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THE SPATIAL DISTRIBUTION OF COPERNICIA ALBA (MORONG) IN THE
DISTRICT OF BAHIA NEGRA, PARAGUAY

By

Michelle E. Cisz

A THESIS

Submitted in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
(Forestry)

MICHIGAN TECHNOLOGICAL UNIVERSITY
2011

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This thesis, “The Spatial Distribution of *Copernicia alba* (Morong.) in the District of Bahía Negra, Paraguay,” is hereby approved in partial fulfillment of the requirement for the Degree of MASTER OF SCIENCE IN FORESTRY

School of Forest Resources and Environmental Science

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Date _____

Dedication

I would like to dedicate this thesis to those who had supported me the most over the past four years. I would like to thank my family for their unconditional love and support and Blair Orr, who as an advisor, goes above and beyond the call of duty. Both abroad and upon return, his active support speaks to his belief in a program for volunteers making the most of their experience abroad. Lastly, I would like to dedicate this work to the kids and young adults of Bahía Negra that I had the pleasure to spend time with. My wishes are with those who will continue to participate actively in the community and care for the natural environment which they know more intimately than most. As in many parts of Paraguay, Bahía Negra overflows with a full guampa of yerba, a smile, and good old fashioned hospitality

Para la comunidad de Bahía Negra. Donde la yrytu oipeju piro ho'ysa hasy norte hatã.

Aguije ndeve

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Acknowledgements are not complete without mention of the Conservation Non-profit organization, Guyra Paraguay. Their help was essential in directing me to local resources and people who facilitated the research at 3 Giants Reserve (Tres Gigantes). This is not exhaustive. There are still many others who have helped along the way in various means of support. My gratitude is equally measurable in good faith that they know who they are.

Abstract

The Humid Chaco of Northeast Paraguay harbors monoculture palm savannas in which *Copernicia alba* is the only dominant overstory species. The study's objective was to provide the complete spatial distribution of a simple ecosystem lacking confounding factors of overstory competition and changes in slope. Palms within six, 50 x 50m plots were marked by their GPS location and measured for dbh and total stem height. The spatial distribution was individually analyzed for each plot at the local scale up to 12 m using Ripley's K test. For the total population including juvenile and adult plants, the sample plots contained both random and clustered distribution patterns. In each of the six plots, the juvenile populations exhibited more clustered patterns than the adult population of each plot.

Keywords: Chaco, savannah, *palmares*, local scale, conspecific population dynamics

Chapter 1. Introduction

The complete spatial patterns of a plant species can describe the interactions between the plant and its environment and indicate something about conspecific population dynamics. Scale is an important element in considering the patterns of a plant species. Climate, disturbances such as fire and flood, plant community associations, and geomorphic processes are key physical characteristics of this savanna ecosystem that could drive patterns of a plant population at both the landscape and regional scales. In comparison, the local scale also gives insights to specific mechanisms of that particular species (Gillson 2003, Caylor 2006). Palms in open savanna ecosystems of Africa have been found clustered as juveniles and adults less clustered (Barot et al. 1999). Other palm distribution studies in ecosystems with less vegetative food resources have found seed predation as a driving factor for palm patterns. (Wehncke et al. 2009). Differences could depend upon both physiological difference particular to that palm species such as root systems and fruit size, and also on underlying characteristics of environment.

The purpose of this study was to assess the local spatial distribution of the palm, *Copernicia alba* (Morong.), as an overstory dominant species within the savanna, occupying the outskirts of a lowland, alluvial plain. The hypothesis was that *C.alba* is randomly distributed. In addition to the total palm population being analyzed individually per plot, palms were divided into juvenile and adult classes for post hoc statistical analysis. While total populations varied between random and slightly clustered patterns, juvenile populations were consistently found more clustered than the adult populations in each of the six plots.



Figure 1.1. Map of Paraguay by Michelle Cisz (Data source FAO 2009).

Since the study was conducted at the local scale of less than 12 m, Chapter 2 (Background) briefly describes *C. alba*'s physical attributes, the natural behavior in seed and flower production, and aspects of its development growth, based upon the available literature and observations from the field. Chapter 3 (Methods) covers field data collection and statistical analysis. Chapter 4 (Data) contains demographic summaries of six plots in monoculture stands. Chapter 5 (Results and Discussion) presents the spatial patterns for the entire palm populations greater than 1 m for each plot. In addition to the total palm populations, spatial distributions of juveniles and adults were also analyzed for each plot. Discussions of what processes could be influencing the clustered juveniles, and less clustered adults are discussed as they relate to both intrinsic and extrinsic mechanisms of *C. alba* populations at the local scale.

Chapter 2. Background

The sections “The Gran Chaco Basin” and “Habitat and Stem Development” provide a brief overview of *C. alba*’s natural habitat in Northern Paraguay. Since the study assesses the palm at a local scale, the subsequent sections of this chapter (Fronds and Petiole Sheathes, Inflorescence, and Seed Dispersal) focus on the physical and behavioral characteristics of *C. alba*.

The Gran Chaco Basin

The Chaco is part of a great river basin south of the Amazon. The Chaco extends across Argentina, Paraguay, and Bolivia, and is approximately 1,000,000 km² in size. Fire is a historically common disturbance agent to the dry and humid Chaco as well as the neighboring Pantanal wetlands in Brazil (Bravo et al. 2008). Northern Paraguay supports diverse vegetation types including, but not limited to thorny scrub forests, wetlands, and grasslands. The bedrock is covered by a thick layer of fine grained sediment. As part of a lowland floodplain created in the Pleistocene Epoch, the Paraguay River supports a broken landscape of monoculture palm forests and riparian edges rich in species characteristic of the Brazilian Amazon and cerrado (Hay 1993; Iriondo 1993; Gardner et al. 1995; Oliveira et al. 2002; Renshaw 2002).

Habitat and Stem Development

Copernicia alba (Morong.) has been documented from latitudes 14°S to 27°S and longitudes 56°3’W to 66°W, along the Pilcomayo and Paraguay Rivers. Mature palms occupy the overstory in both forest and grassland habitats. Within forests, they codominate the overstory as adults and can be found occupying midstories. Throughout the Chaco they are associated with flat alluvial flood zones that cycle between floods and long periods of drought (Moraes 1991; Degen 1998; Mereles 2001; Yamashita & Barros 2003, Vogt and Mereles 2005).

A member of the Arecaceae family, *C. alba* was first officially documented by Thomas Morong during the two years he spent in Paraguay from 1888 to 1890 (Britton

1894). Three species were originally described by Morong: *Copernicia blanca* (white palm), *Copernicia roja* (red palm), and *Copernicia negra* (black palm). They are now considered the same species, but of different developmental stages (Valente 1957; Michalowski 1958; Moraes 1991; Mereles 2001). The palm's common name is Caranday or in Guaraní, *Karanda'y*, meaning "water palm".

Young palms can appear bristly with scaled petiole fronds attached. With age and growth in height, the petiole leaves are shed and the stem (trunk) can appear in various shades of light gray. This is the "white palm" where the xylem is pliable and less dense. The meristem fibers become denser and increase in lignin content as the palm develops from white to brown (referred to as "red palm" in Spanish), and eventually to black (Valente 1957). *C. alba* is resistant to most fires in the savannas, which can spread quickly by wind and are of light intensity. Occasionally, palms were found within the study site with deep meristem burns (Figure 2.1). The vascular meristem is also well adapted to floods and grows primary and secondary adventitious roots to help support the palm while maintaining root aeration (Figure 2.2).



Figure 2.1. Fires are generally fast and of light intensity although palm trees can be found on occasion with deep vascular meristem burns.



Figure 2.2. Palms adaptation to flooding within the gallery forests result in primary and secondary adventitious root structures.

Fronds and Petiole Sheathes

C. alba is 10 to 13 meters tall, with some specimen heights reaching 25 m. Their dbhs can range from 10 to 30cm (Valente 1957; Neiff 2001), with the widest palms having 40 cm diameters (Dahlgren & Glassman 1963; López et al. 1987; and Neiff 2001).

After *C. alba*'s energy is invested into developing a crown of spiral fronds, the palms invest energy resources into height growth. Since they are monocots, the palms do not undergo secondary growth as dicotyledonous trees do. New fronds grow from the terminal apex of the stem, adding height through the development of the vascular meristem. With the new added growth, older rachises that appear lower on the stem eventually detach. In doing so, they form a “skirt” at the base of the crown (Figure 2.3). The frond rachises themselves normally vary in length from 0.5 to 0.7 m, having a maximum length of 1.5 m (López et al. 1987; Noblick et al. 1992; Degen 1998; Neiff 2001; Peña-Chocarro et al. 2006). Before complete detachment, the fronds droop down forming the bottom “skirt” of the crown (Figure 2.3). When leaf shoots are new, they are yellowish green. They mature to a darker green, retaining a waxy luster to the ventral side (Figure 2.4). Leaves at the bottom of the skirt are similar in color to leaves on the ground; often pale shades of yellow, to light tan, or gray.



Figure 2.3. Characteristic “skirt” shape on Plot 5 (Photo by Joan Ngo).



Figure 2.4. Waxy, bifid leaves of *C. alba* join at the rigid hastula only present on one side of the leaf (Photo Courtesy of Joan Ngo).

After a frond falls off, it leaves behind a reduced bract or leaf scars, giving the palm stem a scaled appearance. As *C. alba* ages, generally these scales are lost (Peña-Chocarro et al. 2006). Fronds that make up the crown are secured to the trunk or stem apex by a fibrous interwoven sheath called the cirrus (Figure 2.5)



Figure 2.5 Inflorescence and frond petioles are secured by sheathes of cirrus and arranged in whorls. This adult was harvested adult from Plot 5 (Photo by Joan Ngo).

Inflorescence

C. alba can bloom twice between the months of August to October (Figure 2.6). The flowers have a potently sweet fragrance. Honey bees (*Hymenoptera*) have been observed as pollinators in Alto Paraguay. Flies and beetles are known pollinators for other palm species within the Arecaceae family and suspected for *C.alba*. Birds are another potential pollinator for the hermaphroditic palm (Moraes 1991; Mereles 1999, 2001).

The inflorescence rachises are found toward the center of the crown (Figure 2.5). The rachises are 0.5 m to 2 m long. The main axis contains smaller branches that carry clusters of trimeric flowers (Tomlinson 1979; Peña-Chocarro et al. 2006).



Figure 2.6. Budding trimeric flowers November, 2010 (Photo by Joan Ngo).

Seed Dispersal

Seed dispersal is often considered a key variable when interpreting spatial distribution patterns of a particular species (Barot et al. 1999). *C. alba* have an R species reproduction strategy. A single palm can produce up to 97,000 light brown, ovoid fruits per year (Grassia 2010). The fruits are smaller when compared to other palm species in Paraguay, ranging in size from 1.0 to 1.5 cm (López et al. 1987; Schessl 1993; Peña-Chocarro et al. 2006). Once palm fruits fall from the tree, they can take up to 4 months to germinate (Grassia 2010).

C. alba has been found to flower twice per year, but as a whole population, the palms do not all produce their flowers or fruits in sync (Mereles 1999). Although palms may bloom and produce fruit irregularly throughout the seasons, the majority of palm populations drop their fruits in the late winter and early spring. This time of year coincides with the sporadic rainfalls, strong northern winds, and fire season (Mereles 1999, 2001). Wind could be an important factor for palms' seed dispersal, dislodging the light fruits that remain tightly attached to the inflorescence (Orozco-Segovia et al. 2003).

C. alba's fruits provide food for both forest and savanna animals. The Greater Rhea (*Rhea Americana*) and White-lipped peccary (*Tayassu pecari*) are among the animals that scavenge fruits during the dry season when the diversity of food sources is low (Moraes 1991; Renshaw 2002; Keuroghlian et al. 2009). Bats, the maned wolf (*Chrysocyon brachyurus*), and small rodents are other potential predators of the fruit (seed) (Orozco-Segovia et al. 2003; Almeida & Galetti 2007).

Use by Humans

Since the palm is readily accessible, it has been used locally in projects such as building tree fences, garbage receptacles, roofs, and stages for community events (Michalowski 1958; López et al. 1987; Moraes 1989). More commonly, *C. alba* stems are harvested for telephone poles and housing frames. Local residents acknowledge that the palm is not as durable as some of the other local woods, yet the palm still provides them with a wood resource because it is more readily available and more economical in the short term. Families state that the black palms can last 5 to 10 years before rotting.

In the 1970s, *C. alba* was harvested to sell in Argentina as electric poles. This provided jobs for some of the Chamacoco Indians. In Argentina, they are also used as plant holders, drinking fountains, and in urban landscaping at shopping malls and street medians (Grassia 2010).

Palms are used both for household materials and for food consumption among different indigenous tribes of the Chaco. The Chamacoco (Ishyr tribe) of Bahía Negra District weave emergent leaf shoots into hats, fans, pot-holders, baskets, and other decorative crafts (López et al. 1987). Fallen palm inflorescences are also used to make brooms. The Chamacoco harvest the meristem heart as a food source while other tribes, such as the Ayoreo, boil it or cook it in burning ashes. It can also be eaten raw. Along with other palms species, *C. alba* is used as a salt substitute (López et al. 1987; Schmeda-Hirschmann 1994; Renshaw 2002; Peña-Chocarro et al. 2006).

Chapter 3. Methods

Site Description

The study site falls within the Humid Chaco palm savannas of Paraguay, bordering Brazil, W 20°04-5', S 58°17-16', with elevations of 82-85 m. Temperature ranges from 12°celsius to 40° C with average rainfall of 995mm per year (DMH 2011; Riveros 2010; WMO 2011). The rainy season is from September to April, with December and January having the greatest rainfall (Figure 3.1) (Mereles 2001; DMH 2011). Southerly winds bring cooler temperatures while northerly winds generate warmer temperatures. Winds are strongest during the end of the dry season when fires are more common (Tutiempo World Weather 2010).

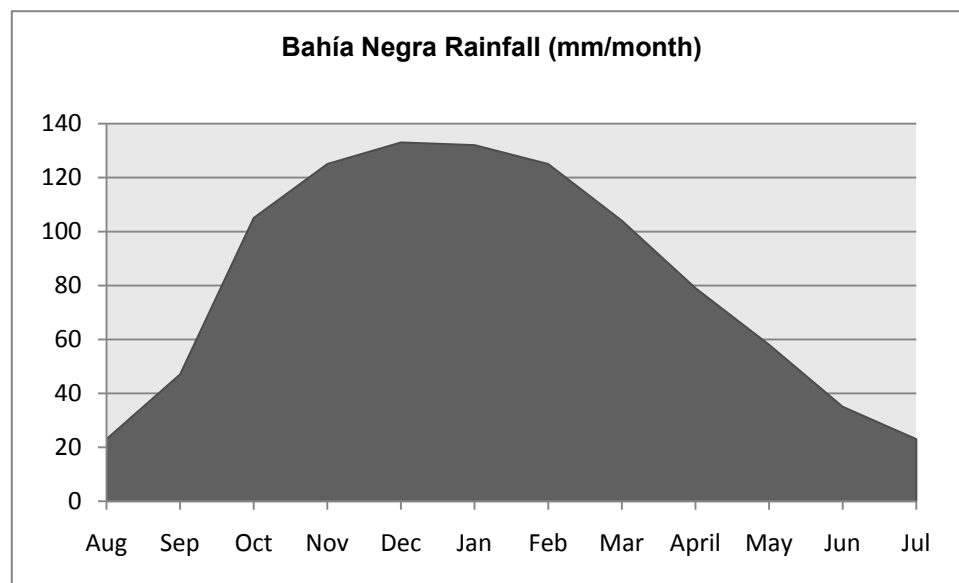


Figure 3.1 Monthly precipitation averaged over 64 years (Data Source WMO 2011)

The study was conducted on the Biological Reserve, Tres Gigantes, which is a part of an alluvial floodplain. Spanning west from the Pantanal wetlands at the Paraguay River, the vegetative communities change from riparian forests and frequently flooded monoculture stands of *C. alba* to drier open savannas that are less frequently flooded. Continuing west the land gradually increases in altitude and the vegetation is influenced by

seasonal rainfall. Aside from the cattle ranchers that occupy the land less than fifty km west of the Paraguay River, this region of the Chaco fosters remnants of *quebracho* forests that were heavily harvested in the late 1960s through the 1970s. The Chaco scrub forests support tree species including, but not limited to, *Acacia* spp., algarrobo (*Prosopis* spp.), guayacán (*Cesalpinia paraguariensis*), mistol (*Ziziphus mistol*), guaimi pire (*Ruprechtia triflora*), *Lonchocarpus nudiflores* and “labonales” containing *Schinopsis balansae* and *Tabebuia nodosa*. (Navarro 2005; Mereles 2005).

C. alba dominates both the overstory and the midstory of the study plots. The understory is codominated by members of Poaceae and Fabaceae family (*Acacia* and *Albizia* genera) with heights found at 1 to 2.5 meters (Figure 3.3) and accompanied by members of the Verbenaceae, Asteraceae, and Apocynaceae families. Two seasonal ponds fell more than 200 meters away from study plots. Other changes in landscape included 2 woody scrub patches. A small woody patch was found 30 meters north of Plot 3 (Figure 3.4), while the edge of a longer fragmented strip (less than 50 meters) of woody scrub was in the northeast side of Plot 5.

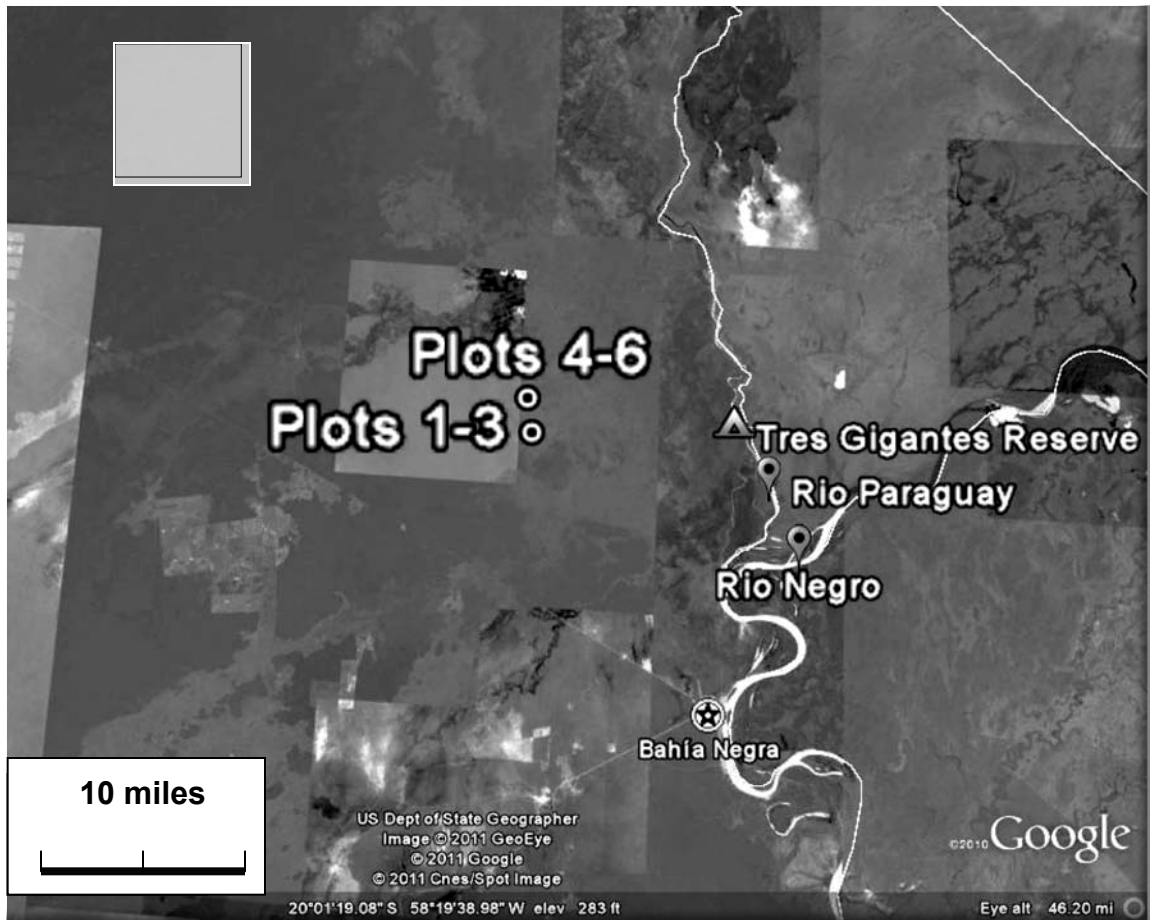


Figure 3.2. Study plots within 14 km (8.7 miles) of the Biological Reserve, *Tres Gigantes*.



Figure 3.3. Juvenile palms in understory codominated with grasses, and regenerating woody scrub.



Figure 3.4. Woody scrub patch of *Fabacea spp* 30 meters north of Plot 3 (Square flag against tree trunk is 0.28 x 0.22m).

Fire disturbance occurs regularly throughout the region. The region had experienced its last fire in September of 2009 and has a fire return interval of one to five years. The pasture clearing practices of ranchers located beyond the north and eastern borders along with strong northerly winds are often the cause for the spread of fires. Prior to the land reserve purchase, the land was previously owned by three to seven families between the 1960s and 1970s. The land was used for small scale ranching carrying over 3,000 cattle and palm harvesting. The land is not suitable for continuous ranching due to irregular large scale floods.

Site Selection & Data Collection

Plots were chosen randomly from savanna palm stands within a 0.5 km radius of two focal points. Each plot was a 50x 50m quadrant. Random coordinates were generated from two focal points within an area appearing to have similar succession patterns. The plots are not replicates and statistical analysis was performed on each plot separately.

A preliminary trip to the savannas was made in April of 2010 and the first set data was collected from Plots 1-3 during the middle of the-dry season (winter). Field measurements for Plots 4-6 were taken during the end of a light drought in November, 2010. Any palms completely defoliated or showing signs of stem damage were noted and included in the data set.

All palms with a stem of at least 1 m height were marked using a handheld global positioning system (GPS) (Garmin Etrex, Garmin Ltd., Kansas, USA). Several sets of ground truthed points showed that the measurements were typically accurate within 1 to 2 m. Diameter breast heights were recorded only for palms of at least 1.5 m stem height and lacking petiole sheathes which could bias diameter measurements. Juveniles had an established stem of at least 1.0 m and were less than 3.5 m in height. Height in this study does not include crowns. Adults were classified as all palms with stem heights ≥ 3.5 m. Palms which did not bear fronds were included. In measuring heights, the hypsometer technique was used for palms ≥ 5 m while shorter palms were measured directly using a flagged, three meter pole. Understory vegetation of study area was photographed during each excursion: late rainy season, dry season, and late dry season. Herbarium samples were submitted to Universidad Nacional de Asunción to assist in identification.

Data Analysis

Ripley's K was calculated using the Spatstat package (Baddeley & Turner 2005) in R project software (www.r-project.org; R Development Core Team 2010). Ripley's K, Diggle's F, and Diggle's G tests were executed to assess total palms with stems ≥ 1 m (Baddeley & Turner 2005). All three were used because each function offers different sensitivities. Diggle's F and G consider the total area of a population, and are more dependent of density than Ripley's K. Diggle's G is more sensitive to patterns of regularity while F is more sensitive to clustering. The transformed Ripley's K using $L(r)$ is sensitive to clustering, but offers the advantage of considering a population independent of its density (Ripley 1981; Cressie 1993; Barot et al. 1999). After analyzing the first population listed below with Diggle's F, Diggle's G, and Ripley's K, the population was separated into adult and juvenile classes based upon reproductive height of *C. alba* (Moraes 1991). The juvenile and adult populations were analyzed using the transformed Ripley's K method.

The three populations analyzed with Ripley's K method include:

- 1.) Total palms: all palms per plot of at least 1 meter height
- 2.) Juveniles: palms with stem heights of at least 1 m, less than 3.5m
- 3.) Adults: palms with stem heights greater than 3.5 m

Each of the six plots contained the three palm populations, resulting in 18 different graphs displaying the transformed Ripley's K. The null hypothesis for all 18 calculation sets was that the given population was randomly distributed. The alternative hypothesis was that patterns were either clustered (aggregated) or more dispersed (regular or repulsed).

The theoretical line on these graphs was generated using the following formula:

$$L(r) = \sqrt{\frac{A \sum_{i=1}^N \sum_{j=1, j \neq i}^N k(i, j)}{\pi N(N-1)}}$$

Where $L(r)$ is transformed Ripley's K , N is the number of palm individuals with an established stem of at least 1 m. The k reflects the relationship between two palm trees. Any initial palm reference (i) on the plot and a tally of all other palm trees (j) that fall within palm i 's neighborhood as defined by the radial distance (r), in meters.

Confidence envelopes were generated using 35 Monte Carlo simulations. These pseudo-forests modeling random distribution were compared to the observed values $L(r)$ values for a given palm population. When an observed $L(r)$ value is greater than the theoretical $L(r)$ and lies outside of the gray confidence envelopes, the pattern is clustered and spatial randomness is rejected as a null hypothesis. When the $L(r)$ values lie below the theoretical and outside the lower envelope, spatial randomness is again rejected and patterns are considered more dispersed. Regularity and repulsion are types of more dispersed patterns.

Chapter 4. Data

A total of 363 palms were measured in the six 50x50m plots. The complete data set is shown in Appendix A. Palm number, dbh size distribution, the mean heights, and stand height structure varied considerably from plot to plot (Figure 4.1, Table 4.1, Figure 4.2, Table 4.2). Plot 1 has the highest number of juveniles, 43, and Plot 2 has the lowest with 14 (Figure 4.1). Plot 4 had the highest number of adults. Plots 3 and 6 had approximately 1:1 ratios of adults to juveniles.

Basal area and palm densities varied among the six plots (Table 4.1). Plot 4 has the highest basal area and palm densities, with 63% of the population represented by adult palms. Basal area was more directly proportional to the percent of adult population than to total palm densities.

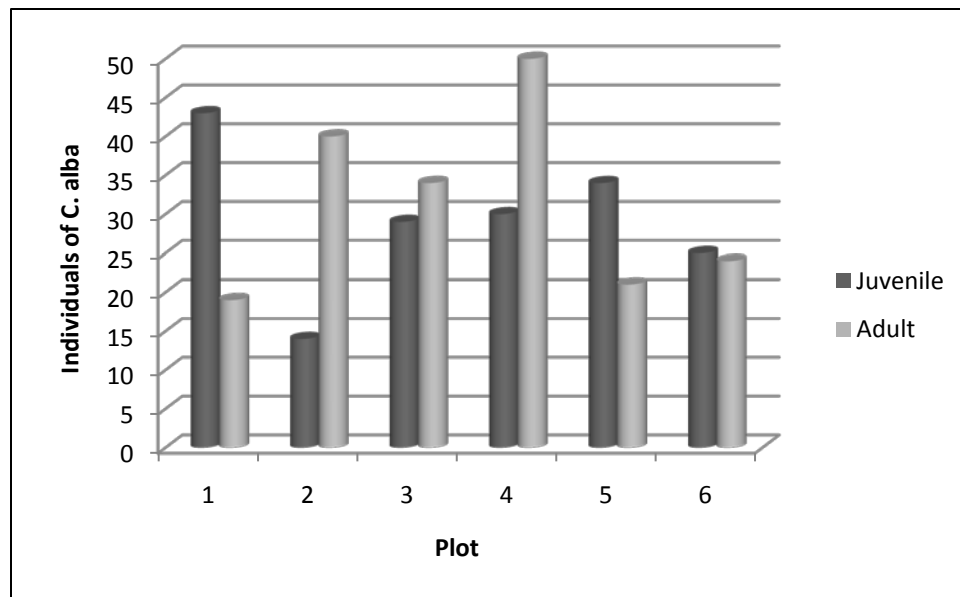


Figure 4.1. Palms with stem height 1m to 3.5m are juveniles, while adults are all standing palms ≥ 3.5 m height.

Table 4.1
Total palm individuals with stem height ≥ 1 m

Plot	Total	Palms ha ⁻¹	% Adults	Basal area	Juvenile:	Mean Ht
				m ² ha ⁻¹	Adult	
1	62	248	30.6	3.42	2.3 : 1.0	2.8
2	54	216	74.1	3.02	0.4 : 1.0	7.2
3	63	252	53.1	2.37	0.9 : 1.0	5.5
4	80	320	63.3	4.89	0.6 : 1.0	4.7
5	55	220	38.2	1.73	1.6 : 1.0	3.6
6	49	196	49.0	2.52	1.0 : 1.0	4.0

*Basal area does not include juvenile palms of a height less than 1.5 m

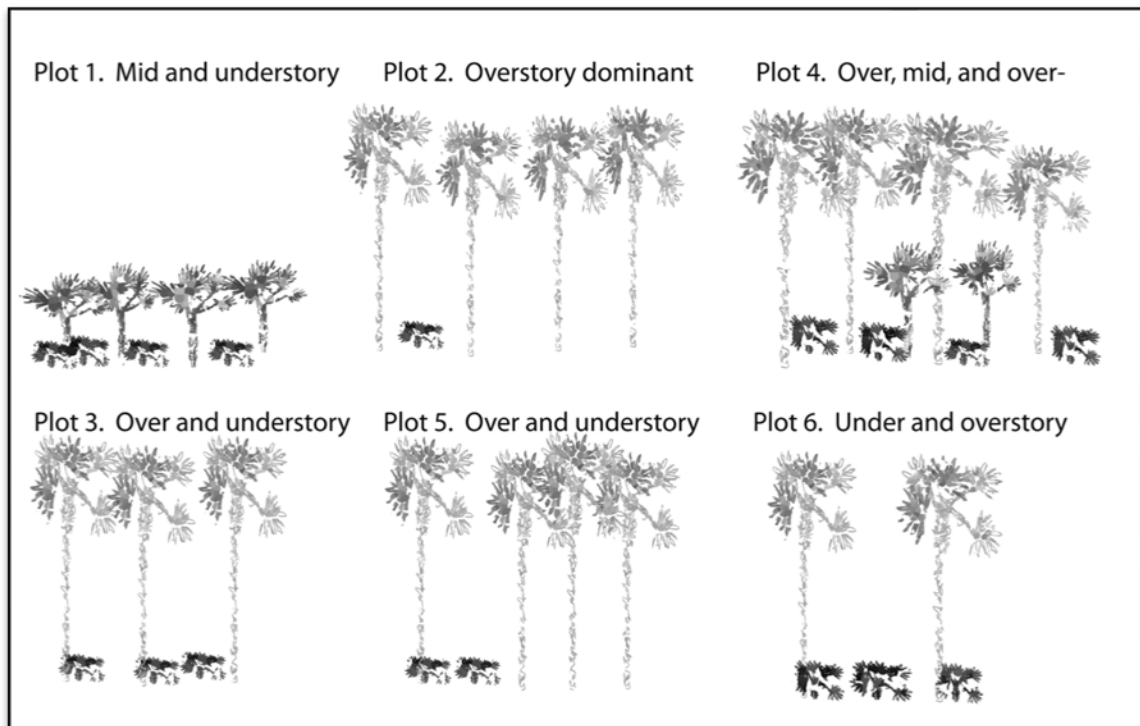


Figure 4.2. The height structure of palms in each plot occupying the under, mid, and overstory. Palms with heights ≤ 3 meters were defined as understory, while midstory was defined for palms of 3.5 to 5.5 meter heights. Overstory palms had heights of 5.5 to 15.5 meters. Each palm figure represents 10 to 15 palms rounded up to the nearest ten (see Table 4.2).

Table 4.2**The number of palms distributed by height class into stand structure for each plot.**

Stand Level	Height	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
	Bracket						
Understory	1.0 m	2	1	10	25	34	25
Understory	1.1-3.0 m	41	13	20	2	0	0
Midstory	3.1-5.5 m	36	3	1	16	0	3
Overstory	5.5-15 m	0	36	33	38	21	21

Each plot had a different stand height structure with the exception of Plots 3 and 6 having nearly 1:1 ratios of juveniles to adults. Plots 1, 2, and 4 were differ in demographic composition (Figure 4.2 top row & Table 4.2). Plot 1 is a young stand comprised mostly of palms in the understory. Plot 2 is an older stand comprised with the most palms occupying the overstory. Both stands had palms too small (<1 m height) to be included in this study (Figure 3.3 Plot 2). Plot 4 had the most prominent midstory, giving it the most even structure as well. Plots 3, 5, and 6 each have population demographics divided among the understory and overstory (Figure 4.2 bottom row). Plots 3 and 6 were most similar in structure. A patch of midstory woody scrub was located approximately 30 meters north of Plot 3 (Figure 3.4). Plot 5 contain a patches of woody scrub in its northeast quadrant, and like plot 3, appeared to have less recruitment of young seedlings than Plots 1 and 2 (Figures 3.4 and 4.3).



Figures 4.3 and Figure 4.4. (Photo above is Plot 5 and photo below is a stand near plots 4, 5, and 6). Stands are of similar succession type but varying in plant height and succession stage.

Chapter 5. Results

The first section, “Total Palms Population;” describes the random and clustered results generated from all palms with a stem height greater than 1 m. The second section, “Juveniles and adults” presents the results where juveniles are clustered and adults consistently have lower $L(r)$ values than juveniles.

Total Palms Population

When Ripley’s K was calculated for palms with a stem height greater than 1 m, clustering and randomness were not consistent for all six plots (Figure 5.1). Both clustered and random distributions were found at various scales in Plots 1, 2, 5, and 6. Plots 3 and 4 showed random distributions at nearly all scales. Plot 3 patterns fluctuated above and below the theoretical line within the confidence envelope for random distribution while Plot 4 exhibited random patterns with clustering tendencies at all scales. The Diggle’s F and G tests did not show any significant patterns based upon density (Appendix B).

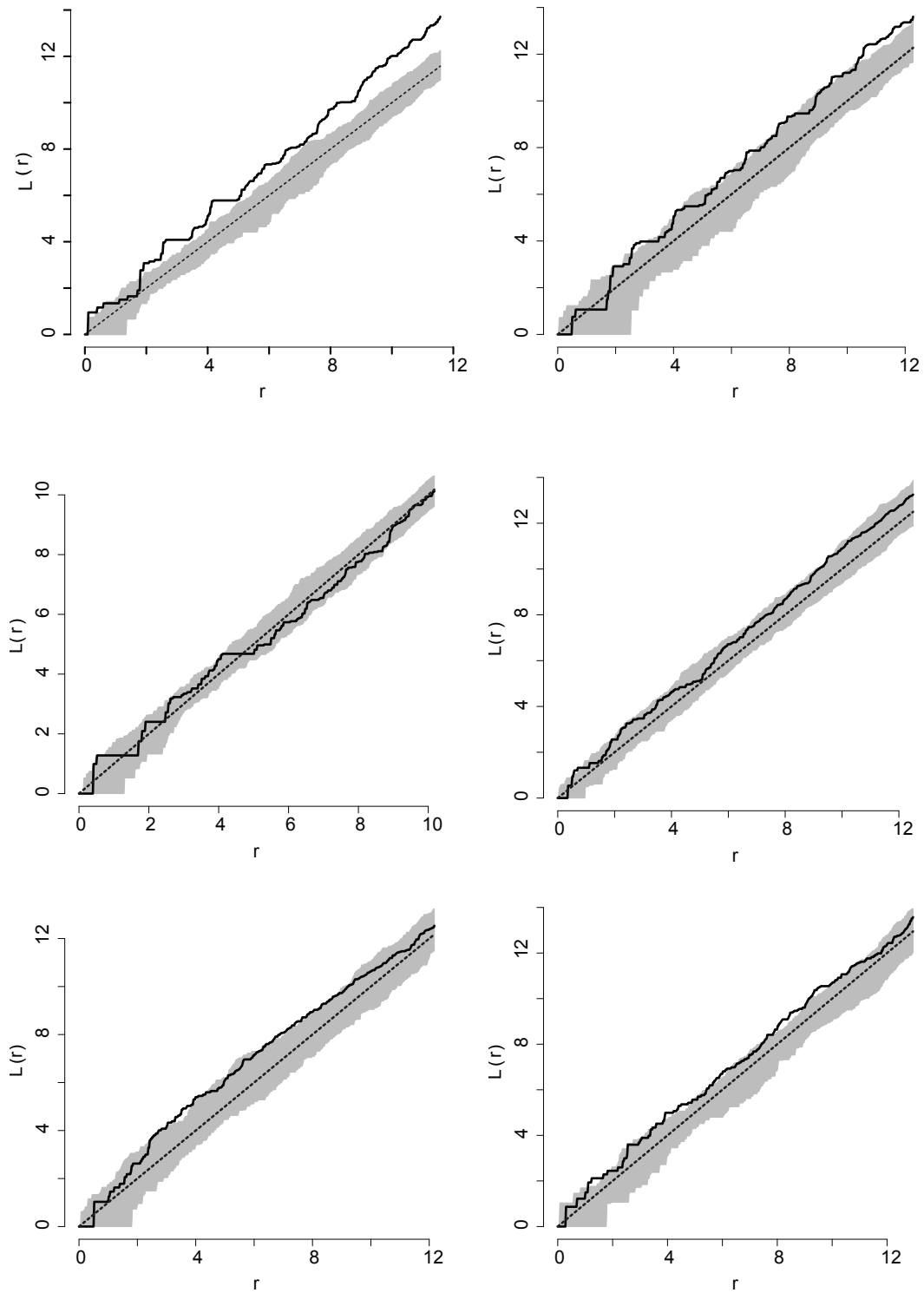


Figure 5.1. Ripley's K test for total palm populations. Plots 1 & 2 (top row), Plots 3 & 4 (middle), and Plots 5 & 6 (bottom) are shown where r = radius and $L(r)$ = the transformed Ripley's K. Total populations display both random and clustered patterns with the exception of Plots 3 and 4.

Juveniles and Adults

When the data set was separated by height class, juveniles tended to cluster while adults were more randomly distributed. This occurred in Plots 1, 2, 4, and 5. For Plots 3 and 6, both juveniles and adults were randomly distributed; however, the adults had lower $L(r)$ values than the juvenile populations for any given r (Figures 5.2 and 5.3)

In Plot 1, Figure 5.2 (top row), clusters were observed among juveniles at distances 2 m to 12 m and adults were found randomly distributed at distances 0 to 12m. This plot had the highest number of juveniles (Figure 4.1 and Table 4.1) and the lowest number of adults of all six plots. There was a larger confidence envelope in the adult population because the sample size was only comprised of 19 individuals compared to the 43 juveniles.

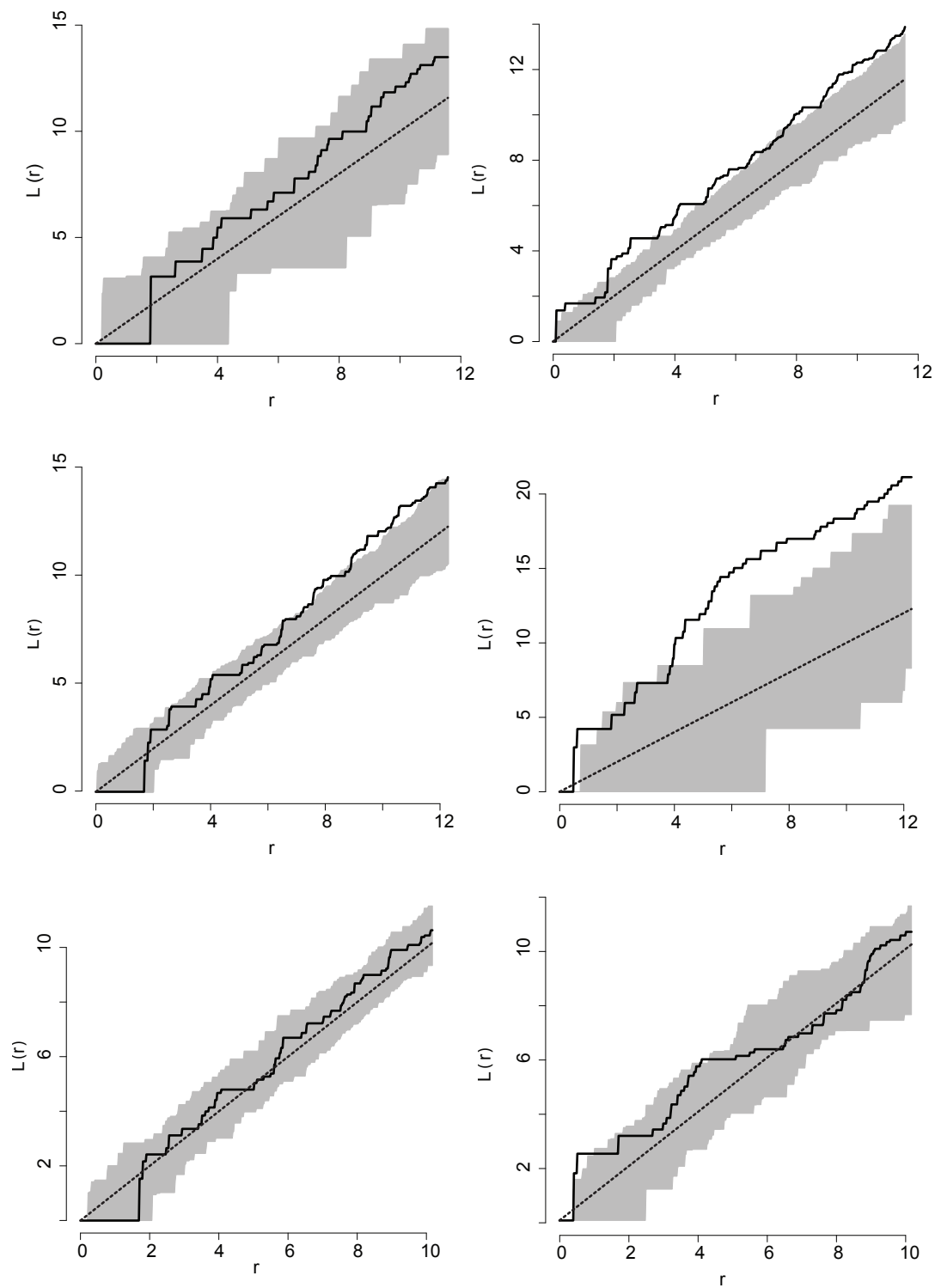


Figure 5.2. Ripley's K test for randomness in adult (left column) and juvenile populations (right column) for Plot 1 (top row), Plot 2 (middle), and Plot 3 (bottom) where r = radius and $L(r)$ = the transformed Ripley's K. Adult populations are less clustered than juveniles, having lower $L(r)$ values than the expected or theoretical values for spatial randomness.

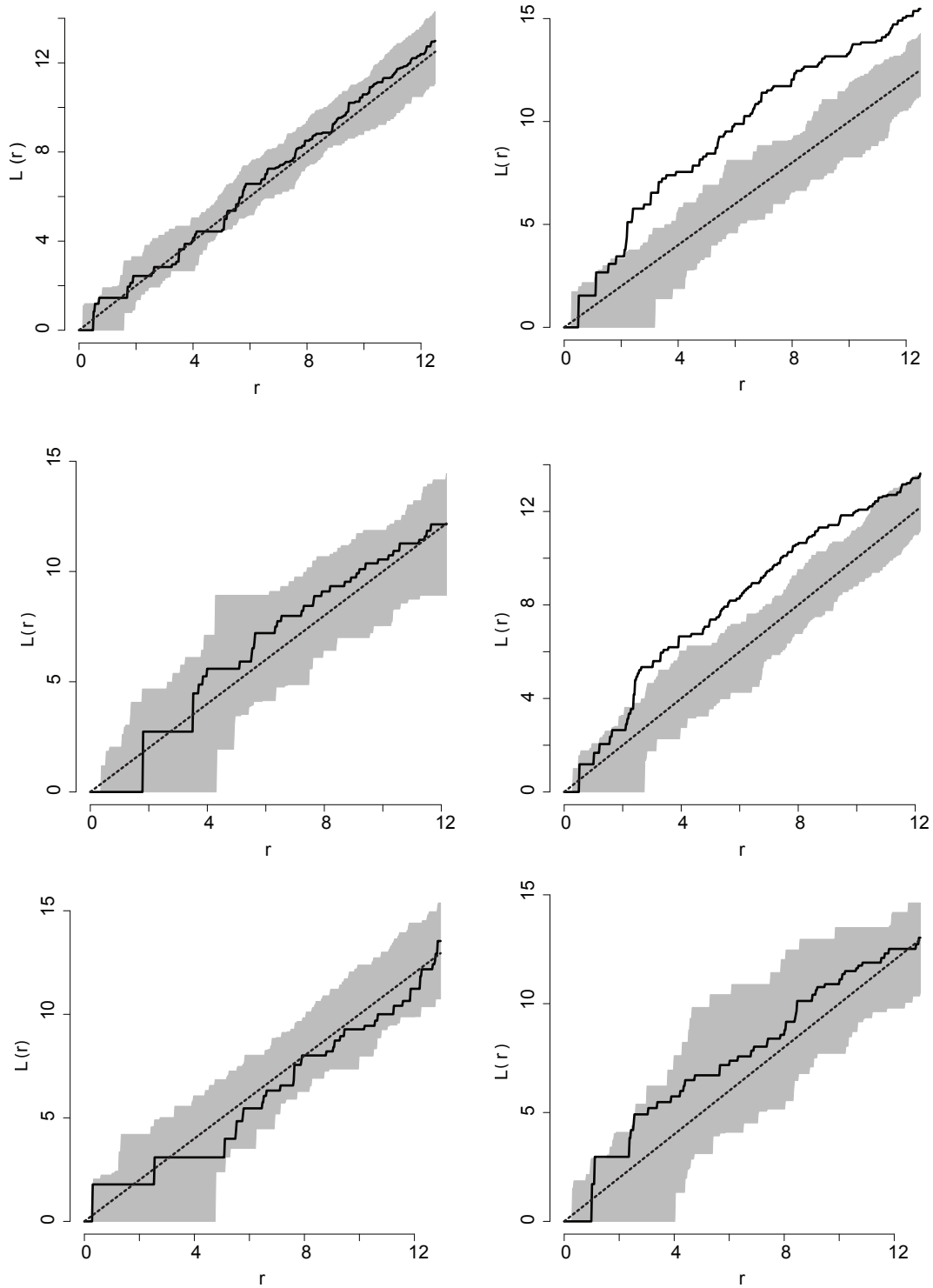


Figure 5.3. Ripley's K test for randomness in adult (left column) and juvenile populations for Plot 4 (top row), Plot 5 (middle), and Plot 6 (bottom) where r = radius and $L(r)$ = the transformed Ripley's K. Adult populations are less clustered than juveniles.

The same basic pattern, where juveniles were clustered while adults were randomly distributed, was found in Plots 2, 4 and 5 at distances 4 m to 10 m (Figure 5.3). In Plots 3 and 6, juveniles exhibited a random distribution. Across all plots, however, adults remained less clustered than the juvenile population. In Plot 2, for example, adults were found clustered at 9 to 12m (Figure 5.2). The juveniles of plot 2, however, were found clustered along the entire distance 4 to 12 m and have higher $L(r)$ values, extending farther from the confidence envelopes than the adult population. Most adult clustering in this plot was accounted for by two linear patches (Figure 5.4). The number of juveniles was low and so most of the clustering represented was from a single circular clump (Figure 5.4). In Plots 3 and 6, the random distributions of juveniles had $L(r)$ values above theoretical random line at distances up to 6.5 meters, fluctuating between random and clustered patterns. The adults, on the other hand, remained close to the theoretical projection for randomness. Plot 6 juveniles also had higher $L(r)$ values than the adult population that exhibited more regular or dispersed patterns. Spatial symbol diagrams are included in Appendix C.

For the total palms with stems greater than 1 meter, three plots exhibited a random distribution and three plots exhibited a clustered distribution. In separating each plot population by into juvenile and adult height classes a consistent shift from clustered juveniles to less clustered adults was found among all six plots. This shift was found despite differences in density, height ratios, and stand height structure among plots (Table 4.1, Table 4.2, Figure 4.3, Figure 4.4).

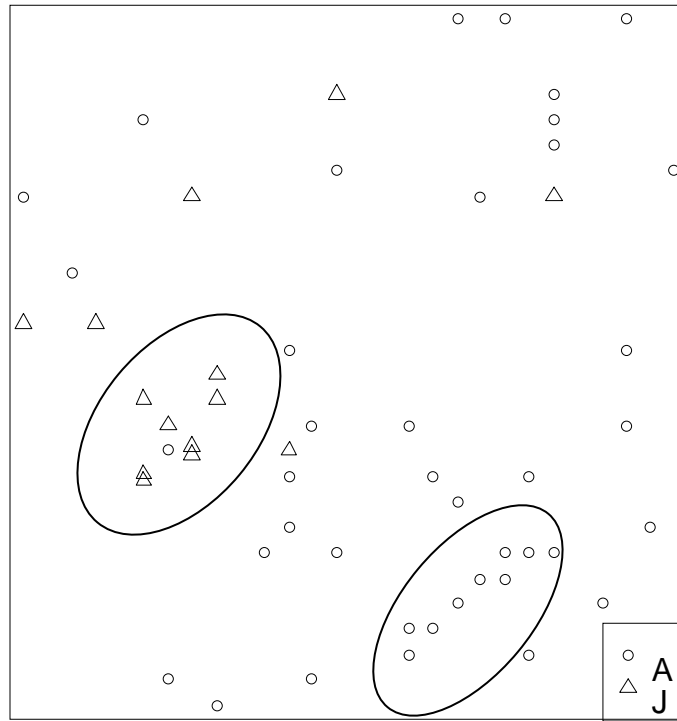


Figure 5.4: Plot 2. A primary patch of adults (small circles) and a patch of juveniles (triangles) attribute to clustering.

Chapter 6. Discussion

This shift from clustered juveniles and less clustered adults has also been found in other palm species, both in savanna and montane rain forests (Barot et al. 1999; Svenning 2001), and in other tree species (Pielou 1962; Antonovics & Primack 1980; Sterner et al. 1986; He 1997; Wiegand et al. 2007; Fangliang et al. 2009) and dominant shrubs (Gibson 1994).

Factors influencing this shift within the palm populations can be separated into two categories:

1. Intrinsic factors- variables innately characteristic to the palms' population dynamics, relative to self-thinning and seed dispersion.
2. Extrinsic factors- elements in the environment, relative to the local scale and time. Examples include moisture availability, soil substrate, fire, wind, and seed dispersers.

Since *C. alba* is an R strategy species with high fecundity, intrinsic factors such as self thinning and seed dispersion are potential drivers of the shift of patterns in the six plots. Localized seed dispersion may explain the clustering in juveniles, while self-thinning may explain the more random distributions found in adults (Barot et al. 1999; Pielou 1962). Self-thinning among juveniles is reliant on palms reaching equilibrium within a given carrying capacity of their environment. Throughout time *C. alba* could require different levels of nutrients or moisture at different stages of development.

The influence of water availability, soil substrate, and fire disturbance on vegetation patterns are generally more apparent at mesoscales and metascales (Greig-Smith 1979; Svenning et al. 2001; Overgaard 2010). Even so, isolated events of fire disturbance, local differences in soil nutrients, and differences in localized moisture availability could alter palm distribution at scales less than 12 meters.

Mechanisms drawn between *C. alba*'s distribution and water availability at the local scale could be affected by soil drainage and climate. The terrain of the study site is fairly flat; however, slight inclines and differences in soil substrate could lead to uneven moisture availability. In terms of climate, the amount of rainfall and time-frame in which

it falls can vary from year to year. Cloud cover and temperatures that follow rain could affect the rate of soil evaporation and ultimately affect the ability of seedlings to establish roots when the soil is hardened clay

C. alba, like many species, is able to maintain a widespread presence within the floodplains, through traits which serve in both floods and droughts (Parolin 2004). Even so, droughts and large scale flood that might extend inland could induce mortality among juveniles and seedlings. Conversely, both events could play a role in triggering germination. Soil substrates and nutrient patches could also influence the recruitment and clustering (Barot et al. 1999; Svenning et al. 2001). This is particularly important in considering *C. alba*'s spatial patterns because the plant is often associated with alluvial flood plains carrying heterogeneous deposits of salt and sediment (Neiff 2001; Hamilton 2002; Vidaurre et al. 2008; Keuroghlian et al. 2009; Navarro et al. 2011). *C. alba* has been associated with magnesium and heavy silts, but at larger scales across the Chaco (Navarro et al. 2011).

Fire disturbance could affect mortality or trigger seed germination similar to moisture availability (Neiff 2001). Occasionally burnt juveniles were found in the plots (Figure 6.1). Long-term studies assessing meristem burns, palm vitality, and the height of burns on the stems could reveal more about the natural disturbances affect on the palm population. As many savanna fires are light in intensity and move fairly fast using grass as the primary fire fuel, this could provide an environment of reduced competition for the seedlings. Fires can enhance soil quality at a local scale level through the addition of available nutrients. For established plants such as the juveniles, fire could stimulate growth whether it be from increased nutrient loads in soils or from hypercellular repair mechanisms. For adults, fire could possibly stimulate the production of fruit. In relation to plant to plant interactions, annual fires may cause dieback, maintaining woody species in the understory, which ultimately could affect competition of juveniles (Hoffmann 1999; Cabral 2003). Although savanna fires can drive vegetation and trees to cluster at the landscape scale (Fulé & Covington 1998; Caylor 2006), fire impacts at a local scale are less predictable.



Figure 6.1 Juvenile mortality. Photo taken six months after the 2009 fire.

Lastly, extrinsic factors can also play a role in seed dispersal mechanisms. The wind patterns can play a role in distance and direction in which seeds may be dispersed. Small rodents, bats, and birds can distribute seeds at varying distances, altering spatial patterns. Proximity to forest corridors and seasonal ponds should also be taken into consideration for their ability to harbor a higher diversity and higher population of seed predators (Naiman et al. 1993). Plots 3 and 5 border small patches of scrub less than 0.2 km and 1.0 km in diameter, respectively. Over a long-period of time, these patches and corridors can change with fire disturbance.

Future studies addressing the influence of fire, soil, or population dynamics of the palm could help understand the mechanisms driving the clustering in juveniles and less clustering in adults at a small scale. Long-term studies would lead to a deeper understanding of how these ecosystems are changing in response to fire and large scale river floods. These processes can be useful in understanding the basis of savanna ecology and also in understanding the change of patterns over longer periods of climate change and more frequent fire regimes.

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[Appendix A](#). Summary Tables and Raw Data

Table A.1
Palms with stem height $\geq 1\text{m}$

Plot	Juvenile	Adult	Total
1	43	19	62
2	14	40	54
3	29	34	63
4	30	50	80
5	34	21	55
6	25	24	49

Table A.2

Data: Field dbh, height (Ht), and calculations for dbh distributions.

Plot	GPS	BA Calc	BA	DBH Count	DBH Count	DBH Count	DBH Count	DBH raw	Ht
#	way	dbh/ 200	(m ²)	Null (cm)	10cm to 14.9 cm	15cm to 19.9 cm	≥20 cm	(cm)	(m)
P1	55	0.000	0.000	1	0	0	0	0.0	1.0
P1	62	0.000	0.000	1	0	0	0		1.0
P1	54	0.000	0.000	1	0	0	0		1.2
P1	52	0.000	0.000	1	0	0	0		1.3
P1	63	0.000	0.000	1	0	0	0		1.3
P1	53	0.000	0.000	1	0	0	0		1.4
P1	61	0.000	0.000	1	0	0	0		1.4
P1	50	0.000	0.000	1	0	0	0		1.5
P1	51	0.000	0.000	1	0	0	0		1.5
P1	64	0.000	0.000	1	0	0	0		1.5
P1	56	0.000	0.000	1	0	0	0		1.7
P1	60	0.000	0.000	1	0	0	0		1.7
P1	57	0.000	0.000	1	0	0	0		1.8
P1	59	0.000	0.000	1	0	0	0		1.8
P1	28	0.000	0.000	1	0	0	0		2.0
P1	32	0.000	0.000	1	0	0	0		2.0
P1	58	0.000	0.000	1	0	0	0		2.0
P1	49	0.000	0.000	1	0	0	0		2.1
P1	11	0.075	0.017	0	1	0	0	14.9	2.5
P1	14	0.069	0.015	0	1	0	0	13.8	2.5
P1	24	0.068	0.015	0	1	0	0	13.6	2.5
P1	29	0.071	0.016	0	1	0	0	14.1	2.5
P1	34	0.081	0.020	0	0	1	0	16.1	2.5
P1	38	0.068	0.014	0	1	0	0	13.5	2.5
P1	45	0.072	0.016	0	1	0	0	14.4	2.5
P1	46	0.079	0.020	0	0	1	0	15.8	2.5

P1	7	0.082	0.021	0	0	1	0	16.3	3.0
P1	12	0.078	0.019	0	0	1	0	15.6	3.0
P1	13	0.068	0.014	0	1	0	0	13.5	3.0
P1	16	0.077	0.018	0	0	1	0	15.3	3.0
P1	18	0.068	0.014	0	1	0	0	13.5	3.0
P1	19	0.099	0.031	0	0	1	0	19.8	3.0
P1	20	0.065	0.013	0	1	0	0	13.0	3.0
P1	23	0.071	0.016	0	1	0	0	14.1	3.0
P1	25	0.083	0.021	0	0	1	0	16.5	3.0
P1	26	0.081	0.021	0	0	1	0	16.2	3.0
P1	27	0.088	0.024	0	0	1	0	17.5	3.0
P1	30	0.079	0.019	0	0	1	0	15.7	3.0
P1	33	0.075	0.018	0	0	1	0	15.0	3.0
P1	39	0.075	0.017	0	1	0	0	14.9	3.0
P1	41	0.076	0.018	0	0	1	0	15.2	3.0
P1	43	0.090	0.025	0	0	1	0	18.0	3.0
P1	44	0.063	0.012	0	1	0	0	12.6	3.0
P1	3	0.089	0.025	0	0	1	0	17.7	3.5
P1	6	0.067	0.014	0	1	0	0	13.3	3.5
P1	15	0.077	0.018	0	0	1	0	15.3	3.5
P1	17	0.062	0.012	0	1	0	0	12.4	3.5
P1	31	0.087	0.024	0	0	1	0	17.3	3.5
P1	35	0.079	0.019	0	0	1	0	15.7	3.5
P1	36	0.060	0.011	0	1	0	0	12.0	3.5
P1	37	0.082	0.021	0	0	1	0	16.3	3.5
P1	47	0.101	0.032	0	0	0	1	20.2	3.5
P1	48	0.087	0.024	0	0	1	0	17.4	3.5
P1	5	0.080	0.020	0	0	1	0	15.9	4.0
P1	8	0.081	0.020	0	0	1	0	16.1	4.0
P1	9	0.076	0.018	0	0	1	0	15.2	4.0
P1	21	0.076	0.018	0	0	1	0	15.1	4.0
P1	40	0.105	0.035	0	0	0	1	21.0	4.0
P1	42	0.090	0.025	0	0	1	0	17.9	4.0
P1	22	0.071	0.016	0	1	0	0	14.1	4.5
P1	4	0.101	0.032	0	0	0	1	20.2	5.0

P1	10	0.070	0.015	0	1	0	0	13.9	5.0
P1	Sums	→	3.420	18	17	24	3		
P2	107	0.000	0.000	1	0	0	0		1.0
P2	108	0.000	0.000	1	0	0	0		1.2
P2	104	0.000	0.000	1	0	0	0		1.3
P2	113	0.000	0.000	1	0	0	0		1.3
P2	97	0.000	0.000	1	0	0	0		1.4
P2	98	0.000	0.000	1	0	0	0		1.4
P2	114	0.000	0.000	1	0	0	0		1.4
P2	100	0.000	0.000	1	0	0	0		1.5
P2	106	0.000	0.000	1	0	0	0		1.5
P2	112	0.000	0.000	1	0	0	0		1.5
P2	111	0.000	0.000	1	0	0	0		1.6
P2	95	0.000	0.000	1	0	0	0		1.7
P2	105	0.000	0.000	1	0	0	0		1.7
P2	110	0.000	0.000	1	0	0	0		1.9
P2	85	0.069	0.015	0	1	0	0	13.8	3.8
P2	120	0.104	0.034	0	0	0	1	20.8	4.0
P2	73	0.065	0.013	0	1	0	0	12.9	4.3
P2	89	0.077	0.019	0	0	1	0	15.4	5.8
P2	118	0.081	0.020	0	0	1	0	16.1	6.5
P2	77	0.075	0.017	0	1	0	0	14.9	7.0
P2	80	0.071	0.016	0	1	0	0	14.2	7.3
P2	119	0.078	0.019	0	0	1	0	15.5	7.5
P2	122	0.074	0.017	0	1	0	0	14.7	8.0
P2	70	0.063	0.012	0	1	0	0	12.6	8.3
P2	92	0.081	0.021	0	0	1	0	16.2	8.5
P2	117	0.077	0.019	0	0	1	0	15.4	8.5
P2	90	0.080	0.020	0	0	1	0	16.0	8.8
P2	71	0.080	0.020	0	0	1	0	15.9	8.9
P2	96	0.074	0.017	0	1	0	0	14.8	8.9
P2	91	0.073	0.017	0	1	0	0	14.5	9.0
P2	99	0.083	0.022	0	0	1	0	16.6	9.0

P2	109	0.073	0.017	0	1	0	0	14.6	9.0
P2	83	0.079	0.019	0	0	1	0	15.7	9.3
P2	101	0.080	0.020	0	0	1	0	16.0	9.3
P2	76	0.080	0.020	0	0	1	0	15.9	9.5
P2	102	0.095	0.028	0	0	1	0	18.9	9.5
P2	66	0.072	0.016	0	1	0	0	14.4	9.7
P2	72	0.084	0.022	0	0	1	0	16.7	9.7
P2	81	0.077	0.018	0	0	1	0	15.3	10.0
P2	88	0.070	0.015	0	1	0	0	13.9	10.0
P2	103	0.083	0.021	0	0	1	0	16.5	10.0
P2	69	0.087	0.024	0	0	1	0	17.4	10.3
P2	93	0.069	0.015	0	1	0	0	13.7	10.3
P2	94	0.068	0.014	0	1	0	0	13.5	10.3
P2	87	0.087	0.024	0	0	1	0	17.4	10.4
P2	79	0.069	0.015	0	1	0	0	13.7	10.5
P2	121	0.099	0.030	0	0	1	0	19.7	10.7
P2	123	0.062	0.012	0	1	0	0	12.4	10.7
P2	74	0.073	0.017	0	1	0	0	14.6	10.8
P2	67	0.068	0.014	0	1	0	0	13.5	11.0
P2	68	0.069	0.015	0	1	0	0	13.7	11.3
P2	75	0.088	0.024	0	0	1	0	17.5	12.0
P2	78	0.079	0.019	0	0	1	0	15.7	14.5
P2	116	0.073	0.017	0	1	0	0	14.6	15.0
P2	Sums	→	3.017	14	19	20	1		
P3	133	0.000	0.000	1	0	0	0		1.0
P3	138	0.000	0.000	1	0	0	0		1.0
P3	140	0.000	0.000	1	0	0	0		1.0
P3	146	0.000	0.000	1	0	0	0		1.0
P3	152	0.000	0.000	1	0	0	0		1.0
P3	158	0.000	0.000	1	0	0	0		1.0
P3	163	0.000	0.000	1	0	0	0		1.0
P3	172	0.000	0.000	1	0	0	0		1.0
P3	175	0.000	0.000	1	0	0	0		1.0
P3	178	0.000	0.000	1	0	0	0		1.0

P3	160	0.000	0.000	1	0	0	0	1.1	
P3	170	0.000	0.000	1	0	0	0	1.1	
P3	176	0.000	0.000	1	0	0	0	1.1	
P3	141	0.000	0.000	1	0	0	0	1.2	
P3	127	0.000	0.000	1	0	0	0	1.3	
P3	166	0.000	0.000	1	0	0	0	1.3	
P3	167	0.000	0.000	1	0	0	0	1.3	
P3	139	0.000	0.000	1	0	0	0	1.4	
P3	147	0.000	0.000	1	0	0	0	1.4	
P3	165	0.000	0.000	1	0	0	0	1.4	
P3	177	0.000	0.000	1	0	0	0	1.4	
P3	132	0.000	0.000	1	0	0	0	1.5	
P3	174	0.000	0.000	1	0	0	0	1.5	
P3	173	0.000	0.000	1	0	0	0	1.6	
P3	142	0.000	0.000	1	0	0	0	1.7	
P3	182	0.000	0.000	1	0	0	0	1.8	
P3	187	0.000	0.000	1	0	0	0	1.8	
P3	135	0.000	0.000	1	0	0	0	2.0	
P3	190	0.000	0.000	1	0	0	0	2.0	
P3	168	0.000	0.000	1	0	0	0	2.2	
P3	184	0.088	0.024	0	0	1	0	17.6	4.3
P3	144	0.092	0.026	0	0	1	0	18.3	6.5
P3	134	0.069	0.015	0	1	0	0	13.7	7.0
P3	171	0.069	0.015	0	1	0	0	13.8	7.5
P3	143	0.073	0.017	0	1	0	0	14.6	7.6
P3	129	0.081	0.021	0	0	1	0	16.2	7.7
P3	164	0.097	0.030	0	0	1	0	19.4	7.7
P3	169	0.082	0.021	0	0	1	0	16.4	8.0
P3	154	0.072	0.016	0	1	0	0	14.4	8.3
P3	151	0.067	0.014	0	1	0	0	13.3	8.4
P3	181	0.068	0.015	0	1	0	0	13.6	8.7
P3	185	0.064	0.013	0	1	0	0	12.8	8.7
P3	186	0.060	0.011	0	1	0	0	11.9	8.7
P3	137	0.059	0.011	0	1	0	0	11.8	9.0
P3	157	0.084	0.022	0	0	1	0	16.8	9.0

P3	179	0.085	0.023	0	0	1	0	17.0	9.0
P3	183	0.069	0.015	0	1	0	0	13.8	9.0
P3	134	0.065	0.013	0	1	0	0	12.9	9.3
P3	180	0.077	0.018	0	0	1	0	15.3	9.3
P3	149	0.075	0.017	0	1	0	0	14.9	9.4
P3	155	0.063	0.012	0	1	0	0	12.6	9.4
P3	156	0.076	0.018	0	0	1	0	15.2	9.4
P3	130	0.075	0.018	0	0	1	0	15.0	9.5
P3	162	0.061	0.011	0	1	0	0	12.1	9.6
P3	188	0.085	0.023	0	0	1	0	17.0	10.0
P3	136	0.057	0.010	0	1	0	0	11.4	10.3
P3	145	0.069	0.015	0	1	0	0	13.8	10.4
P3	153	0.081	0.021	0	0	1	0	16.2	10.4
P3	159	0.074	0.017	0	1	0	0	14.7	10.4
P3	191	0.078	0.019	0	0	1	0	15.6	10.6
P3	148	0.082	0.021	0	0	1	0	16.3	10.7
P3	150	0.078	0.019	0	0	1	0	15.5	10.7
P3	189	0.081	0.020	0	0	1	0	16.1	11.0
P3	161	0.061	0.011	0	1	0	0	12.1	12.4
P3	Sums	→	2.371	30	18	16	0		
P4	48	0.000	0.000	1	0	0	0	1.0	
P4	49	0.000	0.000	1	0	0	0	1.0	
P4	50	0.000	0.000	1	0	0	0	1.0	
P4	51	0.000	0.000	1	0	0	0	1.0	
P4	61	0.000	0.000	1	0	0	0	1.0	
P4	62	0.000	0.000	1	0	0	0	1.0	
P4	63	0.000	0.000	1	0	0	0	1.0	
P4	64	0.000	0.000	1	0	0	0	1.0	
P4	65	0.000	0.000	1	0	0	0	1.0	
P4	66	0.000	0.000	1	0	0	0	1.0	
P4	67	0.000	0.000	1	0	0	0	1.0	
P4	68	0.000	0.000	1	0	0	0	1.0	
P4	69	0.000	0.000	1	0	0	0	1.0	
P4	70	0.000	0.000	1	0	0	0	1.0	

P4	71	0.000	0.000	1	0	0	0		1.0
P4	72	0.000	0.000	1	0	0	0		1.0
P4	73	0.000	0.000	1	0	0	0		1.0
P4	74	0.000	0.000	1	0	0	0		1.0
P4	75	0.000	0.000	1	0	0	0		1.0
P4	76	0.000	0.000	1	0	0	0		1.0
P4	77	0.000	0.000	1	0	0	0		1.0
P4	78	0.000	0.000	1	0	0	0		1.0
P4	79	0.000	0.000	1	0	0	0		1.0
P4	80	0.000	0.000	1	0	0	0		1.0
P4	81	0.000	0.000	1	0	0	0		1.0
P4	6	0.000	0.000	1	0	0	0		1.3
P4	25	0.077	0.018	0	0	1	0	15.3	2.3
P4	28	0.099	0.031	0	0	1	0	19.8	3.1
P4	7	0.098	0.030	0	0	1	0	19.5	3.5
P4	32	0.095	0.028	0	0	1	0	19.0	3.7
P4	19	0.103	0.033	0	0	0	1	20.6	3.9
P4	3	0.093	0.027	0	0	1	0	18.5	4.0
P4	18	0.090	0.025	0	0	1	0	18.0	4.0
P4	13	0.092	0.027	0	0	1	0	18.4	4.4
P4	14	0.075	0.017	0	1	0	0	14.9	4.5
P4	17	0.095	0.028	0	0	1	0	19.0	4.7
P4	11	0.090	0.025	0	0	1	0	18.0	4.9
P4	22	0.082	0.021	0	0	1	0	16.3	4.9
P4	44	0.100	0.031	0	0	1	0	19.9	4.9
P4	15	0.101	0.032	0	0	0	1	20.2	5.2
P4	27	0.085	0.022	0	0	1	0	16.9	5.3
P4	42	0.108	0.037	0	0	0	1	21.6	5.5
P4	47	0.107	0.036	0	0	0	1	21.4	5.5
P4	45	0.097	0.030	0	0	1	0	19.4	6.0
P4	52	0.072	0.016	0	1	0	0	14.3	6.3
P4	60	0.105	0.035	0	0	0	1	21.0	6.4
P4	2	0.098	0.030	0	0	1	0	19.5	6.5
P4	24	0.095	0.028	0	0	1	0	18.9	6.6
P4	41	0.075	0.017	0	1	0	0	14.9	6.7

P4	8	0.101	0.032	0	0	0	1	20.1	6.8
P4	10	0.089	0.025	0	0	1	0	17.7	6.9
P4	26	0.079	0.020	0	0	1	0	15.8	6.9
P4	29	0.071	0.016	0	1	0	0	14.2	6.9
P4	34	0.108	0.036	0	0	0	1	21.5	6.9
P4	31	0.081	0.021	0	0	1	0	16.2	7.0
P4	38	0.071	0.016	0	1	0	0	14.2	7.0
P4	56	0.073	0.017	0	1	0	0	14.5	7.1
P4	12	0.102	0.032	0	0	0	1	20.3	7.2
P4	23	0.085	0.022	0	0	1	0	16.9	7.3
P4	30	0.084	0.022	0	0	1	0	16.7	7.3
P4	53	0.074	0.017	0	1	0	0	14.8	7.3
P4	43	0.066	0.014	0	1	0	0	13.2	7.4
P4	4	0.068	0.014	0	1	0	0	13.5	7.6
P4	54	0.070	0.015	0	1	0	0	14.0	7.7
P4	55	0.080	0.020	0	0	1	0	15.9	7.9
P4	16	0.073	0.017	0	1	0	0	14.6	8.0
P4	40	0.085	0.022	0	0	1	0	16.9	8.0
P4	21	0.094	0.027	0	0	1	0	18.7	8.1
P4	35	0.071	0.016	0	1	0	0	14.2	8.3
P4	46	0.065	0.013	0	1	0	0	13.0	8.3
P4	20	0.083	0.022	0	0	1	0	16.6	8.4
P4	33	0.087	0.024	0	0	1	0	17.3	8.4
P4	37	0.070	0.015	0	1	0	0	13.9	8.5
P4	59	0.072	0.016	0	1	0	0	14.3	8.6
P4	39	0.077	0.018	0	0	1	0	15.3	8.7
P4	57	0.086	0.023	0	0	1	0	17.2	8.7
P4	58	0.075	0.018	0	0	1	0	15.0	8.9
P4	36	0.061	0.012	0	1	0	0	12.2	9.3
P4	9	0.071	0.016	0	1	0	0	14.2	9.4
P4	Sums	→	4.891	26	17	28	8		
P5	115	0.000	0.000	1	0	0	0		1.0
P5	116	0.000	0.000	1	0	0	0		1.0
P5	117	0.000	0.000	1	0	0	0		1.0

P5	118	0.000	0.000	1	0	0	0	1.0	
P5	119	0.000	0.000	1	0	0	0	1.0	
P5	120	0.000	0.000	1	0	0	0	1.0	
P5	121	0.000	0.000	1	0	0	0	1.0	
P5	122	0.000	0.000	1	0	0	0	1.0	
P5	123	0.000	0.000	1	0	0	0	1.0	
P5	124	0.000	0.000	1	0	0	0	1.0	
P5	125	0.000	0.000	1	0	0	0	1.0	
P5	126	0.000	0.000	1	0	0	0	1.0	
P5	127	0.000	0.000	1	0	0	0	1.0	
P5	128	0.000	0.000	1	0	0	0	1.0	
P5	129	0.000	0.000	1	0	0	0	1.0	
P5	130	0.000	0.000	1	0	0	0	1.0	
P5	131	0.000	0.000	1	0	0	0	1.0	
P5	132	0.000	0.000	1	0	0	0	1.0	
P5	133	0.000	0.000	1	0	0	0	1.0	
P5	134	0.000	0.000	1	0	0	0	1.0	
P5	135	0.000	0.000	1	0	0	0	1.0	
P5	136	0.000	0.000	1	0	0	0	1.0	
P5	137	0.000	0.000	1	0	0	0	1.0	
P5	138	0.000	0.000	1	0	0	0	1.0	
P5	139	0.000	0.000	1	0	0	0	1.0	
P5	140	0.000	0.000	1	0	0	0	1.0	
P5	141	0.000	0.000	1	0	0	0	1.0	
P5	142	0.000	0.000	1	0	0	0	1.0	
P5	143	0.000	0.000	1	0	0	0	1.0	
P5	144	0.000	0.000	1	0	0	0	1.0	
P5	145	0.000	0.000	1	0	0	0	1.0	
P5	146	0.000	0.000	1	0	0	0	1.0	
P5	147	0.000	0.000	1	0	0	0	1.0	
P5	148	0.000	0.000	1	0	0	0	1.0	
P5	86	0.080	0.020	0	0	1	0	15.9	6.5
P5	95	0.077	0.018	0	0	1	0	15.3	6.6
P5	102	0.074	0.017	0	1	0	0	14.8	6.7
P5	101	0.084	0.022	0	0	1	0	16.8	6.9

P5	84	0.073	0.017	0	1	0	0	14.5	7.0
P5	94	0.076	0.018	0	0	1	0	15.2	7.0
P5	88	0.082	0.021	0	0	1	0	16.3	7.1
P5	85	0.085	0.023	0	0	1	0	17.0	7.2
P5	107	0.090	0.025	0	0	1	0	17.9	7.2
P5	108	0.085	0.022	0	0	1	0	16.9	7.2
P5	92	0.075	0.017	0	1	0	0	14.9	7.4
P5	105	0.085	0.023	0	0	1	0	17.0	7.6
P5	87	0.065	0.013	0	1	0	0	13.0	7.7
P5	96	0.092	0.027	0	0	1	0	18.4	7.7
P5	103	0.077	0.018	0	0	1	0	15.3	8.0
P5	83	0.074	0.017	0	1	0	0	14.8	8.1
P5	97	0.085	0.023	0	0	1	0	17.0	8.3
P5	89	0.069	0.015	0	1	0	0	13.7	8.4
P5	104	0.085	0.022	0	0	1	0	16.9	8.9
P5	82	0.101	0.032	0	0	0	1	20.1	9.0
P5	106	0.082	0.021	0	0	1	0	16.3	12.9
P5	Sums	→	1.726	34	6	14	1		
P6	152	0.000	0.000	1	0	0	0		1.0
P6	154	0.000	0.000	1	0	0	0		1.0
P6	155	0.000	0.000	1	0	0	0		1.0
P6	156	0.000	0.000	1	0	0	0		1.0
P6	159	0.000	0.000	1	0	0	0		1.0
P6	160	0.000	0.000	1	0	0	0		1.0
P6	161	0.000	0.000	1	0	0	0		1.0
P6	164	0.000	0.000	1	0	0	0		1.0
P6	165	0.000	0.000	1	0	0	0		1.0
P6	166	0.000	0.000	1	0	0	0		1.0
P6	167	0.000	0.000	1	0	0	0		1.0
P6	171	0.000	0.000	1	0	0	0		1.0
P6	175	0.000	0.000	1	0	0	0		1.0
P6	176	0.000	0.000	1	0	0	0		1.0
P6	177	0.000	0.000	1	0	0	0		1.0
P6	178	0.000	0.000	1	0	0	0		1.0

P6	181	0.000	0.000	1	0	0	0	1.0
P6	182	0.000	0.000	1	0	0	0	1.0
P6	183	0.000	0.000	1	0	0	0	1.0
P6	184	0.000	0.000	1	0	0	0	1.0
P6	190	0.000	0.000	1	0	0	0	1.0
P6	191	0.000	0.000	1	0	0	0	1.0
P6	193	0.000	0.000	1	0	0	0	1.0
P6	198	0.000	0.000	1	0	0	0	1.0
P6	201	0.000	0.000	1	0	0	0	1.0
P6	196	0.102	0.032	0	0	0	1	20.3 4.5
P6	192	0.090	0.025	0	0	1	0	17.9 5.1
P6	157	0.100	0.031	0	0	0	1	20.0 5.3
P6	199	0.067	0.014	0	1	0	0	13.3 6.0
P6	162	0.084	0.022	0	0	1	0	16.7 6.3
P6	172	0.092	0.026	0	0	1	0	18.3 6.5
P6	151	0.077	0.019	0	0	1	0	15.4 6.6
P6	170	0.083	0.022	0	0	1	0	16.6 6.8
P6	174	0.086	0.023	0	0	1	0	17.1 6.8
P6	188	0.088	0.024	0	0	1	0	17.5 6.9
P6	189	0.087	0.024	0	0	1	0	17.4 7.0
P6	173	0.108	0.036	0	0	0	1	21.5 7.1
P6	194	0.093	0.027	0	0	1	0	18.5 7.1
P6	163	0.076	0.018	0	0	1	0	15.2 7.5
P6	200	0.110	0.038	0	0	0	1	22.0 7.5
P6	186	0.089	0.025	0	0	1	0	17.7 7.6
P6	149	0.092	0.026	0	0	1	0	18.3 7.7
P6	153	0.092	0.027	0	0	1	0	18.4 7.7
P6	179	0.078	0.019	0	0	1	0	15.5 7.7
P6	197	0.100	0.031	0	0	0	1	20.0 7.7
P6	187	0.114	0.041	0	0	0	1	22.8 8.3
P6	15	0.078	0.019	0	0	1	0	15.6 8.7
P6	180	0.119	0.044	0	0	0	1	23.7 8.8
P6	158	0.075	0.018	0	0	1	0	15.0 9.7
P6	Sums	→	2.524	25	1	16	7	

Table A.3
GPS waypoints of palm stems converted from decimal degrees

Plot	GPS pt#	Y (ddm)	X (ddm)	Y_Met (meters)	X_Met (meters)	Field Notes
P1	55	20.088100	58.283783	2223838.6	6099226.2	NW quad,71m
P1	62	20.088400	58.283550	2223871.8	6099201.8	NW quad,71m
P1	54	20.088117	58.283750	2223840.5	6099222.7	SW
P1	52	20.088267	58.283700	2223857.5	6099217.4	NW quad,71m
P1	63	20.088283	58.283717	2223858.9	6099219.2	SE
P1	53	20.088267	58.283733	2223857.1	6099220.9	NW quad,71m
P1	61	20.088333	58.283517	2223864.4	6099198.3	NW quad,71m
P1	50	20.088233	58.283667	2223853.5	6099214	SW
P1	51	20.088233	58.283667	2223853.4	6099214	NW,too scaled for dbh SE quad,too scaled for
P1	64	20.088267	58.283700	2223857.1	6099217.4	dbh NE quad,too scaled for
P1	56	20.088000	58.283850	2223827.5	6099233.1	dbh
P1	60	20.088333	58.283433	2223864.4	6099189.5	NE,too scaled for dbh
P1	57	20.088133	58.283483	2223842.3	6099194.8	internal xylem burned
P1	59	20.088133	58.283417	2223842.3	6099187.8	
P1	28	20.088317	58.283550	2223862.6	6099201.8	NE, No DBH, too branchy
P1	32	20.088367	58.283733	2223868.1	6099220.9	NW quad
P1	58	20.088167	58.283467	2223846	6099193	
P1	49	20.088200	58.283683	2223849.7	6099215.7	
P1	11	20.088050	58.283500	2223833.1	6099196.5	curved stem
P1	14	20.088250	58.283433	2223855.2	6099189.5	
P1	24	20.088383	58.283467	2223870	6099193	
P1	29	20.088350	58.283617	2223866.3	6099208.7	overstory
P1	34	20.088283	58.283700	2223858.9	6099217.4	
P1	38	20.088200	58.283783	2223849.7	6099226.2	
P1	45	20.088200	58.283700	2223849.7	6099217.4	
P1	46	20.088167	58.283683	2223846	6099215.7	
P1	7	20.088167	58.283550	2223846	6099201.8	day 2 finish NE quad
P1	12	20.088117	58.283483	2223840.5	6099194.8	

P1	13	20.088217	58.283450	2223851.5	6099191.3	
P1	16	20.088350	58.283367	2223866.3	6099182.6	intermediate story
P1	18	20.088333	58.283433	2223864.5	6099189.5	
P1	19	20.088350	58.283433	2223866.3	6099189.5	
P1	20	20.088367	58.283417	2223867.5	6099187.8	
P1	23	20.088367	58.283467	2223868.1	6099193	
P1	25	20.088317	58.283500	2223862.6	6099196.5	SW Quad
P1	26	20.088300	58.283500	2223860.8	6099196.5	
P1	27	20.088267	58.283550	2223857.1	6099201.8	
P1	30	20.088350	58.283650	2223866.3	6099212.2	curved at base of stem
P1	33	20.088317	58.283683	2223862.6	6099215.7	insect damg; dwd
P1	39	20.088151	58.283810	2223844.3	6099229	right on west edge?
P1	41	20.088100	58.283767	2223838.6	6099224.4	ctr guideline
P1	43	20.088150	58.283900	2223844.1	6099238.4	obsev, photo #, diseases
P1	44	20.088183	58.283700	2223847.8	6099217.4	
P1	3	20.088267	58.283600	2223857.1	6099207	
P1	6	20.088167	58.283600	2223846	6099207	DWD
P1	15	20.088250	58.283400	2223855.2	6099186.1	
P1	17	20.088300	58.283417	2223860.8	6099187.8	
P1	31	20.088383	58.283667	2223870	6099214	
P1	35	20.088217	58.283683	2223851.5	6099215.7	no leaves. Dead
P1	36	20.088217	58.283750	2223851.5	6099222.7	
P1	37	20.088200	58.283750	2223849.7	6099222.7	
P1	47	20.088150	58.283683	2223844.1	6099215.7	
P1	48	20.088167	58.283717	2223846	6099219.2	
P1	5	20.088233	58.283583	2223853.4	6099205.2	
P1	8	20.088100	58.283550	2223838.6	6099201.8	
P1	9	20.088083	58.283583	2223836.8	6099205.2	intermediate story
P1	21	20.088367	58.283417	2223868.1	6099187.8	
P1	40	20.088150	58.283800	2223844.1	6099227.9	intermediate story
P1	42	20.088067	58.283833	2223834.9	6099231.4	shoots
P1	22	20.088367	58.283450	2223868.1	6099191.3	
P1	4	20.088250	58.283583	2223855.2	6099205.2	
P1	10	20.088067	58.283633	2223834.9	6099210.5	

P2	107	20.088467	58.276183	2223879.2	6098430.9	
P2	108	20.088433	58.276150	2223875.5	6098427.4	DWD
P2	104	20.088500	58.276100	2223882.9	6098422.1	
P2	113	20.088400	58.276133	2223871.5	6098425.6	DWD, DBH on petioles
P2	97	20.088417	58.276167	2223873.4	6098429.1	
						DWD, low petioles on
P2	98	20.088650	58.276267	2223899.5	6098439.6	stem
P2	114	20.088417	58.276233	2223873.7	6098436.1	10x10m of 11, 1m regen
P2	100	20.088583	58.276167	2223892.1	6098429.1	
P2	106	20.088450	58.276133	2223877.4	6098425.6	
P2	112	20.088400	58.276133	2223872	6098425.6	
P2	111	20.088417	58.276167	2223874	6098429.1	
P2	95	20.088583	58.276417	2223892.1	6098455.3	45° stem 1.9m long
P2	105	20.088500	58.276050	2223882.9	6098416.9	DWD
P2	110	20.088450	58.276183	2223877.4	6098430.9	
P2	85	20.088433	58.276467	2223875.5	6098460.5	No leaves, dead?
P2	120	20.088483	58.276233	2223881	6098436.1	no leaves
P2	73	20.088333	58.276367	2223864.4	6098450	
P2	89	20.088700	58.276467	2223905	6098460.5	
P2	118	20.088367	58.276233	2223868.1	6098436.1	
P2	77	20.088300	58.276317	2223860.8	6098444.8	no leaves
P2	80	20.088283	58.276400	2223858.9	6098453.5	DWD
P2	119	20.088433	58.276250	2223875.5	6098437.8	
P2	122	20.088250	58.276183	2223855.2	6098430.9	
P2	70	20.088400	58.276400	2223871.8	6098453.5	insect holes
P2	92	20.088700	58.276350	2223905	6098448.3	
P2	117	20.088350	58.276217	2223866.3	6098434.3	
P2	90	20.088633	58.276417	2223897.7	6098455.3	insect holes, moving east
P2	71	20.088350	58.276417	2223866.3	6098455.3	DWD
P2	96	20.088583	58.276367	2223892.1	6098450	
P2	91	20.088700	58.276383	2223905	6098451.8	
P2	99	20.088600	58.276267	2223894	6098439.6	
P2	109	20.088417	58.276150	2223873.7	6098427.4	DWD

P2	83	20.088367	58.276483	2223868.1	6098462.2	
P2	101	20.088633	58.276133	2223897.7	6098425.6	DWD
P2	76	20.088300	58.276333	2223860.8	6098446.5	NW quad
P2	102	20.088583	58.276050	2223892.1	6098416.9	
P2	66	20.088433	58.276317	2223875.5	6098444.8	
P2	72	20.088350	58.276400	2223866.3	6098453.5	insect holes
P2	81	20.088317	58.276450	2223862.6	6098458.8	insect holes
P2	88	20.088600	58.276500	2223894	6098464	
P2	103	20.088533	58.276083	2223886.6	6098420.4	DWD
P2	69	20.088350	58.276383	2223866.3	6098451.8	w/in2m of waypt 93
P2	93	20.088650	58.276417	2223899.5	6098455.3	DWD
P2	94	20.088617	58.276417	2223895.8	6098455.3	curved
P2	87	20.088483	58.276467	2223881	6098460.5	
P2	79	20.088267	58.276250	2223857.1	6098437.8	
P2	121	20.088267	58.276150	2223857.1	6098427.4	
P2	123	20.088350	58.276267	2223866.3	6098439.6	curved
P2	74	20.088317	58.276350	2223862.6	6098448.3	
P2	67	20.088400	58.276333	2223871.8	6098446.5	
P2	68	20.088383	58.276350	2223870	6098448.3	
P2	75	20.088333	58.276383	2223864.4	6098451.8	
P2	78	20.088283	58.276317	2223858.9	6098444.8	
P2	116	20.088400	58.276233	2223871.8	6098436.1	on West edge,DWD
P3	133	20.089117	58.275867	2223951.2	6098397.7	DWD
P3	138	20.089067	58.275733	2223946	6098383.8	
P3	140	20.089083	58.275717	2223948	6098382	
P3	146	20.089033	58.275533	2223941.9	6098362.8	
P3	152	20.089033	58.275417	2223941.5	6098350.6	
P3	158	20.089283	58.275433	2223969.6	6098352.4	
P3	163	20.089200	58.275533	2223960.4	6098362.8	
P3	172	20.089367	58.275550	2223978.8	6098364.6	
P3	175	20.089333	58.275550	2223975.6	6098364.6	
P3	178	20.089367	58.275650	2223978.8	6098375	
P3	160	20.089233	58.275500	2223964.1	6098359.3	DWD

P3	170	20.089333	58.275400	2223975.1	6098348.9	
P3	176	20.089300	58.275550	2223971.5	6098364.6	near center
P3	141	20.089050	58.275650	2223943.8	6098375	
P3	127	20.089183	58.275617	2223958.5	6098371.6	
P3	166	20.089250	58.275583	2223965.9	6098368.1	
P3	167	20.089283	58.275467	2223969.6	6098355.9	
P3	139	20.089067	58.275733	2223945.6	6098383.8	
P3	147	20.089017	58.275500	2223940.1	6098359.3	
P3	165	20.089250	58.275600	2223965.9	6098369.8	
P3	177	20.089367	58.275633	2223978.8	6098373.3	
P3	132	20.089083	58.275717	2223948.5	6098382	
P3	174	20.089333	58.275550	2223975.1	6098364.6	
P3	173	20.089367	58.275550	2223978.8	6098365	
P3	142	20.089083	58.275633	2223947.5	6098373.3	
P3	182	20.089283	58.275800	2223969.6	6098390.7	
P3	187	20.089300	58.275767	2223971.5	6098387.3	
P3	135	20.089017	58.275850	2223940.1	6098396	
P3	190	20.089350	58.275833	2223977	6098394.2	
P3	168	20.089283	58.275500	2223969.6	6098359.3	
P3	184	20.089250	58.275767	2223965.9	6098387.3	
P3	144	20.089150	58.275700	2223954.9	6098380.3	
P3	134	20.089033	58.275850	2223942	6098396	
P3	171	20.089367	58.275483	2223978.8	6098357.6	
P3	143	20.089100	58.275650	2223949.3	6098375	
P3	129	20.089183	58.275733	2223958.5	6098383.8	
P3	164	20.089267	58.275583	2223967.8	6098368.1	
P3	169	20.089300	58.275417	2223971.5	6098350.6	no leaves
P3	154	20.089133	58.275467	2223953	6098355.9	
P3	151	20.089033	58.275417	2223941.9	6098350.6	
P3	181	20.089267	58.275767	2223967.8	6098387.3	DWD
P3	185	20.089267	58.275800	2223967.8	6098390.7	
P3	186	20.089267	58.275783	2223967.8	6098389	
P3	137	20.089017	58.275767	2223940.1	6098387.3	SW corner
P3	157	20.089283	58.275400	2223969.6	6098348.9	
P3	179	20.089300	58.275650	2223971.5	6098375	

P3	183	20.089267	58.275717	2223967.8	6098382	
P3	134	20.089150	58.275733	2223954.9	6098383.8	
P3	180	20.089317	58.275750	2223973.3	6098385.5	
P3	149	20.089100	58.275500	2223949.3	6098359.3	DWD
P3	155	20.089167	58.275433	2223956.7	6098352.4	DWD
P3	156	20.089183	58.275450	2223958.5	6098354.1	Moving E, to scrub patch
P3	130	20.089217	58.275783	2223962.2	6098389	
P3	162	20.089200	58.275550	2223960.4	6098364.6	
P3	188	20.089250	58.275850	2223965.9	6098396	insect holes
P3	136	20.089033	58.275783	2223942.5	6098389	no leaves
P3	145	20.089050	58.275550	2223943.8	6098364.6	
P3	153	20.089117	58.275467	2223951.2	6098355.9	
P3	159	20.089217	58.275500	2223962.2	6098359.3	
P3	191	20.089317	58.275783	2223973.3	6098389	moving south
P3	148	20.089067	58.275500	2223945.6	6098359.3	
P3	150	20.089083	58.275400	2223947.5	6098348.9	
P3	189	20.089333	58.275817	2223975.1	6098392.5	
P3	161	20.089217	58.275517	2223962.2	6098361.1	
P4	48	20.067420	58.287680	2221549.2	6099633.9	
P4	49	20.067430	58.287730	2221550.4	6099639.2	
P4	50	20.067420	58.287740	2221549.2	6099640.2	
P4	51	20.067510	58.287750	2221559.2	6099641.3	
P4	61	20.067570	58.288080	2221565.9	6099675.8	
P4	62	20.067540	58.288040	2221562.5	6099671.6	
P4	63	20.067520	58.288080	2221560.3	6099675.8	
P4	64	20.067500	58.288060	2221558.1	6099673.7	
P4	65	20.067490	58.288060	2221557	6099673.7	
P4	66	20.067470	58.288060	2221554.8	6099673.7	
P4	67	20.067490	58.288080	2221557	6099675.8	
P4	68	20.067490	58.288080	2221557.5	6099675.8	
P4	69	20.067470	58.288120	2221554.8	6099680	
P4	70	20.067350	58.288100	2221541.5	6099677.9	
P4	71	20.067390	58.288050	2221545.9	6099672.7	

P4	72	20.067370	58.288050	2221543.7	6099672.7	
P4	73	20.067300	58.288070	2221536	6099674.8	
P4	74	20.067300	58.288020	2221536	6099669.5	
P4	75	20.067220	58.287780	2221527.1	6099644.4	
P4	76	20.067200	58.287670	2221524.9	6099632.9	
P4	77	20.067360	58.287750	2221542.6	6099641.3	
P4	78	20.067450	58.287750	2221552.6	6099641.3	
P4	79	20.067470	58.287760	2221554.8	6099642.3	
P4	80	20.067490	58.287760	2221557	6099642.3	
P4	81	20.067550	58.287780	2221563.6	6099644.4	
P4	6	20.067360	58.288050	2221542.6	6099672.7	
P4	25	20.067283	58.287817	2221534.1	6099648.2	no leaves on palm 2m NE
P4	28	20.067267	58.287817	2221532.3	6099648.5	
P4	7	20.067450	58.288050	2221552.6	6099672.7	
P4	32	20.067267	58.287717	2221532.3	6099637.8	
P4	19	20.067183	58.287983	2221523	6099665.7	insect damage
P4	3	20.067367	58.288067	2221543.3	6099674.4	
P4	18	20.067217	58.288033	2221526.7	6099670.9	
P4	13	20.067250	58.287967	2221530.4	6099663.9	
P4	14	20.067267	58.288017	2221532.3	6099669.2	
P4	17	20.067267	58.288000	2221532.3	6099667.4	
P4	11	20.067300	58.288167	2221536	6099684.9	
P4	22	20.067267	58.287883	2221532.3	6099655.2	
P4	44	20.067400	58.287683	2221547	6099634.3	
P4	15	20.067300	58.287883	2221536	6099655.2	
P4	27	20.067267	58.287817	2221532.5	6099648.2	
P4	42	20.067400	58.287883	2221547	6099655.2	no leaves
P4	47	20.067483	58.287683	2221556.3	6099634.3	extreme burn damage
P4	45	20.067400	58.287650	2221547	6099630.8	
P4	52	20.067583	58.287800	2221567.3	6099646.5	Northwest quad
P4	60	20.067550	58.288050	2221563.6	6099672.7	
P4	2	20.067383	58.287967	2221545.2	6099663.9	
P4	24	20.067183	58.287833	2221523	6099650	no leaves
P4	41	20.067417	58.287867	2221548.9	6099653.5	
P4	8	20.067417	58.288067	2221548.9	6099674.4	

P4	10	20.067333	58.288150	2221539.7	6099683.1	no leaves
P4	26	20.067267	58.287817	2221532	6099648	
P4	29	20.067267	58.287767	2221532.3	6099643	
P4	34	20.067283	58.287650	2221534.1	6099630.5	
P4	31	20.067233	58.287750	2221528.6	6099641.3	
P4	38	20.067367	58.287767	2221543.3	6099643	
P4	56	20.067500	58.288000	2221558.1	6099667.4	
P4	12	20.067317	58.288033	2221537.8	6099670.9	
P4	23	20.067250	58.287933	2221530.4	6099660.5	
P4	30	20.067217	58.287750	2221526.7	6099641.3	
P4	53	20.067533	58.287967	2221561.8	6099663.9	
P4	43	20.067400	58.287700	2221547	6099636	
P4	4	20.067317	58.288067	2221537.8	6099674.4	
P4	54	20.067550	58.288017	2221563.6	6099669.2	
P4	55	20.067567	58.287883	2221565.5	6099655.2	Southeast quad
P4	16	20.067250	58.288000	2221530.4	6099667.4	
P4	40	20.067400	58.287833	2221547	6099650	
P4	21	20.067333	58.287950	2221539.7	6099662.2	
P4	35	20.067350	58.287683	2221541.5	6099634.3	Northeast quad
P4	46	20.067433	58.287650	2221550.7	6099630.8	
P4	20	20.067350	58.287900	2221541.5	6099657	
P4	33	20.067283	58.287650	2221534.1	6099631	
P4	37	20.067350	58.287733	2221541.5	6099639.5	
P4	59	20.067617	58.287983	2221571	6099665.7	Southwest quad
P4	39	20.067367	58.287800	2221543.3	6099646.5	
P4	57	20.067567	58.288000	2221565.5	6099667.4	Northeast quad
P4	58	20.067617	58.288000	2221571	6099667.4	
P4	36	20.067350	58.287733	2221542	6099640	
P4	9	20.067450	58.288167	2221552.6	6099684.9	
P5	115	20.067583	58.286383	2221567.3	6099498.3	
P5	116	20.067590	58.286360	2221568.1	6099495.8	
P5	117	20.067670	58.286230	2221576.9	6099482.2	
P5	118	20.067640	58.286250	2221573.6	6099484.3	

P5	119	20.067660	58.286260	2221575.8	6099485.3
P5	120	20.067740	58.286180	2221584.7	6099477
P5	121	20.067760	58.286220	2221586.9	6099481.2
P5	122	20.067780	58.286230	2221589.1	6099482.2
P5	123	20.067810	58.286210	2221592.4	6099480.1
P5	124	20.067830	58.286210	2221594.6	6099480.1
P5	125	20.067970	58.286330	2221610.1	6099492.7
P5	126	20.067960	58.286310	2221609	6099490.6
P5	127	20.067940	58.286380	2221606.8	6099497.9
P5	128	20.067960	58.286400	2221609	6099500
P5	129	20.067960	58.286420	2221609.5	6099502.1
P5	130	20.067960	58.286420	2221609	6099502.1
P5	131	20.067990	58.286480	2221612.3	6099508.4
P5	132	20.067980	58.286500	2221611.2	6099510.5
P5	133	20.067950	58.286520	2221607.9	6099512.6
P5	134	20.067940	58.286540	2221606.8	6099514.6
P5	135	20.067880	58.286580	2221600.2	6099518.8
P5	136	20.067740	58.286510	2221584.7	6099511.5
P5	137	20.067700	58.286490	2221580.2	6099509.4
P5	138	20.067700	58.286480	2221580.2	6099508.4
P5	139	20.067710	58.286470	2221581.4	6099507.3
P5	140	20.067730	58.286480	2221583.6	6099508.4
P5	141	20.067760	58.286460	2221586.9	6099506.3
P5	142	20.067690	58.286460	2221579.1	6099506.3
P5	143	20.067690	58.286410	2221579.1	6099501
P5	144	20.067700	58.286420	2221580.2	6099502.1
P5	145	20.067710	58.286420	2221581.4	6099502.1
P5	146	20.067720	58.286360	2221582.5	6099495.8
P5	147	20.067740	58.286350	2221584.7	6099494.8
P5	148	20.067760	58.286330	2221586.9	6099492.7
P5	86	20.067667	58.286233	2221576.6	6099482.6
P5	95	20.067783	58.286283	2221589.5	6099487.8
P5	102	20.067933	58.286350	2221606.1	6099494.8
P5	101	20.067933	58.286317	2221606.1	6099491.3
P5	84	20.067667	58.286317	2221576.6	6099491.3

P5	94	20.067817	58.286217	2221593.2	6099480.8
P5	88	20.067583	58.286167	2221567.3	6099475.6
P5	85	20.067683	58.286267	2221578.4	6099486
P5	107	20.067550	58.286533	2221563.6	6099513.9
P5	108	20.067700	58.286433	2221580.2	6099503.5
P5	92	20.067733	58.286133	2221583.9	6099472.1
P5	105	20.067817	58.286400	2221593.2	6099500
P5	87	20.067600	58.286200	2221569.2	6099479.1
P5	96	20.067850	58.286133	2221596.8	6099472.1
P5	103	20.067800	58.286350	2221591.3	6099494.8
P5	83	20.067750	58.286317	2221585.8	6099491.3
P5	97	20.067850	58.286167	2221596.8	6099475.6
P5	89	20.067583	58.286150	2221567.3	6099473.8
P5	104	20.067833	58.286400	2221595	6099500
P5	82	20.067750	58.286283	2221585.8	6099487.8
P5	106	20.067883	58.286400	2221600.5	6099500

P6	152	20.068850	58.287160	2221707.6	6099579.5
P6	154	20.068760	58.287200	2221697.6	6099583.7
P6	155	20.068780	58.287190	2221699.8	6099582.7
P6	156	20.068780	58.287150	2221699.8	6099578.5
P6	159	20.068920	58.287090	2221715.3	6099572.2
P6	160	20.068930	58.287070	2221716.4	6099570.1
P6	161	20.068940	58.287070	2221717.5	6099570.1
P6	164	20.069070	58.287040	2221731.9	6099567
P6	165	20.069100	58.286960	2221735.2	6099558.6
P6	166	20.069110	58.287040	2221736.3	6099567
P6	167	20.069130	58.287030	2221738.6	6099565.9
P6	171	20.069080	58.287110	2221733	6099574.3
P6	175	20.069080	58.287270	2221733	6099591
P6	176	20.069090	58.287270	2221734.1	6099591
P6	177	20.069070	58.287310	2221731.9	6099595.2
P6	178	20.069070	58.287300	2221731.9	6099594.2
P6	181	20.069070	58.287380	2221731.9	6099602.6

P6	182	20.069050	58.287430	2221729.7	6099607.8	
P6	183	20.068960	58.287430	2221719.7	6099607.8	
P6	184	20.068970	58.287410	2221720.8	6099605.7	
P6	190	20.068840	58.287310	2221706.4	6099595.2	
P6	191	20.068860	58.287300	2221708.7	6099594.2	
P6	193	20.068800	58.287360	2221702	6099600.5	
P6	198	20.068760	58.287400	2221697.6	6099604.6	
P6	201	20.068850	58.287220	2221707.6	6099585.8	
P6	196	20.068717	58.287367	2221692.8	6099601.2	
P6	192	20.068817	58.287350	2221703.9	6099599.4	NW corner,no coord
P6	157	20.068850	58.287117	2221707.6	6099575	
P6	199	20.068750	58.287450	2221696.5	6099609.9	
P6	162	20.069017	58.287033	2221726	6099566.3	
P6	172	20.069100	58.287183	2221735.2	6099582	
P6	151	20.068833	58.287133	2221705.7	6099576.7	
P6	170	20.069133	58.287067	2221738.9	6099569.8	
P6	174	20.069100	58.287183	2221735.5	6099582	
P6	188	20.068867	58.287333	2221709.4	6099597.7	
P6	189	20.068833	58.287300	2221705.7	6099594.2	
P6	173	20.069033	58.287167	2221727.8	6099580.2	
P6	194	20.068767	58.287317	2221698.3	6099595.9	
P6	163	20.069067	58.287017	2221731.5	6099564.5	
P6	200	20.068683	58.287250	2221689.1	6099588.9	
P6	186	20.068983	58.287417	2221722.3	6099606.4	
P6	149	20.068867	58.287250	2221709.4	6099588.9	
P6	153	20.068767	58.287200	2221698.3	6099583.7	
P6	179	20.069100	58.287300	2221735.2	6099594.2	
P6	197	20.068733	58.287350	2221694.6	6099599.4	
P6	187	20.068933	58.287383	2221716.8	6099602.9	
P6	15	20.068883	58.287183	2221711.2	6099582	
P6	180	20.069117	58.287350	2221737.1	6099599.4	
P6	158	20.068900	58.287017	2221713.1	6099564.5	

Appendix B. Diggle's F tests for Plots 1-6 for Total Palms Population.

Non-theoretical lines *above* the theoretical signify repulsion, and those *below* the line signify aggregation.

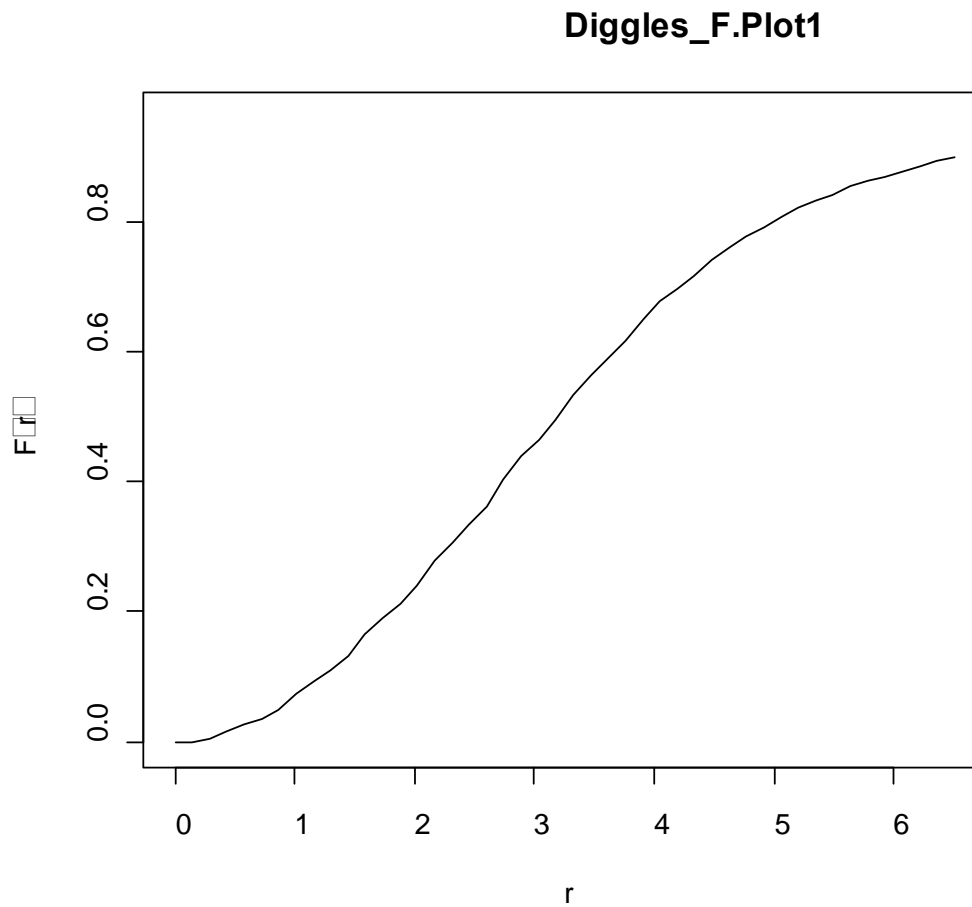


Figure B.1. Observed values do not deviate far from theoretical line.

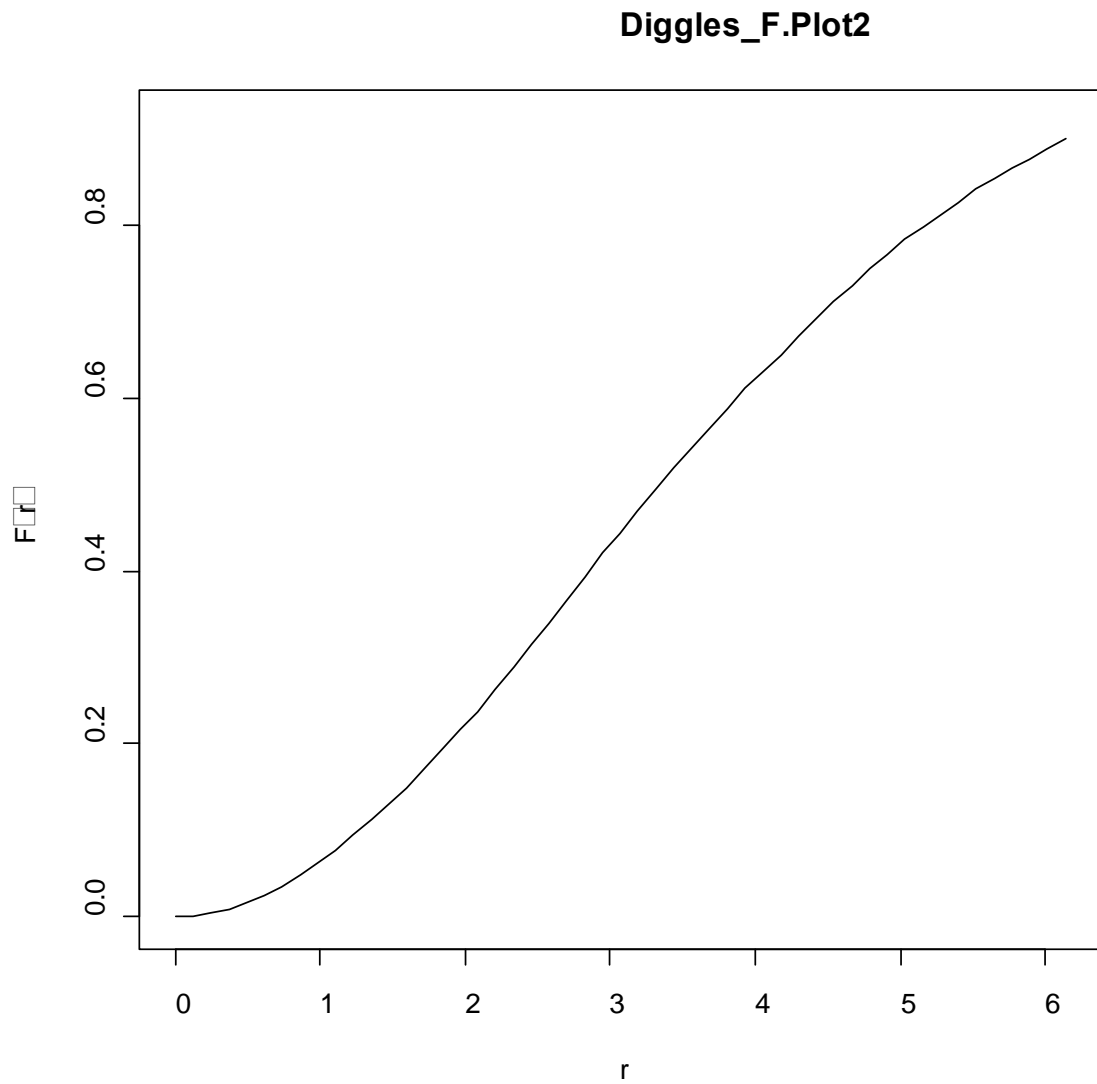


Figure B.2. Observed values does not deviate far from theoretical value, but do conform slightly below the theoretical line signifying the clustering at larger scales.

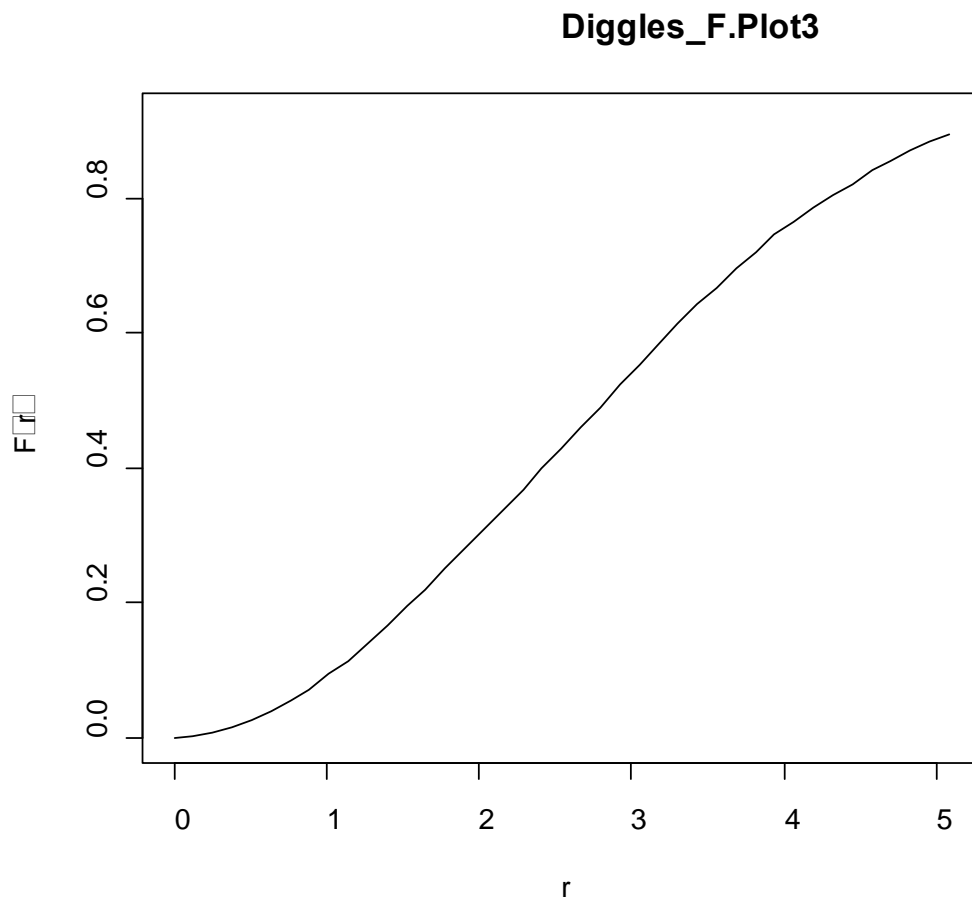


Figure B.3. Observed values does not deviate far from theoretical line, but do conform slightly below the theoretical line signifying the clustering.

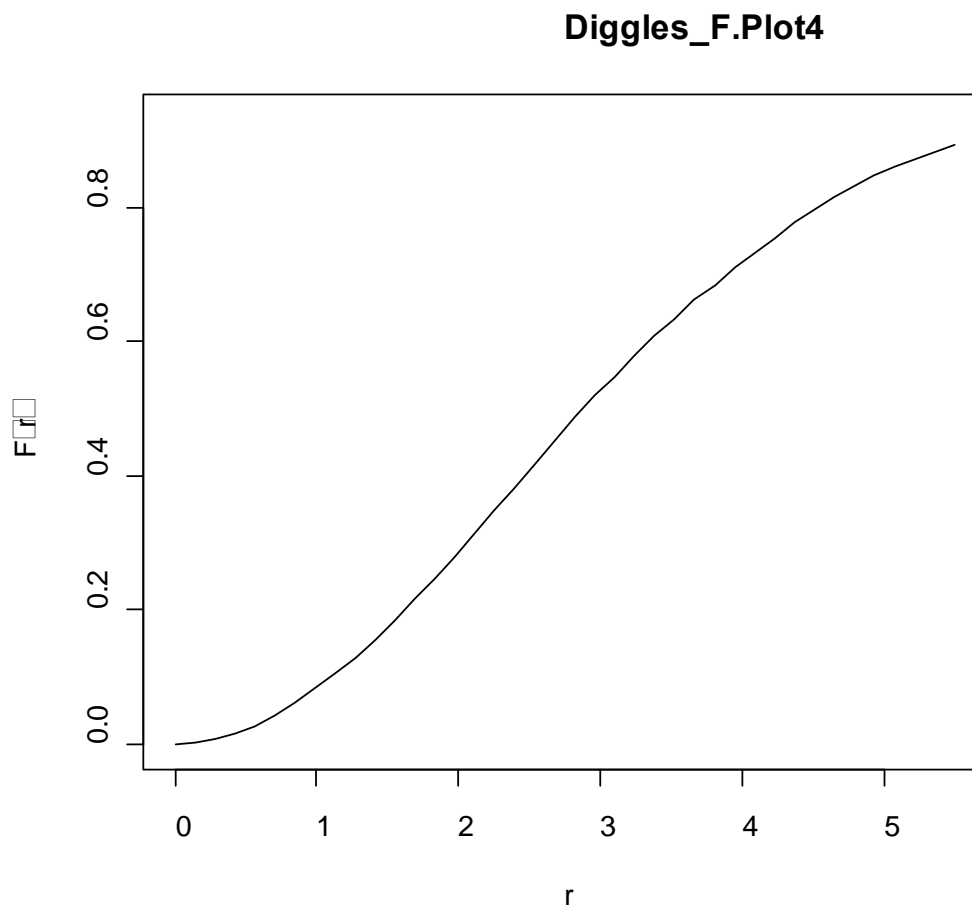


Figure B.4. Observed values does not deviate far from theoretical value, but do conform slightly below the theoretical line signifying the clustering.

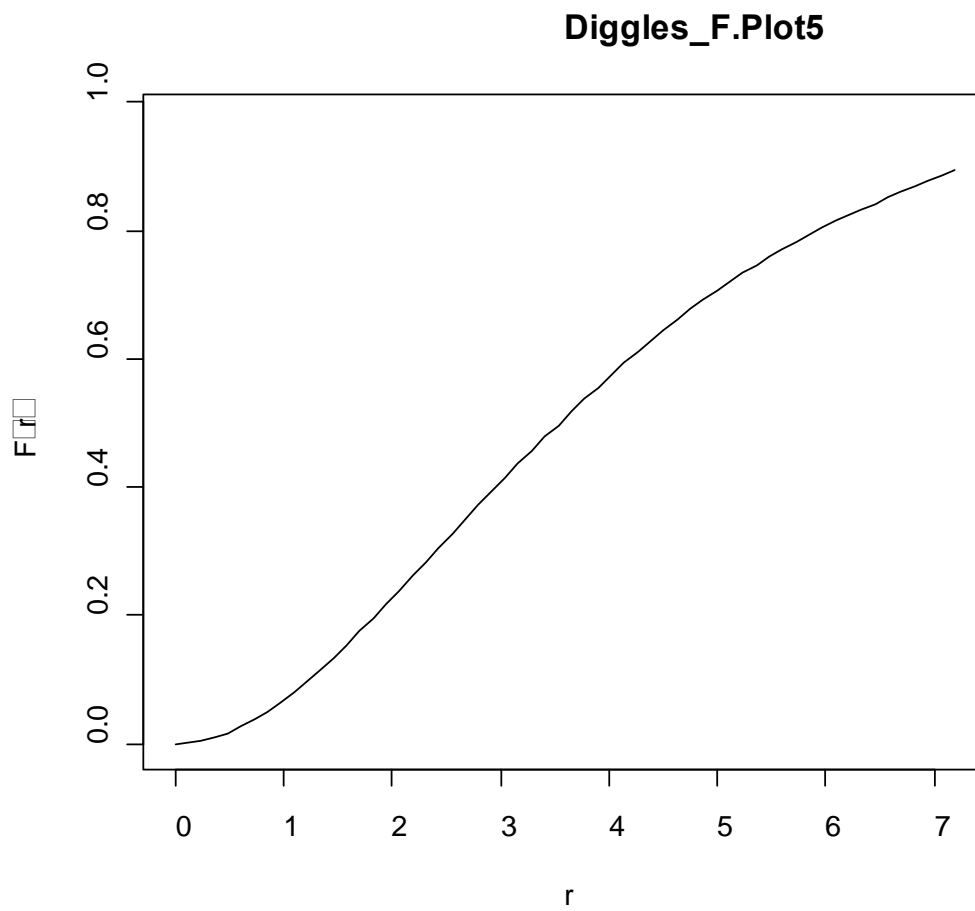


Figure B.5. Observed values deviate below the theoretical line at larger scales signifying the cluster.

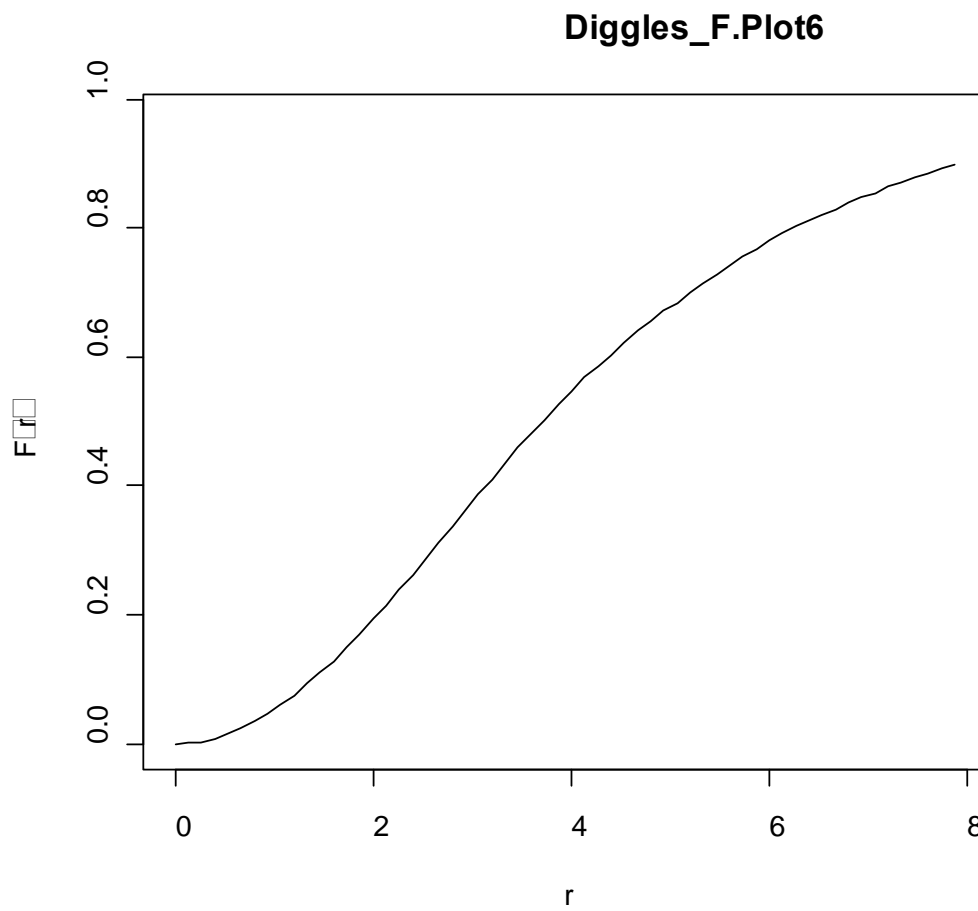


Figure B.6. Observed values deviate below the theoretical line at larger scales signifying the cluster.

[Appendix C](#). Spatial Symbol Diagrams with juveniles and adults for each 6 plots.

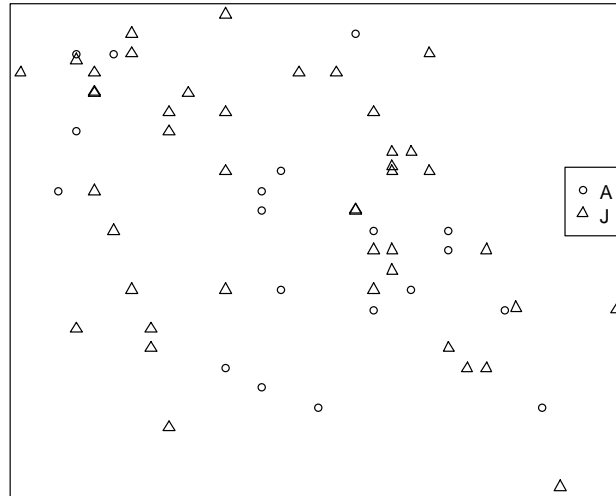


Figure C.1. Plot 1. Spatial Distribution of palms with stems ≥ 3.5 m height (adults = A) and palms with stems ≥ 1 meter and < 3.5 m (juveniles = J).

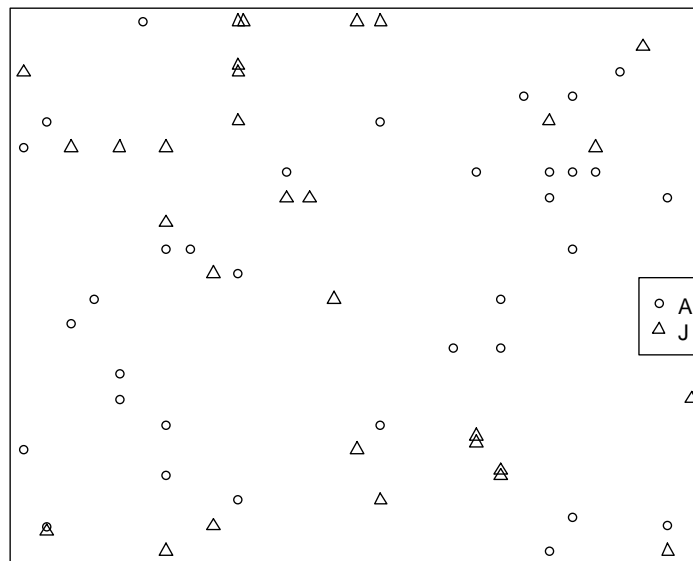


Figure C.2. Plot 3. Spatial Distribution of palms with stems ≥ 3.5 m height (adults = A) and palms with stems ≥ 1 meter and < 3.5 m (juveniles = J).

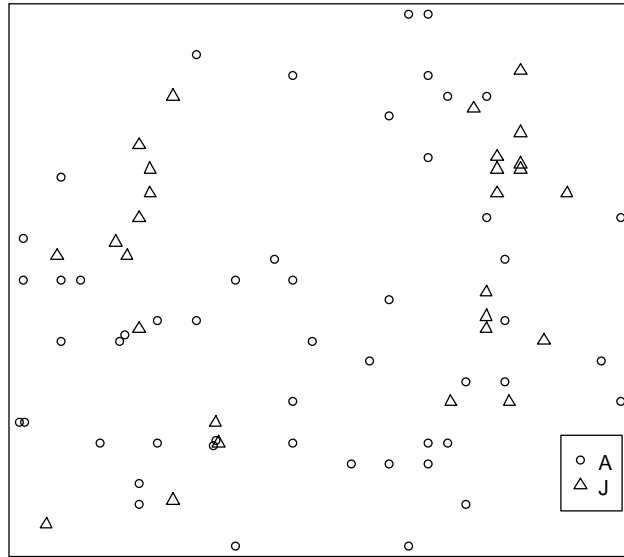


Figure C.3. Plot 4. Spatial Distribution of palms with stems ≥ 3.5 m height (adults = A) and palms with stems ≥ 1 meter and <3.5 m (juveniles = J).

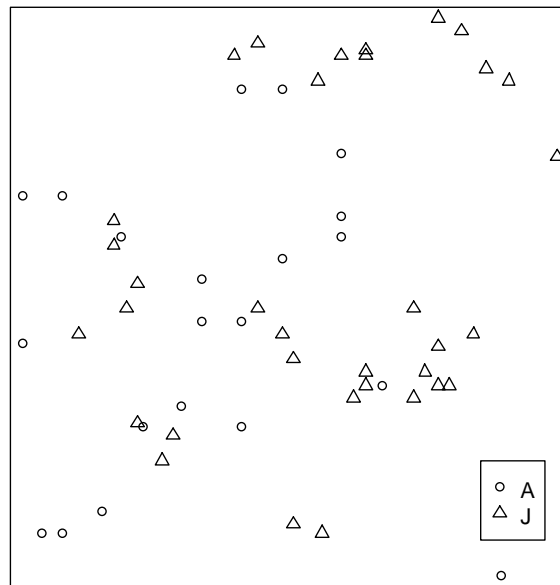


Figure C.4. Plot 5. Spatial Distribution of palms with stems ≥ 3.5 m height (adults = A) and palms with stems ≥ 1 meter and <3.5 m (juveniles = J).

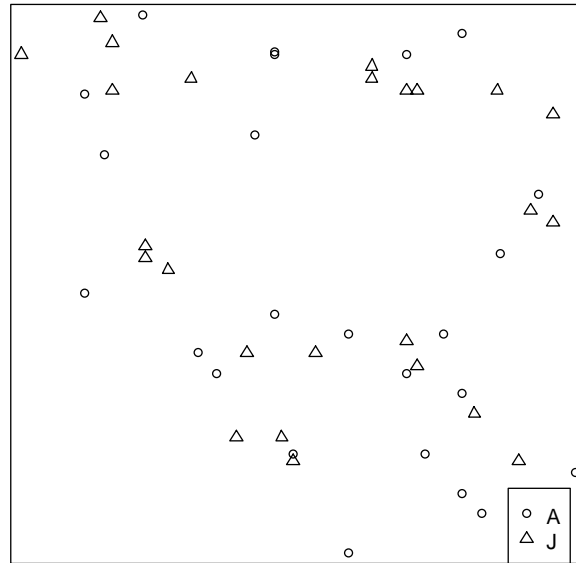


Figure C.5. Plot 6. Spatial Distribution of palms with stems ≥ 3.5 m height (adults = A) and palms with stems ≥ 1 meter and < 3.5 m (juveniles = J).

[Appendix D](#). Diameter Distributions for each of the 6 plots.

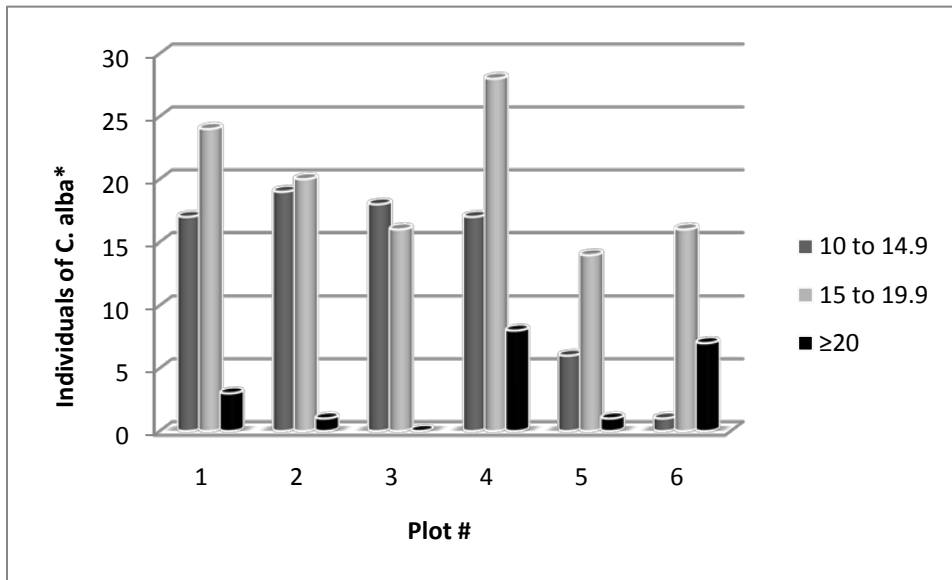


Figure D.1. Diameter distributions in cm.

Appendix E. Permission and Use

Hi Michelle,
Yes, you have full permission to use the photos of Bahia Negra
attached to this email in your thesis.

Joan Ngo
On Sat, Mar 5, 2011 at 9:03 PM, Michelle Cisz <cisz.michelle@gmail.com> wrote:

Permission from an email for pictures as cited from Joan Ngo.

Figure 3.2 was adapted from Google Earth. Please see the following website for permission of use:

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