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Kathleen Sullivan Sealey
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Ethan Freid

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Thomas A. Rothfus

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SIMILARITY BETWEEN SEED BANK AND ABOVE-GROUND VEGETATION IN A *CONOCARPUS ERECTUS* L. (COMBRETACEAE) DOMINATED COMMUNITY ON SAN SALVDOR ISLAND, THE BAHAMAS

Kendall A. Hanley
Department of Biological Sciences
SUNY Oswego
133 Piez Hall
Oswego, New York 13126 USA

Brianne M. Walsh and Todd P. Egan
Division of Mathematics and Natural Sciences
Elmira College
1 Park Place
Elmira, NY, 14901 USA

ABSTRACT

Along the Fresh Lake causeway on San Salvador Island, The Bahamas, the seed bank was compared to the above ground vegetation in May 2006. The vegetation in this area was dominated by a canopy of *Conocarpus erectus* shrubs. A 49 m primary transect was run along the south side of the Fresh Lake causeway road, and 10 secondary transects were randomly run from the primary transect towards Fresh Lake. Percent above ground cover was determined, and soil cores were taken along secondary transects at 0, 1, and 2 m. Percent above ground cover was calculated in 15 x 15 cm quadrats. A 6.0 cm diameter x 7.5 cm deep bulb planter was used to collect soil samples (n=30). Species diversity was low, with only *Borrichia aborescens* (1.7%), *Sporobolus virginicus* (16.8%), and a member of the Poaceae (<1%) representing the aboveground vegetation. *Conocarpus erectus* was found only in the canopy. The majority of each quadrat along the secondary transects was bare ground. Percent above ground vegetation along the transects was determined then compared to number of seeds present. Only 43 (15208.326 seeds/m^2) *Conocarpus erectus* seeds were present in the entire seed bank, and were found at plots 2, 8, and 10. Shrubs of this species were found at plots 1, 2, 7, and 10. No seeds of any other species were found in any transect. Tidal action may be the main force in distributing seeds along the causeway and out of our sampled area. A second factor accounting for low seed numbers in the seed bank may have been that seeds germinated but seedlings died before being recruited into the canopy.

INTRODUCTION

This study was performed on San Salvador Island, Bahamas in May 2006. San Salvador is located about midway down the Bahamian archipelago at 24° 3'N latitude and 74° 30'W longitude, approximately 640 km southeast of Miami, Florida (Murphy and Cornell 1998). San Salvador is 11.2 km east to west and 19.25 km north-south. The Antilles Current, part of the North Atlantic Gyre, flows past San Salvador and cools the island in the summer when temperatures range from 22-32°C, and warms the island in the winter when temperatures range from 17-27°C. San Salvador averages 100 cm of annual rainfall. The rainy season runs from September to November and is caused by tropical depressions, tropical storms, and hurricanes (Gerace *et al.* 2005).

Soils on the island are often shallow, poorly developed, and retain little water. Therefore, the island is home to species that can survive poor soil conditions, full sun, and periods of drought. Vegetation is generally scrub, with 524 species of vascular plants, representing 265 genera in 26 families. The island is divided into three vegetatitive zones—coastal, nearshore, and inland. The interior of the island is made up of many saline or hypersaline lakes, surrounded by white or red mangroves. Vegetation in mangrove areas is sparse, and tends to grow in cracks between rocks. Shrub communities are dominated by haulback (*Mimosa bahamensis* L.), red calliandra (*Calliandra haematomma* L.) and poison wood (*Metopium toxiferum* L.). Nearshore vegetation is further from the ocean, and therefore less affected by salt spray. This community consists of silverthatch, shrub, and thicket (Gerace, Ostrander and Smith 2005).

Seed Bank Overview

Seed banks are ecologically important for many reasons. One reason is that they store seeds for future generations. Another important aspect is that they allow seed germination to occur during a more favorable time of year (Ungar 1995). Seed banks are especially important in highly stressful environments because they allow for recruitment of species during times of devastating stress (Ungar 1991, Egan and Ungar 2000). Persistent seed banks allow populations to recover quickly from environmental hazards that cause mortality, and diminish the numbers of a certain species in an area (Ungar 1991). Seed germination and plant establishment occurs during favorable environmental conditions when soil salinity levels are reduced (Ungar 1991).

Seed banks can vary in size, mainly being affected by the number of seeds produced by the above ground vegetation, and seeds of various species can be found in all vegetation zones (Ungar 1995). However, above ground vegetation zones within seed banks may shift from year to year (Ungar 1995), and seeds often remain in the soil after the germination period to form a persistent seed bank (Ungar 1991).

Zonation of plant species may occur in the above ground vegetation even though seeds of all species are found along a salt marsh's salinity gradient (Egan and Ungar 2000). Zonation of vegetation in salt marshes suggests that location of different species is related to a species' ability to compete along a salinity gradient. Halophytic species are limited to zones based on a plant's ability to compete with other species and tolerate a saline environment (Egan and Ungar 1999). A plant's ability to compete is often negatively correlated with its ability to withstand a saline environment (Egan and Ungar 2001).

When seeds from limited salt tolerant species are dispersed into soil with a high salt concentration they may not germinate due to physiological restrictions. However, when seeds from highly salt tolerant species are dispersed into soils with low salt concentration they may not survive because they because they are poor competitors. As salt tolerance increases, the ability to compete decreases (Egan and Ungar 2000). Many halophyte seeds can withstand long periods of exposure to highly stressful conditions, then are able to germinate after the osmotic stress is removed (Ungar 1991).

Dominant species in aboveground vegetation do not normally appear as the dominant species present in the seed bank (Ungar 1991). Hyper-saline conditions appear to inhibit halophyte seed germination, thus maintaining a persistent seed bank (Egan and Ungar 2000). An increase in salinity appears to decrease seed germination (Egan and Ungar 1999), and salinity may inhibit the germination process at salinities greater than an adult plant of that species can tolerate (Ungar 1991).

Soil salinity helps determine whether or not germination will occur, and if a plant will grow to maturity (Egan and Ungar 2000). Seed germination usually occurs during periods of high precipitation, when soil salinities are reduced in saline environments (Ungar 1982). Halophytes have adapted various germination strategies in order to establish a plant community within saline communities (Ungar 1995). Avoidance mechanisms appear to allow halophytes to resist stress, and halophytic species have evolved different mechanisms of dormancy in order to prevent seeds from germinating under extremely saline conditions (Ungar 1995).

Precipitation is heaviest in the spring or fall months in temperate climates (Ungar 1995), and from September to November on San Salvador, The Bahamas (Murphy *et al.* 1998). It has been found that a decrease in soil salinity due to rainy seasons stimulates the germination of halophytic species (Ungar 1995). Soil salinity increases during the summer months due to a decrease in soil moisture caused by increasing evaporation in warmer temperatures (Ungar 1995).

Conocarpus erectus Overview

Conocarpus erectus is a halophytic member of the Combretaceae and is native to Bermuda, southern Florida, The Bahamas, the West Indies, the coasts of Mexico, Central and South America, and the Galapagos Islands (Francis 2007). *Conocarpus erectus* is also known as Button Mangrove and Buttonwood (Francis 2007), however it is not considered a true mangrove because it is not restricted to a typical mangrove habitat (Rathcke *et al.* 1996). *Conocarpus erectus* provides a reproductive habitat and food for many animals (Rathcke *et al.* 1996) and helps prevent soil erosion (Francis 2007).

Conocarpus erectus flowers throughout the year in the Bahamas (Rathcke *et al.* 1996), producing purple and white flowers (Gilman and Watson 1993). The plants may have male, perfect, or female flowers (Rathcke *et al.* 1996). Kass *et al.* (2007) describe *Conocarpus erectus* as cryptically hermaphroditic because 11% of plants with apparently male flowers had low fruit sets. Therefore these "male" flowers had a functional ovule (Kass *et al.* 2007). Pollination does not appear to rely on insects (Rathcke *et al.* 1996). *Conocarpus erectus* males produce no fruiting heads; female flowers produced high fruit set, while perfect flowers have low fruit set (Rathcke *et al.* 1996). *Conocarpus erectus* produces achene fruits (Guppy 1917). The compact fruiting heads are referred to as "buttons" (Rathcke *et al.* 1996), and seeds are densely packed into 5 to 15 mm spherical clusters (Francis 2007). The fruits are dry, and can be brown or red in color (Gilman and Watson 1993); often with 35 to 56 fruits seeds per head (Francis 2007). In many cases however, the plant will produce many achene fruits, but very few fruits will have mature seeds (Guppy 1917).

Conocarpus erectus usually occurs open-grown (Francis 2007) and can tolerate clay, loamy, sandy, acidic, and alkaline soils (Gilman and Watson 1993). *Conocarpus erectus* needs full sunlight to grow, and is shade intolerant (Francis 2007); however it is drought tolerant (Gilman and Watson 1993).

Water is the main source of seed dispersal, and *C. erectus* can grow up to 20 m tall; however, this species is usually found in shrub from with a height of 1.5 to 4 m (Francis 2007). Plants can live for several years and has a medium growth rate (Francis 2007). *Conocarpus erectus* usually grows above the high tide line, just landward of other mangroves, and along beaches (Francis 2007). Tolerant to salt water spray and over-wash from storm surges; *C. erectus* is able to live near bodies of water with high salinities (Francis 2007). The plant's bark is gray or brown in color and approximately 8 mm thick (Francis 2007). *Conocarpus erectus* may have one or multiple trunks (Francis 2007); leaves are somewhat fleshy and range from 2 to 10 cm long (Francis 2007). The leaves are oblong in shape, simple, exhibit pinnate venation, and are alternately arranged (Gilman and Watson 1993).

Ungar (1991) states that the above ground vegetation does not always reflect the seed bank. Therefore, we hypothesized that seeds in the soil will be different from the above ground vegetation along the Fresh Lake causeway. Thus, not many *C. erectus* seeds may be present in the soil.

MATERIALS AND METHODS

Study Site

The study occurred on San Salvador Island, The Bahamas, and focused on the Fresh Lake causeway seed bank (long. 74° 2.837' W, lat. 24° 06.008' N). Fresh Lake is a hypersaline lake, and therefore vegetation is limited. Plants growing along the causeway included *Conocarpus erectus* L., *Borrichia aborescens* L., *Sporoblus virginicus* L., and Poaceae.

Seed Bank

A primary 49 m transect was run parallel to the road along the Fresh Lake causeway. Ten secondary transects were selected along the primary transect at determined meter intervals using a random numbers table. Off the primary transect at 0, 1, and 2 meter intervals on the south side of the road and into Fresh Lake we determined percent ground cover and took soil cores to ascertain the seed bank. At each interval percent ground cover was recorded using a 15x15 cm quadrat. Soil cores (6.0 cm diameter x 7.5 cm) were taken on the alternate side of the transect. A coin toss was used to determine if the right or left side of the secondary transect would be an aboveground quadrat measurement, or a soil sample. There were a total of 30 quadrats and 30 soil cores.

After the soil cores were extracted, they were dried and placed in plastic bags. Upon return to the U.S., samples were sorted into trays and sifted using a no. 10 (2mm) soil sieve. Seeds were identified using reference samples collected directly from *Conocarpus erectus* shrubs.

RESULTS

Seed Dispersal

Conocarpus erectus shrubs were found at 4 out of 10 plots (plots 1, 2, 7, and 10), where as seeds of this species were only present in 3 plots (plots 2, 8, and 10). Along transect number 2, seeds were found at 1 and 2 meters from the primary transect line, with 4 and 3 seeds, respectively. A total of 7 (2475.774 seeds/m^2) seeds were collected from soil core 2. In plot 8, seeds were found at 0 and 2 meters from the primary transect line, with 1 (353.682 seeds/m^2) seed at each secondary plot. A total of 2 seeds were collected from plot 8. In plot 10, seeds were found at 0, 1, and 2 meters from the primary transect line, with 3 (1061.046 seeds/m^2), 15 (5305.23 seeds/m^2), and 16 (5658.912 seeds/m^2) seeds, respectively. A total of 34 (12025.188 seeds/m^2) *Conocarpus erectus* seeds were collected from secondary transect 10 (Fig. 1). Seeds of no other species were found. Overall, the seed bank was small and not diverse in regard to seed species.

Above Ground Vegetation

The majority of the 49 m transect was dominated by bare ground, however three plants were present in various secondary transects aside from *C. erectus*. Plant species included *Borrichia aborescens*, *Sporobolus virginicus*, and Poaceae. In secondary transects 1 through 6, *Sporobolus virginicus* was usually the only plant, and covered most of the area. An exception to this trend was secondary transect 2, where *Borrichia aborescens* (16.7% cover) was present along with *Sporobolus virginicus* (13.3% cover). In secondary transects 7 through 9, no above ground vegetation was present. Secondary transect 10 consisted predominately of bare ground, with one species of Poaceae present (3.3% cover) (Fig. 2). Overall, there was low diversity in above ground coverage along the causeway.

There was low species diversity with under the *Conocarpus erectus* canopy; *Borrichia aborescens* (1.7%), *Sporobolus virginicus* (16.8%), and a member of the Poaceae (<1%) representing the aboveground vegetation. The remainder was bare ground.

Similarity Between Vegetation and Seed Bank

Similarities between the seed bank and above ground vegetation for each of the zones varied. *Conocarpus erectus* seeds were found in soil cores at secondary transects 2, 8, and 10, and of these secondary transect 2 had *Borrichia aborescens* (16.7% cover) and *Sporobolus virginicus* (13.3% cover) both present; however bare ground was the dominant feature. Also, at secondary transect numbers 2 and 7 seeds of *C. erectus* were found, along with *C. erectus* shrubs. Secondary transect 8 was comprised of bare ground because no aboveground vegetation was present, 2 (707.364 seeds/m^2) *Conocarpus* seeds were found, but no shrub was present. Secondary transect 10 was dominated by bare ground; however, a small percentage of Poaceae was present (3.3% cover). Also in secondary transect 10, 34 (12025.188 seeds/m^2) *C. erectus* seeds were found, along with a shrub (Figs. 1 and 2). *C. erectus* shrubs were found at secondary transects 1 and 7; however, no seeds were collected in these zones. Secondary transect 1 contained 38.3% *S. virginicus* while secondary transect 7 had 100% bare ground (Fig. 2). From the samples gathered at the Fresh Lake causeway it appears that above ground vegetation and seed bank were fairly similar; however, only *C. erectus* seeds were found within the seed bank and no other species of seeds were present.

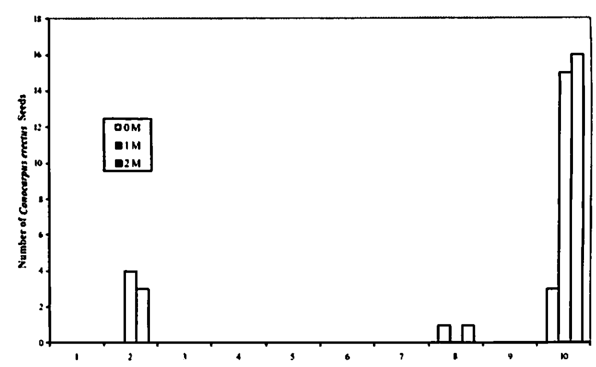

Fig. 1. Distribution of Conocarpus erectus *seeds on 7 May 2006 at the San Salvador Island Fresh Lake Causeway along a 49 m transect on the road's south side. A total of 10 plots were sampled at 0, 1, and 2 m in from the edge of the road.* Conocarpus erectus *plants were located in plots 1, 2, 7, and 10 (*C. e.*). Numbers above bars indicate the number of seeds/m^2 in core samples at each of three, 1 m^2 quadrats. No seeds where found at plots 1, 3, 4, 5, 6, 7, or 9. Not all secondary transects containing seeds had seeds present at each sub-plot (0, 1, and 2 m).*

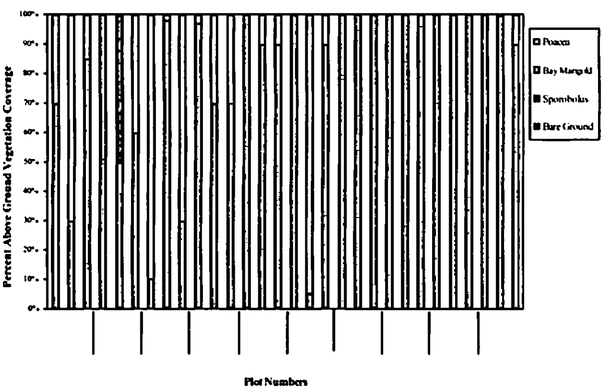

Fig. 2. Percentage of above ground vegetation present under a Conocarpus erectus *canopy along a 49 m transect on 7 May 2006 on the San Salvador Island Fresh Lake Causeway. Ten plots were sampled using 15 cm x 15 cm quadrat samples taken at 0, 1, and 2 m in from the edge of the road.*

DISCUSSION

Results did not appear to support our hypothesis that the seed bank and above ground vegetation along the Fresh Lake causeway would be dominated by different species. While, the number of seeds recovered in the samples was low, the entire seed bank consisted only of *Conocarpus erectus* seeds. The above ground vegetation along the causeway was dominated by *Conocarpus erectus* shrubs.

Ungar and Woodell (1993) observed that similarity between aboveground vegetation and seed banks in a perennial dominated community like our *C. erectus* community is low. Seed banks may also over-represent some halophyte species, while under representing other halophyte species, and annuals normally produce a large persistent seed bank, while perennials generally do not (Ungar 1995; Ungar and Woodell 1996). The results of our seed bank study were contrary to this trend, even though numbers were low. Only seeds of the perennial *C. erectus* were present in the May 2006 samples of the Fresh Lake causeway seed bank. Seeds of other perennials represented in the above ground vegetation including *Borrichia arborescens*, and *Sporobolus virginicus* were not present. However, the lack of annuals in the seed bank should not be too surprising since there was only one potentially annual species, a grass, and that was poorly represented. In addition, many grasses spread via rhizomes and reproduction by seeds is less important. The question of why there were so few annual species present at this site would also make an interesting study.

Although our seed bank contrasted with many other studies in that it was dominated by perennials and not annuals, our data were consistent with other halophyte seed bank studies reporting that the above ground vegetation was dominated by a perennial species (Ungar 1995; Ungar and Woodell 1996).

The number of *C. erectus* seeds found within the May 2006 samples at the Fresh Lake causeway was lower than expected based on the dominance of this species. Environmental and biological factors may reduce the number of seeds in a seed bank, but we believe that since our study site was in a tidal zone it was tidal action that was the main force in dispersing seeds from our sample area (Ungar 1991; Ungar 1995; Ungar and Woodell 1996). *Conocarpus erectus* seeds have been noted to be buoyant due to spongy aerenchyma layer which develops on the outer wall of the seed (Guppy 1917). Buoyancy would allow the seeds to be carried away from the seed bank by tidal action. Another factor that may have contributed to the low number of seeds in the seed bank is that most of the seeds may germinate soon after being shed, but then die before being recruited into the canopy (Ungar and Woodell 1993; Ungar 1995).

Soil samples at Fresh Lake causeway were collected during the May 2006 study. However, the rainy season occurs from September to November on San Salvador Island, and the seed bank soil may have had elevated salt content which may kill *C. erectus* seedlings. Halophytes usually remain dormant during exposure to high saline levels (Ungar 1982), however salinity tests were not performed, and salinity tolerance levels for *C. erectus* is only now being studied.

Lack of dormancy mechanisms, death of seeds, and poor salt tolerance may also have contributed to the lack of a persistent seed bank (Ungar 1995). Seed dormancy appears to be an important survival mechanism in halophytes because seeds can avoid extreme environmental conditions by delaying germination, and remain within the seed bank until a period of reduced salt stress occurs (Ungar 1982; Ungar 1995). Seed dormancy appears to occur due to physiological, physical, or morphological factors, and appears to allow seeds to germinate in conditions with moderate soil salinities. This may increase the likelihood of survival and recruitment (Ungar 1995). Dormancy mechanisms of *C. erectus* are not yet known.

Additional factors that may have decreased the number of seeds in the seed bank include herbivory by birds, mammals, insects, and arthropods; water logging; hypersaline conditions; and fungi and bacterial parasitism (Ungar and Woodell 1993; Ungar 1995).

Further research on the *C. erectus* seed bank appears to be necessary to understand the relationship between above ground coverage and seed bank composition. Further research on the salt tolerance and dormancy mechanism of *C. erectus* also appears to be necessary. To help answer these questions, seed bank studies of *C. erectus* that vary sampling at different times of the year are suggested.

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