Rare Plant Monitoring and Restoration on Long Pine Key, Everglades National Park

FINAL REPORT, YEAR 5
Cooperative Agreement #H5284-03-0044

George D. Gann, Kirsten N. Hines, Sonali Saha and Keith A. Bradley

March 12th, 2009

Submitted by
The Institute for Regional Conservation
22601 S.W. 152 Avenue, Miami, Florida 33170
George D. Gann, Executive Director

Submitted to
Jimi L. Sadle
Contracting Officer Technical Representative
Everglades National Park
40001 State Road 9336
Homestead, Florida 33034

TABLE OF CONTENTS

<u>List of Tables</u>

List of Figures

SUMMARY OF ACTIVITIES

Background

Long Pine Key is composed of an elevated ridge of limestone that separates the Taylor Slough and Shark River Slough drainage ways in the eastern portion of Everglades National Park (EVER). It is the southernmost portion of the Miami Rock Ridge, which extends south and west from the Miami River area near present-day downtown Miami. The vegetation of Long Pine Key is dominated by pine rocklands, marl prairies and rockland hammocks. These ecosystems harbor a number of rare plant and animal species including federally-listed species and candidates, South Florida endemics, and tropical species at or near the northern limit of their ranges. Long Pine Key has long been recognized as one of the most important regions in southern Florida for vascular plant diversity and has been researched by a number of prominent botanists and naturalists including John Kunkel Small, Frank C. Craighead and George N. Avery. Like several other regions of southern Florida, Long Pine Key has also been long noted for its loss of rare plant diversity and abundance due to anthropogenic factors including poaching, fire suppression and dry-season fires, hydrologic modifications, including drainage and impoundment, and other factors.

In 2002, The Institute for Regional Conservation (IRC) published the book *Rare Plants of South Florida: Their History, Conservation, and Restoration* (Gann *et al.* 2002). This book identified 355 taxa of plants that were ranked as presumed extirpated, possibly extirpated or critically imperiled in South Florida – defined as the 10 southernmost counties of Florida and roughly extending from the northern shore of Lake Okeechobee south. Of these, 30 species had been previously recorded or reported for the Long Pine Key area. Twenty of the 30 species were thought to be extant in the Long Pine Key area and 10 species were reported as presumed or possibly extirpated there (Table 1). Only one species thought to be extirpated in the Long Pine Key area was known to be extant elsewhere in Everglades National Park (*Oncidium undulatum*). Three of the nine remaining species possibly extirpated in the Long Pine Key area and in Everglades National Park were known to be present elsewhere in South Florida. The remaining six species reported as presumed or possibly extirpated in Everglades National Park were reported as presumed or possibly extirpated in the South Florida region and the continental United States.

In 2003, George D. Gann (IRC) and Thomas V. Armentano (EVER) submitted a 5-year proposal to the U.S. Department of the Interior's Critical Ecosystems Study Initiative (CESI) to survey and map the 30 rare species identified in Gann *et al.* (2002), to establish a long-term monitoring program to evaluate population responses of these species to Everglades restoration, and to augment or reintroduce populations of select species if warranted. While the Everglades restoration presumably should have a positive effect on rare plant populations, there is some potential for negative impacts and it is in fact unknown whether the proposed restoration and associated hydrological modifications will have a positive or negative impact on these species.

Cover Photo: Principal-Investigator George Gann planting *Brassia caudata* at Hattie Bauer Hammock as a reintroduction trial. Photo by IRC Biologist Kirsten Hines.

Table 1. Gann *et al.* (2002) rankings for 30 plants previously recorded for the Long Pine Key area of Everglades National Park.

Taxon	Status in South Florida	Status in Everglades National Park	Status on Long Pine Key
Adiantum melanoleucum	Critically Imperiled	Present	Present
Anemia wrightii	Critically Imperiled	Present	Present
Basiphyllaea corallicola	Critically Imperiled	Present	Present
Bourreria cassinifolia	Critically Imperiled	Present	Present
Brassia caudata	Presumed Extirpated	Presumed Extirpated	Presumed Extirpated
Croton lobatus	Critically Imperiled	Assumed Present (last observed in 1987)	Assumed Present (last observed in 1987)
Dalea carthagenensis var. *floridana*	Critically Imperiled	Possibly Extirpated	Possibly Extirpated
Desmodium lineatum	Critically Imperiled	Present	Present
Digitaria pauciflora	Critically Imperiled	Present	Present
Eltroplectris calcarata	Critically Imperiled	Present	Present
Galeandra beyrichii	Critically Imperiled	Present	Present
Govenia utriculata	Possibly Extirpated	Possibly Extirpated	Possibly Extirpated
Helenium flexuosum	Critically Imperiled	Present	Present
Lomariopsis kunzeana	Critically Imperiled	Present	Present
Macradenia lutescens	Presumed Extirpated	Presumed Extirpated	Presumed Extirpated
Oncidium ensatum	Critically Imperiled	Present	Present
Oncidium undulatum	Critically Imperiled	Present	Presumed Extirpated
Passiflora sexflora	Critically Imperiled	Assumed Present (reported)	Assumed Present (reported)
Pecluma plumula	Critically Imperiled	Present	Present
Ponthieva brittoniae	Possibly Extirpated	Possibly Extirpated	Possibly Extirpated
Prescotia oligantha	Presumed Extirpated	Presumed Extirpated	Presumed Extirpated
Schizaea pennula	Critically Imperiled	Presumed Extirpated (reported)	Presumed Extirpated (reported)
Sideroxylon reclinatum subsp. austrofloridense	Critically Imperiled	Present	Present
Spiranthes costaricensis	Critically Imperiled	Present	Present
Spiranthes torta	Critically Imperiled	Present	Present
Sporobolus compositus var. *clandestinus*	Critically Imperiled	Present	Present
Thelypteris reticulata	Critically Imperiled	Present	Present
Thelypteris serrata	Critically Imperiled	Assumed Present (needed verification)	Assumed Present (needed verification)
Tillandsia fasciculata var. *clavispica*	Presumed Extirpated	Presumed Extirpated	Presumed Extirpated
Trichomanes punctatum subsp. *floridanum*	Critically Imperiled	Presumed Extirpated	Presumed Extirpated

Relation to the Comprehensive Everglades Restoration Plan

Hydrology is a key ecosystem property that affects rare plant distributions and their viability. Historically sheet flow from Shark River Slough and Taylor Slough did not reach the upland portions of Long Pine Key. During the wet season, however, increased surface water flow in the sloughs generated a rise in ground water levels across the region. Even the dry upland areas of Long Pine Key received water as solution holes filled with groundwater and short-hydroperiod transverse glades (a.k.a. marl prairies) diverted excess sheet flow from the main sloughs. As a result, soil water availability and other moisture conditions in upland hammock and pineland habitats were sufficient to maintain populations of moisture dependent plants such as orchids, ferns, bromeliads and ecologically related species. As artificial drainage became more widely practiced, however, regional groundwater supplies declined. A study by Ewe *et al.* (1999) on water usage by pineland and hardwood tree species in Long Pine Key led them to speculate these regional groundwater declines could adversely affect growth of these species, especially during droughts. While their study focused on tree species, it seems evident that water stress would similarly affect understory and herbaceous plants, particularly if they (unlike epiphytes) depend on higher levels of soil and solution hole moisture that once characterized upland habitats. Epiphytic species that primarily meet their water needs from the atmosphere could also be adversely affected by decreased moisture levels. Both terrestrial and epiphytic plants could be affected by lower temperatures during freezing events and more intense and penetrating fires, both linked to lowered humidity.

In addition to the potential impacts of artificial drainage, historic patterns of water flow through Long Pine Key are further confounded by existing roads. Water flow through Long Pine Key (Figure 1) was originally concentrated in the marl prairies that traversed the area in a north-south direction. Construction of the main park road dissected Long Pine Key in an east-west direction, thus impeding sheet flow across Long Pine Key. Water was either impounded to the north of the main park road or was diverted around the southern part of Long Pine Key through Taylor Slough and Shark River Slough. Research Road is believed to similarly affect the water supply of the southern portions of Long Pine Key.

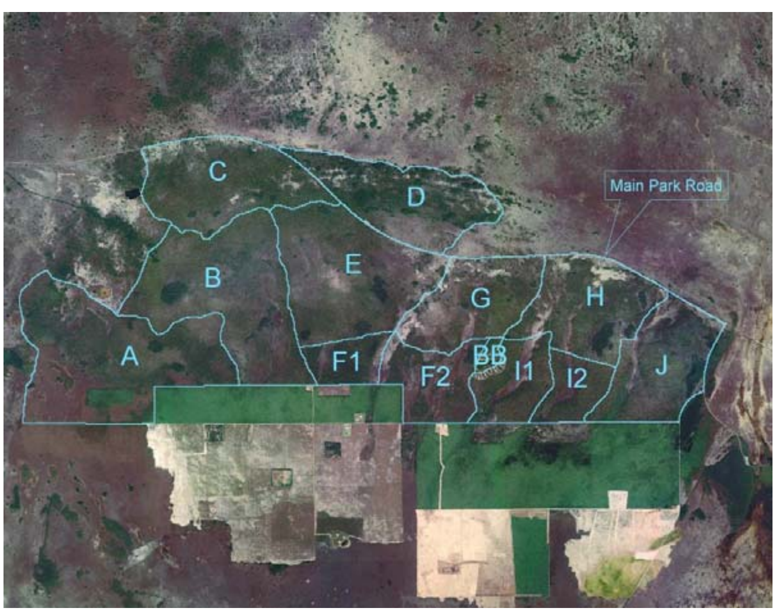


Figure 1. Long Pine Key (Pine Blocks A-J), Everglades National Park.

Presumably, if hydrological restoration is successful, ground water levels will be raised, wet season flows will return to the marl prairies and fire intensities will decrease, resulting in improved growing conditions for rare plants, including those in hammocks and pinelands. However, such a benefit must be verified by conducting field measurements of habitats and populations. Implementation of the Comprehensive Everglades Restoration Plan (CERP) could also lead to further impoundment of water north of the main park road, possibly flooding rare plant populations while failing to provide relief to habitats on Long Pine Key that are compartmentalized by the Main Park Road and Research Road and have suffered from long-term drainage.

Project Approval and Permits

Following review, the Gann & Armentano proposal was approved and in August, 2003 IRC and EVER signed cooperative agreement H5284-03-0044, Rare Plant Monitoring and Restoration on Long Pine Key, Everglades National Park. Following subsequent annual reviews, the project was approved for Years 2 and 3 with Craig S. Smith (Botanist, EVER) replacing Tom Armentano as co-Principal Investigator, and in Year 4, with Jimi L. Sadle (Botanist, EVER) replacing Craig Smith as co-Principal Investigator. Jimi Sadle continued as co-Principal Investigator through the end of the project. Research has been conducted under permits EVER-2003-SCI-0084, EVER-2004-SCI-0098 and EVER-2007-SCI-0010. In Year 4, IRC also hired Everglades Vegetation Biologist Jesse Hoffman, in conjunction with EVER (Modification # 5). This position is based at the park, follows park research regulations and reports jointly to IRC and EVER. The creation of this position has allowed timely expansion of certain aspects of this study, particularly plant augmentation and reintroduction trials, as permits are not required for research conducted by the Everglades Vegetation Biologist. In Year 5 Sonali Saha replaced Jesse Hoffman for this position. This is the final report for this project and summarizes activities from October 1, 2003 through September 30, 2008.

Initial Project Goals

The project initially had three primary goals:

1. Establish a long-term monitoring program to evaluate population responses of rare and imperiled species to regional restoration.
2. Contribute to the understanding of environmental requirements of rare and imperiled species.
3. Restore and enhance species diversity of uplands and the Everglades region by reintroduction of plants of extirpated or depleted species considered as rare or imperiled as a result of direct or indirect actions by man.

Modified Project Goals

Implementation and evaluation of this project led to minor modifications of the goals in order to clarify research methods and results. The modified goals were:

1. Conduct surveys and map populations of rare plants in the Long Pine Key area.
2. Establish a long-term monitoring program to evaluate population and habitat responses of rare species to regional restoration.

3. Restore and enhance species diversity of the Long Pine Key area and Everglades National Park through the augmentation or reintroduction of plants considered rare as a result of direct or indirect actions by man.
4. Contribute to a broader understanding of the environmental requirements of rare species both inside and outside of Everglades National Park.

Methods to carry out these goals were developed into tasks as described below.

Activities

Goal 1: Conduct surveys and map populations of rare plants in the Long Pine Key area.

Summary of Survey Methods

Surveys were conducted for the 30 target rare species identified in Gann *et al.* (2002) and one additional species (*Hypelate trifoliata*), which was re-ranked as critically imperiled in South Florida following the publication of Gann *et al.* (2002). Prior to the initiation of this study, there were 43 known locations for the 31 target rare plant species in the Long Pine Key area of Everglades National Park, representing 89 rare plant occurrences (Table 2). Previously known locations varied from very precise (e.g. a small, named hammock) to imprecise (e.g. Pine Block D). In every case, all known locations were surveyed by at least two biologists who walked transects within view of each other. Surveys were conducted until the study species was located or until the entire locality was surveyed. Discrete stations were mapped and documented. At least one GPS coordinate was recorded for each rare plant occurrence and in many cases multiple stations within an occurrence location were recorded. When appropriate, herbarium vouchers were collected and deposited at a NPS-approved herbarium. In order to provide a baseline for future monitoring work, population estimates or counts were made for each newly recorded occurrence and station. Estimates were based on a $\log_{10}$ scale. Counts of individuals were made for all occurrences and stations with 10 or fewer plants and whenever practical. Target areas were visited at least once during the course of this project with some areas receiving multiple visits on separate years in an attempt to capture ephemeral species.

Summary of Survey Results

During Year 1, 39 historical locations for critically imperiled taxa on LPK were surveyed, resulting in the re-documentation of 50 rare plant occurrences. In addition, five new occurrences for critically imperiled taxa reported by Tom Armentano (EVER) were confirmed. Surveys of historical and new locations resulted in the discovery of 26 new occurrences for critically imperiled taxa in the LPK area. Two critically imperiled species classified by IRC as possibly extirpated in EVER (*Thelypteris reticulata, T. serrata*) were rediscovered, one in its original location (*T. reticulata* in Royal Palm Hammock). *Ponthieva brittoniae*, a near endemic classified as historical in South Florida, was rediscovered in the Long Pine Key area. A summary of findings can be found in Appendix A.

The following herbarium specimens were collected for documentation during Year 1: **Sadle 393** *Tillandsia fasciculata* var. *densispica*, **Sadle 394** *Desmodium lineatum*, **Sadle 395** *Tillandsia fasciculata* var. *densispica*, **Sadle 396** *Ponthieva brittoniae*, **Sadle 397** *Passiflora sexflora*, **Sadle 398**

Scleria ciliata var. *ciliata*, **Sadle 408** *Rhynchospora grayi*, **Sadle 409** *Galactia* sp.[1], **Sadle 410** *Thelypteris reticulata*, **Sadle 415** *Sporobolus compositus* var. *clandestinus*, **Woodmansee 1363** *Anemia adiantifolia*, **Woodmansee 1364** *Platythelys latifolia*, **Woodmansee 1365** *Jacquemontia curtisii*, **Woodmansee 1366** *Rhynchosia* sp.

By the end of Year 2, 58 previously known rare plant occurrences were re-documented and 49 new occurrences of critically imperiled species were discovered in LPK. Several known locations for plants thought to be possibly extirpated in the Long Pine Key region prior to this study were revisited, but no new species were rediscovered in Year 2. One additional herbarium specimen was collected for documentation during Year 2: **Hodges 118** *Croton lobatus*. By the end of Year 3, 61 previously known rare plant occurrences were re-documented and 20 historic occurrences were determined to be extirpated.

No new locations were surveyed in Year 4 or 5, but follow-up surveys were done in most of the pine blocks. In Year 4, two new stations were discovered for *Spiranthes costaricensis*, one of which was a new occurence. A new station was also recorded for *Desmosidum lineatum*. Surveys in Pine Blocks D, G, F, H and I for *Digitaria pauciflora* indicated shifts in abundance wherein some areas with previously high densities lacked plants and other areas that previously had few to no plants were relatively dense. These abundance shifts were explored further in Year 5 when presence - absence surveys were done at all pine blocks. Pine Block J was the only one of those surveyed (Blocks A-J) that contained no *D. pauciflora*. Follow-up surveys for *Bourreria cassinifolia* (Pine Block F), *Eltroplectris calcarata* (Pay-fee Hammock and Hammock #120 a.k.a. Brookfield Hammock), *Helenium flexuosum* (Pine Block J) and *Spiranthes costaricensis* (Atoll Hammock, Avery Hammock, and Hammock #120 a.k.a. Brookfield Hammock) were also conducted in Year 5, but no new occurrences were discovered. Figure 2 shows a map of all recorded occurrences by the end of the project. Table 3 summarizes the updated status of the 31 target species and their habitat distribution. Table 4 provides final baseline abundance estimates for extant species.

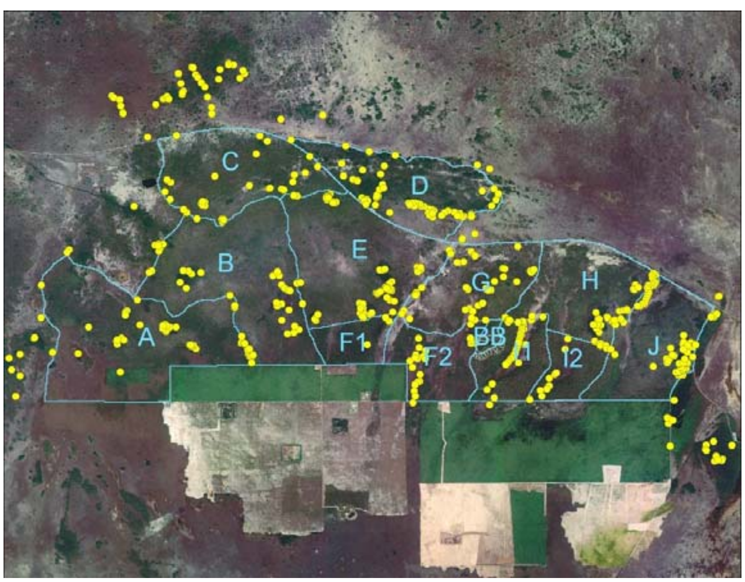


Figure 2. Rare plant stations as of Year 5 in the Long Pine Key area (outliers excluded).

[1] Specimen was originally labeled as *Galactia smallii*, but is currently being reexamined.

Table 2. Known locations of target rare plant species prior to this research.

Location	Species previously recorded
Atoll Hammock	*Spiranthes costaricensis*
Avery Hammock	*Spiranthes costaricensis*
Baker Hammock	*Oncidium ensatum*
Bootlegger Hammock	*Bourreria cassinifolia*
Cadwallader Hammock	*Pecluma plumula*
Deer Hammock	*Brassia caudata, Hypelate trifoliata, Macradenia lutescens, Oncidium ensatum*
Dewhurst Hammock	*Pecluma plumula*
East Boundary	*Dalea carthagenensis* var. *floridana*
Fairchild Hammock	*Spiranthes costaricensis*
Frampton Hammock	*Eltroplectris calcarata, Oncidium ensatum*
Grimshawe Hammock	*Oncidium ensatum*
Hammock #120	*Eltroplectris calcarata, Spiranthes costaricensis*
Hole-in-the-Donut Area	*Digitaria pauciflora, Thelypteris reticulata*
Mosier Hammock	*Eltroplectris calcarata, Galeandra beyrichii*
Mosier Hammock Edge	*Croton lobatus*
North of Long Pine Key	*Sideroxylon reclinatum* subsp. *austrofloridense*
Osteen Hammock	*Adiantum melanoleucum, Brassia caudata, Eltroplectris calcarata, Lomariopsis kunzeana, Macradenia lutescens, Oncidium ensatum, Passiflora sexflora, Spiranthes costaricensis*
Palma Vista Hammock #2	*Bourreria cassinifolia, Eltroplectris calcarata, Govenia utriculata, Oncidium ensatum, Prescotia oligantha, Spiranthes costaricensis, Tillandsia fasciculata* var. *clavispica*
Paradise Key	*Sideroxylon reclinatum* subsp. *austrofloridense*
Pay-Fee Hammock	*Eltroplectris calcarata*
Pfleuger Hammock Area	*Anemia wrightii*
Pilsbry Hammock	*Eltroplectris calcarata*
Pine Block A	*Digitaria pauciflora, Spiranthes torta*
Pine Block B	*Basiphyllaea corallicola, Helenium flexuosum, Hypelate trifoliata*
Pine Block C	*Digitaria pauciflora, Helenium flexuosum*
Pine Block D	*Digitaria pauciflora*
Pine Block E	*Bourreria cassinifolia, Helenium flexuosum, Ponthieva brittoniae*
Pine Block F	*Bourreria cassinifolia, Ponthieva brittoniae*
Pine Block H	*Basiphyllaea corallicola, Bourreria cassinifolia, Desmodium lineatum, Digitaria pauciflora, Sporobolus compositus* var. *clandestinus*
Pine Block I	*Basiphyllaea corallicola*
Pine Block J	*Basiphyllaea corallicola, Desmodium lineatum*
Pine Island area	*Thelypteris reticulata, Thelypteris serrata*
Redd Hammock	*Eltroplectris calcarata, Oncidium ensatum*
Roadside and canal bank, 14 miles SW of Paradise Key	*Dalea carthagenensis* var. *floridana*
Robertson Hammock	*Oncidium ensatum*
Royal Palm Hammock	*Galeandra beyrichii, Macradenia lutescens, Oncidium ensatum, Oncidium undulatum, Passiflora sexflora, Schizaea pennula, Spiranthes costaricensis, Thelypteris reticulata, Trichomanes punctatum* subsp. *floridanum*
Say Hammock	*Oncidium ensatum*
Torre Hammock	*Hypelate trifoliata*
Turkey Hammock	*Brassia caudata, Macradenia lutescens, Oncidium ensatum*
Warren Hammock Area	*Anemia wrightii*
Wild Lime Hammock	*Oncidium ensatum*
Winkley Hammock	*Brassia caudata, Macradenia lutescens, Oncidium ensatum*
Wright Hammock	*Oncidium ensatum*

Table 3. Summary of 31 rare plant species at end of Year 5.

Species	Long Pine Key Status after Year 5	Taxonomic Group	Life Form	Major Habitats
Adiantum melanoleucum	Present	Pteridophyte	Lithophytic herb	Hammock solution holes
Anemia wrightii	Present	Pteridophyte	Lithophytic herb	Hammock/prairie ecotones
Basiphyllaea corallicola	Present	Orchidaceae	Terrestrial herb	Pinelands
Bourreria cassinifolia	Present	Dicot	Shrub	Pinelands, Hammock/ pineland ecotones
Brassia caudata	Presumed extirpated	Orchidaceae	Epiphytic herb	Hammocks
Croton lobatus	Present	Dicot	Terrestrial herb	Hammock/pineland ecotones
Dalea carthagenensis var. *floridana*	Presumed extirpated	Dicot	Shrub	Uncertain
Desmodium lineatum	Present	Dicot	Terrestrial herb	Pinelands
Digitaria pauciflora	Present	Other Monocot	Terrestrial herb	Pineland/prairie ecotones, Prairies
Eltroplectris calcarata	Present	Orchidaceae	Terrestrial herb	Hammocks
Galeandra beyrichii	Present	Orchidaceae	Terrestrial herb	Hammocks
Govenia utriculata	Presumed extirpated	Orchidaceae	Terrestrial herb	Hammocks
Helenium flexuosum	Present	Dicot	Terrestrial herb	Pinelands, Pineland/prairie ecotones
Hypelate trifoliata	Present	Dicot	Shrub	Hammock/pineland ecotones, Pinelands
Lomariopsis kunzeana	Present	Pteridophyte	Lithophytic herb	Hammock solution holes
Macradenia lutescens	Presumed extirpated	Orchidaceae	Epiphytic herb	Hammocks
Oncidium ensatum	Present	Orchidaceae	Epiphytic herb	Hammocks
Oncidium undulatum	Presumed Extirpated	Orchidaceae	Epiphytic herb	Hammocks
Passiflora sexflora	Present	Dicot	Vine	Hammocks
Pecluma plumula	Present	Pteridophyte	Epiphytic herb	Hammocks
Ponthieva brittoniae	Present	Orchidaceae	Terrestrial herb	Pinelands
Prescotia oligantha	Presumed extirpated	Orchidaceae	Terrestrial herb	Hammocks
Schizaea pennula	Presumed Extirpated	Pteridophyte	Terrestrial herb	Hammocks
Sideroxylon reclinatum subsp. *austrofloridense*	Present	Dicot	Shrub	Pinelands, Pineland/prairie ecotones, Prairies
Spiranthes costaricensis	Present	Orchidaceae	Terrestrial herb	Hammocks
Spiranthes torta	Present	Orchidaceae	Terrestrial herb	Pinelands
Sporobolus compositus var. *clandestinus*	Present	Other Monocot	Terrestrial herb	Pinelands
Thelypteris reticulata	Present	Pteridophyte	Terrestrial herb	Cypress dome, Hammocks, Tree islands, *Schinus* thickets
Thelypteris serrata	Present	Pteridophyte	Terrestrial herb	*Schinus* thickets, Tree islands?, Hammocks?
Tillandsia fasciculata var. *clavispica*	Presumed extirpated	Other Monocot	Epiphytic herb	Hammocks
Trichomanes punctatum subsp. *floridanum*	Presumed extirpated	Pteridophyte	Lithophytic herb	Hammock solution holes

Table 4. Baseline abundance estimates for 22 extant rare plant species in the Long Pine Key area of EVER as of September 30, 2008.

Species	Occurrences	Stations recorded	Log_{10} abundance estimate
Adiantum melanoleucum	2	2	2 to 10
Anemia wrightii	2	8	100-1,000
Basiphyllaea corallicola	5	11	11-100
Bourreria cassinifolia	5	14	11-100
Croton lobatus	1	1	100-1,000
Desmodium lineatum	3	15	100-1,000
Digitaria pauciflora	15	113	1,000-10,000
Eltroplectris calcarata	14	48	100-1,000
Galeandra beyrichii	3	3	2 to 10
Helenium flexuosum	9	20	1,000-10,000
Hypelate trifoliata	6	14	11-100
Lomariopsis kunzeana	1	1	2 to 10
Oncidium ensatum	34	102	100-1,000
Passiflora sexflora	1	3	2 to 10
Pecluma plumula	2	3	11-100
Ponthieva brittoniae	3	49	101-1,000
Sideroxylon reclinatum subsp. *austrofloridense*	15	162	10,000-100,000
Spiranthes costaricensis	6	18	100-1,000
Spiranthes torta	1	2	2 to 10
Sporobolus compositus var. *clandestinus*	1	1	101-1,000
Thelypteris reticulata	3	3	2 to 10
Thelypteris serrata	1	3	11-100

Goal 2: Establish a long-term monitoring program to evaluate population and habitat responses of rare species to regional restoration.

Long-term Monitoring Methods

The original scope of work stated that long-term monitoring plots would be established in rare plant habitats in the Long Pine Key area: rockland hammocks, rockland hammock solution holes, pine rocklands, and pine rockland/marl prairie ecotones. Plots for all habitats would be situated both north and south of the main park road. Changes in population status would be correlated with water availability as determined from the EVER hydrological monitoring database, soil water measurements and solution hole water depths. Plots north and south of the main park road would be compared, using appropriate statistical techniques. Additional environmental variables measured would include ground layer and solution hole humidity, soil texture, soil nutrient status and organic content, soil water-holding capacity, and canopy cover. Community composition within 5 m of the rare plant population would be inventoried to help define the habitat and to select promising introduction sites. Plots were to focus especially on those species that may be affected by CERP.

Plots. Twenty-eight initial plots were installed in the dry season of 2004 and additional plots were established as populations of rare plants were discovered throughout the period of this project. As possible, three plots were installed south of the main park road and were matched by an additional three plots north of the road. The minimum goal was to install three plots per species regardless of location, though this was not achieved for species with exceedingly low numbers. Two species, *Digitaria pauciflora* and *Sideroxylon reclinatum*, received twice as many plots to gain a better understanding of their habits since the former appeared ephemeral and the latter occurred both within prairie and pineland habitats. Plots were circular (5 m radius) and centered on an individual or within a population of one of the rare plants being studied. The location of the center of each plot was recorded with a GPS unit and plots were marked with rebar and a numbered tag. Plots were generally visited biannually, once during the dry season (March, April) and once during the wet season (September, October). Rare plant counts, recruitment notes and community composition data were recorded consistently starting with the 2004 dry season, but environmental measures varied through the course of the project. Several methods were tested in an attempt to capture essential information inspite of the high variation in habitat requirements and natural history of target species. The following is a summary of the methods that seemed most effective and that were used consistently after the 2006 wet season. All plots were monitored in the 2007 wet season to ensure a consistent baseline comparison for future monitoring work.

Rare Plant Counts & Recruitment – Populations of the target species were monitored at their plots during the optimal time of year for field identification. For example, *Helenium flexuosum* was monitored in the dry season when it flowers. During these visits, all target species were individually counted when accurate counts could be made. When densities were too high for accurate counts, abundance estimates were made using a $\log_{10}$ scale (11-100, 101-1000, etc.). During this count, signs of reproduction were also recorded. Presence of seedlings, spores or fruiting bodies were all considered signs of reproduction.

Community Composition Data – Community composition data was initially collected at each visit, but the methods were subsequently modified. Each plot has baseline measurements for at least one wet and one dry season with all plots having been sampled in the wet season of 2007 for a common starting point. Funding permitting, future monitoring will include community composition data every three to five years. During data collection, each plot was visually divided into the following four vegetation classes: solution hole (<0 m), herb layer (0-1 m), shrub layer (1-3 m), and sub-canopy and canopy layer (>3 m). All taxa occurring in each class were recorded and percent cover was estimated for each species within each layer (0, <1%, 1-5%, 6-25%, 26-50%, 51-75%, 76-100%).

Environmental Data – One-time measurements were taken at each plot for description of substrate type at the target species, maximum canopy height in the plot and mean tree circumference based on ten randomly selected trees (or fewer if not that many occurred in the plot). If applicable, perimeter measurements were taken for the solution hole nearest to the target species, as well as the distance from the hole to the plant. Canopy cover was measured for at least one dry season and one wet season sampling by using a spherical densiometer placed directly above the target species. At each sampling, temperature and relative humidity (RH) were recorded at the target species using a hand-held hygrometer. Several methods were used to measure water in the plots in order to capture water sources relevant to the habitat requirements of the variety of species included in the study, including a range from terrestrial species to epiphytes. Water depth was recorded at the study plant, at the edge of the solution hole nearest the plant, and at the deepest point in the same solution hole. In plots that become inundated with water, an estimate of overall water coverage was made instead. Coverage estimates use the same scale as is used for community composition (0, <1%, 1-5%, 6-25%, 26-50%, 51-75%, 76-100%).

During the wet seasons of 2005, 2006 and 2007 and in the dry season of 2007, soil samples were collected at 25 plots representing 10 of the target species. Representative substrate samples (*i.e.* rotting log or leaf litter were collected if this was the substrate the plant was growing on) were taken from as close to the target species as possible without disrupting the plants themselves or the surrounding habitat. All samples were delivered to the Institute of Food and Agricultural Sciences, University of Florida (IFAS) for analyses. Samples from wet season 2005, wet 2006 and dry 2007 were analyzed for nutrient content and samples from the wet season of 2007 were analyzed for field water holding capacity.

General Plot Analysis Procedures – Relative population growth rates were calculated by averaging number of individuals of a species across all plots centered on that species each summer or winter season, depending on the species' natural history, starting winter 2004 to summer 2007. Given that the majority of focal species are herbaceous and active only during certain times of the year, we used data from the season of the year relevant to growth and germination of each individual species. Furthermore, analyses began for each species only after the final number of plots for that species had been established causing the temporal range included in the analyses to vary across species. The relative population growth (RGR) was measured as

$$RGR = \ln (N_{t2}) - \ln (N_{t1}) / t \text{ (1 year)}$$

where N is the number of median plants per plot at each sampling event. Table 5 summarizes raw data per sampling event for all the focal species. A population growth rate of 1 suggests stable growth rate, < 1 suggests decline and > 1 suggest an increased growth rate.

We used PC-ORD5 (McCune and Mefford 2006) to summarize the parameters of species composition such as species richness and diversity among focal species plots. Species composition and environmental data were then analyzed simultaneously using CCA ordination to investigate if species abundance in study plots is significantly explained by the abiotic or environmental data characterizing the plot location. Analysis for each of the focal habitat types was done separately and is presented as such below. We excluded infrequent rare species from the analyses by removing any target species with less than three total plots across all locations. Environmental variables in the analysis were – location (north, south, or west of the main park road), substrate, solution hole presence, canopy cover, canopy height, mean tree circumference and RH (wet and dry season measured at one point in time in each season). If a significant effect of an environmental factor was observed, the associated strength of the relationship was reported as a regression coefficient and its associated probability.

Species composition was compared across plot locations using One-Way ANOVA or *t* tests. All significance levels were set at $P < 0.05$. In cases of a significant effect of an environmental variable on community composition, the effects of the variable were also tested on parameters of species composition such as species richness (S) and a species diversity index (H').

Soil nutrient analyses were done for percent nitrogen (% N), percent organic carbon (% C), nitrate (NO3; mg/kg), ammonia (NH4; mg/kg), total phosphorous (TP; mg/kg), percent inorganic carbon (% C), total aluminum (TAlum; mg/kg), total iron (TFe; mg/kg) and total potassium (TK; mg/kg). The 2006 sample set was excluded from analyses because it was incomplete and appeared to be a run error since all values were consistently higher than the other years. The 2005 and 2007 results are presented in effective water holding capacity, the amount of water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water has materially decreased, was also analyzed for all samples. Larger water capacity values indicate greater water retention. An ANOVA was run using JMP 7.0 (SAS Corporation) with species, habitat and season as the fixed variables and soil nutrients/ water holding capacity as the dependent variables.

Transects. Based on observations of plants in the field, it was determined that belt transects would be more appropriate than radius plots for *Digitaria pauciflora* and *Sideroxylon reclinatum* subsp. *austrofloridense*. Both of these species were thought to grow along an elevational gradient that extends from within the marl prairie community up and into the pineland, with higher densities of plants near the ecotone than in either pineland or prairie. Belt transects would allow for observations of plant movements along this elevational gradient in response to regional hydrological restoration. Based on preliminary observations, we hypothesized that *D. pauciflora* would be less likely to have a pineland distribution and that regional restoration would push both species up the elevational gradient. The expected result of restoration would be an increase in *S. reclinatum* subsp. *austrofloridense* abundance in the pineland while *D. pauciflora* would become limited to a narrower band on the prairie side of the ecotone, rarely if ever entering the pineland proper.

The installation of belt transects for these two species was initiated in Year 2 during the 2005 dry season. A total of twelve 50 m transects were installed, three for each species south of main park road and three for each species north of main park road. Six additional transects, three north of the road and three south of the road, were installed for *Digitaria pauciflora* in the 2007 dry season and again in the 2008 dry season to establish a rotating panel sampling regime for long-term monitoring of ephemeral species (see Urquhart and Kincaid 1999 for details). By the end of the project, a total of 24 transects were installed within the LPK region (Figure 3) – six for *Sideroxylon reclinatum* subsp. *austrofloridense* and 18 for *D. pauciflora*, each with half of the plots on either side of the main park road. The original 12 transects were sampled for two consecutive years, the six *Digitaria* transects installed in the 2007 dry season were monitored for one year and six more *Digitaria* transects were installed in the 2008 dry season and have not yet been remonitored. Transects were installed by walking along the prairie-pineland ecotone until one of the target species was observed. A transect was then established perpendicular to the ecotone with the center at the approximate point where the two habitats meet such that roughly half of each transect extended into prairie habitat and the other half into pineland habitat resulting in approximately 25 meters on each side. The endpoints and center of each transect were recorded with a Trimble GPS unit with meter 0 marking the start of the line in the prairie and meter 50 marking the endpoint in the pineland. Transect endpoints were marked with rebar to ensure precise measurements during future, repeated monitoring. At each visit, a measuring tape was extended the entire length of the transect and water level measurements were taken every five meters in 2005 and every meter at all following visits. Transects were also divided into 50 1x1 m quadrats, along one side in 2005 and along both sides in ensuing years for increased sample size, for monitoring target species. An estimate of percent cover of the target species was recorded for each quadrat, and for *D. pauciflora* the number of individuals contributing to this cover were also recorded counting those rooted within and outside the plot separately. During the installation year, and at three year intervals following that in the dry season, dominant species (the species <3 m in height that covering the greatest area in the quadrat) were also recorded for each quadrat.

Transects were visited once in the wet season and once in the dry season each year, though in the dry season of 2008 the rotating panel design was implemented for *Digitaria* transects and the original transects were not visited. Plots installed in the dry 2007 season were monitored and six new transects were established with three each north and south of the road. Funding permitting, future monitoring will follow this pattern for five years with dry season fieldwork including monitoring of transects installed the previous dry season and installation of another set of six transects. All transects visited and installed in the dry season should also be monitored during that year's wet season. After five years, no new transects will be established, but the monitoring rotation will remain the same, cycling through the transects in the order they were installed with each set being monitored for two consecutive years.

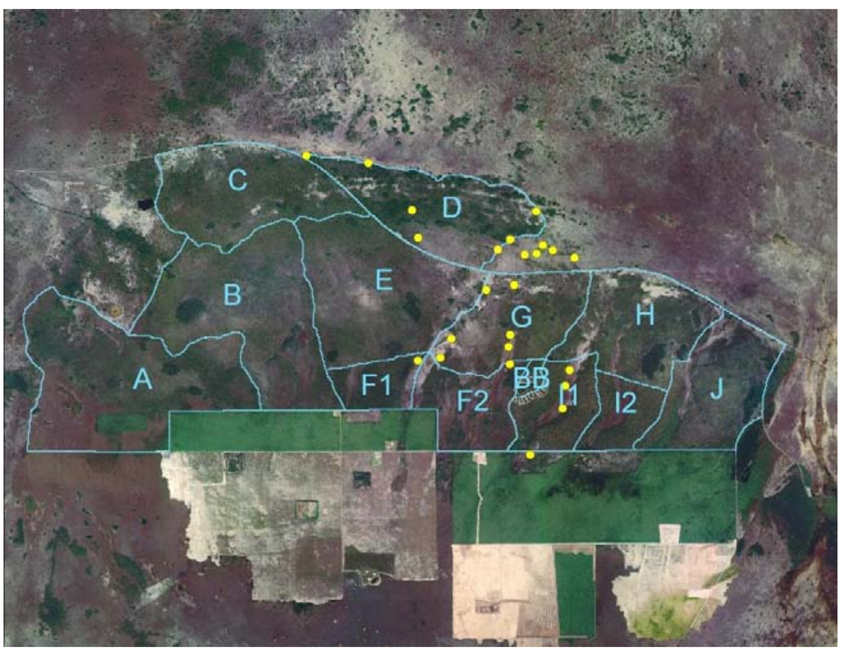


Figure 3. Long-term monitoring transects in the Long Pine Key area.

General Transect Analysis Procedures – Species occurrence was plotted by meter marker along transects to examine if a pattern of species occurrence by location could be discerned. Changes in species composition across years were tested by comparing frequency of species dominance (number of times a species occurred as dominant in pooled transects) across years. Using data from the summers of 2005 and 2007, we analyzed whether the abundance of focal species and overall species composition changed over time with chi-square tests. Only the transects established in 2005, which had paired data, were used for this test. We also looked at whether potential changes in these factors paralleled differences in surface water level across years since 2005 was very wet from repeated hurricanes and 2007 was a drought year. Changes in *Digitaria* and *Sideroxylon* abundance were analyzed in relation to hydrological data. In addition to surface water, ground water data was acquired from two national park monitoring wells located to either side of the main park road – NP 62 (north) and NP 72 (south). No statistics were run on the groundwater data due to low sample size. We did not analyze the data using the rotating panel design framework because not enough data have been generated since the design was adopted.

Long-term Monitoring Results

Plots: By the end of the project in September 2008, a solid baseline was established for long-term monitoring with 79 plots installed in the LPK region of EVER (Figure 4; Appendix B). Fifty-seven were located south of the main park road, 21 north of the road and one west of the road. The 79 plots encompassed all 22 of the extant species included in the study and all major habitat types were sampled both north and south of main park road except for rockland hammock solution hole, which was sampled only in the south (Table 5). Tables 6 and 7 provide a summary of the plots and their characteristics.

Few study species were found north of main park road and none that are strictly associated with hammock solution holes: *Anemia wrightii*, *Digitaria pauciflora*, *Oncidium ensatum*, *Helenium flexuosum*, *Pecluma plumula* and *Sideroxylon reclinatum* subsp. *austrofloridense*; only *D. pauciflora* and *S. reclinatum* subsp. *austrofloridense* were fairly abundant there. *Pecluma plumula* was not found south of main park road, while the remainder of these species have populations both north and south of main park road. *O. ensatum* has been found only in one hammock north of main park road – it is far more abundant to the south. Because of the small population north of main park road, only two plots of *O. ensatum* were installed in the north, paired with two plots south of main park road. *H. flexuosum*, which grows in low elevation pinelands and along the upland side of the pineland/marl prairie ecotone, does have a small population north of main park road. *A. wrightii*, which grows on the eastern edge of Long Pine Key is the only other species to be found both north and south of main park road. The *A. wrightii* occurrences appear to be a single population that was split in two by the construction of the main park road.

Cumulatively, the plots within LPK contained 372 plant species, or 35% of the flora of EVER. Rare plants in this study were found mostly in association with common species with broad ecological tolerances (Table 8) and rarely with each other. *Sabal palmetto* and *Rapanea punctata* were the most frequently observed species in plots (Table 8) and were observed in virtually every habitat (*R. punctata* was not recorded in marl prairie). Eleven plots had other target species within their boundaries with *Sideroxylon reclinatum* subsp. *austrofloridense* being the most frequently observed additional species (Table 9). Ten species of introduced exotic plants were found growing within LPK rare plant plots and were represented in every habitat type (Table 10). *Ardisia elliptica*, *Oeceoclades maculata*, *Schinus terebinthifolius* and *Spermacoce verticillata* were the only exotic species to occur in more than one plot with *O. maculata* and *S. terebinthifolius* at the highest frequencies. Plots south of the main park road had a higher frequency and variety of exotic species than north or west of the road.

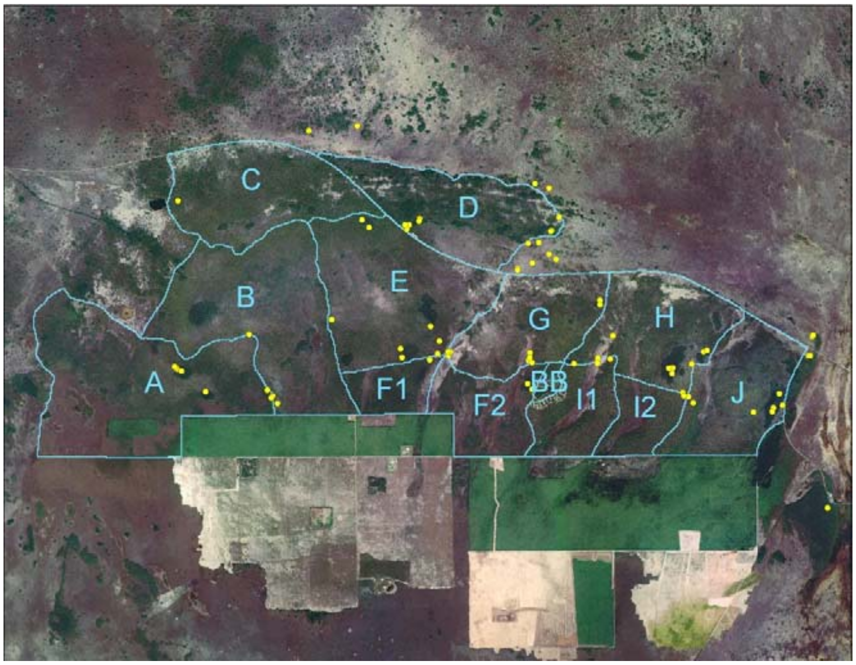


Figure 4. Long-term monitoring plots in the Long Pine Key area (outliers excluded).

Table 5. Summary of monitoring plots in the Long Pine Key area by habitat and location.

Habitat	# plots	Orientation to main park road	Study species
Bayhead-prairie ecotone	2	North	*Anemia wrightii*
Bayhead-prairie ecotone	3	South	*Anemia wrightii*
Firebreak	1	South	*Sporobolus compositus* var. *clandestinus*
Hammock	4	North	*Oncidium ensatum, Pecluma plumula*
Hammock	14	South	*Eltroplectris calcarata, Galeandra beyrichii, Hypelate trifoliate, Oncidium ensatum, Passiflora sexflora, Spiranthes costaricensis, Thelypteris reticulata*
Hammock	1	West	*Pecluma plumula*
Hammock solution hole	4	South	*Adiantum melanoleucum, Lomariopsis kunzeana*
Marl prairie	9	North	*Digitaria pauciflora, Sideroxylon reclinatum* subsp. *austrofloridense*
Marl prairie	9	South	*Digitaria pauciflora, Sideroxylon reclinatum* subsp. *austrofloridense*
Other	2	Southeast	*Thelypteris serrata*
Pineland	6	North	*Helenium flexuosum, Sideroxylon reclinatum* subsp. *austrofloridense*
Pineland	24	South	*Basiphyllaea corallicola, Bourreria cassinifolia, Croton lobatus, Desmodium lineatum, Helenium flexuosum, Hypelate trifoliata, Ponthieva brittoniae, Sideroxylon reclinatum* subsp. *austrofloridense, Spiranthes torta*

Table 6. LPK Monitoring Plot Characterization by Habitat Type based on 2005-2008 Data.

Major Habitat Type	Study Species	# Plots	Avg. # of Species in Plots (Across All Samplings)	Avg. Mean Tree Circum. (cm)	Dominant canopy (>25% cover in one or more plots in one or more sampling period)
Hammocks (South)		**14**	**43.1**	**27.8**	
	Eltroplectris calcarata	3	52.0	34.7	*Lysiloma latisiliquum, Ocotea coriacea, Quercus virginiana, Sideroxylon salicifolium*
	Galeandra beyrichii	1	28.0	22.2	*Gymnanthes lucida*
	Hypelate trifoliata	3	43.0	18.4	*Gymnanthes lucida, Lysiloma latisiliquum, Metopium toxiferum, Ocotea coriacea, Pinus elliottii* var. *densa, Quercus virginiana, Sideroxylon salicifolium*
	Oncidium ensatum	2	55.0	35.6	*Metopium toxiferum, Ocotea coriacea, Quercus virginiana, Sideroxylon salicifolium*
	Passiflora sexflora	1	36.0	21.2	*Coccoloba diversifolia, Prunus myrtifolia, Simarouba glauca*
	Spiranthes costaricensis	3	37.7	28.5	*Ocotea coriacea, Sideroxylon salicifolium*
	Thelypteris reticulata	1	37.0	29.3	*Annona glabra*
Hammocks (North)		**4**	**50.8**	**17.4**	
	Oncidium ensatum	2	59.0	18.4	none
	Pecluma plumula	2	42.5	16.4	*Lysiloma latisiliquum, Sideroxylon salicifolium*
Hammock Solution Hole (South)		**4**	**41.3**	**32.5**	
	Adiantum melanoleucum	2	39.5	36.2	none
	Lomariopsis kunzeana	2	43.0	28.9	none
Pinelands (South)		**24**	**68.0**	**45.9**	
	Basiphyllaea corallicola	3	65.7	71.8	*Pinus elliottii* var. *densa*
	Bourreria cassinifolia	3	64.0	49.9	*Pinus elliottii* var. *densa*
	Croton lobatus	1	67.0	65	none
	Desmodium lineatum	3	64.3	46.4	*Pinus elliottii* var. *densa*
	Helenium flexuosum	3	74.0	29.6	none
	Hypelate trifoliata	3	73.3	49.6	*Gymnathes lucida, Lysiloma latisiliquum, Metopium toxiferum, Ocotea coriacea, Pinus elliottii* var. *densa, Quercus virgiana, Sideroxylon salicifolium*
	Ponthieva brittoniae	3	75.0	27.9	*Pinus elliottii* var. *densa*
	Sideroxylon reclinatum subsp. *austrofloridense*	3	66.3	36.9	*Pinus elliottii* var. *densa*
	Spiranthes torta	2	58.5	36	*Pinus elliottii* var. *densa*
Pinelands (North)		**6**	**58.3**	**38.3**	

	Helenium flexuosum	3	52.7	58.6	none
	Sideroxylon reclinatum subsp. *austrofloridense*	3	64.0	18	none
Prairies (South)		**9**	**52.4**	**none**	
	Digitaria pauciflora	6	52.2	none	none
	Sideroxylon reclinatum subsp. *austrofloridense*	3	53.0	none	none
Prairies (North)		**9**	**50.7**	**none**	
	Digitaria pauciflora	6	49.5	none	none
	Sideroxylon reclinatum subsp. *austrofloridense*	3	53.3	none	none

Table 7. Range of habitat characters for long-term monitoring plots by species preference.

Species/ Total # Plots	Preferred Habitat	Canopy Height (m)	Canopy Cover (%)	Solution Hole Perimeter (cm)	Water Level at Plant (cm)	Water Level at Nearest Depression / SH (cm)*	Substrate Description
Adiantum melanoleucum / 2	100% Solution Hole	9.8 - 10.3	90 - 93	327 - 1486	0	0	Decomposed leaf litter over limestone
Anemia wrightii / 5	100% Pinnacle Rock at Bayhead-Prairie Ecotone	4.1 - 6.2	69 - 100	N/A: Matrix	0 - 45	0 - 64	Decomposed leaf litter over limestone
Basiphyllaea corallicola / 3	100% Pineland	7.9 - >15	19 - 80	None - 497	0	0 - 80	Leaf litter over limestone
Bourreria cassinifolia / 3	100% Pineland	7.1 - 14.5	26 - 56	None - 246	0	0 - 35	Decomposed leaf litter over limestone - Limestone
Croton lobatus / 1	100% Pineland	13.7	47.6 - 54.6	None	0	N/A	Decomposed leaf litter over limestone
Desmodium lineatum / 3	100% Pineland	>15	8 - 43	None	0	N/A	Redland soil pockets over limestone
Digitaria pauciflora / 12	100% Prairie	0	0 - 11	None - 250	0 - 12.4	0 - 3.5	Marl soil / Periphyton over limestone
Electroplectris calcarata / 3	100% Hammock	9.3 - 11.4	91 - 99	None	0	N/A	Decomposed leaf litter
Galeandra beyrichii / 1	100% Hammock	9.2	91	None	0 - 1	N/A	Decomposed leaf litter
Helenium flexuosum / 6	100% Pineland	7.4 - >15	18 - 91	None - 700	0 - 6	0 - 17	Marl soil over limestone
Hypelate trifoliata / 6	50% Pineland, 50% Hammock	7.6 - 12.6	14 - 95	115 - 730	0 - 14	0 - 64	Leaf litter over limestone
Lomariopsis kunzeana / 2	100% Solution Hole	8.5 - >15	96 - 99	261 - 758	0	0	Limestone
Oncidium ensatum / 4	100% Hammock	5.3 - 11.5	72 - 100	None - 1785	0	0 - 48	Decomposed leaf litter
Passiflora sexflora / 1	100% Hammock	9.5	94 - 96	None	0	N/A	Decomposed leaf litter

Pecluma plumula / 3	100% Hammock	6.3 - 11.4	86 - 96	None - 617	0	0 - 80	Rotting logs / Fallen trees
Pontheiva brittoniae / 3	100% Pineland	2.6 - 12.4	19 - 86	345 - 527	0 - 16	0 - 60	Decomposed leaf litter
Sideroxylon reclinatum / 12	50% Pineland, 50% Prairie	0 - >15	0 - 70	None - 520	0 - 8	0 - 12.6	Marl soil / Periphyton over limestone - Limestone
Spiranthes costaricensis / 3	100% Hammock	8.9 - 10.8	92 - 98	None - 600	0	0	Decomposed leaf litter
Spiranthes torta / 2	100% Pineland	10.5 - 12.8	16 - 37	None	0 - 47	N/A	Sandy soil / Marl over limestone - Limestone
Sporolobus compositus / 1	100% Firebreak	3.7 - 8.7	3 - 6	None	0	N/A	Redland soil pockets - Limestone (intact+scraped)
Thelypteris reticulata / 1	100% Hammock	9.2	85 - 93	2750	0	16 - 47	Decomposed leaf litter - Peat
Thelypteris serrata / 2	33% Hammock, 67% Other	4.2 - 5.4	98 - 100	None	0 - 8	N/A	Humic soil

Table 8. Thirty most frequently observed species in long-term monitoring plots (based on 2007 wet season sampling).

Species	Life Form	# Plots	# Layers	Layers	Major Habitats
Sabal palmetto	Shrub/ tree	61	123	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland, Prairie
Rapanea punctata	Shrub/ tree	57	142	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland
Smilax auriculata	Vine	53	120	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland
Solidago stricta	Herb	52	86	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Ardisia escallonioides	Shrub/ tree	51	135	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland
Dyschoriste angusta	Herb	51	73	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Metopium toxiferum	Shrub/ tree	51	131	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland
Sideroxylon salicifolium	Shrub/ tree	51	137	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland
Mikania scandens	Vine	49	93	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Randia aculeata	Shrub	48	71	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Morinda royoc	Vine	46	90	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland
Passiflora suberosa	Vine	46	75	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland, Prairie
Anemia adiantifolia	Herb	45	76	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland
Piriqueta caroliniana	Herb	44	59	Canopy, shrub, herb, solution hole	Other, Pineland, Prairie
Myrica cerifera	Shrub/ tree	43	103	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Tetrazygia bicolor	Shrub	43	99	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland
Hyptis alata	Herb	42	82	Canopy, shrub, herb, solution hole	Other, Pineland, Prairie

Polygala grandiflora	Herb	41	54	Canopy, shrub, herb, solution hole	Other, Pineland, Prairie
Schizachyrium rhizomatum	Herb	41	58	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Angadenia berteroi	Herb	39	61	Canopy, shrub, herb, solution hole	Pineland, Prairie
Muhlenbergia capillaris	Herb	39	70	Canopy, shrub, herb, solution hole	Other, Pineland, Prairie
Ruellia succulenta	Herb	39	55	Canopy, shrub, herb, solution hole	Other, Pineland, Prairie
Aristida purpurascens	Herb	38	40	Shrub, herb, solution hole	Other, Pineland, Prairie
Chiococca parvifolia	Shrub	38	65	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Chrysobalanus icaco	Shrub	38	81	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Cladium jamaicense	Herb	38	98	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Eugenia axillaris	Shrub/ tree	38	107	Canopy, shrub, herb, solution hole	Hammock, Hammock solution hole, Other, Pineland, Prairie
Persea palustris	Shrub/ tree	38	91	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Pinus elliottii var. *densa*	Tree	38	115	Canopy, shrub, herb, solution hole	Hammock, Other, Pineland, Prairie
Cassytha filiformis	Vine	37	71	Canopy, shrub, herb, solution hole	Other, Pineland, Prairie

Table 9. Incidence of target species occurring in plots of other target species.

Plot Species	**Other Target Species in Plot**
Adiantum melanoleucum	*Spiranthes costaricensis*
Anemia wrightii	*Sideroxylon reclinatum* subsp. *austrofloridense*
Bourreria cassinifolia	*Basiphylleae corallicola, Sideroxylon reclinatum* subsp. *austrofloridense*
Desmodium lineatum	*Sideroxylon reclinatum* subsp. *austrofloridense*
Digitaria pauciflora	*Sideroxylon reclinatum* subsp. *austrofloridense*
Eltroplectris calcarata	*Oncidium ensatum, Galeandra beyrichii*
Helenium flexuosum	*Sideroxylon reclinatum* subsp. *austrofloridense*
Hypelate trifoliata	*Ponthieva brittoniae*
Sideroxylon reclinatum subsp. *austrofloridense*	*Helenium flexuosum, Digitaria pauciflora*
Spiranthes costaricensis	*Passiflora sexflora*
Spiranthes torta	*Basiphylleae corallicola*

Table 10. Distribution of introduced exotic species in long-term monitoring plots.

Introduced Exotic Species	Affiliated Focal Species	# Plots	Plot Locations	Habitat Types
Ardisia elliptica	*Helenium flexuosum, Thelypteris serrata*	3	North, South	Other, Pineland
Bothriochloa pertusa	*Sporobolus compositus* var. *clandestinus*	1	South	Firebreak
Emilia sp.	*Thelypteris reticulata*	1	South	Hammock
Eremochloa ophiuroides	*Desmodium lineatum*	1	South	Pineland
Oeceoclades maculata	*Adiantum melanoleucum, Anemia wrightii, Eltroplectris calcarata, Galeandra beyrichii, Hypelate trifoliata, Lomariopsis kunzeana, Passiflora sexflora, Pecluma plumula, Spiranthes costaricensis*	17	North, South & West	Hammock, Hammock Solution Hole, Other
Rhynchelytrum repens	*Sideroxylon reclinatum* subsp. *austrofloridense*	1	South	Pineland
Richardia scabra	*Croton lobatus*	1	South	Pineland
Schinus terebinthifolius	*Anemia wrightii, Basiphyllaea corallicola, Bourreria cassinifolia, Helenium flexuosum, Hypelate trifoliata, Oncidium ensatum, Passiflora sexflora, Pecluma plumula, Pontheiva brittoniae, Spiranthes costaricensis, Thelypteris reticulata, Thelypteris serrata*	21	North, South & West	Hammock, Hammock Solution Hole, Other, Pineland
Spermacoce verticillata	*Helenium flexuosum, Sporobolus compositus* var. *clandestinus*	2	South	Firebreak, Pineland
Sporobolus indicus var. *pyramidalis*	*Thelypteris reticulata*	1	South	Hammock

Rare Plant Counts & Recruitment – Based on the total number of individuals occurring each sampling season (Table 11), we analyzed the population growth rates of focal plants in the LPK area. The raw data summarized in Table 11 suggests that the majority of rare plants had fluctuating population growth. Population growth rates are depicted in Figures 5a-d where each panel represents a grouping of plants based on taxonomy or habit. Functional similarity among plants in a group is not necessarily implied, but may exist. *Sporobolus compositus* var. *clandestinus* was not included in the population growth rate figures because of uncertain population figures from the final monitoring in October 2007. No plants were observed during this monitoring, but that is not necessarily an indication that plants no longer exist since the flowering season is short and may have occurred at an off-season time.

In summary, herbaceous plants, especially the orchids and ferns, experienced declining populations for three consecutive years in 2005, 2006 and 2007. Exceptions were *Basiphyllaea* and *Eltroplectris calcarata* whose growth rates fluctuated annually between stable and declining. Adult populations of the woody shrubs *Bourreria cassinifolia* and *Hypelate trifoliata* were relatively constant across years, though the juvenile numbers fluctuated. Herbaceous forbs such as *Helenium flexuosum* and *Desmodium lineatum* showed annual fluctuation between decline and increase in population size.

Table 11. Total number of individuals per species across years inside the LPK area. Numbers are collapsed across all populations per species to provide overall trends in population fluctuation across years.

	Sampling Season (D=dry; W=wet)							
Species	2004 (D)	2004 (W)	2005 (D)	2005 (W)	2006 (D)	2006 (W)	2007 (D)	2007 (W)
Adiantum melanoleucum				4		4		5
Anemia wrightii						189		173
Basiphyllaea corallicola		0*		3		1		1
Bourreria cassinifolia Adults				13		13		13
Bourreria cassinifolia Juveniles				6		6		11
Desmodium lineatum				14		58		47
Digitaria pauciflora							211	
Eltroplectris calcarata	30		84		5		10	
Galeandra beyrichii				1		2		1
Helenium flexuosum			118		111		189	
Hypelate trifoliata Adults				8		9		8
Hypelate trifoliate Juveniles				8		0		2
Lomariopsis kunzeana		4		2		4		3
Oncidium ensatum				14		11		18
Passiflora sexflora		2		2		2		4
Pecluma plumula				84		113		128
Ponthieva brittoniae	39		30		5		11	
Sideroxylon reclinatum							18	
Spiranthes costaricensis								263
Spiranthes torta						3		0*
Sporobolus compositus						106		0*
Thelypteris reticulata						2		2
Thelypteris serrata						8		6

*0 indicates sampling was done and no plants were found. An empty cell indicates that sampling was not done at that time.

Hammock Plots – Twenty hammock plots representing eight focal species were distributed within LPK. Five were located north of the main park road, 14 south of the road and one was west of the road (Table 5). The mean species richness of plots south of the road was 40 ± 2.4 species and 50 ± 5.2 species north of the road. There are no significant differences in species composition between plots north and south of the road. Figure 6 shows the distribution of plots along CCA axes. Despite a slightly more restricted distribution for plots north of the road, there were no significant differences between the locations and there were no apparent correlations with environmental variables.

Solution hole presence did not affect species richness or diversity significantly in the plots, though the species richness was greater in plots with solution hole presence ($t_{120} = 1.48$, $P > 0.05$, Species richness in plots with solution holes = 46, without solution holes = 40). Focal species in plots with solution holes were *Hypelate trifoliata, Oncidium ensatum* and *Thelypteris reticulata*.

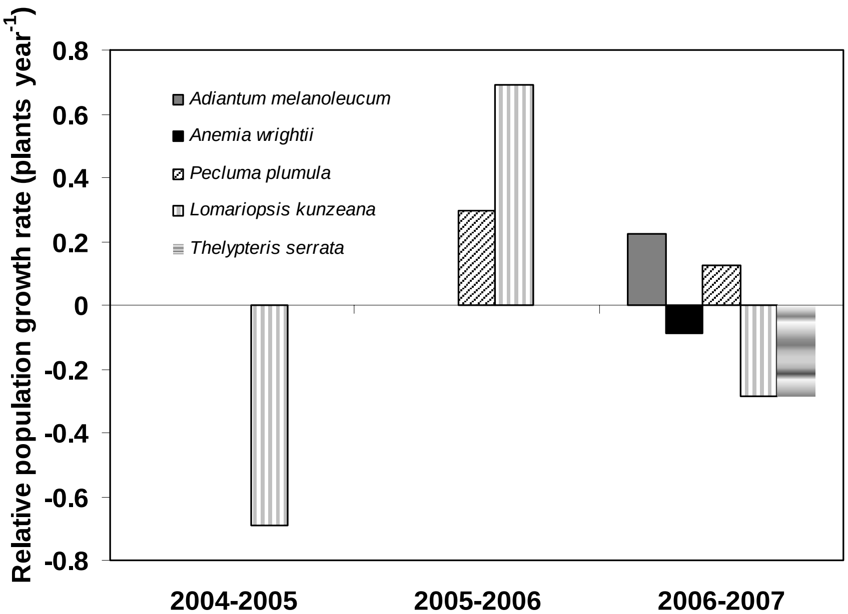


Figure 5a. Population growth rates of ferns.

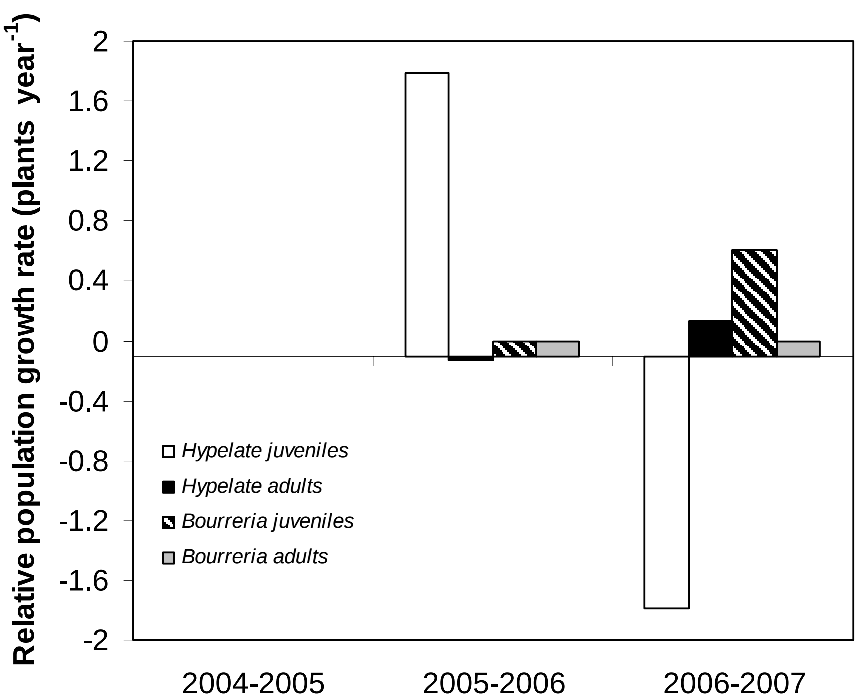


Figure 5b. Population growth rates of woody shrubs.

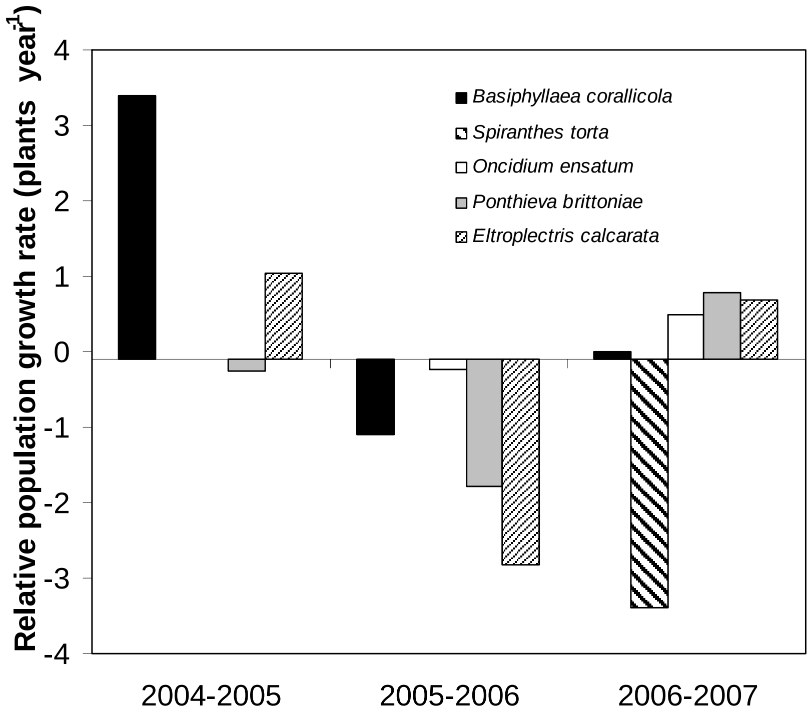


Figure 5c. Population growth rates of terrestrial orchids.

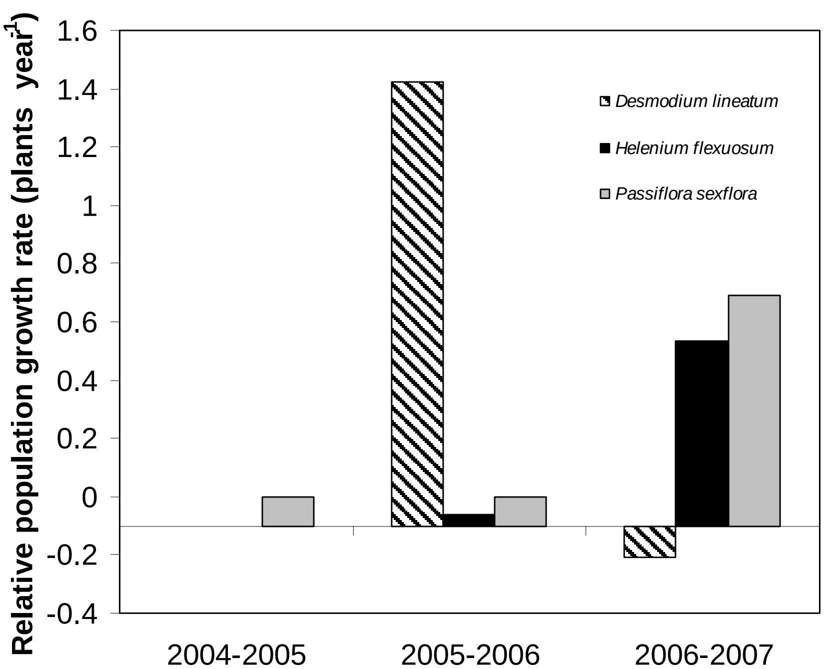


Figure 5d. Population growth rates of other species, excluding *Sporobolus compositus* var. *clandestinus*.

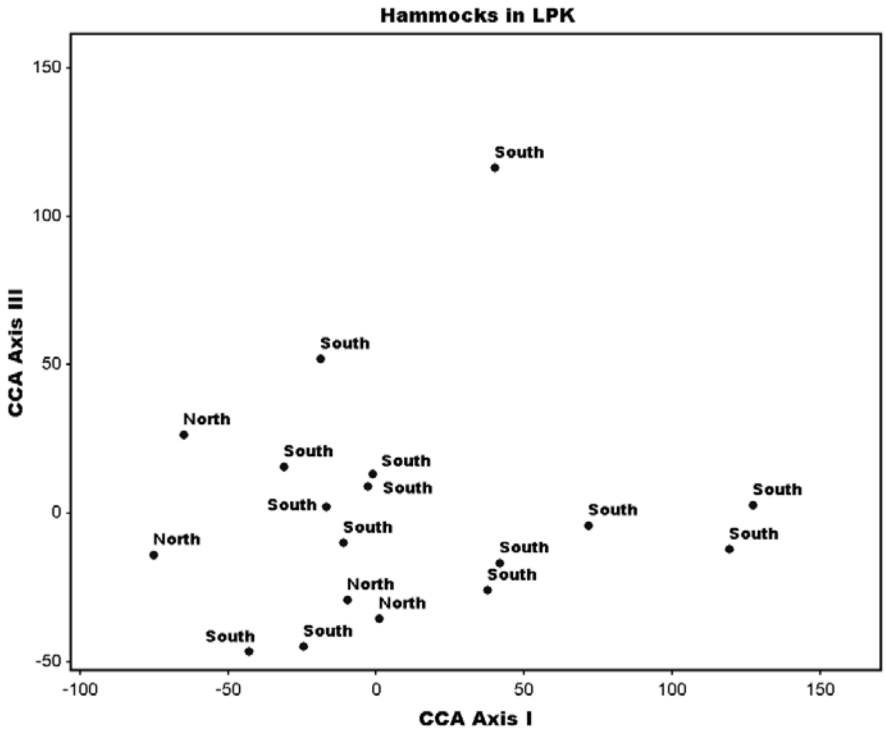


Figure 6. A CCA ordination of Hammock plots located in the LPK area. The plots in the south have a wider distribution along axis I, while the plots in the north are relatively restricted. The distribution does not correlate with any of the environmental variables in this study.

Pineland Plots – Thirty pineland plots were distributed within LPK with six north of the main park road and 24 south of the road. Pineland plot species richness was significantly explained by functional (including all vegetation layers above the focal species) canopy cover ($P < 0.001$; Figure 7). Plots to the north of the main park road had lower species richness ($t_{1,28} = 3.01$, $P < 0.05$) and diversity ($t_{1,28} = 5.43$, $P < 0.01$) than those located south of the road. This was likely driven by both sample size (greater in south) and physiognomy of the pinelands since northern plots had significantly greater functional canopy cover than southern plots ($t_{1,28} = -2.85$, $P = 0.046$). We performed an analysis of covariance with location as a categorical variable and functional canopy cover as a covariate using *Helenium flexuosum* and *Sideroxylon reclinatum* plots only because these species were common in both locations. The test revealed a marginally non-significant correlation between functional canopy cover and species richness irrespective of plot location. ($F_{1, 11} = 4.40$, $P = 0.058$, canopy effect, Location effect, $F_{1, 11} = 0.51$, $P > 0.1$).

Fire is an important element of pineland habitat so a regression analysis of mean fire frequency per plot (average burn frequency calculated from fire records) was conducted with fire frequency as the independent variable and species richness, species diversity and functional canopy cover as dependent variables. Fire frequency did not have a significant impact on species richness, functional canopy cover and species diversity. It should be noted, however, that analyses might not detect actual differences because fire patchiness is not always well reflected in burn data.

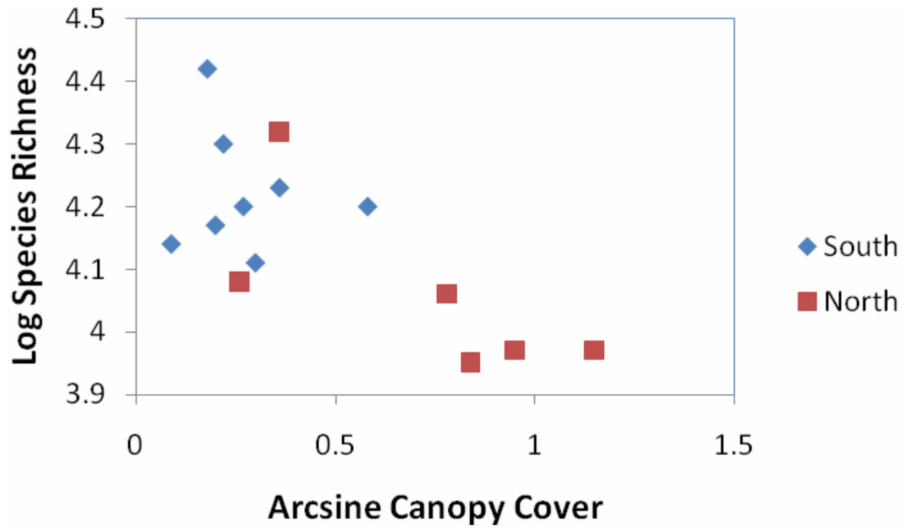


Figure 7. Comparison of functional canopy cover versus species richness for *Helenium* and *Sideroxylon* plots based on location in relation to main park road.

Prairie Plots – Eighteen marl prairie plots were distributed within LPK with nine north of the main park road and nine south of the road. The prairie plots did not show significant differences in species richness and diversity based on their location north or south of the main park road. The environmental variables did not significantly explain species composition in the prairies.

Hammock Solution Hole Plots – Four hammock solution hole plots were distributed within LPK, all south of the main park road. The mean species richness for these plots was 41.2 ± 2.4. Given the small sample size associated with only four plots, no statistical tests were performed for species composition and environmental variables. The variation in environmental variables was minimal, however, suggesting a degree of homogeneity in the abiotic factors.

Soils – The soil nutrient and effective water holding capacity means and standard errors are presented by species, habitat and season in Table 12. *Desmodium lineatum* appears to have the most unique soil attributes. The soils in *D. lineatum* plots have significantly lower levels of nitrogen than *Adiantum melanoleucum*, *Eltroplectris calcarata*, *Pecluma plumula* and *Oncidium ensatum* ($F = 3.82$; $P = 0.0015$). Organic carbon levels are also significantly lower than for *P. plumula* and *O. ensatum* ($F = 2.84$; $P = 0.01$). In addition, *D. lineatum* plots had higher levels of aluminum ($F = 5.01$; $P = 0.003$) and iron ($F = 4.49$; $P = 0.005$) than most (*Passiflora sexflora* and *Basiphylleae corallicola* are exceptions for aluminum) or all other species respectively. The only other species to significantly differ from the others in terms of soil nutrients is *A. melanoleucum* which had higher levels of nitrate than any other species ($F = 3.32$; $P = 0.004$) and higher ammonium than *Anemia wrightii*, *B. corallicola*, *D. lineatum* and *Ponthieva brittoniae* ($F = 2.95$; $P = 0.008$). These species differences correspond with observed trends in the habitat data wherein pineland soils generally had significantly lower levels of nutrients while hammock habitat had significantly higher levels. The other general trend for habitat comparisons was that hammock and solution hole soils were generally not different

Table 12. Mean Results and Standard Error for Soil Nutrient Analyses and Water Holding Capacity by Species, Habitat and Season.

Factor		% N	% C (organic)	NO3	NH4	TP	% C (inorganic)	TAlum	TFe	TK	H2O
		Soil Measure									
Species											
Adiantum melanoleucum	Mean	2.36	32.97	321.91	443.68	716.26	0.40				
	Standard Error	0.36	7.36	319.08	403.35	131.87	0.09				
Anemia wrightii	Mean	1.04	19.34	8.58	34.60	323.19	4.48	1896.05	1187.82	129.91	
	Standard Error	0.41	7.78	3.59	13.10	101.16	2.34	584.97	359.86	86.38	
Basiphyllaea corallicola	Mean	0.77	31.99	7.37	28.65	251.80	2.45	38587.59	22775.88	331.50	49.99
	Standard Error	0.18	6.25	3.72	6.95	54.67	1.65	21683.92	12973.52	60.90	2.04
Desmodium lineatum	Mean	0.40	13.46	8.53	14.27	222.26	0.75	80186.21	45521.09	463.05	48.17
	Standard Error	0.11	3.89	4.99	2.13	15.62	0.33	23205.37	13818.99	96.27	5.43
Eltroplectris calcarata	Mean	1.95	35.11	34.52	227.04	318.56	0.79	2350.65	1929.95	345.08	43.91
	Standard Error	0.12	2.95	30.07	52.80	76.90	0.33	1073.00	728.65	157.53	10.88
Lomariopsis kunzeana	Mean	1.50	23.03	6.06	216.27	877.71	3.77				
	Standard Error	0.83	9.94	1.54	170.71	486.94	3.01				
Oncidium ensatum	Mean	1.74	38.95	1.66	210.66	555.99	0.50	411.62	293.09	154.65	34.15
	Standard Error	0.09	1.24	0.69	43.09	30.32	0.06	143.93	148.29	31.44	3.68
Passiflora sexflora	Mean	1.95	26.39	150.71	131.80	989.08	0.48				
	Standard Error	0.56	13.33	149.53	124.22	154.15	0.27				
Pecluma plumula	Mean	1.81	41.93	5.80	103.03	712.38	0.58	1634.70	1716.63	164.94	27.26
	Standard Error	0.25	1.09	2.98	33.39	135.60	0.12	846.38	797.24	25.76	4.64
Ponthieva brittoniae	Mean	0.90	27.26	64.36	19.17	443.32	4.80	2625.64	1749.96	171.05	
	Standard Error	0.18	5.69	27.90	5.09	125.20	2.36	827.27	253.98	20.73	
Habitat											
Hammock	Mean	1.84	37.43	27.67	175.40	574.99	0.62	5623.27	3430.92	223.66	35.46
	Standard Error	0.10	1.76	19.38	27.01	66.25	0.05	3398.20	1747.65	40.57	2.93
Other	Mean	1.04	19.33	8.58	34.60	323.19	4.49	1896.05	1187.82	129.91	
	Standard Error	0.28	5.40	3.59	13.10	101.16	2.34	584.97	359.86	86.38	
Pineland	Mean	0.69	24.23	26.75	20.70	305.80	2.80	40466.48	23348.98	321.87	49.08
	Standard Error	0.10	3.58	11.35	3.23	50.61	0.96	10535.77	6082.55	39.18	1.56
Solution hole	Mean	1.79	26.34	111.34	292.08	823.89	2.43	1626.55	347.29	173.30	
	Standard Error	0.27	5.40	105.93	157.49	311.71	1.85	843.95	100.91	40.34	
Season											
Dry	Mean	1.71	36.52	2.79	134.27	623.54	0.75				

	Standard Error	0.16	1.96	0.67	41.18	88.87	0.09				
Wet	Mean	0.94	21.84	67.39	99.35	331.93	3.89	17239.95	9962.21	241.72	41.01
	Standard Error	0.14	3.03	28.08	27.12	48.33	1.15	6366.19	3650.45	31.73	2.91

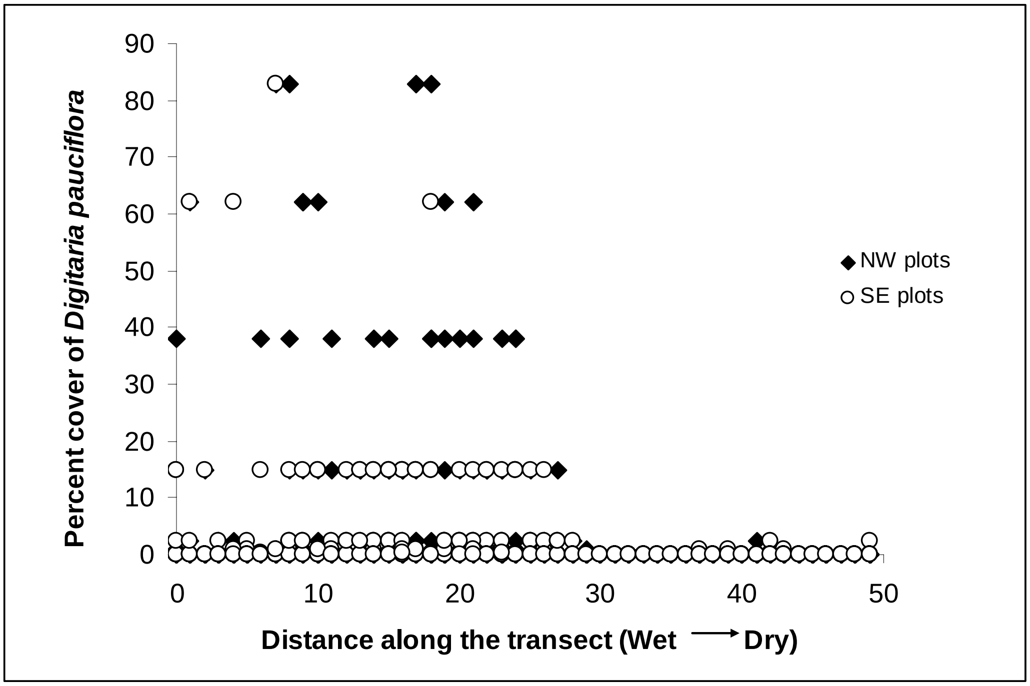
statistically from one another while pineland soils grouped with "other" (*A. wrightii* habitat) as not different statistically. The only nutrients that yielded significant differences among habitat soils were nitrogen (%), organic carbon, ammonium and total phosphorous. There were also statistical differences between wet and dry season soils. Nitrogen ($F = 12.83$; $P = 0.0008$), organic carbon ($F = 16.59$; $P = 0.0002$) and total phosphorous ($F = 8.31$; $P = 0.0059$) were all significantly higher in the dry season while nitrate ($F = 5.29$; $P = 0.03$) and total aluminum ($F = 0.0019$; $P = 11.01$) were both higher in the wet season.

Transects: The transect data reveal important ecological and geographical patterns for *Digitaria pauciflora* and *Sideroxylon reclinatum* subsp. *austrofloridense* in the LPK area. *Digitaria* exhibited strong habitat preference and occurred almost exclusively in the longer hydroperiod marshes while *Sideroxylon* had a broader distribution (Figure 8).

Overall, transects to the south of the main park road had higher frequencies of the target species than those to the north of the road based on presence-absence data (Table 13). This may be linked to differences in ground water level since EVER well data indicates that the northern area is wetter than the south (Figure 9). Regardless, general field observations suggested that *Digitaria* may undergo fluctuations in population numbers over short periods without affecting total cover since plants appear to migrate within an area. The transect data showed a vague trend toward movement of *Digitaria* along the transect meters over time, but further observations are needed to discern solid patterns.

Dominant species richness was also greater for transects south of the main park road compared to those located north of the road. Total dominant species richness among transects in the north was 33 and 14 respectively in the wet 2007 and dry 2008 seasons, and was 39 and 23 for wet 2007 and dry 2008 seasons for transects located south of the park road. Species richness in *Digitaria* and *Sideroxylon* transects was similar, but the species composition differed. Total species richness among transects in the north was 31, 35, 20 and 15 in dry 2005, wet 2007, dry 2007 and dry 2008 respectively and 29, 42, 25 and 22 in dry 2005, wet 2007, dry 2007, and dry 2008 respectively for transects south of the road. The dominant taxa confined to *Digitaria* transects were *Panicum* spp, *Magnolia virginiana*, *Oxypolis filiformis*, *Paspalum monostachyum* and *D. pauciflora*. The dominant species restricted to *Sideroxylon* transects were *Andropogon ternarius*, *Cassytha filiformis*, *Croton linearis*, *Hyptis alata* and *Spermacoce terminalis*. Table 14 summarizes the dominant species composition for the most frequently observed species along transects for each of the focal species and changes in composition between 2005 and 2007. A Chi-square test did not detect any change in species distribution across years for both *Digitaria* and *Sideroxylon* transects ($P > 0.05$). While species composition did not change at a community level, some individual species showed a dramatic change between the years (Table 14). *Conocarpus erectus* and *Cladium jamaicense* showed the largest increases along *Digitaria* transects while *Serenoa repens* and *Eupatorium leptophyllum* increased most dramatically along *Sideroxylon* transects. *Myrica cerifera* and *Chrysobalanus icaco* decreased the most along *Digitaria* transects and *Sideroxylon* itself showed the greatest decline along the *Sideroxylon* transects.

In order to increase our knowledge of *Digitaria* and *Sideroxylon* ecology and distribution within LPK, and to better understand potential impacts of hydrological restoration associated with CERP restoration recommendations, species composition data and focal species distribution data were related to hydrology. Simultaneous analyses of paired water level, based on measurements by IRC personnel, were conducted to examine if patterns



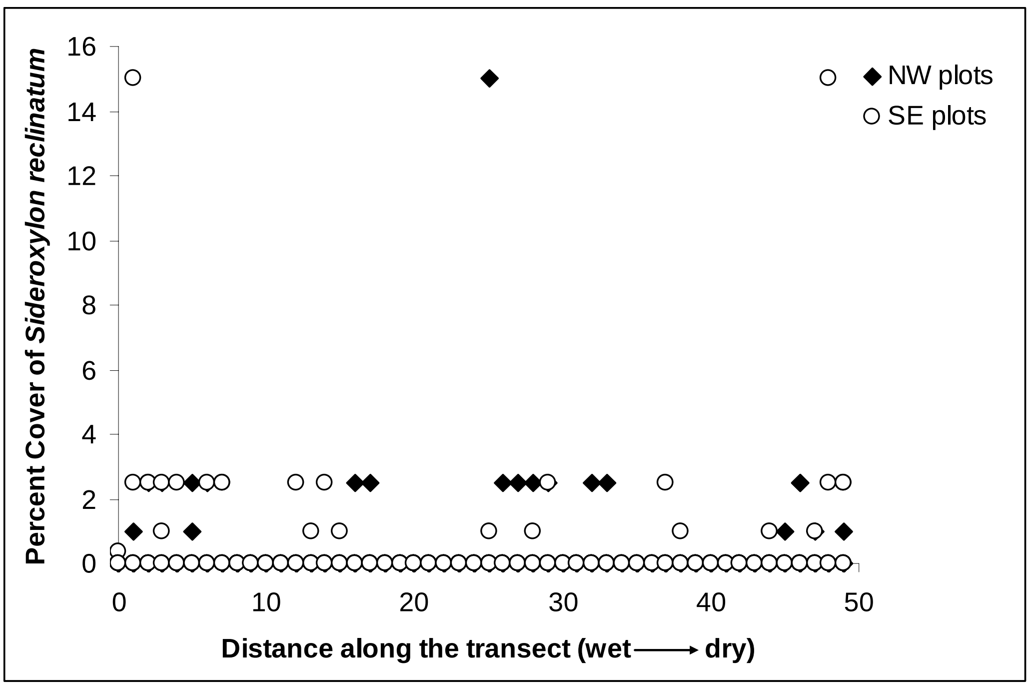


Figure 8. Percent cover of *Digitaria* and *Sideroxylon* along the gradient of wet to dry along the transects depicts habitat specificity for *Digitaria* and a generalist distribution for *Sideroxylon.*

observed in the species abundance data could be explained by patterns in the hydrologic data, especially to test if transects got wetter or drier across the years. A correlation analysis was done on paired data across all transects. A strong correlation coefficient would suggest no change while deviation from a linear trend would hint at diverging patterns in water depth across years. The paired data of dominant species from 2007 and 2008 were strongly correlated ($r^2 = 0.95$, $P < 0.001$) and thus did not show a change from 2005 to 2007.

The ground water levels, when normalized for elevation, yielded longer and deeper both inundation events north of the park road in comparison to the south (Figure 9). These data also yielded variation in ground water level across years, with 2005 being wetter than 2006 and 2007. Surface water levels measured by IRC staff along the transects did not show a significant difference between locations (north or south of the road) in any season.

Table 13. Percent frequency of focal species along transects based on the number of quadrats with the focal species present divided by the total possible quadrats for that sampling. Due to the implemented rotating panel design, transects only overlap every two years (*i.e.* Dry 2005 and Dry 2006 sample the same transects; Dry 2007 and Wet 2007 sample the same transects; and Dry 2008 is unique).

		Season				
Species	**Location**	Dry 2005	Dry 2006	Dry 2007	Wet 2007	Dry 2008
Digitaria pauciflora	North	2.40%	2.00%	8.42%	6.92%	10.75%
	South	11.20%	11.00%	11.83%	11.58%	20.67%
Sideroxylon reclinatum	North	2.80%	4.83%	2.83%	4.50%	NA
	South	15.60%	12.67%	14.17%	9.17%	NA

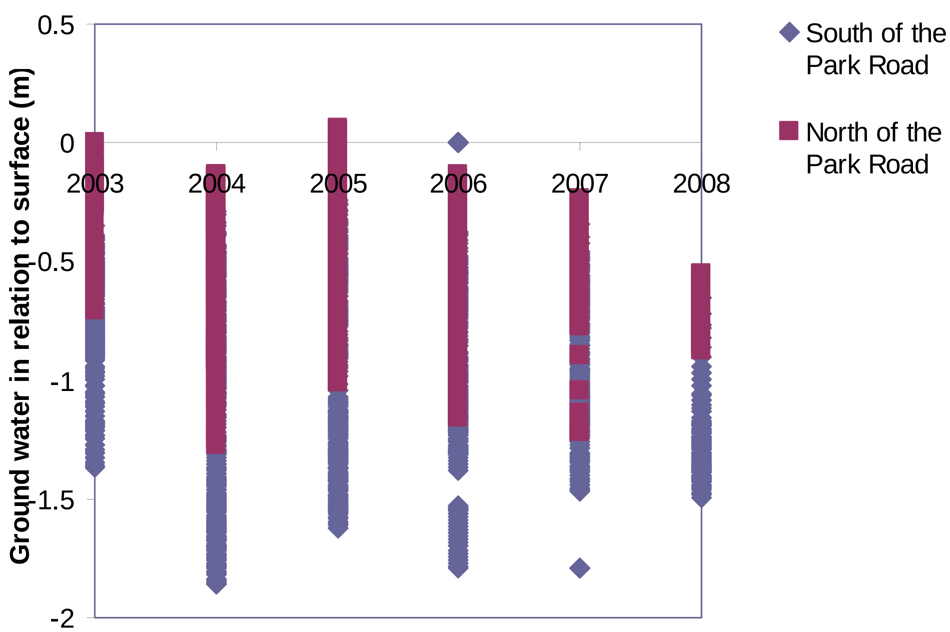


Figure 9. Groundwater data south and north of the road based on National Park Service hydrology wells.

Table 14. Comparison of dominant species along *Digitaria* and *Sideroxylon* transects that were sampled both in the wet seasons of 2005 and 2007. Included species occurred in three or more quadrats in at least one of the sampling years.

***Digitaria pauciflora* transects**			***Sideroxylon reclinatum* transects**		
Frequency Wet 05	**Frequency Wet 07**	**Dominant Species**	**Frequency Wet 05**	**Frequency Wet 07**	**Dominant Species**
0	3	*Panicum virgatum*	0	8	*Eupatorium leptophyllum*
0	3	*Cassytha filiformis*	0	7	*Rhynchospora colorata*
1	4	*Metopium toxiferum*	2	8	*Sideroxylon salicifolium*
6	0	*Sideroxylon reclinatum*	6	6	*Byrsonima lucida*
7	4	*Sabal palmetto*	6	5	*Guettarda scabra*
11	5	*Digitaria pauciflora*	6	11	*Myrica cerifera*
12	7	*Paspalum monostachyum*	6	3	*Persea palustris*
13	12	*Schizachyrium rhizomatum*	8	13	*Conocarpus erectus*
16	9	*Myrica cerifera*	9	2	*Sideroxylon reclinatum*
17	27	*Conocarpus erectus*	14	26	*Serenoa repens*
18	12	*Chrysobalanus icaco*	17	22	*Schizachyrium rhizomatum*
53	57	*Muhlenbergia capillaris*	28	35	*Sabal palmetto*
68	73	*Cladium jamaicense*	58	57	*Cladium jamaicense*
			60	59	*Muhlenbergia capillaris*

Goal 3: Restore and enhance species diversity of the Long Pine Key area in Everglades National Park through the augmentation or reintroduction of plants considered rare as a result of direct or indirect actions by man.

Restoration and Enhancement Methods.
The original scope of work stated that the appropriateness and feasibility of augmenting populations of rare study species in imminent danger of being extirpated from EVER would be investigated, including the feasibility of augmenting populations of these species in the Long Pine Key area. Opportunities for the reintroduction of plants that had been extirpated from the Long Pine Key area would also be investigated. This latter group included species that are presumed extirpated in the continental United States (e.g., *Brassia caudata*) as well as species that are still extant in Everglades National Park (e.g., *Oncidium undulatum*) or elsewhere in South Florida (e.g., *Trichomanes punctatum* subsp. *floridanum).* If appropriate and feasible, augmentation and reintroduction trials would be initiated, using community composition data and measurements of environmental variables to help identify favorable reintroduction sites. NPS compliance review would be conducted when required.

Collaborations –
Initially, meetings and field visits were held to assess augmentation and reintroduction needs and to develop management recommendations for all species being studied. Collaborators attending one or more of these sessions included Craig Smith of EVER, Joyce Maschinski and Jennifer Possley from Fairchild Tropical Botanical Garden (FTBG) and Bruce Holst, Harry Luther, Wesley Higgins and John Beckner from Marie Selby Botanical Gardens (MSBG). During Year 2, the collaboration with FTBG was broadened to include Miami-Dade County's Natural Areas Management group (NAM) to allow for research and germplasm collection by IRC and FTBG at sties in Miami-Dade County outside of EVER. At the end of Year 2, augmentation and reintroduction recommendations were revised based on the results of several meetings and site visits (see Table 15). In Year 3, Valerie Pence,

Table 15. Augmentation and Reintroduction Recommendations (2005).

Taxon	Recommendation	Reason	Location
Adiantum melanoleucum	Augment	In imminent danger of extirpation	Hattie Bauer Hammock (Outside EVER)/Royal Palm Hammock
Anemia wrightii	No action at present	Population not obviously depleted	
Basiphyllaea corallicola	No action at present	Population not obviously depleted	
Bourreria cassinifolia	No action at present	Population not obviously depleted	
Brassia caudata	Reintroduce	Extirpation documented	Royal Palm Hammock
Croton lobatus	No action at present	Population not obviously depleted	
Dalea carthagenensis var. *floridana*	No action at present	Perhaps never established in EVER	
Desmodium lineatum	No action at present	Population not obviously depleted	
Digitaria pauciflora	No action at present	Abundant	
Eltroplectris calcarata	No action at present	Population not obviously depleted	
Galeandra beyrichii	Augment	In imminent danger of extirpation	Hattie Bauer Hammock (Outside EVER)/Royal Palm Hammock
Govenia utriculata	Not Decided	Taxonomic difficulty	
Helenium flexuosum	No action at present	Habitat in EVER not well understood, but augmentation trials could increase understanding	
Hypelate trifoliata	No action at present	Population not obviously depleted	
Lomariopsis kunzeana	Augment	In imminent danger of extirpation	Hattie Bauer Hammock (Outside EVER)/Royal Palm Hammock
Macradenia lutescens	Reintroduce	Extirpation documented	Royal Palm Hammock
Oncidium ensatum	Augment	Population depleted	Hattie Bauer Hammock (Outside EVER)/Royal Palm Hammock
Oncidium undulatum	Reintroduce	Extirpation documented	Royal Palm Hammock
Passiflora sexflora	Augment	In imminent danger of extirpation	Hattie Bauer Hammock (Outside EVER)/Royal Palm Hammock
Pecluma plumula	Augment	In imminent danger of extirpation	Royal Palm Hammock
Ponthieva brittoniae	No action at present	Population not obviously depleted	
Prescotia oligantha	No action at present	Perhaps introduced in EVER	
Schizaea pennula	No action at present	Presence reported, never documented	
Sideroxylon reclinatum subsp. *austrofloridense*	No action at present	Abundant	
Spiranthes costaricensis	No action at present	Population not obviously depleted	
Spiranthes torta	Not Decided	Habitat in EVER not well understood	
Sporobolus compositus var. *clandestinus*	Not Decided	Habitat in EVER not well understood	
Thelypteris reticulata	Augment	In imminent danger of extirpation	Royal Palm Hammock
Thelypteris serrata	Augment	In imminent danger of extirpation	Royal Palm Hammock
Tillandsia fasciculata var. clavispica	No action at present	Perhaps never well established in EVER	
Trichomanes punctatum subsp. *floridanum*	Reintroduce	Extirpation documented	Hattie Bauer Hammock (Outside EVER)/Royal Palm Hammock

Director of Plant Research at the Center for Conservation and Research of Endangered Wildlife (CREW) in Cincinnati, began collaborating with MSBG on propagation and cultivation techniques for the more difficult fern species. In Year 4, Jimi Sadle replaced Craig Smith as the EVER representative for the last two years of the project.

Germplasm Collection –

Twelve species were identified as in need of augmentation or reintroduction in the LPK area (Table 15). Efforts were made to collect fertile material from each of these species from the nearest geographic population. IRC, FTBG and MSBG staff visited populations of these species within LPK, in EVER outside of LPK and outside EVER in MDCPR properties. When possible, germplasm was collected from target species and was sent to MSBG or CREW for propagation and cultivation. The type of germplasm collected depended on the species and included seeds, spores and pieces of mature plants. Over the course of the project, germplasm was collected from *Adiantum melanoleucum* (spores from outside EVER), *Galeandra beyrichii* (seeds from LPK), *Lomariopsis kunzeana* (spores from outside EVER), *Oncidium ensatum* (seeds from LPK), *Oncidium undulatum* (seeds from inside EVER), *Passiflora sexflora* (seeds from outside EVER), *Pecluma plumula* (spores from LPK), *Thelypteris serrata* (spores from LPK) and *Trichomanes punctatum* var. *floridanum* (mature plant pieces from outside EVER). MSBG also obtained seeds of *Brassia caudata* with Jamaican provenance for propagation trials and two *Oncidium undulatum* plants from Jamaica for mycorrhizae experiments. Germplasm was not acquired for *Macradenia lutescens*.

In the process of collecting germplasm for *Oncidium undulatum*, it became apparent that a small fly, *Melanagromyza miamiensis*, was impacting the plants in Coot Bay Hammock. Spikes were found on *O. undulatum*, but most appeared to be dying back due to the reproduction of this fly which deposits its eggs in the inflorescence where the larvae develop. A trial hand-pollination was conducted in Year 3 on two *O. undulatum* plants to see if the lack of a pollinator might also be involved. Seed capsules developed on these the pollinated plants so a larger hand pollination experiment was run in Year 4 wherein IRC and MSBG jointly placed mesh bags around five *O. undulatum* flower spikes in order to exclude *M. miamiensis*. Three of the spikes had already been infected by the fly and were destroyed, but the remaining two spikes, as well as two more that were discovered on unbagged plants, were hand-pollinated in April 2007. A total of 40 flowers were pollinated on eight different flower spikes and about half of those developed into capsules. Additonal flowers were pollinated by other means. Capsules were thinned to reduce energy expenditure and prevent abortion; nine capsules remained at the end of Year 4. Three mature capsules and one green pod were sent to MSBG in Year 5 to increase the genetic diversity in their propagation trials and to develop new propagation techniques in situ. The remaining pods were left on the plants for natural seed dispersal.

Propagation and Cultivation –

Propagation trials began in Year 2 with *Adiantum melanoleucum, Lomariopsis kunzeana, Passiflora sexflora, Thelypteris reticulata* and *Trichomanes punctatum* subsp. *floridanum*. *Oncidium ensatum* seeds were also sown in Year 2, though trials did not start in earnest until Year 3 for this species. Additional plants of *A. melanoleucum* and *O. ensatum* were brought into cultivation in Year 3 and new propagation trials began for *Brassia caudata* and *Pecluma plumula*. In Year 4, propagation trials began for *Galeandra beyrichii, O. undulatum* and *Thelypteris serrata*. Additional plants of *O. ensatum* were also brought into cultivation. Propagation trials were begun for 11 of the 12 target species and nine of the species currently remain in cultivation (Table 16).

Table 16. Plants in cultivation at MSBG as of November 2008.

Species	Source	Stock
FERNS		
Adiantum melanoleucum	spores outside EVER	1" pots: 145
		Trays: 2 (young spermatophytes) 11 phytaboxes (w/ sporophytes; CREW)
Lomariopsis kunzeana	spores outside EVER	Trays: 4 (all gametophytes)
Pecluma plumula	spores inside EVER	4" pots: 22
Thelypteris serrata	spores inside EVER	1" pots: 58
		4" pots: 96
Trichomanes punctatum var. *floridanum*	pieces of mature adults from outside EVER	6" pots: 6 (MSBG) 20 soil boxes w/ sporophytes (CREW)
ORCHIDS		
Brassia caudata	seeds of Jamaican origin	Flasks: 650
		3" pots: 60
Galeandra beyrichii	seeds inside EVER	40 germinated seeds, no differentiation
Oncidium ensatum	seeds inside EVER	Flasks: 65
		3" pots: ~50
Oncidium undulatum	seeds inside EVER	Flasks: 1856
		3" pots: ~300

Figure 10. MSBG fern grower Pat Clendenin holding propagated *Pecluma plumula* and *Thelypteris serrata*.

The propagation trials for *Oncidium undulatum* and *Oncidium ensatum* led to extra work both in the field and in the lab to isolate and identify their mycorrhizal fungi in order to increase survival rates during augmentation. In Year 3, two *O. undulatum* plants from Jamaica were obtained for mycorrhizae experiments, and MSBG began work to isolate mycorrhizae from greenhouse-grown *O. ensatum*. During Year 4, root samples were collected from *O. undulatum* and *O. ensatum* in EVER and were transferred to MSBG for fungal isolation experiments. In addition, 200 mesh *O. ensatum* seed packets were placed at two adjacent locations in Grimshawe Hammock in May 2007 to serve as fungal baits. Each month for a year, 15 packets were collected and transferred to MSBG for isolation of fungus associated with any germinating seeds. Over 200 fungal samples were collected for the project. To date, 33 have been tested and none appeared to be the associate. Testing will continue on the remaining 125 samples.

Outplanting and Reintroduction –
Five outplanting trials were done over the course of this project for four different species: *Adiantum melanoleucum*, *Brassia caudata*, *Oncidium undulatum* and *Passiflora sexflora*. The first trial was conducted under the leadership of FTBG in Year 3 and involved augmentation of *P. sexflora* at Hattie Bauer Hammock (outside EVER). One hundred and six plants were planted in June 2006 with 61 placed in a gap within the hammock and 45 placed at another location along the hammock edge. Survivorship was higher at the edge site with almost 30 plants still present at a December 2008 survey and less than five at the gap site.

Using material provided by FTBG and NAM, 30 *Passiflora sexflora* plants were planted along the Old Ingrahm Highway trail running through Royal Palm Hammock in December 2006 (Year 4). Fifteen plants were placed in a hammock gap, seven plants were placed on a north-facing edge and eight plants were placed on a south-facing edge. The plants were monitored monthly for the first ten months, then once every dry and wet season. At each visit, largest visible spread and height of plants was measured in centimeters. All fruits, flowers and buds were counted and general plant condition was recorded as Excellent, Good, Fair, Poor or Dead. A few fruits and flowers were recorded in the first couple of months, but none were observed after the March 2007 monitoring. Figure 11 presents the growth trends for height and spread, as well as tracking mortality. By the end of Year 5, seven plants remained. Five of those plants were in the hammock gap and the other two were from the planting on the north-facing edge.

In May 2008 (Year 5), IRC, EVER and MSBG staff collaborated on an outplanting of *Oncidium undulatum* in Royal Palm Hammock. *O. undulatum* seeds were mixed into a banana paste and were injected onto the bark of trees using a syringe. All spots were marked with twine and were recorded with a GPS. Fifty-eight injections were placed on 20 different trees. Eleven of the injected trees were live oaks and the remaining trees included an assortment of willow bustic (*Sideroxylon salicifolium*), fig (*Ficus* spp.), wild mastic (*Sideroxylon foetidissimum*), pond apple (*Annona glabra*), wild tamarind (*Lysiloma latisiliquum*) and royal palm (*Roystonea regia*). Trees were distributed in various light conditions and at varying distances from the road. A week later, the sites were revisited and it appeared that an animal had gnawed the bark where the banana paste was placed. Only a couple of spots appeared undisturbed. The sites were visited again in August 2008 to check for potential germination, but no signs of the seeds or plant growth were visible.

Also during August 2008 (Year 5), an outplanting trial of *Brassia caudata* and *Adiantum melanoleucum* was performed at Hattie Bauer Hammock by IRC and MSBG staff. Twelve *B. caudata* were affixed to oak trees in the Hattie Bauer Hammock using clumps of moss and panty hose strips (Figure 12). Three plants were attached to four different trees. All trees were marked with flagging tape and metal tags and the GPS locations were recorded. At the same time, eight *A. melanoleucum* plants were planted directly in soil pockets along the upper edge of a solution hole (see front cover photo). Plantings were monitored in October and three *Brassia* and four *A. melanoleucum* remained alive, though many of the remaining plants appeared to be water stressed. Frequent watering for at least the first month is recommended for future plantings.

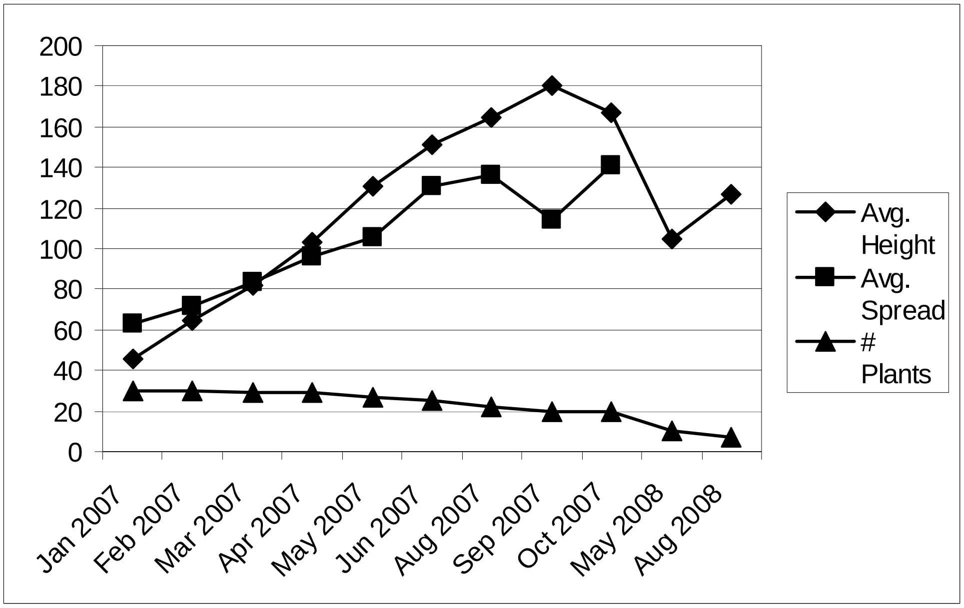


Figure 11. Monitoring of *Passiflora sexflora* outplanting in Royal Palm Hammock.

Other proposed outplantings include *Trichomanes punctatum* subsp. *floridanum* in Royal Palm Hammock, *Adiantum melanoleucum* in Rattlesnake Hammock, *Thelypteris serrata* in areas of Pine Island and Royal Palm Hammock and augmentations of *Pecluma plumula* and *Oncidium ensatum* at existing sites in LPK. The plants are ready to plant and will be upon approval by an EVER compliance review and pending funding.

Figure 12. *Brassia caudata* outplanting trial at Hattie Bauer Hammock.

Goal 4: Contribute to a broader understanding of the environmental requirements of rare species both within and outside of Everglades National Park.

<u>Environmental Requirements Methods</u>

By Year 2 it had become clear that some study species were sufficiently rare inside the Long Pine Key area of EVER to warrant the collection of additional data defining their environmental requirements. These data were needed both to obtain a better understanding of extant populations inside the Long Pine Key area, as well as to glean information that might be helpful in augmenting or reintroducing populations. Off-site characterization plots were established for species with fewer than three long-term monitoring plots in the Long Pine Key area, as well as for species extirpated in the Long Pine Key area with extant populations either elsewhere in EVER or outside of the park. Plots located outside of EVER were marked with GPS points and flagging tape, but not with rebar.

Off-site characterization plots were visited at least once each during a wet and a dry season. The *Anemia wrightii* plots in the Context Road area were the exception and were only sampled in the dry season due to their inaccessibility during the wet season. Plot methods were identical to those described above in Goal 2 for the long-term monitoring plots within LPK. While community composition data collection remained unchanged throughout the study, environmental data methods were modified at various points in the study (see Goal 2). Data collection at the off-site characterization plots mirrored what was being done in LPK at the time. At a minimum all plots have comparable data for canopy height, tree circumference, water level at plant and relative humidity.

In addition, three control plots each were created within LPK during the wet 2005 season for the following species: *Adiantum melanoleucum, Galeandra beyrichii, Lomariopsis kunzeana, Oncidium ensatum,* and *Passiflora sexflora.* A paired design was chosen to compare plant composition and environmental factors between areas that supported these species and areas that did not, using baseline data collected from established long-term monitoring plots. Plots were located in the same hammock or a hammock adjacent to where the study species was known to occur, but control plots did not contain the target species. Data was collected from these plots in the wet 2005 and dry 2006 seasons. After initial assessments of the control plot data, it was decided that the information did not sufficiently contribute to our understanding of these species and their requirements so no further monitoring nor analyses were conducted. These data are available for further analyses if deemed appropriate at a later date.

General Analysis Procedures –

In general, the same methods were used to analyze compiled plot data (LPK and off-site characterization plots) as were described in Goal 2 (please refer to Goal 2 analysis methods for details). In cases where only one or two off-site characterization plots existed, no statistical comparisons are presented between locations because of the limited impact on analysis results.

In order to gain a better understanding of habitat differences potentially associated with fragmentation (since the Miami-Dade sites are distributed within an urban matrix), we compared floristic quality across locations per habitat type by using the Floristic Quality Index (FQI). The FQI is a biotic index (Washington 1984, Rooney and Rogers 2002) based on a numerical score called the Coefficient of Conservatism (C). C values range from 0–10 and are assigned to each plant species within a local flora by a panel of experienced botanists. The C values used in this case were developed by Bradley and Gann (unpublished) for a Miami-Dade County project in 2004. The theory behind C is that plant species vary in their fidelity to remnant natural habitats based on their differing tolerance to the type, frequency, and amplitude of disturbance (Swink and Wilhelm 1994). High C-values are assigned to species that are least tolerant of disturbance and which are most commonly found in remnant patches of pre-settlement habitat. The C-value 0 is allocated to exotic species, generally associated with degraded habitats. We derived an overall habitat quality score for each plot by averaging the FQI scores of all the individual species in the plot. Overall habitat quality was also determined for each focal species by averaging the FQI scores among the study plots containing the given focal species.

Environmental Requirements Results

Twenty off-site characterization plots were established for twelve of the target species by the end of the project (Table 17). Of those, six were located inside EVER (outside LPK) and an additional 14 were located outside EVER, mostly in Miami-Dade County Parks and Recreation (MDCPR) managed properties. The 20 plots included species from all the major habitat types. Cumulatively, the off-site characterization plots contained just over half as many plants as in the long-term monitoring plots at almost 230 species. In addition to the lower diversity, off-site characterization plots had nearly three times the number of introduced exotic species as were found growing within LPK rare plant plots (Appendix C). *Schinus terebinthifolius* and *Bischofia javanica* were the most frequently observed. A summary of plot characteristics for off-site monitoring species (table includes information from long-term monitoring plots as well) can be found in Appendix D.

Table 17. Summary of plots for study species with off-site characterization plots.

Study Species	Long-term Monitoring Plots in the Long Pine Key Area	Off-Site Characterization Plots inside EVER	Off-Site Characterization Plots outside EVER	Total number of plots
Adiantum melanoleucum	2	0	1	3
Anemia wrightii	5	2	0	7
Croton lobatus	1	0	2	3
Galeandra beyrichii	1	0	1	2
Lomariopsis kunzeana	2	0	1	3
Oncidium undulatum	0	3	0	3
Passiflora sexflora	1	0	2	3
Spiranthes torta	2	0	1	3
Sporobolus compositus var. *clandestinus*	1	0	1	2
Thelypteris reticulata	1	1	1	3
Thelypteris serrata	2	0	1	3
Trichomanes punctatum subsp. *floridanum*	0	0	3	3
Total	**18**	**6**	**14**	**38**

Hammock Plots – There were 41 total hammock plots established in this study. In addition to the 32 hammock plots inside LPK, three other plots were located within EVER outside of LPK (Coot Bay Hammock), and six additional plots were located outside of EVER on MDCPR properties.

The species richness of plots located outside of LPK, including those still within EVER, is significantly lower than plots within LPK ($F_{3,28} = 12.58$, $P < 0.0001$). The mean species richness of plots outside LPK is 22 ± 2.2 compared to 40 ± 2.4 species in LPK plots south of the road and 50 ± 5.2 species in LPK plots north of the road. There are no significant differences in species composition between plots north and south of the road within the LPK area.

When all the hammock plots with solution holes were analyzed including the plots outside of LPK area, solution hole presence had a nearly significant effect on species richness ($t_{1,30}$ = 3.88, P = 0.058). Plots with solution holes had greater species richness and harbored *Hypelate trifoliate*, *Oncidium ensatum* and *Thelypteris reticulata*.

Species composition was strongly impacted by plot location, probably because of environmental factors not documented in this study since the environmental variables measured in this study explained minimal variation. For example, canopy height, which had the greatest impact, only explained 7% of species composition variation and factors such as canopy cover and RH had no effect. Plots outside the LPK area within EVER (*i.e.* Coot Bay Hammock) had a distinct species composition and lower species richness (Figure 13). The plots in Coot Bay Hammock were different based on an abundance of epiphytic and salt tolerant species such as *Encyclia boothiana* var. *erythronioides*, *Hippomane mancinella*, *Rhabdadenia biflora*, *Sesuvium portulacastrum*, *Tillandsia paucifolia* and *Tillandsia usneoides*.

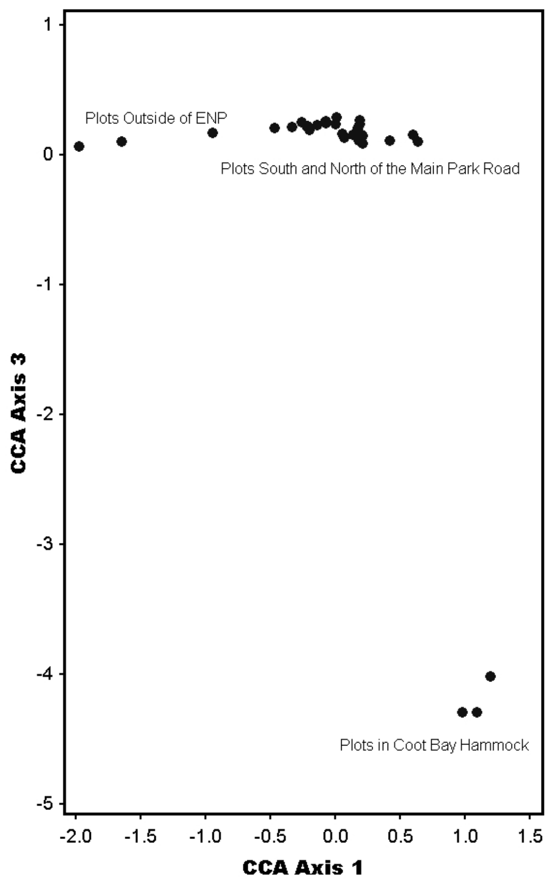


Figure 13. CCA plots with weighted average of site scores based on species composition.

Pineland Plots – Thirty one pineland plots, representing ten species, were installed and monitored during the course of this project. Thirty plots were distributed within LPK and only one plot was located outside of EVER on MDCPR property. The pineland plot outside of EVER had species richness of 44, 0% canopy cover and mean tree height of 3.7 m. These values were all lower than the averages observed within LPK, which included a species richness of 66, 40% canopy cover and 12.3 m mean tree height. When all plots were analyzed together, none of the environmental variables explained the patterns in species composition.

Prairie Plots – Out of the 19 total marl prairie plots in the project, only one was located outside of LPK and it was located on MDCPR property. This plot, located in Martinez Prairie (harboring the rare orchid *Spiranthes torta*), was the most distinct floristically, with only 19 species as opposed to the mean species richness of 50 and 52 species respectively in the plots north and south of the park road in LPK.

Hammock Solution Hole Plots – Nine hammock solution hole plots, representing three species, were installed and monitored during the course of this project. Four plots were distributed within LPK, all south of the main park road. The remaining five plots were located outside of EVER on MDCPR properties.

The hammock solution hole plots outside EVER had 18 exotic species recorded in the plots as opposed to only one (*Oeceoclades maculata*) for plots within the park. The presence of exotic species, such as *Jasminum fluminense*, *Youngia japonica*, and *Bischofia javanica*, led to a minor separation of offsite plots from the EVER plots. All three axes together explained 46% of variation in species composition (Figure 14). Axis I with eigen value of 0.32 significantly explained 26% of variation in community composition and was strongly correlated to plot location (r^2 = 0. 0.51). Axis II explained 11% variation and was significantly correlated with plot substrate (r^2 = 0.36). Axis III explained 10% of variation in the dataset and was significantly correlated with canopy height (r^2 = 0.436). Canopy height was lower in plots inside EVER (mean height of 12.4 m) than outside the park (10.2 m). These results suggest that the species and environmental data were significantly correlated.

Floristic Quality Index – We derived the habitat quality of each plot using a Floristic Quality Index (FQI) and made comparisons of habitat quality across locations (Table 18). Plots located inside EVER were of comparable quality while the lowest observed habitat quality for all habitat types occurred outside of EVER. Habitat quality requirements varied across species, with some species occurring in highly disturbed habitats (*Thelypteris serrata* for example, Table 19) while species such as *Lomariopsis kunzeana* and *Hypelate trifoliata* occurred consistently in habitats with high FQI values (Table 19).

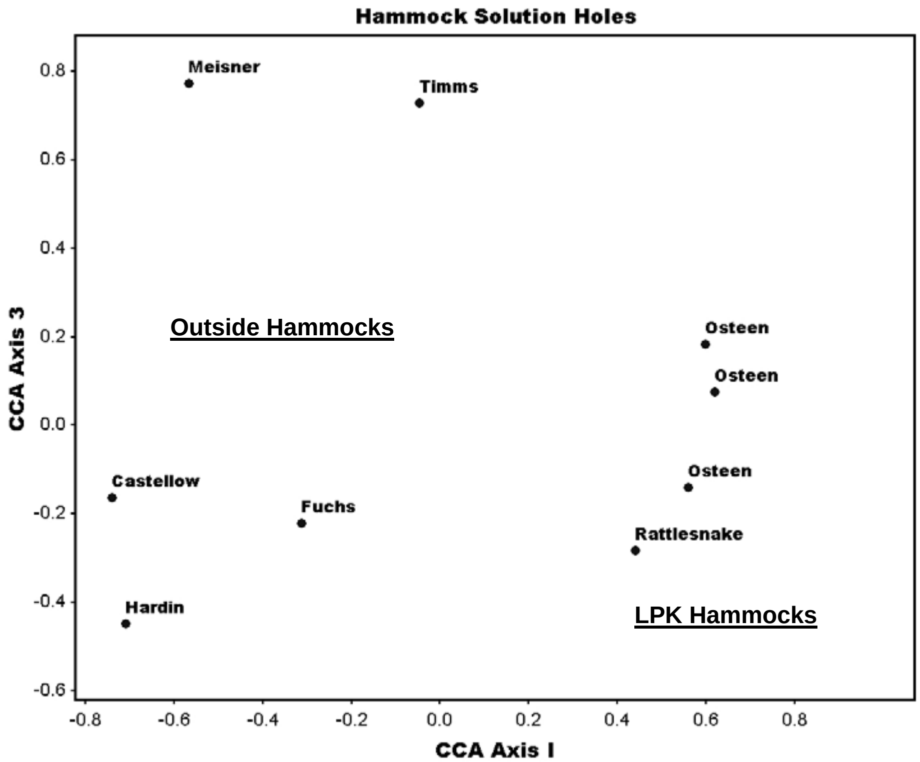


Figure 14. A significant effect of plot location, canopy height and substrate was observed in this CCA ordination done on solution hole plots. Plots inside EVER had similar species composition and lower canopy height, while plots outside had greater canopy height and more exotic and invasive species.

Table 18. Mean Floristic Quality Index for Monitoring Plots by Habitat Type and Location.

Location	Habitat	Mean Floristic Quality Index	Lower Bound	Upper Bound
LPK: North of Park Road	Disturbed Uplands			
	Firebreak			
	Hammock	5.16	4.71	5.62
	Hammock SH			
	Other	5.15	4.51	5.79
	Pineland	5.31	4.94	5.68
	Prairie	5.59	5.29	5.89
LPK: South of Park Road	Disturbed Uplands			
	Firebreak	4.88		
	Hammock	5.62	5.38	5.86
	Hammock SH	6.21	5.76	6.66
	Other	4.49	4.08	4.89
	Pineland	5.55	5.37	5.74
	Prairie	5.59	5.28	5.89
LPK: West of Park Road	Disturbed Uplands			
	Firebreak			

	Hammock	6.16		
	Hammock SH			
	Other			
	Pineland			
	Prairie			
Outside EVER	Disturbed Uplands	3.46	2.56	4.37
	Firebreak			
	Hammock	4.37	4.00	4.74
	Hammock SH	4.9	4.49	5.30
	Other			
	Pineland	5.14	4.23	6.04
	Prairie	5.15	4.25	6.06
Outside LPK (in EVER)	Disturbed Uplands			
	Firebreak			
	Hammock	5.66	5.02	6.29
	Hammock SH			
	Other	5.08	4.44	5.72
	Pineland			
	Prairie			

Table 19. Mean Floristic Quality Index for Focal Species.

Species- Description	Mean Floristic Quality Index	95% Confidence Interval	
		Lower Bound	Upper Bound
Thelypteris serrata- fern	3.33	2.86	3.80
Croton lobatus- forb	4.00	3.53	4.46
Thelypteris reticulata- fern	4.51	4.04	4.98
Trichomanes punctatum- fern	4.69	4.22	5.16
Sporobolus compositus- grass	5.01	4.44	5.58
Passsiflora sexflora- vine	5.13	4.67	5.60
Anemia wrightii- fern	5.16	4.86	5.47
Galeandra beyrichii- orchid	5.53	4.97	6.10
Oncidium ensatum- orchid	5.37	4.96	5.77
Helenium flexuosum- forb	5.37	5.04	5.70
Ponthieva brittoniae- forb	5.38	4.91	5.85
Oncidium undulatum- orchid	5.47	5.00	5.93
Sideroxylon reclinatum- woody	5.48	5.24	5.71
Pecluma plumula- fern	5.49	5.03	5.96
Spiranthes torta- orchid	5.51	5.05	5.98
Adiantum melanoleucum- fern	5.51	5.05	5.98
Bourreria cassinifolia- woody	5.57	5.10	6.04
Eltroplectris calcarata- fern	5.57	5.11	6.04
Digitaria pauciflora- grass	5.57	5.34	5.81
Desmodium lineatum- forb	5.61	5.15	6.08
Spiranthes costaricensis- orchid	5.65	5.19	6.12
Basiphyllaea corallicola- orchid	5.67	5.20	6.13
Hypelate trifoliate- woody	5.82	5.49	6.15
Lomariopsis kunzeana- fern	6.24	5.77	6.70

Discussion of Project Findings

Surveys –

Surveys of known and new locations have resulted in the discovery of 65 new occurrences of rare plant species in the Long Pine Key area, representing a 74% increase in the total number of known rare plant occurrences in the area (extant and extirpated), and a 105% increase in the number of known extant occurrences. All previously documented species included in Gann *et al.* (2002) and thought to be extant in the LPK area of EVER at the start of this study have been re-documented. In addition, at least one GPS coordinate was recorded for each occurrence location, clarifying the locality data for previously imprecise locations. In the future, we can expect to find new occurrences of *Oncidium ensatum* in additional small hammocks, and new occurrences of *Digitaria pauciflora* and *Sideroxylon reclinatum* subsp. *austrofloridense*. Both of the latter two species appear to have much wider ranges and much larger populations than thought previous to this study. Some historical occurrences of the ephemeral terrestrial orchids *Basiphyllaea corallicola*, *Eltroplectris calcarata*, and *Spiranthes costaricensis* continued to elude us through the study, but this is to be expected and they are likely to reappear at some point in the future.

Plants associated with hammocks, hammock solution holes, or hammock edges represent about two-thirds of the species in this study and all of the species thought to be extirpated on LPK except for *Dalea carthagenensis* var. *floridana*. However, *D. carthagenensis* var. *floridana* was documented only two times in EVER (Gann *et al.* 2002), and both of these records may represent waif populations established on road fill or disturbed soil. Also, *Schizaea pennula*, a fern more typically associated with swamps in our area (e.g. Everglades tree islands), was reported only once for Royal Palm Hammock in the Long Pine Key area of Everglades National Park (Small 1938). Hammock species in this study are all herbs with the exception of one vine which is typically herbaceous but sometimes woody (*Passiflora sexflora*), and two shrubs typical of hammock/pineland ecotones (*Bourreria cassinifolia, Hypelate trifoliata*). These herbs grow on several substrates including soil (terrestrial), rocks (lithophytes) and other plants (epiphytes). Nine of the hammock plants are orchids, seven are ferns or their allies, and five are from other taxonomic groups.

All of the confirmed extirpated hammock herbs are orchids (Orchidaceae) with the exception of one fern, *Trichomanes punctatum* subsp. *floridanum*, which was collected a single time in Royal Palm Hammock in 1909, and one bromeliad (Bromeliaceae), *Tillandsia fasciculata* var. *clavispica*, which was collected two times in Palma Vista Hammock #2 in the 1950s. Harry Luther of Marie Selby Botanical Gardens (personal communication) believes that this latter taxon is ephemeral in South Florida, with new populations becoming quickly genetically swamped through hybridization with the very common *Tillandsia fasciculata* var. *densispica*. Most of the extant hammock species appear to have suffered significant declines since the beginning of the 20th century. Population declines and/or the extirpation of hammock species have been casually linked to a variety of factors, including poaching, off-season fires or improper burning, and hydrological modifications, especially drainage.

A second group of ten species (with some overlap) are associated with pinelands. Life forms include terrestrial herbs and shrubs and a variety of taxonomic groups are represented. Surveys during this study indicate that most of the species in this group are more abundant than previously thought. The only species to be rediscovered on LPK, *Ponthieva brittoniae*, also belongs here.

Six species are associated with wetland habitats. Three of these are associated with low elevation pinelands and pineland/marl prairie ecotones that flood each summer: *Digitaria pauciflora*, *Helenium flexuosum*[2] and *Sideroxylon reclinatum* subsp. *austrofloridense*. *D. pauciflora* and *S. reclinatum* subsp. *austrofloridense* are both federal candidates for listing under the Endangered Species Act. *H. flexuosum* is a temperate species with a disjunct distribution in South Florida and a unique morphological character – it lacks the ray flowers of its northern counterparts. All three of these species appear to be fairly abundant, but due to the lack of baseline data it is impossible to say whether they are more or less abundant than they were prior to widespread hydrological modification. Based upon data collected in Year 1, *S. reclinatum* subsp. *austrofloridense* was down-ranked to imperiled in South Florida by IRC, but was maintained in the study due to its status as a candidate for federal listing.

Two fern species, *Thelypteris reticulata* and *Thelypteris serrata*, are historically associated with wet hammocks or, more typically, swamps in South Florida. *T. reticulata* is known from three locations in and around Royal Palm Hammock, including a cypress dome and disturbed wetlands in the Hole-in-the-Donut area. Historically, this species was reported as common and widespread in the southern Everglades and Big Cypress Swamp, although by the 1930s its habitat had been largely "destroyed by fire" (Small 1938). *T. serrata* is also known to grow in disturbed wetlands as well as in cypress domes and other types of forested wetlands. Apparently, it was never common in the LPK area of EVER and, at present, is not known from any natural habitat there.

The last wetland species, *Anemia wrightii*, is limited to hammock/prairie ecotones with extremely jagged limestone outcrops. Plants in the LPK area are limited to one small area on either side of main park road. Other plants in EVER are known from the Context Road area to the northeast of LPK.

Population Growth Rates –
This study is the first to examine the population dynamics of 22 rare plant species by marking year-to-year variation in the population sizes of these plants from 2004 to 2007. The population growth data suggests that most of the focal species in this study had declining populations during the sample period, since growth rates for a majority of the species were less than one (for terrestrial orchids, we only observed aboveground growth and healthy populations may persist underground). Some of the observed variation in visible populations can be attributed to weather patterns, demographic stochasticity, occurrence of disturbance events such as fire, and combinations of these factors. However, population growth rates remain low and suggest a possible declining trend for a majority of the species. While droughts are difficult to classify and monitor over time, one possible explanation for this may be frequent periods of lower than average rainfall during the study period (U.S. Drought Monitor; http://drought.unl.edu/dm). The prolonged impacts of decreased water availability may result in a slow decline of rare plant populations over time. This trend is likely to occur over a long time period and will impact individual species differently, including potentially substantial fluctuations in growth rate in the short-term. It is also possible that populations

---

[2] *Helenium flexuosum* appears to be native to pineland/marl prairie ecotones and very low elevation pinelands on Long Pine Key. It is also found in linear bands upland of these habitats along the margins of fire breaks, where it may be dispersed by canalized bands of water.

will respond positively to normal or above normal rainfall, potentially exposing natural, long-term population cycles. Only the woody shrubs, *Hypelate trifoliata* and *Bourreria cassinifolia*, and the woody vine *Passiflora sexflora* displayed relatively stable adult populations. While fluctuations can be somewhat expected in short-lived species, prolonged declines may indicate deficiencies in environmental conditions for germination and survival to adulthood.

Dispersal also plays a role in the spatial organization of population structure and hence, a decline in numbers of plants at a plot may not reflect an overall decline in population size but rather an extinction event of a sub-population. Patterns in the long-term dynamics of rare plants in the entire LPK area might be better elucidated if spatial structure of populations are considered and if the dispersal component is incorporated into studying recruitment and mortality of populations. Having said this, local dispersal may not play as important a role in the population dynamics and spatial structure of more permanent species such as the woody shrubs. *Hypelate trifoliata* had the same numbers of adult individuals over time, though large fluctuations in population growth were observed if juvenile dynamics in the same plots were considered. Similarly, *Bourreria cassinifolia*, another woody shrub, did not show changes in adult population size. A similar trend in growth rate (stable population number, little recruitment) of *B. cassinifolia* was observed by Possley and Maschinski (2007) in the habitats outside of EVER.

This study pools plants from several plots of the same species to obtain population growth rates. In the future, spatial variation in species growth rates can be monitored by increasing the number of plots per location, with the exception of extremely rare species where pooling might be necessary due to low abundances. To understand the dynamics of selected or keystone species, such as wetland indicators for example, it might be imperative to use a mark recapture method by tagging plants in study plots and monitoring their fate over a period of time.

Digitaria pauciflora and Sideroxylon reclinatum subsp. austrofloridense Dynamics –
This study provides an expanded illustration of *Digitaria* and *Sideroxylon* distribution in the LPK region of EVER, and reveals some characteristic features of population dynamics. Our data revealed that *Digitaria* is a specialist species occurring in the prairie/pineland ecotone while *Sideroxylon* is more of a generalist species in terms of habitat preference. Both species appear to occur more frequently south of the main park road. There were no obvious links between this distribution and hydrological patterns, but the relationship may merit further exploration. A previous study suggested that *Digitaria* had low to negligible recruitment rates, especially in areas exposed to summer burns followed by high water levels (Herndon 1998). However, our field observations suggest that *Digitaria* may experience relatively rapid turnover wherein the overall cover remains relatively constant. Our data shows some movement of *Digitaria* along individual transects, but long-term data collection will be necessary to elucidate clear patterns.

Community Composition and Environmental Correlates of Rare Plant Habitats –
Our data show the obvious differences across habitats in physiognomy and environmental variables. For example, canopy cover was greatest in hammocks and lowest in prairies, while soil carbon and relative humidity were greatest in hammocks as well. Species richness per plot was greatest in hammocks and pinelands, irrespective of location, and lowest in prairies. In addition to using conventional indices of species composition, such as species richness and species diversity, we used a Floristic Quality Index to assess the habitat quality and compare species composition across locations.

The trend in general was that the areas north of the main park road had lower overall species richness than the areas south of the road. Two factors contributed to the greater total species richness in the south. First, the mere area of suitable habitats to the north is lower than the south. Secondly, both pinelands and hammocks north of main park road are less well developed than in the south and are composed of more generalist species.

In pine rocklands, we demonstrate that shade imparted by understory shrubs and pine canopy determines overall species richness. However, we realize the importance of evaluating shade effects among habitats that are floristically and physiognomically the same. For example, we use the pine rockland plots from the habitats that harbored *Helenium flexuosum* and *Sideroxylon reclinatum* subsp. *austrofloridense* because the habitats are similar across the entire LPK area. It is important as well to clearly define the methods used to determine functional canopy cover as light levels show huge degrees of spatial and temporal variation.

Plant community composition was also impacted by the presence or absence of solution holes in the hammock ecosystems. Solution holes are unique habitats with a specific flora and a combination of environmental variables that must be maintained to ensure that the rare plants populations are conserved and perpetuated. In EVER, the FQI for habitats harboring solution hole specialists was the highest, emphasizing that the solution holes occurring within the hammocks are unique habitats and must be a top priority for conservation and restoration. The key environmental parameters that might impact plants in solution holes, such as RH and water depth, should be monitored in real time.

Our ordination analyses show that Coot Bay Hammock plots are floristically distinct from all other hammock plots. The species richness in Coot Bay Hammock was the lowest compared to other hammocks, and species composition revealed tolerances to salinity and flooding. However, as a result of using species richness in conjunction with FQI to measure habitat quality, the data indicate that Coot Bay Hammock plots are comparable in providing niches for native species with specific and narrow habitat requirements in relation to other hammocks in EVER. Coot Bay Hammock represents coastal buttonwood hammock habitat in the EVER and harbors species with variable salinity and flood tolerance, and contains high epiphytic plant richness. Sample species from this habitat are rare epiphytes, such as *Oncidium undulatum* (a focal species in this study), *Cyrtopodium punctatum,* and other rare forbs (e.g. *Chromolaena frustata, Kosteletzkya depressa*) that are threatened by sea-level rise.

Habitat fragmentation and disturbance appear to play a greater role than any of the measured environmental variables in determining species composition and floristic quality of habitats outside the park. The richness of exotic species in hammocks outside EVER is higher than hammocks inside EVER while the FQI of habitats outside is lower than inside. However, the FQI of the plots shows a broad range of values, indicating that at least some rare species can tolerate a wide range of habitat conditions. For example, *Trichomanes punctatum* and *Lomariopsis kunzeana* both occur in solution holes but rank disparately along the FQI continuum, probably due to a greater abundance of exotics in *T. punctatum* plots that occur in Castellow Hammock and pristine conditions observed in Timm's Hammock for *L. kunzeana*. From a conservation perspective, it is desirable to eradicate exotic species from native habitats, given that several rare plants are already extirpated from South Florida. However, if the exotic species fulfill the ecosystem function of providing desirable light conditions for rare plants below, it should be ensured that sufficient native plants are present to provide similar conditions if the exotics are removed. Regardless, our results highlight the importance of small conservation areas (albeit fragmented) to support rare plant richness in addition to larger protected areas such as national parks (Gann *et. al* 2002). The fact that we had to locate target rare plants such as *T. punctatum*, *Galeandra beyrichii* and *L. kunzeana* outside of the EVER to ensure adequate sampling is testimony to the importance of maintaining small reserves and broad partnerships.

The sustainability of rare plant populations outside of EVER is impossible to determine given the current data set. Given that the size of rare plant habitats is limited and that the rare plants have low population growth rates, we posit that in fragmented landscapes rare plant populations may experience a perpetual bottleneck in which population expansion is limited unless the extent of and/or quality of suitable habitats is increased.

This study provides a sound baseline for assessing rare plant responses to future hydrological modifications and planning for proactive species-level restoration actions (see below). Expanded studies are clearly needed, including additional research on basic natural history (such as vegetative and reproductive phenology, leaf longevity) population dynamics (includes the longevity of individual plants) and rare species recruitment and survival. For the rarest species, experimental studies on seed-bank composition and dynamics, fecundity, pollination, and dispersal would be especially useful. Adaptive management would dictate that monitoring rare plant responses to Everglades restoration be combined with species-level research to enhance the effectiveness of regional restoration.

Rare Plant Augmentation and Reintroduction –
Despite the large size and apparent protection provided to rare plants in Everglades National Park populations of some focal species have declined since its establishment. The goal of this portion of the project was to begin the process of supplementing populations of rare species that were extirpated or nearly so and to restore historic populations as appropriate. We identified 12 species as possibly benefiting from augmentations or reintroductions and successfully propagated all but two of these. We also initiated outplanting trials for four species, including two orchids, a fern and a vine. However, from the work completed to date, it is clear that augmenting and reintroducing rare plant populations in EVER will be challenging.

One potentially confounding factor in restoring populations of extirpated species is that of maintaining the genetic structure of historical populations. Maintaining the genetic integrity of extirpated populations can be challenging when local populations no longer exist and plants with the closest genetic affinities are from entirely different geographical regions. *Brassia caudata* planted out at Hattie Bauer, for example, were from Jamaican germplasm and may be unsuitable for planting out at EVER. Nonetheless, augmenting and reintroducing rare plant species is expected to be an essential component of overall restoration of EVER. Funding permitting, trials with rare plants will continue leading to improved methods and success rates.

Publication History

One arcticle on the conflict between *Oncidium undulatum* and *Melanagromyza miamiensis* was published during Year 4:
Higgins, W.E. and **G.D. Gann**. 2007. The conservation dilemma. Lankesteriana 7(1-2): 141-146.

One article on *Passiflora sexflora* augmentation was accepted for publication in Year 4:
Possley, J., **K. Hines**, J. Maschinski, J. Dozier and C. Rodriguez. 2007. A common passion: multiple agencies and volunteers unite to reintroduce goatsfoot passionflower to rockland hammocks of Miami, Florida. Native Plants 8(3): 252-258.

Two articles on the rediscovery of *Ponthieva brittoniae* were published during Year 2:
Sadle, J.L. 2005. *Ponthieva brittoniae*: Rediscovering a population of Mrs. Britton's Shadow Witch. Orchids (May): 380-382.

Sadle, J.L., **S.W. Woodmansee**, **G.D. Gann**, and T.V. Armentano. 2005. Rediscovery of *Ponthieva brittoniae* (Orchidaceae) in Everglades National Park. Sida 21(3): 1917-2920.

Presentations

One science track talk in Year 4 providing an overview of the project:
Gann*, G.D., **K.N. Hines** and **J.M. Hoffman**. 2007. The rarest of the rare: Native plant conservation in Everglades National Park. 27th Annual Conference, Florida Native Plant Society. Gainesville, Florida.

One talk in Year 4 on the conflict between *Oncidium undulatum* and *Melanagromyza miamiensis*:
Higgins*, W.E. & **G.D. Gann**. 2007. The conservation dilemma. Third International Orchid Conservation Congress. San Jose, Costa Rica.

Media

"Scientists working to save endangered plant species." Article by Toni Whitt in the March 29, 2007 issue of the Sarasota Herald-Tribune discussing the collaboration between EVER, IRC and MSBG for the augmentation portion of this project.

Research Personnel

George D. Gann was principal investigator on this project and oversaw organization and development for the five-year period. Tom Armentano (EVER) was co-principal investigator for Year 1 of the project. Craig Smith assumed this role for Years 2 and 3, and Jimi Sadle served as the EVER co-principal investigator for Years 4 and 5. IRC project managers were Jimi Sadle for Year 1, Emilie Verdon Grahl for Years 2 and 3, and Kirsten Hines for Years 4 and 5. Fieldwork was conducted by the following IRC staff over the course of the project: Melissa Abdo, Keith Bradley, Patricia Castillo-Trenn, Anne Frances, Eric Fleites, George Gann, Emilie Verdon Grahl, Steven Green, Kirsten Hines, Stephen Hodges, Jesse Hoffman, Herbert Kesler, Josh Mahoney, Jimi Sadle, Sonali Saha, Hannah Thornton and Steve Woodmansee. Rare plant restoration and enhancement collaborators included CREW (Valerie Pence), FTBG (Joyce Maschinski, Jennifer Possley), MSBG (Pattie

Clendenin, Wesley Higgins, Heather Hill, Bruce Holst, Harry Luther, Rosalind Rowe) and NAM (Jane Dozier, Joe Maguire, Sonya Thompson). Soil collection, methodology, and analysis were developed in collaboration with Yuncong Li and Kati Migliaccio of The Institute of Food and Agricultural Sciences, University of Florida (IFAS). All soil samples were analyzed in their labs. Tom Philippi and Tiffany Troxler of Florida International University assisted with plot and transect design and data analysis.

ATTACHMENTS

Location data, population estimates and field notes from rare plant surveys during Year 5 are included with this report in an Access database entitled IRC_LPK_RarePlantResults_Year5. Vegetation plot, control plot, and belt transect data and locations are included as tables in the same Access database. Copies of the original field datasheets are also provided.

CITATIONS

Gann, G.D. and N.L. Gerson. 1996. Rare plant mitigation in Florida. In: Restoring Diversity (eds. D.L. Falk, C.I. Millar, and M. Olwell). Island Press, Washington DC, USA. pp 373-394.

Gann, G.D., K.A. Bradley and S.W. Woodmansee. 2002. Rare Plants of South Florida: Their History, Conservation, and Restoration. Miami, FL: The Institute for Regional Conservation.

Herndon, A. 1998. Life history studies of some plants endemic to pine rocklands in Everglades National Park. Final Report submitted to Everglades National Park: Life history studies of plants endemic to southern Florida, # CA 5280-5-9019.

Ewe, S., L. da Silvera Lobo Steinburg, and D. Busch. 1999. Water use patterns in pineland and hammock communities of South Florida. Forest Ecology and Management 118:139-148.

McCune, B. and M. J. Mefford. 2006. PC-ORD. Multivariate Analysis of Ecological Data. Version 5. MjM Software, Gleneden Beach, OR, USA.

Possley, J. and J. Maschinski. 2007. Development and Implementation of a Biological Monitoring Program for Rare Plants in Miami-Dade County Natural Areas. Year 5 Report to Dade County # R-841-02.

Rooney, T.P. and D.A. Rogers. 2002. The modified floristic quality index. Natural Areas Journal 22:340-344.

Small, J.K. 1938. Ferns of the Southeastern States. Lancaster: The Science Press.

Swink, F.A. and G.S. Wilhelm. 1994. Plants of the Chicago Region (4^{th} ed). Morton Arboretum. Lisle, IL, USA.

Urquhart, N.S. and T.M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. Journal of Agricultural, Biological and Environmental Statistics 4(4): 404-414.

Washington, H.G. 1984. Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems. Water Resources 18:653-694.

Appendix A. Rare Plant Occurrences in the Long Pine Key area.

Species	Location	Surveys complete?	Status	New Occurrence?
Adiantum melanoleucum	Osteen Hammock	Yes, Year 1	Present	No
Adiantum melanoleucum	Rattlesnake Hammock	Yes, Year 2	Present	Yes, Year 2
Anemia wrightii	Pfleuger Hammock Area	Yes, Year 1	Present	No
Anemia wrightii	Warren Hammock Area	Yes, Year 1	Present	No
Basiphyllaea corallicola	Pine Block A	Yes, Year 1	Present	Yes, Year 1
Basiphyllaea corallicola	Pine Block B	Yes, Year 1	Present	No
Basiphyllaea corallicola	Pine Block C	Yes, Year 3	Potential	-
Basiphyllaea corallicola	Pine Block D	Yes, Year 3	Potential	-
Basiphyllaea corallicola	Pine Block E	Yes, Year 1	Present	Yes, Year 1
Basiphyllaea corallicola	Pine Block F	Yes, Year 1	Present	Yes, Year 1
Basiphyllaea corallicola	Pine Block G	Yes, Year 3	Potential	-
Basiphyllaea corallicola	Pine Block H	Yes, Year 5	Possibly extirpated	No
Basiphyllaea corallicola	Pine Block I	Yes, Year 3	Possibly extirpated	No
Basiphyllaea corallicola	Pine Block J	Yes, Year 1	Present	No
Bourreria cassinifolia	Bootlegger Hammock	Yes, Year 3	Present	No
Bourreria cassinifolia	Palma Vista Hammock #2	Yes, Year 1	Present	No
Bourreria cassinifolia	Pine Block E	Yes, Year 1	Present	No
Bourreria cassinifolia	Pine Block F	Yes, Year 5	Possibly extirpated	No
Bourreria cassinifolia	Pine Block H	Yes, Year 1	Present	No
Bourreria cassinifolia	Pine Block J	Yes, Year 2	Present	Yes, Year 2
Brassia caudata	Deer Hammock	Yes, Year 1	Presumed extirpated	No
Brassia caudata	Osteen Hammock	Yes, Year 1	Presumed extirpated	No
Brassia caudata	Turkey Hammock	Yes, Year 1	Presumed extirpated	No
Brassia caudata	Winkley Hammock	Yes, Year 1	Presumed extirpated	No
Croton lobatus	Mosier Hammock Edge	Yes, Year 2	Present	No
Dalea carthagenensis var. *floridana*	East boundary	Yes, Year 1	Presumed extirpated	No
Dalea carthagenensis var. *floridana*	Roadside and canal bank, 14miles SW of Paradise Key	Yes, Year 1	Presumed extirpated	No
Desmodium lineatum	Pine Block H	Yes, Year 1	Present	No
Desmodium lineatum	Pine Block I	Yes, Year 1	Present	Yes, Year 1
Desmodium lineatum	Pine Block J	Yes, Year 1	Present	No
Digitaria pauciflora	Hole-in-the-Donut area	Yes, Year 3	Present	No
Digitaria pauciflora	Pine Block A	Yes, Year 1	Present	No
Digitaria pauciflora	Pine Block B	Yes, Year 1	Present	Yes, Year 1
Digitaria pauciflora	Pine Block C	Yes, Year 1	Present	No
Digitaria pauciflora	Pine Block D	Yes, Year 2	Present	No
Digitaria pauciflora	Pine Block E	Yes, Year 1	Present	Yes, Year 1
Digitaria pauciflora	Pine Block F	Yes, Year 1	Present	Yes, Year 1
Digitaria pauciflora	Pine Block G	Yes, Year 2	Present	Yes, Year 2
Digitaria pauciflora	Pine Block H	Yes, Year 2	Present	No
Digitaria pauciflora	Pine Block I	Yes, Year 2	Present	Yes, Year 2

Digitaria pauciflora	Pine Block J	Yes, Year 5	Potential	-
Digitaria pauciflora	Pinelands west of Pine Block A	Yes, Year 1	Present	Yes, Year 1
Digitaria pauciflora	Pinelands west of Pine Block B	Yes, Year 1	Present	Yes, Year 1
Digitaria pauciflora	Prairies and transitional pinelands north and west of Pine Block D	Yes, Year 3	Present	Yes, Year 3
Eltroplectris calcarata	Clench Hammock	Yes, Year 3	Present	Yes, Year 3
Eltroplectris calcarata	Fairchild Hammock	Yes, Year 1	Present	Yes, Year 1
Eltroplectris calcarata	Frampton Hammock	Yes, Year 1	Present	No
Eltroplectris calcarata	Grimshawe Hammock	Yes, Year 1	Present	Yes, Year 1
Eltroplectris calcarata	Brookfield Hammock (Hammock #120)	Yes, Year 5	Possibly extirpated	No
Eltroplectris calcarata	Mosier Hammock	Yes, Year 2	Present	No
Eltroplectris calcarata	Osteen Hammock	Yes, Year 1	Present	No
Eltroplectris calcarata	Palma Vista Hammock #1	Yes, Year 1	Present	Yes, Year 1
Eltroplectris calcarata	Palma Vista Hammock #2	Yes, Year 1	Present	No
Eltroplectris calcarata	Pay-Fee Hammock	Yes, Year 5	Possibly extirpated	No
Eltroplectris calcarata	Pilsbry Hammock	Yes, Year 1	Present	No
Eltroplectris calcarata	Rattlesnake Hammock	Yes, Year 1	Present	Yes, Year 1
Eltroplectris calcarata	Redd Hammock	Yes, Year 1	Present	No
Eltroplectris calcarata	Winkley Hammock	Yes, Year 1	Present	Yes, Year 1
Galeandra beyrichii	Mosier Hammock	Yes, Year 2	Present	No
Galeandra beyrichii	Pay-Fee Hammock	Yes, Year 2	Present	Yes, Year 2
Galeandra beyrichii	Royal Palm Hammock	Yes, Year 1	Present	No
Govenia utriculata	Palma Vista Hammock #2	Yes, Year 2	Presumed extirpated	No
Helenium flexuosum	Pine Block A	Yes, Year 3	Present	Yes, Year 3
Helenium flexuosum	Pine Block B	Yes, Year 1	Present	No
Helenium flexuosum	Pine Block C	Yes, Year 3	Present	No
Helenium flexuosum	Pine Block D	Yes, Year 1	Present	Yes, Year 1
Helenium flexuosum	Pine Block E	Yes, Year 1	Present	No
Helenium flexuosum	Pine Block F	Yes, Year 2	Present	Yes, Year 2
Helenium flexuosum	Pine Block G	Yes, Year 3	Present	Yes, Year 3
Helenium flexuosum	Pine Block H	Yes, Year 1	Present	Yes, Year 1
Helenium flexuosum	Pine Block I	Yes, Year 3	Present	Yes, Year 3
Helenium flexuosum	Pine Block J	Yes, Year 5	Potential	-
Hypelate trifoliata	Deer Hammock	Yes, Year 1	Present	No
Hypelate trifoliata	Pine Block A	Yes, Year 1	Present	Yes, Year 1
Hypelate trifoliata	Pine Block B	Yes, Year 1	Present	No
Hypelate trifoliata	Pine Block F	Yes, Year 2	Present	Yes, Year 2
Hypelate trifoliata	Torre Hammock	Yes, Year 1	Present	No
Hypelate trifoliata	Unnamed Hammock west of Baker Hammock	Yes, Year 2	Present	Yes, Year 2
Lomariopsis kunzeana	Osteen Hammock	Yes, Year 1	Present	No
Macradenia lutescens	Deer Hammock	Yes, Year 1	Presumed extirpated	No
Macradenia lutescens	Osteen Hammock	Yes, Year 1	Presumed extirpated	No

Macradenia lutescens	Royal Palm Hammock	Yes, Year 1	Presumed extirpated	No
Macradenia lutescens	Turkey Hammock	Yes, Year 1	Presumed extirpated	No
Macradenia lutescens	Winkley Hammock	Yes, Year 1	Presumed extirpated	No
Oncidium ensatum	Baker Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Bequaert Hammock	Yes, Year 2	Present	Yes, Year 2
Oncidium ensatum	Brookfield Hammock (Hammock #120)	Yes, Year 3	Present	Yes, Year 3
Oncidium ensatum	Courrier Hammock	Yes, Year 3	Present	Yes, Year 3
Oncidium ensatum	Decamp Hammock	Yes, Year 3	Present	Yes, Year 3
Oncidium ensatum	Deer Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Frampton Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Gifford Hammock	Yes, Year 2	Present	Yes, Year 2
Oncidium ensatum	Grimshawe Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Henderson Hammock	Yes, Year 1	Present	Yes, Year 2
Oncidium ensatum	Jones Hammock	Yes, Year 3	Present	Yes, Year 3
Oncidium ensatum	Junk Hammock	Yes, Year 2	Present	Yes, Year 2
Oncidium ensatum	Mystery Hammock	Yes, Year 1	Present	Yes, Year 1
Oncidium ensatum	Osteen Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Palma Vista Hammock #1	Yes, Year 1	Present	Yes, Year 1
Oncidium ensatum	Palma Vista Hammock #2	Yes, Year 1	Present	No
Oncidium ensatum	Poppenhager Hammock	Yes, Year 3	Present	Yes, Year 3
Oncidium ensatum	Rattlesnake Hammock	Yes, Year 1	Present	Yes, Year 1
Oncidium ensatum	Redd Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Robertson Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Royal Palm Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Say Hammock	Yes, Year 2	Presumed extirpated	No
Oncidium ensatum	Simmons Hammock	Yes, Year 2	Present	Yes, Year 2
Oncidium ensatum	Torre Hammock	Yes, Year 1	Present	Yes, Year 1
Oncidium ensatum	Turkey Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Unnamed Hammock 200m NW of Pineland Trail	Yes, Year 1	Present	Yes, Year 1
Oncidium ensatum	Unnamed Hammock 550m SW of Pine Glades Lake	Yes, Year 1	Present	Yes, Year 1
Oncidium ensatum	Unnamed Hammock in Pine Block C	Yes, Year 3	Present	Yes, Year 3
Oncidium ensatum	Unnamed Hammock in Pine Block D	Yes, Year 3	Present	Yes, Year 3
Oncidium ensatum	VonPaulsen Hammock	Yes, Year 3	Present	Yes, Year 3
Oncidium ensatum	Wild Lime Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Winkley Hammock	Yes, Year 1	Present	No
Oncidium ensatum	Wright Hammock	Yes, Year 1	Present	No
Oncidium undulatum	Royal Palm Hammock	Yes, Year 1	Presumed extirpated	No
Passiflora sexflora	Osteen Hammock	Yes, Year 1	Present	No
Passiflora sexflora	Royal Palm Hammock	Yes, Year 1	Presumed extirpated	No

Pecluma plumula	Cadwalader Hammock	Yes, Year 1	Present	No
Pecluma plumula	Dewhurst Hammock	Yes, Year 1	Present	No
Ponthieva brittoniae	Pine Block A	Yes, Year 1	Present	Yes, Year 1
Ponthieva brittoniae	Pine Block B	Yes, Year 1	Present	Yes, Year 1
Ponthieva brittoniae	Pine Block E	Yes, Year 1	Present	No
Ponthieva brittoniae	Pine Block F	Yes, Year 1	Presumed extirpated	No
Prescotia oligantha	Palma Vista Hammock #2	Yes, Year 2	Presumed extirpated	No
Schizaea pennula	Royal Palm Hammock	Yes, Year 1	Presumed extirpated	No
Sideroxylon reclinatum subsp. *austrofloridense*	East of Pine Block J	Yes, Year 1	Present	Yes, Year 1
Sideroxylon reclinatum subsp. *austrofloridense*	North of Long Pine Key	Yes, Year 1	Present	No
Sideroxylon reclinatum subsp. *austrofloridense*	Paradise Key	Yes, Year 1	Present	No
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block A	Yes, Year 1	Present	Yes, Year 1
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block B	Yes, Year 3	Present	Yes, Year 3
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block C	Yes, Year 3	Present	Yes, Year 3
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block D	Yes, Year 1	Present	Yes, Year 1
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block E	Yes, Year 1	Present	Yes, Year 1
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block F	Yes, Year 2	Present	Yes, Year 2
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block G	Yes, Year 2	Present	Yes, Year 2
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block H	Yes, Year 1	Present	Yes, Year 1
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block I	Yes, Year 1	Present	Yes, Year 1
Sideroxylon reclinatum subsp. *austrofloridense*	Pine Block J	Yes, Year 1	Present	Yes, Year 1
Sideroxylon reclinatum subsp. *austrofloridense*	Prairies and transitional pinelands west of Pine Block D	Yes, Year 3	Present	Yes, Year 3
Spiranthes costaricensis	Atoll Hammock	Yes, Year 5	Possibly extirpated	No
Spiranthes costaricensis	Avery Hammock	Yes, Year 5	Possibly extirpated	No
Spiranthes costaricensis	Fairchild Hammock	Yes, Year 1	Present	No
Spiranthes costaricensis	Brookfield Hammock (Hammock #120)	Yes, Year 5	Possibly extirpated	No
Spiranthes costaricensis	Osteen Hammock	Yes, Year 1	Present	No
Spiranthes costaricensis	Palma Vista Hammock #2	Yes, Year 1	Present	No
Spiranthes costaricensis	Pilsbry Hammock	Yes, Year 4	Present	Yes, Year 4
Spiranthes costaricensis	Rattlesnake Hammock	Yes, Year 1	Present	Yes, Year 1
Spiranthes costaricensis	Royal Palm Hammock	Yes, Year 1	Present	No

Spiranthes costaricensis	Winkley Hammock	Yes, Year 1	Present	Yes, Year 1
Spiranthes torta	Pine Block A	Yes, Year 1	Present	No
Sporobolus compositus var. *clandestinus*	Pine Block H	Yes, Year 2	Present	No
Thelypteris reticulata	East Boundary Cypress Dome	Yes, Year 1	Present	Yes, Year 1
Thelypteris reticulata	Hole-in-the-Donut area	Yes, Year 1	Present	No
Thelypteris reticulata	Pine Island area	No, Year 1	Possibly extirpated	No
Thelypteris reticulata	Royal Palm Hammock	Yes, Year 1	Present	No
Thelypteris serrata	Pine Island area	Yes, Year 1	Present	No
Tillandsia fasciculata var. *clavispica*	Palma Vista Hammock #2	Yes, Year 1	Presumed extirpated	No
Trichomanes punctatum subsp. *floridanum*	Royal Palm Hammock	Yes, Year 1	Presumed extirpated	No

Appendix B. Long-term Monitoring Plots in the Long Pine Key area.

Study Species	Year Established	Specific Habitat	Orientation from main park road and general location
Adiantum melanoleucum	Year 1	Rockland hammock solution hole (bowl shaped)	South, Osteen Hammock
Adiantum melanoleucum	Year 2	Rockland hammock solution hole (bowl shaped)	South, Rattlesnake Hammock
Anemia wrightii	Year 1	Rocky prairie along hammock edge	North, Warren Hammock area
Anemia wrightii	Year 3	Rocky prairie along hammock edge	North, Warren Hammock area
Anemia wrightii	Year 1	Rocky prairie along hammock edge	South, Pfleuger Hammock area
Anemia wrightii	Year 1	Rocky prairie along hammock edge	South, Pfleuger Hammock area
Anemia wrightii	Year 3	Rocky prairie along hammock edge	South, Pfleuger Hammock area
Basiphyllaea corallicola	Year 1	Higher elevation pineland	South, Pine Block B
Basiphyllaea corallicola	Year 1	Higher elevation pineland	South, Pine Block E
Basiphyllaea corallicola	Year 1	Higher elevation pineland	South, Pine Block J
Bourreria cassinifolia	Year 2	Higher elevation pineland	South, Pine Block E
Bourreria cassinifolia	Year 2	Higher elevation pineland	South, Pine Block J
Bourreria cassinifolia	Year 2	Higher elevation pineland	South, Pine Block H
Croton lobatus	Year 3	Pineland/hammock ecotone	South, Mosier Hammock edge
Desmodium lineatum	Year 1	Pineland (Redland soil pockets)	South, Pine Block H
Desmodium lineatum	Year 1	Pineland (Redland soil pockets)	South, Pine Block I
Desmodium lineatum	Year 1	Pineland (Redland soil pockets)	South, Pine Block J
Digitaria pauciflora	Year 3	Prairie	North, east of Pine Block D
Digitaria pauciflora	Year 3	Prairie	North, east of Pine Block D
Digitaria pauciflora	Year 3	Prairie	North, northeast of Pine Block D
Digitaria pauciflora	Year 3	Prairie	South, Pine Block G
Digitaria pauciflora	Year 3	Prairie	South, Pine Block G
Digitaria pauciflora	Year 3	Prairie	South, Pine Block H
Digitaria pauciflora	Year 4	Prairie	North, east of Pine Block D
Digitaria pauciflora	Year 4	Prairie	North, east of Pine Block D
Digitaria pauciflora	Year 4	Prairie	North, east of Pine Block D
Digitaria pauciflora	Year 4	Prairie	South, Pine Block G
Digitaria pauciflora	Year 4	Prairie	South, Pine Block G
Digitaria pauciflora	Year 4	Prairie	South, Pine Block H
Eltroplectris calcarata	Year 1	Rockland hammock	South, Grimshawe Hammock

Eltroplectris calcarata	Year 1	Rockland hammock	South, Pilsbry Hammock
Eltroplectris calcarata	Year 1	Rockland hammock	South, Rattlesnake Hammock
Galeandra beyrichii	Year 2	Rockland hammock	South, Mosier Hammock
Helenium flexuosum	Year 2	Pineland (low elevation)	North, Pine Block D
Helenium flexuosum	Year 2	Pineland (low elevation)	North, Pine Block D
Helenium flexuosum	Year 2	Pineland (low elevation)	North, Pine Block D
Helenium flexuosum	Year 2	Pineland (low elevation)	South, Pine Block E
Helenium flexuosum	Year 2	Pineland (low elevation)	South, Pine Block E
Helenium flexuosum	Year 2	Pineland (low elevation)	South, Pine Block F
Hypelate trifoliata	Year 2	Pineland	South, Pine Block A
Hypelate trifoliata	Year 2	Pineland	South, Pine Block B
Hypelate trifoliata	Year 2	Pineland	South, Pine Block A
Hypelate trifoliata	Year 2	Rockland hammock edge	South, Deer Hammock
Hypelate trifoliata	Year 2	Rockland hammock edge	South, Deer Hammock
Hypelate trifoliata	Year 2	Rockland hammock edge	South, Torre Hammock
Lomariopsis kunzeana	Year 1	Rockland hammock solution hole (cylinder shaped)	South, Osteen Hammock
Lomariopsis kunzeana	Year 1	Rockland hammock solution hole (cylinder shaped)	South, Osteen Hammock
Oncidium ensatum	Year 1	Rockland hammock (near edge)	North, Unnamed hammock in Pine Block D
Oncidium ensatum	Year 1	Rockland hammock (near edge)	South, Grimshawe Hammock
Oncidium ensatum	Year 1	Rockland hammock (near edge)	South, Robertson Hammock
Oncidium ensatum	Year 3	Rockland hammock (near edge)	North, Unnamed hammock in Pine Block D
Passiflora sexflora	Year 1	Rockland hammock (edge)	South, Osteen Hammock
Pecluma plumula	Year 1	Rockland hammock	North, Cadwalader Hammock
Pecluma plumula	Year 1	Rockland hammock	North, Cadwalader Hammock
Pecluma plumula	Year 1	Prairie hammock	West, Dewhurst Hammock
Ponthieva brittoniae	Year 1	Pineland sinkhole	South, Pine Block A
Ponthieva brittoniae	Year 1	Pineland sinkhole	South, Pine Block B
Ponthieva brittoniae	Year 1	Pineland sinkhole	South, Pine Block E
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Pineland	North, northeast of Pine Block D
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Pineland	North, east of Pine Block D
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Pineland	North, northwest of Pine Block D
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Pineland	South, Pine Block E
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Pineland	South, Pine Block G
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Pineland	South, Pine Block H
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Prairie	North, northeast of Pine Block D
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Prairie	North, east of Pine Block D
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Prairie	North, northwest of Pine Block D

Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Prairie	South, Pine Block G
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Prairie	South, Pine Block G
Sideroxylon reclinatum subsp. *austrofloridense*	Year 3	Prairie	South, Pine Block H
Spiranthes costaricensis	Year 2	Rockland hammock	South, Palma Vista Hammock #2
Spiranthes costaricensis	Year 4	Rockland hammock	South, Osteen Hammock
Spiranthes costaricensis	Year 4	Rockland hammock	South, Pilsbry Hammock
Spiranthes torta	Year 3	Pineland	South, Pine Block A
Spiranthes torta	Year 3	Pineland	South, Pine Block A
Sporobolus compositus var. *clandestinus*	Year 4	Pineland	South, Pine Block H southwest of Rattlesnake Hammock
Thelypteris reticulata	Year 3	Cypress dome	South, east boundary cypress dome
Thelypteris reticulata	Year 3	Rockland hammock	Hole-in-the-Donut area
Thelypteris serrata	Year 3	Schinus thicket	South, Pine Island area
Thelypteris serrata	Year 3	Schinus thicket	South, Pine Island area

Appendix C. Soil Results for Sampled Plots in LPK.

Species	Habitat	Plot	Year	Season	%N	%C (Organic)	NO3	NH4	TP	%C (Inorganic)	Talum	Tfe	TK	H2O
Adiantum melanoleucum	solution hole	3898	2007	dry	2.72	40.32	2.83	847.03	848.13	0.50				
Adiantum melanoleucum	solution hole	3898	2005	wet	2.00	25.61	640.99	40.33	584.39	0.31	3098.08	285.03	139.75	48.12
Anemia wrightii	other	3886	2007	dry	1.97	38.49	9.04	78.97	573.57	0.71				
Anemia wrightii	other	3886	2005	wet	0.02	1.09	6.80	7.01	79.87	9.46	1587.44	1001.97	32.14	
Anemia wrightii	other	3887	2007	dry	1.96	34.67	2.46	60.52	590.48	0.72				
Anemia wrightii	other	3887	2005	wet	0.11	1.86	25.81	7.22	141.83	10.91	3027.67	1882.91	302.14	
Anemia wrightii	other	3888	2007	dry	1.95	36.87	4.17	47.91	472.15	0.62				
Anemia wrightii	other	3888	2005	wet	0.21	3.03	3.19	5.99	81.22		1073.05	678.59	55.44	
Basiphyllaea corallicola	pineland	3890	2007	dry	1.37	38.87	0.45	15.44	469.37	0.62				
Basiphyllaea corallicola	pineland	3890	2005	wet	0.43	12.00	13.87	32.81	245.14	1.19	81848.43	48539.95	347.45	50.65
Basiphyllaea corallicola	pineland	3891	2007	dry	0.52	51.21	0.38	27.93	114.43	0.58				
Basiphyllaea corallicola	pineland	3891	2005	wet	0.24	15.51	22.62	13.08	142.85	9.03	14320.57	7230.05	218.96	53.16
Basiphyllaea corallicola	pineland	3892	2007	dry	1.04	40.97	0.93	59.97	195.57	0.83				
Basiphyllaea corallicola	pineland	3892	2005	wet	1.02	33.38	6.00	22.69	343.44		19593.76	12557.63	428.09	46.17
Desmodium lineatum	pineland	3874	2007	dry	0.30	12.55	0.61	7.80	198.15	0.38				
Desmodium lineatum	pineland	3874	2005	wet	0.93	30.13	26.41	22.76	298.40	0.41	34213.43	17913.40	270.94	55.33
Desmodium lineatum	pineland	3875	2007	dry	0.44	17.46	0.45	10.42	218.55	0.48				
Desmodium lineatum	pineland	3875	2005	wet	0.14	3.79	0.85	16.23	199.37		97663.96	58204.68	548.01	51.65
Desmodium lineatum	pineland	3877	2007	dry	0.33	11.11	0.86	15.63	215.86	1.73				
Desmodium lineatum	pineland	3877	2005	wet	0.23	5.72	21.98	12.77	203.27		108681.24	60445.19	570.19	37.53
Eltroplectris calcarata	hammock	3876	2007	dry	2.43	40.62	0.92	120.00	451.62	0.43				
Eltroplectris calcarata	hammock	3876	2005	wet	1.62	35.38	9.24	395.13	177.31	0.46	4152.79	3076.47	162.35	22.57
Eltroplectris calcarata	hammock	3878	2007	dry	1.75	23.53	11.41	86.98	165.90	2.44				
Eltroplectris calcarata	hammock	3878	2005	wet	1.82	29.54	184.54	251.06	509.37	0.51	2458.64	577.64	658.71	58.26
Eltroplectris calcarata	hammock	3879	2007	dry	2.15	41.32	0.66	149.15	104.11	0.48				
Eltroplectris calcarata	hammock	3879	2005	wet	1.93	40.27	0.37	359.94	503.05	0.41	440.52	2135.74	214.18	50.91
Lomariopsis kunzeana	solution hole	3895	2007	dry	2.86	38.94	7.07	136.78	1178.18	0.67				
Lomariopsis kunzeana	solution hole	3895	2005	wet	0.06	0.81	1.54	1.98	78.40		174.74	212.17	253.62	
Lomariopsis kunzeana	solution hole	3896	2007	dry	3.02	40.67	7.15	719.76	2125.06	0.86				
Lomariopsis kunzeana	solution hole	3896	2005	wet	0.06	11.70	8.48	6.56	129.18	9.80	1606.84	544.66	126.52	
Oncidium ensatum	hammock	3880	2007	dry	1.85	41.03	1.30	148.86	548.70	0.53				
Oncidium ensatum	hammock	3880	2005	wet	1.45	33.15	5.00	126.42	476.55	0.31	151.86	586.19	189.36	33.41

Oncidium ensatum	hammock	3883	2007	dry	1.85	38.15	0.85	142.23	665.83	0.48				
Oncidium ensatum	hammock	3883	2005	wet	1.49	40.64	1.26	312.68	526.74		648.92	185.78	91.88	40.87
Oncidium ensatum	hammock	3884	2007	dry	1.95	39.85	1.27	158.76	623.37	0.51				
Oncidium ensatum	hammock	3884	2005	wet	1.83	40.86	0.30	375.00	494.72	0.66	434.07	107.29	182.71	28.17
Passiflora sexflora	hammock	3897	2007	dry	2.50	39.72	1.18	256.02	834.93	0.74				
Passiflora sexflora	hammock	3897	2005	wet	1.39	13.07	300.24	7.58	1143.23	0.21	43041.75	22490.24	242.61	38.61
Pecluma plumula	hammock	3881	2007	dry	2.22	41.60	0.74	25.58	981.86	0.50				
Pecluma plumula	hammock	3881	2005	wet	1.78	41.72	19.71	247.67	633.23		236.24	640.30	181.86	29.17
Pecluma plumula	hammock	3899	2007	dry	2.78	39.90	0.94	124.28	1078.77	0.62				
Pecluma plumula	hammock	3899	2005	wet	1.49	40.85	7.21	109.23	244.62	1.01	3159.95	3273.56	198.64	18.44
Pecluma plumula	hammock	3900	2007	dry	1.08	47.16	1.20	27.84	908.50	0.50				
Pecluma plumula	hammock	3900	2005	wet	1.50	40.34	5.01	83.57	427.34	0.26	1507.91	1236.03	114.33	34.17
Ponthieva brittoniae	pineland	3889	2007	dry	1.31	37.51	1.35	28.19	403.87	0.92				
Ponthieva brittoniae	pineland	3889	2005	wet	0.82	22.75	157.57	9.00	300.23	10.38	4052.65	2246.14	200.60	
Ponthieva brittoniae	pineland	3893	2007	dry	1.45	38.93	10.06	22.85	697.02	1.34				
Ponthieva brittoniae	pineland	3893	2005	wet	0.46	10.15	107.90	6.85	167.54	10.78	2637.29	1407.71	131.08	
Ponthieva brittoniae	pineland	3894	2007	dry	0.96	41.55	1.41	37.84	924.38	0.57				
Ponthieva brittoniae	pineland	3894	2005	wet	0.40	12.66	107.84	10.30	166.88		1186.97	1596.03	181.47	

Appendix D. Distribution of exotic species in all plots, long-term monitoring and off-site characterization.

Introduced Exotic Species	Affiliated Focal Species	# Plots	Plot Locations	Habitat Types
Adenanthera pavonina	*Croton lobatus*	1	Outside	Hammock
Albizia lebbeck	*Croton lobatus*	1	Outside	Hammock
Alstonia macrophylla	*Croton lobatus*	1	Outside	Hammock
Ardisia elliptica	*Adiantum melanoleucum, Helenium flexuosum, Thelypteris reticulata, Thelypteris serrata*	7	Outside, EVER, LPK	Hammock, Hammock Solution Hole, Other, Pineland
Bischofia javanica	*Croton lobatus, Galeandra beyrichii, Lomariopsis kunzeana, Passiflora sexflora, Trichomanes punctatum* var. *floridanum*	8	Outside	Hammock, Hammock Solution Hole
Blechum pyramidatum	*Croton lobatus*	1	Outside	Hammock
Bothriochloa pertusa	*Sporobolus compositus* var. *clandestinus*	1	LPK	Firebreak
Costus spicatus	*Croton lobatus*	1	Outside	Hammock
Dioscorea bulbifera	*Lomariopsis kunzeana, Passiflora sexflora*	2	Outside	Hammock, Hammock Solution Hole
Emilia sp.	*Thelypteris reticulata*	1	LPK	Hammock
Epipremnum pinnatum cv. *aureum*	*Croton lobatus*	1	Outside	Hammock
Eremochloa ophiuroides	*Desmodium lineatum*	1	LPK	Pineland
Eugenia uniflora	*Passiflora sexflora*	1	Outside	Hammock
Euphorbia graminea	*Croton lobatus*	2	Outside	Hammock, Pineland
Jasminum dichotomum	*Croton lobatus, Passiflora sexflora, Thelypteris serrata, Trichomanes punctatum* var. *floridanum*	4	Outside	Hammock, Hammock Solution Hole
Jasminum fluminense	*Croton lobatus, Galeandra beyrichii, Passiflora sexflora, Trichomanes punctatum* var. *floridanum*	6	Outside	Hammock, Hammock Solution Hole
Merremia tuberosa	*Croton lobatus*	1	Outside	Hammock
Momordica charantia	*Croton lobatus, Passiflora sexflora, Trichomanes punctatum* var. *floridanum*	3	Outside	Hammock, Hammock Solution Hole, Pineland
Nephrolepis multiflora	*Passiflora sexflora*	1	Outside	Hammock
Oeceoclades maculata	*Adiantum melanoleucum, Anemia wrightii, Eltroplectris calcarata, Galeandra beyrichii, Hypelate trifoliata, Lomariopsis kunzeana, Passiflora sexflora, Pecluma plumula, Spiranthes costaricensis, Trichomanes punctatum* var. *floridanum*	21	Outside, LPK	Hammock, Hammock Solution Hole, Other
Pteris tripartita	*Passiflora sexflora*	1	Outside	Hammock
Pteris vittata	*Adiantum melanoleucum, Passiflora sexflora*	3	Outside	Hammock, Hammock Solution Hole
Ptychosperma elegans	*Croton lobatus, Trichomanes punctatum* var. *floridanum*	3	Outside	Hammock, Hammock Solution Hole
Rhynchelytrum repens	*Croton lobatus, Sideroxylon reclinatum* subsp. *austrofloridense, Spiranthes torta*	3	Outside, LPK	Pineland, Prairie

Richardia scabra	*Croton lobatus*	1	LPK	Pineland
Rubus niveus	*Thrichomanes punctatum* var. *floridanum*	1	Outside	Hammock Solution Hole
Schefflera actinophylla	*Adiantum melanoleucum, Galeandra beyrichii, Trichomanes punctatum* var. *floridanum*	5	Outside	Hammock, Hammock Solution Hole
Schinus terebinthifolius	*Adiantum melanoleucum, Anemia wrightii, Basiphyllea corallicola, Bourreria cassinifolia, Helenium flexuosum, Hypelate trifoliata, Oncidium ensatum, Passiflora sexflora, Pecluma plumula, Pontheiva brittoniae, Spiranthes costaricensis, Thelypteris reticulata, Thelypteris serrata, Trichomanes punctatum* var. *floridanum*	29	Outside, EVER, LPK	Hammock, Hammock Solution Hole, Other, Pineland
Selenicereus pteranthus	*Oncidium undulatum*	1	EVER	Hammock
Sorghum arundinaceum	*Croton lobatus*	1	Outside	Pineland
Spermacoce verticillata	*Helenium flexuosum, Sporobolus compositus var. clandestinus*	2	LPK	Firebreak, Pineland
Sporobolus indicus var. *pyramidalis*	*Thelypteris reticulata*	1	LPK	Hammock
Syngonium podophyllum	*Croton lobatus, Galeandra beyrichii, Trichomanes punctatum* var. *floridanum*	3	Outside	Hammock, Hammock Solution Hole
Syzygium cumini	*Thrichomanes punctatum* var. *floridanum*	1	Outside	Hammock Solution Hole
Tectaria incisa	*Adiantum melanoleucum*	1	Outside	Hammock Solution Hole
Youngia japonica	*Adiantum melanoleucum, Passiflora sexflora, Trichomanes punctatum* var. *floridanum*	5	Outside	Hammock, Hammock Solution Hole

Appendix E. Summary of plot characteristics of species with off-site characterization plots. Presented data includes information from both off-site characterization plots and long-term monitoring plots.

Species/ Total # Plots	Preferred Habitat	Canopy Height (m)	Canopy Cover (%)	Solution Hole Perimeter (cm)	Water Level at Plant (cm)	Water Level at Nearest Depression / SH (cm)	Substrate description
Adiantum melanoleucum/3	100% Solution Hole	9.8 - >15	90 - 93	327 - 1486	0	0	Decomposed leaf litter over limestone
Anemia wrightii/7	100% Pinnacle Rock at Bayhead-Prairie Ecotone	3.8 - 6.2	69 - 100	Matrix	0 - 45	0 - 45	Decomposed leaf litter over limestone
Croton lobatus/3	67% Pineland, 33% Hammock	3.7 - >15	0 - 91	None - 95	0	0	Decomposed leaf litter over limestone
Galeandra beyrichii/3	100%Hammock	4.9 - >15	91 - 100	None	0 - 1	N/A	Decomposed leaf litter

Lomariopsis kunzeana/3	100% Solution Hole	8.5 - >15	94 - 99	261 - 758	0	0	Limestone
Oncidium undulatum/3	100% Hammock	4.6 - 9.6	51 - 70	None	0	N/A	Host tree trunks
Passiflora sexflora/ 3	100% Hammock	9.5 - >15	94 - 96	None	0	N/A	Decomposed leaf litter
Spiranthes torta/3	67% Pineland, 33% Prairie	0 - 12.8	0 - 37	None	0 - 47	N/A	Sandy soil / Marl over limestone - Limestone
Sporolobus compositus/2	50% Pineland, 50% Firebreak	3.7 - 8.7	0 - 6	None	0	N/A	Redland soil pockets - Limestone (intact+scraped)
Thelyptris reticulata/3	67% Hammock, 33% Other	7.5 - 9.2	85 - 98	None - 2570	0	0 - 47	Decomposed leaf litter - Peat
Thelyptris serrata/3	33% Hammock, 67% Other	4.2 - 9.2	92 - 100	None	0 - 8	N/A	Humic soil
Trichomanes punctatum/3	100% Solution Hole	5.2 - >15	87 - 94	78 - 4250	0	0	Limestone