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Cover image - Patch reef near the wall off Grotto Beach (photo by Lee Florea).

Density, size, growth, and reproduction in two populations of Caribbean silver thatch palm (*Coccothrinax argentata*) [Family Arecaceae] on San Salvador Island, The Bahamas; a preliminary report

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1. Abstract

In June 2012, we casually observed what seemed to be a high level of mortality of silver thatch palms (*Coccothrinax argentata*) in one population at Grotto Beach on San Salvador, Bahamas. To determine the validity of our observation we quantified the densities of live and dead trees in this population as well as a population at Rocky Point that did not appear to have the same level of mortality. We also measured tree size (diameter at breast height and trunk height), growth (annual production of new leaves and trunk height), reproduction (number of seeds attached to inflorescences), and recruitment (numbers of seedlings near the trunks). The density of dead trees was three times greater in the Grotto Beach population than at Rocky Point and the density of live trees at Rocky Point was nearly four times greater than at Grotto Beach. Neither tree size nor growth were significantly different between the two populations. The number of seeds and seedling density was significantly greater in the Rocky Point population. The magnitude of the difference in live to dead tree proportions supports our observation of higher mortality in the Grotto Beach population. Equivalent growth rates in the populations suggest that the populations are currently experiencing similar environmental conditions for growth. If our measures of reproduction and recruitment are representative of longer term dynamics, they may indicate that the Rocky Point population is in a better state of continued population growth and may be able to withstand and recover from potential disturbance. If the greater proportion of dead to live trees at Grotto Beach represents a continuing trend, then this population may be declining and less able to recover from future disturbances. This is the first data of a planned long-term study of the population dynamics of the silver thatch palms on San Salvador. The project was also designed to provide field research experiences for students.

2. Introduction

Baseline ecological data are crucial to our understanding of the ecology of palms, as well as being informative in devising conservation and management strategies for populations of concern. Ecological characteristics such as density, and survival and growth rates allow an assessment of changes occurring through time and can be used to determine whether a population is increasing, stable or in decline. In addition, baseline ecological data can serve as a control against which the effects of disturbance can be assessed.

Island populations may be particularly vulnerable to short-term negative ecological impacts due to their small population size, limited habitat, reduced genetic variation, and increased inbreeding compared to mainland populations (Frankham 1997, 1998). Negative impacts include population reduction and even extinction in the case of endemic species that only occur on islands (Frankham 1997; Davis et al. 2007).

The silver thatch palm *Coccothrinax argentata*, (Jacquin) L.H. Bailey (Bailey 1939), occurs on islands in the western Caribbean (Bahamas, Caiman Islands, Jamaica, Cuba, Florida Keys, and mainland coastal regions of southern Florida, Mexico and Honduras; Henderson et al. 1995). It is classified as a threatened species in Florida (Florida Administrative Code 1998), but as Apparently Secure (G4) at the global level (NatureServe

2015). This rank identifies it as "Uncommon but not rare; some cause for long-term concern due to declines or other factors" (NatureServe 2015).

On San Salvador the silver thatch palm occurs in low frequency across much of the island's inland and coastal regions (pers. obs.) but three main coastal populations have been described (Kass 1986). It is probably the dominant palm on the island and forms distinctive palm forests. Smith (1993) describes the habitat of these palm forests as coastal coppice, consisting of *Coccothrinax*-shrub communities in which *Coccothrinax* is the dominant tree that forms a canopy over smaller shrubs.

We studied two of the main populations on San Salvador. One population is near Rocky Point on the northwest end of the island and the other is near the southwest end of the island near Grotto Beach (Figure 1). Two personal observations peaked our interest in these particular populations: first, the larger palm populations occur near beautiful beaches where habitat destruction due to resort construction is an ever increasing possibility, and second, there seemed to be a dramatic difference in the number of dead trees between these populations.

In addition to the collection of ecological data, the project was designed to provide field research experiences for undergraduate students through the course *Tropical Island Biology* (Department of Biological Sciences at Florida Gulf Coast University) taught on San Salvador at the Gerace Research Centre. In 2014, students helped collect, analyze, and interpret data they collected as part of the course.

3. Methods

3.1. Study sites and transects

In June 2013 and 2014, we collected data from populations at Rocky Point and Grotto Beach (Figure 1). Permanent 50-meter transect lines were established at both field sites; two at Rocky Point and one at Grotto Beach in 2013, and a second permanent transect line was established at Grotto Beach in 2014. Five to six randomly selected points were permanently marked along each 50-m transect line for sampling.

The plotless point-centered quarter method was used to estimate the density of live and dead trees along the transect lines. In short, four trees were associated with each random point along the transect line. The point-centered quarter method uses four quadrants established at each random point (quadrants at 0-90°, 90-180°, 180-270°, and 270-360°). Within each quadrant, the distance to the nearest tree from the point was then used to calculate the density (see Cottam and Curtis (1956) for a complete description of the method and calculations).

The randomly selected trees that were used in the density determination were also used to obtain data on size, growth, reproductive potential, and recruitment of seedlings in the populations. Tree size was measured as trunk height and diameter at breast height (DBH). Trunk height was measured from the point where the roots initiate from the base of the trunk to the point of insertion of the petiole of the lowest (oldest) live leaf on the top of the trunk. Annual growth rate was estimated as the number of new leaves produced in one year. To measure annual growth a tag was placed on the youngest fully emerged leaf in the first year and then the number of new leaves were counted the following year. As a measure of reproductive potential the number of seeds attached to inflorescences were counted during 2014.

Recruitment of new individuals into populations was determined from measures of seedling density. Two 1-m^2 quadrats were placed adjacent to each of the sampled trees. Plants were considered seedlings if they had no discernable above-ground trunk formation.

3.2. Statistical analyses

T-tests were used to compare the means

Figure 1. Field sites on San Salvador. Map data: Google, SIO, NOAA, US Navy, NGA, GEBCO, DigitalGlobe, CNES/Astrium.

between the two populations with the assumption of unequal variance for DBH, trunk height, number of new leaves per year, number of seeds per tree, and seedling density. The difference in tree density (both live and dead), was also compared using a t-test, but with only two independent replicates (i.e., two transects at each site served as replicates).

4. Results

Substantial differences were found between the two populations for density, reproductive potential, and recruitment but not for size or growth (Table 1). Density of live trees in the Rocky Point population was almost four times greater than the density of live trees in the Grotto Beach population (Table 1, Figure 2). While substantial, this difference was not statistically significant using a t-test with only two replicates. Density of dead trees was three times greater at Grotto Beach than at Rocky Point (Table 1, Figure 2). Similarly, while substantial, this difference was not statistically significant using a t-test with only

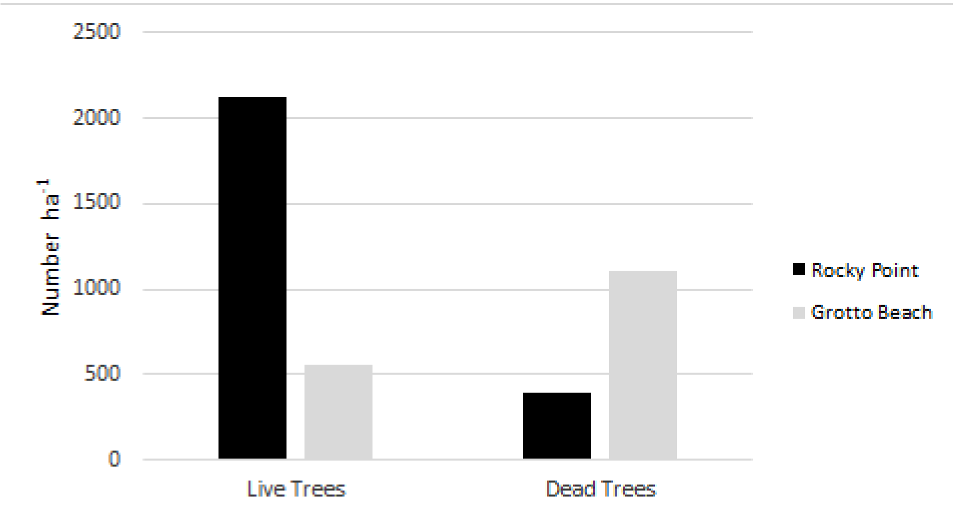

Figure 2. Live tree and dead tree density (# ha^{-1}) at Rocky Point and Grotto Beach.

two replicates.

Mean diameter at breast height and trunk height of trees was not significantly different between the two populations (Table 1). Growth, as measured by the mean number of new leaves produced per tree annually, was not significantly different between the two populations. Reproduction, measured as the number of seeds on trees, was significantly greater in the Rocky Point population ($p < 0.01$; Table 1).

Recruitment, as measured by seedling density, was significantly greater in the Rocky Point population ($p < 0.05$; Table 1 and Figure 3). The population at Rocky Point had approximately three times the number of seedlings compared to Grotto Beach.

5. Discussion

5.1. Differences between populations

The two populations differed substantially in the density of living trees with the density of live trees at Rocky Point being much greater than Grotto Beach (almost 4x greater). Despite the large difference in density there was not a statistically significant difference ($p > 0.05$). However, we suspect that the difference is large enough to be biologically important and that statistical significance would become apparent with more replication (i.e., more transects) within the two populations. The low level of replication and subsequent high variance produced very low power in the statistical analysis. The density of dead trees was much greater (almost 3x greater) in the Grotto Beach population. However, no statistically significant difference is apparent for the same reasons described earlier in the statistical analysis of live trees.

A comparison within each population of live to dead tree density ratios (live:dead) was revealing as density ratios were substantially different between populations. The density of live trees within the Rocky Point population was six times greater than the density of dead trees. The opposite trend of live to dead trees occurred in the Grotto Beach population where the number of live trees was half the density of dead trees. These live to dead tree ratios are indicative of higher mortality occurring in the Grotto Beach population. If the lower proportion of live trees represents a continuing dynamic, the Grotto Beach population would be expected to exhibit a declining population relative to the Rocky Point population.

The mean number of seeds was much greater

Table 1. Ecological characteristics for Rocky Point and Grotto Beach populations. Values shown for tree size, growth, reproduction and recruitment are means (standard error).
(* = p<0.05; ** = p<0.01)

Population demographic	Rocky Point	Grotto Beach
Live tree density (ha^{-1})	2122	558
Dead tree density (ha^{-1})	394	1104
Tree Size – DBH (cm)	5.6 (0.14)	6.8 (0.26)
Tree Size – Trunk height (cm)	231.9 (24.9)	194.2 (23.0)
Growth (# new leaves yr^{-1})	9.94 (0.58)	10.3 (0.73)
Reproduction (# seeds $plant^{-1}$)	56.4**(11.9)	1.3 (1.25)
Recruitment (# seedlings m^{-2})	1.82* (0.73)	0.6 (0.17)

in the Rocky Point population. If this measured characteristic was representative of the annual seed production within the populations then the current reproductive potential would seem to be greater in the Rocky Point population. However, without further observations based throughout the reproductive season this is only speculative.

Seedling density was also significantly greater in the Rocky Point population. This may also seem to represent a healthier population in terms of reproductive output (seed production) and perhaps better germination rates, but knowledge of seedling age, seed dispersal patterns, and germination rates would be needed to make this a firm interpretation of the data.

Mean growth rates were not different between the two populations as measured by annual leaf production. We were somewhat surprised to find that on average a tree replaces the entire crown every year. Palms in the *Coccothrinax* genus are generally considered to be slow growing (Henderson et al. 1995). However, field studies of growth are rare if not non-existent for this species. Growth rates of a related species, *C. readii* were estimated in a Mexican population (Olmsted and Alvarez-Buylla 1995). The similarity in growth rates in this study suggests that current environmental characteristics were similar at both sites 2013-1014. The greater proportion of dead trees and lower density of live trees at Grotto Beach may reflect an episodic cause of mortality in the past.

5.2. Management and conservation implications

The higher density of live trees, greater reproductive potential and seedling recruitment in the Rocky Point population indicate that the Rocky Point population is currently in a better or more stable state. The greater abundance of dead trees, and in particular, the ratio of live to dead trees at Grotto further support this notion.

The differences in ecological characteristics in these populations suggest that the Grotto population is currently more vulnerable to disturbance. This situation may be likely given the lower density of live trees, lower seed production, and seedling recruitment at Grotto Beach. However, lower seed production and seedling recruitment may be reflective of the sampling frequency, lower density of live trees, or representative of short-term variation in environmental factors affecting these populations differently. For instance there appear to be small-scale differences in precipitation patterns on the island, and we suspect that timing and production of seeds, as well as germination success are dependent on

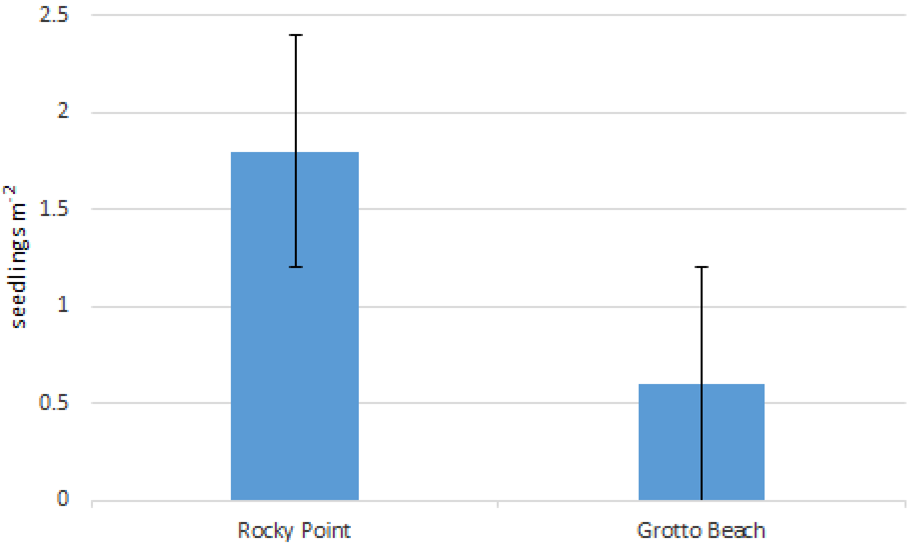

Figure 3. Mean seedling density (m^{-2}) at Rocky Point and Grotto Beach. Error bars are standard errors ($n = 168$, $p < 0.05$).

rainy season precipitation patterns.

Future study will include installation of weather stations at both of these sites to measure the amount and variability of precipitation. We will also be examining differences in soil characteristics such as moisture content, organic matter, and soil salinity. While firm conclusions regarding the relative vulnerability of these populations obviously require further study over a longer period of time, the data are at least suggestive that the population at Grotto is at a greater initial risk to disturbance and perhaps would face a longer time period to recover following a disturbance such as a hurricane.

5.3. Educational implications

This project provided opportunities for students to participate in field research. We noticed that many students do not appreciate the difference between original research and carefully vetted lab exercises which they often see in their courses. They also do not seem to not fully appreciate the difference between simple observations and carefully measured differences when forming conclusions.

To involve students in real field research we had them collect data during the day in their field notebooks. In the evening, they compiled their data into a shared database file and made written summaries, predicting meaningful differences based on their observations. Instructors conducted the statistical analyses overnight, which allowed the students to compare their predictions with the statistical analyses.

Two cases exemplify the kind of learning students participated in:

5.3.1. Example 1.

Although students could not observe differences in tree height, they logically predicted that trees would have grown in height by several centimeters. When they compared their height measurements to the previous year's height data to determine the amount of growth, some trees did not grow, and in fact, had apparently shrunk. After some thought, students identified the need to measure height from a repeatable point on the tree (the root line), not just at the surface of the ground. Height was re-measured the second day from the root line. In addition, if the root line was below the surface of the ground they marked a reference point with fingernail polish as a permanent marker for measuring height in subsequent years. So the students identified a logical cause of the outliers in the data, and found a feasible low-tech solution for the problem.

5.3.2. Example 2.

Our observation before initiating the study was that the population at Grotto Beach had more dead trees than the population at Rocky Point. Students predicted this from their preliminary trips to the field sites to make observations on anything they saw that was interesting to them, and then had the opportunity to collect actual data and verify that there was a difference between the two populations. However, since each population had only two density data points (each transect was one replicate) the results were not statistically significant. This engendered discussion on the use of statistically significant differences within ecological studies, and the recognition of statistical issues related to low replication often seen in field studies. This also allowed the opportunity to discuss the difference between statistical significance and biological or ecological significance in research.

Finally, with this project students learned to appreciate the difficulty of conducting field research on a hot isolated island, the need to identify causes and solutions for spurious data, and the value and limits of statistical analyses. The project reinforced our strong belief in the importance of field research for students who plan on a career in the sciences. There is no substitute for the experience of being immersed in a field research project on an island, being exposed to real-time problems that arise, and having to think through problems and come up with solutions with very limited resources and time.

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