coastal Rock, Sand Strand and Uniola, Coastal Coppice, Fresh-

water Formations, Whiteland, Mangrove, and Blackland (Correll, 1979). Using these categories, Smith (1993) prepared a plant community map for San Salvador (Figure 3).

Of Smith's seven communities, only two, the Freshwater Formation and the Blacklands Community, could support Pepper Trees. Smith provided descriptions of these as follows.

The Freshwater Formation Community is divided into Palmetto Flat and Typha Marshlands Subcommunities. Water levels fluctuate both seasonally and yearly, and salinities vary. The soil is sandy with varying amounts of organic matter. The presence of the Sabal Palm (*Sabal palmetto* (Walt.) Lodd. Ex Roem. Schulte. f., Arecaceae; Kass, 2005:116) in the Palmetto Flat areas (Figure 4) differentiates it from the Typha Marshland Subcommunity. Recent (2004) harvesting of Sabal Palms has led to a high degree of disturbance in many of these areas.

The Blacklands Community is the most extensive on the island. The soil is either red (Pineapple loam; see Figure 5) or a dark fertile loam. The area is characterized by dense vegetation and a lack of dominant species. Smith identifies four Subcommunities: Agricultural, Coppice, Thicket, and Sinkhole. The Agricultural Subcommunity consists of re-growth within abandoned or rotating slash-and-burn garden plot areas. The Coppice zone supports dense and diverse vegetation, including many varieties of ferns. Thicket areas exist in locations which have thin soils and exposed bedrock. The pesky Haulback (*Mimosa bahamensis* Benth., Leguminosae; Kass, 2005:96) is prevalent here. Sinkholes, referred to locally as "banana holes," often contain a thick layer of soil, which has accumulated as eroded soil. Many sinkholes are really large depressions and may seasonally contain a meter or more of freshwater and support large trees, including Sabal Palms (Gentry & Davis, 2006).

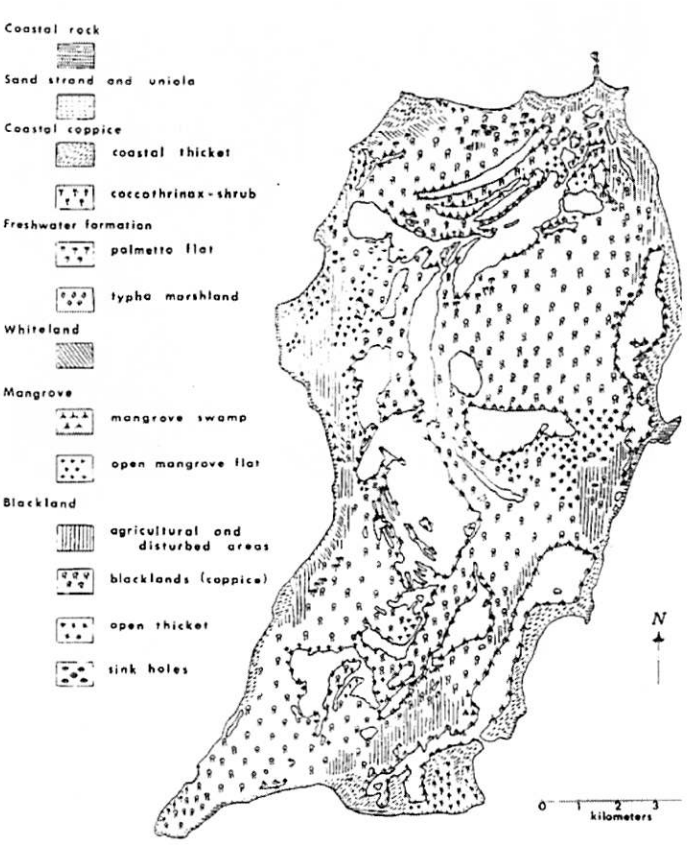

Figure 3. Plant communities of San Salvador Island, Bahamas (Smith, 1993).

Figure 4. Palmetto Flats, Freshwater Wetlands, near Montreal Settlement, San Salvador Island, Bahamas (see Figure 6 for location).

Figure 5. Pineapple loam at soil sample location nvh8, near North Victoria Hill Wetland.

The Brazilian Pepper Tree on San Salvador

The Pepper Tree was first planted on San Salvador sometime in the late 1960's or early 1970's as an ornamental at the old campus of the Pan American Teachers College, now the Club Med (D. Gerace & K. Gerace, pers. comm., 2004). Smith (1982:51,76) included it as an ornamental in his first list of the island's cultivated plants; and Correll & Correll (1982) also included it in their region 5 (San Salvador and Rum Cay). Over the years, the authors have found it in many other places on the island. Where it is found, it usually occurs in dense stands. The apparent spread of the Pepper Tree since its first planting was the impetus for this paper.

STUDY AREA AND METHODS

After an extensive search of the island and discussions with other researchers, we located major stands of Pepper Trees in four areas for further study: North Victoria Hill, Duck Pond, Airstrip Wetlands, and Cockburn Town (Figure 6). In addition, a few individuals were seen near the airport in roadside patches. The North Victoria Hill Wetlands, Duck Pond, and Airport areas are freshwater wetlands. The Cockburn Town stand and the roadside patches are in disturbed areas.

Field research took place during January and April 2004. Of the seven plant communities found on the island, Pepper Tree had only been found previously (RLD) in the Freshwater Formation areas. We (JAS, RLD) first searched the island for these types of environments based on advice received from island inhabitants as well as other researchers familiar with the island's interior. During much of the year it is easy to spot the trees with their bright red berries from a far distance (Figure 2). Unfortunately, these berries were frequently not present during our springtime visits and we quickly learned to identify the tree by the widespread branches and aforementioned seven-leaf pattern.

We used a high-accuracy global positioning system (GPS) unit to collect spatial data (in the Universal Trans Mercator, UTM, Zone 18, North American Datum 27 coordinate system), including tree locations and data collection positions. Tree data included all individuals >1 m tall. Due to the Pepper Tree's low height and dense growth, tree diameter was measured 5-10 cm above ground level. In doing our surveys, each individual tree that we examined was flagged and numbered with a marking pen.

Data were obtained on 260 individual trees at four sites. At North Victoria Hill (Figure 6), 182 trees were examined. At the Airport Wetlands, five isolated trees were also sampled and recorded. Due to the huge number of trees here and elsewhere (Figure 7) at the study sites, data were collected by random sampling. These included 64 additional trees at the Airport Wetlands and 9 trees at Duck Pond.

Soil samples were collected at seven locations with Pepper Trees (Figure 8) and seven locations with no Pepper Trees. Soil samples were tested for Nitrate Nitrogen (kg/hectare), Phosphorous (kg/hectare), Ammonia Nitrogen, Nitrite Nitrogen (parts/million), Humus, and Potassium (parts/hectare), within 1-2 days using a Hach® soil testing lab kit.

To investigate soil depth influences on the tree, depth to bedrock (cm) was measured. Soil moisture values were obtained using a soil

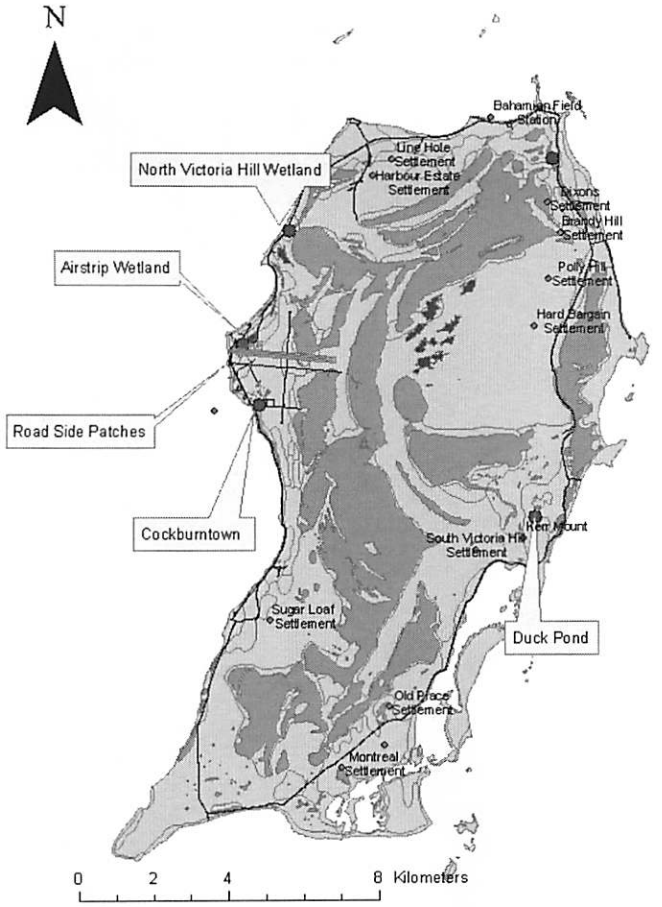

Figure 6. Study sites for Brazilian Pepper Trees on San Salvador Island, Bahamas (after Robinson & Davis, 1999).

moisture sensor. Gypsum soil sensors were placed 6 cm below the surface at each sampling location, left in place for two days, and available soil moisture was recorded during morning hours using a soil moisture meter. All data were placed onto digital maps from the San Salvador Island GIS Database (Robinson & Davis, 1999). This database includes information on topography and natural, physical, geologic, biological, and cultural features.

We used our data to compare tree locations with landscape features, such as soil type, as well as proximity to freshwater wetlands, roads, and disturbed areas.

Figure 7. Dense patch of Brazilian Pepper Tree near sampling location nvh5, North Victoria Hill, San Salvador Island, Bahamas.

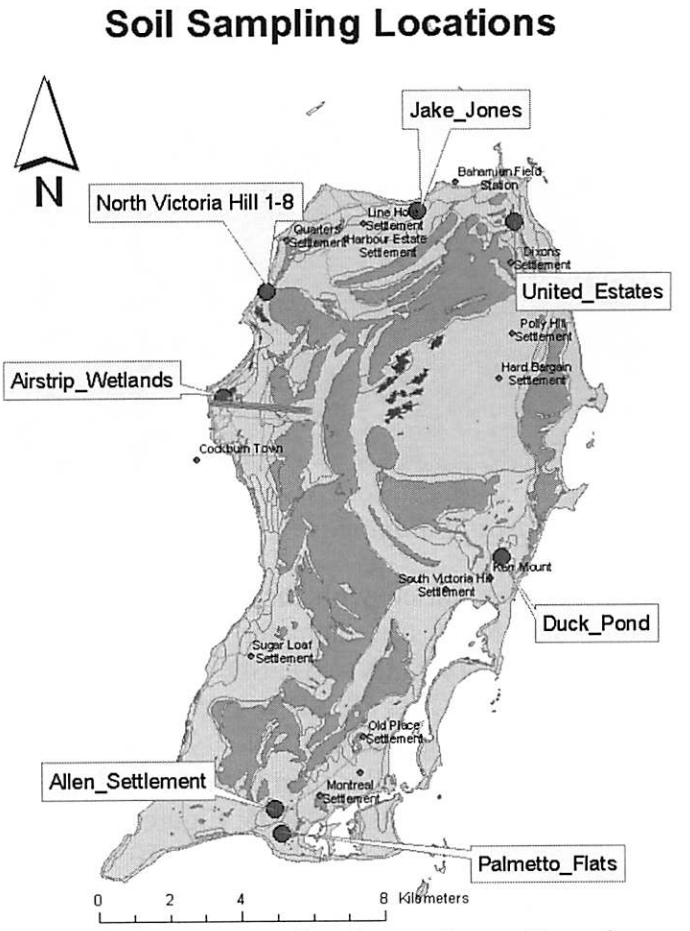

Figure 8. Locations of soil samples collected on San Salvador Island, Bahamas.

RESULTS

North Victoria Hill Wetlands

The North Victoria Hill Wetlands (nvh) are bordered by both abandoned and in-use garden plots (Figure 9). The soil type here is an orange Pineapple loam (Figure 5). One hundred and eighty-two trees were sampled. Mean tree diameter (Figure 11) was 22.7 cm, with individuals ranging from 2-143 cm. The mean tree height (Figure 10) was 2.79 m, with a range from 1-6 m.

Of the 182 trees sampled at the North Victoria Hill Wetlands, 17% were located within 10 m of the edge of the wetlands area, 45% were within 20 m, and 95% were within 30 m (Figure 7). No trees were found more than 40 m from the wetland (Figures 10 and 11).

Figure 9. Garden plot, North Victoria Hill, San Salvador Island, Bahamas.

Tree size varied with distance from the wetland edge. Mean tree diameter was 28.5 cm at a distance of 0-10 m (N = 31, SD = 18.2) and 30.0 cm at 10-20 m (N = 50, SD = 23.5). The 15.6 cm mean diameter at 20-30 m (N = 91, SD = 15.7) was statistically smaller than both the 0-10 m and 10-20 m range (t-tests, $P \leq 0.05$; Figure 12).

Mean tree height was 2.9 m at 0-10 m, 3.1 m at 10-20 m, and 2.5 m at 20-30 m from the wetlands edge (Figure 13). There was no statistically significant difference in size between the 0-10 m

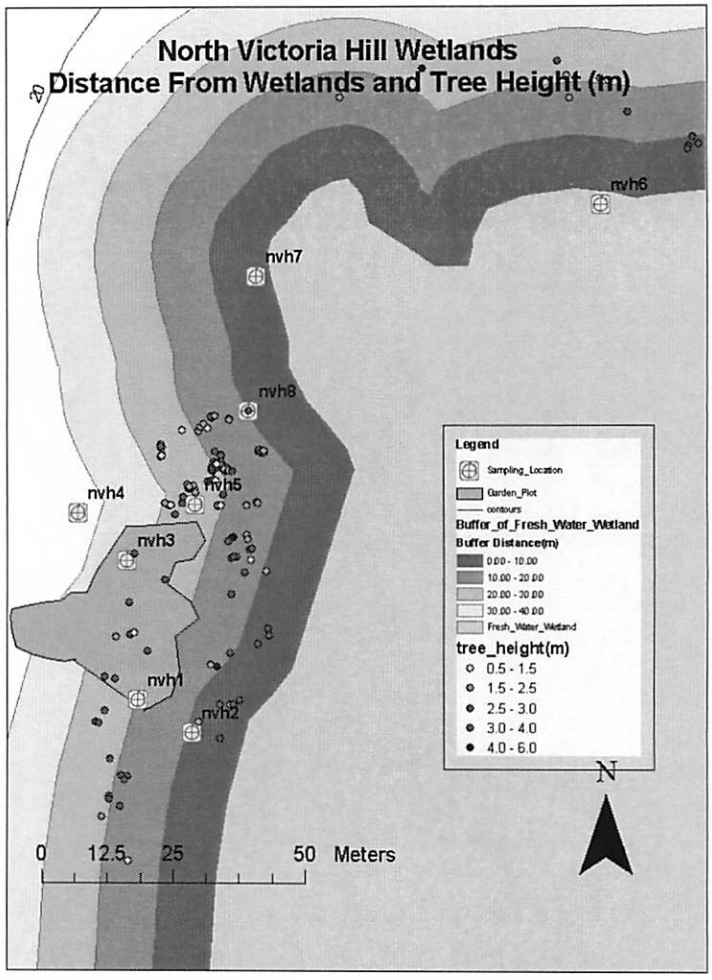

Figure 10. Digital nap of North Victoria Hill (nvh) Wetlands, San Salvador Island, Bahamas, including all 182 trees sampled there, arranged by tree height (m). Tree heights ranged from 1-6 m, with a 2.79 m average. Tree sizes varied with distance from wetlands edge.

and 10-20 m trees. However, mean tree height in the 20-30 m range was statistically smaller than both the 0-10 m and 10-20 m range trees (t-tests, $P \leq 0.05$).

Percent available soil moisture at the eight North Victoria Hill Wetlands locations (Figure 14) varied from 67.1-98.1%. Two localities had <71.5% soil moisture readings. No trees were found within 8 m of these low-moisture areas (Figure 14). Location nvh6 had a moisture content of 98.1%, yet had only one tree within a 5 m radius. This is likely due to its location within the seasonally-inundated wetlands border. We did not include location nvh6 in our later analyses.

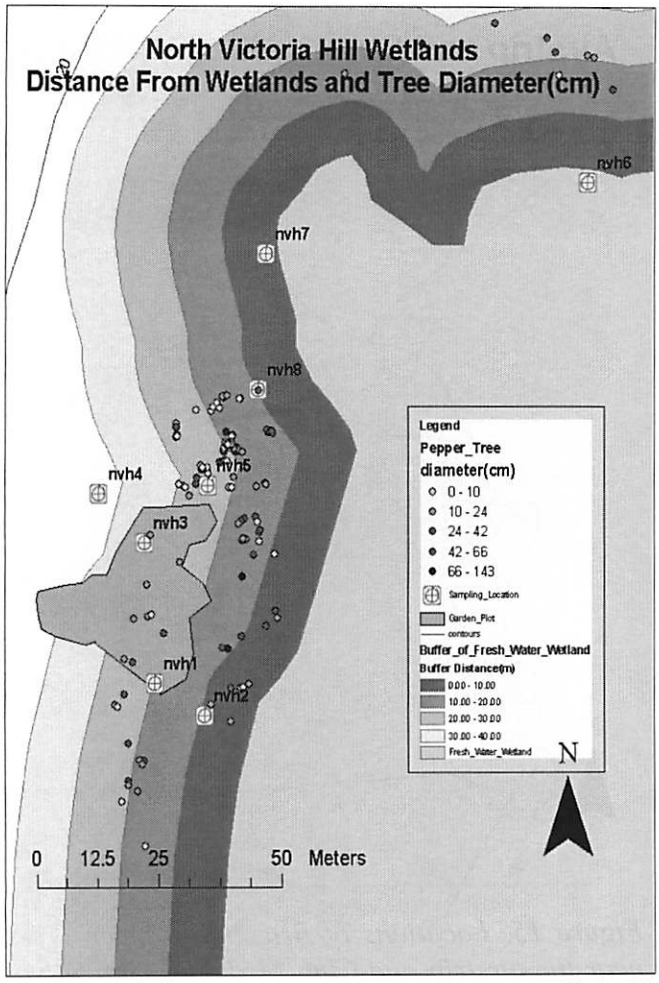

Figure 11. Digital map of North Victoria Hill (nvh) Wetlands, San Salvador Island, Bahamas, including all 182 trees sampled, arranged by tree diameter (cm). Tree diameters ranged from 2-143 cm with an average of 22.7 cm, measured 10-20 cm from ground level. Tree diameters were smaller moving away from the wetlands edge.

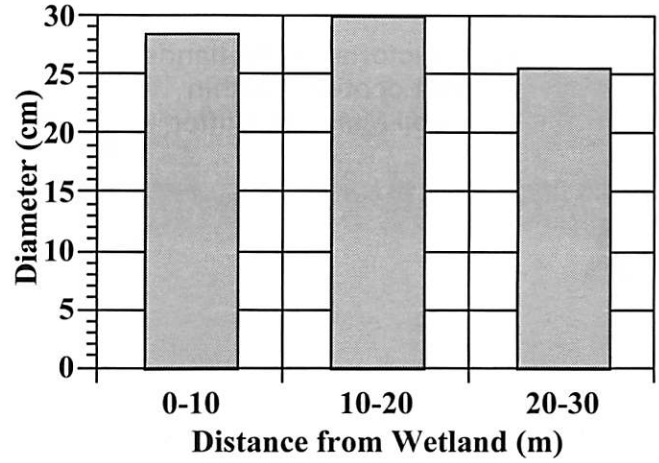

Figure 12. Variation in mean tree diameter at categorized distances from wetlands border within the North Victoria Hill Wetlands, San Salvador Island, Bahamas.

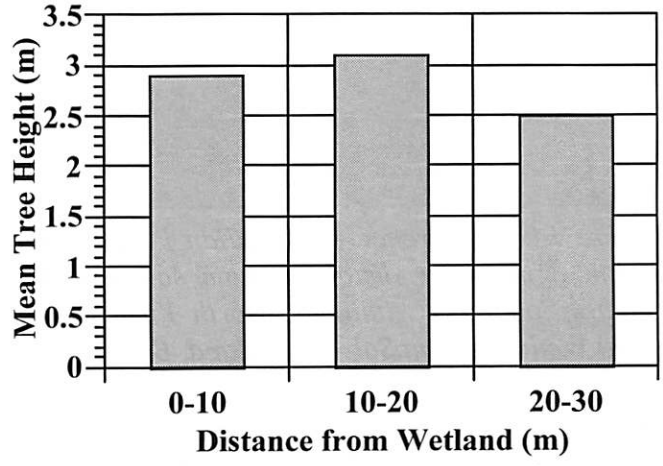

Figure 13. Variation in mean tree height at categorized distances from wetlands border within the North Victoria Hill Wetlands, San Salvador Island, Bahamas.

Regression analysis was used to correlate the number of trees within 8 m of each soil moisture sampling location with the soil moisture values ($R^2 = 0.304$). The R-squared value for this correlation increased to 0.519 when not including location nvh6 (compare Figures 14, 10, 11), which had a very dense cluster of very small trees, possibly due to root suckering.

Soil Nutrient concentrations for Potassium (non-recordable), Nitrite Nitrogen (<1%), and Ammonium Nitrogen (very low) did not vary amongst the eight soil sampling locations. Nitrate Nitrogen was 2.8 kg/ha at locations nvh2 and nvh4 and 1.8 kg/ha elsewhere. The highest Phosphorous concentrations were at sampling locations nvh3 and nvh4 (4.6 kg/ha); all other locations were 1.8 kg/ha. Humus values were "very low" at every location except nvh3 (low).

Airport Wetlands

According to the local "legend" (Gerace, pers. comm.., 2004), the Pepper Tree first appeared on the island at the site currently occupied by Club Med. This was formerly the site of the

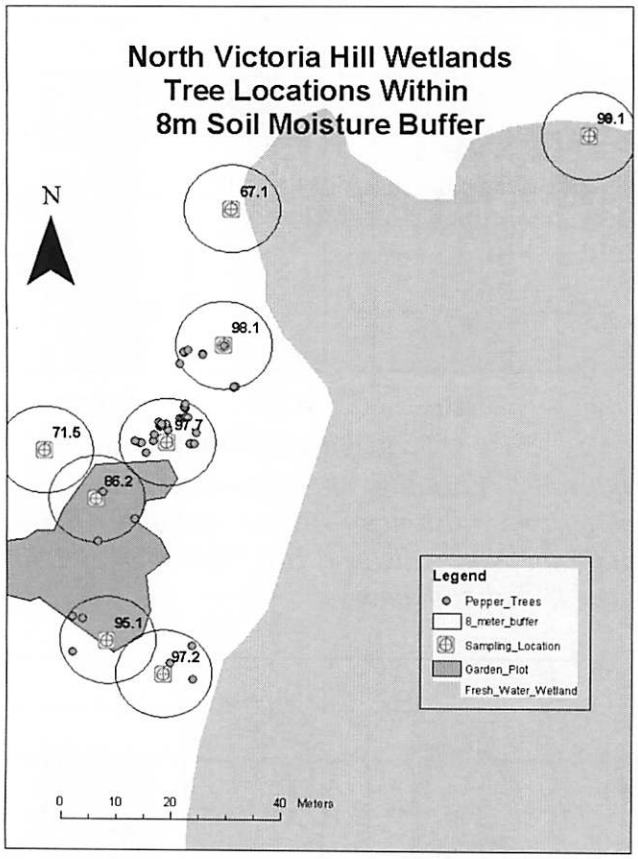

Figure 14. Occurrence of Brazilian Pepper Tree within 8 m buffer distances from soil moisture reading locations within the North Victoria Hill (nvh) Wetlands, San Salvador Island, Bahamas.

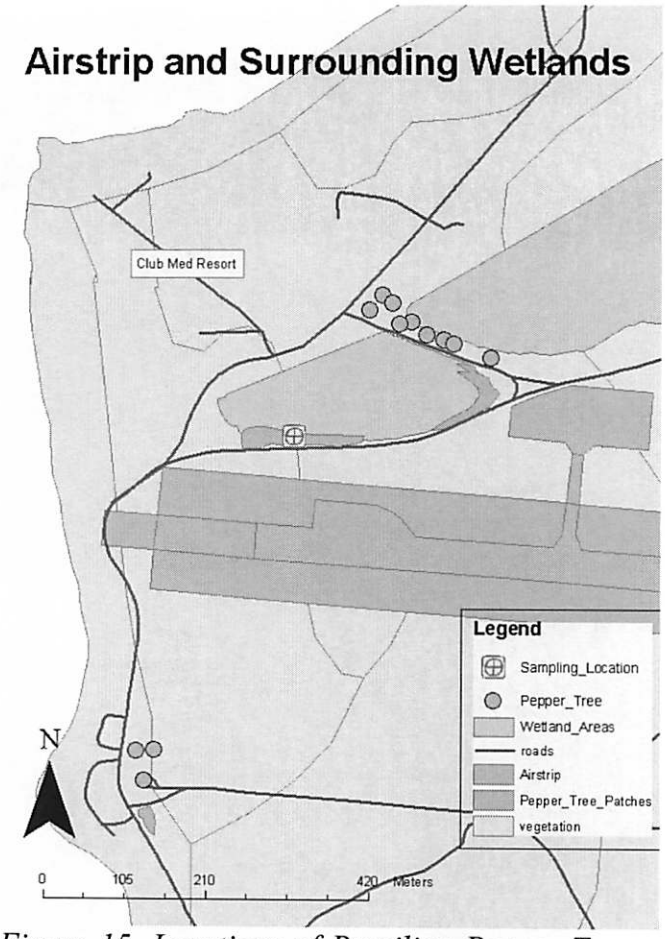

Figure 15. Locations of Brazilian Pepper Trees near the airstrip and Club Med sites, San Salvador Island, Bahamas. Two large, dense, monoclonal patches were present on the edge of the wetlands, north of the airstrip, within a disturbed sandy limestone soil. The largest trees found on the island were located along the causeway between Club Med and the airstrip.

island high school. Not surprisingly, the largest Pepper Trees were across the road from Club Med, along the causeway leading to the airstrip (Figure 15).

In addition, two large (approximately 5,250 and 4,650 m^2), dense, monoclonal patches of Pepper Tree were located across the road from Club Med, on the southern and western sides of the wetland bordering the Airport. The soil was disturbed limestone sand with very little organic material (Figure 16).

Tree sizes were fairly uniform in this area. The tall straight trunks, lack of low branches, and the condition of soil here suggest that the trees invaded an open area created by human activity (Figure 16). In a meter square, randomly-sampled area, 64 trees were found ranging in height from 2-4.5 m and diameter from 4-10 cm. Mean tree height (3.6 m) here was almost 1 m more than trees in the North Victoria Hill Wetlands (2.8 m). However, mean tree diameter (6 cm) was much smaller than the 22.7 cm at North Victoria Hill.

Duck Pond

Duck Pond is an undisturbed wetland located well within the island's eastern interior (Figure 6). Before April 2004, the presence of Pepper Tree was not previously documented on this side of San Salvador.

The trees were growing densely (for example, nine individuals in one 4 x 4 m area) on the south

Figure 16. Dense Monoclonal Tree Patch, Airport Wetlands, San Salvador Island, Bahamas.

side of the wetlands area up through existing vegetation. The soil here was high in organic content and had the highest Phosphorous concentrations (9.2 kg/ha) of all 14 locations sampled on the island.

The trees were very tall, with a mean height of 5.4 m within a 4 x 4 m randomly-sampled area. The trees ranged in height from 4-7 m. Mean tree diameter was 15.8 cm with a range in size of 11-21 cm.

Cockburn Town and Roadside Patches

The Pepper Trees located along the roadsides and in the neighborhoods of Cockburn Town (Figure 6) were not included in our detailed studies. Since most of these trees were located on private property, they were observed but no data were collected. The large trees found in the yards and roadsides throughout Cockburn Town appeared to benefit from road and roof rainfall runoff. We found no evidence of current tree cultivation by island residents.

During a field trip to Jake Jones Road (Figure 8), with the participants of the 11th Symposium on the Natural History of the Bahamas (June 2005), Ethan Fried, University of Florida, Beverly Rathcke, University of Michigan, and Lee Kass came upon a young Pepper Tree growing alongside a wet area on this road. They pulled up the plant, which was not in flower or fruit, and used it as a living demonstration with the symposium poster presentation of this paper. Many of the poster-session participants commented that the living specimen helped them to recognize the plant and they would make note of it as they traveled around the island.

ANALYSIS AND CONCLUSIONS

Based on previous studies and the data presented here, it seems that the Pepper Tree can survive in soils with very low fertility on San Salvador. Soil moisture and proximity to wetlands were the only limiting factors contributing to tree growth and distribution. This limitation was most evident in the North Victoria Hill Wetlands, where tree height and diameter had a statistically significant reduction moving away from the wetlands edge.

Soil concentrations of Nitrate Nitrogen, Phosphorous, Ammonia Nitrogen, Nitrite Nitrogen, Potassium, and Humus had no detectable effect on tree size or individual distribution. Depth to bedrock in the areas sampled varied greatly over short distances and it was often difficult to differentiate between subsurface unconsolidated material and bedrock. Depth to bedrock data may still prove very useful in determining Pepper Tree size and distribution. Studies by Kass *et al.* (1993) indicate that soil salinity may play a part in distribution of Mangroves on San Salvador. In future studies, we plan to measure soil salinity for possible effect on growth and distribution of Pepper Tree.

Within the North Victoria Hill Wetlands area, all trees in the 66-143 cm diameter category were located in the 10-20 m distance-from-wetland buffer area. This finding suggests that, within the 0-10 m zone, the trees are being limited by periods of inundation or excessive soil moisture. An assessment of the area at various times during the season is needed to confirm this.

Although dense monoclonal patches of Pepper Tree exist, such as the two large areas bordering the Airport Wetlands, the overall GIS mapping

indicated that larger diameter trees have a less dense distribution (Figure 11). Despite the inability to obtain tree ring age data, this pattern suggests that tree patch density becomes less with competitive growth.

Overall, due to the island's lack of well-developed soil, extensive saline inland water bodies, mangrove-dominated areas, undulating relic dune topography, and limited freshwater, the Pepper Tree has been limited to a less-invasive growth pattern on San Salvador than the staggering growth currently in southern Florida.

However, the tree appears to be an aggressive invader in certain portions of the island. These areas include abandoned or rotating garden plots and other disturbed areas, especially those within freshwater wetland borders. This invasive growth is very evident in the airport wetlands area. The small population of Pepper Trees noted in 1992 by Moyroud (2000) has spread into two large, dense, monoclonal patches with a combined area of almost 10,000 m^2 (Figures 15 and 16).

The tree's ability to thrive in very low fertility soils and also establish itself in the largely undisturbed freshwater area around Duck Pond (Figure 6) is important in determining the risk of further plant invasion. These factors indicate that even the most pristine and remote freshwater wetland borders on the island are at risk to Pepper Tree establishment.

The vegetation on San Salvador remains very different from its pre-colonial agricultural era. With the soil severely eroded, it remains to be seen where and to what extent large hardwoods such as the native Mahogany (*Swietenia mahagoni* (L.) Jacq., Meliaceae) can persist. In the very long term, it is possible in many of the areas where Pepper Tree is well established that the tree will be out competed by larger and hopefully more-native hardwoods species when the area is left undisturbed.

The 2004 hurricane season was very severe on San Salvador. The amount of damage to the island's remote natural areas may not be known for many years. Hurricane disturbance could be a large factor in creating new areas for the Pepper Tree to establish itself. For example, on Jake Jones Road, a newly established plant was observed by Kass in June 2005. With future additions to the newly created Pepper Tree Geodatabase, this is another factor which would be interesting to explore further.

The tree is very likely present in large abundance in other yet-to-be-discovered parts of the island. Any region having a reasonable amount of moist soil with low salinity should be subjected to further investigation.

The Commonwealth of the Bahamas has taken a proactive position on eradicating pest species. His Excellency, Keod M. Smith, Ambassador for the Environment, points out in *The National Invasive Species Strategy for the Bahamas* (BEST, 2003:5) that, "Island states like the Bahamas are...highly susceptible to invasion because of their particularly vulnerable native biodiversity and predominantly import driven economies."

In an effort to preserve the country's biodiversity and economic infrastructure, the BEST Commission (2003:17) recommended five plant species for eradication: Suckering Australian Pine (*Casuarina glauca* Sieber, Casuarinaceae), Melaleuca [*Melaleuca quinquenervia* (Cav.) S. T. Blake, Myrtaceae], Monkey Tamarind [*Mucuna purien* (L.) DC., Leguminosae], Hawaiian Seagrape [*Scaevola taccada* (now *S. sericea* Vahl), Goodineaceae; Eshbaugh & Wilson, 1986], and the Pepper Tree. Of these, only the Pepper Tree had been known from San Salvador until 1992, when Hawaiian Seagrape was planted as an ornamental in Cockburn Town (Kass, 2005:108), which unfortunately now has the potential to displace our native Inkberry (*Scaevola plumieri* (L.) Vahl; Kass, 2005:108).

One organism directly affected by recommended-for-eradication species is the San Salvador Rock Iguana (*Cyclura rileyi rileyi*). A subspecies of more common Rock Iguanas, they currently have a population of less than one thousand individuals and are found nowhere else in the world outside of San Salvador Island, Bahamas (Balduff *et al.*, 2005:1). Rock Iguanas subsist on native plants and use loose sand for nesting sites. During a March 1992 field expedition, the International Iguana Society observed the extensive root systems of Australian Pine trees interfering with Rock Iguana reproduction (Moyroud, 2000).

The Pepper Tree also may interfere with Rock Iguana nesting sites (Moyroud, 2000). Moyroud (2000) noted that "Near the airport on San Salvador Island, one small population of fruiting *S. terebinthifolius* was observed in June of 1994; it may still be possible to eradicate this species...before the populations expand to unmanageable dimensions."

San Salvador researchers Lee Kass and Beverly Rathcke (pers. comm., February 2004) noted one plant, approximately 1.5 m, growing along the causeway at Fresh Lake in 1993.

We plan to compile a Global Information Systems (GIS) Geodatabase for the invasive Brazilian Pepper Tree on San Salvador. This can be used for reference, and may be expanded by incorporating future research data.

Using the data from our study, future tree growth or decline rates could be examined by comparing the recorded tree sizes and locations from this study with newer data.

ACKNOWLEGEMENTS

We thank Dr. Donald T. Gerace, Chief Executive Officer, and Vincent Voegeli, Executive Director of the Gerace Research Center, San Salvador, Bahamas, and their Staff for logistical support for this study; and the Bahamas Department of Agriculture for permits to conduct research in the Bahamas. JAS offers sincere thanks to: Christiane and Sophie Slusher for their support and patience; Professor Beverly Rathcke for suggesting this project; Professor Don and Kathy Gerace for helpful discussions; Professor Jonathan Winter, Owen Zimmerman, Roman Zajac, Steve Citron-Pousty and Cara Gentry for their contributions; and sincerest thanks to the people of San Salvador for their hospitality and genuine kindness. LBK acknowledges the Faculty and Staff of the L. H. Bailey Hortorium, Department of Plant Biology, Cornell University, and GRC Executive Director Voegeli for logistical support and travel funds to present this work at the Bahamas Symposium. JAS and RLD acknowledge the financial support of the University of New Haven.

REFERENCES

Balduff, N., W. K. Hayes, R. L. Carter, and J. Johnson. 2005. Social and spatial relationships, mating tactics, and mating system of the endangered Bahamian Rock Iguana, *Cyclura rileyi.* Pg.1 *in The 11th Symposium on the Natural History of the Bahamas, Abstracts and Program,* June 23-27, 2005. Gerace Research Center, San Salvador, Bahamas.

BEST Commission. 2003. *The National Invasive Species Strategy for The Bahamas.* BEST, Nassau, The Bahamas, 517 pp.

Correll, D. S. 1979. The Bahama Archipelago and its plant communities. Taxon 28:35-40.

Correll, D. S., and H. B. Correll. 1982. *Flora of the Bahama Archipelago.* J. Cramer, Vaduz. Koenigstein, Germany, 1692 pp.

Curnutt, J. L. 1989. Breeding bird use of a mature stand of Brazilian pepper. Fl. Ornithol. Soc. 17:53-76.

Eshbaugh, W. H., and T. K. Wilson. 1986. *Scaevola sericea* (Goodinaceae) in the Bahamas. Pp. 79-83 *in* Smith, R. R., ed., *Proceedings of the 1st Symposium on the Botany of the Bahamas, 1985.* College Center of the Finger Lakes, Bahamian Field Station, San Salvador, Bahamas.

Ewel, J. J. 1979. Ecology of *Schinus.* Pp. 7-21 *in* Workman, R., ed., *Schinus—Technical Proceedings of Techniques for Control of Schinus in South Florida: A Workshop for Natural Area Managers.* The Sanibel-Captiva Conservation Foundation, Inc., Sanibel, Florida, U.S.A.

Ewel, J. J., D. S. Ojima, D. A. Karl, and W. F. DeBusk. 1982. Schinus *in Successional Ecosystems of Everglades National Park.* South Florida Research Center Report T-676. Everglades National Park, Florida, 141 pp.

Ewel, J. J., 1986. Invasibility: lessons from South Florida. Pp. 214-230 *in* Mooney, H. A., and J. A. Drake, eds., *Ecology of Biological Invasions of North America and Hawaii.* Springer-Verlag, New York, U.S.A.

Ferriter, A. 1997. *Brazilian Pepper Management Plan for Florida, A report from the Brazilian Pepper Task Force.* Florida Exotic Pest Plant Council. City of Sanibel, Natural Resources Department, Sanibel, Florida, U.S.A.

FLEPPC. 1999. Florida Exotic Plant Council's 1999 List of Florida's Most Invasive Species. Data available at: http://www.fleppc.org/ (Accessed February 2005).

Gentry, C. L., and R. L. Davis. 2006. Geomorphological and hydrological controls on fresh water wetlands, San Salvador Island, Bahamas. *In* Davis, R. L., and D. W. Gamble, eds., *Proceedings of the 12th Symposium on the Geology of the Bahamas.* Gerace Research Center, San Salvador, Bahamas.

Gillis, W. T. 1970. Isle of Columbus. Fairchild Tropical Garden Bulletin 25(4):5-7.

Kass, L. B. 2005. *An Illustrated Guide to Common Plants of San Salvador Island, Bahamas*, 2nd edition. Gerace Research Center, San Salvador, Bahamas, 148 pp.

Kass, L., and I. Miller. 2006. A new look at illustrations for Flora of the Bahama Archipelago. The Bahamas Naturalist and Journal of Science. 1(1):37-41.

Kass, L. B., L. J. Stephens, and J. D. Carter. 1993. Continued studies of mangrove ecosystems on San Salvador Island, Bahamas. Pp. 50-56, *in* Kass, L., ed., *Proceedings of the 5th Symposium on the Natural History of the Bahamas,* 1993. Bahamian Field Station, San Salvador, Bahamas.

LaRosa, A. M., R. F. Doren, and L. Gunderson. 1992. Alien plant management in the Everglades National Park: an historical perspective. Pp. 47-63 *in* Stone, C. P., C. W. Smith, and J. T. Tunison, eds., *Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research.* University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu, Hawaii, U.S.A.

Meyer, J. R., J. D. Keith, and L. J. Stephens. 2003. Determination of nutrient concentration levels in soil samples taken from slashed and burned fields on San Salvador Island, Bahamas. Pp. 57-60 *in* Smith, D. L., and S. Smith, eds., *Proceedings of the 9th Symposium on the Natural History of the Bahamas.* Gerace Research Center, San Salvador, Bahamas.

Morton, J. F. 1978. Brazilian pepper – its impact on people, animals and the environment. Econ. Bot. 32:353-359.

Moyroud, R. 2000. Exotic weeds threaten Caribbean, a brief overview and early alarm call. Wildland Weeds 3:4-8.

Mytinger, L., and G. B. Williamson. 1987. The invasion of *Schinus* into saline communities of Everglades National Park. Fl. Sci. 50:7-12.

Nilson, E., and W. Muller. 1980. A comparison of the relative naturalization ability of two *Schinus* species in southern California. I. Seed germination. *Bull. Torrey Bot. Club* 107:51-56.

Robinson, M. C., and R. L. Davis. 1999. *San Salvador Island GIS Database.* University of New Haven and Bahamian Field Station.

Smith, R. R. 1982. *Field Guide to the Vegetation of San Salvador Island, The Bahamas.* The CCFL Bahamian Field Station, San Salvador, Bahamas, 135 pp.

Smith, R. R. 1993. *Field Guide to the Vegetation of San Salvador Island, The Bahamas*, 2nd edition. Bahamian Field Station, San Salvador, Bahamas, 120 pp.

Tomlinson, P. B. 1980. *The Biology of Trees Native to Tropical Florida.* Harvard Printing and Publications Services, Allston, Massachusetts, U.S.A.

Uphof., J. C. 1968. *Dictionary of Economic Plants*. Stechert-Hafner Service Agency, Inc., New York, New York, U.S.A.

Yoshioka, E. R., and G. P. Markin. 1991. Efforts of biological control of Christmas Berry (*Schinus terebinthifolius*) in Hawaii. Pp. 377-387 *in Proceedings of the Symposium on Exotic Pest Plants.* Technical Report NPS/NREVER/NRTR-91/06. National Park Service, Washington, D.C., U.S.A.