Restoration of *Jacquemontia reclinata* to the South Florida Ecosystem

Final Report to the United States Fish and Wildlife Service for Grant Agreement 1448-40181-99-G-173

April 30, 2003

FAIRCHILD TROPICAL GARDEN

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Acknowledgments

This research would not have been possible without the help of many minds and hands in the field and laboratory. For their contributions we wish to thank the following people:

Land managers, biologists and permitters at each of the *J. reclinata* sites—Steve Bass, Paul Davis, Janice Duquesnel, Dennis Eshleman, Dave Farmer, Jim Gibson, Liz Golden, Frank Griffiths, Jim Higgins, Jim King, Ernie Lynk, Joe Maguire, Gretel McCausland, Linda McDonald, Carol Morgenstern, Ginny Powell, Renate Skinner, Kurt Volker and Joe Weldon—for expertise, advice, enthusiasm and dedication to conservation and rare plant management in South Florida.

Dawn Jennings and David Martin at the United States Fish and Wildlife Service.

Jennifer Possley for advice regarding GIS analysis and Megan Fellows for assistance with permitting.

Gerald Guala, Scott Zona and the Institute for Regional Conservation, especially Steve Woodmansee, for assistance with plant identification. We are also grateful for the IRC Floristic Inventory of South Florida Database, which provided reference plant lists for coastal habitats.

Dan Austin, Rob Barron, Paul Davis, Janice Duquesnel, George Gann, Tiffany Troxler Gann, Liz Golden, Ann Johnson, Christopher Kernan, Ginny Powell, Joan Rikon (National Oceanic and Atmospheric Administration) and Steve Woodmansee for generously providing information regarding the history of *J. reclinata* and coastal dune conservation in south Florida.

Yuncong Li and Randy Ploetz from the Tropical Research and Education Center and A& L Laboratories for assistance with soil analyses.

Tom Phillipi, Jenny Richards and Steven Travis for advice regarding project design and statistical analysis.

Volunteers, interns, FTG staff, graduate students and friends who generously donated their time to assist with field work or report preparation: Matthew Brown, Burr Camp, Alexandra Chitty, Ginnie Cronk, Carla Delfino, Eva Doll, Megan Fellows, Anne Frances, Ginger Garte (and the Carnival Cruise Lines Environmental Group), Thomas Greenwood, Thomas Hedges, Maggie Hoover, Maria Ibanez, Malcolm Jones, Joanna Kadi, Joseph La Puma, Susan La Puma, Tracy Magellan, Dwight Monteith, Adrianna Muir, Greg Noe, Jennifer Possley, Catherine Rosell, Jimi Sadle, Ralph Saporito, Renee Savary, Erik Schlein, Kam Scott, Carlos Siso, Sonya Thompson, David Thornton, Jo Thornton, Jennifer Trusty, Lynka Woodbury, Matthew Wright, Boy Scout Troop333 and students from Boca Raton High School.

This project has been supported by grants from the U.S. Fish and Wildlife Service (1448-40181-99-G-173) (to FTG), the Florida International University Tropical Biology Program (to HEBT and EPT), the Center for Plant Conservation/Garden Clubs of America (to HEBT and EPT), the Florida Native Plant Society (to HEBT and EPT) and a faculty research grant from the graduate school of Valdosta State University (to JBP).
Art by Wes Jurgens.

Project Summary

Listing *Jacquemontia reclinata* (Beach Jacquemontia) as endangered in 1993 under the Endangered Species Act signaled a warning to land managers that populations of this fragile coastal dune species warranted special attention. Rising to the need for further information about this species, USFWS granted Fairchild Tropical Garden funds to pursue research that examined the species' biology, its populations, and provided opportunities for land managers to work with scientists to develop management plans. This final report represents the culmination of three and one-half years of research under agreement 1448-40181-99-G-173. This research, and the collaborations that arose from it, provide a solid foundation for the recovery of the species.

Major accomplishments of the research and collaborations include 1) a complete inventory with GIS maps that document the existing populations, 2) the rediscovery of three new sites, 3) identification and ranking of potential sites for restoration, 4) the development of site-specific management plans, 5) the development of protocols for seed storage, germination, reintroductions, and monitoring, and 6) important revelations about the species' biology.

In general at Crandon Park and South Beach, *J. reclinata* tended to grow in areas that have comparatively more sun, fewer salts, fewer cations (Mg), and lower soil moisture than was measured in unoccupied microhabitats. *Jacquemontia reclinata* sites tended to be more open and have more grasses and vines, and fewer woody species. It was noteworthy that there were striking differences between the sites, which indicated that evaluation of reintroduction locations should be site specific. In particular salt spray, sand change, soil moisture, and plant species composition and abundance varied. We were able to demonstrate that for many of the environmental variables tested, there was a gradient that extends from the coast moving inland. However, the nature of that gradient varies with the environmental variable. As expected, salt spray and sand movement (change) were greatest near the coast. Other variables, such as many of the nutrients, were higher away from the coast.

Jacquemontia reclinata populations have great year-to-year variation in growth, mortality and recruitment. Our demographic studies suggest that long-term demographic monitoring will be necessary to assess accurately population viability. From 2001-2003, patches within populations were stable for the first two years, then declined in the third year.

Small fragmented populations of *J. reclinata* generally had lower genetic diversity than larger populations. Contrary to our expectations, we found low levels of genetic variation between populations and high levels of genetic variation within populations. The population with the greatest genetic distinction was the population at Hugh Taylor Birch State Park.

Even though *J. reclinata* has a mixed mating system and can set viable seed through selfing or outcrossing, pollinations across populations had the greatest likelihood of setting fruit and seed. Genetic analysis indicates that there is gene flow across populations and no significant relationship between geographic and genetic distance. Because none of the 22 insects that were observed visiting *J. reclinata* flowers have unusually long flight distance, it is likely that long-distance dispersal of seeds rather than long-distance dispersal of pollen explains this finding.

Jacquemontia reclinata seeds are easily propagated in light or dark. Germination rates varied from 0-90% depending upon collection site, parent, storage technique and duration. Seeds stored for 62 months had 25% viability.

Field and greenhouse germination tests indicate that despite the fact that thousands of seeds are produced each year, there is little or no seed bank. Buried seeds can germinate as long as there is enough water, and few seeds remain viable in the seed bank for any appreciable time.

Several factors influence plant growth in cultivation and have implications for reintroductions. In general maintaining plants in containers for more than 18 months is problematic, however our horticultural studies revealed factors that improved plant growth. Plants growing in full-sun had more root growth than plants developed while growing in shade. Arbuscular mycorrhizal fungi (AMF) were found in roots under natural conditions in native habitat, and greenhouse experiments showed that seedling growth was promoted by AMF when grown with native maritime hammock/dune soil. Transplanted plants inoculated with mycorrhizal symbionts had greater survival than controls. Fertilization prior to transplanting also improved plant survival. Conversely, salt accumulation on shoot surfaces due to evaporation of sea water spray can be detrimental to leaf growth, shoot tip growth, and leaf health within 3 wk. It is possible that inundation with salt water caused mortality of plants transplanted 6 meters from high tide line at Bill Baggs State Park.

Trial reintroductions indicated that *J. reclinata* can be successfully transplanted into dune habitat, however success varied with planting location and trial. At Bill Baggs State Park, only 8 remain (8 % survival rate) of the original 93 plants outplanted in February 2003. But the remaining plants have been observed to flower, fruit and seed through the year. A second reintroduction trial done in 2002 had a 72% survival rate one

year following transplant. Distance and location significantly correlated with salt conductivity, and significantly influenced growth rate of *J. reclinata,* but not survival. Our experimental trials have helped us understand the species' needs and have contributed to the development of reintroduction protocols.

Table of contents

Introduction

Jacquemontia reclinata (Beach Jacquemontia) was listed as endangered in 1993 under the Endangered Species Act, signaling a warning to land managers that populations of this fragile coastal dune species warranted special attention. Rising to the need for further information about this species, USFWS granted Fairchild Tropical Garden funds to pursue research that examined the species' biology, its populations, and provided opportunities for land managers to work with scientists to develop management plans. This final report represents the culmination of three and one-half years of research under agreement 1448-40181-99-G-173. This research, and the collaborations that arose from it, provide a solid foundation for the recovery of the species.

Jacquemontia reclinata Status/Threats

Habitat loss and modification pose a serious threat to the continued existence of *J. reclinata*. Most of the primary habitat of this species—coastal beach strand —has been destroyed. The remaining habitat has been fragmented and modified for parking lots, pedestrian routes, picnic areas, and other park uses. Habitat has also been lost to beach erosion at some sites (USFWS 1996, Johnson et al. 1990, Pilkey et al. 1984).

The range of *J. reclinata* extends from Jupiter Island to Key Biscayne, a distance of approximately 85 miles. Florida's east coast barrier islands in this range are entirely urbanized except for a few small parks and private estates. A 1990 inventory of all tracts of native coastal vegetation in southeast Florida greater than 10 acres in size found only 24 such tracts in the known range of *J. reclinata*. Five of these tracts are entirely or mostly in private ownership (Johnson 1990). These tracts have approximately 214 total acres of beach strand vegetation in public ownership, 26 acres in private ownership, and 66 acres of maritime hammock in public ownership (USFWS 1996).

Taken together, the limited geographic distribution, fragmentation of remaining habitat into isolated segments, and small sizes of *J. reclinata* populations seriously challenge the viability of the existing populations. The fact that the southeast Florida coast is subject to frequent hurricanes further complicates the issue. Historically, hurricanes may have been beneficial to the survival of this species by creating openings in the maritime hammock, but now they may pose a serious threat to small remnant and fragmented populations (USFWS 1996).

Habitat degradation due to invasion of exotic plant species, including *Casuarina equisetifolia* (Australian pine), *Schinus terebinthifolius* (Brazilian pepper) and *Colubrina asiatica* (coinvine) has adversely affected *J. reclinata* populations. Sites in northern Palm Beach County are being overgrown with Brazilian pepper, and a colony of *Jacquemontia reclinata* was nearly destroyed between 1970 and 1991 by the expansion of a large stand of coinvine (USFWS 1996). Mowing, herbicide application, and other park maintenance practices may also threaten certain populations.

Taxonomy

Previous taxonomic examinations of the genus *Jacquemontia* and the species *J. reclinata* have been based on morphology. Homer D. House first described *J. reclinata* as a new species based on specimens collected in 1903 by John Kunkel Small and Joel J. Carter on Bull Key, opposite Lemon City, Florida (Small 1905). Though Roberty, in a later treatment of the genus *Convolvulus* and its close relatives, considered *J. reclinata* to be a synonym of *J. havanensis* (Roberty 1952), Robertson (1971) upheld House's treatment of this taxon as a distinct species. Robertson describes *J. reclinata* as being closely related to *J. havanensis*, distinguishable by hairy sepals, and succulent leaves. Robertson also names *J. curtissii* (Pine Rockland Jacquemontia) and *J. cayensis* as close relatives of *J. reclinata*. Fairchild Tropical Garden researchers have plans to use DNA sequence data to further elucidate and confirm the phylogenetic relationships within the Caribbean members of the genus *Jacquemontia*.

Biology and Ecology

Mature plants of *J. reclinata* spread numerous lateral stems in all directions from a stout, woody rootstock (Robertson 1971, Austin 1979). The species name, *reclinata*, refers to the tendency of these stems to recline across the sand as they grow, sometimes twining and ascending over other plants. The alternate leaves, 1 to 3 cm long, are narrowly to broadly oval and have smooth margins with blunt or slightly indented tips (Garvue 1999). The older leaves and stems can be smooth and hairless, but the distinctive hairiness of younger leaves and stems can make them appear whitish. This hairiness and fleshiness of its leaves distinguish *J. reclinata* from other local, morphologically similar species of *Jacquemontia*. The delicate white to light pink flowers occur alone or in small groups in the leaf axils, and the five petals of each flower form a funnel-shaped corolla, 2.5 to 3 cm in diameter (Garvue 1999). The fruit is a brown capsule about 4-5 mm long (Robertson 1971).

The flowering season of *J. reclinata* is from November to May, although plants may flower throughout the year (Pinto-Torres, personal observation). Plants of this species may propagate vegetatively, although when this occurs and how important it is to the species' survival are not yet known.

Jacquemontia reclinata thrives in open, sunny areas of coastal strand vegetation. Individuals are typically found alongside larger shrubs and dwarfed trees like Sea Grape (*Coccoloba uvifera*), Poisonwood (*Metopium toxiferum*), and Trema (*Trema mycrantha*), as well as smaller herbs like Beach sunflower (*Helianthus debilis*), Sand spur (*Cenchrus incertus*), and Stinging nettle (*Cnidoscolus stimulosus*). *J. reclinata* also shares habitat with other endangered species like Beach star (*Remirea maritima*) and beach peanut (*Okenia hypogaea*). Individuals generally occur on the crest and lee sides of stable dunes, but are also known to colonize and restabilize disturbed areas behind the dunes.

Initial findings of a study of the ecology of *Jacquemontia reclinata* at Crandon Park by Fairchild Tropical Garden (USFWS 1996) indicated that older individual plants with reduced above ground biomass that retain a substantial root mass can persist under heavy mats of *Stenotaphrum secundatum* (St. Augustine grass) and other weeds. These individuals responded to release from competition with vigorous growth and flowering. Since this study, researchers have observed large, unsuppressed adult plants in exposed microsites, spreading from rootstocks centered under shading shrubs. These adult plants flower, set fruit, and disperse seed prolifically, but few seedlings or young plants are ever found near them (H. Thornton, D. LaPuma, personal observation). Some researchers have suggested that this may be due to a lack of suitable microhabitat conditions and locations for successful germination, while others have suggested seed loss to granivores (USFWS 1999).

Approach

The goals of this research partnership were to fill gaps in the knowledge of the biology and ecology of *J. reclinata* and to provide a basis for conservation and recovery of the species. Consequently, the project included multiple types of investigation. Research regarding seeds and seedling biology focused on potential dispersal mechanisms, dormancy in the seed bank, and germination requirements. Research into the mating system of *J. reclinata* determined if the observed low rate of recruitment was due to self-incompatibility in small, isolated populations. Research that attempted to characterize the micro- and macrohabitat variables that most intensely affected *J. reclinata* populations considered both abiotic factors (in particular, soil chemistry and salt tolerance) and biotic factors (in particular, competition with taller species, and pollinator and mycorrhizal mutualisms). Finally, research determined the patterns of genetic variability within the species and designated appropriate seed sources for outplantings. This information is essential to planning successful reintroductions of the species and maintaining current populations.

Effective conservation of *J. reclinata* also depends on the creation and maintenance of partnerships between researchers and land managers. Such partnerships promote long-term monitoring and maintenance of existing and reintroduced populations, and facilitate the exchange of information about the species and about the success of management plans. Through thorough surveying and mapping of existing populations and extensive research into the plant's biology and ecology, the research team identified the biological factors most important to the survival of *J. reclinata*. With the input of local land managers, this information was incorporated into site-specific management plans.

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Output 1: Existing and Potential *J. reclinata* sites identified, mapped and described – Hannah Thornton and David La Puma

Introduction

In order to begin research and management of *Jacquemontia reclinata*, three things were necessary: an accurate count of individuals, accurate data regarding the locations of those individuals, and clear, descriptive maps to help researchers and managers find those individuals. With that in mind, an extensive project was completed to survey and map all known existing populations of *J. reclinata*.

Materials and Methods

Surveying Populations

Sites supporting populations of *J. reclinata* were located with the help of naturalists, land managers and researchers throughout south Florida. Christopher Kernan compiled a list of 16 putatively extant populations of *J. reclinata* (Figure 1.**1**). Based on that list, Dena Garvue completed an extensive survey of coastal natural areas to confirm existence or extirpation of *J. reclinata*. Populations were located with the help of the following people: Paul Davis (Lake Worth Inlet, Atlantic Dunes, Carlin Park and Loggerhead Park), Steve Bass (Red Reef and South Beach Parks), Ginny Powell (South Inlet Park), Carol Morgenstern (Hillsboro Beach—Private property) and Janice Duquesnel (Hugh Taylor Birch State Park). Additional populations on private property in Palm Beach County (addresses unknown to protect privacy of landowners) were located with the help of Rob Barron. A previously outplanted population at Bill Baggs State Park was identified with the help of Liz Golden. (Table 1.**1** lists contact information for land managers at each site.)

Once identified, sites were surveyed to determine the extent of the *J. reclinata* population. Methods of surveying varied by site depending on the density of *J. reclinata* cover, the density of surrounding vegetation, and the instability of the dune system. Researchers made all attempts to avoid trampling plants and exacerbating dune erosion. In large sites, or sections of sites, containing a relatively low number of *J. reclinata* plants (i.e. southern section of Red Reef Park, Loggerhead Park, Hugh Taylor Birch State Park, Atlantic Dunes Park), broad sweeps were made of an entire area and exploration was intensified where *J. reclinata* was found. In South Beach Park, subpopulations of *J. reclinata* occur in large dune openings that alternate with dense monospecific stands of *Coccoloba uvifera* and *Serenoa repens*. At this site, dune openings containing *J. reclinata* were divided into northern and southern halves, and each half was censused in a zigzag pattern by one of two observers. To survey subpopulations of *J. reclinata* at Carlin Park, South Inlet Park and in the northern section of Red Reef Park, transects were created at 2m intervals across the subpopulation, and each transect was surveyed individually. Because Crandon Park is the largest of all sites (904 acres), surveys within this park were based on GIS maps reporting the locations of *J. reclinata* individuals prior to a 1996 fire in the Bear Cut Nature Preserve (Christopher Kernan, FTG). Locations identified on pre-fire maps were revisited and thoroughly surveyed. Additionally, 5m wide transects were walked east to west across the southern portion of Crandon Park.

Methods of locating and identifying plants were consistent at all sites. In every case, visible stems of *J. reclinata* were followed, by hand, back to their rootstock, and the rootstock was tagged with fireproof, stainless steel wire and numbered tags. Individuals were identified as thick, woody stems that traveled into the ground and could not be visibly or tactilely connected to any other stem.

Using GPS to Map Populations

For each population, researchers recorded the locations of *J. reclinata* individuals and contextual information relevant to locating those individuals. All data was collected using a Trimble Pro XRS GPS System with an Integrated GPS/Beacon Antenna and a TDC1 Datalogger. All data was collected in Latitude/Longitude (unprojected) format in order to maintain maximum versatility when importing the data into a GIS. Fifteen to twenty signals were collected per feature, using a minimum of 4 satellites, and a PDOP limit of 6.0. For most populations, measurements were taken with a 2.52m antenna; however, in some cases, taller vegetation, denser canopy cover and nearby buildings necessitated the use of a taller antenna. Point features were logged for all tagged plants at a site; point, line and area features were logged for all landmarks. Landmarks included trails (boardwalks, dirt trails maintained by mowing or cutting and footpaths), permanent structures (recreation facilities, lifeguard towers, non-park buildings, roads, parking lots and fences) and significant non-permanent structures (irrigation pipes, stakes and signs). Finally, information was recorded regarding areas of vegetation that bordered, or impacted the growth of *J. reclinata* populations (large trees near groupings of plants, stumps and areas of overgrowth).

Constructing Population Maps

All data were downloaded into GPS Pathfinder Office (GPSPFO) 2.70 (Trimble Navigation Ltd.), and then exported in Arcview GIS (Environmental Systems Research Institute) shapefile format. While collecting certain data, poor reception caused the loss of the real-time differential correction signal. These data were manually corrected in GPSPFO using base files downloaded from the base station at the Everglades National Park Research Center (Contact: Gordon Anderson, ENP SFNRC, 40001 SR 9336, Homestead, FL 33034-6733,Phone: (305) 242 7800).

Ground control points (GCP's) were identified for use in georeferencing aerial imagery. Aerial photographs were obtained from NASA and NOAA (Output 1.1) and used to identify a minimum of four significant landmarks surrounding each population of *J. reclinata*. Latitude and longitude were recorded for each landmark following the protocol described above. Scanned aerial photographs were georeferenced in ERDAS Imagine 8.5 (Erdas, Inc.).

All maps were constructed using Arcview GIS 3.2 for Windows NT (Environmental Systems Research Institute).

Results and Discussion

Nine of the ten extant natural populations of *J. reclinata* were surveyed, and a total of 760 individuals were located (see Table 1.**1** for population sizes per site). For eight out of ten populations, maps were constructed showing the general location of the site along the south Florida coastline (Figure 1.**1**), the general location of *J. reclinata* populations within the site (Appendix A) and the specific locations of individual plants within those populations (Appendix A). A preliminary survey identified approximately 20 *J. reclinata* individuals throughout the fore- and backdune areas of a [rivate property in Hillsboro Beach (approximately 1 mi south of Hillsboro Blvd. on A1A); however, we were not able to obtain landowner permission to map this population. A single individual was located in Palm Beach County, in the area directly south of the Lake Worth inlet by Paul Davis (Latitude = 26°46.204, Longitude = 80°02.106); however, FTG researchers were not able to locate this individual for mapping.

Certain significant observations were made throughout the survey process. Early maps of Crandon Park showed GPS locations of *J. reclinata* individuals prior to the 1996 fire. Most individuals could not be relocated after the fire (Christopher Kernan, pers. comm.) and were considered dead. In the course of the surveys reported here, *J. reclinata* individuals were located in many of the same positions recorded before the fire (although exact positive identification is impossible because many of the original aluminum identification tags also burned in the fire). The fire burned intensely enough to melt glass, and left the entire natural area smoldering for approximately one week (Christopher Kernan, pers. comm.) This lends support to the idea that *J. reclinata* is fire tolerant. Researchers also occasionally observed *J. reclinata* individuals rooting from lateral stems, especially when those stems were buried by sand (Carlin Park), dense vegetation or organic matter (Atlantic Dunes Park).

Figure 1.1: Allsites map.

Table 1.**1**. Population location, population size, and management information for *Jacquemontia reclinata* throughout south Florida.

Site	N	Contact	Agency	Department	Address of Contact
Bill Baggs State Park*	70	Liz Golden	State of Florida	Parks and Recreation	1200 South Crandon Blvd., Key Biscayne, FL 33149
Crandon Park	144	Ernie Lynk	Miami-Dade County	Parks and Recreation	4000 Crandon Blvd., Key Biscayne, FL 33149
Hugh Taylor Birch State Park	96	Jim Gibson	State of Florida	Parks and Recreation	3109 Sunrise Blvd., Ft. Lauderdale, FL 33304
Hillsboro Beach**	10	Carol Morgenstern	Broward County	Parks and Recreation	1000 NW 38 St. Oakland Park, FL 33309
South Inlet Park	27	Paul Davis	Palm Beach County	Environmental Resource Management	3323 Bellvedere Rd., Bld. 502, W Palm Beach 33406
		Ginny Powell	Palm Beach County	Environmental Resource Management	3323 Bellvedere Rd., Bld. 502, W Palm Beach 33406
South Beach Park	245	Steve Bass	City of Boca Raton	Parks and Recreation	1801 N. Ocean Blvd. Boca Raton, FL 33432
Red Reef Park	177	Steve Bass	City of Boca Raton	Parks and Recreation	1801 N. Ocean Blvd. Boca Raton, FL 33432
Atlantic Dunes Park	26	Joe Weldon	City of Delray	Parks and Recreation	50 NW 1st Ave., Delray Beach, FL 33444
Lake Worth Inlet	1	Paul Davis	Palm Beach County	Environmental Resource Management	3323 Bellvedere Rd., Bld. 502, W Palm Beach 33406
Loggerhead Park	5	Greg Atkinson	Palm Beach County	Parks and Recreation	2700 Sixth Ave. South, Lake Worth, FL 33146
		Paul Davis	Palm Beach County	Environmental Resource Management	3323 Bellvedere Rd., Bld. 502, W Palm Beach 33406
Carlin Park	32	Paul Davis	Palm Beach County	Environmental Resource Management	3323 Bellvedere Rd., Bld. 502, W Palm Beach 33406
		Frank Griffiths	Palm Beach County	Environmental Resource Management	3323 Bellvedere Rd., Bld. 502, WPalm Beach 33406

N = population size ; *Outplanted; **Private Property—population size is estimated

Output 1.1. Aerial photos of existing and potential sites digitized and georeferenced – Hannah Thornton

In order to obtain accurate and current geographic information regarding the wild populations of *J. reclinata*, aerial photographs of *J. reclinata* sites from the years 2001 (Dade County) and 1999 (all other counties) were acquired from the Miami-Dade County Public Access Information Technology Department and the National Geodetic Information Center of the National Oceanic Atmospheric Administration (Contact: Joan Rikon, National Geodetic Information Center, 1315 East West Highway Station 9321, Silver Springs, MD 20910). These photographs display recent construction and development at all sites, as well as recent changes in vegetation. They replace 1994 NASA infra-red aerial photographs as background coverages in site maps.

Aerial photographs were obtained in two formats. Digital Ortho Quads georeferenced in the State Plane 1983 projection system were obtained for sites within Miami-Dade County. For all other *J. reclinata* sites, transparencies of aerial photos were obtained, scanned and georeferenced as reported above. For all sites, ground control points (GCP's) were recorded on hard copies of aerial photographs and latitude and longitude coordinates for all GCP's were organized and stored. FTG will maintain this information for future use.

Outputs 1.2 and 1.3 Establish permanent vegetation plots in all sites and collect vegetation and abiotic data and Use plot data to ordinate and classify vegetation and to define important environmental gradients - Cynthia Lane and Samuel Wright

Environmental gradients and associated vegetation

The objective of this research component was to measure key environmental gradients influencing *Jacquemontia reclinata* habitat at two occupied sites. Several environmental factors vary across the gradient from foredune to coastal maritime hammock including salt spray, sand movement, soil moisture, nutrients, texture, and wind speed (Cheplick and Demitri 1999, Olff *et al*. 1993, Martinez and Moreno-Casacola 1996, Baldwin and Maun 1983, Van der Valk 1974). The composition and abundance of associate plant species may also influence populations of *J. reclinata*. However, few studies have examined an array of environmental variables or their effect on vegetation, and none of these types of studies have been done on the coastal areas in South Florida on the Atlantic coast. Also, the coastal regions in South Florida have been severely impacted by human activities, and it is unknown how these activities have affected coastal processes. An understanding of these processes is an important aspect of restoration and management planning.

In order to test the hypothesis that key environmental factors vary across *J. reclinata* sites, and to characterize the influence of these factors on associated vegetation, we conducted the following studies.

Methods

Study sites
Two sites were selected for the habitat characterization research, Crandon Park on Key Biscayne and South Beach Park in Boca Raton (Figure 1.**1**). These two sites were chosen because they support the largest *J. reclinata* populations and also support the largest extent of remaining coastal ecosystem. Both sites have been impacted by human activities, ranging from agricultural use to road construction. The topography varies significantly (Figures 1.3.**1**-1.3.**4**) between the sites, with the topography at Crandon being relatively flat while at South Beach the dunes rise steeply near the coast.

Sampling transects
Eleven transects selected randomly were established perpendicular to the coast at the two sites (1-5 at Crandon, 11-16 South Beach). Sample plots were placed 10m apart and extended 6m from the high tide line to one plot past areas with *J. reclinata*. It should be noted that the management practice of raking removes the seed bank, and seaweed from the beach of South Beach. Whereas the plots at Crandon Park start 6m from the high tide line, the plots at South Beach start 6m from the start of the vegetation that is approximately 12 m from the high tide line. This resulted in 8 to 11 plots per transect at Crandon

and 3 to 5 plots at South Beach, for a total of 72 plots. Plots were labeled with letters; plot A being closest to the coast. Galvanized rebar was placed at the northwestern corner of each plot to assure future relocation. The plot size selected for sampling was 3 x 8m. This plot size was selected based on preliminary vegetation sampling. Table 1.3.**1** lists the types of data collected at each plot and the date samples were collected.

Vegetation sampling

For each sample plot the following data were collected. The total cover of each life form and each species was estimated by visually surveying the site. Life forms were categorized as woody, vine, graminoid (grasses and sedges) and forbs (herbaceous plants). Woody plants were divided into three height classes for estimating cover: 0-.5 m, .5-2 m, and >2 m. Vines were also split into three groups based on the growth form of the vine (V0, V1, V2). An eight-point modification of the Braun-Blanquett vegetation classification method was used to estimate cover and abundance classes: 0%, 1%, 1-5%, 5-10%, 10-25%, 25-50%, 50-75%, and 75-100%. In order to increase the accuracy and consistency of cover estimates, wire flag markers were placed at 2m intervals along the 8 m side of the plot to create 0.25m sections (Figure 1.3.**5**). In addition, PVC squares were constructed that were 1, 5, and 10 percent of the plot. These squares were placed in the corner of the plot and referred to for smaller cover estimates. Also in order to reduce observer bias the same observer was used to visually estimate every plot.

Duff and soil collection

Soil and samples were collected during two time periods: July 31, 2001(wet season) and March 13, 2002 (dry season) from Crandon Park, and on August 8, 2001 and March 14, 2002 from South Beach. Duff was collected only during the 2001 sampling period. Because soil and duff sampling techniques would potentially effect vegetation within the plot, samples were collected from three points just outside the plot (Figure 1.3.**5**). The sampling point was selected by measuring outwards 17.5 cm, at 90º from the plot edge. Duff and soil samples from the three points were aggregated into one sample. For duff collection a .25m^2 PVC square was placed over each sampling point. Hand pruners were used to clip overlapping duff at the edge of the square. All duff/dead organic material that had 18mm circumference or larger was collected. Duff was placed in a lunch style paper bag. Extra bags were used when needed. All bags were then labeled with site/transect/plot and date using a permanent marker. After the 3rd sample within the plot was collected the open end of the bag was folded shut and sealed with masking tape. Upon return from the field duff samples were kept in paper bags and stored temporarily at room temperature in upright storage cabinets. All samples were placed in a Lane® upright dryer for at least 72 hours at a temperature of 32º C. To limit weight variance due to absorption of air moisture, samples were processed one at a time. The remaining samples were kept in the dryer until needed. Duff samples were weighed with a Denver Instrument® scale (XP-3000) and then recorded.

Soil samples were collected at two depths; a shallow sample was collected at a depth of 0 –15cm,and a 46-61cm deep sample. The two samples represented the range of depths where *J. reclinata* roots were found (Output 4.1a). To collect the shallow sample, a 83.8cm chrome-plated AMS® soil probe was used to obtain a soil core from 0(soil surface) to 15cm. Three cores were collected from each of the three sampling points (described above), and mixed thoroughly to create one sample per plot. A one-piece 147.3cm soil auger with a 7cm bucket head was used to collect the deep samples. After one sample was collected from each of the three sampling points per plot, all three samples were mixed thoroughly and aggregated for the deep soil sample. Once samples were aggregated, two cups of the mixed soil were placed in plastic freezer bags and labeled. Upon return from the field, bagged samples were refrigerated for overnight storage to prevent soil moisture loss between collection and weighing.

The following day one cup of soil was transferred from the freezer bag to a soil-testing labeled bag. Samples were shipped for chemical and texture/classification analysis to A & L Southern Agricultural Laboratories in Pompano Beach. Wet season samples were shipped on August 3rd 2001 for Crandon and August 10th 2001 for South Beach and combined dry season samples were shipped on August 5, 2002. Soil analysis followed standard protocol (Council on Soil Testing and Plant Analysis 1980, and Gavlak *et. al.* 1997) to determine percent organic matter, estimated nitrogen release, available P, exchangeable K, Mg, Ca, Na, H, Zn, Mn, Fe, Cu, soil pH, cation exchange capacity (CEC), soluble salts, and % base saturation of cation elements. Also on August 27, 2001 soil was tested for soil texture and classification at one transect (3, 13) per site. Minor nutrients (Zn, Mn, Fe, Cu) and soluble salts were eliminated from the second (dry) sampling period due to the high costs of the soil tests and because they were shown to be insignificant across the dune gradient during preliminary statistical analysis.

In addition one-cup of the dry season samples were shipped to the University of Florida's Tropical Research Education Center (TREC) located in Homestead for nitrogen analysis. The soil samples were air-dried at room temperature for three weeks, ground, sieved through a 2 mm sieve and stored in plastic lined soil bags. Total carbon and nitrogen were analyzed using a CNS analyzer (Vario Max, Elementar Americas, Inc., Mt. Laurel, NJ). Soils were extracted with 2 M KCl and analyzed for NH4 -N and NO3 -N using an Autoanalyzer (AA3, Bran+Luebbe, Buffalo Grove, IL).

Soil moisture for both sampling periods was determined using the gravimetric method (Pearcy et al. 1989). Aluminum soil weighing dishes were weighed prior to use (weight #1). Two tablespoons (approximately 40g) of soil were removed from each sample bag and placed in labeled aluminum weighing dishes and weighed (weight #2). Following weighing, samples were placed in a preheated Precision® gravity convection oven set at 40° C. The samples were kept in the drying oven for 24 hours. Samples were then removed and the dishes and contents weighed together (weight #3). The following calculation was done to determine soil moisture:

$$\text{Moisture (\%)} = (\text{weight2}-\text{weight3})/\text{weight3}-\text{weight1})*100$$

Sand movement
To document sand movement and accretion, yellow pine wooden stakes (2.5 x 5 x 61cm.) were centered at each plot. Half the stake (30.5cm) was measured and marked with a line. A plastic transparent ruler was centered and attached at the halfway point of the stake. Stakes were installed in the ground to the halfway line. Location of the partially buried ruler made it possible to observe negative and positive depth change. Using the attached ruler, accretion was measured to the nearest millimeter. Since preliminary tests showed no change in sand accretion until the third month, stakes were monitored every three months.

Salt spray
Salt spray traps were installed at the center of the plots of Crandon Park on February 20, 2002 and South Beach Park on February 22, 2002. Two separate heights were chosen to capture salt spray. First a 122 cm pine stake facing the ocean was buried 30.5 cm at the center of the plot. Then a 3.81cm x 30cm grosgrain white woven ribbon was attached vertically to the top of the stake using two stainless steel pins to keep the ribbon in place. A smaller 30.5 cm stake was placed .5 m north of the larger stake. Another stake was drilled on top of the smaller stake facing horizontally up with a ribbon attached to the top of the stake using the pins. The smaller stake measured approximately 10 cm above of the ground, which would represent the height of a *J. reclinata* plant.

Ribbons were collected once a month at each site (See Table 1.3.1) and placed in labeled small paper bags. Bags were stored at room temperature overnight. The next day ribbons were placed in a beaker with 200ml of dionized water and agitated with a New Brunswick Scientific® incubator shaker for 10 minutes. After completion of agitation, water was analyzed for conductivity (µS/cm at 21ºC) using a Denver Instrument Company® model 220 conductivity meter. The conductivity meter was calibrated before each analysis period to insure greater accuracy and reduce drift.

Temperature and humidity

Microclimate
Both relative humidity and temperature are affected by vegetation and topography, exhibiting different levels as one nears the ground, especially where dense vegetation occurs (Baldwin and Maun 1982).To capture temperature/ relative humidity changes across the dune from the coast inland, Hobo® weatherproof loggers were placed in the central transects of each site. The loggers were placed in the first four plots (A-D) in Crandon (Transect 3) and South Beach (Transect 13), and in plot J of Crandon. Each logger was situated inside a solar radiation shield and then attached to a pressure treated post, which was installed at a depth of 76.2cm. Using BoxCar® Pro 4.0 software, each logger's logging intervals were customized to take temperature and relative humidity measurements every 15 minutes.

Loggers were left in the field, and at regular monthly intervals, handheld Hobo shuttles were used to offload data and transport back to the lab. At the end of April 2002 dataloggers were collected and logging intervals were changed to every hour. Upon return from the field, recorded data from the shuttles were then downloaded into spreadsheets and charts used for later analysis.

Topography
The topography at each study site was mapped from two transects at each site using a Criterion 400 Survey Laser unit. Height readings, relative to the high tide line, were taken every two meters along each transect.

Statistical analyses

Soil nutrient/characteristic data was analyzed by first conducting a four-way ANOVA (date X distance (plot) X sample depth X site), on data sets to determine if sites, dates, depths should be analyzed separately or together. Based on the results of this analysis (available upon request), it was determined that dates and sites could be combined for most soil nutrients/characteristics. For these soil nutrients/characteristics ANOVA (SAS Institute, 1997) was conducted for each nutrient/characteristic testing for the effect of distance to high tide line on nutrient/characteristic levels. The exceptions were ammonium and nitrate nitrogen, and duff, where sites were analyzed separately, and soil moisture, where sites and dates were analyzed separately in two and three way ANOVA. Sand change was evaluated by running a 2-way ANOVA (distance X date) on the absolute value of sand height change for each sampling date. Salt spray was also analyzed with a 2-way ANOVA (distance X date). In all cases the Bonferroni mean separation method (SAS Institute, 1997) was used to test for differences between means.

Various summary tables were created for the vegetation data to observe general species and life form trends. Detrended correspondence analysis (DCA) (PC-ORD 1999) was applied to both vegetation (main matrix) and environmental data (secondary matrix) to evaluate relationships. Only the environmental variables where values were significantly different with distance (above analyses) were included.

Results

Environmental Variables

Vegetation
A total of 108 species was observed in the study plots (Table 1.3.**2**). The three species observed in the greatest number of plots were *Coccoloba uvifera, Pithecellobium keyense* and *Bidens alba var. radiata* in 68, 55, and 51, respectively, of 72 total plots. Several species observed were only present in one of the sampling plots.

Species diversity, number of species per plot, was greater for most plots at the Crandon sites (Table 1.3.3). The exception was the 6 m distance, where species diversity was similar at both sites. The number of forbs and grass species was lowest for South Beach plots farthest from the coast – where number of woody species was high. Average species abundance (Table 1.3.**4**) showed similar trends with low forb and grass abundance at South Beach sites where abundance of woody and vine species was high.

Duff
Duff was variable throughout the sites and not found to be significantly different between distances (Table 1.3.**5**) based on ANOVA for duff at each site. However, mean separation tests showed plots at the 6 m distance to have the lowest average duff amounts (61.2 g) and plots farthest from the coast (215.6 g for the 122 m distance) to have the highest duff amounts at the Crandon site. A similar trend was observed for the South Beach site but means were not significantly different based on Bonferroni tests. The range in values was smaller than that for Crandon, although amounts were generally higher, with 123.8 g at the 6 m distance and 273.2 g at the 45 m distance.

Soil nutrients/chemistry
No statistical analysis was performed on rainy season (August 2001) soil data. Preliminary analysis (mean and standard deviation) and raw data is reported in table format (Tables 1.3.**6** to 1.3.**20**). Raw data, as well as means and standard deviations, from the dry season (March 2002) soil data are provided in Tables 1.3.**21** to 1.3.**31**. Figures 1.3.**7** to 1.3.**9** provide a graphic illustration of means (with error bars) for each site and soil sampling depth. Table 1.3.**32** and 1.3.**33** show the results of Bonferroni mean separation tests and ANOVA's. For the shallow soil sample, 0-15 cm deep, all nutrients were found to be significantly different between plots near the coast and those more inland, except potassium (Table 1.3.**32**). Mean separation tests show that nutrient levels and CEC were almost consistently lowest near the coast (also see Figures 1.3.**6** to 1.3.**8**). In particular, the plot 6 m from the high tide line has lower values than the other samples. Soil pH was highest at the coast and lowest at plots farthest from the coast.

For the deep, 41- 61 cm soil samples, there was less variation along the distance gradient than for the shallow soil samples above (Table 1.3.**32** and 1.3.**33**). No means were separated as different based on the Bonferroni test (Table 1.3.**32**) and only magnesium, calcium and cation exchange capacity were significantly different based on the results of ANOVA (Table 1.3.**18**). The trends were similar for shallow and deep soil samples, with nutrient values increasing with sample distance from the coast.

Analysis was run separately for each site for ammonium and nitrate nitrogen, and results of the analyses are shown in Tables 1.3.**34** and 1.3.**35**. No differences were found between ammonium nitrate samples at different distances for either the Bonferroni test or ANOVA. In contrast, nitrate nitrogen levels were found to vary in three of four sample sites/depths (Table 1.3.**34**). Similar to other soil nutrients sampled (above), nitrate nitrogen levels were lowest near the coast, and increased with distance from the coast (Table 1.3.**35**).

Soil texture/classification
Data (Table 1.3.**36**) shows very little variation between plots in transects for each site although with only one set of data per site, it was not possible to analyze the data statistically.

Soil moisture
Raw data for soil moisture is shown in Tables 1.3.**37** and 1.3.**38**. Preliminary analysis found soil moisture to vary significantly with sampling date and so mean separation tests and ANOVA were run separately for each site and sampling date. Percent soil moisture was highest at plots farthest from the coast (Tables 1.3.**39** and 1.3.**40**). The greatest differences observed were for the August soil sample at the South Beach site where values for the 45 and 58 meter distances were on the order of two to six times those for plots near the coast or plots at the same distance for the March sampling date (Table 1.3.**38**).

Sand change
Tables 1.3.**41** – 1.3.**43** show the results of ANOVA and Bonferroni mean separation test on change in sand height with plot distance. Change in sand height was found to be greatest near the coast and date had a significant influence on change in sand height. The greatest change in sand height was observed for plots 6m from the coast at the South Beach site (Tables 1.3.**41** and 1.3.**43**). These changes included both sand accretion and erosion. Another interesting result was that sand change was highly variable throughout the site and seemed to occur at a relatively small scale; that is, for plots near to each other, one plot could experience a significant amount of sand accretion or erosion, while the other plot might have no change.

Salt spray
Analysis of salt spray samples found both date and distance to have a significant effect on the amount of salt spray at both sites (Tables 1.3.**44** and 1.3.**45**, Figure 1.3.**9**). Salt spray levels were highest for the South Beach site, in particular for the upper, vertical sampling unit. The amount of salt spray measured was highly variable with date (Tables 1.3.**44** and 1.3.**45**). The first four sampling dates tended to have greater readings than the last two dates. For some dates, levels for these samples were an order of magnitude greater than those for similar samples at Crandon (Table 1.3.**44**).

Temperature & Humidity
As with soil texture there was only one set of data per site, making it not possible to analyze the data statistically. However, averages for four-hour periods for approximately one month of sampling dates were graphed to observe general trends. The highest temperatures and lowest relative humidity was measured during the fall sampling period, at both sites (Figure 1.3.**10**). Peak values occurred for the period of time between 12:00 and 15:45.

Topography
Topography was very different between the two sites (Figures 1.3.**1** - 1.3.**4**). Other than a small foredune, and occasional high and low points, the Crandon site was relatively flat (Figures 1.3.**1** and 1.3.**2**). In contrast, the entire South Beach site had a steep fore dune and a relatively large, steep secondary dune that flattened gently as it sloped back toward the west (Figure 1.3.**3** and 1.3.**4**).

Environmental variables & Vegetation

Results of the DCA ordination of the vegetation and key environmental variables were consistent with patterns observed for individual analysis of environmental variables above. Salt spray and pH were associated with plots closer to the coast (Figures 1.3.**11** and 1.3.**12**). Other environmental variables, including organic matter, estimated nitrogen release, phosphorus, calcium and cation exchange capacity were associated with plots farther from the coast.

DCA plots for species and environmental variables showed similar trends (figures not included). High pH and salt levels were associated with greater abundance of plant species found near the coast where high values of the other environmental variables were associated with species typical of more inland vegetation types.

Discussion

We were able to demonstrate that for many of the environmental variables tested, there is a gradient that extends from the coast moving inland. However, the nature of that gradient varies with the environmental variable. As expected, salt spray and sand movement (change) were greatest near the coast. Other variables, such as many of the nutrients, were higher away from the coast. The trends were similar for both study sites, but the magnitude of change varied. The observed patterns are likely a result of both increased exposure to wind and salt near the coast, and effects of vegetation cover (species and abundance) on soil nutrients and other characteristics. The higher values and/or variability observed for many environmental variables at the South Beach site is likely due to the more extreme topography at this site.

It was expected that sand accretion and erosion would be greatest near the coast because of greater exposure to wind and waves. Also, these observations were consistent with sand change dynamics observed at Bill Baggs (see Output 4.3). The fact that sand change was “patchy” across the sites suggests that distance from the coast is but one factor, and that plant cover, disturbance, (such as from human activities), and other influences also affect sand dynamics.

The higher nutrient levels and moisture associated with areas farther from the coast are likely to be both a result of vegetative cover and in turn tend to encourage even more dense growth by woody species. If so, this trend would create conditions where woody shrub and tree species would compete with low stature dune plants such as *J. reclinata*.

The relatively large differences observed between the two study sites suggest that restoration planning should be site specific. In particular salt spray, sand change, soil moisture, and plant species composition and abundance vary. For example, plantings at sites similar to South Beach (sites with steep dunes exposed to wind) are likely to be more susceptible to salt spray and soil accretion/erosion. Also, if some of the differences observed between the two study sites are a result of dune topography, then restoring dune structure will be an important aspect of rehabilitating disturbed sites. In particular, historically the Crandon site had a series of larger dunes that have now been removed. Based on this research, species lists and abundances can be created for each coastal zone – which would provide a useful guide for restoration planning.

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Figure 1.3.1. South Beach site sample 1 topographic profile.

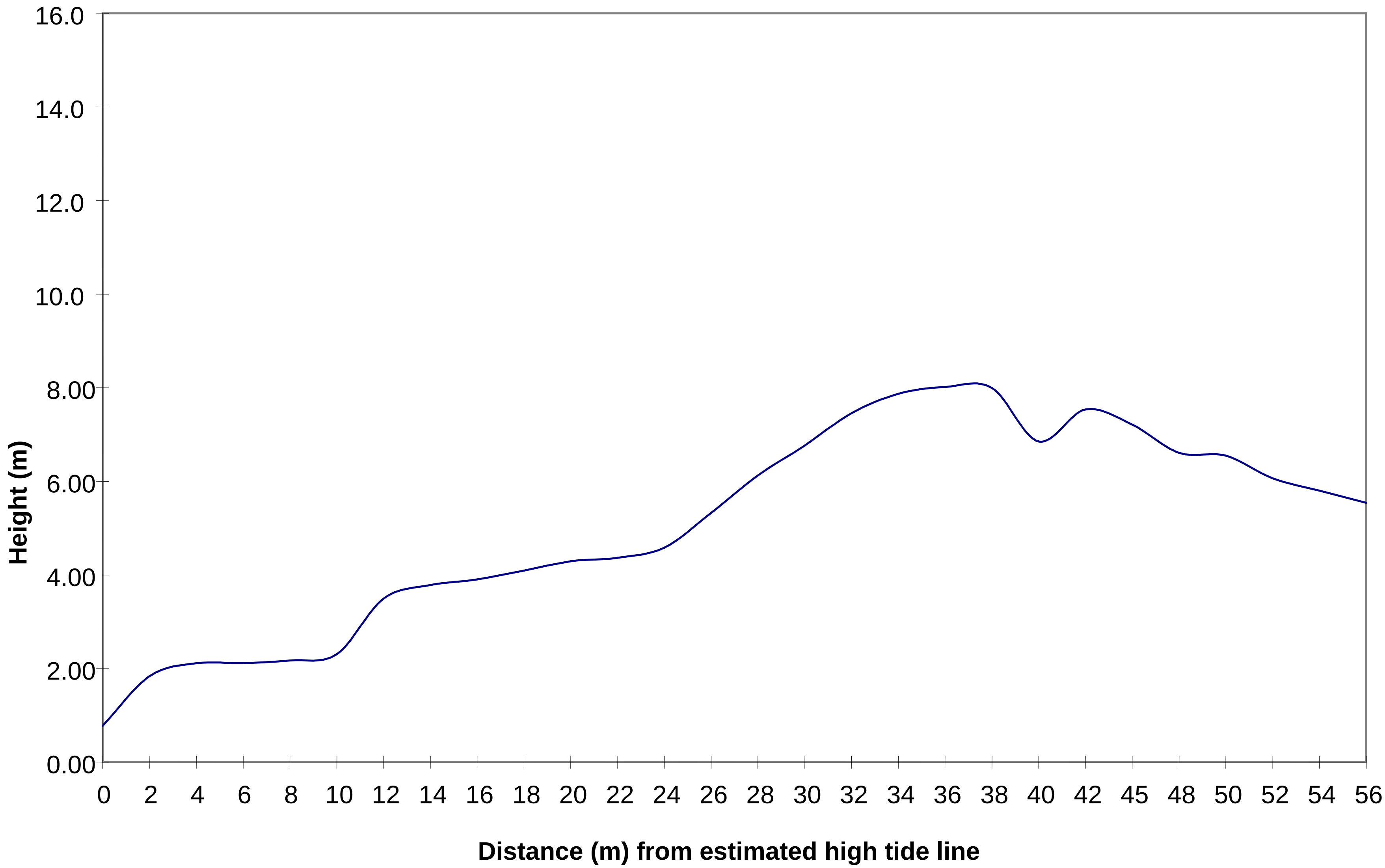

Figure 1.3.2. South Beach site sample 2 topographic profile.

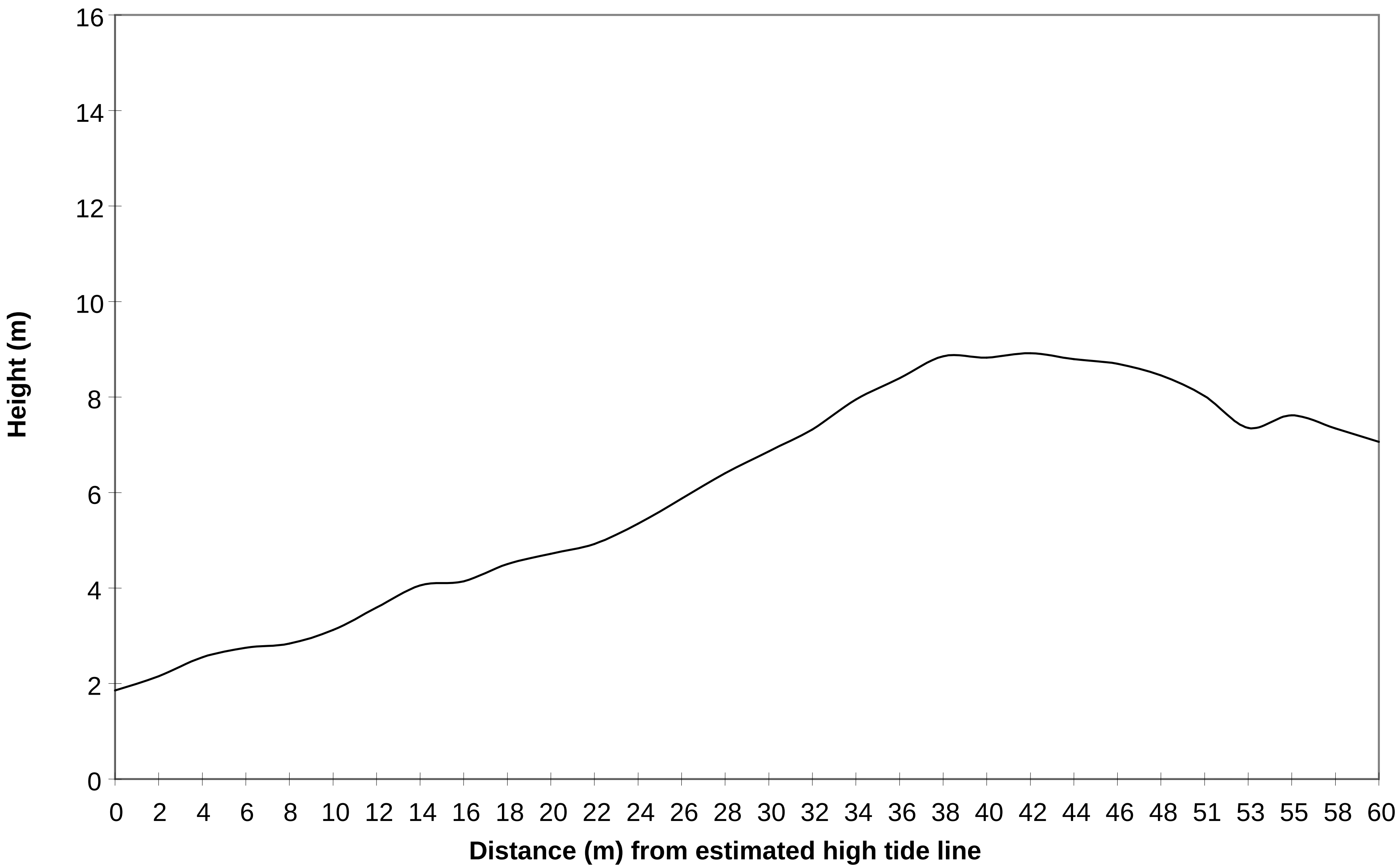

Figure 1.3.3. Crandon site sample 1 topographic profile.

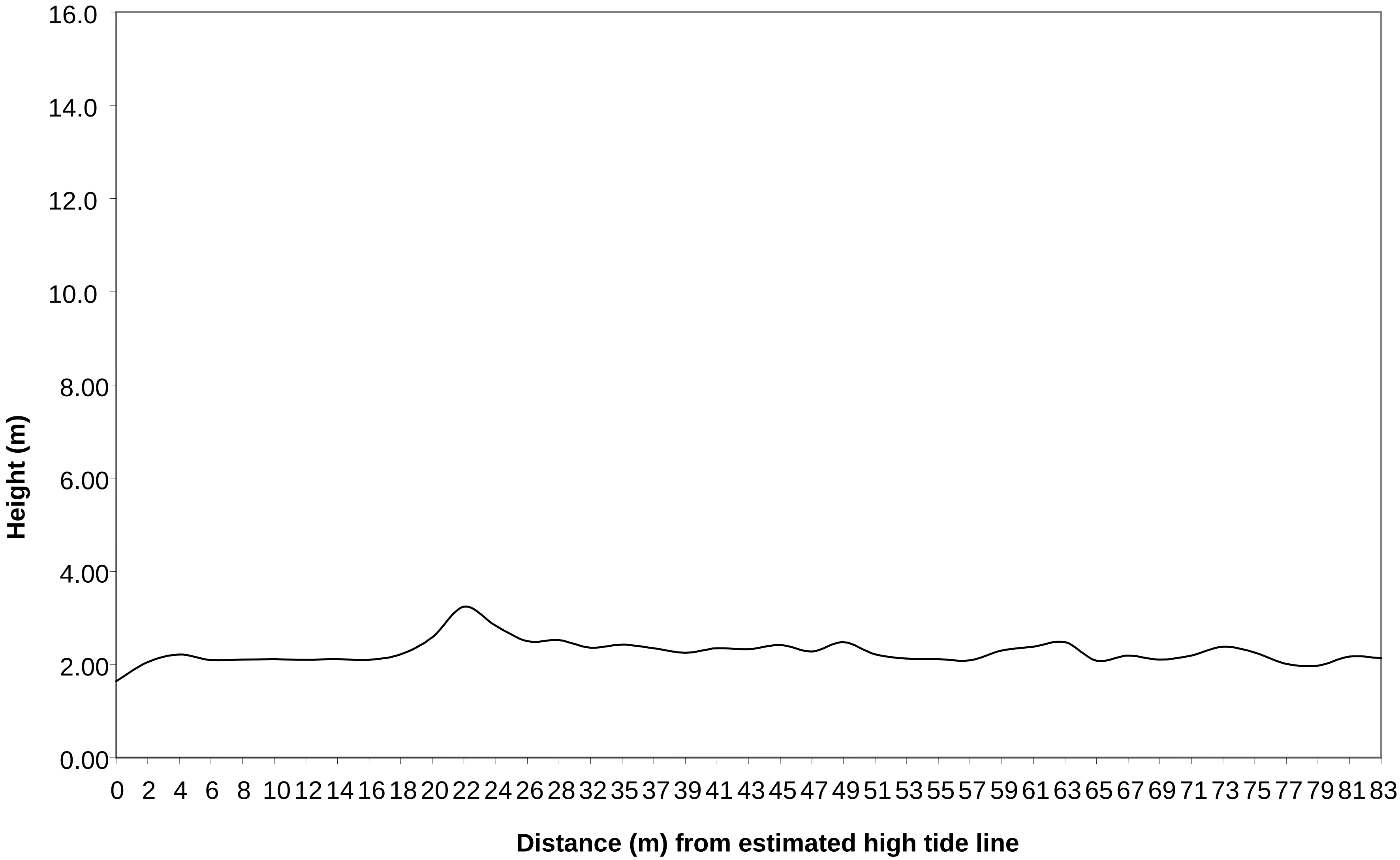

Figure 1.3.4. Crandon site sample 2 topographic profile.

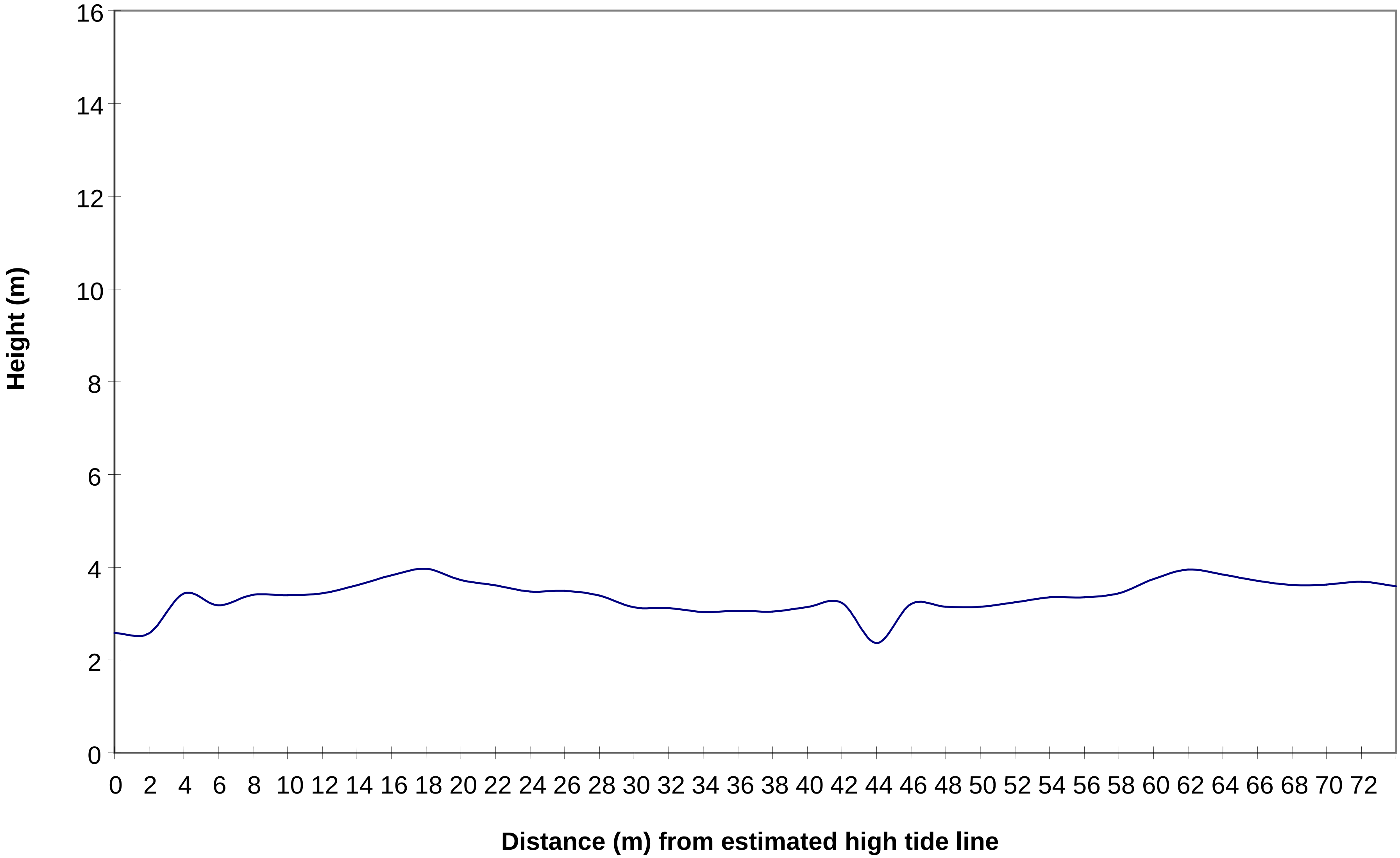

Table 1.3.**1** Type of data collected and dates sampled for environmental gradients and associated vegetation study.

Element/item	**Dates sampled**
Organic matter 1	July 31, August 8, 2001;March 13, 14, 2002
Estimate nitrogen release	July 31, August 8, 2001;March 13, 14, 2002
Phosphorus (Weak Bray)	July 31, August 8, 2001;March 13, 14, 2002
Phosphorus (Strong Bray)	July 31, August 8, 2001;March 13, 14, 2002
Exchangeable Potassium	July 31, August 8, 2001;March 13, 14, 2002
Magnesium	July 31, August 8, 2001;March 13, 14, 2002
Calcium	July 31, August 8, 2001;March 13, 14, 2002
pH	July 31, August 8, 2001;March 13, 14, 2002
Cation exchange capacity	July 31, August 8, 2001;March 13, 14, 2002
Ammonium nitrogen	March 13, 14, 2002
Nitrate nitrogen	March 13, 14, 2002
Soil moisture	July 31, August 8, 2001; March 13, 14, 2002
Salt spray	
Crandon	January 17, February 20, March 19, April 23, July 4, August 1, 2002
South Beach	January 20, February 22, March 21, April 25, July 5, August 2, 2002
Sand change	
Crandon	January 17, March 26, June 20, September 26, 2002
South Beach	March 27, June 26, September 25, 2002

Figure 1.3.**5**. Sampling plot used for vegetation, duff, soil and sand accretion data collection**.**

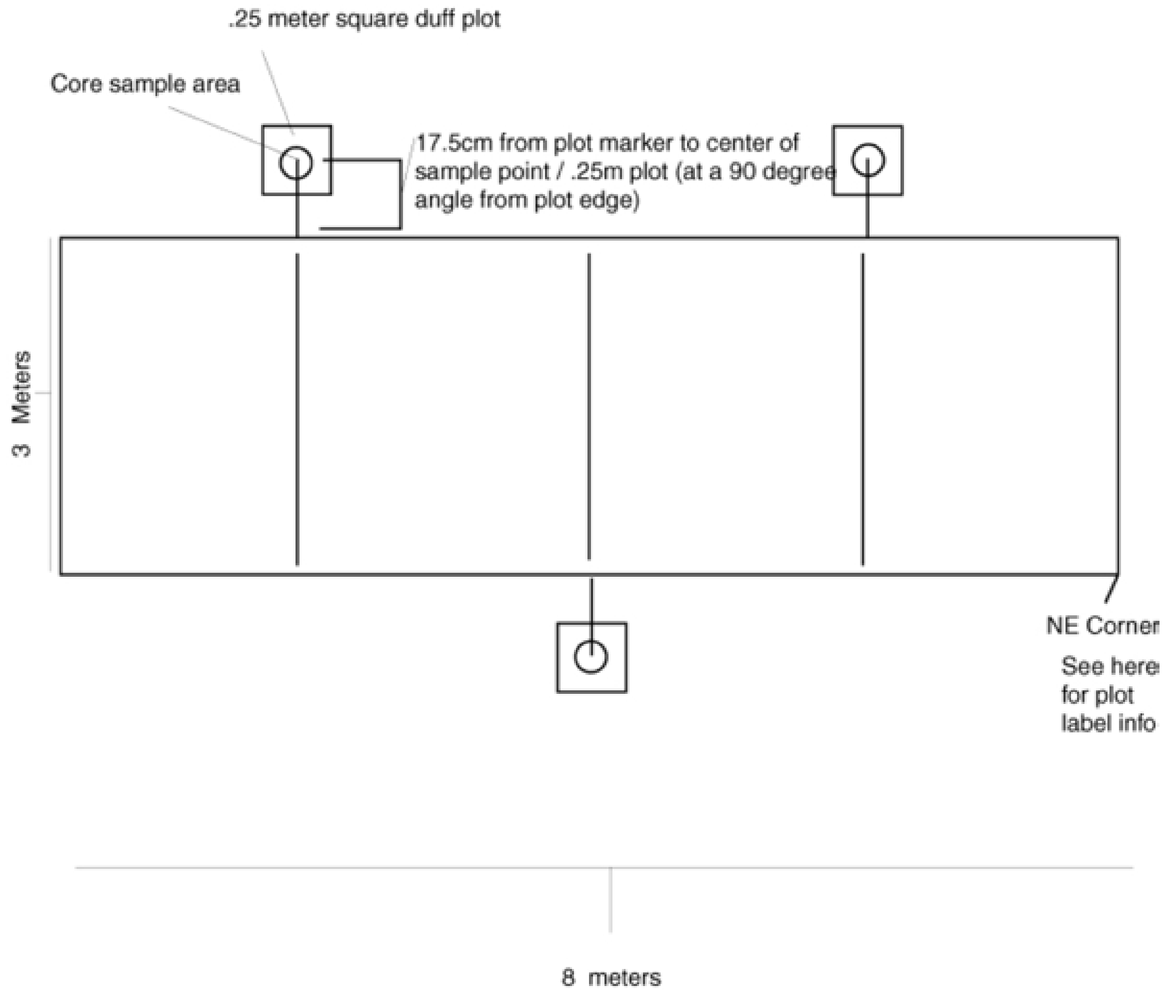

Table 1.3.2. List of species identified in study plots and number of plots where species was present, both study sites. Ordered by life form and alphabetically by species, and ordered by life form and number of plots where species was present

LIFE FORM	GENUS	SPECIES	# PLOTS PRESENT	GENUS	SPECIES	# PLOTS PRESENT
Forb	*Alternanthera*	*flavescens*	29	*Bidens*	*alba*	51
F	*Ambrosia*	*artemisiifolia*	6	*Cnidoscolus*	*stimulosus*	46
F	*Bidens*	*alba*	51	*Catharanthus*	*roseus*	33
F	*Boerhavia*	*diffusa*	3	*Croton*	*glandulosus*	33
F	*Catharanthus*	*roseus*	33	*Alternanthera*	*flavescens*	29
F	*Chamaecrista*	*nictitans*	1	*Physalis*	*walteri*	25
F	*Chamaesyce*	*blodgettii*	14	*Helianthus*	*debilis*	24
F	*Chamaesyce*	*mesembrianthemifolia*	7	*Poinsettia*	*cyathophora*	23
F	*Cnidoscolus*	*stimulosus*	46	*Commelina*	*erecta*	22
F	*Commelina*	*erecta*	22	*Verbesina*	*virginica*	22
F	*Conzya*	*canadensis*	7	*Polygala*	*grandiflora*	20
F	*Crotalaria*	*pumila*	12	*Melanthera*	*nivea*	16
F	*Crotalaria*	*rotundifolia*	2	*Galium*	*hispidulum*	15
F	*Croton*	*glanduosus*	33	*Chamaesyce*	*blodgettii*	14
F	*Croton*	*punctatus*	3	*Crotalaria*	*pumila*	12
F	*Desmodium*	*tortuosum*	4	*Trichostema*	*dichotomum*	12
F	*Eupatorium*	*capillifolium*	1	*Sida*	*acuta*	11
F	*Galium*	*hispidulum*	15	*Chamaesyce*	*mesembrianthemifolia*	7
F	*Gaura*	*angustifolia*	1	*Conyza*	*canadensis*	7
F	*Helianthus*	*debilis*	24	*Mentzelia*	*floridana*	7
F	*Heliotropium*	*angiospermum*	1	*Ambrosia*	*artemisiifolia*	6
F	*Iresine*	*diffusa*	5	*Iresine*	*diffusa*	5
F	*Licania*	*michauxii*	2	*Desmodium*	*tortuosum*	4
F	*Melanthera*	*nivea*	16	*Boehavia*	*diffusa*	3
F	*Mentzelia*	*floridana*	7	*Croton*	*punctatus*	3
F	*Nephrolepis*	*exaltata*	1	*Crotalaria*	*rotundifolia*	2
F	*Physalis*	*walteri*	25	*Licania*	*michauxii*	2
F	*Phytolacca*	*americana*	1	*Rhynchosia*	*minima*	2
F	*Poinsettia*	*cyathophora*	23	*Chamaecrista*	*nictitans*	1
F	*Polygala*	*grandiflora*	20	*Eupatorium*	*capillifolium*	1
F	*Portulaca*	*oleracea*	1	*Guara*	*angustifolia*	1
F	*Rhynchosia*	*minima*	2	*Heliotropium*	*angiospermum*	1
F	*Richardia*	*grandiflora*	1	*Nephrolepis*	*exaltata*	1
F	*Sida*	*acuta*	11	*Phytolacca*	*americana*	1
F	*Stylosanthes*	*hamata*	1	*Portulaca*	*oleracea*	1
F	*Trichostema*	*dichotomum*	12	*Richardia*	*grandiflora*	1
F	*Verbesina*	*virginica*	22	*Stylosanthes*	*hamata*	1
Graminoid	*Cenchrus*	*incertus*	5	*Stenotaphrum*	*secundatum*	26
G	*Cyperus*	*planifolius*	12	*Panicum*	*amarum*	24
G	*Cyperus*	*tetragonus*	1	*Paspalum*	*setaceum*	21
G	*Dactyloctenium*	*aegyptium*	15	*Uniola*	*paniculata*	21
G	*Eustachys*	*petraea*	13	*Dactyloctenium*	*aegyptium*	15

Table 1.3.2 (continued)

LIFE FORM	GENUS	SPECIES	# PLOTS PRESENT	GENUS	SPECIES	# PLOTS PRESENT
G	*Panicum*	*amarum*	24	*Setaria*	*macrosperma*	14
G	*Paspalum*	*setaceum*	21	*Eustachys*	*petraea*	13
G	*Rhynchelytrum*	*repens*	7	*Cyperus*	*planifolius*	12
G	*Setaria*	*macrosperma*	14	*Rhynchelytrum*	*repens*	7
G	*Spartina*	*patens*	1	*Cenchrus*	*incertus*	5
G	*Stenotaphrum*	*secundatum*	26	*Cyperus*	*tetragonus*	1
G	*Uniola*	*paniculata*	21	*Spartina*	*patens*	1
Vine	*Canavalia*	*rosea*	15	*Galactia*	*volubilis*	44
V	*Cassytha*	*filiformis*	20	*Smilax*	*auriculata*	43
V	*Echites*	*umbellata*	10	*Ipomea*	*indica*	34
V	*Galactia*	*volubilis*	44	*Parthenocissus*	*quinquefolia*	30
V	*Ipomea*	*indica*	34	*Passiflora*	*suberosa*	27
V	*Ipomea*	*pes-caprae*	8	*Momordica*	*charantia*	21
V	*Jacquemontia*	*reclinata*	8	*Cassytha*	*filiformis*	20
V	*Momordica*	*charantia*	21	*Canavalia*	*rosea*	15
V	*Okenia*	*hypogaea*	4	*Vitis*	*rotundifolia*	13
V	*Parthenocissus*	*quinquefolia*	30	*Echites*	*umbellata*	10
V	*Passiflora*	*suberosa*	27	*Ipomea*	*pes-caprae*	8
V	*Pentalinon*	*luteum*	1	*Jacquemontia*	*reclinata*	8
V	*Rhynchosia*	*minima*	1	*Okenia*	*hypogaea*	4
V	*Smilax*	*auriculata*	43	*Vigna*	*luteola*	4
V	*Tribulus*	*cistoides*	2	*Tribulus*	*cistoides*	2
V	*Vigna*	*luteola*	4	*Pentalinon*	*luteum*	1
V	*Vitis*	*rotundifolia*	13	*Rhynchosia*	*minima*	1
Woody	*Ardisia*	*escallonioides*	12	*Coccoloba*	*uvifera*	68
W	*Caesalpinia*	*bonduc*	10	*Pithecellobium*	*keyense*	55
W	*Callicarpa*	*americana*	2	*Randia*	*aculeata*	42
W	*Chiococca*	*parvifolia*	4	*Serenoa*	*repens*	38
W	*Chromolaena*	*odorata*	9	*Sabal*	*palmetto*	31
W	*Chrysobalanus*	*icaco*	1	*Psychotria*	*nervosa*	30
W	*Coccoloba*	*uvifera*	68	*Metopium*	*toxiferum*	29
W	*Coccothrinax*	*argentata*	11	*Schinus*	*terebinthifolius*	28
W	*Conocarpus*	*erectus*	1	*Trema*	*micranthum*	24
W	*Dalbergia*	*ecastaphyllum*	5	*Lantana*	*involucrata*	19
W	*Ernodea*	*littoralis*	1	*Rhus*	*copallinum*	16
W	*Erythrina*	*herbacea*	2	*Ardisia*	*escallonioides*	12
W	*Eugenia*	*foetida*	9	*Coccothrinax*	*argentata*	11
W	*Ficus*	*aurea*	9	*Caesalpinia*	*bonduc*	10
W	*Genipa*	*clusiifolia*	2	Zamia	pumila	10

Table 1.3.2 (continued)

LIFE FORM	GENUS	SPECIES	# PLOTS PRESENT	GENUS	SPECIES	# PLOTS PRESENT
W	*Guapira*	*discolor*	5	*Chromolaena*	*odorata*	9
W	*Iva*	*imbricata*	5	*Eugenia*	*foetida*	9
W	*Lantana*	*involucrata*	19	*Ficus*	*aurea*	9
W	*Metopium*	*toxiferum*	29	*Yucca*	*aloifolia*	7
W	*Morinda*	*royoc*	1	*Dalbergia*	*ecastaphyllum*	5
W	*Myrica*	*cerifera*	5	*Guapira*	*discolor*	5
W	*Opuntia*	*humifusa*	2	*Iva*	*imbricata*	5
W	*Opuntia*	*stricta*	1	*Myrica*	*cerifera*	5
W	*Pithecellobium*	*keyense*	55	*Chiococca*	*parvifolia*	4
W	*Pithecellobium*	*unguis-cati*	1	*Rapanea*	*punctata*	3
W	*Psychotria*	*nervosa*	30	*Callicarpa*	*americana*	2
W	*Randia*	*aculeata*	42	*Erythrina*	*herbacea*	2
W	*Rapanea*	*punctata*	3	*Genipa*	*clusiifolia*	2
W	*Rhus*	*copallinum*	16	*Opuntia*	*humifusa*	2
W	*Rivina*	*humilis*	2	*Rivina*	*humilis*	2
W	*Sabal*	*palmetto*	31	*Scaevola*	*sericea*	2
W	*Scaevola*	*plumieri*	1	*Sophora*	*tomentosa*	2
W	*Scaevola*	*sericea*	2	*Zanthoxylum*	*coriaceum*	2
W	*Schinus*	*terebinthifolius*	28	*Chrysobalanus*	*icaco*	1
W	*Serenoa*	*repens*	38	*Conocarpus*	*erectus*	1
W	*Sophora*	*tomentosa*	2	*Ernodea*	*littoralis*	1
W	*Tournefortia*	*gnaphalodes*	1	*Morinda*	*royoc*	1
W	*Toxicodendron*	*radicans*	1	*Opuntia*	*stricta*	1
W	*Trema*	*micranthum*	24	*Pithecellobium*	*unguis-cati*	1
W	*Yucca*	*aloifolia*	7	*Scaevola*	*plumieri*	1
W	*Zamia*	*pumila*	10	*Tournefortia*	*gnaphalodes*	1
W	*Zanthoxylum*	*coriaceum*	2	*Toxicodendron*	*radicans*	1

Table 1.3.3. Average number of species per life form type per site for each plot distance to coast.

		DISTANCE										
SITE	**LIFE FORM**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**	**Total**
Crandon	Forb	49	48	45	41	54	39	48	40	16	19	399
	Grass	17	19	18	16	25	13	17	16	7	7	155
	Vine 0	5	2	6	9	5	5	5	8	1	4	50
	Vine 1	5	12	20	20	19	21	22	21	18	16	174
	Vine 2	1	2	1	4	2	2	4	2	1	1	20
	Woody 0 -.5m	2	16	12	13	14	31	26	29	20	14	177
	Woody .5 - 2m	5	8	7	11	12	12	21	21	14	9	120
	Woody > 2m	1	6	1	6	6	8	11	13	10	7	69
		85	113	110	120	137	131	154	150	87	77	1164
South Beach	Forb	36	15	22	1	1						75
	Grass	14	11	6		1						32
	Vine 0	7	5	5	2	2						21
	Vine 1	3	6	7	2	3						21
	Woody 0 -.5m	11	10	19	7	5						52
	Woody .5 - 2m	11	5	7	7	5						35
	Woody > 2m		10	14	18	10						52
		82	62	80	37	27						288

Table 1.3.4. Average abundance per life form type per site for each plot distance to coast.

		DISTANCE										
SITE	**LIFE FORM**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**	**Total**
Crandon	Forb	1.4	2.5	1.6	2.0	1.7	2.0	1.5	1.6	1.3	1.8	1.8
	Grass	11.7	4.0	6.9	5.0	2.1	1.2	1.5	1.6	1.0	1.6	4.0
	Vine 0	1.8	2.0	4.4	1.2	1.4	1.4	1.0	1.3	1.0	2.0	1.8
	Vine 1	1.4	4.0	3.0	4.5	3.6	3.8	2.6	9.9	5.4	7.9	4.8
	Vine 2	7.5	17.5	3.0	27.1	5.3	12.5	14.3	1.0	3.0	3.0	16.7
	Woody 0 -.5m	10.0	6.8	9.5	5.5	3.6	3.8	6.9	5.7	3.8	3.9	5.6
	Woody .5 - 2m	4.3	5.2	18.3	3.4	8.8	6.7	6.5	7.9	4.5	6.4	7.1
	Woody > 2m	3.0	7.8	62.5	11.0	15.8	6.6	19.8	26.7	5.8	2.5	14.0
South Beach	Forb	2.1	5.8	2.1	1.0	1.0						2.8
	Grass	18.0	2.7	2.4		1.0						9.3
	Vine 0	9.4	1.8	1.4	1.0	19.3						5.8
	Vine 1	1.7	5.2	8.9	4.3	7.8						6.2
	Woody 0 -.5m	12.7	4.8	4.6	14.3	6.4						9.4
	Woody .5 - 2m	9.6	7.4	6.3	9.3	6.4						7.6
	Woody > 2m		7.7	13.8	8.7	12.6						10.6

Table 1.3 **5**. Duff biomass in study plots at Crandon and South Beach *Jacquemontia reclinata* sites. Samples collected on 7-31-01 for Crandon Park and 8-08-01 for South Beach, units in grams. Mean and standard deviation given for each distance (plot) from coast.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	28.5	228.7	80.1	118.1	105.2	209.2	186.1	175.1		
	2	107.4	157	74.8	171.4	0	86.6	50.4	209	273.4	301.9
	3	39.3	133.2	139.9	86.7	123.6	82.7	58.3	93.6	126.9	166.4
	4	62.2	118.9	159.3	104.4	163.9	200.4	110.4	100.9	155.5	178.4
	5	68.5	167.9	71.5	73.8	221.5	174.2	236	184.9	142.3	
	Mean	61.2	161.1	105.1	110.9	122.8	150.6	128.2	152.7	174.5	215.6
	Std. Dev.	30.6	42.4	41.3	37.8	81.9	61.6	81.0	52.2	66.9	75.0
SOUTH BEACH	11	228.6	254.1	204.3	269.2						
	12	48.2	305.7	295.2	378.4	311.5					
	13	79.6	27	305.3	137.4	241.1					
	14	144.2	338.2	203.4	307.9						
	15	32.2	243.3	10.5		263.2					
	16	210	372.9	205.5							
	Mean	123.8	256.9	204.0	273.2	271.9					
	Std. Dev.	83.5	122.9	105.9	101.2	36.0					

Table 1.3.**6**. Percent Organic matter at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon Park and 08-08-01 from South Beach.

			DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**		**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON		1	3.80	6.40	5.40	5.80	7.20	8.90	5.30	8.90		
0-15cm depth		2	3.50	3.90	3.70	6.90	2.80	1.70	2.20	2.90	2.70	2.70
		3	0.60	1.20	2.60	4.10	4.80	2.80	2.30	3.80	4.70	3.10
		4	1.00	1.50	1.50	0.90	1.50	2.00	2.50	3.50	4.60	4.30
		5	0.60	1.90	2.90	2.90	2.60	4.00	5.50	6.20	6.00	
	Mean		1.90	2.98	3.22	4.12	3.78	3.88	3.56	5.06	4.50	3.37
	Std. Dev.		1.61	2.18	1.45	2.37	2.25	2.94	1.68	2.49	1.36	0.83
46-61cm depth		1	3.60	6.10	3.30	4.40	4.10	3.00	3.80	4.80		
		2	0.60	1.00	1.50	1.10	0.80	1.30	1.40	1.70	1.30	2.00
		3	1.60	1.30	1.60	2.20	1.50	1.30	1.10	1.00	1.80	3.20
		4	0.40	0.40	0.40	0.60	0.60	1.00	1.60	0.70	1.10	1.00
		5	1.20	1.20	0.60	0.70	0.50	1.50	1.20	0.80	1.00	
	Mean		1.48	2.00	1.48	1.80	1.50	1.62	1.82	1.80	1.30	2.07
	Std. Dev.		1.28	2.32	1.15	1.59	1.50	0.79	1.12	1.72	0.36	1.10
SOUTH BEACH		11	1.70	2.80	2.20	2.70						
0-15cm depth		12	0.90	2.50	3.50	3.50	3.30					
		13	1.80	1.00	3.30	3.30	4.10					
		14	1.60	4.70	5.50	6.20						
		15	0.90	2.30	1.70		6.20					
		16	3.50	1.10	0.80							
	Mean		1.73	2.40	2.83	3.93	4.53					
	Std. Dev.		0.95	1.35	1.65	1.55	1.50					
46-61cm depth		11	0.40	0.90	2.20	2.10						
		12	0.50	0.40	1.50	1.90	3.10					
		13	0.40	0.60	1.70	2.00	3.30					
		14	0.50	1.60	2.20	2.50						
		15	0.40	0.50	1.40		2.10					
		16	2.90	1.60	2.10							
	Mean		0.85	0.93	1.85	2.13	2.83					
	Std. Dev.		1.01	0.54	0.36	0.26	0.64					

Table 1.3.**7**. ENR (Estimated nitrogen release) organic matter at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon and 08-08-01 from South Beach. Units measured in lbs/acre
.

		DISTANCE(m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	120.00	172.00	152.00	160.00	188.00	222.00	150.00	222.00		
0-15cm depth	2	114.00	122.00	118.00	182.00	100.00	78.00	88.00	102.00	98.00	98.00
	3	55.00	68.00	96.00	126.00	140.00	100.00	90.00	120.00	138.00	106.00
	4	64.00	74.00	74.00	62.00	74.00	84.00	94.00	114.00	136.00	130.00
	5	55.00	82.00	102.00	102.00	96.00	124.00	154.00	168.00	164.00	
	Mean	81.60	103.60	108.40	126.40	119.60	121.60	115.20	145.20	134.00	111.33
	Std. Dev.	32.59	43.67	29.03	47.34	45.04	58.88	33.69	49.73	27.18	16.65
46-61cm depth	1	116.00	166.00	110.00	132.00	126.00	104.00	120.00	140.00		
	2	55.00	64.00	74.00	66.00	60.00	70.00	72.00	78.00	70.00	84.00
	3	76.00	70.00	76.00	88.00	74.00	70.00	66.00	64.00	80.00	108.00
	4	50.00	50.00	50.00	55.00	55.00	64.00	76.00	57.00	66.00	64.00
	5	68.00	68.00	55.00	57.00	52.00	74.00	68.00	60.00	64.00	
	Mean	73.00	83.60	73.00	79.60	73.40	76.40	80.40	79.80	70.00	85.33
	Std. Dev.	26.15	46.72	23.62	32.08	30.59	15.84	22.47	34.60	7.12	22.03
SOUTH BEACH	11	78.00	100.00	88.00	98.00						
0-15cm depth	12	62.00	94.00	114.00	114.00	110.00					
	13	80.00	64.00	110.00	110.00	126.00					
	14	76.00	138.00	154.00	168.00						
	15	62.00	90.00	78.00		168.00					
	16	114.00	66.00	60.00							
	Mean	78.67	92.00	100.67	122.50	134.67					
	Std. Dev.	19.04	27.01	32.98	31.09	29.96					
46-61cm depth	11	50.00	62.00	88.00	86.00						
	12	52.00	50.00	74.00	82.00	106.00					
	13	50.00	55.00	78.00	84.00	110.00					
	14	52.00	76.00	88.00	94.00						
	15	50.00	52.00	72.00		86.00					
	16	102.00	76.00	86.00							
	Mean	59.33	61.83	81.00	86.50	100.67					
	Std. Dev.	20.93	11.70	7.24	5.26	12.86					

Table 1.3.**8**. Phosphorus (weak bray) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon and 08-08-01 from South Beach. Units measured in ppm.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	3.00	4.00	6.00	7.00	7.00	11.00	10.00	8.00		
0-15cm depth	2	2.00	2.00	6.00	9.00	6.00	4.00	8.00	11.00	8.00	8.00
	3	4.00	4.00	11.00	8.00	9.00	9.00	10.00	8.00	7.00	13.00
	4	2.00	2.00	5.00	3.00	6.00	9.00	18.00	13.00	18.00	15.00
	5	4.00	4.00	12.00	8.00	12.00	14.00	8.00	9.00	18.00	
	Mean	3.00	3.20	8.00	7.00	8.00	9.40	10.80	9.80	12.75	12.00
	Std. Dev.	1.00	1.10	3.24	2.35	2.55	3.65	4.15	2.17	6.08	3.61
46-61cm depth	1	3.00	3.00	3.00	3.00	4.00	5.00	4.00	5.00		
	2	3.00	2.00	4.00	3.00	2.00	3.00	4.00	4.00	4.00	5.00
	3	4.00	4.00	3.00	5.00	4.00	6.00	3.00	3.00	4.00	3.00
	4	3.00	2.00	4.00	4.00	6.00	9.00	8.00	5.00	5.00	4.00
	5	4.00	4.00	4.00	5.00	4.00	4.00	3.00	3.00	4.00	
	Mean	3.40	3.00	3.60	4.00	4.00	5.40	4.40	4.00	4.25	4.00
	Std. Dev.	0.55	1.00	0.55	1.00	1.41	2.30	2.07	1.00	0.50	1.00
SOUTH BEACH	11	5.00	7.00	11.00	10.00						
0-15cm depth	12	4.00	7.00	11.00	10.00	13.00					
	13	4.00	4.00	10.00	10.00	15.00					
	14	7.00	10.00	11.00	10.00						
	15	4.00	5.00	7.00		11.00					
	16	7.00	3.00	10.00							
	Mean	5.17	6.00	10.00	10.00	13.00					
	Std. Dev.	1.47	2.53	1.55	0.00	2.00					
46-61cm depth	11	2.00	4.00	5.00	6.00						
	12	3.00	3.00	4.00	5.00	6.00					
	13	4.00	4.00	6.00	6.00	5.00					
	14	8.00	3.00	7.00	6.00						
	15	3.00	2.00	6.00		5.00					
	16	4.00	4.00	7.00							
	Mean	4.00	3.33	5.83	5.75	5.33					
	Std. Dev.	2.10	0.82	1.17	0.50	0.58					

Table 1.3.**9**. Phosphorus (strong bray) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon and 08-08-01 from South Beach. Units measured in ppm.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	1.00	1.00	2.00	1.00	2.00	1.00	1.00	2.00		
0-15cm depth	2	2.00	1.00	2.00	2.00	2.00	1.00	2.00	1.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	14.00	18.00	16.00	11.00	9.00	9.00
	4	11.00	18.00	15.00	7.00	16.00	13.00	25.00	20.00	21.00	19.00
	5	6.00	5.00	16.00	10.00	21.00	26.00	14.00	10.00	38.00	
	Mean	4.40	5.40	7.40	4.40	11.00	11.80	11.60	8.80	17.50	10.00
	Std. Dev.	4.16	7.23	7.40	3.91	8.60	10.89	10.11	7.73	15.76	8.54
46-61cm depth	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00		
	2	2.00	1.00	2.00	2.00	2.00	1.00	1.00	2.00	2.00	2.00
	3	5.00	6.00	5.00	14.00	12.00	11.00	10.00	13.00	12.00	13.00
	4	5.00	6.00	13.00	5.00	17.00	10.00	9.00	6.00	8.00	6.00
	5	5.00	7.00	7.00	7.00	6.00	6.00	5.00	5.00	6.00	
	Mean	3.60	4.20	5.60	5.80	7.60	5.80	5.20	5.60	7.00	7.00
	Std. Dev.	1.95	2.95	4.77	5.17	6.80	4.76	4.27	4.51	4.16	5.57
SOUTH BEACH	11	19.00	8.00	11.00	15.00						
0-15cm depth	12	8.00	8.00	11.00	14.00	17.00					
	13	6.00	8.00	12.00	14.00	14.00					
	14	22.00	9.00	18.00	20.00						
	15	5.00	9.00	8.00		16.00					
	16	11.00	5.00	16.00							
	Mean	11.83	7.83	12.67	15.75	15.67					
	Std. Dev.	7.08	1.47	3.67	2.87	1.53					
46-61cm depth	11	4.00	5.00	7.00	9.00						
	12	5.00	5.00	12.00	6.00	7.00					
	13	6.00	5.00	7.00	6.00	8.00					
	14	9.00	4.00	8.00	7.00						
	15	6.00	5.00	7.00		9.00					
	16	9.00	5.00	8.00							
	Mean	6.50	4.83	8.17	7.00	8.00					
	Std. Dev.	2.07	0.41	1.94	1.41	1.00					

Table 1.3.**10**. Potassium (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-03 from Crandon and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	6.00	6.00	7.00	4.00	7.00	5.00	4.00	4.00		
0-15cm depth	2	5.00	3.00	6.00	15.00	13.00	10.00	8.00	14.00	12.00	15.00
	3	3.00	7.00	11.00	19.00	8.00	6.00	4.00	13.00	10.00	14.00
	4	2.00	2.00	4.00	4.00	6.00	11.00	19.00	10.00	9.00	15.00
	5	6.00	13.00	9.00	15.00	11.00	15.00	70.00	26.00	29.00	
	Mean	4.40	6.20	7.40	11.40	9.00	9.40	21.00	13.40	15.00	14.67
	Std. Dev.	1.82	4.32	2.70	6.95	2.92	4.04	28.07	8.05	9.42	0.58
46-61cm depth	1	1.00	6.00	6.00	4.00	5.00	2.00	2.00	2.00		
	2	2.00	6.00	7.00	10.00	3.00	5.00	3.00	5.00	3.00	6.00
	3	2.00	3.00	2.00	8.00	2.00	3.00	1.00	1.00	2.00	2.00
	4	2.00	1.00	4.00	3.00	2.00	3.00	8.00	6.00	4.00	3.00
	5	2.00	3.00	3.00	2.00	2.00	4.00	3.00	3.00	4.00	
	Mean	1.80	3.80	4.40	5.40	2.80	3.40	3.40	3.40	3.25	3.67
	Std. Dev.	0.45	2.17	2.07	3.44	1.30	1.14	2.70	2.07	0.96	2.08
SOUTH BEACH	11	6.00	23.00	17.00	21.00						
0-15cm depth	12	5.00	11.00	18.00	33.00	30.00					
	13	10.00	12.00	11.00	9.00	20.00					
	14	12.00	11.00	21.00	27.00						
	15	5.00	18.00	8.00		22.00					
	16	22.00	6.00	6.00							
	Mean	10.00	13.50	13.50	22.50	24.00					
	Std. Dev.	6.54	6.02	6.02	10.25	5.29					
46-61cm depth	11	2.00	9.00	11.00	8.00						
	12	2.00	5.00	16.00	12.00	12.00					
	13	2.00	2.00	2.00	8.00	8.00					
	14	3.00	7.00	11.00	11.00						
	15	2.00	5.00	8.00		12.00					
	16	3.00	12.00	9.00							
	Mean	2.33	6.67	9.50	9.75	10.67					
	Std. Dev.	0.52	3.50	4.59	2.06	2.31					

Table 1.3.**11**. Magnesium (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	74	145	147	169	186	197	93	169		
0-15cm depth	2	86	109	150	206	136	99	138	124	125	153
	3	75	92	171	243	187	111	103	123	146	114
	4	87	68	96	116	145	191	151	161	148	270
	5	93	139	138	179	149	205	132	230	270	
	Mean	83	110.6	140.4	182.6	160.6	160.6	123.4	161.4	172.25	179
	Std. Dev.	8.22	32.22	27.61	46.98	24.11	51.17	24.44	43.70	65.99	81.18
46-61cm depth	1	84	142	101	88	126	124	58	99		
	2	84	83	110	105	82	80	79	73	72	105
	3	86	100	102	146	112	83	50	65	75	72
	4	80	102	89	69	63	61	93	69	61	84
	5	72	112	76	75	52	105	63	76	58	
	Mean	81.2	107.8	95.6	96.6	87	90.6	68.6	76.4	66.5	87
	Std. Dev.	5.59	21.78	13.28	30.88	31.51	24.34	17.27	13.30	8.27	16.70
SOUTH BEACH	11	92	210	119	167						
0-15cm depth	12	48	161	105	250	230					
	13	60	69	94	101	158					
	14	76	210	174	240						
	15	53	172	57		154					
	16	250	59	39							
46-61cm depth	**Mean**	96.5	146.83	98	189.5	180.67					
	Std. Dev.	76.91	67.21	47.84	69.64	42.77					
	11	46	92	53	85						
	12	32	70	65	113	106					
	13	30	36	57	58	101					
	14	38	75	80	134						
	15	40	60	54		72					
	16	93	113	67							
	Mean	46.5	74.33	62.67	97.5	93					
	Std. Dev.	23.49	26.46	10.25	33.11	18.36					

Table 1.3.**12**. Calcium (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01from Crandon and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	1770	2000	2000	2040	1970	2090	2020	2460		
0-15cm depth	2	1770	1880	1840	2170	2010	1840	2050	2130	2390	2150
	3	1770	1780	2020	2470	2060	2040	2120	2330	2320	2260
	4	1650	1730	1860	1930	2110	2800	2300	2790	2330	2350
	5	1940	2210	2200	2350	2210	2370	2590	2640	2750	
	Mean	1780	1920	1984	2192	2072	2228	2216	2470	2447.5	2253.33
	STD. Dev.	103.44	192.22	145.19	220.50	93.38	371.58	235.65	258.17	204.02	100.17
46-61cm depth	1	1790	1930	1840	1820	1890	1820	1840	2050		
	2	1820	1750	1860	1730	1770	1840	1820	1990	1960	2000
	3	1820	1810	1850	2010	1800	1880	1890	1820	1900	1750
	4	1770	1790	1910	1990	1880	1990	2030	1670	1990	2170
	5	2000	1790	1830	1830	1940	2070	1960	1890	2040	
	Mean	1840	1814	1858	1876	1856	1920	1908	1884	1972.5	1973.33
	STD. Dev.	91.92	68.41	31.14	119.92	69.50	106.54	87.01	148.93	58.52	211.27
SOUTH BEACH	11	1920	2390	2590	2540						
0-15cm depth	12	1840	2040	2580	2780	3070					
	13	1880	2080	2470	2430	2780					
	14	1950	2550	3390	2970						
	15	1950	2160	2280		2790					
	16	2300	1920	1890							
	Mean	1973.33	2190	2533.33	2680	2880					
	STD. Dev.	165.61	235.80	494.23	242.35	164.62					
46-61cm depth	11	1840	2070	2170	2300						
	12	1870	1960	2210	2300	2480					
	13	1850	1950	2290	2280	2540					
	14	1950	2090	2480	2460						
	15	1910	1980	2250		2300					
	16	2360	2030	2300							
	Mean	1963.33	2013.33	2283.33	2335	2440					
	STD. Dev.	198.56	58.88	108.01	83.86	124.9					

Table 1.3.**13**. Soil pH at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	8.60	8.30	8.30	8.30	8.30	8.20	8.10	8.00		
0-15cm depth	2	8.60	8.50	8.30	8.10	8.00	8.10	8.10	8.10	8.10	8.10
	3	8.80	8.40	8.50	7.90	7.80	7.90	7.90	7.80	7.80	8.00
	4	8.60	8.60	8.10	8.10	8.00	7.80	7.90	7.80	7.80	7.70
	5	8.80	8.40	8.20	8.20	8.10	8.00	7.90	7.90	7.80	
	Mean	8.68	8.44	8.28	8.12	8.04	8.00	7.98	7.92	7.88	7.93
	Std. Dev.	0.11	0.11	0.15	0.15	0.18	0.16	0.11	0.13	0.15	0.21
46-61cm depth	1	9.00	8.60	8.70	8.70	8.60	8.60	8.60	8.50		
	2	8.90	8.80	8.50	8.70	8.80	8.60	8.70	8.60	8.60	8.50
	3	8.70	8.40	8.30	8.10	8.30	8.30	8.50	8.40	8.40	8.70
	4	8.70	8.70	9.00	8.90	8.90	8.70	8.50	8.70	8.70	8.80
	5	9.00	8.90	8.80	8.70	8.80	8.50	8.80	8.60	8.60	
	Mean	8.86	8.68	8.66	8.62	8.68	8.54	8.62	8.56	8.58	8.67
	Std. Dev.	0.15	0.19	0.27	0.30	0.24	0.15	0.13	0.11	0.13	0.15
SOUTH BEACH	11	7.90	8.00	7.90	7.90						
0-15cm depth	12	8.20	8.10	7.90	7.70	7.60					
	13	8.20	8.10	8.00	8.00	7.70					
	14	8.30	8.00	7.70	7.90						
	15	8.30	8.20	8.10		7.80					
	16	8.10	8.50	8.70							
	Mean	8.17	8.15	8.05	7.88	7.70					
	Std. Dev.	0.15	0.19	0.34	0.13	0.10					
46-61cm depth	11	8.20	8.20	8.20	8.10						
	12	8.30	8.40	8.20	8.10	8.00					
	13	8.60	8.60	8.30	8.20	8.00					
	14	8.60	8.50	8.00	8.10						
	15	8.60	8.70	8.30		8.10					
	16	8.00	8.60	8.20							
	Mean	8.38	8.50	8.20	8.13	8.03					
	Std. Dev.	0.26	0.18	0.11	0.05	0.06					

Table 1.3.**14**.Cation Exchange Capacity (meq/100g) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon and 08-08-01 from South Beach

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	9.60	11.30	11.30	11.70	11.50	12.20	11.00	13.80		
0-15cm depth	2	9.70	10.40	10.60	12.70	11.30	10.20	11.50	11.80	13.10	12.20
	3	9.60	9.80	11.70	14.60	12.00	11.30	11.60	12.90	13.00	12.40
	4	9.10	9.30	10.30	10.80	11.90	15.80	13.00	15.50	13.00	14.20
	5	10.60	12.40	12.30	13.50	12.50	13.80	15.00	15.40	16.20	
	Mean	9.72	10.64	11.24	12.66	11.84	12.66	12.42	13.88	13.83	12.93
	Std. Dev.	0.54	1.23	0.81	1.49	0.47	2.19	1.62	1.60	1.58	1.10
46-61cm depth	1	9.70	11.00	10.10	9.90	10.60	10.20	9.70	11.20		
	2	9.90	9.60	10.40	9.70	9.60	10.00	9.80	10.60	10.50	11.00
	3	9.90	10.00	10.20	11.40	10.00	10.20	9.90	9.70	10.20	9.40
	4	9.60	9.90	10.40	10.60	10.00	10.60	11.10	9.10	10.60	11.60
	5	10.70	10.00	9.90	9.90	10.20	11.40	10.40	10.20	10.80	
	Mean	9.96	10.10	10.20	10.30	10.08	10.48	10.18	10.16	10.53	10.67
	Std. Dev.	0.43	0.53	0.21	0.70	0.36	0.56	0.58	0.81	0.25	1.14
SOUTH BEACH	11	10.60	14.10	14.10	14.40						
0-15cm depth	12	9.80	11.90	14.00	16.30	17.60					
	13	10.10	11.20	13.30	13.20	15.50					
	14	10.60	14.90	18.60	17.20						
	15	10.40	12.80	12.10		15.50					
	16	14.20	10.30	9.90							
	Mean	10.95	12.53	13.67	15.28	16.20					
	Std. Dev.	1.62	1.75	2.88	1.81	1.21					
46-61cm depth	11	9.70	11.40	11.40	12.40						
	12	9.70	10.60	11.80	12.60	13.50					
	13	9.60	10.20	12.10	12.10	13.80					
	14	10.20	11.30	13.30	13.70						
	15	10.00	10.60	11.90		12.30					
	16	12.80	11.30	12.20							
	Mean	10.33	10.90	12.12	12.70	13.20					
	Std. Dev.	1.23	0.50	0.64	0.70	0.79					

Table 1.3.**15.** Zinc (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon Park and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	0.10	0.30	0.10	0.20	0.30	0.40	0.20	0.30		
0-15cm depth	2	0.20	0.20	0.10	0.20	0.10	0.10	0.10	0.10	0.20	0.10
	3	0.10	0.10	0.20	0.10	1.50	1.40	1.40	1.30	1.00	0.70
	4	1.30	0.80	3.90	3.30	1.20	1.80	1.60	1.90	1.80	1.80
	5	1.60	1.20	0.80	0.40	0.70	0.80	1.40	1.30	0.90	
	Mean	0.66	0.52	1.02	0.84	0.76	0.90	0.94	0.98	0.98	0.87
	Std. Dev.	0.73	0.47	1.64	1.38	0.59	0.70	0.73	0.76	0.66	0.86
46-61cm depth	1	0.20	0.40	0.10	0.10	0.10	0.10	0.10	0.10		
	2	0.10	0.10	0.10	0.20	0.20	0.10	0.10	0.10	0.20	0.20
	3	0.80	1.40	1.30	0.40	0.20	0.40	0.50	0.40	0.50	0.40
	4	1.50	0.60	1.00	1.10	1.00	1.70	1.40	1.60	1.20	1.40
	5	0.80	0.90	1.10	0.80	0.90	0.70	0.80	0.90	0.50	
	Mean	0.68	0.68	0.72	0.52	0.48	0.60	0.58	0.62	0.60	0.67
	Std. Dev.	0.56	0.50	0.58	0.42	0.43	0.66	0.54	0.64	0.42	0.64
SOUTH BEACH	11	1.60	0.60	0.40	0.50						
0-15cm depth	12	1.00	0.20	0.60	0.30	0.40					
	13	0.50	0.50	3.70	1.30	4.80					
	14	1.70	0.20	0.40	0.50						
	15	0.70	0.40	0.40		0.50					
	16	0.40	0.20	0.60							
	Mean	0.98	0.35	1.02	0.65	1.90					
	Std. Dev.	0.56	0.18	1.32	0.44	2.51					
46-61cm depth	11	0.60	0.30	0.30	0.90						
	12	0.80	0.40	0.50	0.40	0.40					
	13	0.30	0.40	1.20	0.40	0.80					
	14	0.30	0.40	0.40	0.30						
	15	0.60	0.50	0.30		0.20					
	16	0.40	2.30	0.30							
	Mean	0.50	0.72	0.50	0.50	0.47					
	Std. Dev.	0.20	0.78	0.35	0.27	0.31					

Table 1.3.**16**. Manganese (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon Park and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	2.00	2.00	3.00	3.00	3.00	4.00	3.00	4.00		
0-15cm depth	2	3.00	1.00	2.00	3.00	4.00	4.00	4.00	4.00	3.00	5.00
	3	2.00	2.00	5.00	4.00	4.00	3.00	3.00	5.00	4.00	5.00
	4	1.00	2.00	2.00	2.00	3.00	4.00	4.00	5.00	6.00	9.00
	5	2.00	2.00	3.00	4.00	4.00	4.00	3.00	5.00	10.00	
	Mean	2.00	1.80	3.00	3.20	3.60	3.80	3.40	4.60	5.75	6.33
	Std. Dev.	0.71	0.45	1.22	0.84	0.55	0.45	0.55	0.55	3.10	2.31
46-61cm depth	1	2.00	3.00	2.00	2.00	2.00	2.00	3.00	3.00		
	2	3.00	2.00	3.00	3.00	4.00	3.00	3.00	5.00	3.00	5.00
	3	2.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	3.00	3.00
	4	2.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	3.00	3.00
	5	2.00	2.00	3.00	3.00	2.00	3.00	2.00	2.00	3.00	
	Mean	2.20	2.40	2.60	2.40	2.60	2.60	2.60	2.80	3.00	3.67
	Std. Dev.	0.45	0.55	0.55	0.55	0.89	0.55	0.55	1.30	0.00	1.15
SOUTH BEACH	11	2.00	4.00	4.00	5.00						
0-15cm depth	12	2.00	4.00	4.00	5.00	5.00					
	13	3.00	3.00	6.00	6.00	6.00					
	14	2.00	4.00	5.00	5.00						
	15	3.00	3.00	4.00		5.00					
	16	3.00	3.00	3.00							
	Mean	2.50	3.50	4.33	5.25	5.33					
	Std. Dev.	0.55	0.55	1.03	0.50	0.58					
46-61cm depth	11	2.00	3.00	4.00	4.00						
	12	2.00	3.00	4.00	4.00	5.00					
	13	7.00	2.00	4.00	5.00	6.00					
	14	2.00	3.00	3.00	4.00						
	15	3.00	3.00	3.00		4.00					
	16	4.00	3.00	3.00							
	Mean	3.33	2.83	3.50	4.25	5.00					
	Std. Dev.	1.97	0.41	0.55	0.50	1.00					

Table 1.3.**17**. Iron (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon Park and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	2.00	2.00	2.00	1.00	1.00	2.00	1.00	1.00		
0-15cm depth	2	2.00	2.00	1.00	2.00	5.00	6.00	3.00	3.00	4.00	2.00
	3	5.00	3.00	3.00	2.00	6.00	6.00	5.00	7.00	2.00	2.00
	4	10.00	8.00	9.00	8.00	5.00	7.00	6.00	5.00	6.00	6.00
	5	5.00	2.00	2.00	5.00	4.00	5.00	6.00	4.00	5.00	
	Mean	4.80	3.40	3.40	3.60	4.20	5.20	4.20	4.00	4.25	3.33
	Std. Dev.	3.27	2.61	3.21	2.88	1.92	1.92	2.17	2.24	1.71	2.31
46-61cm depth	1	3.00	2.00	3.00	3.00	2.00	2.00	1.00	2.00		
	2	6.00	4.00	3.00	3.00	4.00	3.00	3.00	5.00	3.00	2.00
	3	3.00	6.00	7.00	7.00	3.00	3.00	4.00	4.00	3.00	4.00
	4	5.00	6.00	5.00	2.00	4.00	2.00	1.00	1.00	2.00	1.00
	5	9.00	6.00	3.00	2.00	3.00	2.00	3.00	3.00	2.00	
	Mean	5.20	4.80	4.20	3.40	3.20	2.40	2.40	3.00	2.50	2.33
	Std. Dev.	2.49	1.79	1.79	2.07	0.84	0.55	1.34	1.58	0.58	1.53
SOUTH BEACH	11	1.00	2.00	1.00	1.00						
0-15cm depth	12	2.00	2.00	2.00	1.00	2.00					
	13	2.00	2.00	3.00	3.00	2.00					
	14	3.00	2.00	1.00	2.00						
	15	2.00	2.00	2.00		2.00					
	16	2.00	1.00	2.00							
	Mean	2.00	1.83	1.83	1.75	2.00					
	Std. Dev.	0.63	0.41	0.75	0.96	0.00					
46-61cm depth	11	3.00	1.00	2.00	2.00						
	12	2.00	1.00	2.00	1.00	2.00					
	13	3.00	2.00	2.00	1.00	2.00					
	14	1.00	2.00	1.00	2.00						
	15	1.00	2.00	1.00		1.00					
	16	2.00	2.00	1.00							
	Mean	2.00	1.67	1.50	1.50	1.67					
	Std. Dev.	0.89	0.52	0.55	0.58	0.58					

Table 1.3.**18**. Copper (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon Park and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	0.40	0.40	0.20	0.10	0.10	0.30	0.30	0.20		
0-15cm depth	2	0.50	0.10	0.40	0.20	0.50	0.20	0.20	0.50	0.40	0.70
	3	0.50	0.40	0.40	0.80	0.70	0.70	0.80	0.80	0.30	0.60
	4	0.30	0.60	0.90	0.50	0.40	0.50	0.60	0.50	0.70	0.70
	5	0.30	0.80	0.50	0.80	0.40	0.60	0.50	0.30	0.70	
	Mean	0.40	0.46	0.48	0.48	0.42	0.46	0.48	0.46	0.53	0.67
	Std. Dev.	0.10	0.26	0.26	0.33	0.22	0.21	0.24	0.23	0.21	0.06
46-61cm depth	1	0.50	0.20	0.50	0.10	0.10	0.10	0.10	0.10		
	2	0.60	0.40	0.40	0.40	0.50	0.30	0.40	0.30	0.20	0.40
	3	0.70	0.60	0.50	0.40	0.20	0.60	0.40	0.40	0.60	0.50
	4	0.50	0.30	0.60	0.50	0.50	0.50	0.60	0.30	0.70	0.30
	5	0.60	0.70	0.70	0.50	0.50	0.40	0.30	0.20	0.40	
	Mean	0.58	0.44	0.54	0.38	0.36	0.38	0.36	0.26	0.48	0.40
	Std. Dev.	0.08	0.21	0.11	0.16	0.19	0.19	0.18	0.11	0.22	0.10
SOUTH BEACH	11	0.50	0.40	0.30	0.40						
0-15cm depth	12	0.40	0.00	0.40	0.40	0.30					
	13	0.30	0.30	1.50	0.20	0.40					
	14	0.20	0.10	0.90	0.70						
	15	0.40	0.40	0.10		0.30					
	16	0.70	0.30	0.60							
	Mean	0.42	0.25	0.63	0.43	0.33					
	Std. Dev.	0.16	0.15	0.46	0.18	0.05					
46-61cm depth	11	0.50	0.30	0.40	0.20						
	12	0.20	0.30	0.10	0.30	0.50					
	13	0.20	0.40	0.20	0.30	0.40					
	14	0.30	0.40	0.40	0.60						
	15	0.20	0.30	0.70		0.50					
	16	0.60	0.60	0.50							
	Mean	0.33	0.38	0.38	0.35	0.47					
	Std. Dev.	0.16	0.11	0.20	0.15	0.05					

Table 1.3.**19**. Soluble Salts (mmhos/cm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon Park and 08-08-01 from South Beach.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	0.05	0.09	0.08	0.09	0.10	0.11	0.08	0.11		
0-15cm depth	2	0.05	0.07	0.09	0.12	0.07	0.07	0.08	0.09	0.08	0.09
	3	0.03	0.05	0.07	0.08	0.09	0.07	0.07	0.11	0.11	0.10
	4	0.04	0.05	0.07	0.07	0.11	0.15	0.14	0.13	0.12	0.15
	5	0.04	0.07	0.07	0.08	0.09	0.12	0.12	0.17	0.14	
	Mean	0.04	0.07	0.08	0.09	0.09	0.10	0.10	0.12	0.11	0.11
	Std. Dev.	0.01	0.02	0.01	0.02	0.01	0.03	0.03	0.03	0.03	0.03
46-61cm depth	1	0.04	0.09	0.06	0.06	0.07	0.06	0.05	0.08		
	2	0.03	0.05	0.06	0.05	0.04	0.06	0.04	0.05	0.04	0.05
	3	0.04	0.06	0.06	0.08	0.06	0.07	0.05	0.05	0.05	0.04
	4	0.04	0.07	0.03	0.03	0.03	0.04	0.06	0.03	0.04	0.03
	5	0.03	0.05	0.04	0.04	0.04	0.05	0.04	0.05	0.05	
	Mean	0.04	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.04
	Std. Dev.	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01
SOUTH BEACH	11	0.06	0.15	0.10	0.14						
0-15cm depth	12	0.05	0.15	0.10	0.17	0.19					
	13	0.08	0.11	0.10	0.11	0.22					
	14	0.09	0.19	0.17	0.16						
	15	0.05	0.22	0.11		0.17					
	16	0.28	0.05	0.03							
	Mean	0.10	0.15	0.10	0.15	0.19					
	Std. Dev.	0.09	0.06	0.04	0.03	0.03					
46-61cm depth	11	0.04	0.10	0.08	0.09						
	12	0.03	0.08	0.09	0.11	0.13					
	13	0.04	0.06	0.08	0.10	0.15					
	14	0.04	0.09	0.13	0.15						
	15	0.03	0.07	0.11		0.12					
	16	0.13	0.07	0.10							
	Mean	0.05	0.08	0.10	0.11	0.13					
	Std. Dev.	0.04	0.01	0.02	0.03	0.02					

Table 1.3.**20**. Chloride (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on 07-31-01 from Crandon Park and 08-08-01 from South Beach
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		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1.00	108.00	101.00	120.00	100.00	125.00	130.00	80.00	120.00		
0-15cm depth	2.00	100.00	125.00	120.00	135.00	20.00	30.00	46.00	143.00	68.00	65.00
	3.00	57.00	32.00	61.00	41.00	70.00	190.00	180.00	150.00	190.00	170.00
	4.00	180.00	190.00	170.00	180.00	150.00	95.00	120.00	170.00	150.00	160.00
	5.00	115.00	150.00	150.00	154.00	150.00	145.00	130.00	108.00	155.00	
	Mean	112.00	119.60	124.20	122.00	103.00	118.00	111.20	138.20	140.75	131.67
	Std. Dev.	44.21	59.01	41.21	53.86	56.75	59.85	50.96	24.58	51.66	57.95
46-61cm depth	1.00	150.00	170.00	125.00	120.00	70.00	104.00	130.00	115.00		
	2.00	40.00	67.00	87.00	30.00	62.00	99.00	69.00	69.00	58.00	47.00
	3.00	180.00	180.00	160.00	190.00	140.00	190.00	184.00	195.00	180.00	160.00
	4.00	180.00	130.00	130.00	138.00	160.00	180.00	185.00	125.00	106.00	190.00
	5.00	120.00	190.00	105.00	95.00	170.00	95.00	180.00	190.00	150.00	
	Mean	134.00	147.40	121.40	114.60	120.40	133.60	149.60	138.80	123.50	132.33
	Std. Dev.	58.14	50.39	27.52	58.74	50.90	47.16	50.60	53.41	53.20	75.41
SOUTH BEACH	11.00	76.00	107.00	82.00	82.00						
0-15cm depth	12.00	93.00	101.00	108.00	81.00	100.00					
	13.00	73.00	120.00	142.00	106.00	180.00					
	14.00	68.00	62.00	86.00	89.00						
	15.00	130.00	134.00	90.00		76.00					
	16.00	128.00	50.00	60.00							
	Mean	94.67	95.67	94.67	89.50	118.67					
	Std. Dev.	27.90	32.98	27.85	11.56	54.45					
46-61cm depth	11.00	90.00	90.00	72.00	86.00						
	12.00	88.00	90.00	71.00	70.00	85.00					
	13.00	88.00	66.00	79.00	56.00	66.00					
	14.00	96.00	92.00	98.00	106.00						
	15.00	70.00	98.00	110.00		62.00					
	16.00	46.00	49.00	58.00							
	Mean	79.67	80.83	81.33	79.50	71.00					
	Std. Dev.	18.65	19.08	19.20	21.50	12.29					

Table 1.3.**21**. Organic matter (%) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on March 13 and 14, 2002 respectively.

			DISTANCE(m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**		**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON		1	0.4	0.6	2.2	1.7	2.2	2	1.3	2.4		
0-15cm depth		2	0.2	0.9	1.5	2.3	2.2	0.9	1.8	1.3	1.9	2.7
		3	0.2	0.7	1.6	2	1.7	1.4	1.3	2.2	1.8	1.4
		4	0.2	0.5	0.6	0.6	0.9	1.8	1.7	2.3	1.4	1.7
		5	0.3	0.7	1.8	1.8	1.7	1.7	1.8	2.9	2.4	
	Mean		0.26	0.68	1.54	1.68	1.74	1.56	1.58	2.22	1.88	1.93
	Std. Dev.		0.09	0.15	0.59	0.65	0.53	0.43	0.26	0.58	0.41	0.68
46-61cm depth		1	0.2	1.5	0.2	0.3	0.4	0.2	0.2	0.4		
		2	0.2	0.2	0.6	0.5	0.3	0.2	0.2	0.3	0.2	0.5
		3	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3
		4	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3
		5	0.2	0.2	0.4	0.2	0.2	0.2	0.5	0.5	1	
	Mean		0.20	0.46	0.34	0.32	0.26	0.20	0.26	0.32	0.40	0.37
	Std. Dev.		0.00	0.58	0.17	0.11	0.09	0.00	0.13	0.13	0.40	0.12
SOUTH BEACH		11	0.8	1.6	2.7	2.9						
0-15cm depth		12	0.6	1.8	2.9	3.1	2.9					
		13	0.7	0.6	3.1	2.5	3.3					
		14	0.7	2.2	2.4	3.3						
		15	0.9	1.2	1.7		2.7					
		16	0.3	1.7	0.2							
	Mean		0.67	1.52	2.17	2.95	2.97					
	Std. Dev.		0.21	0.55	1.08	0.34	0.31					
46-61cm depth		11	0.2	0.5	0.8	1.4						
		12	0.2	0.4	0.9	1.6	1.6					
		13	0.2	0.3	1.3	1.1	1.4					
		14	0.2	0.6	1.3	1.4						
		15	0.2	0.3	0.8		1.5					
		16	2.3	0.5	1.4							
	Mean		0.55	0.43	1.08	1.38	1.50					
	Std. Dev.		0.86	0.12	0.28	0.21	0.10					

Table 1.3.**22.** Estimated nitrogen release (lbs/acre) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on March 13 and 14, 2002 respectively.

		DISTANCE(m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	50	55	88	78	88	84	70	92		
0-15cm depth	2	45	62	74	90	88	62	80	70	82	98
	3	45	57	76	84	78	72	70	88	80	72
	4	45	52	55	55	62	80	78	90	72	78
	5	47	57	80	80	78	78	80	102	92	
	Mean	46.40	56.60	74.60	77.40	78.80	75.20	75.60	88.40	81.50	82.67
	Std. Dev.	2.19	3.65	12.20	13.33	10.64	8.56	5.18	11.61	8.23	13.61
46-61cm depth	1	45	74	45	47	50	45	45	50		
	2	45	45	55	52	47	45	45	47	45	52
	3	45	45	47	47	45	45	45	45	45	47
	4	45	45	45	47	45	45	45	45	45	47
	5	45	45	50	45	45	45	52	52	64	
	Mean	45	50.8	48.4	47.6	46.4	45	46.4	47.8	49.75	48.67
	Std. Dev.	0	12.97	4.22	2.61	2.19	0	3.13	3.11	9.5	2.89
SOUTH BEACH	11	60	76	98	102						
0-15cm depth	12	55	80	102	106	102					
	13	57	55	106	94	110					
	14	57	88	92	110						
	15	62	68	78		98					
	16	47	78	45							
	Mean	56.33	74.17	86.83	103	103.33					
	Std. Dev.	5.20	11.39	22.70	6.83	6.11					
46-61cm depth	11	45	52	60	72						
	12	45	50	62	76	76					
	13	45	47	70	66	72					
	14	45	55	70	72						
	15	45	47	60		74					
	16	90	52	72							
	Mean	52.5	50.5	65.67	71.5	74					
	Std. Dev.	18.37	3.15	5.57	4.12	2					

Table 1.3.**23.** Phosphorus (Weak Bray) (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on March 13 and 14 respectively.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	2	3	5	4	8	6	10	8		
0-15cm depth	2	2	2	4	5	4	6	4	11	7	7
	3	1	2	6	11	6	6	9	5	5	7
	4	2	2	2	2	2	8	7	6	10	7
	5	2	2	6	6	8	6	5	5	13	
	Mean	1.8	2.2	4.6	5.6	5.6	6.4	7	7	8.75	7
	Std. Dev.	0.45	0.45	1.67	3.36	2.61	0.89	2.55	2.55	3.5	0
46-61cm depth	1	2	2	1	1	1	1	2	2		
	2	2	1	2	2	2	1	2	1	1	2
	3	2	2	2	2	2	2	2	2	2	2
	4	2	2	2	2	2	2	2	2	2	2
	5	2	2	2	2	2	2	2	2	2	
	Mean	2	1.8	1.8	1.8	1.8	1.6	2	1.8	1.75	2
	Std. Dev.	0	0.45	0.45	0.45	0.45	0.55	0	0.45	0.5	0
SOUTH BEACH	11	2	4	7	6						
0-15cm depth	12	2	2	8	4	5					
	13	2	2	5	3	4					
	14	2	5	5	7						
	15	2	2	5		3					
	16	2	2	5							
	Mean	2	2.83	5.83	5	4					
	Std. Dev.	0	1.33	1.33	1.83	1					
46-61cm depth	11	1	2	3	2						
	12	2	2	3	3	2					
	13	2	2	2	2	2					
	14	2	2	4	3						
	15	2	2	3		3					
	16	2	2	3							
	Mean	1.83	2	3	2.5	2.33					
	Std. Dev.	0.41	0	0.63	0.58	0.58					

Table 1.3.**24.** Phosphorus (Strong Bray) (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on March 13 and 14, 2002 respectively.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	3	4	11	6	25	11	21	19		
0-15cm depth	2	4	3	7	12	11	7	24	17	19	11
	3	3	3	13	22	39	28	28	17	23	22
	4	4	3	3	4	5	38	24	32	35	23
	5	3	3	17	25	25	26	15	12	25	
	Mean	3.4	3.2	10.2	13.8	21	22	22.4	19.4	25.5	18.67
	Std. Dev.	0.55	0.45	5.40	9.39	13.34	12.79	4.83	7.50	6.81	6.66
46-61cm depth	1	3	4	2	2	2	2	4	3		
	2	6	3	4	4	7	4	3	3	2	4
	3	4	3	3	3	4	3	3	4	5	6
	4	4	3	3	3	4	4	3	3	3	4
	5	4	3	5	4	4	3	3	3	3	
	Mean	4.2	3.2	3.4	3.2	4.2	3.2	3.2	3.2	3.25	4.67
	Std. Dev.	1.10	0.45	1.14	0.84	1.79	0.84	0.45	0.45	1.26	1.15
SOUTH BEACH	11	4	8	22	20						
0-15cm depth	12	3	5	32	28	22					
	13	3	4	19	10	11					
	14	3	8	20	9						
	15	6	5	13		14					
	16	3	4	12							
	Mean	3.67	5.67	19.67	16.75	15.67					
	Std. Dev.	1.21	1.86	7.23	9.00	5.69					
46-61cm depth	11	2	3	4	4						
	12	4	3	6	4	5					
	13	3	3	4	3	4					
	14	3	4	7	7						
	15	3	4	8		7					
	16	3	3	6							
	Mean	3	3.33	5.83	4.5	5.33					
	Std. Dev.	0.63	0.52	1.60	1.73	1.53					

Table 1.3.**25.** Potassium (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites.
Samples were collected at two depths on March 13 and 14, 2002 respectively.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	4	5	7	6	7	6	4	11		
0-15cm depth	2	2	5	6	12	8	4	5	5	8	13
	3	3	4	6	7	4	3	5	9	6	7
	4	2	3	3	3	4	5	7	7	5	9
	5	2	3	6	10	6	6	6	7	8	
	Mean	2.6	4	5.6	7.6	5.8	4.8	5.4	7.8	6.75	9.67
	Std. Dev.	0.89	1	1.52	3.51	1.79	1.30	1.14	2.28	1.5	3.06
46-61cm depth	1	1	3	1	1	2	1	2	2		
	2	1	2	2	3	1	1	2	1	1	2
	3	2	1	1	2	1	1	2	1	2	1
	4	1	2	1	1	2	1	2	1	1	2
	5	12	1	1	1	2	1	1	1	2	
	Mean	3.4	1.8	1.2	1.6	1.6	1	1.8	1.2	1.5	1.67
	Std. Dev.	4.83	0.84	0.45	0.89	0.55	0	0.45	0.45	0.58	0.58
SOUTH BEACH	11	5	15	12	14						
0-15cm depth	12	3	9	12	19	13					
	13	8	7	5	8	18					
	14	2	14	8	13						
	15	2	4	2		9					
	16	2	10	7							
	Mean	3.67	9.83	7.67	13.5	13.33					
	Std. Dev.	2.42	4.17	3.93	4.51	4.51					
46-61cm depth	11	2	2	5	2						
	12	2	4	2	3	3					
	13	2	2	2	2	1					
	14	2	2	1	2						
	15	2	2	2		3					
	16	2	3	3							
	Mean	2	2.5	2.5	2.25	2.33					
	Std. Dev.	0	0.84	1.38	0.5	1.15					

Table 1.3.**26**. Magnesium (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on March 13 and 14, 2002 respectively.

		DISTANCE(m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**		**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON		1	78	78	170	121	207	180	87	144		
0-15cm depth		2	79	130	131	240	179	94	134	87	107	250
		3	73	90	155	203	171	131	115	143	101	104
		4	89	119	93	100	118	132	103	142	113	174
		5	87	123	124	270	171	121	81	240	198	
	Mean		81.2	108	134.6	186.8	169.2	131.6	104	151.2	129.75	176
	Std. Dev.		6.65	22.66	29.69	73.96	32.22	31.10	21.45	55.25	45.76	73.02
46-61cm depth		1	77	94	73	67	75	77	51	69		
		2	78	78	71	83	64	62	59	59	50	76
		3	74	72	67	85	81	53	44	55	36	59
		4	82	77	79	78	79	46	56	65	59	57
		5	80	66	78	79	66	52	61	66	70	
	Mean		78.2	77.4	73.6	78.4	73	58	54.2	62.8	53.75	64
	Std. Dev.		3.03	10.43	4.98	6.99	7.65	12.06	6.83	5.67	14.38	10.44
SOUTH BEACH		11	73	250	125	165						
0-15cm depth		12	64	148	119	248	189					
		13	72	86	114	143	199					
		14	58	261	130	247						
		15	58	132	59		128					
		16	52	231	111							
	Mean		62.83	184.67	109.67	200.75	172					
	Std. Dev.		8.40	72.24	25.78	54.73	38.43					
46-61cm depth		11	36	85	71	56						
		12	36	62	51	84	87					
		13	37	48	58	48	66					
		14	40	77	59	68						
		15	40	70	43		78					
		16	39	89	71							
	Mean		38	71.83	58.83	64	77					
	Std. Dev.		1.90	15.25	11.03	15.66	10.54					

Table 1.3.**27.** Calcium (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on March 13 and 14, 2002 respectively.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	1740	1730	2450	2110	2440	2210	1930	2590		
0-15cm depth	2	1740	1920	2020	2270	2280	1800	2230	1970	2370	2550
	3	1790	1830	2080	2100	2100	2230	2260	2490	2510	2210
	4	1830	1950	1850	1870	1940	2420	2160	2800	2010	2150
	5	1790	1930	2220	2370	2170	2180	2080	2670	2360	
	Mean	1778	1872	2124	2144	2186	2168	2132	2504	2312.5	2303.333
	Std. Dev.	38.34	91.76	225.4551	190.4731	188.0957	226.2079	132.5519	319.3431	212.975	215.7159
46-61cm depth	1	1850	1940	1740	1850	1740	1790	1840	1810		
	2	1860	1740	1970	1940	1730	1680	1730	1820	1830	1860
	3	1930	1790	1840	1810	1790	1930	1900	1940	1980	1960
	4	1920	1850	1860	1840	1770	1780	1800	1870	1740	1980
	5	1940	1760	1770	1750	1760	1800	1940	1890	1980	
	Mean	1900	1816	1836	1838	1758	1796	1842	1866	1882.5	1933.333
	Std. Dev.	41.83	80.81	89.61	69.07	23.87	89.05	82.58	53.20	118.43	64.29
SOUTH BEACH	11	1740	2130	2720	2760						
0-15cm depth	12	1610	1810	2450	2480	2490					
	13	1740	1830	2300	2400	2650					
	14	1620	2380	2480	3020						
	15	1670	1790	1980		2380					
	16	1700	2070	2110							
	Mean	1680	2001.667	2340	2665	2506.667					
	Std. Dev.	56.92	234.6416	268.4027	282.5479	135.7694					
46-61cm depth	11	1590	1730	2270	1910						
	12	1630	1710	1970	2100	2080					
	13	1670	1790	2000	1930	2160					
	14	1660	1810	1990	2110						
	15	1690	1770	2020		2200					
	16	1660	1780	2100							
	Mean	1650	1765	2058.333	2012.5	2146.667					
	Std. Dev.	35.21	37.82	113.0339	107.1992	61.10					

Table 1.3.**28.** pH at Crandon and South Beach *Jacquemontia reclinata* study sites.
Samples were collected at two depths on March 13 and 14, 2002 respectively.

			DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**		**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON		1	8.2	8.2	8	7.9	7.9	7.9	7.9	7.7		
0-15cm depth		2	8.3	8.1	8	7.9	7.7	8	7.9	7.8	7.7	7.7
		3	8.4	8	7.9	8	7.8	7.8	7.8	7.7	7.7	7.8
		4	8.3	8.2	8.1	8	8	7.7	7.7	7.6	7.8	7.7
		5	8.1	8.1	7.9	7.9	7.9	7.7	7.7	7.7	7.5	
	Mean		8.26	8.12	7.98	7.94	7.86	7.82	7.8	7.7	7.68	7.73
	Std. Dev.		0.11	0.08	0.08	0.05	0.11	0.13	0.1	0.07	0.13	0.06
46-61cm depth		1	8.5	8.2	8.5	8.5	8.4	8.4	8.5	8.4		
		2	8.5	8.4	8.3	8.3	8.4	8.5	8.4	8.2	8.4	8.3
		3	8.5	8.4	8.3	8.2	8.3	8.5	8.4	8.3	8.4	8.2
		4	8.5	8.5	8.6	8.4	8.4	8.3	8.3	8.2	8.3	8.2
		5	8.5	8.4	8.3	8.3	8.3	8.3	8.2	8.3	8.1	
	Mean		8.5	8.38	8.4	8.34	8.36	8.4	8.36	8.28	8.3	8.23
	Std. Dev.		0	0.11	0.14	0.11	0.05	0.1	0.11	0.08	0.14	0.06
SOUTH BEACH		11	8	7.9	7.5	7.4						
0-15cm depth		12	8.3	8.3	7.7	7.6	7.6					
		13	8.2	8.1	7.7	7.8	7.5					
		14	8.2	7.8	7.6	7.7						
		15	8.4	8.3	8		7.7					
		16	8.6	8.1	7.9							
	Mean		8.28	8.08	7.73	7.63	7.6					
	Std. Dev.		0.20	0.20	0.19	0.17	0.1					
46-61cm depth		11	7.8	8.1	8.1	7.9						
		12	8.3	8.6	8.3	8.3	8.1					
		13	8.5	8.4	8.4	8.4	8.1					
		14	8.5	8.4	8.4	8						
		15	8.4	8.6	8.5		8.1					
		16	8.6	8.3	8.1							
	Mean		8.35	8.4	8.3	8.15	8.1					
	Std. Dev.		0.29	0.19	0.17	0.24	0.00					

Table 1.3.**29.** Cation exchange capacity (meq/100g) at Crandon and South Beach *Jacquemontia reclinata* study sites. Samples were collected at two depths on March 13 and 14, 2002 respectively.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	9.4	9.3	13.7	11.6	13.9	12.6	10.4	14.2		
0-15cm depth	2	9.4	10.7	11.2	13.4	12.9	9.8	12.3	10.6	12.8	14.9
	3	9.6	9.9	11.7	12.2	11.9	12.2	12.3	13.7	13.4	11.9
	4	9.9	10.7	10	10.2	10.7	13.2	11.7	15.2	11	12.2
	5	9.7	10.7	12.1	14.1	12.3	11.9	11.1	15.4	13.5	
	Mean	9.6	10.26	11.74	12.3	12.34	11.94	11.56	13.82	12.68	13
	Std. Dev.	0.21	0.64	1.35	1.53	1.19	1.29	0.82	1.93	1.16	1.65
46-61cm depth	1	9.9	10.5	9.3	9.8	9.3	9.6	9.6	9.6		
	2	10	9.4	10.4	10.4	9.2	8.9	9.1	9.6	9.6	9.9
	3	10.3	9.6	9.8	9.8	9.6	10.1	9.9	10.2	10.2	10.3
	4	10.3	9.9	10	9.9	9.5	9.3	9.5	9.9	9.2	10.4
	5	10.4	9.4	9.5	9.4	9.4	9.4	10.2	10	10.5	
	Mean	10.18	9.76	9.8	9.86	9.4	9.46	9.66	9.86	9.88	10.2
	Std. Dev.	0.22	0.46	0.43	0.36	0.16	0.44	0.42	0.26	0.59	0.26
SOUTH BEACH	11	9.3	12.8	14.7	15.2						
0-15cm depth	12	8.6	10.3	13.3	14.5	14.1					
	13	9.3	9.9	12.5	13.2	15					
	14	8.6	14.1	13.5	17.2						
	15	8.8	10.1	10.4		13					
	16	8.9	12.3	11.5							
	Mean	8.92	11.58	12.65	15.03	14.03					
	Std. Dev.	0.32	1.73	1.53	1.67	1.00					
46-61cm depth	11	8.3	9.4	12	10						
	12	8.5	9.1	10.3	11.2	11.1					
	13	8.7	9.4	10.5	10.1	11.4					
	14	8.6	9.7	10.4	11.1						
	15	8.8	9.4	10.5		11.7					
	16	8.6	9.6	11.1							
	Mean	8.58	9.43	10.8	10.6	11.4					
	Std. Dev.	0.17	0.21	0.65	0.64	0.3					

Table 1.3.**30.** Ammonium nitrogen (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites.
Samples were collected at two depths on March 13 and 14, 2002 respectively.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	8.3	9.03	4.4	3.21	6.16	10.37	6.82	6.65		
0-15cm depth	2	7.13	5.2	1.97	2.37	2.58	13.04	2.6	1.84	1.97	2.67
	3	1.34	2.16	2.68	2.89	2.61	2.71	2.4	2.42	3.4	3.15
	4	2.5	2.22	2	1.96	2.07	2.21	2.5	2.14	2.79	3.55
	5	1.46	1.79	2.44	2.44	3.53	2.41	3.09	3.13	2.52	
	Mean	4.15	4.08	2.70	2.57	3.39	6.15	3.48	3.24	2.67	3.12
	Std. Dev.	3.32	3.09	1.00	0.49	1.64	5.16	1.88	1.97	0.59	0.44
46-61cm depth	1	6.25	4.37	4.48	8.17	3.69	5.47	6.72	5.28		
	2	1.51	12.39	10.47	9.16	8.38	8.54	8.67	1.74	2.54	4.54
	3	1.3	1.43	1.61	1.66	1.36	1.33	1.45	1.5	1.52	1.95
	4	4.47	3.67	2.01	1.61	1.78	1.85	2.97	1.95	2.09	1.93
	5	1.51	0.86	1.31	2.82	3.13	4.7	4.21	3.43	3.45	
	Mean	3.01	4.54	3.98	4.68	3.67	4.38	4.80	2.78	2.40	2.81
	Std. Dev.	2.24	4.63	3.84	3.68	2.80	2.93	2.90	1.59	0.81	1.50
SOUTH BEACH	11	5.74	4.1	3.56	2.9						
0-15cm depth	12	1.23	1.76	1.52	2.59	1.75					
	13	3.58	3.72	3.68	4.26	6.03					
	14	2.6	2.1	1.85	2.62						
	15	1.67	2.24	2.24		1.6					
	16	2.14	1.63	2.24							
	Mean	2.83	2.59	2.52	3.09	3.13					
	Std. Dev.	1.64	1.05	0.90	0.79	2.52					
46-61cm depth	11	1.47	1.24	1.42	2.18						
	12	1.14	1.18	2.81	2.59	2.63					
	13	4.6	1.46	2.19	1.82	1.84					
	14	1.75	4.41	1.65	1.44						
	15	1.3	1.2	1.62		1.81					
	16	2.13	1.98	2.36							
	Mean	2.07	1.91	2.01	2.01	2.09					
	Std. Dev.	1.29	1.26	0.53	0.49	0.47					

Table 1.3.**31.** Nitrate nitrogen (ppm) at Crandon and South Beach *Jacquemontia reclinata* study sites.
Samples were collected at two depths on March 13 and 14, 2002 respectively.

			DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT**		**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON		1	1.63	2	4.5	3.84	4.01	4.32	2.8	3.33		
0-15cm depth		2	1.79	2.46	3.57	3.96	4.08	2.7	4.29	3.47	5.02	5.23
		3	1.02	3.44	2.01	3.73	3.49	2.1	4.11	5.78	2.35	2.34
		4	0.94	1.96	1.28	2	2.34	4.05	2.75	4.47	2.37	5.39
		5	1.62	2.64	4.06	3.72	3.95	2.86	1.93	8.69	9.24	
	Mean		1.4	2.5	3.08	3.45	3.57	3.21	3.18	5.15	4.75	4.32
	Std. Dev.		0.39	0.60	1.38	0.82	0.73	0.94	1.00	2.21	3.25	1.72
46-61cm depth		1	1.03	2.3	1.8	1.76	1.65	2.08	2.14	1.77		
		2	1.04	1.44	2.59	2.13	1.77	1.43	1.77	2.28	1.49	2.35
		3	1.14	1.47	1.9	1.61	1.85	1.4	1.79	1.94	1.61	1.33
		4	0.91	0.87	0.44	1.87	1.86	1.73	1.18	1.69	1.3	2.49
		5	0.72	1.04	1.55	1.66	1.72	1.4	2.21	2.35	2.84	
	Mean		0.97	1.42	1.66	1.81	1.77	1.61	1.82	2.01	1.81	2.06
	Std. Dev.		0.16	0.55	0.78	0.21	0.09	0.30	0.41	0.30	0.70	0.63
SOUTH BEACH		11	5.38	6.4	5.04	9.39						
0-15cm depth		12	1.35	3.59	4.5	6.99	9.36					
		13	2.26	4.29	5.62	3.23	11.45					
		14	4.3	8.85	9.56	5.08						
		15	2.03	5.12	3.59		12.03					
		16	1.45	7.3	3.61							
	Mean		2.80	5.93	5.32	6.17	10.95					
	Std. Dev.		1.66	1.97	2.22	2.64	1.40					
46-61cm depth		11	1.11	1.57	1.47	3.59						
		12	1.62	1.34	1.64	2.36	4.66					
		13	0.9	1.3	1.48	1.83	2.45					
		14	1.74	2.4	4.31	1.99						
		15	0.78	1.69	2.09		3.91					
		16	1.11	1.6	2.55							
	Mean		1.21	1.65	2.26	2.44	3.67					
	Std. Dev.		0.39	0.40	1.09	0.80	1.12					

Figure 1.3.**6**. Values for organic matter, estimated nitrogen release, phosphorus (Strong Bray), and phosphorus (Weak Bray), per distance and site.

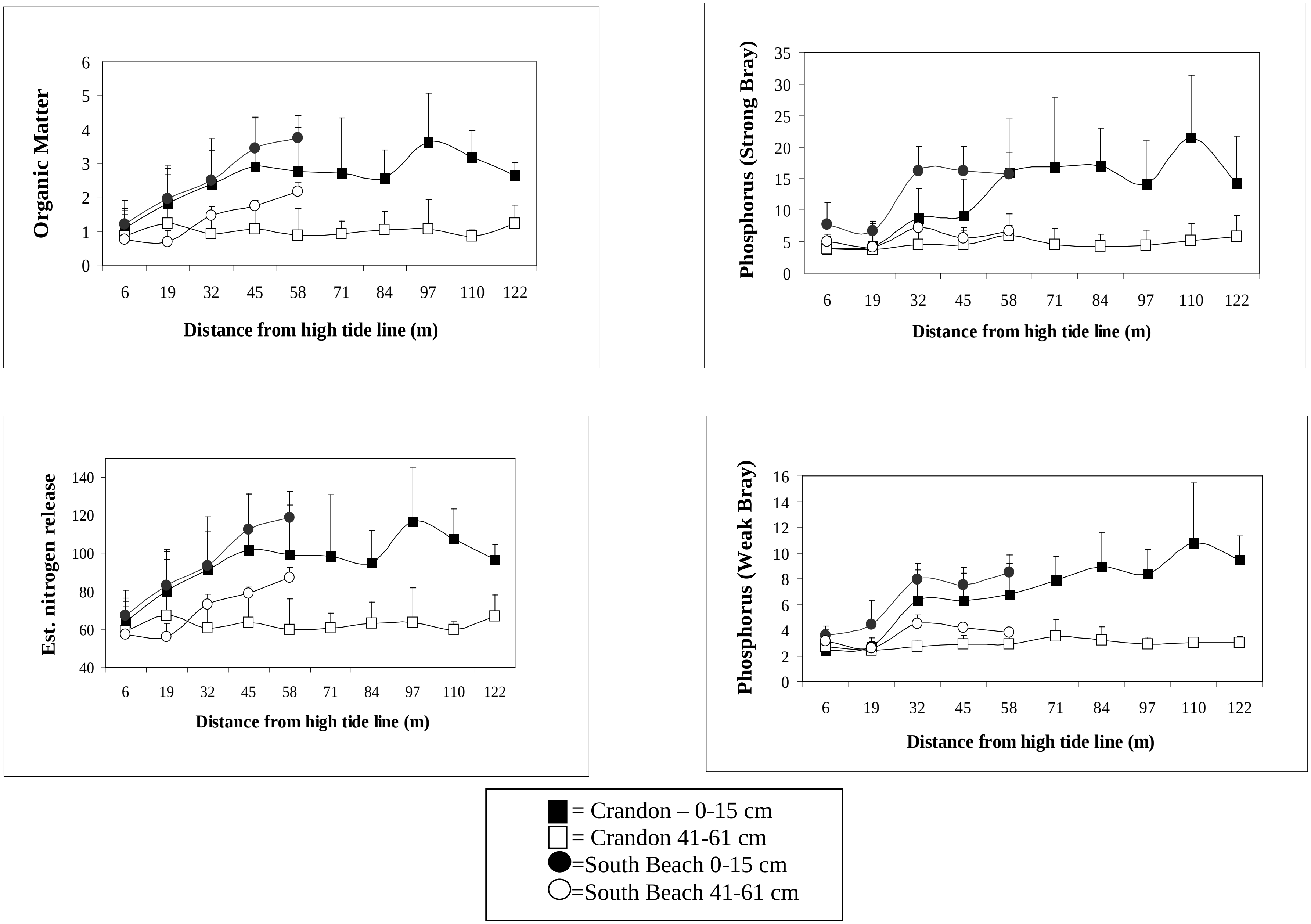


Figure 1.3.**7.** Values for potassium, magnesium, calcium and pH per distance and site.

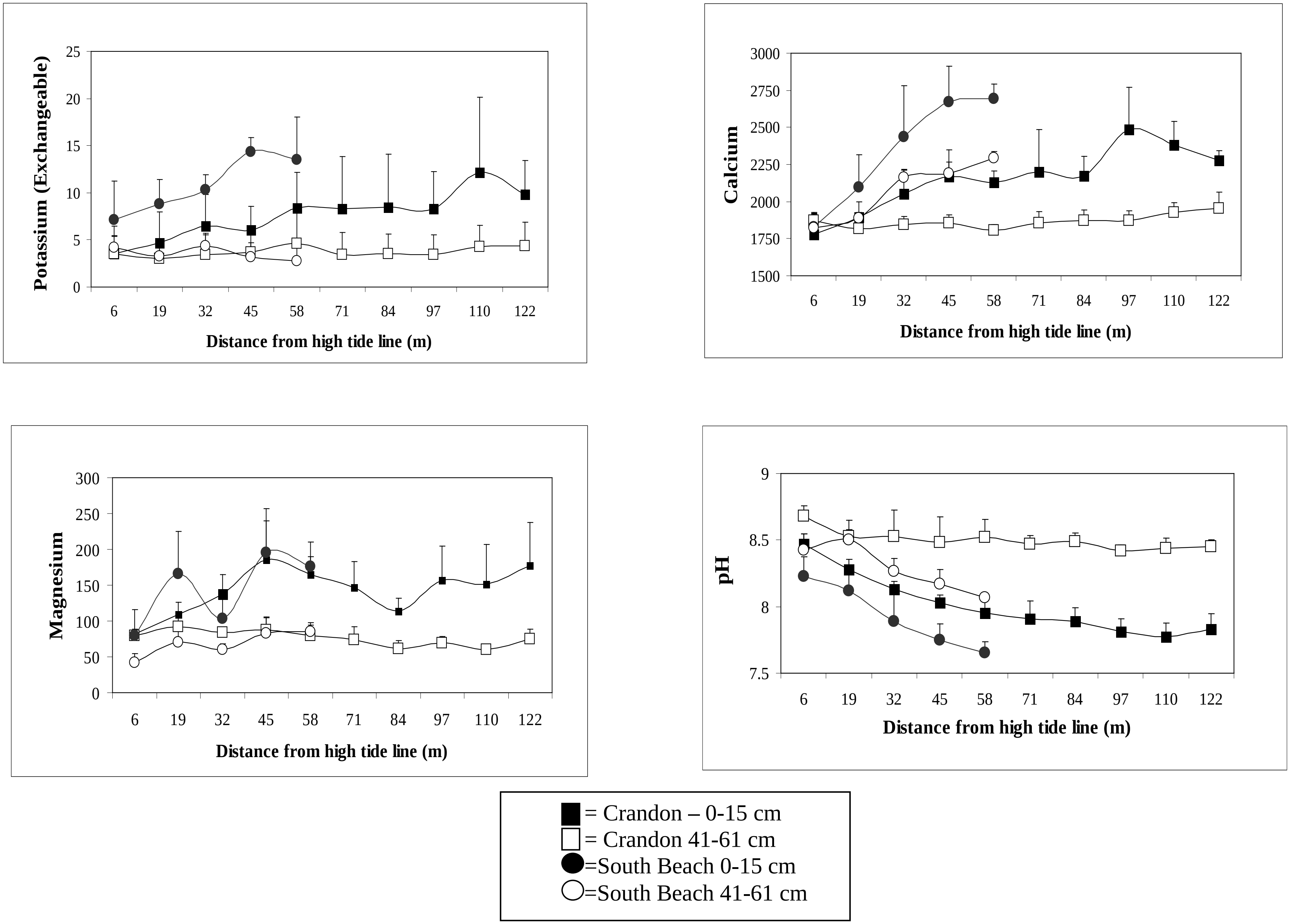


Figure 1.3.**8**. Values for cation exchange capacity and ammonium nitrate, per distance and site.

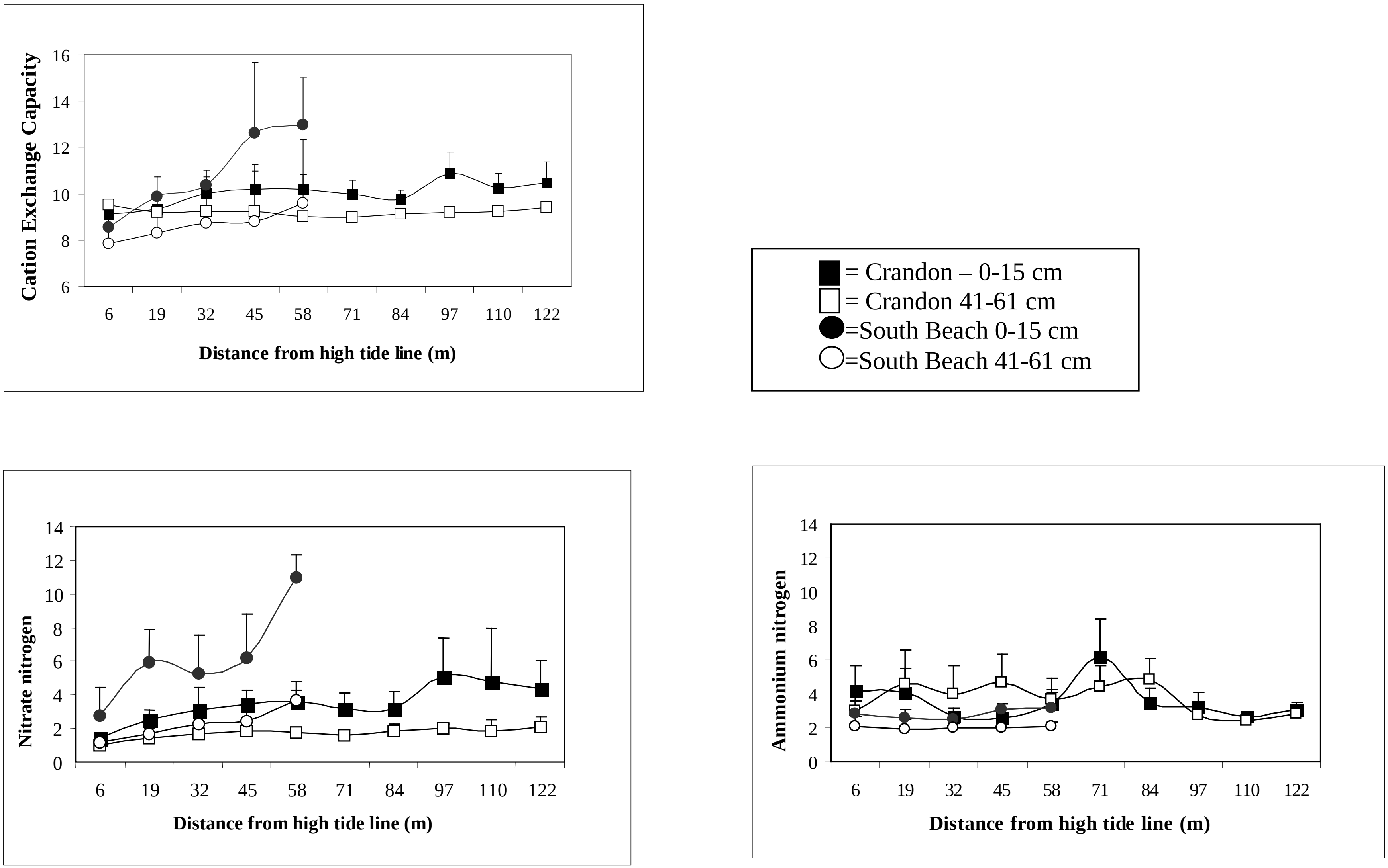


Table 1.3.**32**. Means and results of Bonferroni mean separation test, values with different lower case letters are significantly different.

Distance from coast (m)	**n**	**Organic matter**	**Estimated nitrogen release**	**Phosphorus (Weak Bray)**	**Phosphorus (Strong Bray)**	**Potassium**	**Magnesium**	**Calcium**	**pH**	**Cation exchange capacity**
0-15 cm soil depth										
6	22	1.14 a	116.8 a	3.04 a	6.00 ab	5.32 a	80.8 a	1805 a	8.34 a	9.81 a
19	22	1.90 ab	107.7 ab	3.64 ab	5.64 a	8.68 a	140.1 abc	2005 ab	8.19 ab	11.33 ab
32	22	2.44 ab	92.7 ab	7.18 bc	12.82 bc	8.73 a	119.1 ab	2262 bc	8.00 bc	12.40 bc
45	19	3.14 ab	106.7 ab	6.83 abc	12.28 abc	13.28 a	189.3 c	2392 c	7.90 bc	13.67 c
58	16	3.13 ab	106.6 ab	7.44 bc	15.88 bc	11.62 a	169.2 bc	2340 bc	7.84 c	13.22 bc
71	10	2.72 ab	98.4 ab	7.90 c	16.90 c	7.10 a	146.1 bc	2198 bc	7.91 bc	12.30 bc
84	10	2.57 ab	95.4 ab	8.90 c	17.00 c	13.20 a	113.7 ab	2174 abc	7.89 c	11.99 abc
97	10	3.64 ab	116.8 b	8.40 c	14.10 c	10.60 a	156.3 bc	2487 c	7.81 c	13.85 c
110	8	3.18 ab	107.7 ab	10.75 c	21.50 c	10.87 a	151.0 bc	2380 bc	7.77 c	13.25 bc
122	6	2.65 b	97.0 ab	9.50 c	14.33 c	12.17 a	177.5 bc	2278 bc	7.83 c	12.97 bc
41-61 cm soil depth										
6	22	0.76 a	57.32 a	2.82 a	4.36 a	2.36 a	59.27 a	1835 a	8.51 a	9.74 a
19	22	0.93 a	61.18 a	2.54 a	3.91 a	3.78 a	81.96 a	1855 a	8.49 a	10.06 a
32	22	1.21 a	67.59 a	3.69 a	5.86 a	4.45 a	71.59 a	2023 a	8.38 a	10.80 a
45	18	1.37 a	70.44 a	3.44 a	5.06 a	3.81 a	84.50 a	1998 a	8.33 a	10.78 a
58	16	1.36 a	70.19 a	3.25 a	6.19 a	3.81 a	81.87 a	1989 a	8.35 a	10.70 a
71	9	0.87 a	59.67 a	3.22 a	3.78 a	2.11 a	73.33 a	1855 a	8.49 a	9.94 a
84	10	1.04 a	63.40 a	3.20 a	4.20 a	2.60 a	61.40 a	1875 a	8.49 a	9.92 a
97	10	1.06 a	63.80 a	2.90 a	4.40 a	2.30 a	69.60 a	1875 a	8.42 a	10.01 a
110	8	0.85 a	59.87 a	3.00 a	5.12 a	2.38 a	60.12 a	1927 a	8.43 a	10.20 a
122	6	1.22 a	67.00 a	3.00 a	5.83 a	2.67 a	75.50 a	1953 a	8.45 a	10.43 a

Table 1.3.**33**. Results of ANOVA of each soil nutrient/characteristic, significant to P = 0.05, degrees of freedom = 9, 134

Soil nutrient/characteristic	**F**	**P**
0-15 cm soil depth		
Organic matter	3.44	0.001
Estimated nitrogen release	3.55	0.001
Phosphorus (Weak Bray)	9.79	0.0001
Phosphorus (Strong Bray)	5.47	0.0001
Potassium	1.81	ns
Magnesium	8.22	0.0001
Calcium	9.48	0.0001
pH	11.92	0.0001
Cation Exchange Capacity	9.45	0.0001
41-61 cm soil depth		
Organic matter	0.66	ns
Estimated nitrogen release	0.70	ns
Phosphorus (Weak Bray)	0.90	ns
Phosphorus (Strong Bray)	1.30	ns
Potassium	1.62	ns
Magnesium	3.20	0.01
Calcium	2.74	0.01
pH	1.22	ns
Cation Exchange Capacity	2.80	0.01

Table 1.3.**34**. Results of ANOVA ammonium and nitrate nitrogen data, significant to P = 0.05.

SITE/Depth	**F**	**P**
0-15 cm soil depth		
CRANDON (df = 9, 37)		
Ammonium nitrogen	0.48	ns
Nitrate nitrogen	4.01	0.01
SOUTH BEACH (df = 4, 20)		
Ammonium nitrogen	0.19	ns
Nitrate nitrogen	7.24	0.001
41-61 cm soil depth		
CRANDON		
Ammonium nitrogen	0.29	ns
Nitrate nitrogen	2.35	ns
SOUTH BEACH		
Ammonium nitrogen	0.19	ns
Nitrate nitrogen	7.17	0.001

Table 1.3.**35**. Ammonium and nitrate nitrogen, Crandon site. Untransformed means shown, Bonferroni mean separation test run on log transformed means. Values with different lower case letters are significantly different.

Distance from coast (m)	**n** Crandon/ South Beach	**Ammonium nitrogen**		**Nitrate nitrogen**	
0-15 cm soil depth		*Crandon*	*South Beach*	*Crandon*	*South Beach*
6	5/6	4.15 a	2.83 a	1.40 a	2.80 a
19	5/6	4.08 a	2.59 a	2.50 ab	5.92 ab
32	5/6	2.70 a	2.51 a	3.08 ab	5.32 ab
45	5/4	2.57 a	3.09 a	3.45 b	6.17 ab
58	5/3	3.39 a	3.13 a	3.57 b	10.95 b
71	5	6.15 a		3.21 ab	
84	5	3.49 a		3.18 ab	
97	5	3.24 a		5.15 b	
110	4	2.67 a		4.74 b	
122	3	3.12 a		4.32 b	
41-61 cm soil depth					
6	5/6	3.00 a	2.06 a	0.97 a	1.21 a
19	5/6	4.54 a	1.91 a	1.42 a	1.65 ab
32	5/4	3.67 a	2.01 a	1.65 a	2.57 abc
45	5/3	4.68 a	2.01 a	1.80 a	2.44 bc
58	5	3.67 a	2.09 a	1.77 a	3.67 c
71	5	4.38 a		1.61 a	
84	5	4.80 a		1.82 a	
97	5	2.78 a		2.00 a	
110	4	2.40 a		1.81 a	
122	3	2.81 a		2.06 a	

Table 1.3.**36**. Soil texture analysis. Samples were collected at a depth of 0-15cm and amounts are given in percentage.

Crandon Park		3A	3C	3E	3G	3I
Texture	Sand	95	95	95	95	93
	Silt	2	2	2	2	2
	Clay	3	3	3	3	5
Classification		Sand	Sand	Sand	Sand	Sand

South Beach		13A	13B	13C	13D	13E
Texture	Sand	95	95	93	95	95
	Silt	2	2	4	2	2
	Clay	3	3	3	3	3
Classification		Sand	Sand	Sand	Sand	Sand

Table 1.3.**37.** Soil moisture from July (Crandon) and August (South Beach) 2001 sample

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	0.0281	0.0525	0.0250	0.0257	0.0356	0.0412	0.0754	0.0854		
0-15 cm depth	2	0.0247	0.0359	0.0280	0.0541	0.0436	0.0264	0.0250	0.0420	0.0535	0.0668
	3	0.0295	0.0357	0.0309	0.0380	0.0428	0.0333	0.0432	0.0393	0.0454	0.0475
	4	0.0251	0.0773	0.0347	0.0361	0.0265	0.0536	0.0481	0.0526	0.0664	0.0589
	5	0.0268	0.0455	0.0342	0.0389	0.0397	0.0539	0.0692	0.0927	0.0882	
	Mean	0.0268	0.0494	0.0305	0.0385	0.0376	0.0417	0.0522	0.0624	0.0634	0.0577
	Std. Dev.	0.0020	0.0171	0.0041	0.0102	0.0070	0.0122	0.0204	0.0249	0.0187	0.0097
46-61 cm depth	1	0.0476	0.0601	0.0454	0.0359	0.0391		0.0421	0.0569		
	2	0.0558	0.0405	0.0433	0.0425	0.0464	0.0367	0.0707	0.0465	0.0559	0.0646
	3	0.0580	0.0472	0.0359	0.0490	0.0435	0.0355	0.0496	0.0534	0.0515	0.0456
	4	0.0574	0.0569	0.0543	0.0507	0.0446	0.0456	0.0471	0.0457	0.0444	0.0836
	5	0.0571	0.0464	0.0398	0.0418	0.0510	0.0500	0.0544	0.0512	0.0647	
	Mean	0.0552	0.0502	0.0438	0.0440	0.0449	0.0419	0.0528	0.0507	0.0541	0.0646
	Std. Dev.	0.0043	0.0081	0.0069	0.0060	0.0044	0.0070	0.0110	0.0047	0.0085	0.0190
SOUTH BEACH	11	0.0406	0.1018	0.1186	0.1450						
0-15 cm depth	12	0.0370	0.0807	0.0927	0.1549	0.2165					
	13	0.0324	0.0304	0.1078	0.1300	0.1452					
	14	0.0342	0.0797	0.1454	0.1806						
	15	0.0322	0.0603	0.0190		0.1162					
	16	0.0732	0.0417	0.0571							
	Mean	0.0416	0.0658	0.0901	0.1526	0.1593					
	Std. Dev.	0.0177	0.0224	0.0484	0.0253	0.0516					
46-61 cm depth	11	0.0299	0.0533	0.0654	0.0771						
	12	0.0324	0.0514	0.0694	0.0777	0.0970					
	13	0.0306	0.0381	0.0762	0.0758	0.0919					
	14	0.0292	0.0463	0.0722	0.0927						
	15	0.0329	0.0370	0.0266		0.0736					
	16	0.0384	0.0510	0.0514							
	Mean	0.0322	0.0462	0.0602	0.0808	0.0875					
	Std. Dev.	0.0035	0.0069	0.0205	0.0092	0.0123					

Table 1.3.**38.** Soil moisture from March 2002 sample

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
	TRANSECT #	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	0.0118	0.0165	0.024	0.0197	0.0235	0.0192	0.0229	0.0271		
0-15 cm depth	2	0.0154	0.0154	0.0182	0.017	0.0169	0.0125	0.0159	0.0189	0.0197	0.0317
	3	0.0176	0.0133	0.0125	0.0369	0.0408	0.0149	0.0214	0.0589	0.0259	0.025
	4	0.0102	0.0149		0.0133	0.0114	0.0167	0.0132	0.0243	0.0216	0.0176
	5	0.0154	0.0125	0.0124	0.0199	0.0099	0.0161	0.0153	0.019	0.016	
	Mean	0.0141	0.0145	0.0168	0.0214	0.0205	0.0159	0.0177	0.0296	0.0208	0.0248
	Std. Dev.	0.0030	0.0016	0.0055	0.0091	0.0125	0.0025	0.0042	0.0167	0.0041	0.0071
46-61 cm depth	1	0.0251	0.017	0.0162	0.0218	0.0118	0.0184	0.0166	0.0185		
	2	0.0191	0.0123	0.0196	0.0141	0.0164	0.0088	0.0137	0.0585	0.0154	0.0203
	3	0.0214	0.0151	0.0123	0.0182	0.0184	0.0115	0.0149	0.0188	0.0192	0.0166
	4	0.0217	0.0177	0.0171	0.0177	0.0162	0.0145	0.0147	0.0153	0.013	0.0282
	5	0.0241	0.0118	0.0103	0.0234		0.0155	0.0158	0.0152	0.018	
	Mean	0.0223	0.0148	0.0151	0.0190	0.0157	0.0137	0.0151	0.0253	0.0164	0.0217
	Std. Dev.	0.0024	0.0027	0.0038	0.0037	0.0028	0.0037	0.0011	0.0187	0.0028	0.0059
SOUTH BEACH	11	0.0093	0.0186	0.0219	0.0266						
0-15 cm depth	12	0.0265	0.0192	0.0241	0.0298	0.0304					
	13	0.0075	0.0092	0.0252	0.0201	0.0323					
	14	0.0071	0.0221	0.0205	0.0218						
	15	0.0083	0.0135	0.0108		0.0221					
	16	0.0107	0.0203	0.0197							
	Mean	0.0116	0.0172	0.0204	0.0246	0.0283					
	Std. Dev.	0.0082	0.0054	0.0057	0.0052	0.0054					
46 - 61 cm depth	11	0.0122	0.0312	0.0062	0.0133						
	12	0.0116	0.016	0.0141	0.0149	0.0182					
	13	0.0117	0.0129	0.0144	0.0118	0.0142					
	14	0.0118	0.0107	0.0107	0.0133						
	15	0.011	0.0144	0.0132		0.0166					
	16	0.014	0.0164	0.0144							
	Mean	0.0121	0.0169	0.0122	0.0133	0.0163					
	Std. Dev.	0.0011	0.0023	0.0016	0.0016	0.0020					

Table 1.3.**39**. Means and results of Bonferroni mean separation test on soil moisture. Untransformed means shown, Bonferroni run on log transformed means. Values with different lower case letters are significantly different.

Distance from coast (m)	**n** Crandon/ South Beach	**August**		**March**	
0-15 cm soil depth		*Crandon*	*South Beach*	*Crandon*	*South Beach*
6	5/6	0.027 a	0.042 a	0.013 a	0.012 a
19	5/6	0.049 abc	0.067 ab	0.016 ab	0.017 ab
32	5/6	0.030 ab	0.090 ab	0.018 ab	0.020 ab
45	5/4	0.038 abc	0.153 b	0.023 ab	0.024 b
58	5/3	0.038 abc	0.159 b	0.024 ab	0.028 b
71	5	0.042 abc		0.015 ab	
84	5	0.052 abc		0.016 ab	
97	5	0.062 bc		0.030 b	
110	4	0.063 bc		0.021 ab	
122	3	0.058 bc		0.025 ab	
41-61 cm soil depth					
6	5/6	0.055 ab	0.032 a	0.017 a	0.011 a
19	5/6	0.050 ab	0.046 ab	0.016 a	0.017 a
32	5/6	0.044 b	0.060 bc	0.014 a	0.020 a
45	5/4	0.044 ab	0.081 c	0.016 a	0.024 a
58	5/3	0.045 ab	0.087 c	0.016 a	0.028 a
71	5	0.042 b		0.014 a	
84	5	0.052 ab		0.015 a	
97	5	0.051 ab		0.025 a	
110	4	0.054 ab		0.016 a	
122	3	0.064 b		0.022 a	

Table 1.3.**40**. Results of Soil moisture ANOVA, site and depth analyzed separately, significant to P < 0.05.

SITE/Depth	**F**	**P**
0-15 cm soil depth		
CRANDON (df = 9, 37)		
August	4.44	0.001
March	3.13	0.01
SOUTH BEACH (df = 4, 20)		
August	6.81	0.01
March	6.05	0.01
41-61 cm soil depth		
CRANDON		
August	2.74	0.05
March	.70	ns
SOUTH BEACH		
August	15.00	0.0001
March	1.81	ns

Table 1.3.**41**. Change in sand height from start to finish of sampling period.

		DISTANCE (m) FROM ESTIMATED HIGH TIDE LINE									
SITE	**TRANSECT #**	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON	1	7	0	2	2	0	0	10			
	2	-2	6	5	3	1	0	5	3	3	
	3	11	2	21	0	6	0	5	1	2	0
	4	0	0	4	0	0	-2	0	1	2	
	5	1	1	0	-7	0	-2	0	0		
	Mean	3.4	1.8	6.4	-0.4	1.4	-0.8	4	1.25	2.33	0
	Std. Dev.	5.41	2.49	8.38	3.91	2.61	1.10	4.18	1.26	0.58	
SOUTH BEACH	11	-2	-2	0							
	12	56	-1	-1							
	13	-7	-22	1	0						
	14	-4	2	0							
	15	-3	1	-16							
	16	23	-5	1							
	Mean	10.5	-4.5	-2.5	0						
	Std. Dev.	24.83	8.92	6.66							

Table 1.3.**42**. Results of ANOVA absolute value of maximum change in sand height.

SITE	df	F	P
Crandon			
plot	9, 127	2.46	0.05
date	3, 127	22.67	0.0001
plot*date	27, 127	1.45	ns
South Beach			
plot	2, 45	5.41	0.01
date	2, 45	8.85	0.001
plot*date	4, 45	2.27	ns

Table 1.3.**43.** Maximum change in sand height, untransformed means shown, Bonferroni mean separation test run on square root transformed means. Values with different lower case letters are significantly different.

Distance from coast (m)	**Maximum change in sand height**	
	Crandon	*South Beach*
6	1.3 a	5.3 a
19	0.4 a	1.8 b
32	0.2 a	1.0 b
45	0.6 a	
58	0.5 a	
71	0.2 a	
84	0.5 a	
97	0.3 a	
110	0.6 a	
122	0.0 a	

Table 1.3.**44**. Salt spray readings per site, date and distance. Conductivity reported as µS/cm at 21ºC.

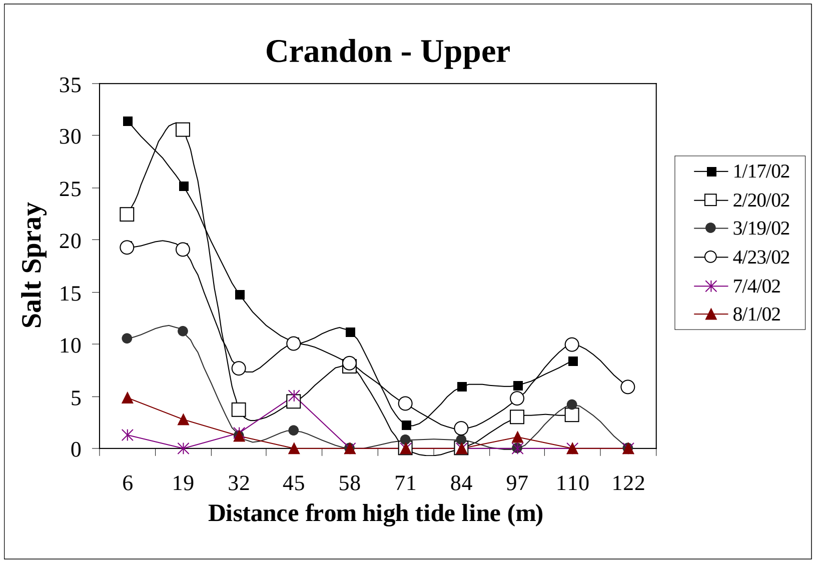
	DISTANCE(m) FROM THE ESTIMATED HIGH TIDE LINE									
SITE/DATE	**6**	**19**	**32**	**45**	**58**	**71**	**84**	**97**	**110**	**122**
CRANDON										
Upper/vertical										
1/17/02	31.45	25.15	14.80	10.17	11.24	2.32	5.93	6.07	8.43	
2/20/02	22.46	30.55	3.67	4.47	7.85	0.00	0.00	2.98	3.14	
3/19/02	10.48	11.16	1.18	1.67	0.00	0.79	0.82	0.00	4.19	0.00
4/23/02	19.28	19.04	7.64	10.04	8.11	4.26	1.85	4.78	9.87	5.81
7/4/02	1.24	0.00	1.49	5.08	0.00	0.00	0.00	0.00	0.00	0.00
8/1/02	4.85	2.73	1.18	0.00	0.00	0.00	0.00	1.05	0.00	0.00
Lower/horizontal										
1/17/02	0.00	2.69	2.93	4.88	3.26	4.29	8.32	4.13	9.37	
2/20/02	4.67	4.30	2.98	3.24	3.05	2.06	0.00	3.00	3.45	
3/19/02	1.53	3.86	1.63	1.51	0.00	0.00	0.68	1.06	1.81	0.00
4/23/02	7.93	12.51	4.93	8.20	6.71	9.72	4.41	6.59	10.99	12.50
7/4/02	0.00	0.00	1.88	0.00	0.00	0.00	1.00	0.74	2.27	0.00
8/1/02	0.00	0.00	1.34	1.77	1.24	0.00	2.73	0.00	0.00	0.00

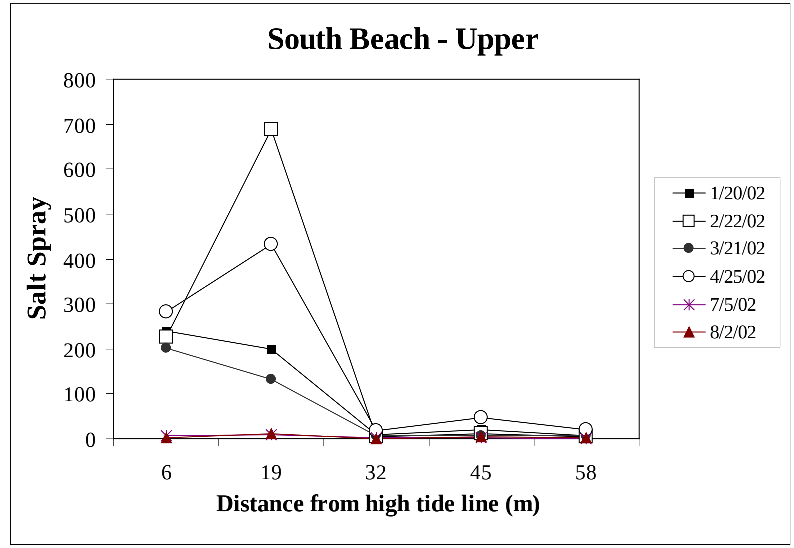
SOUTH BEACH					
Upper/vertical					
1/20/02	239.50	199.50	9.64	20.55	5.98
2/22/02	226.50	688.50	4.18	10.10	5.37
3/21/02	201.82	131.87	5.68	6.26	6.21
4/25/02	281.50	431.45	18.30	46.01	21.07
7/5/02	6.95	8.07	1.15	1.29	0.00
8/2/02	2.99	10.95	0.45	3.61	1.50
Lower/horizontal					
1/20/02	3.54	7.46	26.30	23.30	12.10
2/22/02	1.88	5.36	17.16	9.56	7.14
3/21/02	59.60	42.26	36.28	30.73	13.37
4/25/02	69.77	109.12	62.42	28.94	28.47
7/5/02	1.52	6.59	0.80	2.61	0.00
8/2/02	2.68	9.39	3.47	3.79	3.50

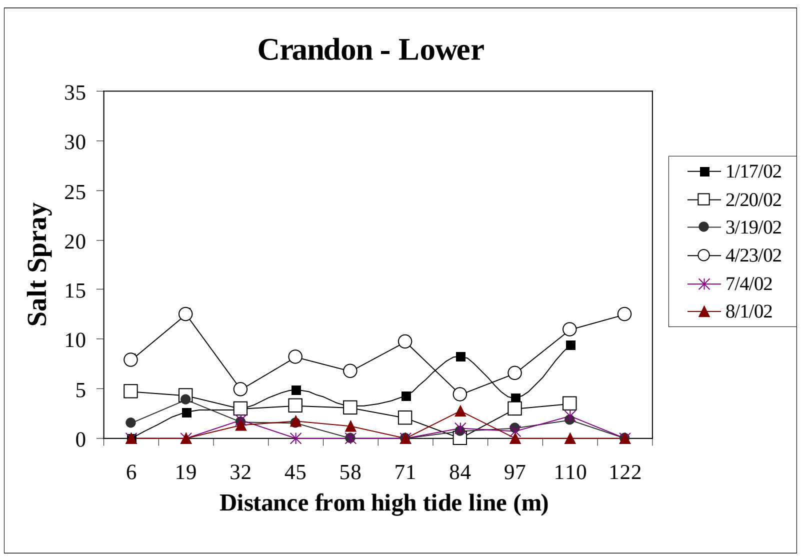
Table 1.3.**45** Results of upper/vertical and lower/horizontal salt spray samples ANOVA: plot X date, significant to P < 0.05.

SITE	df	F	P
Crandon			
Upper/vertical	9, 146	20.61	0.0001
plot	5, 146	47.22	0.0001
date	43, 146	2.29	0.0001
plot*date			
Lower/horizontal			
plot	9, 146	1.08	ns
date	5, 146	36.17	0.0001
plot*date	43, 146	1.26	Ns
South Beach			
Upper/vertical			
plot	4, 93	35.44	0.0001
date	5, 93	20.20	0.0001
plot*date	20, 93	3.83	0.0001
Lower/horizontal			
plot	4, 93	1.66	ns
date	5, 93	36.74	0.0001
plot*date	20, 93	1.57	ns

Figure 1.3.**9**. Salt spray(μS/cm) readings per date and site for upper/vertical and lower/horizontal sampling units.







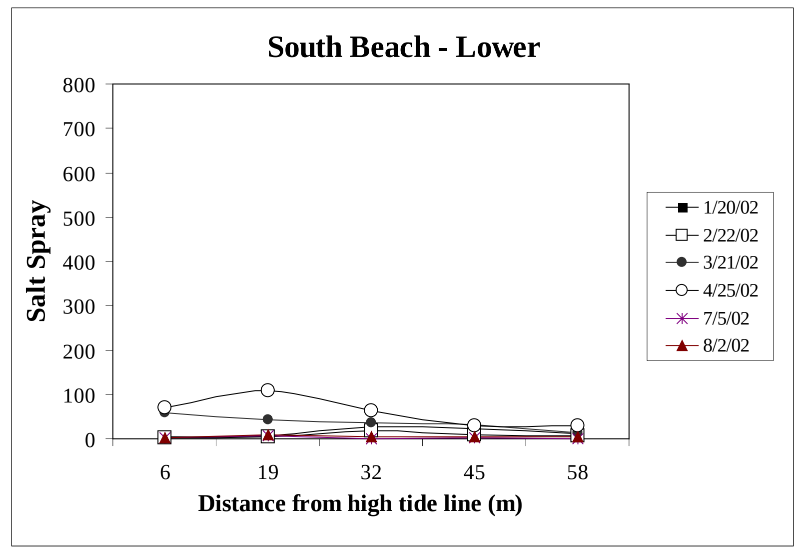
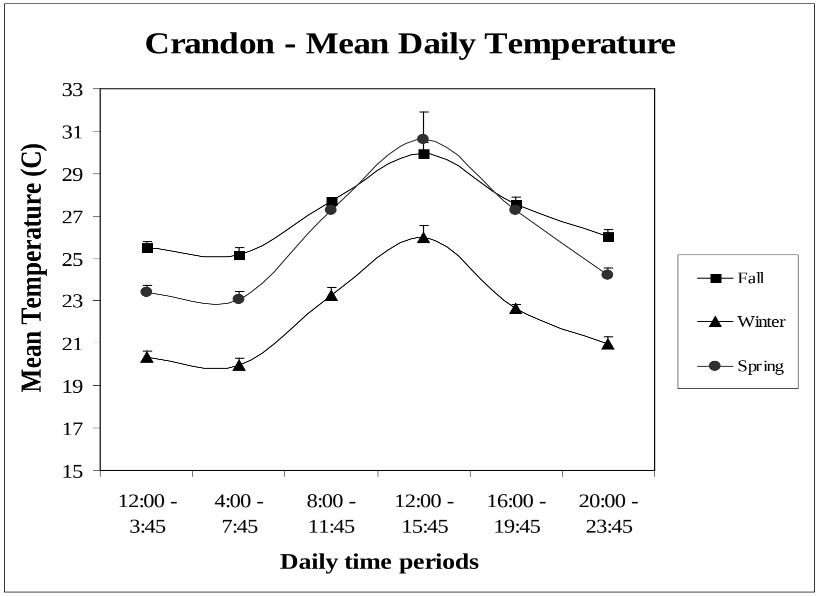
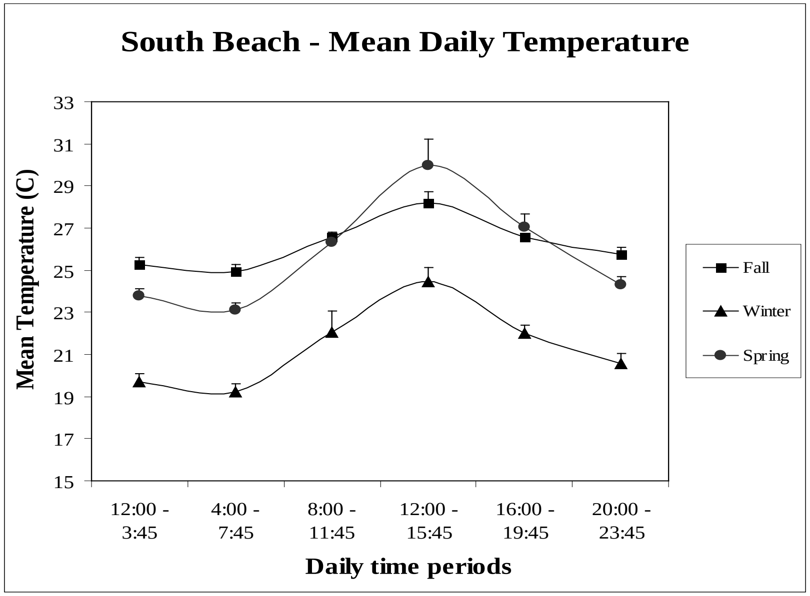
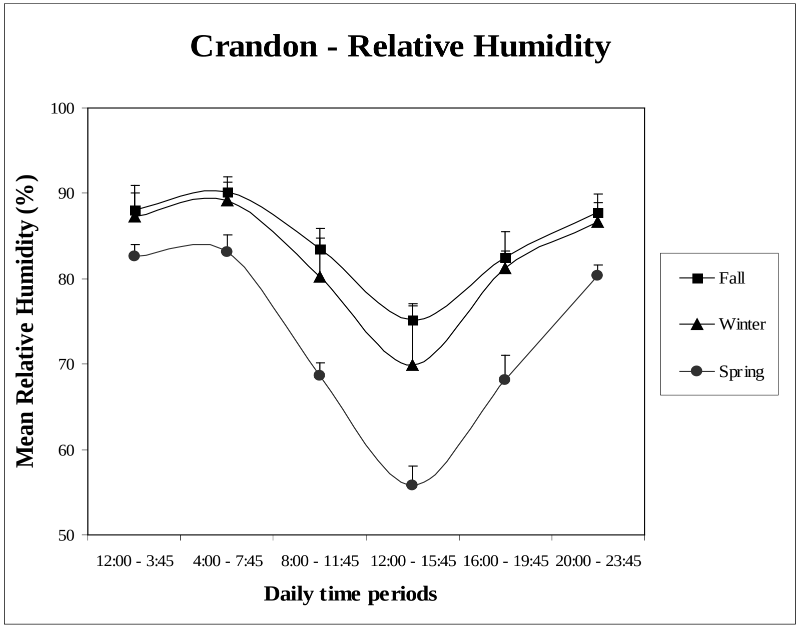


Figure 1.3.**10**. Average temperature and humidity from Hobo data loggers, per site for three seasons.







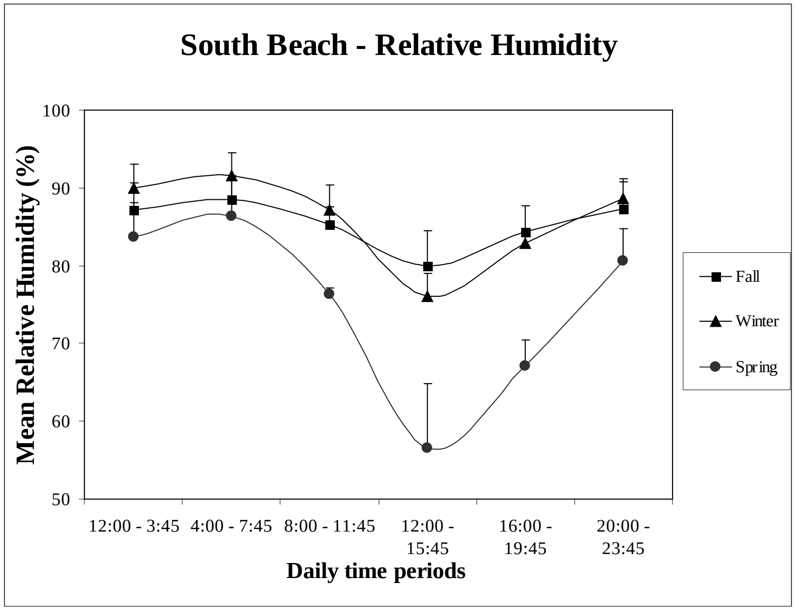


Figure 1.3.**11**. DCA plot, Axis 1 and 2, for Crandon vegetation plots and environmental variables measured.

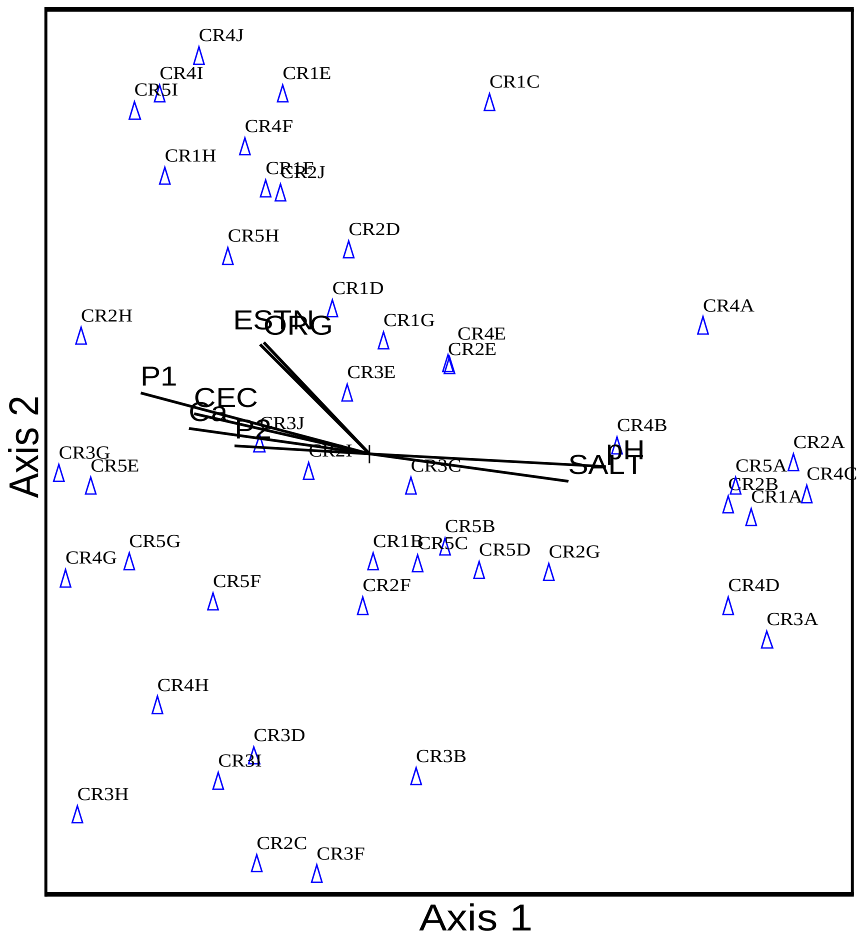
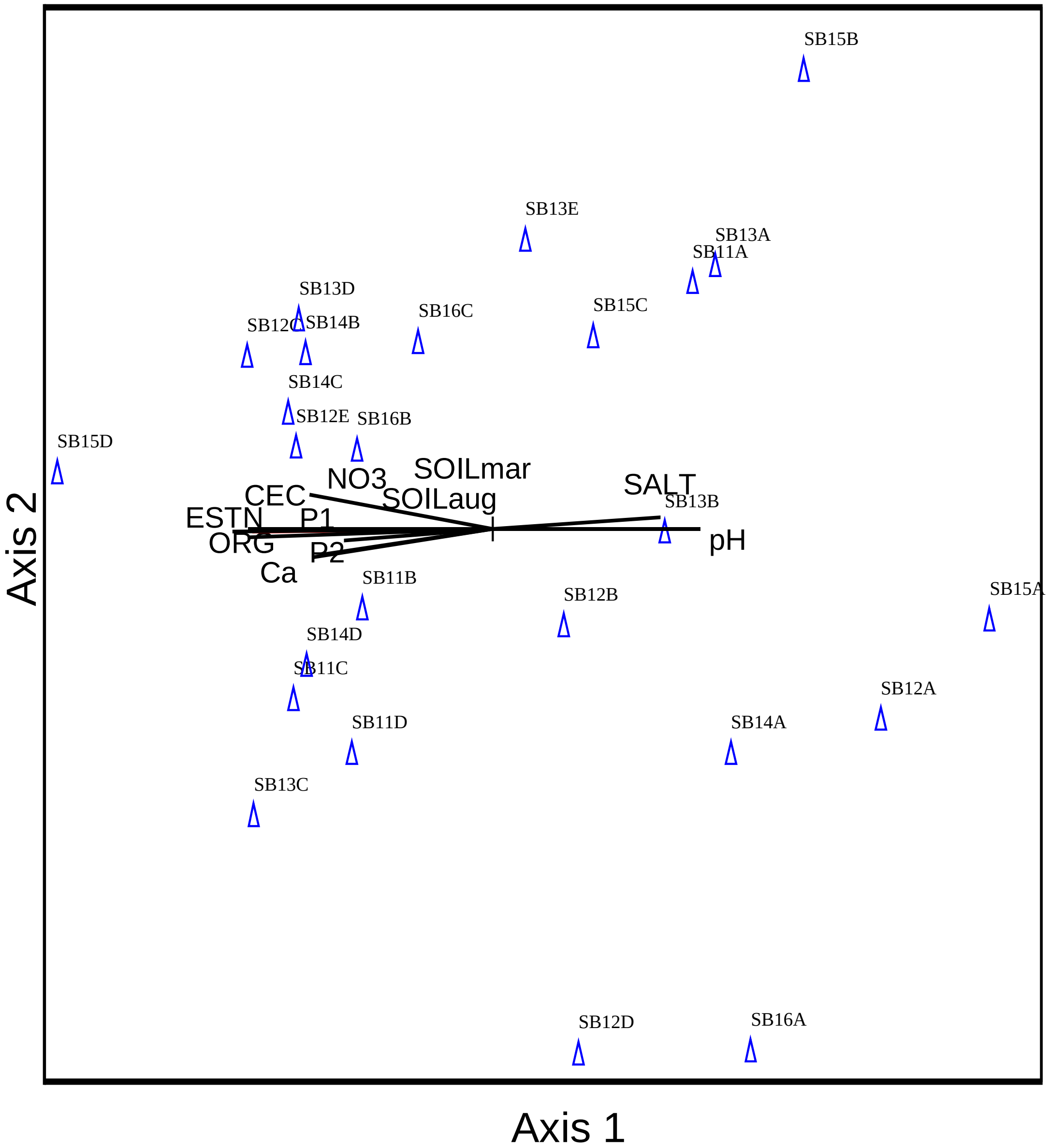


Figure 1.3.**12**. DCA plot, Axis 1 and 2, for South Beach vegetation plots and environmental variables measured.



Output 1.4 Develop site vegetation maps from aerial imagery and analysis of vegetation plot data. – Samuel J. Wright

Through the use of GIS technology, FTG researchers have mapped the locations of the remaining *J. reclinata* individuals and populations (Output 1 introduction). This information has increased our understanding of the distribution and abundance of the species. Since each site where *J. reclinata* occurs is in its own way environmentally distinct, it is important to classify associated vegetation coverage as well as species diversity at each site. Such data can be used to rank potential restoration sites and develop restoration and management plans. Completed site vegetation maps have been incorporated into existing GIS databases and maps distributed to associated land managers.

Methods

Study sites

Sites surrounding the seven originally known wild populations of *J. reclinata* and one site supporting an outplanting were selected for vegetation mapping. These sites include Bill Baggs State Recreation Area and Crandon Park in Miami-Dade County; Hugh Taylor Birch State Park in Broward County; and South Inlet Park, South Beach Park, Red Reef Park, Loggerhead Park and Carlin Park in Palm Beach County. Due to time constraints, the three rediscovered populations have not been included in this report.

Aerial Photography

Aerial photographs were obtained from the Miami-Dade County Public Access Information Technology Department and the National Geodetic Information Center of the National Oceanic Atmospheric Administration. Photos were scanned with a AFGA® Duoscan model T1200 scanner and used to visually identify general vegetation stand composition and boundaries with ArcView GIS 3.2. Photos of each site were printed out at an approximate scale of 1:1000, laminated and used during groundtruthing surveys of each site.

Vegetation sampling

The semi-quantitative rapid assessment (RA) and releve' (Sawyer and Keeler-Wolf 1995) sampling methods were implemented to classify vegetation and estimate coverage using ocular estimates. These methods were used together to quickly classify vegetation and habitats over a large area. Each site received reconnaissance visits in which vegetation stands (units of vegetation) identified on aerial photographs were groundtruthed. Upon starting the RA, stands of vegetation and boundaries needed to be identified. Areas were surveyed for vegetation and habitat homogeneity. Stands were determined to be homogenous if vegetation structure and composition were similar throughout. Once stand integrity was determined, stands were classified into three categories—coastal beach dune, coastal strand, and maritime hammock—according to descriptions used by the Florida Natural Areas Inventory (http://www.fnai.org). Depending on vegetation composition some sites may have more than one habitat stand per category. Through the ocular surveys during the RA, a species list was compiled for each vegetation stand ranking the ten most dominant species in order by abundance within each stand. Estimated percent cover was determined only for the top three species within each stand according to the following coverage classes: 1%, 1-5%, 5-10%, 10-25%, 25-50%, 50-75%, and 75-100%. Stand classification and boundaries were documented on laminated maps. This information was utilized when digitizing stand categories onto vegetation coverage maps.

After completion of the RA, a 15 x 15 m releve' plot was selected within stands to conduct a complete vegetation census per stand A plot was selected that best represented each strand in plant composition integrity. Not every stand received a releve plot, only those with existing, potential or adjacent *J. reclinata* habitat. Plots in coastal strand and hammock stands were excluded if species composition consisted of one dominant species (>50%). Plot size was selected based on preliminary vegetation sampling. Because of the size of some stands, plots of one type sometimes overlapped with adjacent stands. Measures were taken to capture as much of the represented stand as possible. In each plot, total cover of each life form and species was estimated by visual surveys. Life forms were categorized as woody (three heights: 0 – 0.5m, 0.5 – 2m, and >2m), vine, graminoid (grasses and sedges) and forb (herbaceous plants). Using the same methods as described above in the RA method, data related to % coverage was documented.

Coordinates of all plots and stand areas have been documented using GIS equipment (Output 1 intro) and incorporated into GIS databases. This data in combination with documented stand coverage from laminated maps was used when digitizing stand coverages onto georeferenced aerial photographs using ArcView software. Species, species coverage, habitats, and habitat area acreage are reported (Tables 1.4.**1** - 1.4.**16**). Area % coverage is reported as the mean value of % cover classes**.** Also an ArcView user interface has been created to allow researchers to query species, coverages and area databases that are connected with the maps. These databases will be housed at FTG's GIS laboratory and hard copies of the information will be provided to the land managers.

Conclusions

To characterize the site vegetation we surveyed 36 habitat stands within eight coastal sites totaling128.38 acres of existing or adjacent *Jacquemontia reclinata* habitat. Number of stands per site ranged from 1 (Hugh Taylor Birch) to 6(multiple sites); sizes of stands, species diversity and abundance varied throughout all sites; coastal strand habitat had the highest diversity of all habitat types. Occasionally vegetation structure and composition overlapped between stands, blurring habitat boundaries, and it became difficult to define a habitat simply as coastal dune, coastal strand, or hammock In these cases stands were acknowledged as transition zones (e.g. coastal strand/ hammock). We also found variation within the same habitat type at a single site; so that some sites (e.g. Crandon Park) had multiple stands of coastal strand habitat (Table 1.4.**3**). Due to the predominance of mature hammocks and the absence of coastal strand habitat we surveyed only a single stand at Hugh Taylor Birch State Park. We found two areas within Hugh Taylor that could be restored to coastal strand habitat (Appendix A, map A37), one of which (site 2) was once designated as a possible site for reintroduction (Lippincott 1990).

Although coastal strands was found to be the most diverse habitat type, stands of this habitat were not large in size, and this may be due to the encroachment of maritime hammock vegetation. Without the natural process of fire, which is thought to have once occurred every 4-5 years in coastal strand (Austin et al. 1977), open coastal strand habitat might not be able to persist. From our surveys, we conclude that without disturbance, natural or anthropogenic, the open coastal strand habitat will eventually give way to hardwood hammock species. Land managers may have to resort to manual removal of hardwood species in order to maintain open strand-type areas.

References

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Sawyer, J. O., and T. Keehler-Wolfe, 1995. Manual of California Vegetation, California Native Plant Society, Sacramento, CA.

Table 1.4.**1**. Bill Baggs species list by habitat compiled during site vegetation rapid assessment survey. Estimated percent cover was determined only for the top three species within each stand according to the following coverage classes: 1%, 1-5%, 5-10%, 10-25%, 25-50%, 50-75%, and 75-100%.

Community/Habitat Type	**Total acres surveyed**
Coastal Dune	19.40
Coastal Strand 1	4.14
Coastal Strand 2	8.10
Hammock 1	16.60
Hammock 2	14.78

Community/Habitat Type	**Species by abundance**	**% cover**			
Coastal Dune	*Uniola paniculata*	37.5	Hammock 1	*Coccoloba uvifera*	62.5
	Panicum amarum	37.5		*Caesalpinia bonduc*	17.5
	Iva imbricata	17.5		*Ficus aurea*	7.5
	Ipomoea pes-caprae ssp. brasiliensis			*Lantana involucrata*	
	Coccoloba uvifera			*Lantana cf. camara*	
	Trichostema dichotomum & Croton pumila			*Dalbergia ecastaphyllum*	
	Sesuvium portulacastrum			*Parthenocissus quinquefolia*	
	Suriana maritima			*Scaevola sericea*	
	Croton punctatus			*Bidens alba var. radiata*	
	Helianthus debilis			*Cestrum diurnum*	
Coastal Strand 1	*Lantana involucrata*	37.5	Hammock 2	*Conocarpus erectus*	37.5
	Bidens alba var. radiata	37.5		*Bidens alba var. radiata*	37.5
	Helianthus debilis	17.5		*Bursera simaruba*	17.5
	Serenoa repens			*Coccoloba diversifolia*	
	Lantana cf. camara			*Coccoloba uvifera*	
	Caesalpinia bonduc			*Sabal palmetto*	
	Coccoloba uvifera			*Ambrosia artemisiifolia*	
	Baccharis halimifolia			*Ficus aurea*	
	Eustachys petraea			*Parthenocissus quinquefolia*	
	Spermacoce verticillata			*Forestiera segregata*	
Coastal Strand 2	*Verbesina virginica*	62.5			
	Eupatorium capillifolium	17.5			
	Baccharis halimifolia	17.5			
	Mentzelia floridana				
	Ambrosia artemisiifolia				
	Cestrum diurnum				
	Bidens alba var. radiata				
	Ficus aurea				
	Helianthus debilis				

Table 1.4.**2**. Bill Baggs species list of habitats collected from releve' plots.

	Community/ Habitat Type	
Species	**Coastal Dune**	**Coastal Strand 1**
Alternanthera flavescens		x
Ambrosia artemisiifolia	x	x
Bidens alba var. radiata		x
Caesalpinia bonduc	x	
Canavalia rosea		x
Cha nictitans var. aspera	x	
Chamaesyce mesembrianthemifolia	x	
Chamaesyce ssp.	x	x
Cnidoscolus stimulosus	x	
Coccoloba uvifera	x	x
Cocos nucifera	x	
Conocarpus erectus		x
Crotalaria pumila	x	x
Croton punctatus	x	x
Cyperus pedunculatus		x
Dactyloctenium aegyptium	x	x
Eugenia foetida		x
Eustachys petraea	x	x
Fimbristylis cymosa	x	
Helianthus debilis	x	x
Hymenocallis latifolia		x
Ipomoea pes-caprae		x
Iva imbricata	x	
Lantana involucrata	x	x
Panicum amarum	x	
Parthenocissus quinquefolia		x
Polygala grandiflora	x	x
Randia aculeata		x
Saltgrass complex	x	x
Scaevola plumieri	x	
Serenoa repens		x
Sida acuta		x
Spermacoce verticillata		x
Stenotaphrum secundatum		x
Suriana maritima		x
Trichostema dichototum	x	x
Uniola paniculata	x	x
Unknown shrub		x

Table 1.4.**3**. Crandon Park species list by habitat compiled during site vegetation rapid assessment survey. Estimated percent cover was determined only for the top three species within each stand according to the following coverage classes: 1%, 1-5%, 5-10%, 10-25%, 25-50%, 50-75%, and 75-100%.

Community/Habitat Type	**Total acres**	**Community/Habitat Type**	**Total acres**
Coastal Dune	4.507	Coastal Strand 3	8.336
Coastal Strand 1	3.207	Disturbed Coastal Strand	3.759
Coastal Strand 2	2.638	Coastal Strand Hammock	8.035

Community/Habitat Type	**Species**	**% cover**			
Coastal Dune	*Uniola paniculata*	87.5	Coastal Strand 3	*Sabal palmetto*	37.5
	Iva imbricata	7.5		*Serenoa repens*	17.5
	Coccoloba uvifera	3.0		*Metopium toxiferum & Myrica cerifera*	7.5
	Ipomoea pes-caprae ssp. brasiliensis			*Randia aculeata*	
	Helianthus debilis			*Dalbergia ecastaphyllum*	
	Cakile lanceolata			*Coccoloba uvifera*	
	Croton punctatus			*Lantana cf. camara*	
	Lantana cf. camara			*Smilax auriculata*	
	Scaevola plumieri			*Caesalpinia bonduc*	
	Sesuvium portulacastrum			*Eugenia foetida*	
Coastal Strand 1	*Caesalpinia bonduc*	62.5	Distributed Strand	*Dalbergia ecastaphyllum*	87.5
	Bidens alba var. radiata	32.5		*Parthenocissus quinquefolia*	62.5
	Panicum amarum	17.5		*Caesalpinia bonduc*	37.5
	Helianthus debilis			*Zanthoxylum clava-herculis*	
	Cassytha filiformis			*Rhus copallinum*	
	Trema micranthum			*Trema micranthum*	
	Coccoloba uvifera			*Helianthus debilis*	
	Serenoa repens			*Coccoloba uvifera*	
	Pithecellobium keyense			*Sabal palmetto*	
	Conocarpus erectus			*Lantana cf. camara*	
Coastal Strand 2	*Smilax auriculata*	32.5	Coastal Strand/ Hammock	*Rhus copallinum*	37.5
	Metopium toxiferum	17.5		*Coccoloba uvifera*	17.5
	Coccoloba uvifera	17.5		*Trema micranthum*	17.5
	Serenoa repens			*Vitus rotundifolia*	
	Pithecellobium keyense			*Smilax auriculata*	
	Lantana cf. camara			*Sabal palmetto*	
	Eugenia foetida			*Pithecellobium keyense*	
	Sabal palmetto			*Parthenocissus quinquefolia*	
	Guapira discolor			*Metopium toxiferum*	
	Trema micranthum			*Lantana cf. camara*	

Table 1.4.**4**. Crandon Park species list of habitats collected from releve' plots.

	Community/ Habitat Type			
Species	**Coastal Dune**	**Coastal Strand 2**	**Coastal Strand 3**	**Coastal Strand/ Hammock**
Alternanthera flavescens		x	x	x
Alternanthera flavescens	x	x	x	x
Ardisia escallonioides				x
Bidens alba var. radiata	x	x	x	x
Caesalpinia bonduc		x	x	
Callicarpa americana		x		
Canavalia rosea		x		x
Cassytha filiformis			x	
Catharanthus rosea		x	x	x
Cenchrus incertus		x	x	
Chamaecrista nictitans var. aspera	x		x	x
Chamaesyce mesembrianthemifolia	x			
Chamaesyce ssp.	x		x	
Chromolaena odorata			x	
Cnidoscolus stimulosus	x	x	x	x
Coccoloba uvifera	x	x	x	x
Coccothrinax argentata		x	x	
Commelina erecta				x
Conyza canadensis			x	
Crotalaria pumila	x		x	x
Croton glandulosus			x	x
Croton punctatus	x			
Cyperus planifolius				x
Cyperus tetragonus			x	
Dactyloctenium aegyptium		x	x	x
Dalbergia ecastaphyllum			x	
Dalea carthagenensis var. floridana				x
Desmodium tortuosum	x		x	
Eugenia axillaris				x
Eugenia foetida			x	
Eustachys petrae	x	x	x	
Ficus aurea		x	x	
Galactia volubilis	x	x	x	x
Galium hispidulum				x
Guapira discolor		x		
Helianthus debilis	x	x	x	x
Ipomoea indica		x	x	
Ipomoea pes-caprae ssp. brasiliensis	x		x	
Iva imbricata	x			
Lantana cf. camara	x	x	x	
Lantana involucrata	x	x	x	x
Melanthera nivea			x	x
Mentzelia floridana		x		
Metopium toxiferum		x	x	x
Myrica cerifera				x
Nephrolepis exalata		x		

Table 1.4.**4** cont.

	Community/ Habitat Type			
Species	**Coastal Dune**	**Coastal Strand 2**	**Coastal Strand 3**	**Coastal Strand/ Hammock**
Panicum amarum	x	x	x	
Parthenocissus quinquefolia		x		x
Paspalum setaceum			x	
Passiflora suberosa			x	x
Physalis walteri	x	x	x	x
Pithecellobium keyense		x	x	x
Poinsettia cyathophora		x	x	
Polygala grandiflora	x		x	
Psychotria nervosa				x
Randia aculeata		x	x	x
Rhus copallinum				x
Rhynchelytrum repens			x	x
Sabal palmetto		x	x	x
Saltgrass complex	x	x	x	
Schinus terebinthifolius		x	x	x
Serenoa repens			x	
Setaria macro		x	x	
Setaria parviflora			x	
Sida acuta		x	x	x
Smilax auriculata	x	x	x	x
Stenotaphrum secundatum			x	x
Trema micranthum		x		
Trichostema dichotomum			x	x
Uniola paniculata	x			
Verbesina virginica		x		x
Vigna luteola	x			
Vitus rotundifolia			x	
Yucca aloifolia	x	x		
Zamia pumila		x		

Table 1.4.**5**. Hugh Taylor Birch top ten species of coastal strand habitat compiled during RA survey

Community/Habitat Type	Total acres surveyed
Coastal Strand	1.276

Community/Habitat Type	Species by abundance	% cover
Coastal Strand	*Coccoloba uvifera*	62.5
	Metopium toxiferum	32.5
	Abrus precatorius	32.5
	Pithecellobium keyense	
	Sabal palmetto	
	Eugenia foetida	
	Simarouba glauca	
	Licania michauxii	
	Lantana involucrata	
	Zanthoxylum clava-herculis	

Table 1.4.**6**. Hugh Taylor Birch species list of coastal strand habitat containing *J. reclinata.* Data collected from releve' plots.

Species within Coastal Strand habitat	
Abrus precatorius	*Polygala grandiflora*
Bidens alba	*Psychotria nervosa*
Boerhavia diffusa	*Rhynchelytrum repens*
Catharanthus rosea	*Sabal palmetto*
Cnidoscolus stimulosus	*Schinus terebinthifolius*
Coccoloba uvifera	*Simarouba glauca*
Coccothrinax argentata	*Smilax auriculata*
Coco nucifera	*Stenotaphrum secundatum*
Crotalaria pumila	*Trichostema dichotomum*
Dactyloctenium aegyptium	*Zanthoxylum clava-herculis*
Ernodea littoralis	
Eugenia foetida	
Eustachys petrae	
Forestiera segregata	
Galactia volubilis	
Galium hispidulum	
Helianthus debilis	
Jacquemontia reclinata	
Lantana cf. camara	
Lantana involucrata	
Metopium toxiferum	
Opuntia stricta	
Parthenocissus quinquefolia	

Psychotria nervosa

Table 1.4.**7**. South Inlet top ten species list by habitat compiled during site vegetation rapid assessment survey

Community/Habitat Type	**Total acres surveyed**
Coastal Dune	0.599
Coastal Strand 1	0.082
Coastal Strand 2	0.103
Coastal Strand 3	0.150
Hammock	1.802

Community/Habitat Type	**Species**	**% cover**
Coastal Dune	*Uniola paniculata*	87.5
	Canavalia rosea	17.5
	Panicum amarum	17.5
	Iva imbricata	
	Ipomoea pes-caprae ssp. brasiliensis	
	Dalbergia ecastaphyllum	
	Blutaparon vermiculare	
	Chamaesyce cumulicola	
	Bidens alba var. radiata	
	Cyperus pedunculatus	
Coastal Strand 1	*Stenotaphrum secundatum*	37.5
	Bidens alba var. radiata	17.5
	Okenia hypogaea	17.5
	Panicum amarum	
	Spartina patens	
	Canavalia rosea	
	Blutaparon vermiculare	
	Lantana involucrata	
	Schinus terebinthifolius	
	Helianthus debilis	
Coastal Strand 2	*Cyperus pedunculatus*	7.5
	Dactyloctenium aegyptium	7.5
	Canavalia rosea	3.0
	Helianthus debilis	
	Iva imbricata	
	Uniola paniculata	
	Alternanthera flavescens	
	Crotalaria pumila	
	Commelina erecta	
	Lantana cf. camara	
Coastal Strand 3	Saltgrass complex	na
	Panicum amarum	na
	Bidens alba var. radiata	na
	Catharanthus roseus	
	Coccoloba uvifera	
	Helianthus debilis	
	Lantana involucrata	
	Canavalia rosea	
	Ambrosia artemisiifolia	
	Poinsettia cyathophora	
Hammock	*Coccoloba uvifera*	87.5
	Smilax auriculata	62.5
	Parthenocissus quinquefolia	37.5
	Stenotaphrum secundatum	
	Bidens alba var. radiata	
	Canavalia rosea	
	Alternanthera flavescens	
	Ipomoea indica var. acuminata	
	Sabal palmetto	
	Sophora tomentosa var. truncata	

Table 1.4.**8** South Inlet species list of habitats collected from Releve' plots.

	Community/ Habitat Type			
Species	**Coastal Dune**	**Coastal Strand 1**	**Coastal Strand 2**	**Coastal Strand 3**
Alternanthera flavescens	x	x	x	x
Ambrosia artemisiifolia				x
Bidens alba var. radiata	x	x	x	x
Caesalpinia bonduc	x			
Canavalia rosea	x	x	x	x
Catharanthus rosea				x
Cenchrus incertus	x		x	x
Chamaesyce cumulicola	x		x	
Chamaecrista nictitans var. aspera			x	
Chamaesyce mesembrianthemifolia	x			
Cnidoscolus stimulosus		x	x	x
Coccoloba uvifera	x	x	x	x
Commelina erecta		x	x	x
Crotalaria pumila			x	
Croton glandulosus				x
Cyperus pedunculatus	x	x	x	
Dactyloctenium aegyptium			x	x
Desmodium tortuosum	x			
Galactia volubilis	x	x	x	x
Helianthus debilis		x	x	x
Ipomoea indica		x	x	x
Ipomoea violacea	x			
Ipomoea pes-caprae ssp. brasilensis		x		
Iva imbricata	x		x	x
Jacquemontia reclinata				x
Lantana cf. camara		x	x	
Lantana involucrata		x	x	x
Metopium toxiferum			x	
Okenia hypogaea		x		x
Panicum amarum	x	x		x
Parthenocissus quinquefolia		x	x	x
Passiflora suberosa		x		
Poinsettia cyathophora	x	x		x
Polygala grandiflora	x			
Rhynchelytrum minima				x
Sabal palmetto				x
Saltgrass complex	x	x	x	x
Schinus terebinthifolius		x		x
Sesuvium portulacastrum		x	x	
Smilax auriculata		x		
Spartina patens		x		
Stenotaphrum secundatum	x	x	x	
Tribulus cistoides		x		
Uniola paniculata	x		x	

Table 1.4.**9**. South Beach top ten species list by habitat compiled during site vegetation rapid assessment survey

Community/Habitat Type	**Total acres surveyed**		
Coastal Dune	1.848	Gumbo Limbo Hammock	0.302
Coastal Strand/ Hammock	1.871	Coccoloba Hammock	5.247

Community/Habitat Type	**Species by abundance**	**% cover**			
Coastal Dune	*Uniola paniculata*	87.5	Gumbo Limbo Hammock	*Bursera simaruba*	87.5
	Iva imbricata	17.5		*Serenoa repens*	87.5
	Ipomoea pes-caprae ssp. brasiliensis	7.5		*Coccoloba uvifera*	17.5
	Panicum amarum			*Psychotria nervosa*	
	Scaevola plumieri			*Ficus citrifolia*	
	Helianthus debilis			*Rivina humilis*	
	Coccoloba uvifera			*Callicarpa americana*	
	Sesuvium portulacastrum			*Vitus rotundifolia*	
	Cnidoscolus stimulosus			*Ardisia escallonioides*	
	Cenchrus incertus			*Sansevieria hyacinthoides*	
Coastal Strand/ Hammock	*Serenoa repens*	62.5	Coccoloba Hammock	*Coccoloba uvifera*	87.5
	Schinus terebinthifolius	37.5		*Smilax auriculata*	37.5
	Smilax auriculata	37.5		*Parthenocissus quinquefolia*	17.5
	Pithecellobium keyense			*Serenoa repens*	
	Psychotria nervosa			*Canavalia rosea*	
	Ardisia elliptica			*Pithecellobium keyense*	
	Alternanthera flavescens			*Sabal palmetto*	
	Schefflera actinophylla			*Schinus terebinthifolius*	
	Randia aculeata			*Sansevieria hyacinthoides*	
	Conocarpus erectus			*Scaevola sericea*	

Table 1.4.**10**. South Beach species list of habitats collected from releve' plots.

Species within coastal dune	
Alternanthera flavescens	*Helianthus debilis*
Boerhavia diffusa	*Ipomoea pes-caprae ssp. brasilensis*
Canavalia rosea	*Iva imbricata*
Cenchrus incertus	*Jacquemontia reclinata*
Cnidoscolus stimulosus	*Opuntia humifusa*
Coccoloba uvifera	*Panicum amarum*
Commelina erecta	*Polygala grandiflora*
Crotalaria pumila	Saltgrass complex
Croton glandulosus	*Uniola paniculata*
Cyperus pedunculatus	*Vigna luteola*
Galactia volubilis	

Table 1.4.**11**. Red Reef top ten species list by habitat compiled during site vegetation rapid assessment survey

Community/Habitat Type	**Total acres surveyed**
Coastal (Fore)dune	0.452
Coastal Dune	1.706
Coastal Strand/ Hammock	4.450
Coccoloba Hammock	4.092

Community/Habitat Type	**Species by abundance**	**% cover**
Coastal (Fore)dune	*Sesuvium portulacastrum*	37.5
	Saltgrass complex	17.5
	Canavalia rosea	17.5
	Okenia hypogaea	
	Iva imbricata	
	Ipomoea pes-caprae ssp. brasiliensis	
	Dactyloctenium aegyptium	
	Cenchrus incertus	
	Chamaesyce ssp.	
	Uniola paniculata	
Coastal Dune	*Uniola paniculata*	62.5
	Helianthus debilis	37.5
	Bidens alba var. radiata	17.5
	Canavalia rosea	
	Panicum amarum	
	Ipomoea pes-caprae ssp. brasiliensis	
	Spartina patens	
	Alternanthera flavescens	
	Dactyloctenium aegyptium	
	Sophora tomentosa var. truncata	
Coastal Strand/ Hammock	*Coccoloba uvifera*	37.5
	Schinus terebinthifolius	17.5
	Scaevola sericea	17.5
	Serenoa repens	
	Conocarpus erectus	
	Parthenocissus quinquefolia	
	Caesalpinia bonduc	
	Sophora tomentosa var. truncata	
	Scaevola plumieri	
	Cocos nucifera	
Hammock	*Coccoloba uvifera*	87.5
	Capparis cynophallophora	17.5
	Ardisia escallonioides	17.5
	Myrcianthes fragrans	
	Eugenia axillaris	
	Conocarpus erectus	
	Sabal Palmetto	
	Coccoloba diversifolia	
	Psychotria nervosa	
	Callicarpa americana	

Table 1.1.**12.** Red Reef species list of habitats collected from releve' plots.

	Community/ Habitat Type	
Species	**Coastal Dune**	**Coastal Strand/ Hammock**
Agave ssp.	x	
Alternanthera flavescens	x	
Amyris elemifera		x
Ardisia escallonioides		x
Bidens alba var. radiata	x	
Canavalia rosea	x	x
Chamaecrista nictitans var. aspera	x	
Cnidoscolus stimulosus	x	
Coccoloba uvifera	x	x
Cocos nucifera	x	x
Crotalaria pumila	x	
Dactyloctenium aegyptium	x	
Galactia volubilis	x	
Helianthus debilis	x	
Ipomoea indica	x	x
Ipomoea violacea	x	
Ipomoea pes-caprae ssp. brasilensis	x	x
Iva imbricata	x	
Jacquemontia reclinata	x	
Lantana cf. camara	x	
Lantana involucrata	x	
Metopium toxiferum		x
Opuntia humifusa	x	
Parthenocissus quinquefolia	x	x
Passiflora suberosa		x
Polygala grandiflora	x	
Randia aculeata		x
Scaevola sericea	x	
Serenoa repens		x
Sesuvium portulacastrum	x	
Sophora tomentosa	x	x
Tribulus cistoides		x
Uniola paniculata	x	
Yucca aloifolia	x	
Zanthoxylum fagara		x

Table 1.4.**13**. Loggerhead Park top ten species list by habitat compiled during site vegetation survey. [1] Sampling was completed before exotic removal from area.

Community/Habitat Type	**Total acres surveyed**
Coastal Dune	0.226
Coccoloba Hammock	0.930
Schinus Hammock[1]	1.081
Coastal Strand/ Scrub	2.730

Community/Habitat Type	**Species by abundance**	**% cover**
Coastal Dune	*Uniola paniculata*	62.5
	Canavalia rosea	37.5
	Panicum amarum	17.5
	Ipomoea pes-caprae ssp. brasiliensis	
	Vigna luteola	
	Iva imbricata	
	Cyperus pedunculatus	
	Helianthus debilis	
	Dalbergia ecastaphyllum	
	Chamaesyce cumulicola	
Coccoloba Hammock	*Coccoloba uvifera*	87.5
	Panicum amarum	17.5
	Morinda royoc	7.5
	Sansevieria hyacinthoides	
	Verbesina virginica	
	Stenotaphrum secundatum	
	Casuarina equisetifolia	
	Ipomoea violacea	
	Sabal palmetto	
	Schinus terebinthifolius	
Schinus Hammock	*Schinus terebinthifolius*	87.5
	Simarouba glauca	17.5
	Rapanea punctata	7.5
	Morinda royoc	
	Abrus precatorius	
	Sansevieria hyacinthoides	
	Chiococca alba	
	Scaevola sericea	
	Persea borbonia and Psychotria nervosa	
Coastal Strand/ Scrub	*Quercus geminata*	37.5
	Serenoa repens	37.5
	Cassytha filiformis	37.5
	Persea borbonia	
	Sabal palmetto	
	Ximenia americana	
	Smilax auriculata	
	Chamaecrista nictitans var. aspera	
	Rhynchelytrum repens	
	Bidens alba var. radiata	

Table 1.1.**14**. Loggerhead species list of habitats collected from Releve' plots.

	Community/ Habitat Type	
Species	**Coastal Dune**	**Coastal Strand/ Scrub**
Abrus precatorius		x
Alternanthera flavescens		x
Andropogon glomeratus		x
Ardisia escallonoides		x
Boerhavia diffusa		x
Canavalia rosea	x	
Cassytha filiformis		x
Cenchrus incertus	x	
Chamaesyce cumulicola		x
Chamaecrista nictitans var. aspera		x
Chamaesyce ssp.	x	
Chiococca alba		x
Coccoloba uvifera	x	
Cyperus pedunculatus	x	
Dalbergia ecastaphyllum	x	
Emilia fosbergii		x
Erythrina herbacea		x
Galactia volubilis		x
Galium hispidulum		x
Helianthus debilis	x	
Iva imbricata	x	
Morinda royoc		x
Opuntia humifusa		x
Panicum amarum	x	
Persea borbonia		x
Physalis walteri	x	
Poinsettia cyathophora		x
Polygala grandiflora	x	
Psychotria nervosa		x
Quercus geminata		x
Randia aculeata		x
Sabal palmetto		x
Saltgrass complex	x	
Sesuvium portulacastrum	x	
Sisyrinchium xerophyllum		x
Smilax auriculata		x
Uniola paniculata	x	
Vigna luteola	x	
Ximenia americana		x

Table 1.4.**15**. Carlin Park top ten species list by habitat compiled during site vegetation rapid assessment survey.

Community/Habitat Type	Total acres surveyed
Coastal Dune	0.925
Coastal Strand 1	0.295
Coastal Strand 2	0.139
Hammock	4.575

Community/Habitat Type	Species by abundance	% cover	Community/Habitat Type	Species by abundance	% cover
Coastal Dune	*Uniola paniculata*	87.5	Hammock	*Coccoloba uvifera*	87.5
	Canavalia rosea	37.5		*Parthenocissus quinquefolia*	37.5
	Iva imbricata	17.5		*Citharexylum spinosum*	7.5
	Dalbergia ecastaphyllum			*Schinus terebinthifolius*	
	Vigna luteola			*Canavalia rosea*	
	Cenchrus incertus			*Ficus citrifolia*	
	Sesuvium portulacastrum			*Unknown shrub*	
	Helianthus debilis			*Serenoa repens*	
	Saltgrass complex			*Dalbergia ecastaphyllum*	
	Chamaesyce mesembrianthemifolia			*Sansevieria hyacinthoides*	
Coastal Strand 1	*Serenoa repens*	62.5			
	Mentzelia floridana	37.5			
	Parthenocissus quinquefolia	17.5			
	Guapira discolor				
	Momordica charantia				
	Schinus terebinthifolius				
	Rapanea punctata				
	Dalbergia ecastaphyllum				
	Forestiera segregata				
	Erythrina herbacea				
Coastal Strand 2	*Helianthus debilis*	62.5			
	Cyperus pedunculatus	37.5			
	Canavalia rosea	17.5			
	Saltgrass complex				
	Okenia hypogaea				
	Cenchrus incertus				
	Iva imbricata				
	Dactyloctenium aegyptium				
	Cnidoscolus stimulosus & Spartina patens				
	Jacquemontia reclinata				

Table 1.1.**16.** Carlin Park species list of habitats collected from releve' plots.

	Community/ Habitat Type	
Species	**Coastal Dune 1**	**Coastal Strand 2**
Alternanthera flavescens	x	
Canavalia rosea	x	x
Cenchrus incertus	x	x
Chamaesyce cumulicola		x
Chamaesyce mesembrianthemifolia		x
Chamaesyce ssp.		x
Cnidoscolus stimulosus	x	x
Coccoloba uvifera	x	x
Cyperus pedunculatus	x	x
Dactyloctenium aegyptium		x
Dalbergia ecastaphyllum	x	x
Echites umbellata		x
Helianthus debilis	x	x
Iva imbricata	x	
Jacquemontia reclinata	x	x
Okenia hypogaea		x
Panicum amarum	x	
Panicum amarum		x
Physalis walteri	x	x
Poinsettia cyathophora		x
Saltgrass complex		x
Sesuvium portulacastrum	x	
Spartina patens	x	
Uniola paniculata	x	x
Vigna luteola	x	x

Output 1.5 Identify a ranked list of restoration sites for *J. reclinata* and prepare restoration plans for the highest priority sites – Samuel J. Wright and Hannah Thornton

The goal of restoration of *J. reclinata* to the southeast Florida coastline can only be met by creating and maintaining new, self-sustaining populations within coastal natural areas. In order to identify appropriate natural areas for such outplantings, it was necessary to conduct a full survey of all parks within the majority of the species' historic range.

Methods

Selection of sites

Prior to site visits, information (Table 1.5.**1**) regarding location, size, managing entities, and park recreational use was collected for all coastal public parks from Key Biscayne (Dade County) north to northern Palm Beach County. All ocean front public parks were visited by FTG researchers and assessed for potential outplantings.

During visits some sites received immediate exclusion if restoration did not seem favorable due to factors such as high disturbance, and primarily the absence or small quantity of coastal strand for replanting. Sites in which restoration seemed possible were surveyed and ranked according to designated criteria (Table 1.5.**2**) that would be used to prioritize sites. The site ranking system based outplanting priority on main criteria /factors that separate into three categories: 1) ease of implementation, 2) quality of coastal strand habitat, 3) potential of outplanted population to sustain. The presence, size and quantity of coastal natural areas within the park combined with the quality of coastal vegetation will be assessed based on comparison with results from vegetation mapping, habitat gradient and microhabitat studies, and degree of disturbance as indicated by abundance of exotic invasive and native pest plant species. Considerations will also be made for proximity to existing wild populations, past presence of a wild *J. reclinata* population. Each category contains subcategories, which received a grade along a three-to-one scale. Based on these qualitative assessments all scores/criteria have been summed and the sites receiving the lowest scores rank as the sites most appropriate for *J. reclinata* outplantings (Table 1.5.**3**).

Results

Site assessments

Within the 29 parks visited containing potential restorable coastal strand habitat, 32 possible outplanting areas were surveyed. Table 1.5.**3** displays what each area scored for every criteria/subcategory. Total criteria scores ranged from a low 20 to a high of 36. North Beach Park (north parcel) in Hollywood received the best score followed by Virginia Key Hammock (22) and Haulover Beach (23) in Miami, and North Beach Park (south parcel) in Hollywood. It should be mentioned that tied for the next highest score (24) were Delray Beach, Harry Berry Park, Ocean Ridge Hammock Park, and Jupiter Beach Park.

Restoration plans/suggestions

Specific restoration plans have been written for the top four highest priority sites ranked by site assessments. The restoration plans incorporated the results and conclusions of research completed for this grant as well as the recommendations of the managers at the parks in question.

General guidelines for outplanting protocols are discussed in Output 6.3.**4**. This section includes suggested design of outplantings (i.e. site preparation, locations of individuals, protocols for pre-care, planting and post-care, recommendations regarding appropriate genetic stock for outplanting and suggestions for long-term maintenance). Restoration plans for highest ranked sites discuss specific site location, description, observations and recommendations (Tables 1.5.**4** – 1.5.**7**).

References

Johnson A.F., J.W. Muller and K.A. Bettinger. 1993. An assessment of Florida's remaining coastal upland natural communities: southeast Florida. Report to Florida Natural Areas Inventory; Tallahassee, Florida

Kernan, C. 1997. Final Report to the United States Fish and Wildlife Service for Grant Number 1448-00004-94-9123: *Jacquemontia reclinata* Recovery. Pp. 1-66. Fairchild Tropical Garden, Miami, Fl.

Opler, PA. and V. Malikul. 1992. A field guide to eastern butterflies. Peterson field guide. Houghton-Mifflin Co. Boston, Massachusetts

Table 1.5.**1**. Site information regarding beachfront public parks proposed as potential outplant/restoration sites for *Jacquemontia reclinata*. Total size of parks estimated in total acreage.

	Park Name	Address/Directions	Recreational activities	Size	Management
MIAMI-DADE	Bill Baggs State Rec. Area	1200 S. Crandon Park Blvd, Key Biscayne	bicycle rentals, picnic pavilions, running, nature trails, fishing, and snorkeling	432	State of Florida
	Virginia Key Hammock	Sewerline Rd, Virginia Key	picnic areas, interpretive nature trail, bird watching	77	City of Miami
	South Pointe Park	1 Washington Ave., Miami Beach	playground, picnic, trails, fishing pier and vita course	8	City of Miami Beach
	Miami Beach	From 1 Ocean Drive to 7900 Collins Ave	swimming, surfing, volleyball, sailing, wind surfing, kite flying, jogging	na	City of Miami Beach
	North Shore State Rec. Area	7900 Collins Ave., Miami Beach	Playground, picnic, trails, vita course, swimming	40	City of Miami Beach
	Haulover Park	10800 Collins Ave., Miami Beach	bicycle rentals, picnic pavilions, kite rental, and running	180	Miami-Dade County
BROWARD	Hallandale Beach	Hallandale Beach Blvd. and A1A	playground, bocce ball courts	4	City of Hallandale Beach
	Hollywood Beach		swimming, broadwalk for jogging and bike riding	na	City of Hollywood Beach
	North Beach Park	3501 N. Ocean Dr., Hollywood	boardwalk, picnic areas, observation tower, turtle hatchery	56	Broward County
	Dania Public Beach	300 N. Beach Rd., Dania Beach	fishing pier, picnic area, snorkeling, and diving	na	City of Dania
	J.U. Lloyd Beach State Rec. Area	6503 N. Ocean Drive Dania	kayaking, picnic area, bird watching, nature trail	251	State of Florida
	Pompano Beach	Atlantic Blvd. north to N.E. 16th Street	volleyball, swimming, fishing, boating, kayaking, sailing, playground, boardwalk and picnic areas	na	City of Pompano Beach
	Deerfield Beach	SE 21st Avenue, Deerfield Beach	fishing, picnic area, surfing, and volleyball	na	City of Deerfield Beach
PALM BEACH	Spanish River Park	3001 N. State Rd. A1A, Boca Raton	covered shelters and boat docks. 1,680-foot nature trail and large playground area.	95	City of Boca Raton
	Delray Beach Municipal Beach	40 S. Ocean Blvd., Delray Beach	swimming, surfing, volleyball, sailing, wind surfing, snorkeling, and kite flying	na	City of Delray Beach
	Gulfstream Park	4489 N. Ocean Blvd., Gulfstream.	fishing, picnic and children's play area.	6	Palm Beach County
	Boynton Beach Oceanfront Park	6145 N. Ocean Blvd., Boynton Beach	swimming, boardwalk and picnic areas	na	City of Boynton Beach
	Ocean Ridge Hammock Park	6620 N. Ocean Blvd, Ocean Ridge	nature trail, swimming, kitesurfing, fishing	12	Palm Beach County
	Ocean Inlet Park	6990 N. Ocean Blvd., Ocean Ridge	jetty, marina, boat slips (rental), children's play area, ocean overlook, seating pavilion and volleyball area	10	Palm Beach County
	Lantana Municipal Beach	100 Ocean Blvd., Lantana	snorkeling, fishing, volleyball court, and picnic area	na	City of Lantana Beach
	J.D. MacArthur Beach State Park	10900 S.R. 703 (A1A) North Palm Beach	nature and turtle walks, snorkeling, bird watching, kayaking, surfing, and castnetting	317	State of Florida
	Juno Dunes Natural Area	Adjacent to Loggerhead Park	hiking, bird watching	576	Palm Beach County
	Juno Beach	14775 A1A, just north of Loggerhead	grills, picnic sites, fishing pier	5	Palm Beach County
	Radnor Beach Park	Ocean Blvd (A1A). South of Carlin Park	artificial reef, snorkeling	na	Town of Jupiter
	Jupiter Beach	1375 Jupiter Beach Rd., Jupiter	grills, picnic sites, and reserved group shelters	46	Palm Beach County
	Phipps Ocean Park	375 Ocean Blvd., Palm Beach	picnic tables, grills, pavilion, and playground	3	Town of Palm Beach
	Coral Cove Park	19450 S.R. 707, Tequesta	fishing, nature area, picnic area and children's play area.	9	Palm Beach County

Table 1.5.**2**. Potential restoration site criteria datasheet

Date: **Obs:**
Site **Descr:**

Criteria for prioritizing potential restoration site	3	2	1	
Category 1: Ease of Implementation	◄	———	►	
1) Existing prior contact with agency	none	some	good	
2) Accessibility for outplanting purposes	poor	fair	good	
3) Sprinklers present		no	yes	
Category 1 Total				
Category 2 Quality of Coastal Strand Habitat				
1) Diversity of Native Strand Species	low	med	high	
2) Diversity of Invasive Species	high	med	low	
3) Impact of Invasives (coverage)	high	med	low	
4) Size of potential outplanting area	small	med	large	
5) Amount of adjacent habitat	low	med	high	
6) Quality of Adjacent Habitat	bad	fair	good	
7) Location of potential outplanting area	outside	close	within	
8) Amount of public access (disturbance)	high	med	low	
9) Prior J. recl. Existence		no	yes	
Category 2 Total				
Category 3: Potential to self sustain				
1) Proximity to existing wild populations	far	close/obs	close/unobs	
2) Susceptibility to disturbance	high	med	low	
3) Number of Sites within site	1	2	>3	
Category 3 Total				
All Criteria's Total				

NOTES: **<u>INVASIVES</u>** **<u>NATIVES</u>**

Table 1.5.3. Criteria totals for potential (re) introduction sites. [1] Possible private ownership. [2] Site contains *J. reclinata*

	Site	Location	**Cat. 1: Ease of Implementation**	1) Existing prior contact with agency	2) Accessibility for outplanting	3) Sprinklers present	**Category 1 Total**	**Cat. 2 Quality of Coastal Strand**	1) Diversity of Native Strand Species	2) Diversity of Invasive Species	3) Impact of Invasives (coverage)	4) Size of potential outplanting area	5) Amount of adjacent habitat	6) Quality of Adjacent Habitat	7) Location of potential outplanting	8) Amount of public access	9) Prior J. recl. Existence	Category 2 Total	**Cat. 3: Potential to self sustain**	1) Proximity to existing populations	2) Susceptibility to disturbance	3) Number of Sites within site	Category 3 Total	All Criteria's Total
1	Bill Baggs	Key Biscayne		2	1	2	**5**		3	2	2	2	2	2	1	1	1	**16**		2	1	1	**4**	**25**
2a	Virginia Key Beach 1	Virginia Key		1	1	2	**4**		1	2	1	3	1	1	2	1	1	**13**		2	1	2	**5**	**22**
2b	Virginia Key Beach 2	Virginia Key		1	1	2	**4**		1	2	2	3	1	1	1	1	1	**13**		2	1	2	**5**	**22**
3	South Point Park	Miami Beach		3	1	2	**6**		1	3	2	2	3	3	2	3	3	**22**		3	2	3	**8**	**36**
4	South Beach (2nd & 3rd)	Miami Beach		3	1	2	**6**		2	1	1	1	3	2	1	2	3	**16**		3	2	3	**8**	**30**
5	South Beach (8th)	Miami Beach		3	1	2	**6**		2	2	2	1	2	2	1	2	3	**17**		3	2	1	**6**	**29**
6	77th Street (Altos del Mar) [1]	Miami Beach		3	1	2	**6**		1	2	2	1	2	2	1	2	1	**14**		3	2	3	**8**	**28**
7a	North Shore Open Space Park 1	Miami Beach		2	1	1	**4**		1	3	2	3	1	1	1	2	1	**15**		3	2	1	**6**	**25**
7b	North Shore Open Space Park 2	Miami Beach		2	1	2	**5**		1	2	2	1	2	2	1	2	1	**14**		3	2	1	**6**	**25**
8	Haulover Beach	North Miami		1	1	2	**4**		1	2	2	1	2	2	1	1	2	**14**		3	1	1	**5**	**23**
9	Hallandale Beach	Hallandale		3	1	2	**6**		3	2	2	3	3	3	1	3	1	**21**		3	3	2	**8**	**35**
10	Harry Berry Park	Hollywood Beach		3	1	2	**6**		2	2	1	1	2	1	1	1	1	**12**		3	2	1	**6**	**24**
11	Harrison & Surf	Hollywood Beach		3	1	2	**6**		2	3	1	2	2	2	1	1	1	**15**		3	2	1	**6**	**27**
12	North Beach Park (south parcel)	Hollywood Beach		1	1	2	**4**		2	1	1	2	2	2	1	1	1	**13**		3	2	1	**6**	**23**
13	North Beach Park (north parcel)	Hollywood Beach		1	1	2	**4**		1	1	1	2	1	1	1	2	1	**11**		3	1	1	**5**	**20**
14	John U. Lloyd	Dania Beach		2	2	2	**6**		1	2	1	2	1	1	1	3	2	**14**		3	3	1	**7**	**27**
15	Pompano Beach	Pompano		3	1	2	**6**		2	2	1	2	2	2	1	1	1	**14**		3	1	1	**5**	**25**
16	Red Reef [2]	Boca Raton		1	1	2	**4**		3	1	1	3	2	1	1	1	1	**14**		1	1	3	**5**	**23**
17	Spanish River	Boca Raton		1	1	2	**4**		1	3	2	3	2	2	1	1	1	**16**		2	2	1	**5**	**25**
18	Delray Beach	Delray Beach		2	1	2	**5**		1	2	1	2	2	2	1	2	1	**14**		2	1	2	**5**	**24**
19	Gulfstream Park	Boynton Beach		1	1	1	**3**		2	3	3	3	2	3	1	1	1	**19**		2	1	3	**6**	**28**
20	Boynton Beach Park	Boynton Beach		3	2	2	**7**		2	1	1	3	2	2	1	1	2	**15**		3	1	2	**6**	**28**
21	Ocean Ridge Hammock Park	Boynton Beach		1	2	2	**5**		1	1	1	3	1	2	1	1	2	**13**		3	1	2	**6**	**24**
22	Ocean Inlet Park [1]	Manalapan		1	2	2	**5**		1	3	2	3	2	1	1	1	3	**17**		3	2	3	**8**	**30**
23	R. G. Kreulser Memorial Park	Lake Worth		1	1	2	**4**		3	1	2	3	3	2	1	1	3	**19**		3	2	2	**7**	**30**
24	Riviera Beach Municipal Beach	Riviera Beach		3	2	2	**7**		2	1	1	2	2	2	1	1	3	**15**		3	1	2	**6**	**28**
25	Ocean Reef Park	Singer Island		1	1	2	**4**		1	2	2	3	2	1	1	1	3	**16**		3	2	2	**7**	**27**
26	J. D. Macarthur Beach State Park	North Palm Beach		2	3	2	**7**		2	2	3	3	1	2	1	1	3	**18**		3	2	2	**7**	**32**
27	Jupiter Beach Park	Jupiter		1	1	2	**4**		1	2	2	3	2	2	1	1	1	**15**		2	2	1	**5**	**24**
28	Coral Cove Southern Addition	Jupiter		1	1	2	**4**		2	1	1	3	2	2	2	1	1	**15**		3	2	2	**7**	**26**
29a	Coral Cove Northern Addition 1	Jupiter		1	2	2	**5**		2	1	1	3	3	2	2	1	1	**16**		3	2	2	**7**	**28**
29b	Coral Cove Northern Addition 2	Jupiter		1	1	2	**4**		2	1	2	3	2	1	1	1	1	**14**		3	2	3	**8**	**26**

Table 1.5.4 Site: North Beach Park (north parcel)

aka: North Beach Strand, or Dania Strand/Tract
Rank/Score: 1/20
Location: Hollywood
Management: Broward County (Kurt Volker)
Total size: 30 acres
Background: Eight-block long property owned by the state, and managed by Broward County. Area is bordered by A1A to the west and Surf Road to the east, which is adjacent to the dune vegetation. Each block contains parking for beach patrons perpendicular to Surf Road. Site was once acknowledged by FNAI (Florida Natural Areas Inventory) as suitable habitat for introduction of *J. reclinata* (Johnson et al. 1993)
Outplanting area description: Area contains high diversity of native strand vegetation and extremely low diversity of invasive exotics. Open, low herbaceous cover includes *Helianthus debilis* (beach sunflower), *Ernodea littoralis* (beach creeper), *Ipomoea pes-caprae ssp. brasiliensis* (railroad vine), and *Crotalaria pumila* (low rattlebox). Low to medium size woody shrubs consists of *Coccoloba uvifera* (seagrape), *Chrysobalanus icaco* (coco-plum) and *Lantana involucrata* (wild-sage).
GPS coordinates of area: na
Size of potential outplanting area: 1200 m^2
Amount of potential outplanting areas within site: >3
Distance from mean high tide line: 93 meters
Other notable species on site: beach star (*Cyperus pedunculatus*), Florida Lantana (*Lantana cf. depressa*)
Site observations: Observed cats foraging from plates and bowls put out by residents.
Nearest site for outplanting material: Hugh Taylor Birch to the north and Crandon Park to the south. It should be noted that genetic studies (Output 2.4) have shown that the Hugh Taylor Birch population could be genetically unique. Due to this information we do not recommend using stock from Hugh Taylor Birch for outplanting material and suggest South Beach, Boca Raton as the northern alternative.
Management suggestions: Continue to protect area from public disturbance (trampling). Maintain already existing healthy strand habitat, and continue the successful exotic removal program. Educate the local public to discourage feeding of the numerous feral cats on the property.

Table 1.5.5. Site: Virginia Key Hammock

Rank/Score: 2/22
Location: Virginia Key
Management: City of Miami (Juan Fernandez)
Total size: 77 acres
Background: After the destruction of Hurricane Andrew in 1992, The City of Miami Parks and Recreation Department began restoration of the Virginia Key Hammock. Invasive exotic plant species were removed and native species replanted throughout a 15-acre hammock area. After exotic removal, the hammock began to naturally recolonize itself with native hammock species including the state endangered *Zanthoxylum coriaceum* (Biscayne prickly-ash). The City of Miami has taken advantage of this opportunity for educational purposes and made the area accessible to the local community by creating an interpretive nature trail.
Outplanting area description: Small coastal strand habitats west of dunes and interpretive trail. Open low shrub cover contains *H. debilis, Bidens alba var. radiata* (Spanish needles), *Alternanthera flavescens* (joyweed), and *C. uvifera.*
GPS coordinates of area: na
Size of potential outplanting area: 420 m^2
Amount of potential areas within site: 2
Distance from mean high tide: 30 meters
Other notable species on-site: *Okenia hypogaea* (beach peanut), *Z. coriaceum*
Site observations: The interpretative trail is extremely informative and a great tool for education of the public regarding preservation and protection of natural areas.
Nearest site for outplanting material: Nearby Crandon Park could act as appropriate stock for outplanting at Virginia Key Hammock
Management suggestions: Continue already established successful exotic removal and native revegetation program. *Dactyloctenium aegyptium* (Durban crowfoot grass) within the potential area was observed to be very dominant and should be treated. Also treatment of exotics should be followed by total removal. Remaining woody material and duff could increase the nutrient level of the naturally low nutrient coastal dune habitat (see Output 1.3). Additional observed co-existing exotics that should be removed: *Scaevola sericea* (beach napuka), *Schinus terebinthifolius* (Brazilian pepper), and *Wedelia trilobata* (creeping wedelia).

Table 1.5.6. Site: Haulover Beach

Rank/Score: 3/23
Location: North Miami Beach
Management: Miami-Dade County (Joe Maguire)
Total size: 180 acres
Park background: County park with high recreational use such as biking, walking, and running on boardwalk. Large areas designated for picnics and BBQ. A narrow, long vegetated strand/ dune area borders the boardwalk for the mile and a half stretch of the beach. The park is undergoing major renovations, which include exotic plant removal mostly *S. sericea* along the strand/dune.
Outplanting area description: Thin and long open coastal strand east of the boardwalk recently cleared of exotics. Area contains existing and replanted native species such as *Canavalia rosea* (bay bean), *Suriana maritima* (baycedar), *H. debilis*, *Serenoa repens* (saw palmetto), *Scaevola plumieri* (inkberry) and *Uniola paniculata* (sea-oats).
GPS coordinates of area: 25º54'39" N, 80º07'18" W
Size of potential outplanting area: 3000m^2
Amount of potential areas within site: >3
Distance from mean high tide: 50 meters
Other notable species on site: *C. pedunculatus*
Site observations: Dune vegetation trampling could become an issue due to the observed occurrence of sunbathers lying on the dunes. *D. aegyptium* was observed to quickly recolonize open patches after exotic removal.
Nearest site for outplanting material: Nearest wild population is Crandon Park to the South and South Beach to the north.
Management suggestions: Continue removal of exotics along strand/dune, which will open up more opportunities for not only *J. reclinata* outplantings but other coastal species as well**.** To increase the success of outplantings**,** cleared areas should be monitored for the occurrence of *D. aegyptium* and other invasive grasses (e.g. *Stenotaphrum secundatum*) which tend to out compete *J. reclinata* and other lower growing coastal species (Kernan 1997). To control public access, rope fencing on the ocean side should be maintained regularly. Increased signage could also help to limit public disturbance with lifeguards taking an active role in regulating access.

Table 1.5.7. Site: North Beach Park (south parcel)

Rank/Score: 3/23
Location: Hollywood Beach
Management: Broward County (Gretel McCausland)
Total size: 40 acres
Background: Recreational county park includes picnic areas and jogging boardwalk that connects to the 2.2 mile long Hollywood Beach Broadwalk. Park also contains a sea turtle hatchery, which is part of the Endangered Sea Turtle Protection and Relocation Program. Areas adjacent to the boardwalk have small sections of coastal strand and dune habitat.
Outplanting area description: Areas exist just west of the boardwalk with low growing vegetation such as *Panicum amarum* (bitter panicgrass), *C. rosea, H. debilis*, *U. paniculata and C. uvifera.* Site bordered by hammock containing *C. uvifera* and *Dalbergia ecastaphyllum* (coin vine).
GPS coordinates of area: 26º02'09" N, 80º06'50" W
Size of potential outplanting area: 1250m^2
Amount of potential areas within site: >3
Distance from the mean high tide line: 50 meters
Other notable species on site: *C. pedunculatus*, *L. cf. depressa*
Site observations: Potential areas contain low diversity coverage of coastal strand species consisting mostly of *U. paniculata* (>75%).
Nearest site for outplanting material: South Beach Park to the north and Crandon Park to the south.
Management suggestions: Maintain open patchiness containing low herbaceous cover within the coastal strand areas. Replant with coastal native species to increase diversity coverage. Monitor adjacent *D*. *ecastaphyllum*, which has been observed at other sites to crowd out *J. reclinata* (Wright, per. observation). We would not suggest total removal of the shrub since it acts as a host plant for the *Phoebis Statira* (Statira Sulphur) butterfly (Opler and Malikul 1992).

Output 2 Genetic variation within and among *Jacquemontia reclinata* populations studied – Hannah Thornton

Output 2.1. Analyze the genetic variation in wild populations of *J. reclinata* and the *ex situ* collection.

Introduction

This project seeks to answer the following questions: 1) what is the structure of genetic diversity within and between wild populations of *Jacquemontia reclinata*? 2) what are the most appropriate management recommendations to preserve genetic diversity within *J. reclinata*?

Intense fragmentation of the coastal habitat in south Florida has created distances of up to 30 miles between wild populations of *J. reclinata.* Because of this extreme geographic separation, we expected wild populations to be genetically distinct. That is, we expected each wild population to comprise its own unique collection of genotypes. Given the limitations imposed on gene flow by severe fragmentation, we also expected that this genetic differentiation would be correlated with geographic distance. That is, the closer two populations are geographically, the closer we expected them to be genetically. Because population genetic theory predicts that reductions in population size will lead to reductions in genetic diversity (Barrett and Kohn 1991, Hamrick and Godt 1996), we expected wild populations with lower numbers of *J. reclinata* individuals to exhibit reduced genetic diversity relative to larger populations.

Materials and Methods

Sampling

We sampled at least 10% of all known wild populations (See Table 2.1.**1** for exact sample sizes and percentages). In populations with definite subpopulation structure (e.g. Crandon and South Beach Parks), we sampled at least 10% of each subpopulation. For each sample, we collected the first 6 – 10 inches of a single shoot, including approximately 10 green leaves. We placed samples on ice until they could be transferred to storage at 4ºC, where they were kept for no longer than seven days.

For all populations except the population at Carlin Park, we used GIS maps to arbitrarily select individuals for sampling and to delineate subpopulations. Individuals were identified, tagged and mapped in the course of population surveys. We defined an individual as a single stem travelling into the ground that could not be visible or tactilely connected to any other underground stem. We defined subpopulations as groupings of individuals separated from other individuals by minor geographic barriers such as dense vegetation or trails. Shifting sand on the dune at Carlin Park buried the identification tags of many individuals and necessitated a different sampling strategy. When possible, stems to be collected were traced back to tagged rootstocks; however, this was only possible for five individual plants. To sample the rest of the population, we established transects at 2M intervals west to east across the dune. We collected samples of single plant stems at 0, 2, 4, 6, and 8M, when they crossed the transect line.

Extraction/Amplification/Electrophoresis

We extracted DNA from fresh *Jacquemontia reclinata* leaves using a modification of the Epicentre MasterPure Plant Leaf DNA Purification Kit (Hoffman and Moan 1999). We ground 100mg of leaf tissure in 600µl of Extraction Solution using a mortar and pestle, and then added 300µl of Clean-up Solution to the resulting slurry before heating. We subjected extracts to at least three rounds of purification with Clean-up Solution and then eluted DNA in 25µl TE buffer.

We visualized extracted DNA on 1.5 % agarose gels containing Ethidium bromide (EtBr), photographed the gels, and scanned the photographs. We measured DNA concentration from the scanned photographs by comparison to a λHINDIII standard using the public domain program NIH Image ver. 1.63 (developed at the U.S. National Institutes of Health and available on the Internet at http://rsb.info.nih.gov/nih-image/). We diluted DNA extracts to a final concentration of 25 ng/ml for Polymerase Chain Reaction (PCR), and excluded from further analysis all individuals with a total DNA concentration lower than 25ng/ml.

After screening 20 random primers from Qiagen/Operon Technologies, we selected 10 primers to use in further amplification (Table 2.1.**2**). Primers were selected based on their ability to produce clean, bright, easily scorable bands. Primers that did not show variation in the initial screen were excluded from futher study. We completed PCR amplification in a Peltier Thermal Cycler-200 DNA Engine from MJ Research with the following reagent amounts and concentrations: 2.5µl 10X Buffer, 1.5µl 25mM $MgCl_2$, 1µl 10x dNTP's, 1µl 5pmol Primer, 0.25µl 5U Taq polymerase, 2µl 25ng/ml template DNA, water to a final volume of 25µl; and under the following cycling conditions: 1) 94ºC for 3 min., 2) 35ºC for 30 sec., 3) 72ºC for 2 min., 4) 94ºC for 45 sec., 5) 35ºC for 30 sec., 6) 72ºC for 2 min., (repeat from 4, 43 times), 7) 94ºC for 45 sec., and 8) 35ºC for 30 seconds (Morden and Loeffler 1999). After amplification, we combined 20µl of reaction with 5µl of loading dye and applied this mixture to a 1.5 % agarose gel containing EtBr. Gels were electrophoresed for approximately one hour at 95v and photographed.

Band Scoring/Repeat procedures

We examined agarose gel photographs, and scored bands as either present (1) or absent (0) (Lynch and Milligan 1994). In order to identify bands between individuals and between reaction sets, we marked RAPD phenotypes with a 100 bp DNA ladder. We considered failed reactions and ambiguous bands as missing data, and we excluded from further analysis all individuals with greater than 25% missing data. In order to assess reproducibility of results, we randomly chose to repeat five reactions per reaction set (Brunell and Whitkus 1997). Fifteen percent of the reactions were subjected to repeat amplification and scoring.

Statistical Analysis

We could not assume that populations of *Jacquemontia reclinata* were in Hardy-Weinberg Equilibrium (HWE) and so, we employed statistics that do not rely on the assumption of HWE. *J. reclinata* is a rare species with low overall population size and large distances separating individual populations. We expected the amount of gene flow between these populations to be low. Additionally, in the last 10 years, the species has seen drastic reductions in the number of individuals and populations, increasing the likelihood of a historical genetic bottleneck. To quantify genetic diversity, we used similarity indices; and to describe genetic structure, we used Analysis of Molecular Variance (AMOVA) and Shannon's Index of Diveristy.

We generated similarity values for all possible pairs of sampled individuals using the Jaccard Coefficient (Sokal and Sneath 1963), and then converted those values to dissimilarity values by subtraction from one. Within population diversity is represented by the mean of the dissimilarity values for all pairs of individuals within a single population. Genetic distance between two populations is represented by the mean of dissimilarity values for all pairs of individuals within a population pair. Similarity values were generated in NTSYSpc ver. 2.0 (Rohlf 1998), and dissimilarity values, means and standard deviations were calculated in Microsoft Excel 2000.

Cluster analysis and principle components analysis were completed in NTSYSpc ver 2.0. We produced dendrograms for all individuals (using individual dissimilarity values) and for populations (using mean dissimilarity values). We ordinated our data by means of principle components analysis, based on similarity values. Within and between population variation was quantified using the AMOVA (Excoffier et al. 1992) option in the Arlequin ver. 2.0 software package (Schneider et al. 2000), and by calculating Shannon's Index of Diversity (Lewontin 1972) in POPGENE (Yeh et al. 1997).

Results

General

For this study, a total of 183 individuals (24% of total population size) were sampled from eight populations. Twenty-two samples were excluded from RAPD analysis because of low DNA concentration (2 from Carlin Park, 1 from Crandon park, 1 from Hugh Taylor Birch State Park, 7 from Red Reef Park, and 11 from South Beach Park). Eleven individuals were excluded from statistical analysis because of a high percentage of missing data (2 from Carlin park, 1 from Crandon Park, 2 from Red Reef Park, and 6 from South Beach Park). Consequently, these analyses include 150 individuals representing 20% of the total *J. reclinata* population, and 10 to 100% of each individual population (Table 2.1.**1**). Sample sizes varied depending on presence of subpopulations, amount of available material and population size (see *Sampling* above). Linear regression of genetic diversity on percentage of population sampled showed no association between the two (R^2 = 0.015 Significance = 0.77). The 10 Operon primers used in RAPD analysis produced a total of 57 scorable loci, 54 of which (94.7%) were polymorphic.

How genetically diverse is* J. reclinata*?

As a species, *J. reclinata* shows low genetic diversity, measured by dissimilarity coefficient (0.263) and Shannon's Index of Diversity (0.3690), even when compared to other rare species (Table 2.1.**3**). *Jacquemontia reclinata* shows a high level of polymorphism (94.7% polymorphic loci) relative to other rare species (Table 2.1.**3**); however, this measure may be biased because primers were chosen, in part, for their ability to amplify variable sites. When compared at the level of individual populations, all three measures of genetic diversity are congruent (Table 2.1.**1**). Populations at Carlin Park, Atlantic Dunes Park and South Inlet Park show particularly low levels of genetic diversity. Populations at South Beach Park and Crandon Park show consistently high levels of genetic diversity relative to other populations. Loggerhead Park supports the population of smallest size (only 5 individuals), but maintains the third or fourth highest level of genetic diversity, depending on the index. Cluster analysis indicates that a single individual contributes most of the genetic diversity to this small population (Figure 2.1.**1**).

Linear regression of genetic diversity on population size shows genetic diversity increasing with population size (Figures 2.1.**2** and 2.1.**3**). Considering all wild populations, the relationship is significant (Figure 2.1.**2**; R^2 = 0.537; F = 0.039), and when the Loggerhead Park population is excluded from the analysis, the strength of the relationship increases (Figure 2.1.**3**; R^2 = 0.853; F = 0.003).

What is the structure of genetic diversity within* J. reclinata*?

The analyses used to classify (cluster analysis and principle components analysis) and quantify (AMOVA and Shannon's Diversity Index) population genetic structure in *J. reclinata* produced congruent results.

Classification of Genetic Structure-Cluster Analysis

Analysis using the Neighbor-Joining algorithm produced a dendrogram depicting relatedness between all 150 individuals included in this study (Figure 2.1.**1**). Individuals from the Crandon and South Beach Park populations show a high degree of similarity to individuals from all other populations. The Crandon population shares closely related haplotypes with all populations except Hugh Taylor Birch; the South Beach population shares closely related haplotypes with all populations except Carlin and Hugh Taylor Birch. The dendrogram shows some similarity between individuals within Crandon and South Beach Parks, but for the most part, individuals within these two populations are more genetically similar to individuals from other populations.

The population at Hugh Taylor Birch State Park shows the highest amount of differentiation of all eight populations. Sampled individuals form an exclusive, cohesive group. That is, all sampled individuals from Hugh Taylor Birch are more closely related to one another than they are to individuals from other populations. Cluster analysis between populations supports this—the population at Hugh Taylor Birch State Park is genetically distant from the other seven populations (Figure 2.1.**4**).

Populations at Carlin, Red Reef and Atlantic Dunes Parks also show differentiation, but to a lesser degree than the population at Hugh Taylor Birch State Park. All but a single individual from the Carlin Park population form a cohesive group, and this grouping is infiltrated by only four other individuals, three from Crandon Park and one from Loggerhead Park. The Atlantic Dunes Park population also shows cohesive grouping of all but a single sampled individual; however, 16 individuals from other populations (14 from Crandon Park, one from South Beach Park and 1 from Carlin Park) cluster with individuals from Atlantic Dunes. Samples from the Red Reef Park population form a cohesive group that excludes three individuals, and includes eight individuals from the South Beach Park.

Cluster analysis also reveals a remarkable pattern of variation within the Loggerhead Park population. Four of the five individuals within this population show high genetic similarity. The fifth individual appears to be related only distantly to the other four. This single individual contributes most of the genetic diversity present within this population.

Classification of Genetic Structure-Principle Components Analysis

Principle components analysis reveals similar patterns as cluster analysis in the structure of genetic diversity within *J. reclinata* as cluster analysis. The population at Hugh Taylor Birch State Park is, again, most clearly differentiated, clustering tightly and distantly from other populations (Figure 2.1.**5**). Individuals from the Carlin Park population also show a high degree of similarity. The Crandon Park and South Beach Park populations show high variation. The first three axes describe 30% of the variation within the data (1^{st} axis = 13%; 2^{nd} axis = 8%; 3^{rd} axis = 8%).

Quantification of Genetic Variation-Shannon's Diversity Index

Similar to cluster and principle components analyses, results from analyses with Shannon's Diversity Index show more variation within populations than between populations of *J. reclinata* (Table 2.1.**4**). According to Shannon's Index, 61% of the variation within the species is maintained within populations ($H_{pop}/H_{sp} = 0.2256/0.369 = 0.6114$), and 39% is explained by differentiation between populations ($(H_{sp} – H_{pop})/H_{sp} = (0.369 – 0.2256)/0.369 = 0.3886$).

Quantification of Genetic Variation-Analysis of Molecular Variance

Three separate Analyses of Molecular Variance (AMOVA) were conducted to partition variation within and between populations of *J. reclinata* (Table 2.1.**4**). The first AMOVA (Table 2.1.**5**), which included all populations divided into five geographic groups, showed that 72.4% of the variation within *J. reclinata* is maintained within populations, 15.8% is maintained between populations, and 11.8% is maintained between geographic groups. Due to high diversity within the populations at Crandon and South Beach Parks, a second AMOVA was conducted (Table 2.1.**6**) excluding these two populations. Results showed only a moderate increase in differentiation among the remaining five populations, with 22.6% of the variation explained by between population differences, 58.1% maintained within populations, and 19.3% maintained between geographic groups.

In order to determine if these patterns of within and between population variation are mirrored at the subpopulation level, data from the two parks with the most intense subpopulation structure (Crandon and South Beach) were subjected to a third AMOVA (Table 2.1.**7**). This analysis showed a high percentage of total variation maintained within subpopulations (76.5%), a much smaller percentage maintained between subpopulations (14.7%), and even less maintained between the two parks (8.8%).

Is genetic distance correlated with geographic distance?

Mantel test showed no relationship between genetic distance and geographic distance between populations ($r = 0.02$; $p = 0.53$; Figure 2.1.**6**).

Conclusions

Species-level Genetic Diversity
Without a benchmark, it is difficult to characterize *J. reclinata* as either genetically depauperate or rich in variation at the species level. In the absence of previous work quantifying genetic diversity, we cannot make historical comparisons within this species. Diverse evolutionary histories and different ecological pressures confound comparisons between species, and the literature is biased toward studies of genetic diversity in rare species. Additionally, it is difficult to speculate how much molecular genetic diversity will be enough for a species to adequately respond to changes in its environment. Although we can gain from them an overall sense of the diversity present within a species, measurements of genetic diversity may be most relevant when comparing values for individual populations. Based on our results, we can clearly identify three populations that show low genetic diversity relative to the other five: Carlin Park, Atlantic Dunes Park and South Inlet Park. Identification of populations with relatively low levels of genetic diversity is useful in terms of directing efforts to increase and preserve genetic diversity within *J. reclinata* (Output 2.4).

Population and conservation genetic theory predict that small populations of rare species may suffer from reduced genetic diversity (Barrett and Kohn 1991) (Hamrick and Godt 1996). Data on population size and genetic diversity in *J. reclinata* clearly support this hypothesis. Genetic diversity within individual populations increases as population size increases, so that, the two populations with the largest number of individuals also have the highest within population genetic diversity. Based on these data, we believe that population augmentations are necessary within the smallest populations, and additionally, that (re)introduced populations should be founded with a large number of individuals.

Variation Within and Between Populations
Due to intense habitat fragmentation resulting in between-population distances of up to 150 kilometers (94 miles), we did not expect gene flow between populations of *J. reclinata*. The species has a mixed-mating system, and is pollinated most frequently by members of the hymenoptera, diptera and lepidoptera (Pinto-Torres, Table 3.4.**1**). Although actual flight patterns were not known, we suspected that pollinator movement is restricted by intense development and that pollen is not exchanged between distant populations. Additionally, seeds of this species drop short distances from the parent plant and we did not witness seed dispersal by other organisms. Given this apparent lack of gene exchange between populations, we expected to find high levels of between population genetic variation within *J. reclinata*.

Contrary to our expectations, we found low levels of genetic variation between populations and high levels of genetic variation within populations. This result is not uncommon for species with mixed-mating systems (Hamrick and Godt 1996), and is a common pattern among species with wind-dispersed seeds (Godt and Hamrick 2001). Wind has been recognized as a mechanism for long distance seed dispersal in plants (Cain et al. 2000). Given the prevalence of hurricanes along the coastline of south Florida, and the strength and stochastic pattern of hurricane winds, it is possible that gene flow between *J. reclinata* populations is maintained by hurricane or storm dispersal of *J. reclinata* seeds. Such gene flow between distant habitat fragments could account for the low levels of genetic differentiation observed between *J. reclinata* populations. *Jacquemontia reclinata* seeds appear to be recalcitrant; however, individual plants produce thousands of seeds each spring and summer (Pascarella, Output 3.4.2).

Differentiation of Hugh Taylor Birch
One population defies the general pattern of low differentiation between populations. The population at Hugh Taylor Birch State Park is genetically distinct and distant from other populations. The Hugh Taylor Birch population is the only population to occur west of maritime hammock, that is, at least 500m west of any other *J. reclinata* population. The natural history of this site is not well known. Clearly, the area has been subjected to some anthropogenic disturbance—a human-made canal cuts through the hammock; however, large trees indicate the maritime hammock is old, and by all accounts, *J. reclinata* occurs naturally in this area.

Recommendations for Management
See Output 2.4.

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Table 2.1.1. Measures of genetic diversity within wild populations of *J. reclinata*.

Population	**N**	N_s	%N	D	*s.d.*	rank	I	*s.d.*	rank	P	rank
Atlantic Dunes Park	26	10	38	0.183	*0.084*	7	0.1487	*0.23*	7	33.33	6
Carlin Park	32	16	50	0.149	*0.079*	8	0.1359	*0.24*	8	26.32	8
Crandon Park	200	36	18	0.330	*0.106*	2	0.2815	*0.26*	2	63.16	2
Hugh Taylor Birch State Park	96	12	12.5	0.237	*0.084*	5	0.1901	*0.26*	5	38.6	5
Loggerhead Park	5	5	100	0.307	*0.062*	3	0.2429	*0.3*	4	40.35	4
Red Reef Park	177	18	10	0.282	*0.074*	4	0.2693	*0.28*	3	52.63	3
South Beach Park	245	45	18	0.384	*0.133*	1	0.3593	*0.23*	1	82.46	1
South Inlet Park	27	8	29	0.235	*0.062*	6	0.1767	*0.27*	6	31.58	7
Mean	101	18.75	34.4	0.263			0.226			46.1	

N = Population size. N_s = Sample Size. %N = Percentage of total population sampled. D = Genetic diversity measured as 1 – Jaccard Coefficient of similarity, averaged for all pairs of individuals within the population. I = Shannon's Index of Diversity for individual populations (H_{popx}). P = Percent polymorphic loci.

Table 2.1.2. Sequences of Primers used in RAPD amplification.

Primer	**Sequence**
OPH02	TCGGACGTGA
OPH03	AGACGTCCAC
OPH04	GGAAGTCGCC
OPH07	CTGCATCGTG
OPH14	ACCAGGTTGG
OPH19	CTGACCAGCC
OPT04	CACAGAGGGA
OPT05	GGGTTTGGCA
OPT08	AACGGCGACA
OPT12	GGGTGTGTAG
OPT16	GGTGAACGCT

Table 2.1.3. Measures of genetic diversity in various plant species, including *Jacquemontia reclinata*. Coefficient refers to type of similarity coefficient used to calculate D. Blanks indicate measurement was not supplied in cited work.

Species	Family	Mating System	I	P	D	Coefficient	Status	Authors
Jacquemontia reclinata	Convolvulaceae	Mixed	0.369	94.7	0.263	Jaccard	R	This Study
Plathymenia reticulata	Fabaceae	Unreported	0.396	70.8			W	Lacerda, et al., 2001
Swietenia macrophylla	Meliaceae	Outcrossing	0.45				R	Gillies, et al. 1999
Licuala glabra var. *glabra*	Aracaceae	Unreported		74.7	0.139	SM	R	Loo, et al., 1999
Hemigenia exilis	Lamiaceae	Clonal?		97.7	0.378	Nei and Li (Dice)	R	Mattner, et al., 2002
Leucadendron elimense	Proteaceae	Outcrossing		98	0.35	SM	R	Tansley and Brown, 2000
Eriastrum densifolium	Polemoniaceae	Outcrossing		78.8	0.31/0.28	Dice/SM		Brunell and Whitkus, 1997
Haplostachys haplostachya	Lamiaceae	Unreported		42	0.221	Dice	R	Morden and Loeffler, 1999
Zieria prostrata	Rutaceae	Selfing?		37%			R	Hogbin and Peakall, 1999
Senecio vulgaria	Asteraceae	Selfing		35%			W	Muller-Scharer and Fischer, 2001
Acacia raddiana	Fabaceae	Unreported		90.6			R	Shrestha, Goldhirsh and Ward, 2002

I = Shannon's Diversity Index; P = % polymorphic loci; D = Dissimilarity measured by coefficients listed in subsequent column; Status: R = rare, W = widespread.

Table 2.1.4. Percentages of genetic variation within *J. reclinata* partitioned into within population, between population, and between geographic group components by Shannon's Diversity Index (I) and three different AMOVA tests.

	Percentage of Variation			
Level of Variation	I	AMOVA 1	AMOVA 2	AMOVA 3
Within Populations	61.1	72.43	58.1	76.49
Between Populations	38.9	15.76	22.63	14.69
Between Groups		11.81	19.28	8.83

AMOVA 1: Five geographic groups defined as follows. Group 1 = Atlantic Dunes Park. Group 2 = Carlin and Loggerhead Parks. Group 3 = Crandon Park. Group 4 = Red Reef, South Beach and South Inlet Parks. Group 5 = Hugh Taylor Birch State Park; AMOVA 2: Crandon and South Beach excluded and geographic groups defined as follows. Group 1 = South Inlet, Red Reef and Atlantic Dunes, Group 2 = Carlin and Loggerhead, Group 3 = Hugh Taylor Birch; AMOVA 3: Partitioning variation within and between subpopulations of Crandon and South Beach Parks.

Table 2.1.5. Results table for AMOVA 1. All populations were included, and 5 geographic groups were defined as indicated in **Table 2.1.4**.

Source of Variation	d.f.	Sum of Squares	Variance Components	Percentage of Variation
Among Groups	4	176.984	0.76749	11.81
Among Populations (w/in groups)	3	59.087	1.0237	15.76
Within Populations	142	668.156	4.70532	72.43
Total	149	904.947	6.49651	

Table 2.1.6. Results table for AMOVA 2. Crandon and South Beach Park populations were excluded, and geographic groups were defined as indicated in **Table 2.1.4**.

Source of Variation	d.f.	Sum of Squares	Variance Components	Percentage of Variation
Among Groups	3	125.576	1.2332	19.28
Among Populations (w/in groups)	2	34.494	1.4474	22.63
Within Populations	63	234.133	3.7164	58.1
Total	68	872.814	6.397	

Table 2.1.7. Results table for AMOVA 3. Partitioning variation within and between subpopulations of *Jacquemontia reclinata* at Crandon and South Beach Parks.

Source of Variation	d.f.	Sum of Squares	Variance Components	Percentage of Variation
Among Parks	1	22.341	0.38177	8.83
Among Subpopulations (w/in parks)	17	99.839	0.63532	14.69
Within Subpopulations	62	205.117	3.30833	76.49
Total	80	327.296	4.32542	

Figure 2.1.1. Neighbor-Joining clustergram based on measures of genetic dissimilarity between all possible pairs of sampled individuals.

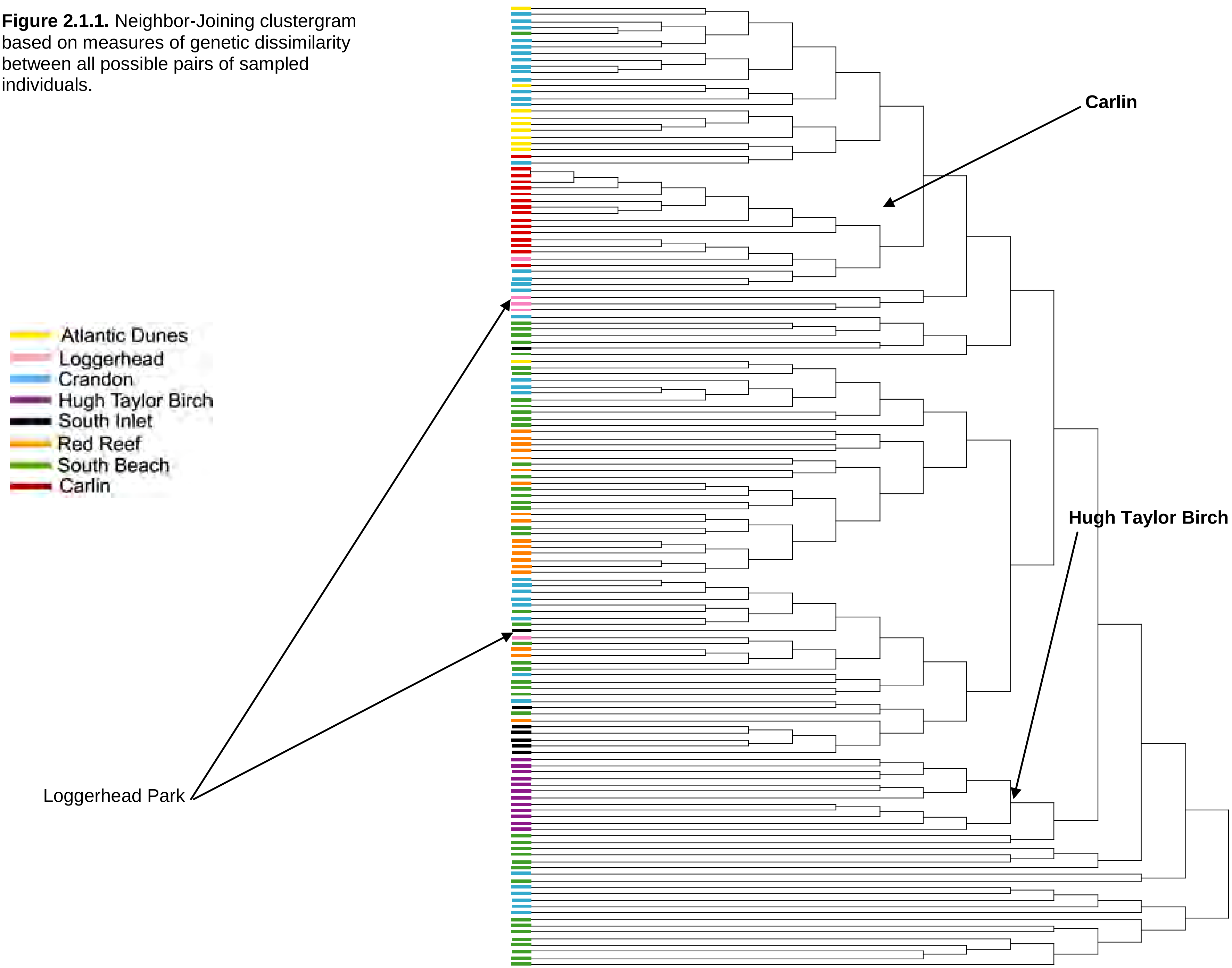


Figure 2.1.2. Linear regression of genetic distance (measured by the dissimilarity coefficient) and population size. Loggerhead Park population is included. R^2 = 0.537 Significance = 0.039.

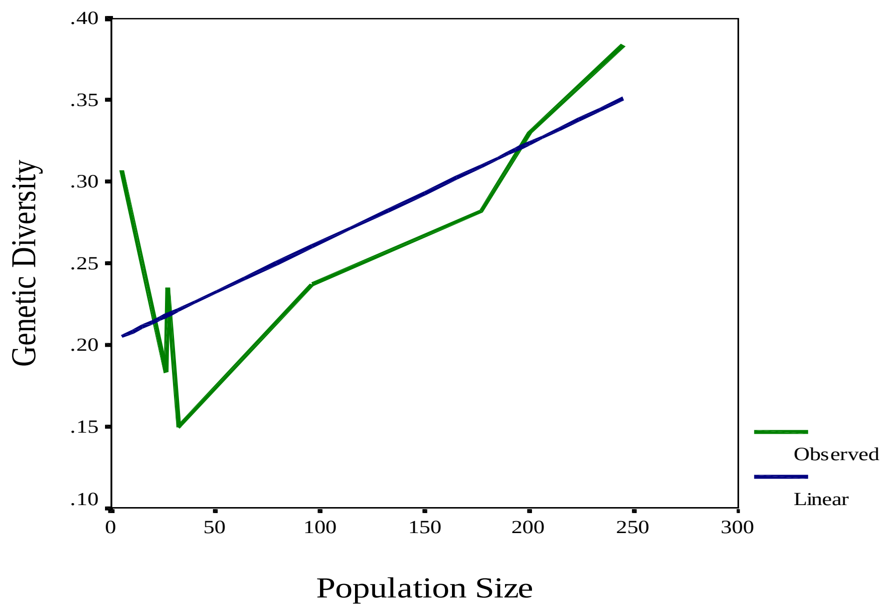


Figure 2.1.3. Linear regression of genetic distance (measured by the dissimilarity coefficient) and population size. Loggerhead Park population is excluded. R^2 = 0.853 Significance = 0.003

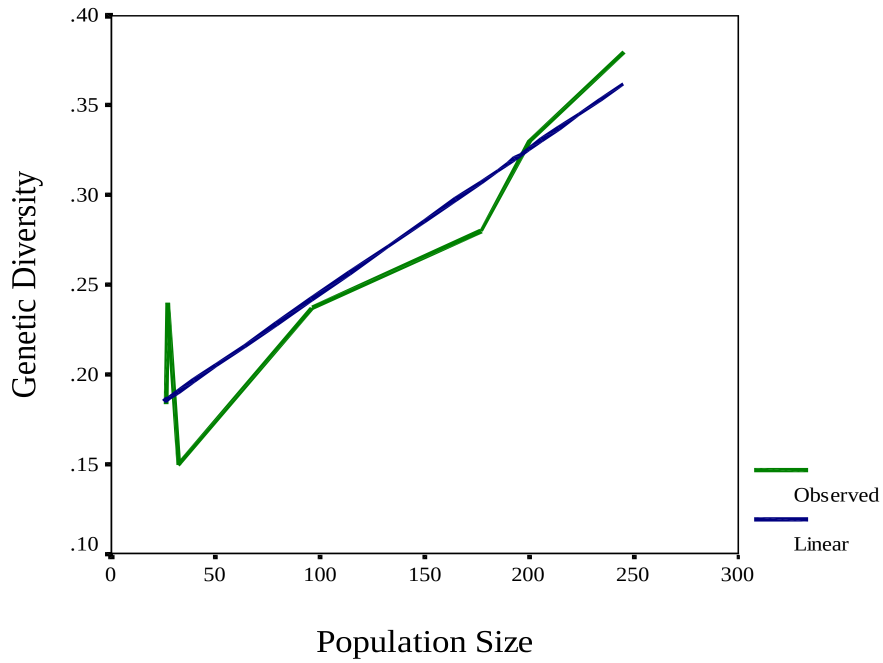
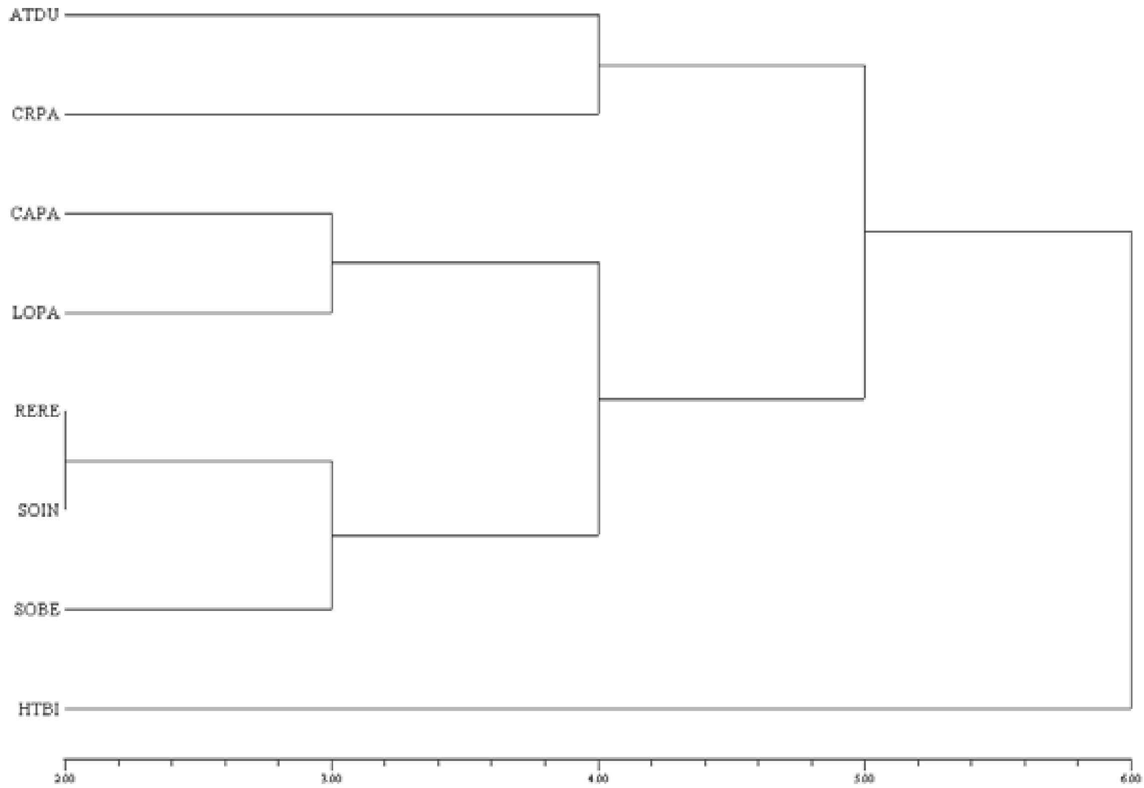
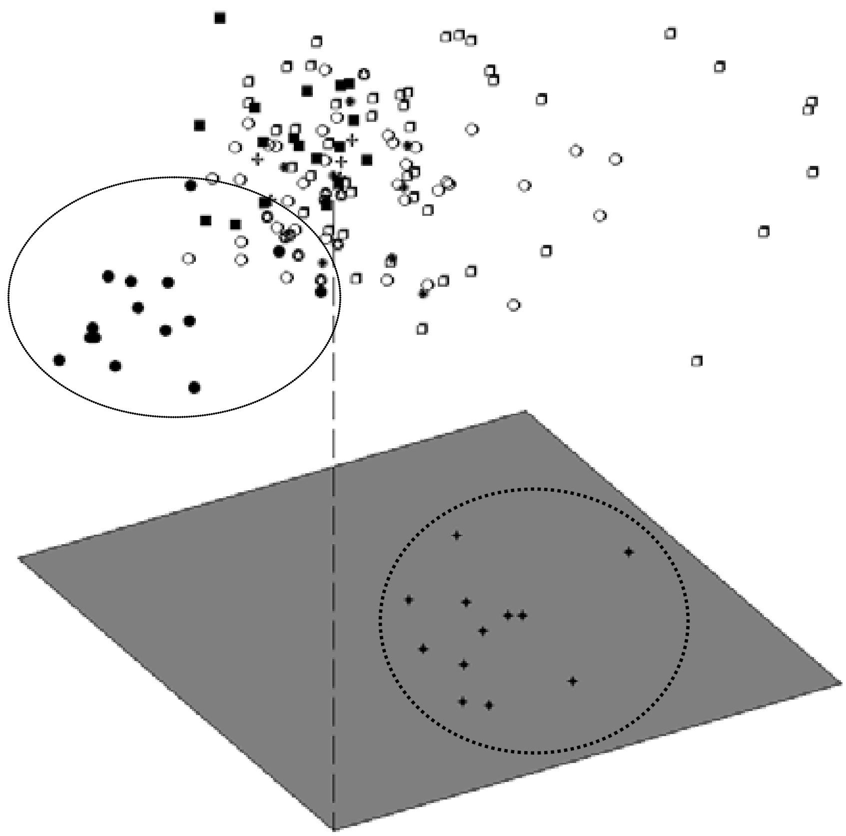


Figure 2.1.4. Neighbor-Joining clustergram based on average genetic dissimilarity between populations.



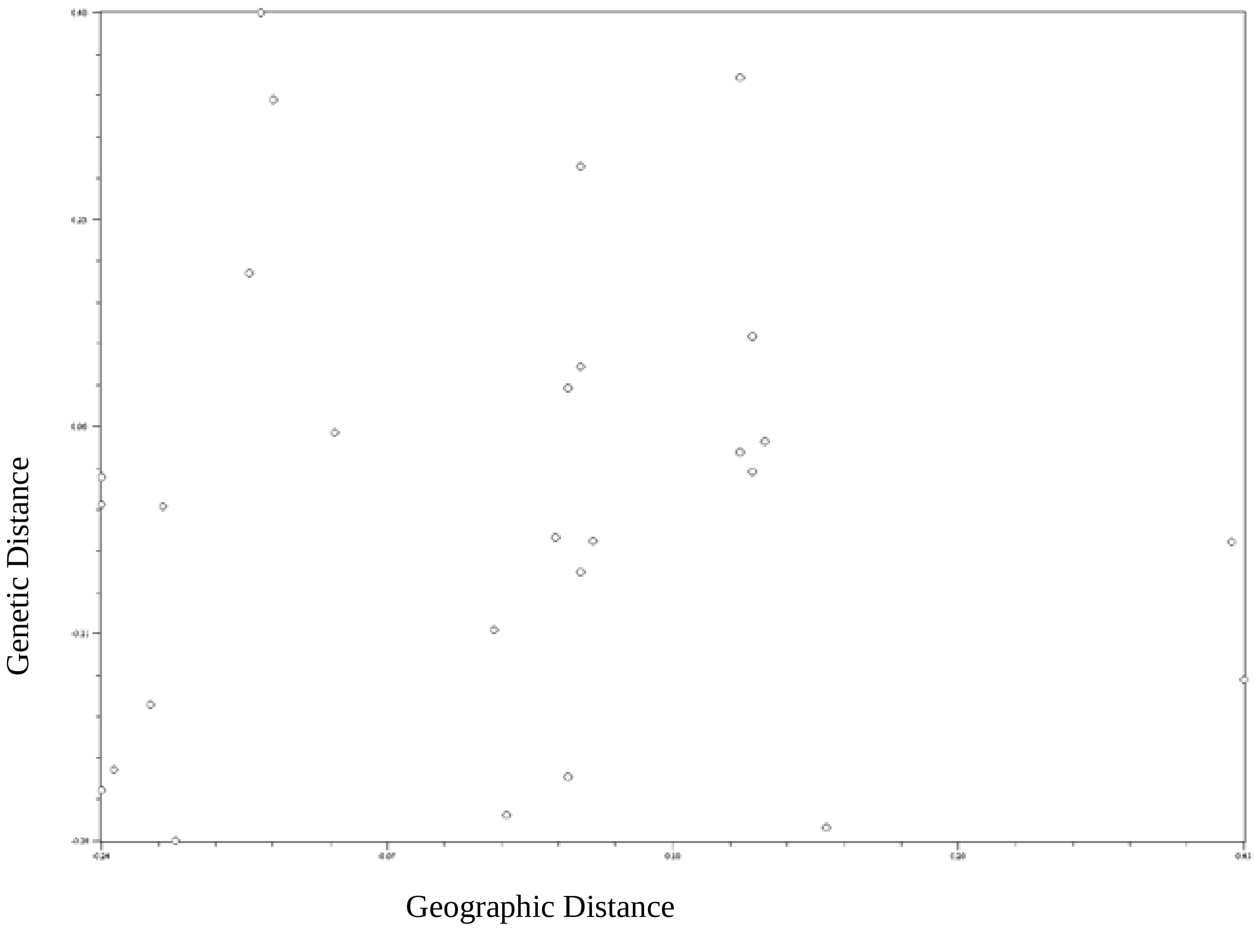
ATDU = Atlantic Dunes Park, CRPA = Crandon Park, CAPA = Carlin Park, LOPA = Loggerhead Park, RERE = Red Reef Park, SOBE = South Beach Park, HTBI = Hugh Taylor Birch State Park.

Figure 2.1.5. Principle Components Analysis based on measures of Jaccard Coefficient of Similarity for all possible pairs of sampled individuals. Circles highlight clustering of Hugh taylor Birch and Carlin Park individuals.



Legend: J Atlantic Dunes; l Carlin Park; mCrandon Park; F Hugh Taylor Birch State Park; B Loggerhead Park; n Red Reef Park; r South Beach Park; Z South Inlet park

Figure 2.1.6. Correlation between geographic distance (X axis) and genetic distance (Y axis) between populations of *Jacquemontia reclinata*. (Mantel Test; r = 0.02; p = 0.53)



2.2 Conduct analysis of genetic variation using allozyme electrophoresis – Hannah Thornton

Analysis of allozyme diversity within *J. reclinata* was attempted with two techniques: cellulose acetate electrophoresis, following protocols outlined in Hebert and Beaton, 1993 and starch gel electrophoresis, following protocols described in Wendel and Weeden, 1989. Cellulose acetate electrophoresis utilizes precast membranes and simple, continuous buffer systems to visualize allozymes in about two hours. Starch gel electrophoresis requires the use of fragile starch gels and different combinations of multiple buffer systems, in a process that can take days to complete. The cellulose acetate method is generally more expensive than starch gel electrophoresis, but the amount of time saved can make this method worthwhile for researchers.

Variations of standard cellulose acetate protocols for extraction of proteins from plant material, enzyme visualization and gel incubation were tested. Based on these protocol variations, activity was found in five enzymes systems (SOD, ACON, FUM, ADH, MDH); however, no enzyme system showed significant migration of bands, and resolution was always poor. Difficulties with band migration and resolution were severe enough to prevent the analysis of banding patterns—isozymes could not be distinguished from allozymes and heterozygotes could not be distinguished at all.

Assuming the difficulties encountered were unique to cellulose acetate electrophoresis, starch gel electrophoresis was tested as a method of assessing allozyme diversity in *J. reclinata*. Variations on standard protocols, especially those used to extract proteins from plant material, and various combinations of enzyme and buffer systems were tested. Activity was found in only two systems (GPI, G6PDH). Similar problems were encountered as with cellulose acetate electrophoresis: bands migrated too slowly, did not separate enough to distinguish heterozygotes and resolution was poor.

Difficulties with allozyme analysis can perhaps be attributed to high levels of multiple secondary compounds in *J. reclinata*. Extracts of leaf material showed distinct color change from green to brown except when high levels of polyvinylpyrrolidone (PVP) were added. Gelatinous blobs formed consistently, throughout all variations of extraction protocols. Perhaps reactivity of secondary compounds with extracted proteins prevented enzyme activity and adequate migration of extracts.

In order to prevent unnecessary losses of time and money, allozyme analysis was abandoned in favor a more in depth, rigorous analysis with RAPD fingerprinting (Output 2.1).

References

Hebert, P.D.N., and M.J. Beaton. 1993. Methodologies for allozyme analysis using cellulose acetate electrophoresis: A practical handbook. Pp. 1 – 31. Helena Laboratories, Ontario.

Wendel, J.F. and N.F. Weeden. 1989. Visualization and interpretation of plant isozymes. Pp. 5 – 45 *in* D.E. Soltis and P.S. Soltis, eds. Isozymes in Plant Biology. Dioscorides Press, Portland, OR.

Output 2.3 Collect tissue from out-of-habitat *J. reclinata* populations. - Hannah Thornton

Tissue was collected in February 2003. DNA was extracted. RAPD analysis was attempted, but was unsuccessful.

Output 2.4 Incorporate results of DNA analysis into site restoration plans – Hannah Thornton

Recommendations for Management

1. Continue acquisition and restoration of coastal habitat. From knowledge of recent extirpations and the results of this project, it is clear that the major endangerment to this species is habitat loss. Increasing the amount of high-quality coastal dune habitat is essential to the preservation of this and other coastal dune species.

2. Augment populations at Carlin, Atlantic Dunes and South Inlet Parks using stock from South Beach Park. These three populations all show low genetic diversity relative to the other five, and they also have three of the four lowest population sizes. Augmentation is important to increase genetic diversity, increase population size and guard against extirpation within these three parks. We recommend augmenting these populations with stock grown from seed collected from the South Beach Park population. The South Beach Park population has high genetic diversity relative to other populations, and is genetically similar to Carlin, Atlantic Dunes and South Inlet Parks. We do not recommend augmenting these small populations by using genotypes from within the same site (e.g. enlarging the Carlin Park population with plants grown from seed collected at Carlin Park), because such action could further reduce genetic diversity and exacerbate inbreeding depression.

***3. Use stock from South Beach Park for outplantings within Palm Beach and northern Broward Counties, and stock from Crandon Park for outplantings within Miami-Dade and southern Broward Counties*. ** The populations at Crandon and South Beach Parks have the highest genetic diversity of all eight wild populations and are genetically similar to all other populations, without regard to geographic location. Outplantings founded with stock from Crandon Park or South Beach Park have the highest probability of being genetically diverse and ecologically fit. To increase genetic diversity within founding populations, outplantings could include additional genetic stock from other populations. Outplantings within Palm Beach and northern Broward Counties could incorporate genetic stock from Red Reef, South Inlet and Carlin Park populations. Outplantings within Miami-Dade and southern Broward Counties could include genetic stock from South Beach as well as Crandon Park.

4. Avoid using the population at Hugh Taylor Birch as a source population for outplantings or augmentations. The population at Hugh Taylor Birch State Park is the most highly differentiated of all eight wild populations. The reasons for this differentiation are unclear—it could be due to ecological, geographic, or evolutionary separation of this population from the others. As this population is genetically distant from the other seven, adding stock from Hugh Taylor Birch to other populations could reduce the fitness of offspring. Conversely, introducing genetic stock from other populations into Hugh Taylor Birch could break up the unique collection of genotypes in this population.

5. Place a high priority on conserving the Loggerhead Park population and on increasing population size at this site. The five plants that currently make up the population at Loggerhead Park represent an important piece of the entire genetic diversity of *Jacquemontia reclinata*. Conservation of these plants is important for preservation of this species. During the years of this study, population size at Loggerhead Park has decreased by half. Given that a single individual contributes most of the genetic diversity to this population, further decreases in population size could cause drastic reductions in genetic diversity. If possible, cuttings should be made of these five plants, and clones should be outplanted, or maintained in the *ex situ* collection at FTG. A population of five individuals is highly susceptible to extirpation; therefore, all efforts should be made to increase population size at this site.

6. Augmentations, outplantings and natural populations should be monitored. Monitoring of augmentations, outplantings and natural populations is important for two reasons. First, it is extremely important to diagnose deleterious impacts of outplantings and augmentations on natural populations, as well as poor fitness in outplanted genotypes. Second, recording the results and effects of outplantings and augmentations will help further the science of endangered species restoration. As more outplantings and augmentations are undertaken in an experimental context, scientists will be better able to refine management recommendations.

Output 3: Pollination, seed and seedling biology of *J. reclinata* studied

3.1 Establish the mating system of *J. reclinata* through experimental crosses – Elena Pinto-Torres and Suzanne Koptur

In order to assess whether *Jacquemontia reclinata* is capable of self-pollination, or whether flowers require pollen from a non- or distantly related donor flower for pollination, a hand-pollination experiment was performed. Seeds resulting from the different treatments were germinated to test seed viability. Demonstrated self-incompatibility of the species has important management implications, since it may mean that existing populations will need to be augmented with genetically less-related individuals, and restoration efforts will need to consider optimal distances between unrelated outplants in order to ensure reproductive success.

Methods

Reproductively mature experimental plants were grown from seed collected in the year 2000 from wild plants at two sites, Bear Cut Preserve at Crandon Park on Key Biscayne, Florida, and South Beach Park in Boca Raton, Florida. The study involved 65 plants, from a total of 16 accession numbers (lineages) (Table 3.1.1). Plants of the same accession number are siblings; they came from the same parental seed source (wild plant). The two sites are separated by 54 mi/86.4 km.

Hand pollination treatments were performed on the 65 plants in a shade house at Fairchild Tropical Garden, between January and June, 2002. The six treatments were: control, self (self pollen applied), sibling (Sib; crossed with sibling), near neighbor (NN; crossed with offspring of another individual in the same wild patch), far neighbor (FN; crossed with offspring of a wild parent from a different patch), and offsite (crossed with pollen from the other site).

All six treatments were bagged using fine tulle, which excluded all but the smallest insects. Although open pollinated treatments were included, the plants were not in their natural habitat; consequently the results are not included here. The treatments investigated autogamy, self-compatibility, and varying degrees of cross-compatibility. The control treatment involved tagging and bagging the flower, but doing nothing else. In all the other treatments, pollen was deposited on the stigma of each flower by direct contact with the surface of a dehisced anther held with clean tweezers. Used anthers were discarded, and a new anther was used for each repetition. Paper jeweler’s tags were attached to the floral pedicels with thread. Each tag noted the treatment, date, and identity of the pollen source.

Mature fruit were collected before they opened to release seeds, and were individually stored in glassine or paper envelopes indoors. A total of 665 hand pollinations were performed, with at least 30 repetitions per treatment. Fruit and seed set were recorded for each of the hand pollinations. Each seed was individually weighed on a Fisher electronic balance to the nearest 0.1 mg.

To explore hand-pollination treatment success, a study of seed viability, offspring growth and survival was conducted using the seeds resulting from the hand-pollinations. After being weighed, each of the 833 seeds was placed into its own labeled well in a plastic microtiter well tray, and a few drops of water were added to each well for hydration. The next day, each seed was planted individually in 6-celled plastic starter pots filled with a mixture of seedling potting soil and sand. The pots were arranged in trays, and the trays were placed on the bench of the seedling germination greenhouse at Fairchild Tropical Garden, where they were misted every five minutes for two seconds each time throughout the day. The temperature of the greenhouse varied from 87 to 90 Fahrenheit. The seed pots were checked every few days for germination and growth and after two weeks were moved to an area in the same greenhouse that was misted once a day. Every week, the pots received an extra soaking of water, and trays were rotated on the bench to avoid position-related effects.

Data Analysis

Statistical analyses were conducted using SPSS version 11.5 (SPSS Inc. 2002). Crosstabulation analysis with Chi square tests and Bonferroni post hoc tests were performed on fruit set. To test for differences in mean number of seeds per fruit, mean total seed weight and mean seed weight among the treatments, one-way analysis of variance (ANOVA) tests were performed with appropriate transformations, with pollination treatment as the main effect. Post hoc analyses were conducted using Tukey's procedure if Levene's test of equal variances was not significant, and Dunnett's C procedure was used if Levene's test was significant. Tests were significant if $p < .05$.

Chi square tests with Bonferroni post hoc tests were performed to test the effect of pollination treatment on percent seed germination. For days to germination, one-way ANOVA with Tukey's post hoc procedure were used.

Results

There were significant differences in mean percent fruit set for the six hand pollination treatments excluding the open treatment, $X^2_{(5, N=637)} = 142.9$, $p < .05$. Crosstabulation post hoc tests using the Bonferroni adjustment found that the control treatment (11.6%) was significantly different from all other treatments except the self treatment (26%), $p < .0033$. The offsite treatment (74.3%) was significantly different from the control, self, sibling (47.5%), and near neighbor (38.7%) treatments, but not from the far neighbor (64.2%) treatments (Fig. 3.1.**1**)

Mean seed set differed significantly among treatments, $X^2_{(5, N=637)} = 157.4$. $p < .001$. The offsite treatment produced the most seed, followed by the far neighbor and sibling treatments, which were indistinguishable from each other. The offsite, far neighbor and sibling treatments set significantly more seed than the control and self treatments (Fig 3.1.**2**).

There were significant differences in the mean seed set per fruit for the hand pollination treatments. Maximum seed set is four seeds per fruit. In all treatments the average seed set was greater than two seeds per fruit, but treatments differed overall, $F_{(5, 283)} = 4.39$, $p < .001$. (Kruskal-Wallis non-parametric test performed on untransformed seed set data grouped by treatment confirmed significance, $p < .001$.) There were significant differences between the offsite treatment and all other treatments except sibling and near neighbor (Fig. 3.1.**3**).

Total seed weight differed significantly among treatments, $F_{(5, 250)} = 5.83$, $p < .001$. The offsite treatment differed significantly from the control and self treatments, and there were significant differences between near neighbor and self treatments (Fig. 3.1.**4**). Mean seed weight did not differ significantly among treatments, $F_{(5, 250)} = 1.86$, $p < .2$ (Fig. 3.1.**5**).

Significant differences in seed germination were found among treatments, $X^2_{(5, N=830)} = 47.95$, $p < .001$. Germination percentages of seeds resulting from near neighbor crosses (10%) were significantly lower than those from all other treatments. The germination percentage for sibling-derived seeds (72%) was significantly different than percentages for near neighbor, far neighbor (48%), and offsite (51%) treatments (Fig. 3.1.**6**). Significant differences in days from planting to cotyledon emergence were found among treatments, $F_{(5, 397)} = 3.91$, $p < .01$. Self differed significantly from offsite and sibling treatments (Fig. 3.1.**7**).

Discussion

Jacquemontia reclinata may be characterized as having a mixed mating system. The percent fruit set for self pollination was low (12%), but not low enough to rule out the possibility that plants may set seed with their own pollen, especially, perhaps, when outcross pollen is unavailable or scarce. This may be seen as a form of bet hedging, with the "preferred" method of full seed set being outcrossing. There was a significant difference in fruit set between self, sibling, far neighbor and offsite crosses, but not between self and near neighbor crosses, or between sibling and near neighbor crosses. Offsite crosses by far were most likely to set fruit, and to produce more seed and significantly more seeds per fruit.

Substantially more seed was set with cross pollinations between siblings, far neighbor and offsite parents than with self pollinations (Fig. 3.1.**2**). The lack of highly significant differences among treatments in seed set per fruit masks the dramatic differences in percent seed set among treatments. The lack of significant differences among treatments in mean seed weight may be explained by the possibility that once a flower receives compatible pollen, resources are directed toward seed development regardless of the pollen source. When treatments were compared by total seed weight, significant differences were due to differences in seed set, or total number of seeds per fruit.

There appears to be a relationship between relatedness and fruit set. Crosses between plants that are least related (or unrelated) and from different sites have the greatest likelihood of setting fruit. They also have the greatest probability of setting four seeds per fruit (maximum seed set). Crosses between distant neighbors come in second for crossing success as measured by fruit and seed set. This points toward the importance of pollinator abundance for the reproductive success of wild plants, which may need to exchange pollen over significant distances to produce viable offspring.

The apparent viability of seeds produced as the result of crosses between genetically similar plants seems to contradict the tendency of the species to rely on outcross pollen for fruit and seed production. However, this phenomenon may be an example of reproductive plasticity. Early seedling vigor is a function of several factors not considered here, including time from planting to germination and emergence, duration of leaf development, and growth rate. A follow-up study in which the F1 progeny of hand-pollinations are planted into a typical habitat would shed some light on whether these seedlings are any different from those resulting from outcross pollinations in their ability to survive and reproduce in the wild.

Table 3.1.**1** Experimental plants used in hand pollinations. Fairchild Tropical Garden (FTG) accession numbers denote plants grown from seed collected from wild plants in two populations. Plants with the same accession number are half siblings.

FTG Accession Number	Number of Plants	Site of Origin
2000-478	8	Crandon
2000-479	1	Crandon
2000-480	4	Crandon
2000-481	1	Crandon
2000-482	8	Crandon
2000-483	7	Crandon
2000-484	6	Crandon
2000-485	9	Crandon
2000-487	2	South Beach
2000-488	2	South Beach
2000-489	4	South Beach
2000-490	1	South Beach
2000-491	1	South Beach
2000-492	2	South Beach
2000-493	4	South Beach
2000-494	5	South Beach
	Total = 65	

Figure 3.1.**1** Mean percentage of flowers producing fruits following six controlled hand pollination treatments. Treatments with the same letter do not differ significantly from each other (p<.05).

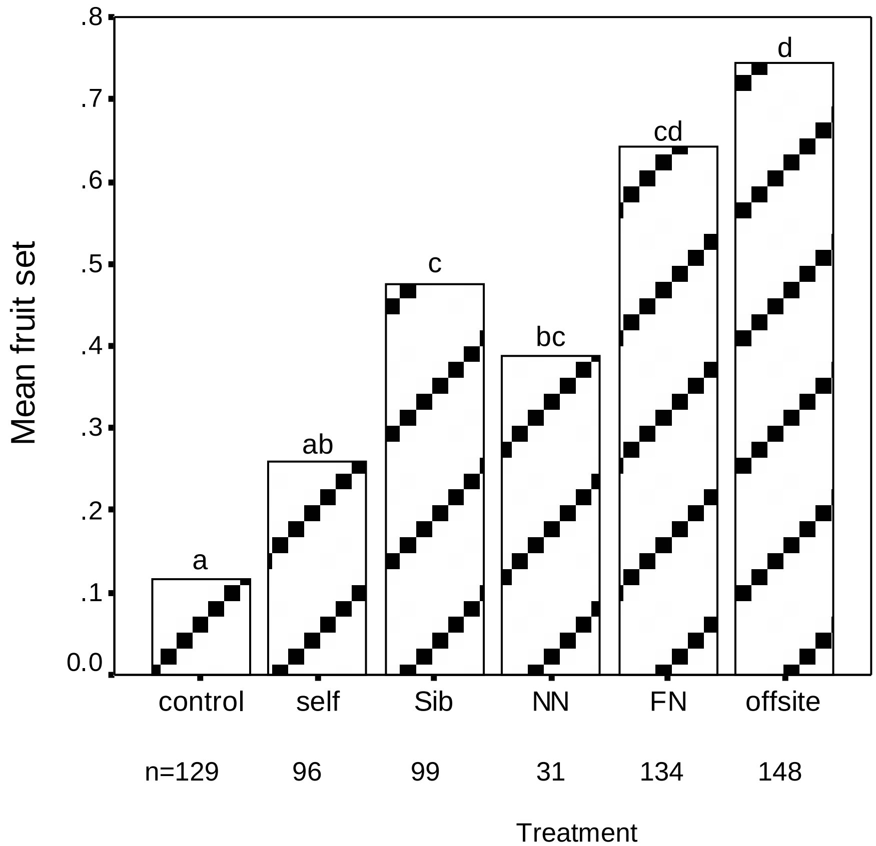


Figure 3.1.**2** Mean seed set (mean number of seeds per flower) per treatment. Treatments with the same letter do not differ significantly from each other.

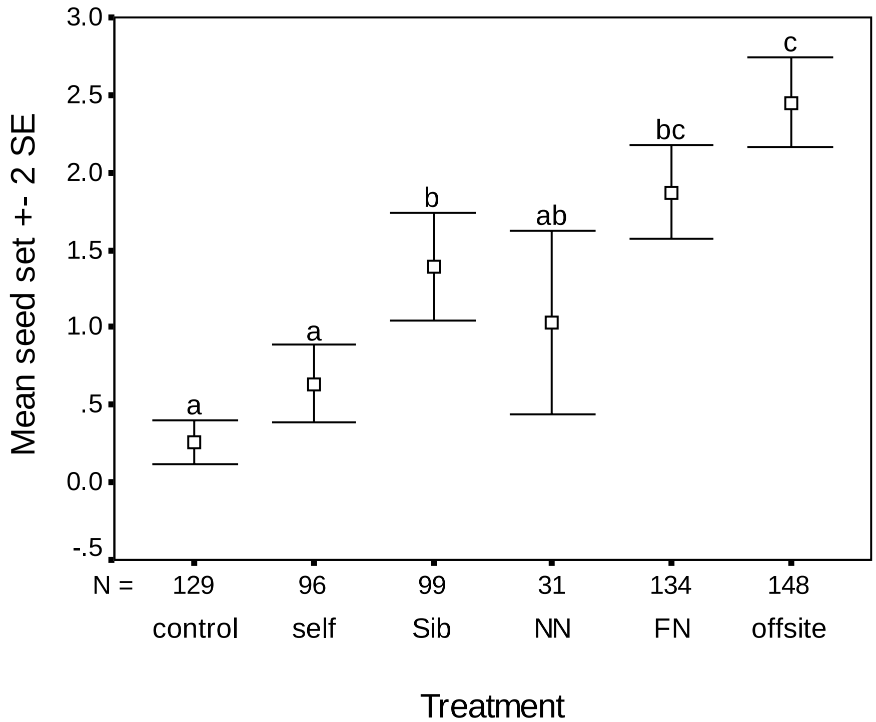


Figure 3.1.**3** Mean number of seeds per fruit resulting from hand pollination treatments. Full seed set is four seeds. Treatments with the same letter do not differ significantly from each other.

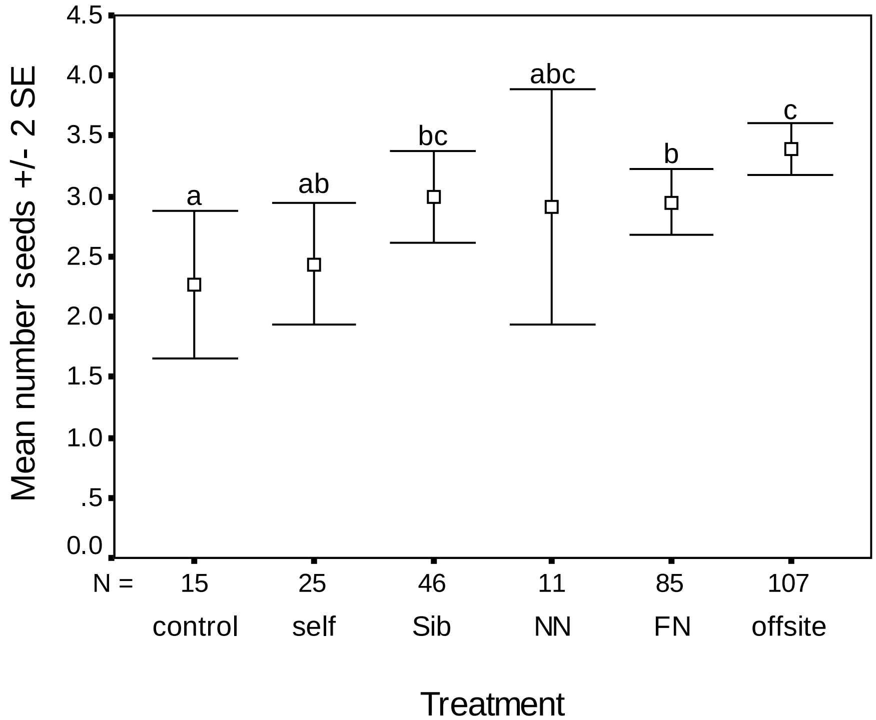


Figure 3.1.**4** Mean total seed weight by treatment. Treatments with the same letter do not differ significantly from each other.

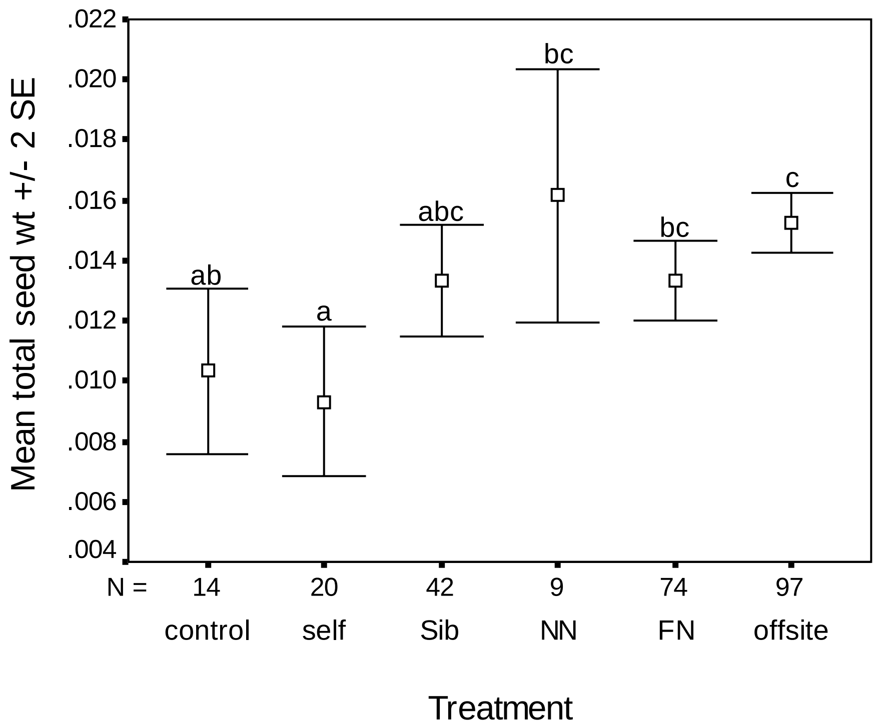


Figure 3.1.**5** Mean seed weight by treatment. Treatments with the same letter do not differ significantly from each other.

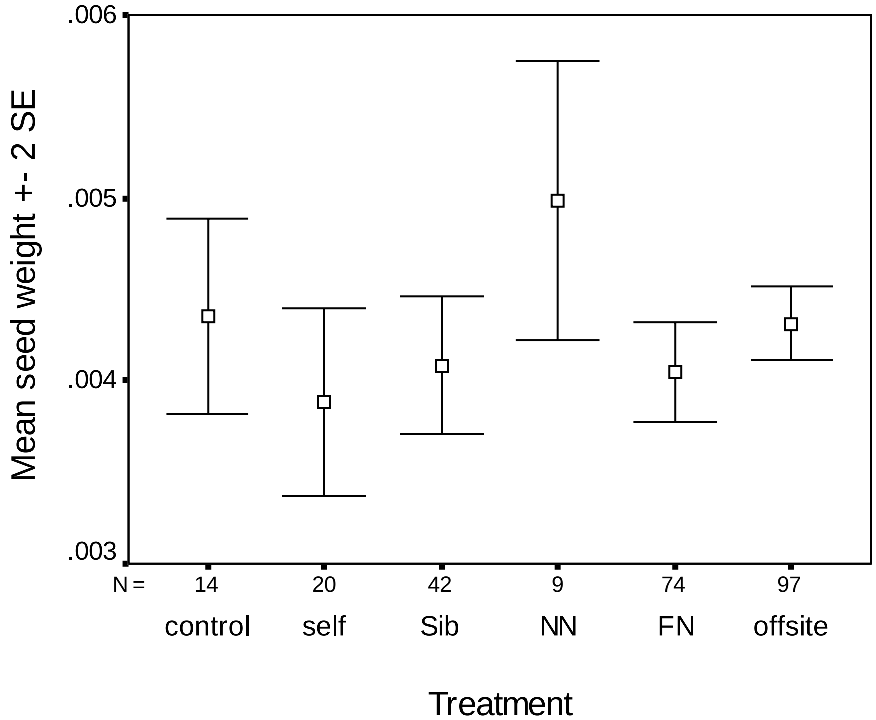


Figure 3.1.**6** Percentage of seeds of each treatment type germinated after 65 days. Sample sizes varied because of differential fruit set among treatments. Percentages with the same letter are not significantly different.

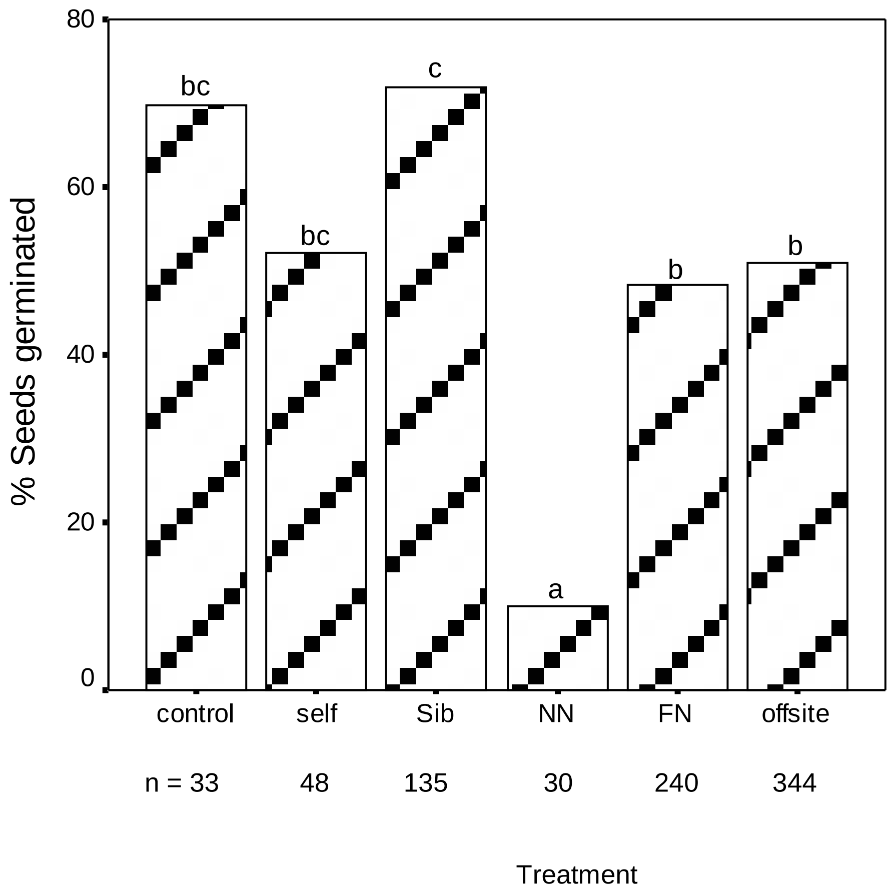
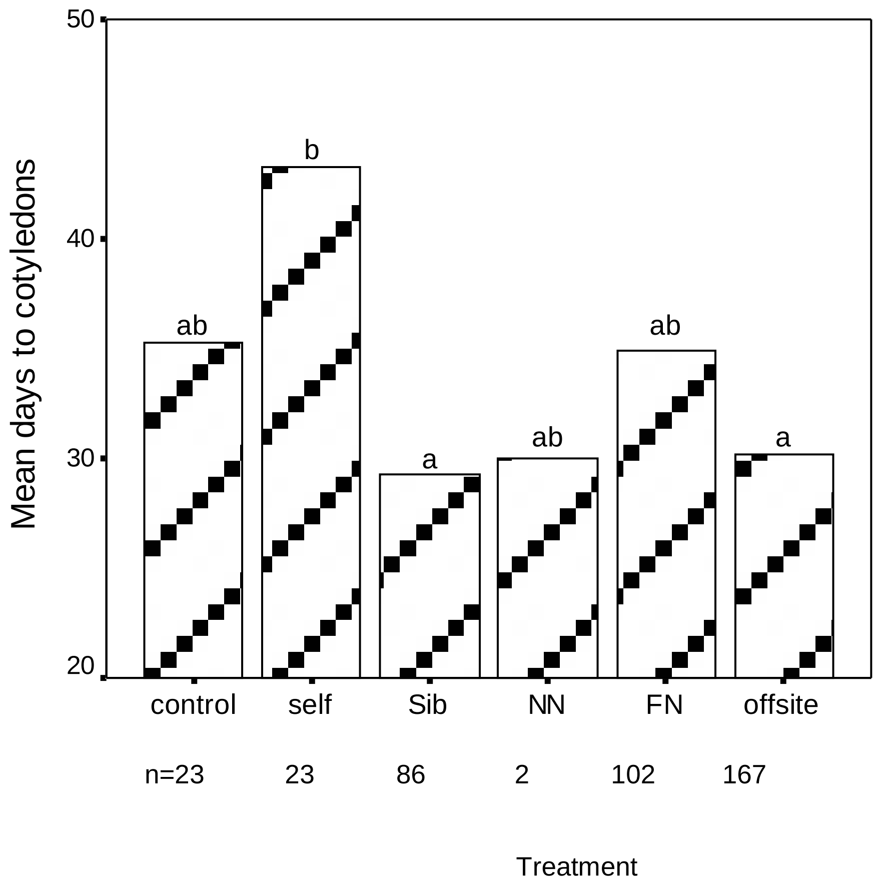


Figure 3.1.**7** Mean days from planting to emergence of cotyledons for seeds resulting from different hand-pollination treatments. Treatments with the same letter do not differ significantly from each other. n = total germinated.



Output 3.2 Determine the response of *J. reclinata* to standard seed storage conditions - Susan Carrara and Dena Garvue

Introduction

Little is known about the seed germination and storage behavior of *Jacquemontia reclinata* and conservation techniques appropriate for this species. *Ex situ* collections can serve as insurance against outright extinction and a source of material for conservation research, including species research and reintroductions. Studies were conducted to identify the germination behavior and protocols, seed storage potential and requirements. Results will provide baseline information needed for building an *ex situ* germplasm conservation collection.

Because knowledge about the flowering and fruit phenology and fecundity of *J. reclinata* was not available to guide seed harvesting, seeds were collected prudently and opportunistically. To reduce the impact of seed harvesting on wild populations, Fairchild Tropical Garden's germplasm collections were used when possible for experimental investigations. Seeds collected from cultivated plants accessioned in FTG's *ex situ* conservation collection of endangered species were used in preliminary trials (Table 3.2.1). After basic germination characteristics had been identified and individual wild plants and populations had been mapped, seeds were extracted from mature fruits collected from selected wild plants (Table 3.2.2). Genetic sampling guidelines were used to obtain a wide range of genetic diversity from populations and taxa for germplasm conservation collections. The genetic origin and identity of all seeds have been recorded and maintained.

Methods

A. Preliminary germination trials using Fairchild Tropical Garden ex situ germplasm

Germination trials were conducted with freshly harvested and stored seeds. Seeds were extracted from mature fruits collected from cultivated plants accessioned in FTG's *ex situ* conservation collection of endangered species. Two accessions were used; both represent germplasm from Crandon Park. Seeds were stored for periods of 1, 3, and 12 months. Seeds that had been stored for 62 months in a general lab at FTG's Research Center were also used in this study. Seeds harvested before the year 2000 were stored in coin envelopes under ambient laboratory conditions and cold storage (general use lab refrigerator) until experiments were initiated. Seeds harvested from the year 2000 on are being stored in foil envelopes under ambient laboratory conditions (23^{o}C) and cold storage (12 and $^-$20^{o}C) at FTG's seed storage laboratory. A total of 1,543 seeds were collected in October and November 1999 and 2000 and January 2001. Seeds were separated into replications for each experimental trial. The number of replications and seeds per replication were based on seed availability (Table 3.2.**1**). Germination tests consisted of sowing seeds on a non-soil growing medium (MetroMix 350) in three-inch containers. Each container was topped with grit and maintained in a greenhouse at FTG's Research Center. Winter high and low temperatures (^{o}C) in the greenhouse were recorded in the low 30s and mid 20s, respectively. Seed germination tests continued for 12-15 weeks. The experiments were monitored once a week and the number of germinated seeds counted. Germination was defined as emergence of the shoot.

B. Crandon Park & South Beach Park Germplasm

Mature fruits were collected from individual plants growing in two wild populations. Germination trials were conducted on freshly harvested and stored seeds. Seeds were stored for 1 and 3 months. Seeds were stored in coin envelopes under ambient laboratory conditions and cold storage (general use lab refrigerator) until experiments were initiated. Seeds were separated into replications for each experimental trial. The number of replications and seeds per replication were based on seed availability (Table 3.2.2). Germination tests consisted of sowing seeds on a non-soil growing medium (MetroMix 350) in three-inch containers. Each container was topped with grit and maintained in a greenhouse at the FTG Research Center. Summer high and low temperatures (^{o}C) in the greenhouse were recorded in the mid 30s and high 20s, respectively. Seed germination tests continued for 12-15 weeks. The experiments were monitored once a week and the number of germinated seeds counted. Germination was defined as emergence of the hypocotyl.

Results

A. Preliminary germination trials using Fairchild Tropical Garden ex situ germplasm
Accession # 89-394 (Table 3.2.**1**)
Ten experiments (Trials 256, 309, 312, 313, 764, 768, 772, 776b, 784, & 916) were conducted to test germination of freshly harvested seed. Total average emergence varied from 45 – 90%.

Two experiments (Trials 257, 258) were conducted to test germination of seeds stored for one month under ambient laboratory environmental conditions and in cold storage. Final average emergence of seeds sown after a month of storage under ambient laboratory environmental conditions was 25%. 35% of the seeds sown after one month of storage in cold storage emerged.

Four experiments (Trials 310, 311, 314, 315) were conducted to test emergence of seed sown after being stored for 3 months under ambient laboratory conditions and in cold storage. Seeds sown after three months of storage under ambient laboratory conditions and in cold storage had a final average emergence of 76% and 81%, respectively.

Two experiments (Trials 350, 352) were conducted to test emergence of seeds stored for 62 months. Seed had been stored under ambient laboratory conditions. An average of 19% of the seeds sown after 62 months of storage emerged in Trial 350 and 30% emerged in Trial 352.

Accession #90-254 & 89-394 (mixed germplasm) (Table 3.2.**1)**
Two experiments (Trials 351, 353) were conducted to test germination of seeds stored for 61 and 62 months, respectively. 430 seeds of mixed germplasm were used in these trials. The final average emergence for Trials 351 and 353 was 42% and 34%, respectively.

B. Crandon Park & South Beach Park Germplasm

Crandon Park (Table 3.2.2)
Twenty-seven experiments were conducted to test emergence of freshly harvested and stored seeds collected from individual plants in the wild population of *Jacquemontia reclinata* at Crandon Park. Seeds were collected from eight tagged and mapped plants during two field outings in April and May 2000. A total of 781 seeds were collected. Germination of freshly harvested seeds ranged from 8% to 85%. Emergence of seeds stored for 1 month under ambient laboratory conditions ranged from 32% to 91%. Emergence of seeds stored for 1 month in cold storage ranged from 18% to 70%. 19% of seeds stored for 3 months under ambient laboratory conditions germinated. 35% of seeds stored for 3 months in cold storage germinated.

South Beach Park (Table 3.2.2)
Seventeen experiments were initiated and/or conducted to test emergence of freshly harvested and stored seeds collected from individual plants in the wild population of *J. reclinata* at South Beach Park. Mature fruits were collected from nine tagged and mapped plants in June 2000. A total of 537 seeds were collected. Germination of freshly harvested seeds varied among individuals. Seeds from two individuals (#2573 and #2574) failed to germinate, whereas an average of 64% of seeds from #2613 germinated. Average total emergence of seeds stored for 1 month under ambient laboratory conditions ranged from 0% to 13%. Average total emergence of seeds stored for 1 month in cold storage was low. 2% of seed stored for 3 months under ambient laboratory conditions germinated. Seeds stored for 3 months in cold storage failed to germinate.

Discussion

Germination of freshly harvested seeds varied among individual plants and by time of year of seed harvesting. Total average emergence of seed varied from 45 – 90% for seed from FTG Accession # 89-394, 8% to 85% for seed from Crandon Park, and 0% to 64% for seed from South Beach. Germination of seeds stored for 1 and 3 months under ambient laboratory conditions and cold storage suggests a potential for short-term seed storage. This further corroborated germination tests of seeds stored for 62 months. Seeds sown after 61 and 62 months of storage under ambient laboratory conditions had a final average emergence of 25%.

Table 3.2.**1**. Effect of storage period, temperature and number of weeks in treatment on seed germination using seed from plants in cultivation. SMC = seed moisture content.

Collection date	Sow Date	Storage period	Storage Temp. °C	Trial number	3 weeks	6 weeks	9 weeks	12 weeks	15 weeks	# seeds/ replicate	# replicates	# seed/ accession
					Total number of seedlings counted							
10/4/99	10/11/99	n/a		256	8	6	6	9		20		
10/4/99	10/11/99	1 mo.	23	257	3	3	5	5		20		
10/4/99	10/11/99	1 mo.	12	258	4	6	7	7		20		60
11/12/99	11/15/99	n/a		309	33	32	31	31		19	2	
11/12/99	11/15/99	3 mo.	12	310	9	26	28	27		19	2	
11/12/99	11/15/99	3 mo.	23	311	19	22	30	33		20	2	116
11/4/99	11/15/99	n/a		312	48	46	45	45		14	4	
11/4/99	11/15/99	n/a		313	28	30	19	8		14	4	
11/4/99	11/15/99	3 mo.	23	314	6	30	41	46		14	4	
11/4/99	11/15/99	3 mo.	12	315	7	24	39	44		14	4	224
10/17/94	12/21/99	62 mo.	23	350	7	12	12	18	26	27	5	135
1/20/94	12/21/99	61 mo.	23	351	8	35	61	74	88	52	4	
mixed												208
10/28/94	12/24/99	62 mo.	23	352	5	33	45	61	74	60	4	
												240
10/17/94	12/27/99	62 mo.	23	353	27	40	50	62	75	37	6	
mixed												222
10/9/00	10/27/00	n/a		764	4	4	5	5		5	2	
		n/a		765	SMC					12	2	
		12 mo.	23	766						5	2	
		12 mo.	12	767						5	2	54
10/16/00	10/27/00	n/a		768	18	18	18	18	18	10	2	
10/16/00	10/27/00	n/a		769	SMC					15	2	
10/16/00	10/27/00	12 mo.	23	770						10	2	
10/16/00	10/27/00	12 mo.	12	771						10	2	90

Table 3.2.**1**. cont. Effect of storage period, temperature and number of weeks in treatment on seed germination using seed from plants in cultivation. SMC = seed moisture content

					Total number of seedlings counted							
Collection date	**Sow Date**	**Storage period**	**Storage Temp. °C**	**Trial number**	**3 weeks**	**6 weeks**	**9 weeks**	**12 weeks**	**15 weeks**	**# seeds/ replicate**	**# replicates**	**# seed/ accession**
10/23/00	10/27/00	n/a		772	30	30	31	31	31	10	4	
10/23/00	10/27/00	n/a		773	SMC					10	2	
10/23/00	10/27/00	12 mo.	12	774						10	6	
10/23/00	10/27/00	12 mo.	-20	775						10	6	
10/23/00	10/27/00	12 mo.	23	776a						10	6	240
11/2/00	11/7/00	n/a		776b	29	30	30	32		9	4	
11/2/00	11/7/00	n/a		777	SMC					9	2	
11/2/00	11/7/00	12 mo.	23	778						9	4	
11/2/00	11/7/00	12 mo.	23	779						9	4	
11/2/00	11/7/00	12 mo.	12	780						9	4	
11/2/00	11/7/00	12 mo.	12	781						9	4	
11/2/00	11/7/00	12 mo.	-20	782						9	4	
.11/2/00	11/7/00	12 mo.	-20	783						9	4	270
11/6/00	11/7/00	n/a		784	25	25	25	25		8	4	
11/6/00	11/7/00	n/a		785	SMC					9	2	
11/6/00	11/7/00	24 mo.	23	786						8	4	
11/6/00	11/7/00	24 mo.	23	787						8	4	114
1/15/01	1/22/01	n/a		916	25	34	34			10	4	
1/15/01	1/22/01	n/a		915	SMC					8	2	
1/15/01	1/22/01	3 mo.	12	917						10	4	
1/15/01	1/22/01	3 mo.	-20	918						10	4	136

Table 3.2.**2**. Effect of storage period, temperature and number of weeks in treatment on seed germination using seed from wild population.

Collection Number	Collection Date	Sow Date	Storage Period	Storage Environ.	Trial #	Total number of seedlings counted: 3 weeks	6 weeks	9 weeks	12 weeks	# of Seeds/ Replicate	# Reps	# Seed/ Accession
Crandon #2301	5/24/00	5/25/00	n/a		512	2	4	4	4	12	3	
	5/24/00	5/25/00	n/a		513	1	4	4	4	12	3	
	5/24/00	5/25/00	n/a		514	0	1	1	1	12	3	108
Crandon # 2302	5/24/00	5/25/00	n/a		515	4	4	4	4	14	2	
	5/24/00	5/25/00	1 mo.	ambient	516	8	8	8	9	14	2	
	5/24/00	5/25/00	1 mo.	cold	517	2	4	4	5	14	2	
	5/24/00	5/25/00	3 mo.	ambient	518	6	4	4	5	13	2	
	5/24/00	5/25/00	3 mo.	cold	519	6	8	9	9	13	2	
	5/24/00	5/25/00	n/a		520	33	32	32	32	17	3	187
Crandon #2386	5/24/00	5/25/00	n/a		521	2	5	5	5	4	2	
	5/24/00	5/25/00	1 mo.	ambient	522	3	6	7	7	5	2	
	5/24/00	5/25/00	1 mo.	cold	523	3	5	6	7	5	2	28
Crandon #2297	4/20/00	5/8/00	n/a		525	9	14	15	15	11	4	
	4/20/00	5/8/00	1 mo.	ambient	526	16	19	21	19	11	4	
	4/20/00	5/8/00	1 mo.	cold	527	6	8	9	10	11	4	132
Crandon #2314	4/20/00	5/8/00	n/a		528	10	11	11	13	6	4	
	4/20/00	5/8/00	1 mo.	ambient	529	8	10	12	11	6	4	
	4/20/00	5/8/00	1 mo.	cold	530	2	6	7	9	6	4	72
Crandon #2318	4/20/00	5/8/00	n/a		531	10	9	12	15	11	2	
	4/20/00	5/8/00	1 mo.	ambient	532	15	16	18	20	11	2	
	4/20/00	5/8/00	1 mo.	cold	533	14	15	14	14	11	2	66
Crandon #2362	4/20/00	5/8/00	n/a		534	13	13	15	17	10	2	
	4/20/00	5/8/00	1 mo.	ambient	535	9	13	13	13	9	2	
	4/20/00	5/8/00	1 mo.	cold	536	9	9	9	9	9	2	56
Crandon #2363	4/20/00	5/8/00	n/a		537	26	30	34	33	11	4	
	4/20/00	5/8/00	1 mo.	ambient	538	12	24	30	30	11	4	
	4/20/00	5/8/00	1 mo.	cold	539	4	11	13	15	11	4	132
South Beach #783	6/19/00	6/21/00	n/a		555	4	4	4	4	7	3	21
South Beach #2564	6/19/00	6/21/00	n/a		556	1	1	1	2	6	2	12

Table 3.2.**2.** cont. Effect of storage period, temperature and number of weeks in treatment on seed germination using seed from wild population.

Collection Number	Collection Date	Sow Date	Storage Period	Storage Environ.	Trial #	Total number of seedlings counted: 3 weeks	6 weeks	9 weeks	12 weeks	# of Seeds/ Replicate	# Reps	# Seed/ Accession
South Beach #2570	6/19/00	6/21/00	n/a		557	0	1	1	2	7	3	
South Beach #2572	6/19/00	6/21/00	n/a		558	1	2	3	3	12	3	
	6/19/00	6/21/00	1 mo.	ambient	559	1	4	4	4	10	3	
	6/19/00	6/21/00	1 mo.	cold	560	0	1	1	1	10	3	96
South Beach #2573	6/19/00	6/21/00	n/a		561	0	0	0	0	13	3	
	6/19/00	6/21/00	1 mo.	ambient	562	0	0	0	0	12	2	
	6/19/00	6/21/00	1 mo.	cold	563	1	1	1	1	12	2	87
South Beach #2574	6/19/00	6/21/00	n/a		564	0	0	0	0	16	3	
	6/19/00	6/21/00	1 mo.	ambient	565	0	0	0	0	14	3	
	6/19/00	6/21/00	1 mo.	cold	566	0	0	0	0	14	3	
	6/19/00	6/21/00	3 mo.	ambient	567	1	1	1	1	13	3	
	6/19/00	6/21/00	3 mo.	cold	568	0	0	0	0	13	3	210
South Beach #2586	6/19/00	6/21/00	n/a		569	3	3	7	11	8	4	32
South Beach #2590	6/19/00	6/21/00	n/a		570	21	23	23	24	14	3	42
South Beach #2613	6/19/00	6/21/00	n/a		571	6	7	8	9	7	2	14

<u>Output 3.3 Experimentally establish the influence of temperature, humidity and light on seed germination and mycorrhizae on juvenile establishment.</u>

Output 3.3.1 Effect of soaking seed in fresh water and removing seed coat pigment upon germination - Matthew Fidelibus & Jack Fisher.

A bright yellow, water-soluble pigment is released when seeds are soaked in water. The nature of the pigment is unknown, but we hypothesized that it could be a germination inhibitor. Since soaking in fresh water extracts these pigments from the seed coat, we tested the hypothesis that the germination rate, total germination, or both might increase with time spent soaking in water. We suggested that this pigment might be removed naturally by rainfall. This fact would influence seed germination of the *in situ* seed bank.

Methods

Seeds were counted into lots of 25 seeds. Each lot was surface sterilized in 10% bleach for 20 min. Then four lots placed on moist filter paper in 4 Petri dishes. The remaining lots were placed in a new volume of 100ml water and agitated. Every 4 h thereafter, four lots were removed from the water and placed in additional filter papers in dishes. Water in the flasks was decanted and replaced every 4 h. The experiment had a water control and soaking treatments of 4, 8, and 12 h. Dishes were kept in a greenhouse with 30% sunlight. Germination was first noted after 8 days. Observations were recorded over the next 10 days. We tested the null hypothesis of no difference among treatments (including control) for the qualitative observations with a modified Chi-square test (Kruskul-Wallis Test) using SAS.

Results

Soaking did remove a bright yellow pigment with successive soakings having less pigment extracted. Control seeds (0 h) had yellow pigment accumulate on the filter paper in contact with them. However, we found no significant difference in germination rates or times related to soaking period. Seeds less than one-year-old had about 75% germination for all treatments after 18 days.

Conclusions

Soaking between 4 and 12 h removes this soluble pigment but did not improve germination beyond that of the control. We conclude that the yellow seed coat pigment is not a critical factor in seed germination.

Output 3.3.2 Effect of light and dark on seed germination - Jack Fisher

It is unclear whether seeds require light to germinate or whether they will also germinate in the dark after wetting. This will be significant behavior for seeds in the natural seed bank. For many species, the soil seed bank must be physically disturbed so that buried seeds are brought to the surface where exposure to light stimulates germination.

Methods

Seeds were collected from *ex situ* plants (FTG2000-483) and stored at room temperature for 1 yr. 25 uniform seeds were placed on filter paper in Petri dishes (90 cm diam.) and wetted with 5 ml tap water. Within 30 min., 6 dishes were wrapped with aluminum foil and 6 dishes sealed with a strip of Parafilm. All dishes were placed on white paper on a greenhouse bench top where light levels were approx. 30% full sun. Dishes were exposed to natural day length and temperature. The null hypothesis of no difference was tested by a Pearson Chi-Square test (using SPSS).

Results

In the light exposed dishes, the first seed germinated after 4 days and the second was seen after 7 days. All dishes were opened after 15 days and the number of seeds in any stage of germination was recorded.

Table 3.3.2.1 Number of seeds germinated in each of 6 dishes, each with 25 seeds, after 15 days.

	Number in each dish	Total out of 150 seeds
Light (natural days)	10, 9, 8, 11, 10, 13	56
Dark (continuous)	7, 15, 8, 6, 11, 9	61

Conclusions

There was no significance difference between light and dark germination after 15 days. These 1-year-old seeds had about a 40% rate of germination. We conclude that seeds on the soil surface and those buried in the soil can germination when kept wet (saturated as in the sealed Petri dishes). The lack of a light requirement for germination indicates that soil disturbance is not required for seed germination.

Output 3.3.3 Effects of salt water on seed germination - Karen Griffin & Jack Fisher

Lab experiments were set up to test the possible effect of soaking of seeds in salt water. The results indicate the vulnerability of the natural seed bank to flooding by storm tide along these coastal habitats.

Methods

Three replicate batches of seed (50 per lot) were placed in 50 ml full-strength seawater ("Instant Ocean") for 0, 2, 8, and 24 h with agitation. The seeds in all treatments (including 0 h control) were rinsed in fresh water before being placed on wet filter paper in Petri dishes in the greenhouse. The rate and percentage of germination was recorded once per week for 3 wk at which time all treatments were similar with an average 47% germination.

Results

An ANOVA of total number of seed germinated per lot (= treatment replicate) and a Pearson Chi-Square of the total seed per treatment (using SPSS) tested the null hypothesis of no difference among treatments. We found there were no significant differences between treatments after weeks 1, 2 and 3.

Conclusions

Soaking seed up to 24 h in seawater did not decrease germination percentage or rate compared to unsoaked seeds. Thus, we find no evidence that inundation of the coastal sites with seawater for up to 24 h will inhibit germination of seeds in the natural seed bank, assuming seeds and substrate are flushed by rain water afterwards, which is reasonable during storm events.

Output 3.3.4 Effect of foliar accumulation of salt on shoot growth and leaf longevity - Karen Griffin and Jack Fisher

A greenhouse experiment was set up to examine the vulnerability of shoots to accumulated salt spray. Potted plants were sprayed with artificial salt water at various frequencies.

Methods

Potted plants were placed in a greenhouse and 5 replicate shoots were selected for treatment. A shoot segment of 5 nodes with mature leaves (old region) and the actively growing shoot tip distal to the mature leaf (young region) were marked. Each pot had one or two experimental shoot at the appropriate stage.

Experiment 1 Salt water ("Instant Ocean" diluted to 25%) was carefully sprayed on these regions 1, 2, and 4 times per week and allowed to evaporate on the leaf and stem surface.

Experiment 2 Repeat of Expt. 1 treatments on different plants but using full-strength sea water (100%). We tested the null hypothesis of no difference among treatments (including control) for the qualitative observations with a modified Chi-square test (Kruskul-Wallis Test) and used a oneway ANOVA on quantitative data (increase in shoot length).

Results

Experiment 1 (diluted salt water). After 4 wk, there was little effect of the treatments on leaf color and senescence, or on shoot tip abortion. However, shoot elongation was significantly reduced (ANOVA test) in shoots treated 4 times per week.

Experiment 2 (full strength salt water). The experiment was repeated using a higher concentration of salt water spray (100%) which caused a more rapid accumulation of salt on the plant surface. Final observations were made after 3 wk. There were significant differences in number of mature living leaves after 3 wk, yellowing of old leaves, distortion of new leaves, and shoot tip abortion. Effects were more pronounced with more frequent spraying.

Conclusions

The results show that salt accumulation on shoot surfaces due to evaporation of sea water spray can be detrimental to leaf growth, shoot tip growth, and leaf health within 3 wk. We must now relate the build up of salt in this greenhouse experiment (concentration of sea salt on plant surfaces) with the observed accumulation of salt on plants or test recording surfaces in the field. Natural salt accumulation will be directly related to wind, relative humidity and frequency and amount of rainfall. However, we hypothesize that natural salt accumulation never reaches damaging levels at locations where plants occur naturally, either due to limit spray and washing by rainwater.

Output 3.3.5 Effect of arbuscular mycorrhizal fungi (AMF) on seedling growth - Jack Fisher and K. Jayachandran

These experiments were completed and their results were reported in Fisher and Jayachandran (2002). Arbuscular mycorrhizal fungi (AMF) are reported and described in the fine roots of *J. reclinata*. Wild-grown plants have typical *Arum*-type arbuscular mycorrhizae. Seedlings of this species were grown in pots with various native soil treatments under greenhouse conditions. Native mixed AMF from soil and roots growing in the natural communities: pine rockland and beach back dune, respectively, were multiplied on Sudan grass and pigeon pea nurse cultures. Native sandy soil is low in available phosphorus (P): ranging from 8-18 ppm at the surface 0-5 cm to 2 ppm at 70 cm depth. AMF significantly increased the dry weight and total P content of seedlings growing on native soil. Additions of phosphate but without AMF also promoted seedling growth. Soil microbe filtrate had no effect on growth. Thus, under natural soil conditions *Jacquemontia* requires AMF but is independent of AMF when P is not limiting.

It appears that AMF inoculation of cultivated plants would be desirable for outplanting into habitats free of potential inoculum, such previously unvegetated sites. Examples of such AMF-absent sites are coastal dredge fills (beach enrichment) or restoration of former parking lots or building locations. In such cases, AMF could replace or reduce the need for phosphate fertilization.

Output 3.3.6 Experimentally establish the influence of light on *Jacquemontia reclinata* seedling growth - Matthew Fidelibus and Samuel J. Wright

Disturbance and destruction of coastal habitats by commercial and residential development has restricted the range of *Jacquemontia reclinata* House ex Small (1905) and contributed, in part, to its status as a federally listed endangered species (Fisher and Jayachandran 2002). Even within appropriate habitats, *J. reclinata* populations are small. According to Lane et al. (2001) there are approximately 700 wild plants, most of which are found in two populations. Factors that affect distribution and abundance of *J. reclinata* are unknown. Anecdotal evidence suggests that the seedlings grow best in the shade (U. S. Fish and Wildlife Service 1999), but the effect of shade on growth has not been tested. Therefore, an experiment was conducted to test the effect of shade on growth and development of *J. reclinata* seedlings.

Methods

Jacquemontia reclinata seeds were collected from plants of the Fairchild Tropical Garden's *ex situ* conservation collection, Coral Gables, Florida. Seeds were germinated in community pots, and sixty seedlings of uniform appearance and stem length (about 0.04 m) were selected for the experiment. Each seedling was transplanted into a separate 750 ml black polyethylene container filled with artificial media (1 perlite: 2 potting soil; v:v). At potting, all plants were top dressed with approximately 7 g of slow release fertilizer (10% N-10% P-17% K; Florikan® Nutricote, Sarasota, FL). Potted plants were placed on black polyethylene benches in full sun. Plants were grown pot-in-pot to insulate the growing media from solar heating.

Four levels of shade were tested; no shade (control), light shade (30% shade cloth), moderate shade (60% shade cloth) and heavy shade (30% + 60% shade cloth). Each level of shade was achieved by placing the plants within chambers that consisted of wooden frames (0.33 m tall x 1 m wide x 1 meter long) covered with the appropriate shade cloth. Control plants were placed on open bench spaces without chambers. There were three replicates of each chamber or open bench space. Within each replicate were five plants. Stem length and leaf number of each plant was measured weekly, and after 47 days, each plant was harvested. At harvest, stems were separated from roots. Substrate was carefully removed from roots by hand. Shoots and clean roots were then oven dried at 65 °C for two days and dry weights were measured.

The chamber average (five plants/chamber) of each measured variable was used for statistical analyses (n = 3). Therefore, the experiment consisted of a randomized complete block design with four treatments and three replicates. Data were subjected to analysis of variance using the general linear model (GLM) procedure (SAS Institute Inc., Cary, NC).

Results

Stem length of *J. reclinata* seedlings, for the duration of the experiment, could be described as a quadratic function of time, regardless of shade treatment (Figure 3.3.6.**1**). A quadratic model was a good fit because the stem extension rate was generally slow in the first eight days of the experiment, but increased markedly thereafter. Plants of all treatments had similar shoot extension rates (Figure 3.3.6.**1**), and after 47 days they also had similar total stem lengths (data not shown) and shoot dry weights (Table 3.3.6.**1**). Stem length and shoot mass might have been reduced slightly by birds that removed a few stem tips from plants in several treatments between 13 June and 6 July.

Shoot growth was not affected by shade treatments, but plants grown under any level of shade amassed only 40 to 70% of the root dry mass of plants grown in full sun (Table 3.3.6.**1**). Because plants grown in shade had less roots than plants grown in sun, the root: shoot ratio of shaded plants was 40 to 50% smaller than that of non-shaded plants. Plants with low root: shoot ratios might be less resistant to environmental stresses, especially water deficit stress, than those with higher root: shoot ratios.

Shade treatments did not affect total plant dry mass (Table 3.3.6.**1**). Because the seedlings had relatively low root: shoot ratios (0.23-0.48), treatment effects on root mass had little effect on total plant dry mass. However, total plant dry mass was positively correlated with root dry mass ($r^2 = 0.61$). Perhaps, plants grown in shade were able to sustain shoot mass at the expense of root mass. All plants had 10 to 20 times greater dry mass than 4 month-old J. reclinata seedlings grown in a glasshouse (70% light exclusion) with less fertilizer (Fisher and Jayachandra, 2002). Thus, *J. reclinata* seedlings are highly responsive to fertilization, even under heavy shade.

Because of their larger root system, plants grown in full sun should have a greater capacity to store carbohydrates and nutrients than plants grown in shade. If so, they might be more resistant to fire and herbivory. In addition, larger root systems may explore a greater volume of soil than smaller root systems and thus should be able to amass more water and nutrition. However, it is not known whether shade would have the same effect on root mass if other resources, such as nutrition or water, were limiting. Moreover, shade might benefit seedlings in nature by creating a microclimate where temperature and vapor pressure deficits are more moderate.

In summary, under conditions of non-limiting soil fertility and moisture, full sun increased growth of *J. reclinata* seedlings. Plants grown in full sun were able to accumulate nearly twice as much root dry mass as plants grown in shade and plants grown in full sun had a greater root: shoot ratio than plants grown in shade. Therefore, beneficial effects of shade, if any, are probably not related to light levels.

References

Fisher, J. B. and K. Jayachandran. 2002. Arbuscular mycorrhizal fungi enhance seedling growth in two endangered plant species from South Florida. International Journal of Plant Science. 163(4): 559-566.

Lane, C., E. P. Pinto-Torres, and H. Thornton. 2001. Final Year 1 Report for USFWS Grant Number 1448-40181-99-G-173: Conservation of *Jacquemontia reclinata*. Pp. 1 - 38. Fairchild Tropical Garden, Miami, FL.

U.S. Fish and Wildlife Service 1999 South Florida multi-species recovery plan. U.S. Fish and Wildlife Service, Atlanta.

Table 3.3.6.**1.** Effect of shade treatments on shoot and root dry mass, root:shoot ratio, and total plant dry mass of *Jacquemontia reclinata*.

Treatment	Shoot dry mass (g)	Root dry mass (g)	Root:shoot (wt/wt)	Total dry mass (g)
Control	2.20[z] a[y]	1.04 a	0.48 a	3.25 a
Light shade	2.41 a	0.66 b	0.28 b	3.07 a
Moderate shade	2.17 a	0.67 b	0.30 b	2.83 a
Heavy shade	1.76 a	0.40 b	0.23 b	2.16 a

[z]Values are treatment means, n = 3.
[y]Means followed by a different letter are significantly different ($\alpha = 0.05$) according to Duncan's Multiple Range Test.

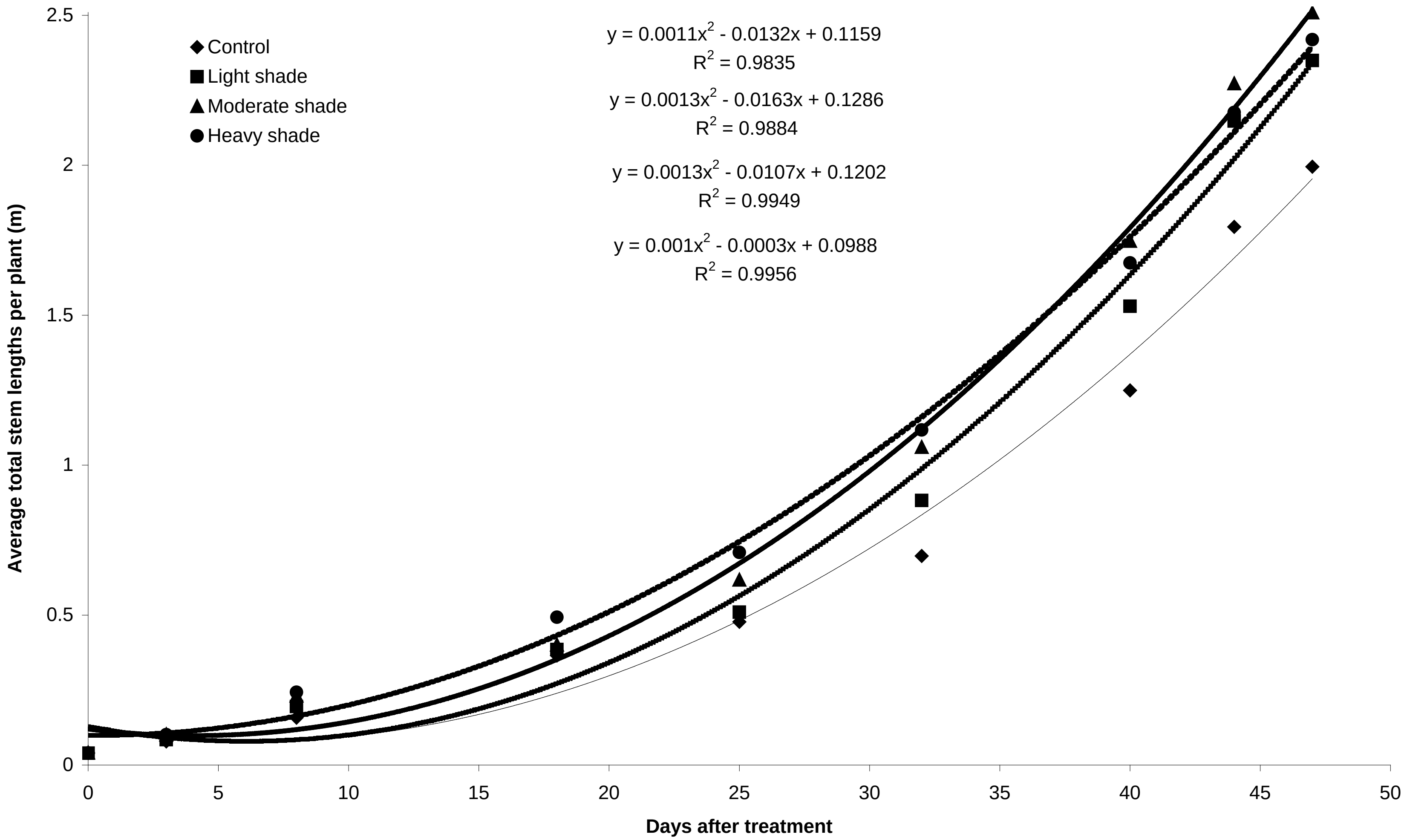


Figure 3.3.6.1. Total stem lengths of plants grown under full sun (control), or light, moderate, or heavy shade, as a function of time.

Output 3.3.7 *Jacquemontia reclinata* Growing in Nursery Conditions – Karen Griffin

Jacquemontia reclinata, while relatively easy to propagate, does not tolerate nursery conditions very well. Seedlings remain healthy for the first year, but decline in health thereafter. *Jacquemontia reclinata* seems to repot at least once or twice without too much trouble, but once the plant is in containers for 1 year or more, the root system deteriorates and readily pulls apart during repotting. Whether the plants are repotted or not, we have observed high mortality rates of plants held in containers for more than one year.

One hypothesis that may explain why the plants do not survive well in regular nursery conditions concerns the root structure of adult specimens in wild populations. Two basic root structures have been observed, a fine, fibrous root mass on the surface, and a secondary lateral root system that runs deeper into the sand dune (Output 4.1.1). These may serve two purposes, the surface root mass may primarily be for nutrient uptake and the lateral root structure for water uptake. It may be that when the plant gets older, it depends on this root differentiation. The deeper lateral roots of *J. reclinata* in the wild population probably allow the plants to take advantage of the constant low to medium moisture levels that exist deep in the sand dune no matter the weather above. The surface roots then can concentrate on gathering what nutrients are available from organic matter that collects within the first few inches of the sand without the plant being affected so much by drought or flood.

In nursery conditions this differentiation does not occur. The root system remains very fine and fibrous and rots very easily with regular irrigation. Our attempts to provide better drainage and/or reduce watering have not solved the problem. Instead the root mass dries out very quickly and the plant dies from dehydration. For purposes of keeping a live *ex-situ* collection, this problem would need to be solved. Otherwise, it is highly recommended to keep the *ex-situ* collection in seed form and propagate and grow plants in the nursery only when necessary.

<u>3.4 Monitor every 2 months the flowering, fruiting and growth phenology of a sample of individuals from the largest wild population</u>

3.4.1 Flowering Phenology and Pollinator Associations of *J. reclinata* – Elena Pinto-Torres and Suzanne Koptur

Methods

Bimonthly surveys of patches of one or more plants in the largest wild population were made for a year, from May 2001 to May 2002. Patches chosen for monitoring had been mapped and tagged by H. Thornton and D. LaPuma in the year 2000 (Year 1 Final Report), and many overlapped with Pascarella's demographic plots (Output 3.4.2, below). The number of open flowers, number of flower buds, number of immature and mature fruit, herbivory, new growth, and mortality were recorded at each survey. Actual numbers of open flowers per patch were counted, and estimates of number of buds, fruits, herbivory, growth, and mortality were made. Mortality was considered to be complete or incomplete, to include dieback of stems as a separate measure from growth. Notes were also made of other flowering species in or adjacent to the patches, and the encroachment or retreat of surrounding vegetation. Seed production was assessed by counting seeds from randomly selected fruits. Observations of individual flowers were conducted to determine timing of floral development. Floral opening and closing times, and anther dehiscence time were recorded.

To determine the identity and behavior of potential pollinators, between May 2001 and May 2002, flower visitor behavior was observed during ten-minute watches. These observations were made on non-rainy days between 7am and 6pm. At each observation period, the following data were recorded: number of open flowers, number of flowers observed during the watch, total number of insect visits to flowers, and time of day. Flower visitors were identified by sight whenever possible and specimens of each visitor species were collected. Data regarding behavior of the insects on the flowers and in the patch of flowers were also recorded, including: length of visit per flower, sequence of visitation (whether roughly linear or random), possible collected reward (pollen, nectar, both, or neither), and visitation of flowers of other species.

Results

Although flowers were observed throughout the year, most flowering occurred during the dry winter season, from November to May. Peak flowering occurred in mid to late spring (April and May), with spikes in flowering following rainy periods (Fig 3.4.1.1). Flowers opened before or shortly after sunrise and closed by late afternoon. The corollas abscised the following morning. Anther dehiscence occurred shortly after sunrise, and later on cloudy or cooler days.

Fruits were produced throughout the flowering season, and continued to ripen and release seeds into late June, when most sexual reproduction gave way to vegetative reproduction. Stem tip growth was heaviest during the rainy summer months, especially August and September. Herbivory was noted year-round, but was minimal in all but a few patches, where encroaching vegetation was overshading plants. Stem dieback was also confined to a few patches, usually those that were being encroached upon by over-shading shrubs and vines. A few new seedlings (previously unaccounted for in surveys), were found, tagged, and mapped, and one mapped patch containing the remains of a tagged rootstock appeared to have been extirpated (confirmed by Pascarella).

During a total of fifteen hours of watch time, 22 species were observed visiting flowers (Table 3.4.1.**1**). The most common visitors were members of the Halictidae (7 species), especially dialictus (“sweat”) bees (4 species). The highest rate of visitation occurred during the four hours following sunrise on mostly cloudless, warm days; less activity was observed on cooler, cloudier days. Visitation to flowers of *J. reclinata* was also influenced by other species in bloom. Most notably, when there were blooming saw palmettos (*Serenoa repens*), sabal palms (*Sabal palmetto*), or prickly pear cactus (*Opuntia humifusa*) nearby, insects were abundant on these plants while the *J. reclinata* flowers were visited less than when no other major blooms were nearby. During some observation periods, there was high activity on *J. reclinata* flowers early in the morning, with the visitors switching later in the morning to alternative sources of pollen and/or nectar.

Discussion

Although a year-long study can not yield a picture of annual changes in the phenology of this relatively healthy population, it did serve to confirm previous observations that flowering and fruiting of the species is seasonal, and is related to within-season variability in rainfall patterns and intensity. Given the apparent importance of open areas in the dune vegetation to the growth and survival of this species, appropriate and feasible methods of vegetation thinning or removal around plants is recommended. Also, monitoring for a period of several years at several sites is essential to understanding super-annual and site-related patterns in the flowering, fruiting, and growth phenology of the species.

Copious fruit production on most plants observed indicates that there is ample flower visitation for pollination of this largely self-incompatible species (see Output 3.1) to take place. John Pascarella first noted, and we concur, that different patches (and possibly individual plants) are on different flowering and fruiting schedules, and do not always overlap in having open flowers. Pollen flow between individuals may therefore not only be determined by pollinators, but by flower availability.

Though individual plants of *J. reclinata* are much larger and vegetatively somewhat distinct from its sister pine rockland endemic (*J. curtissii*), the flowers and floral biology of the two species are remarkably similar. Both of these neoendemic species have generalized, entomophilous flowers with rotate, white corollas, and contain nectar as a reward for visitors. Flowers of both species open in the early morning and last only one day. Both species are visited by a wide array of insects (primarily Hymenoptera, Diptera, and Lepidoptera). At all sites where plants naturally occur, visitors to flowers of *J. reclinata* have been observed, though diversity was greatest at the largest sites where the majority of individual plants exist (Pinto-Torres and Koptur, unpublished data). We surmise that the generalist pollination of this endangered species is beneficial to its persistence in small or isolated populations, as it can be visited and pollinated by a wide variety of insects. More research is needed to know how far these different visitors can move between plants to better understand the natural potential for outbreeding in remnant populations.

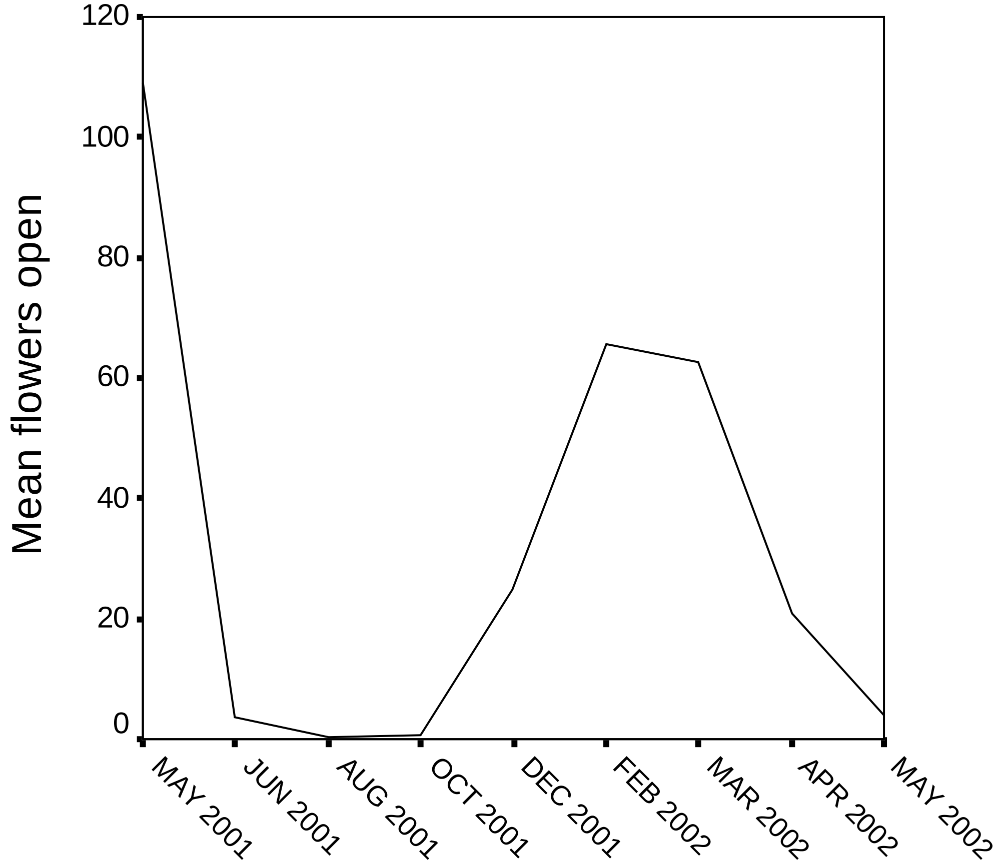
Table 3.4.1.**1** Insect visitors collected at flowers of *Jacquemontia reclinata*

All species on this list were verified with our voucher specimens using the reference collections of Keith Waddington (University of Miami) and Mark Deyrup (Archbold Biological Station). Some specimens still need to be determined at the University of Florida. Our collections were made in Dade County (at Crandon Park and Bill Baggs State Recreation Area). Dan Austin communicated his records to us prior to our studies and we include them in our list below. His collections were most probably made in Palm Beach County. John Pascarella also shared his observations with us early on in the project.

reported by John Pascarella; * reported also by Dan Austin; ** reported only by Dan Austin

Taxon	Family
HYMENOPTERA	
Agapostemon splendens	Halictidae
Augochloropsis anonyma	Halictidae
Augochlora pura	Halictidae *
Augochlorella striata	Halictidae **
Nomia cf. *maneei*	Halictidae **
Dialictus (Evylaeus) nelombensis	Halictidae **
Dialictus sp. 1	Halictidae
Dialictus sp. 2	Halictidae
Dialictus sp.	Halictidae #
Lasioglossum sp.	Halictidae **
Apis mellifera (honeybee)	Apidae *
Melissoides bimaculata	Anthophoridae#
Melissodes communis	Anthophoridae
Megachile brevis pseudobrevis	Megachilidae
Megachile sp. **	Megachilidae
VESPIDAE	
Campsomeris sp.	Vespidae *
Unidentified	Vespidae *
DIPTERA	
Palpada vinetorum	Syrphidae
Systoechus sp.?	Bombyliidae
Unidentified	Bombyliidae**
LEPIDOPTERA	
Agraulis vanillae (gulf fritillary)	Nymphalidae
Unidentified skippers	Hesperiidae

Figure 3.4.1.**1** Mean number of flowers open in Crandon population during monthly surveys between May 2001 and May 2002. Peak in May 2001 followed heavy rains.



Output 3.4.2 Demography of *Jacquemontia reclinata* from March 2000 to March 2003 - John B. Pascarella

Introduction

Jacquemontia reclinata (Convolvulaceae), a coastal perennial vine was listed as endangered under the Endangered Species Act in 1993. It currently is known from seven remnant populations ranging from Palm Beach County to Miami-Dade County, Florida. One key threat to any endangered plant may be long-term demographic decline in population size, leading to local and regional extinction of existing populations. The demography (change in population size over time) of the endangered vine, *Jacquemontia reclinata*, is being studied at four of the existing seven populations. Of the known 733 plants, 147 individual rootstocks, comprising 19 patches, are being studied.

The four study populations span nearly the entire range of *J. reclinata*, with one population from near the northern edge (Loggerhead Park in northern Palm Beach County), two populations in the center portion of the range in southern Palm Beach County (South Beach and South Beach Inlet), and the extreme southernmost population (Crandon Park on Key Biscayne in Miami-Dade County). The populations also occupy the two main habitat types of *J. reclinata*-barrier islands such as Key Biscayne and coastal dunes. Two of the four populations (South Beach and Crandon Park) are the largest remaining populations while South Beach Inlet and Loggerhead have relatively few individuals remaining.

This demographic study was analyzed using a patch dynamic model. First, a matrix model of patch dynamics was constructed. Average survival, growth, and reproductive outputs and their standard deviations were calculated from the three-year demographic study and from the seed longevity, soil seed bank studies, and the planned seed germination study. All patches from the four populations were analyzed averaged over the three years. Patches were classified into appropriate size categories-small, medium, large, and extra-large. Data on patch formation depended upon the observation of new patches forming within the study areas. This patch-model was used to calculate demographic statistics including the patch growth rate (lambda), stable patch structure, reproductive value, sensitivity, and elasticity of the patch. The MATLAB programming language was used for these analyses. In addition, RAMAS matrix modeling software was used to calculate extinction risk probabilities and time to extinction estimates for the populations.

Methods

Nineteen distinct patches from four populations of *J. reclinata* have been monitored during this time period, including Crandon Park (CR-12 patches), South Beach Inlet (SBI-2 patches), South Beach (SB-4 patches), and Loggerhead Park (LG-1 patch). Each patch consists of a discrete area that has at least one individual *J. reclinata* plant growing.

In 2001, a gridded meter square system was laid out around the existing plants using meter tapes and pvc tubes hammered into the sand. Maps were made of the location of the plants, including tagged stems. Using a meter square quadrat that was subdivided into 16 25 by 25cm subquadrats, I recorded the vegetative cover and fruit production during the initial census and in March 2001, 2002, and 2003. In addition, trips were made in July 2000 and December 2000 and December 2001 to record fruit production. During the March 2000 and December 2001 census, only the diagonals within the 1 by 1 m^2 quadrat were sampled for fruit production. In the remaining censuses, all fruits within the entire 1 by 1 m^2 quadrat were recorded. The statistical analyses presented in the results section do not include the most recent census in March 2003.

Total patch size was determined by the number of 1 by 1 m^2 quadrats occupied by plants. Since the grid-plot was set up with at least a 1 to 2 meter buffer zone, lateral movements of the plant could be observed. Death of the patch was recorded when no plants existed in the patch including the buffer zone. Growth was when the patch expanded in size and regression was when the patch got smaller. Occupancy was recorded as the number of occupied subquadrats divided by the total number of subquadrats (16 * the number of meter square quadrats the plant occurred in). Occupancy ranged from 0 to 1 (A patch that completely disappeared was coded as 90. A patch coded as 1 would mean that every subquadrat within the larger quadrats was occupied.

Cover was recorded using the following scale: 0 (plant absent), 1 (cover <25% of subquadrat), 2 (cover 26-<50% of subquadrat), 3 (cover 51-<75% of subquadrat), and 4 (cover >75% of subquadrat). Since values of 0 were not used in calculating the cover, the average cover could range from 1 to 4, with 1 being minimal vegetative coverage and 4 being nearly exclusive coverage. During the spring census period, any new plants (seedlings or root sprouts, etc) were noted. In December 2001, the ground and arboreal cover was recorded in each 1 by 1 m^2 quadrat using the same cover values: however, these were for all species combined and cover primarily is the percent of sky or ground covered by plants.

Fruit values from the first two censuses were corrected for total fruit production by multiplying the number of fruits recorded in the 4 diagonal subplots x 4 times the occupancy of the previous year. Since total fruit production for one census year includes both the December and following March census, three and a half years of fruit data were available for this analysis, including the March 2000 data (1/2 of the 1999-2000 fruit production), the December 2000 and March 2001 fruit data, and the December 2001 and March 2002 fruit production data, as well as the March 2003 census (1/2 the year). The December and March censuses were summed to produce an annual fruit production and an average of the two was also taken. Fruits were multiplied by 3.47 to generate an estimate of seed production (3.47 seeds/fruit, N = 30, Pascarella, *unpublished data*). All censuses were summed to produce a total fruit production estimate. Since the patches varied in size, a standardized measure of fruit production was also recorded as the total fruit production divided by the patch size for fruit production per m^2.

Soil seed banks were studied using from four to six random 2 by 10 cm soil cores at a variety of patches and sites. At South Beach, a soil vacuum technique was also tried. In the soil vacuum technique, a 25 by 25cm^2 subplot located next to a heavily fruiting plant was vacuumed for 90 seconds, approximately filling the hand-vacuum receptacle. At Crandon, 4 packets of 10 seeds each (10 replicates) were buried in March 2001 to test longevity over a 2-yr period. This experiment was repeated in March 2003. In addition to the buried seed longevity study, a seed germination experiment (10 seeds at 13 localities in both shade and sun treatments) was started in March 2003 at Crandon Park and one transect of 10 seeds at 12 locations in the shade was started at South Beach Park.

Results

Stems and Plot Size

A total of 147 individual stems occur in the nineteen patches, ranging from 1 to 38 stems per patch, with a mean of 7.7 stems (Table 3.4.2.**1**). However, most patches have 5 or fewer stems, with only the patches from SB and one patch from SBI with more than 5 stems per patch. There was a statistically significant difference in the number of stems from South Beach compared to Crandon Park (p<0.05, Kruskal-Wallis one way ANOVA, Dunn's pairwise multiple comparison, p<0.05). These two sites had the greatest difference in stems/patch.

Total area of the 19 plots, which includes the patch and a buffer, was 1242 m^2 (range 12 m^2 - 180m^2, mean 65.4m^2). The average patch size though was considerably smaller (range 2m^2 – 83 m^2, mean 22m^2). There was no statistically significant difference in average patch size over the 2-year study among the 4 study sites (KW ANOVA, p=0.153) although South Beach and South Beach Inlet had on average, the largest patches. There was a significant positive correlation of average patch size with the number of stems (R = 0.90, p <0.0001, N =19, Fig. 3.4.2.**1**).

Patch Size

Total patch area of all 19 patches was at a peak in 2000 with 439m^2 of area, declining to 400m^2 in 2001, increasing to 413m^2 in 2002, and declining to 325m^2 in 2003. From all sites combined, there was no significant difference in mean patch size from 2000, 2001, or 2002 (KW ANOVA). Multiple linear regression found that the total change in patch size was significantly related to the original cover in 2000 (p<0.05), with a R of 0.632, N =19, and p < 0.05 but was only weakly explained by the original patch size (*p* = 0.065, Fig. 3.4.2.**2**) and showed little relationship to the original occupancy in 2000. At the patch level, individual patches showed considerable variation in growth. Seven patches increased or stayed the same both years, three patches decreased or stayed the same both years, and nine patches had both negative and positive growth years. The largest variation in patch size was observed at patch 6 at Crandon, which decreased from $41m^2$ to $3m^2$ during the two years. This patch, and presumably *Jacquemontia reclinata*, was infested with the parasitic plant *Cassythia* sp., which may have caused this precipitous decline. By 2002, the plant was barely surviving, the following year it died, and the patch subsequently went extinct. The largest increase was observed at patch 8 at Crandon, where the plant expanded from $7m^2$ to $19m^2$.

Occupancy

Occupancy ranged from 0.145-0.706 across the 4 census periods and averaged 0.491 in 2000, 0.421 in 2001, 0.386 in 2002, and 0.34 in 2003. There was significant variation in average occupancy across the four sites, with SBI being significantly higher than LG and SB and CR being significantly higher than LG. Across the 3 censuses (2000-2002), there was a significant change in average occupancy per census (ANOVA, $p < 0.05$, with 2000 and 2002 being significantly different). The change in occupancy over the two year period was significantly explained by multiple regression, with the occupancy in 2000 ($p = 0.01$) being the most important variable ($R = 0.75$, $N = 19$, $p < 0.01$).

Cover

Average cover per patch per year varied from a low of 1 to a high of 1.78, with an average across all three censuses of 1.31. Average cover varied significantly across the four sites (ANOVA, p <0.05) but there were no significant differences among the individual groups. Average cover per patch per year increased from 1.37 in 2000 to 1.41 in 2001, decreased to 1.14 in 2002, and then increased slightly to 1.16 in 2003 (ANOVA, p <0.001). The cover in 2002 was significantly lower than in both 2001 and 2000. The change in cover over the two year period was significantly explained by multiple regression, with the cover in 2000 ($p < 0.001$) being the most important variable for explaining most variation in patch survival ($R = 0.78$, $N = 19$, $p < 0.01$).

Patch Extinction

Of the 19 patches, four extinctions occurred during the three censuses (2000-2003), with all extinctions occurring during the 2002-2003 census. In the first two years, no patches went extinct. In addition to the four extinctions, two patches, one at Crandon and the single patch monitored at Loggerhead, were nearly extinct in 2003, consisting of a single m^2 of living plants. The average annual survival rate is 93% per year with a standard deviation of 9.95%. Based on this analysis, a stochastic model of the population dynamics of the patches found that the population is declining and there is a 69% chance of total extinction of all 19 patches during the next 50 years (Figs. 3.4.2.**3 & 4**).

Fruit Production

Fruit production was observed in every patch during at least one census (Table 3.4.2.**2**). However, individual patches showed tremendous variation in fruit production (Figs. 3.4.2.**5 & 6**). In 2001, fruit production ranged from 0 to nearly 4000 fruits per plot. When calculated as fruit production per m^2, this ranged from 0 to 57 fruits, with an average of 22 fruits/m^2. Given an average of around 3 seeds per fruit, the 19 plots during 2001 produced an estimated 41,085 seeds. While many plots showed similar levels of fruit production, some increased considerably while others showed a large decrease. Total fruit production ranged from a low of 9 fruits at the 1 patch at Loggerhead to a high of 11,622 fruits at Crandon patch 12.

For the total fruit production, standardized fruit production, fruit production during 2001 and fruit production during the 2002 census period, there was no significant difference among the four sites (ANOVA). Comparing fruit production during the two years using a paired t-test (pairs were fruit production per patch in each year), there was no significant difference although mean fruit production was lower in 2002 than in 2001 (822 vs 1001 fruits). Fruit production in the December census averaged about 78% of that observed in the March census. In the single census during the 2002-2003 period, fruit production totaled 5348 fruits. From all sites and all censuses, 59,425 fruits were produced, each bearing 3-4 seeds for a range of total seed production of 178,275-237,700. A multiple regression analysis of total fruit production found that average patch size over the study period was the best predictor of total fruit production ($R = 0.85$, $N = 19$, $p < 0.001$, Fig. 3.4.2.**7**). In spite of the large seed outputs, no seedlings were noted during the two spring census periods in 2001 or in 2002. During the 2003 census, some possible seedlings were noted and tagged. However, at the very young stage, it is difficult to distinguish *Jacquemontia* seedlings from a number of other species.

Soil seed cores
The soil seed bank was studied both descriptively and experimentally. I initially collected soil seed cores using a standard soil auger in July 2000 from a subset of marked patches. Samples were sieved and total seeds counted. In December 2000 and in both samples in 2001, 6 samples/patch were used instead of 4. There was a decline in the number of seeds from the March or July census to the December census, suggesting that seed number in the soil increases at the end of the fruiting season and then declines as seeds are either eaten, lost, or germinate during the rainy season (Table 3.4.2.**3**). However, the lack of seedlings suggests that successful recruitment is rare and most seeds die, for reasons unknown.

The surface seed sampling using a hand held battery powered vacuum was quite successful (Table 3.4.2.**4**). Compared to the deeper soil core techniques, relatively large numbers of seeds were found during the March and December 2001 censuses, with more seeds present during March and fewer during December. This pattern is consistent with the pattern found from the deeper soil core study with many seeds being deposited on the soil surface during the fruiting period in the spring and early summer and loss of seeds during the summer and fall.

Buried Seed Longevity Experiment.
Ten fine mesh fabric bags each containing four seed packets with 10 seeds each were buried in March 2001 at Crandon Park at approximately 10cm depth. Seed packets were retrieved in December 2001 (9 months) and March 2002 (12 months). Of the seed packets, 9 packets had all seeds decomposed while one packet had 7 remaining viable seeds (Table 3.4.2.**5**). In March 2002, 1 of the seed packets contained 3 viable seeds. Seed packets were harvested after 24 months in March 2003, however, data is not yet available for analysis. In March 2004, the last group of seed packets will be harvested. This study suggests that buried seeds will not persist more than a few months and that a long-term seed bank is not a significant part of the life-history strategy of *J. reclinata*.

Conclusions

During the first two years, I observed stasis in the population dynamics; there was neither patch mortality nor recruitment of new individuals to the patches. Thus, the population was stable during this period. However, the third year was quite distinct, with relatively high mortality levels and general decline in patch size, occupancy, cover, and fruit production. In addition, at a few sites, some possible seedlings and root sprouts were found.

This suggests that long-term data on both mortality and recruitment is necessary in order to accurately model the dynamics of the *Jacquemontia reclinata* population. The study patches will be monitored for at least one more year and possibly longer depending on funding.

The high levels of fruit and seed production, coupled with the lack of recruitment, suggests that the recruitment niche may be highly variable in both space and time. This study has found considerable potential variation in growth, with some individual patches either shrinking or increasing in size relatively rapidly.

Summary Findings

During the first two years, no entire patches went extinct, however during the third year of the study 21% of the patches went extinct. Averaged over three years, annual mortality was 7%. Based on this data, there is a 69% chance all 19 patches will go extinct during a 50-year period.
Some tagged stems have disappeared; new root sprouts have occurred in some patches.

Vegetative growth is highly variable in space and time.Fruit production is highly variable in space and time; some patches highly fecund, others have minimal flowering and fruiting.
No observed recruitment of juvenile plants from seed but some possible seedlings observed in the March 2003 census. The soil seed bank is short-lived; seeds peak in abundance during the seed release period in early spring, then decline during the summer. Most seeds found in top layer of soil, few found in deeper soil layers. Buried seeds show little longevity in soil (97% mortality during 1st year of burial).

Management considerations

Given the lack of recruitment of new individuals, protecting existing patches with known plants should be a priority. Protect existing patches from damage by park workers and visitors. At Loggerhead park, I observed a park worker incidentally pull one plant out of the ground, killing it, when picking up trash along the sidewalk. Prevent damage from vehicles (park maintenance trucks, bicycles) by rerouting or fencing known populations along roadsides (most common at Loggerhead and Crandon).

From a demographic standpoint, seeds appear to be minimally important in the short-term dynamics of the patches, thus seed harvesting should be allowed to occur on all patches, particularly those with large numbers of individuals, those that have unique and or diverse genotypes, and from across the known existing range of the species. Highly fecund patches had highly variable seed production across years. Seed banking offsite should be encouraged for future reintroduction and outplanting.

Although the GIS data is still being analyzed, it is clear that *Jacquemontia reclinata* does not compete well when overgrown. In an experimental framework, paired plots should be selected, with one plot not being managed while in the other plot, woody vegetation is carefully removed. Although the causes of death of the four patches are not known, it is likely that shading and possibly parasitism by the parasite *Cassythia* were the primary causes.

To encourage seed germination, further research is needed to see if plants can be established on site through seed. It is likely that lack of sufficient water during the initial establishment phase of the seedling prevents successful recruitment. Either a watering experiment with planted seeds or small-scale microsoil manipulation to enhance water capture should be attempted.

Table 3.4.2.**1**. Vegetative demographic parameters. Size is the number of square meters occupied by the plant within the study plot, occupancy is the percentage of occupied subplots, and cover is the average cover value in occupied subplots (cover ranges from 1 (<25% cover) to 4 (>75% cover)).

Site	ID#	# stems	Plot size	Size (00)	Size (01)	Size (02)	Size (03)	Occ. (00)	Occ. (01)	Occ. (02)	Occ. (03)	Cover (2000)	Cover (2001)	Cover (2002)	Cover (2003)
LG	1	4	40	10	10	12	1	0.28	0.21	0.26	0.31	1.36	1.32	1.00	1.2
SB	24	6	24	6	10	13	6	0.42	0.23	0.21	0.25	1.00	1.12	1.14	1.00
SB	25	38	176	83	72	74	71	0.42	0.30	0.37	0.29	1.26	1.26	1.02	1.13
SB	26	33	192	69	62	70	62	0.36	0.40	0.40	0.36	1.23	1.18	1.12	1.17
SB	27	13	80	27	34	28	30	0.38	0.52	0.50	0.47	1.26	1.27	1.19	1.32
SBI	21	25	90	37	39	35	29	0.61	0.71	0.54	0.43	1.44	1.53	1.19	1.15
SBI	22	2	42	14	14	17	17	0.46	0.54	0.50	0.50	1.50	1.58	1.39	1.26
CR	1	1	25	9	2	2	Ext.	0.39	0.47	0.22	Ext.	1.43	1.73	1.00	Ext.
CR	2	1	20	6	5	7	1	0.67	0.30	0.28	0.06	1.56	1.67	1.16	1.00
CR	3	2	25	7	9	11	Ext.	0.61	0.42	0.44	Ext.	1.47	1.62	1.10	Ext.
CR	4	3	40	13	8	7	2	0.60	0.31	0.35	0.19	1.42	1.30	1.06	1.00
CR	5	1	72	15	18	26	23	0.47	0.38	0.55	0.50	1.32	1.15	1.14	1.28
CR	6	1	100	41	17	3	Ext.	0.61	0.45	0.21	0.06	1.72	1.65	1.00	
CR	7	4	42	14	12	17	22	0.32	0.51	0.52	0.50	1.33	1.23	1.24	1.31
CR	8	1	35	7	12	19	23	0.61	0.41	0.48	0.51	1.53	1.47	1.42	1.47
CR	9	1	12	2	3	8	9	0.38	0.50	0.46	0.22	1.00	1.13	1.02	1.00
CR	10	5	63	24	18	18	12	0.45	0.45	0.41	0.47	1.23	1.29	1.06	1.10
CR	12	4	128	42	45	43	16	0.66	0.46	0.48	0.29	1.31	1.51	1.49	1.03
CR	13	2	36	13	10	3	Ext.	0.65	0.46	0.15	Ext.	1.56	1.78	1.00	Ext.
Sum	19	147	1242	439	400	413	325								
Average		7.74	65.4	23.1	21.1	21.7	20.3	0.49	0.42	0.39	0.34	1.36	1.41	1.14	1.16

Table 3.4.2.**2** Fruit Production per Site and Patch

Site	ID#	Fruits (4-2000)	Fruits (12-2000)	Fruits (4-2001)	Fruits (12-2001)	Fruits (4-2002)	Fruits (4-2003)	Sum 2001	Sum 2002	SUM (Total)
LG	1	9	0	0	0	0	0	0	0	9
SB	24	6	72	42	51	179	2	114	230	351
SB	25	621	2403	2703	1289	2077	1576	5106	3366	9094
SB	26	983	1404	2468	1268	2403	1284	3872	3671	8526
SB	27	275	615	492	1063	939	857	1107	2002	3384
SBI	21	1111	208	641	211	139	141	849	350	2309
SBI	22	6	12	30	2	20	55	42	22	70
CR	1	40	45	0	17	8	Ext.	45	25	110
CR	2	26	7	0	0	4	0	7	4	37
CR	3	62	249	45	66	33	Ext.	294	99	455
CR	4	193	0	3	47	49	0	3	96	292
CR	5	139	0	12	0	129	288	12	129	280
CR	6	6376	23	941	0	0	0	964	0	7340
CR	7	145	371	757	331	257	498	1128	588	1861
CR	8	318	321	299	519	506	295	620	1025	1962
CR	9	0	13	17	6	15	5	30	21	51
CR	10	648	159	109	375	337	127	268	712	1627
CR	12	3990	2450	1899	1391	1892	220	4349	3283	11622
CR	13	536	152	55	4	0	Ext.	207	4	747
Sum	19	15484	8502	10513	6640	8987	5348	19015	15627	59425[a]
Mean		815	447	553	349	473	334	1001	822	3128
		corrected estimate	corrected estimate	full sample	full sample	full sample	full sample			

[a] This includes an estimate of the fruit production in December 2002 (not shown in table) by multiplying the March 2003 fruit count * 74%.

Table 3.4.2.**3**. Soil auger soil cores. 4 subsamples were taken in July 2000; 6 subsamples were taken in December 2000 and in 2001.

Population	**Patch or plant**	**July 2000**	**December 2000**	**March 2001**	**December 2001**
Crandon	1	0	0	0	0
	2	0	0	0.17	0
	3	ND	0	0	0.17
	4	ND	0	0	0.33
	5	0	0	0	0
	6	0	0.17	0.33	0.5
	7	ND	0	0	0
	8	ND	0	0.17	0
	9	ND	0	0	0
	10	0.25	0	0	0.17
	12	ND	0	0.17	0
	13	ND	0	0.17	0
	14	ND	0.33	ND	ND
	2309	0	ND	ND	ND
	2310	0.25	ND	ND	ND
	2328	0.25	ND	ND	ND
Loggerhead	1	0.25	0	0	0
South Beach	1	0	0.33	ND	ND
	2	0.75	ND	1.33	0.33
	3	1	ND	0.33	0.17
	4	0	ND	0.5	0
South Beach Inlet	1	0.25	0	0.5	0.17
	2	ND	ND	ND	0
Number of patches sampled		14	16	17	18
Average # seeds (+/- standard error)/patch		21.4±0.02	0.05±0.01	21.6±0.02	0.10±0.01

ND=No data

Table 3.4.2.**4**. Seed counts from surface vacuum technique using hand-held battery powered vacuum. Area of surface sampled was one 25 by 25 cm subplot for one minute. All samples were taken at South Beach Park in Palm Beach County, FL.

Patch	**March 2001**	**December 2001**
2	485	ND
3	227	82
4	179	20
Average	297	51

Table 3.4.2.**5**. Seed burial experiment. 10 seeds per packet with 4 packets per patch initially buried at 10cm depth in March 2001 in Crandon Park, Miami-Dade County, FL. Packets were collected in December 2001 and March 2002. Remaining packets will be collected in March 2003 and March 2004.

Patch	Number of seeds surviving (December 2001)	Number of seeds surviving (March 2002)
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	7	3
10	0	0
13	0	0
% Survival	7%	3%

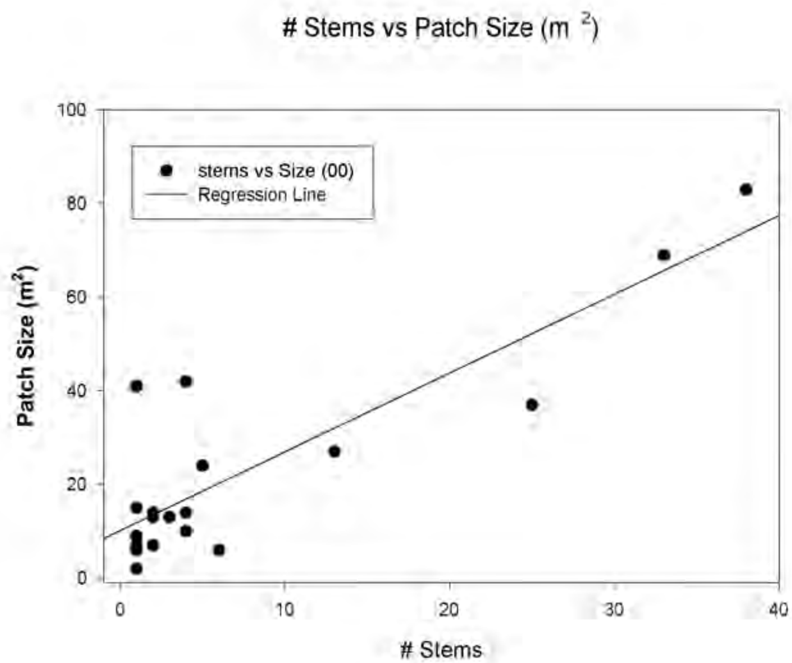


Figure 3.4.2.**1**. The number of stems versus patch size (m^2). The regression line is shown indicating a positive relationship.

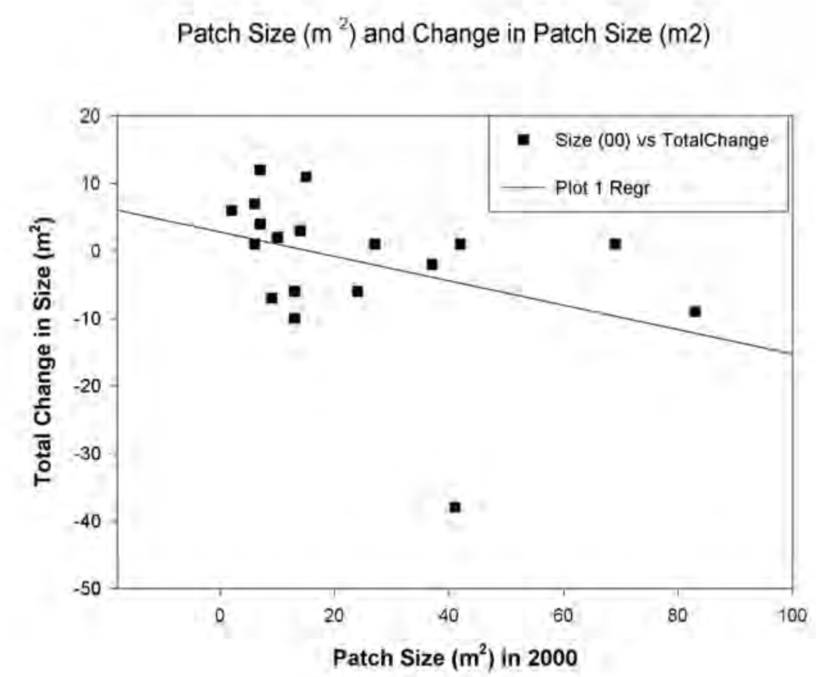


Figure 3.4.2.**2**. Total change in patch size was negatively related to original patch size. Larger patches tended to get smaller, small patches tended to increase or have less of a decrease in total area.

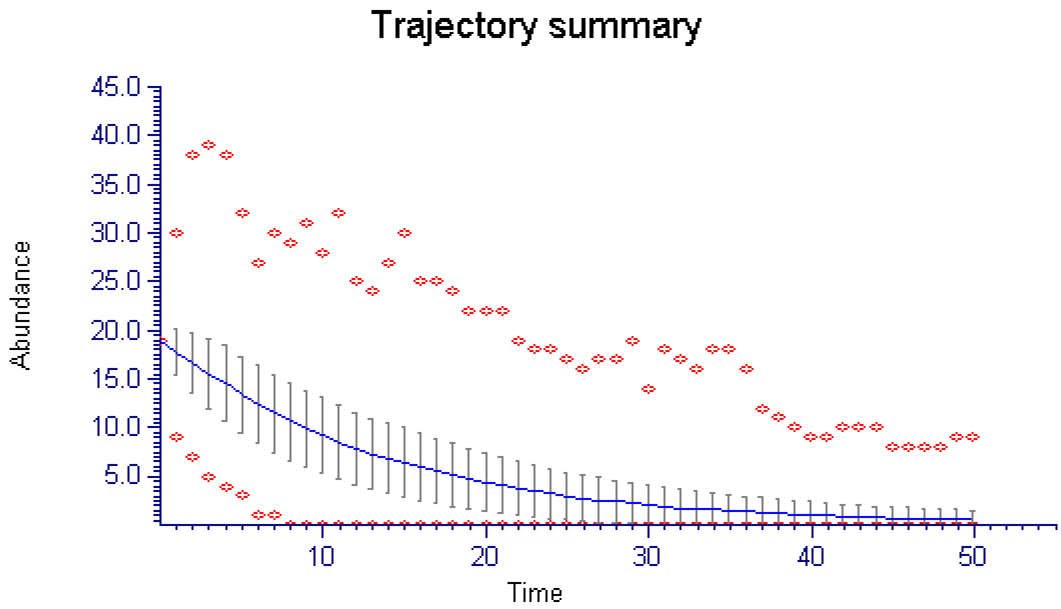


Figure 3.4.2.**3**. The predicted number of patches over time. Model has an annual finite growth rate (λ) of 0.93 and an annual standard deviation of that growth rate of 0.0995. The model assumed the population was growing logistically, with a carrying capacity of 100 patches (ceiling model). The model included both demographic stochasticity and environmental stochasticity (1000 replicates). Model analysis was done using RAMAS modeling software.

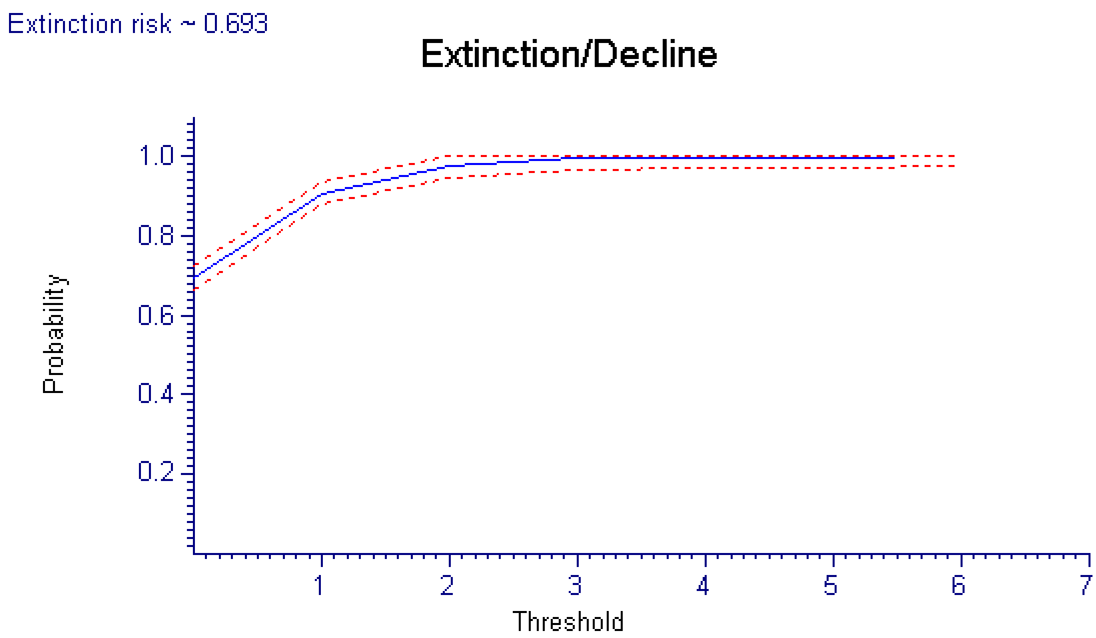


Figure 3.4.2.**4**. The extinction probability of the *Jacquemontia reclinata* population declining during a 50-year period. There is a 69.3% probability the population will go extinct during this time period, with a 100% probability the population will decline to six patches.

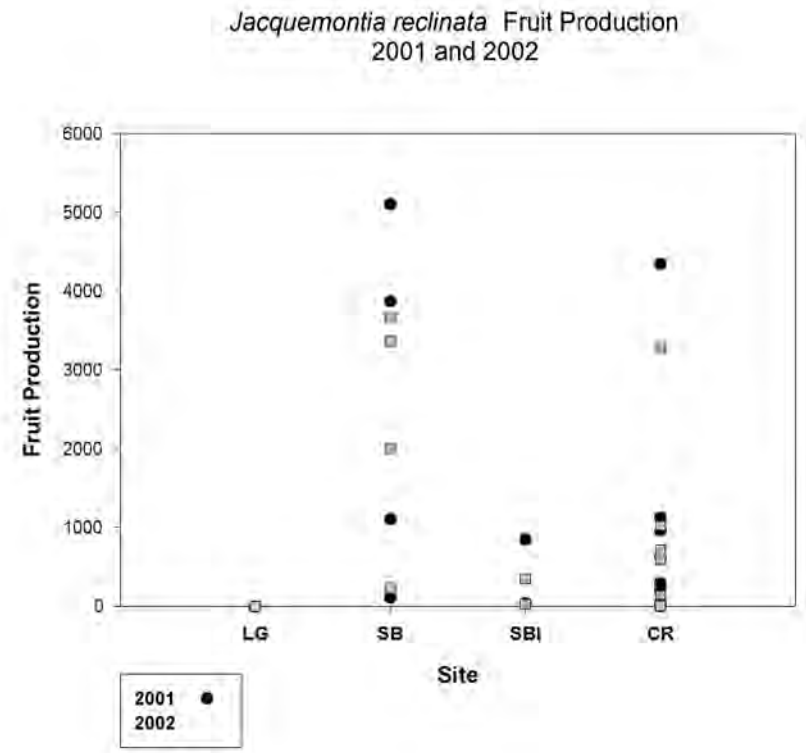


Figure 3.4.2.**5**. Range of fruit production by site and year. 2002 data is colored grey (not shown on the legend).

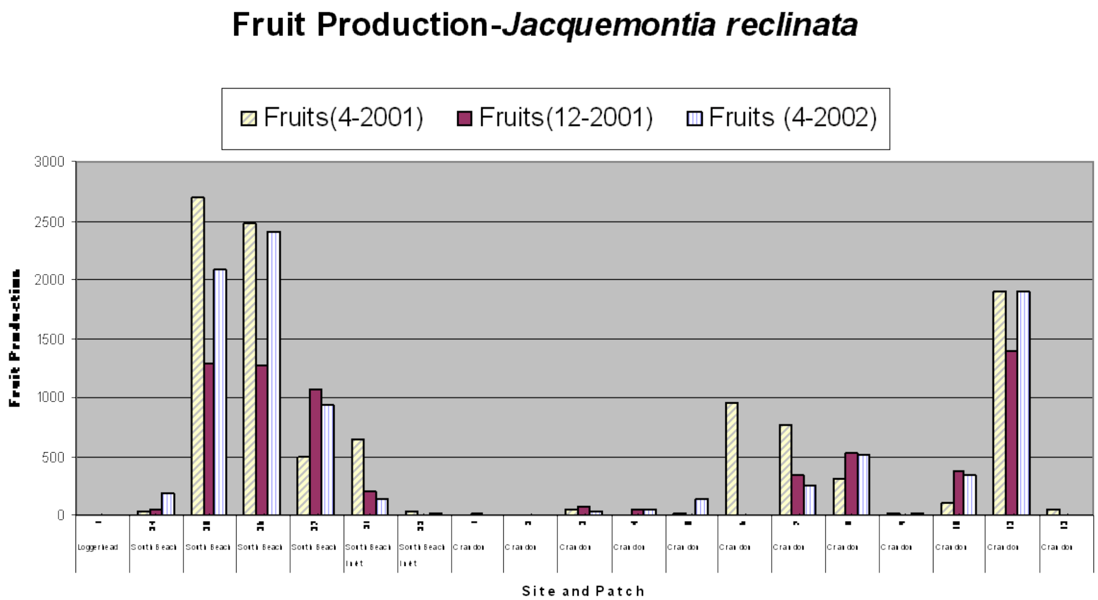


Figure 3.4.2.**6**. Variation in fruit production by site and patch for the three full fruit counts in 2001 and 2002.

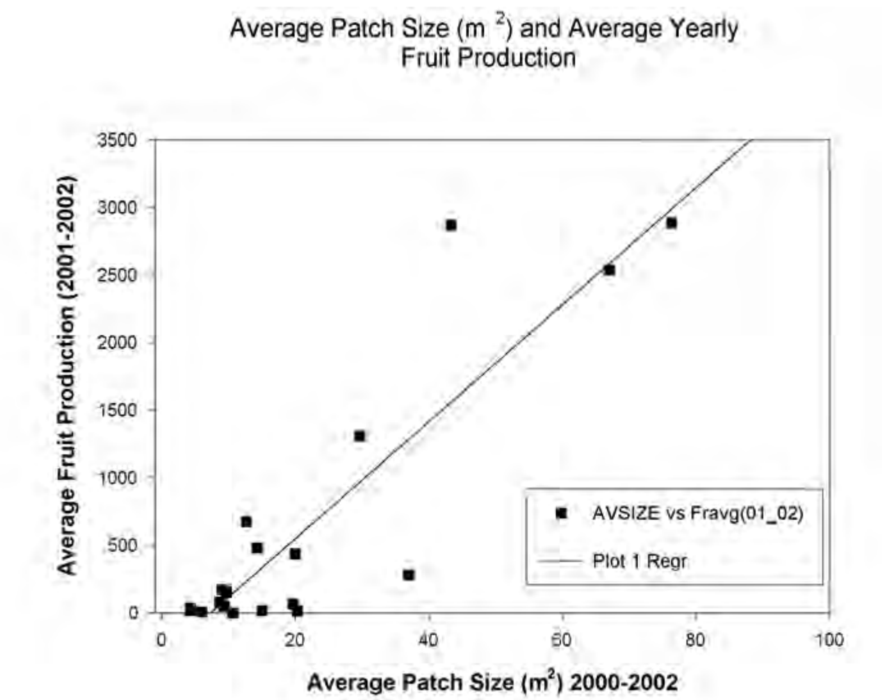


Figure 3.4.2.**8**. Average fruit production versus average patch size. A strong positive relationship is shown by the regression line.

3.5 Summarize the best procedures for out of habitat seed storage and *J. reclinata* propagation as written protocols- Susan Carrara

Storage protocol for *Jacquemontia reclinata*

Seeds were successfully germinated after four years of storage at room temperature (~26^{o}C) at uncontrolled seed moisture contents. Germination percentages ranged from about 40% to 80%. These seeds were simply cleaned after harvesting and stored in paper envelopes. The seeds were germinated following the seed germination protocol outlined below.

Preliminary research with more elaborate storage procedures was undertaken in hope of obtaining higher and more consistent germination after long storage periods. The three main variables in seed storage are: storage temperature, storage duration and percent seed moisture content (%SMC). These factors interact in unpredictable ways. In general, low storage temperatures and %SMC maximize the period of time seeds can be stored and remain viable. However, some seeds can be stored longer if the %SMC is somewhat higher. Preliminary research with *Jacquemontia reclinata* showed that the species could tolerate drying to 5% SMC content and storage at -20^{o}C, although these storage trials were for short durations (1 to 3 months).

The storage procedure can be broken down into four basic steps: determine the seed moisture content of fresh seeds, dry the seed sample that is destined for storage, package the seeds, and finally store the seeds.

1. Determine percent %SMC of fresh seeds

- After harvesting the seeds, select a subsample of seeds. Use the same number of seeds that will be stored in each sample. For instance, if you are storing the seeds in groups of 10, use 10 seeds to determine %SMC. If possible, use replicates for this test
- Grind them finely in a mortar and weigh. For best results, use an analytical balance accurate to 0.001g. Moisture is lost quickly from the ground seeds, so try to process them quickly in order to record accurate seed moisture content.
- Dry the seeds in an oven at 105^{o}C for 24 hours.
- Allow the seeds to come to room temperature, if possible in a desiccator cabinet.
- Weigh the dry seeds.
- Calculate the percent seed moisture content (%SMC).
- % SMC = (weight of fresh seeds – weight of dry seeds)/ weight of fresh seeds X 100

NOTE: Our experiments found that %SMC for *Jacquemontia reclinata* averaged around 12%.

2. Dry the seed sample to the desired %SMC

- Calculate the estimated weight of the seed sample using the following formula:

Goal seed weight = Initial seed weight X (100- initial %SMC) / (100- Goal % SMC)

For example, if you want to store seeds at 5% SMC, and the initial %SMC from step A was 20%, and the weight of the seeds was 2.5 g:

Goal seed weight = 2.50 g X (100 – 20%) / (100 – 5%) = 2.11 g

- Calculate the goal seed weight independently for each sample of seeds.
- Dry the seeds to the goal weight in a desiccator cabinet. A jar with an airtight lid could be partially filled with silica gel and used in place of a desiccator cabinet. Depending on how dry the seeds need to be, the process may take anywhere from several hours to several days.

3. Packaging seeds
Once reaching the desired seed moisture content, package them in foil envelopes and seal with a hot iron. After being sealed, these packets are airtight, and will keep the seeds at a consistent %SMC until they are removed.

4. Seed storage
Storage locations should be kept at as stable a temperature as possible. Until more seed storage trials are carried out, 5°C is the recommended storage temperature.

Seed germination protocol for *Jacquemontia reclinata*

Germination of fresh seeds

Using potting mix:

1. We used commercially available peat-based potting soil graded for seed germination. Also, we used pots or tree tubes rather than flats to minimize root disturbance when the seedlings were transplanted.
2. Pots were prepared by gently tapping soil down in the pot, just enough to create a flat surface. The potting mix was then thoroughly watered. After excess water had drained, the surface of the potting mix was roughed up to about 5 mm depth. Seeds were sown onto this surface. The surface was then covered with about 1 cm of chicken grit. Prepared pots were kept in a greenhouse throughout the germination period, and watered sparingly by hand.
2. Seedlings emerged from the soil about 7 days after sowing. We observed 80% to 90% germination within about 30 days of sowing. The remaining seeds did not germinate when left up to three months in the community seed pot. We recommend that seeds germinated in soil be potted into individual pots no more than 8 weeks after germination to limit damage to the root system.

Germination of seeds from storage

When seeds are removed from storage, they must be hydrated before they are sown. The seeds should be placed in a high relative humidity environment for 24 hours. They should not be in direct contact with liquid water. These conditions allow the seeds to hydrate slowly over the course of 24 hours. We used a dessication chamber whose base had been filled with water, and placed the seeds in small dishes on the chamber's platform. Placing the seeds in cells of an egg carton and floating them in a baking dish full of water can also hydrate seeds. A larger dish should be placed over the top to create the high humidity atmosphere. After the hydration period, seeds were sown according to the protocol described above.

References

The following sources offer more detailed information on issues in seed storage, both practical and theoretical:

Desai, B. B., P.M. Kotecha, and D.K. Salunkhe. 1997. Seeds handbook: Biology, production, processing, and storage. M. Dekker, New York. 627 pp.

Hanson, J. 1985. Procedures for handling seeds in genebanks. Practical manuals for genebanks. No. 1. International Board for Plant Genetic Resources, Rome. 115 pp.

Output 4 Response of *J. reclinata* to microhabitat, habitat gradients and management measured

Output 4.1.1. Measure the attributes of wild *J. reclinata* plants- Samuel J. Wright and David LaPuma

Plant and root excavation

Very little is known of the root system of wild *J. reclinata* plants. Careful excavation and investigation of this plant's root system would hopefully increase our limited knowledge of root size, formation, and branching patterns. Excavation could also help to determine the possibility of whether *J. reclinata* has vegetative reproduction through rhizomes, which has been suggested by past researchers.

Methods

Excavation of 1st *Jacquemontia reclinata plant*

On June 21, 2001 a patch of *J. reclinata* was located >5m from the secondary north-to-south trail at Crandon Park. Closeness to the trails was considered during patch selection to avoid attention during excavation. Also, by choosing a patch far from the trail, new growth of the excavated plant would not be disturbed by foot traffic. Within the patch, plant #2256 was chosen, which appeared healthy: green, full, signs of previous fruit production, etc.

The ideal side of the plant to be excavated was determined by surrounding vegetation. The side with the least amount of adjacent vegetation to be disturbed was chosen. The stems of the plant that overlaid the area to be dug were folded back over the plant. A 2x1x1.5m ditch was purposely dug at a distance from the rootstock so that the underground root structure would not be harmed.

Once the ditch was dug, fingers were used to brush away dirt and maneuver towards the plant and root system. After all substrate was removed from ½ of the plant, main roots were identified and photographs were taken of the entire root system. Length of roots and diameter of the underground root mass was measured. After measurements were recorded, the ditch was filled back with the original excavated soil. The plant was then returned to its natural radial position and watered for several days by Crandon Park personnel.

Excavation of 2nd *Jacquemontia reclinata plant*

On July 17, 2001 a second plant (#2347) was located using the prior methods. The same excavation procedures as above were followed except that the area of the ditch was expanded (3x2x1m). Previous dimensions led to limited mobility, which made it necessary to expand the ditch to accommodate the work area.

Findings from the excavations

From our excavations we cannot make a definitive conclusion on the primary root growth of *J. reclinata*. These plants do not seem to possess a traditional downward taproot, instead appearing to have a large lateral root that is thicker (1.4cm diameter) than the other secondary roots. Several large lateral roots located parallel or at a slight downward angle to the surface characterize the secondary roots (Figure 4.1.1.**1**). Some large roots were found heading straight towards several smaller plants, suggesting the possibility of vegetative reproduction, but no direct connections were observed. Adventitious roots were not observed. Lateral roots protruded in a radial direction indicating the plant's root system is similar to the structure of the aboveground plant. Length of lateral roots (<2m) was measured, as was the diameter of the underground fibrous root mass (~15x10 cm).

Jacquemontia reclinata root structure, consisting of numerous lateral roots, is similar to root structure found in plants growing in dry, warm environments with high photoperiods. Studies have shown this root type is vital for plants growing in dry conditions foraging for water and nutrients (Jenkins 1999). The ability of *J. reclinata* seedlings to obtain water and nutrients through their roots during the South Florida dry season is crucial to seedling survival and establishment.

Figure 4.1.1.**1** *Jacquemontia reclinata* root structure

References

Jenkins, S. 1999. Root establishment strategies of rainforest seedlings. *Using Rainforest Research*. January 1999. Cooperative Research Centre for Tropical Rainforest and Ecology and Management. North Queensland, Australia.

Output 4.1.2 Measure the attributes of wild *J. reclinata* plants and associated habitats/ microenvironments – Samuel J. Wright, Joyce Maschinski, Cynthia Lane, and David LaPuma

Introduction

Coastal ecosystems are characterized by local environmental variation at both the macro and micro scales. At the macro scale, several factors create an environmental gradient from dune to coastal hammock including salt spray, sand movement, soil moisture, nutrients, texture, and wind speed (Cheplick and Demitri 1999, Olff *et al*. 1993, Martinez and Moreno-Casacola 1986, Baldwin and Maun 1983, Van der Valk 1974). At a finer scale, slope, aspect, litter depth, and species composition and structure create localized microhabitats (Seeliger *et al*. 2000, Menges 1999, Baldwin and Maun 1983).

A review of coastal literature and preliminary data suggests that suitable habitat for *Jacquemontia reclinata* is influenced by both large-scale environmental gradients and microhabitat differences (Kernan 1997). The plant is known to occur within specific microhabitats across the dune system such as areas with sparse vegetation along the back dune, dune crest, and depressions between the first and second dunes (Kernan 1997; David LaPuma, personal observation). *J. reclinata* may be absent from areas closer to the ocean as a result of negative impacts of salt spray and sand accretion (Cheplick and Demetri 1999, Martinez *et al*. 1997, Van der Valk 1974), although other species have been shown to benefit from sand burial (Maun 1998; Martinez and Moreno-Casasola 1996; Disraeli 1984). Distribution to more inland areas may be limited by competition from dense vegetation (Menges 1999). Factors such as litter depth, litter cover, and composition and structure of associated plant species have been shown to affect the microhabitat of rare species (Seeliger *et al*. 2000, Menges 1999, Kephart and Paladino 1997).

The objective of this research is to characterize suitable habitat for *J. reclinata* considering environmental gradients and microhabitats. A description of suitable habitat will be critical for developing appropriate habitat management treatments.

Methods

Suitable *J. reclinata* habitat will be characterized by sampling random plots within a large macroplot. Microhabitat will be examined by sampling variables in occurring and non-occurring *J. reclinata* plots. Sampling was conducted on October 23, 2002 for Crandon Park and October 29, 2002 for South Beach.

Selection and establishment of sampling plots

For each of the two study sites (Crandon Park and South Beach Park), a large macroplot containing the majority (>90%) of the *J. reclinata* population was delineated for sampling. ArcView GIS 3.3 software was used to overlay 6 x 6m grid-cell quadrats over the populations, within the macroplots. Boundaries for macroplots were defined by the following criteria: one grid cell (6 x 6m) from the farthest occupied quadrat in each cardinal direction. For example, the eastern border of the macroplot was delineated as one grid cell east of the easternmost plant within the macroplot. An occupied quadrat is defined as a grid containing at least one *J. reclinata* plant.

Due to the clustered nature of the *J. reclinata* population, a stratified random sampling method (Usher 1991) was employed to ensure equal sampling distribution over the entire macroplot. Macroplots were divided into 5 strata (subgroups), with each stratum containing an equal number of plants. This method resulted in some strata being larger than others; however a simple random sampling scheme would have resulted in under-representation of some areas of the population. The random number generating function of Microsoft Excel was used to randomly select eight $6m^2$ plots per stratum (4 with plants + 4 without). Forty temporary sampling plots per site were randomly selected without replacement.

Using maps created in ArcView GIS 3.3 the UTM (Universal Transverse Mercator) coordinates for the center of each plot were determined and documented prior to site visit. Upon site visit, plots with plants were located using previously created maps of the populations (Output 5). GPS equipment was used to navigate to coordinates of plots without plants. Once coordinates/plants were located, a flag was placed to mark the exact center of the plot. A 1 x 1m grid was placed north to south over the sampling plot and a flag was placed at each corner. Characteristics sampled in each plot are described below:

Vegetation Sampling

Methods within the $1m^2$ plots follow exact protocol described in the vegetation sampling section of Output 1.2 and 1.3 except that only one class of vine was used.

Canopy cover

A Forest Densiometer® concave spherical densiometer was used to visually estimate percentage of overstory canopy cover. The densiometer was placed over a plant in each randomly chosen plot or ~10cm above the surface in the center of plots without plants. An image of the canopy was reflected onto the spherical densiometer and the observer counted the number of points on the mirror lacking canopy cover. The assumption was that each dot represented one percent. The total number of points was multiplied by 1.04 to estimate open canopy area. The difference between the multiplied number and 100 gave a percent estimation of canopy cover. To increase precision, replicate measurements were taken in four separate directions (north, west, south, and east) over the same sampling point. The four separate measurements were averaged to give one measurement.

Soil sampling
Soil samples were collected at a depth of 0 -15cm. An 83.8cm chrome-plated AMS® soil probe was used to obtain each soil core. Four cores were collected from each of the four sampling points or corners of all the 1m plots, and aggregated thoroughly to create one sample per plot. Each combined sample was placed in a separate polyethylene freezer bag, labeled, sealed tightly, and transported to the lab. Upon return from the field, bagged samples were refrigerated for overnight storage to prevent soil moisture loss between collection and weighing.

Measurement of soil moisture per sample followed protocol as described in Output 1.2, and 1.3. The following day after each site collection one cup per soil sample was transferred from the freezer bag to a soil testing labeled bag. Samples were shipped for chemical and nutrient analysis to A & L Southern Agricultural Laboratories in Pompano Beach on November 4, 2002. Soil analysis followed standard protocol (Council on Soil Testing and Plant Analysis 1980, and Gavlak *et. al.* 1997) to determine percent organic matter, estimated nitrogen release, available P, exchangeable K, Mg, Ca, H, Zn, soil pH, cation exchange capacity (CEC), soluble salts, and % base saturation of cation elements. In addition on November 18, 2002, one-cup of each sample was shipped to the University of Florida's Tropical Research Education Center (TREC) located in Homestead for nitrogen analysis. Exact protocol for nitrogen analysis was followed as reported in Output 1.2 and 1.3.

Statistical Analysis
To determine what nutrient, soil, or vegetation characters best classified where *J. reclinata* occurs, we performed stepwise discriminant analysis (SYSTAT 10.1). The normality of the nutrient, vegetation, and species data was examined and determined that the species data required log transformation before we performed analysis. Prior to analysis, Pearson correlation analysis determined which variables were highly correlated. Variables having correlations $\geq$ 0.80 and one of any string of variables that were additive were removed. For example, total native, exotic and unknown species summed to 1, therefore unknowns were removed from the analysis as these represented a very small part of the data set and caused correlations within the data set. Species occurrence data was analyzed as a separate analysis from the combined soil nutrients and vegetation summary data. Stepwise analysis determined the most important species influencing the model and then a forced stepwise analysis removing any species with F values < 5.00 was performed. *Jacquemontia reclinata* was eliminated from the species analysis, but it was part of the summary vegetation analysis. Our observations indicated that patterns of *J. reclinata* microsites at Crandon Park and South Beach were very different; therefore we analyzed each site separately to determine fine scale site attributes, but also analyzed the combined sites to determine generalized patterns of *J. reclinata* microsite classification.

Results

Crandon
The most significant nutrient and vegetation factors that discriminated *J. reclinata* microhabitat at Crandon Park were % organic matter, total graminoids, and inorganic C. Both % organic matter and total graminoids were significantly higher in plots that contain *J. reclinata*, whereas inorganic carbon was significantly lower (Table 4.1.2.**1**). Percent organic matter was positively correlated with salts (0.728) and organic carbon (0.659), but negatively correlated with pH (-0.695). Salts and pH are higher in unoccupied plots, whereas organic carbon is lower in unoccupied sites.

The model that best discriminated the microhabitat at Crandon included % organic matter, P1, K, Mg, Ca, soil moisture, % bare ground, % forbs, total graminoids, maximum height, native, exotic, total carbon and organic carbon. Jackknifed classification between plots with and without *J. reclinata* was 100% successful. Characters of occupied and unoccupied microsites significantly differed (Wilks' Lambda F = 59.04, p = 0.00005).

At Crandon Park, the species model was not successful in discriminating between occupied and unoccupied habitat. Discrimination of groups was not significant (Wilks' lambda F = 2.90, p =0.43).

Jackknifed classification between plots with and without *J. reclinata* was 50% successful for unoccupied plots, or no different than chance, and 70% successful for occupied plots (Table 4.1.2.**2**). By far, the nutrient and vegetation summary model was more effective for classifying *J. reclinata* habitat.

South Beach

The most significant nutrient and vegetation factors that discriminated *J. reclinata* microhabitat at South Beach were % canopy cover and total graminoid species, and total woody species. Overstory and total woody species were significantly higher in unoccupied habitat, whereas total graminoid species were significantly higher in plots that contained *J. reclinata* (Table 4.1.2.**1**).

The model that best discriminated the microhabitat at South Beach included Mg, Na, % overstory, total woody species, total graminoid species, and exotic species. Jackknifed classification between plots with and without *J. reclinata* was 90% successful for unoccupied plots and 100% successful for occupied plots. Characters of occupied and unoccupied microsites significantly differed (Wilks' Lambda F = 20.71, p = 0.00005).

At South Beach, the species model significantly discriminated between occupied and unoccupied habitat. The most important species were *Galium hispidulum*, *Randia aculeata, Galactia volubilis, Paspalum setaceum,* and *Ipomoea pes-caprae ssp. brasiliensis*. Discrimination of groups was significant (Wilks' lambda F = 60.48, p =0.00005) and jackknifed classification between plots with *J. reclinata* was 100% and without *J. reclinata* was 90% successful. The complete model included *Alternanthera flavescens*, *Ardisia escallonioides, Bidens alba var. radiata, Boerhavia diffusa, Canavalia rosea, Cnidoscolus stimulosus, Coccoloba uvifera, Commelina erecta, Croton glandulosus, Dactyloctenium aegyptium, Galactia volubilis, Galium hispidulum, Helianthus debilis, Ipomoea indica, Ipomoea pes-caprae ssp. brasiliensis, Iva imbricata, Lantana cf. camara, Mimosa pudica, Opuntia humifusa, Panicum amarum*, *Paspalum setaceum, Passiflora suberosa, Pithecellobium keyense, Randia aculeata,* and *Smilax auriculata* (Table 4.1.2.**2**). Microhabitat of *J. reclinata* was more clearly defined by vegetation at South Beach than at Crandon Park.

Combined Site Classification

The most significant nutrient and vegetation factors that discriminated *J. reclinata* microhabitat at both sites were % Organic matter, Mg, soil moisture, total vine species and total graminoid species. Percent organic matter, Mg, and soil moisture were significantly higher in unoccupied habitat, whereas total vine and total graminoid species were significantly higher in plots that contained *J. reclinata* (Table 4.1.1). Percent organic matter was correlated with K (0.70), Mg (0.66), Ca (0.71), pH (-0.79), CEC (0.76), salts (0.73), and organic carbon ((0.75).

The nutrient/ vegetation model that best discriminated the microhabitat of *J. reclinata* at both sites included organic 1, Mg, soil moisture, total vine species and total graminoid species. Jackknifed classification between plots with and without *J. reclinata* was 83% successful for unoccupied plots and 95% successful for occupied plots. Characters of occupied and unoccupied microsites significantly differed (Wilks' Lambda F = 21.12, p = 0.00005). Clearly, the difference between the two sites decreased our ability to classify *J. reclinata* microsites with as much confidence.

The species model was less successful at discriminating *J. reclinata* habitat. The most important species were *Canavalia rosea* and *Polygala grandiflora.* Discrimination of groups was significant (Wilks' lambda F = 7.37, p =0.00005) and jackknifed classification between plots with *J. reclinata* was 83% and without J. reclinata was 68% successful. The complete model included *Canavalia rosea, Polygala grandiflora, Spartina patens and Guapira discolor* (Table 4.1.2.**2**).

Mean nutrient and vegetation characteristics for plots are reported in Table 4.1.2.**1**. Mean log species percent cover is reported in Table 4.1.2.**2**. Occurrence of species within plots per site and combined sites is reported in Table 4.1.2.**3**.

Discussion

In general at Crandon Park and South Beach, *J. reclinata* tended to grow in areas that have comparatively more sun, fewer salts, fewer cations (Mg), and lower soil moisture than was measured in unoccupied microhabitats. *Jacquemontia reclinata* sites tended to be more open and have more grasses and vines, and fewer woody species.

The striking differences between the sites led to inconsistent trends of some variables. For example, at Crandon Park *J. reclinata* was associated with higher % organic matter, whereas the reverse was true at South Beach. The rank order of occupied vs. unoccupied sites varied for % bare ground, total vine species, maximum woody height, inorganic carbon, total nitrogen, and organic carbon (Table 4.1.**1**).

Models that contained species summaries and nutrient data were more effective for classifying *J. reclinata* microhabitat than were species presence alone. This is in part a function of the multivariate analysis used. It is noteworthy that *Alternanthera flavescens, Bidens alba* var. *radiata, Canavalia rosea, Cnidoscolus stimulosus, Commelina erecta, Dactyloctenium aegyptium, Galactia volubilis*, and *Polygala grandiflora* are all present in more than 50% of the plots and all had higher abundance in plots containing *J. reclinata* (Table 4.1.**2** and 4.1.**3**).

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Table 4.1.2.**1.** Mean Nutrient and Vegetation Characteristics for Plots with and without *J. reclinata*

	Crandon	**Crandon**	**South Beach**	**South Beach**	**Combined Sites**	**Combined Sites**
***J. reclinata* present**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
% Organic matter	1.29	1.655	2.255	1.3	1.773	1.48
Phosphorus (weak)	6.5	4.45	7.25	4.45	6.88	4.45
Phosphorus (strong)	19.5	10.8	13	6.6	16.25	8.70
Potassium	12.75	9.25	22.6	14.35	17.68	11.80
Magnesium	134.3	82.3	181.75	72.05	158.03	77.18
Calcium	2333.5	1874.5	2348.5	1865.5	2341.00	1870.00
Sodium	23.3	19.25	73.45	45.05	48.38	32.15
Soil pH	8.115	7.9	7.875	8.105	8.00	8.00
Cation Exchange Cap	13.025	10.255	13.74	10.255	13.38	10.25
Soluble salts	0.1	0.093	0.187	0.102	0.14	0.10
% Soil moisture	6.396	5.12	3.796	1.626	5.10	3.37
% Canopy cover	41.708	28.968	80.305	19.946	61.01	24.46
% Bareground	6.25	4.5	1.4	16.775	3.83	10.64
% Woody cover	47.425	41.45	73.8	45.775	60.61	43.61
% Vine cover	34.075	46.55	6.35	21	20.21	33.78
% Forb cover	14.35	18.4	3.825	21.175	9.09	19.79
% Graminoid cover	15.05	20.3	11.125	22.7	13.09	21.50
Total Woody species	2.45	1.65	1.75	1.35	2.10	1.50
Total Vine species	3.7	3.45	0.9	2.9	2.30	3.175
Total Graminoid sp.	1.7	2.4	0.35	2.45	1.03	2.43
Maximum woody height	1.8	1.45	2.5	1.3	2.15	1.38
Native species	8.1	8.5	3.4	10.2	5.75	9.35
Exotic species	2	2.1	0.45	0.55	1.23	1.33
Ammonium (NH4N)	1.992	1.855	3.115	2.72	2.55	2.94
Nitrate (NO3N)	9.806	7.21	11.67	4.535	10.74	5.87
Inorganic Carbon	1.89	1.376	5.23	5.656	3.56	3.52
Total Nitrogen	0.122	0.334	0.113	0.064	0.12	0.20
Total Carbon	3.128	3.022	7.547	6.891	5.34	4.96
Organic Carbon	1.239	1.647	2.318	1.235	1.78	1.44

Table 4.1.2.**2** Mean Log Species Percent Cover

	South Beach		Crandon Park		Combined Sites	
Jacquemontia present	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Alternanthera flavescens	0	0.274	0.015	0.06	0.008	0.167
Ambrosia artemisiifolia	0	0	0.045	0.015	0.023	0.008
Ardisia escallonioides	0.237	0	0.14	0.015	0.188	0.008
Bidens alba var. radiata	0	0.015	0.483	0.617	0.242	0.316
Boerhavia diffusa	0	0.352	0	0	0	0.176
Bursera simaruba	0.079	0	0	0	0.04	0
Canavalia rosea	0.046	0.558	0	0.046	0.023	0.302
Cassytha filiformis	0	0	0.373	0.283	0.186	0.141
Catharanthus roseus	0	0	0.09	0.105	0.045	0.053
Cenchrus incertus	0	0	0	0.03	0	0.015
Chamaecrista nictitans var. aspera	0	0	0.06	0.03	0.03	0.015
Chamaesyce ssp.	0	0.03	0.015	0.03	0.008	0.03
Chromolaena odorata	0	0	0.015	0.03	0.008	0.015
Cnidoscolus stimulosus	0.137	0.547	0.09	0.226	0.114	0.386
Coccoloba uvifera	0.779	0.372	0.153	0.507	0.466	0.439
Cocos nucifera	0.079	0	0	0	0.04	0
Colubrina asiaticum	0	0	0.093	0	0.047	0
Commelina erecta	0.172	0.711	0.015	0.153	0.093	0.432
Conyza Canadensis var. pusilla	0	0	0.03	0.03	0.015	0.015
Croton glandulosus	0	0.06	0.045	0.06	0.023	0.06
Crotalaria incana	0	0	0.015	0	0.008	0
Crotalaria pumila	0.045	0.093	0	0	0.023	0.047
Cyperus pedunculatus	0.062	0.513	0	0	0.031	0.257
Cyperus planifolius	0	0	0.015	0	0.008	0
Dactyloctenium aegyptium	0	0.06	0.105	0.262	0.053	0.161
Desmodium tortuosum	0	0	0.045	0.06	0.023	0.03
Echites umbellata	0	0	0.015	0	0.008	0
Ernodea littoralis	0	0	0	0.143	0	0.071
Eugenia foetida	0	0	0.03	0.063	0.015	0.032
Eustachys petraea	0	0	0	0.045	0	0.023
Galactia volubilis	0.107	0.286	0.301	0.334	0.204	0.31
Galium hispidulum	0	0.015	0.03	0.015	0.015	0.015
Guapira discolor	0	0	0	0.063	0	0.032
Helianthus debilis	0.045	0.227	0.139	0.03	0.092	0.129
Ipomea indica var. acuminata	0	0.03	0.167	0.03	0.083	0.03
Ipomea pes-caprae ssp. brasilensis	0.094	0	0.03	0.03	0.062	0.015
Iva imbricata	0.094	0	0	0	0.047	0
Jacquemontia reclinata	0	0.968	0	1.175	0	1.071
Lantana cf. camara	0	0.046	0.187	0.169	0.094	0.108
Lantana involucrata	0	0	0.09	0.063	0.045	0.032
Licania michauxii	0.015	0.5	0	0	0.008	0.25
Melanthera nivea	0	0	0.079	0.075	0.04	0.038
Mentzelia floridana	0	0	0.015	0	0.008	0
Metopium toxiferum	0.063	0.097	0.124	0.135	0.093	0.116

Table 4.1.2.**2 (cont)**						
Mean Log Species Percent Cover		**South Beach**	**Crandon Park**	**Combined Sites**		
Jacquemontia present	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Mimosa pudica	0	0.139	0	0	0	0.069
Momordica charantia	0.094	0	0.09	0.075	0.092	0.038
Myrica cerifera	0	0	0.063	0.063	0.032	0.032
Myrsine cubana	0.195	0	0	0	0.097	0
Opuntia humifusa	0	0.015	0	0	0	0.008
Panicum amarum	0	0.215	0.092	0.03	0.046	0.123
Parthenocissus quinquefolia	0.015	0	0.627	0.263	0.321	0.132
Paspalum setaceum	0	0.045	0.015	0.2	0.008	0.123
Passiflora suberosa	0.045	0.03	0.212	0.107	0.129	0.068
Physalis walteri	0	0	0.045	0.045	0.023	0.023
Pithecellobium keyense	0.079	0	0.142	0.093	0.111	0.047
Poinsettia cyathophora	0	0	0.03	0	0.015	0
Polygala grandiflora	0.045	0.196	0.045	0.09	0.045	0.143
Psychotria nervosa	0	0	0.204	0	0.102	0
Randia aculeata	0	0.092	0.357	0.279	0.179	0.185
Rhus copallinum	0	0	0.172	0.063	0.086	0.032
Rhynchosia minima	0	0.045	0	0.063	0	0.054
Rhynchelytrum repens	0	0	0.274	0.53	0.137	0.265
Rivina humilis	0.03	0	0	0	0.015	0
Sabal palmetto	0	0.161	0.351	0.143	0.175	0.152
Saltgrass complex	0	0.587	0.079	0	0.04	0.294
Schinus terebinthifolius	0.278	0.177	0.062	0.097	0.17	0.137
Serenoa repens	0.838	0.19	0	0	0.419	0.095
Sesuvium portulacastrum	0	0.03	0	0	0	0.015
Setaria macrosperma	0	0	0.152	0.015	0.076	0.008
Smilax auriculata	0.12	0	0.609	0.23	0.365	0.115
Smilax havenensis	0	0.135	0	0	0	0.068
Spartina patens	0	0	0	0.03	0	0.015
Stenotaphrum secundatum	0.161	0.122	0.182	0.322	0.171	0.222
Trema micranthum	0	0	0.302	0.26	0.151	0.13
Tribulus cistoides	0	0.03	0	0	0	0.015
Uniola paniculata	0.233	0.314	0.097	0	0.165	0.157
Unknown Cyperus	0	0	0.045	0.03	0.023	0.015
Unknown Fabaceae	0	0	0	0.015	0	0.008
Unknown Fern	0	0	0	0.015	0	0.008
Unknown Grass	0	0.045	0.03	0.06	0.015	0.053
Verbesina virginica	0	0	0.063	0.204	0.032	0.102
Vigna luteola	0.062	0.046	0.126	0	0.094	0.023
Vitus rotundifolia	0.06	0	0.17	0.12	0.115	0.06

Table 4.1.2.**3** Species occurrences in 1 x 1m plots containing *J. reclinata*. Unknown species and species with total occurrence of 1 excluded from table.

Species	**Crandon (n=20)**	**South Beach (n=20)**	**Combined Sites (n=40)**
Cnidoscolus stimulosus	13	**18**	31
Galactia volubilis	**15**	14	29
Commelina erecta	5	19	24
Polygala grandiflora	5	13	18
Bidens alba var. radiata	14	1	15
Stenotaphrum secundatum	10	4	14
Alternanthera flavescens	2	11	13
Canavalia rosea	1	12	13
Coccoloba uvifera	8	5	13
Saltgrass complex	0	13	13
Boerhavia diffusa	0	12	12
Cyperus pedunculatus	0	12	12
Dactyloctenium aegyptium	8	3	11
Helianthus debilis	1	10	11
Randia aculeata	7	3	10
Rhynchelytrum repens	11	0	11
Licania michauxii	0	9	9
Croton glandulosus	3	4	7
Panicum amarum	1	6	7
Parthenocissus quinquefolia	7	0	7
Passiflora suberosa	4	3	7
Uniola paniculata	0	7	7
Catharanthus roseus	6	0	6
Paspalum setaceum	5	1	6
Smilax havenensis	0	6	6
Cassytha filiformis	5	0	5
Smilax auriculata	5	0	5
Trema micranthum	5	0	5
Chamaesyce ssp.	2	2	4
Lantana cf. camara	3	1	4
Mimosa pudica	0	4	4
Momordica charantia	4	0	4
Pithecellobium keyense	4	0	4
Sabal palmetto	2	2	4
Verbesina virginica	4	0	4
Crotalaria pumila	0	3	3
Ipomea indica var. acuminata	2	1	3
Metopium toxiferum	2	1	3
Rhynchosia minima	1	2	3
Schinus terebinthifolius	1	2	3
Serenoa repens	0	3	3
Cenchrus incertus	2	0	2
Chamaecrista nictitans var. aspera	2	0	2
Chromolaena odorata	2	0	2
Conyza canadensis var. pusilla	2	0	2
Desmodium tortuosum	2	0	2
Ernodea littoralis	2	0	2
Eustachys petraea	2	0	2
Melanthera nivea	2	0	2
Physalis walteri	2	0	2
Sesuvium portulacastrum	0	2	2
Spartina patens	2	0	2
Tribulus cistoides	0	2	2
Vitus rotundifolia	2	0	2

<u>Output 4.2 Collect *J. reclinata* seeds and cuttings from wild populations and propagate experimental plants.</u>

Seeds of wild and cultivated *J. reclinata* individuals were collected in 1999 – 2000 and germinated according to protocol (Outputs 3.2 and 3.5). Plants propagated in this manner, and also plants resulting from seed germination and storage trials, provided experimental plants.

<u>Output 4.3 Outplant propagated *J. reclinata* plants into microhabitat field treatments and measure and analyze their responses.</u>

Output 4.3.1 Effects of fertilizer and arbuscular mycorrhizae on survival of outplanted seedlings - Jack Fisher and K. Jayachandran

Arbuscular mycorrhizal fungi (AMF) were found in roots under natural conditions in native habitat, and greenhouse experiments showed that seedling growth was promoted by AMF when grown with native maritime hammock/dune soil. AMF promoted uptake of phosphorus (P) from these nutrient-poor soils, and seedlings responded to additions of phosphorus in the absence of AMF, which indicated that this species is not an obligate mycorrhizal plant (Fisher & Jayachandran 2002). Since AMF can enhance growth under natural conditions, we wanted to test the effect of AMF on success of outplanting of seedlings. Seedlings were grown in the FTG nursery and then planted into a natural coastal dune habitat and monitored for almost two years (82 wk).

The results are difficult to interpret because survivorship is correlated to plant size, and the largest plants were those fertilized. However, if fertilizer was not used, AMF improved both plant size and survivorship. Thus, if fertilization is not recommended for these natural sites because of fear of eutrophication (especially phosphorus pollution), then AMF inoculation of nursery stock will improve plant growth and survivorship when seedlings are grown on native, nutrient poor soil.

Methods

Seeds (from plants FTG 2000-485 and 2000-394, both derived from the Crandon Park natural population) were sterilized and germinated on Perlite under mist. These AMF-free, 1-month-old seedlings were transplanted into small Tallpots (containing 266 g soil) in a 2X2 factorial experiment: (**1**) with and without slow release fertilizer (2.68 g = 1/2 tsp Florikan Nutricote 10N-10P-17K per pot); and (**2**) with and without AMF inoculation (1 Tsp soil and chopped roots from nurse cultures per pot). Native dune sandy soil was twice steam pasteurized. The AMF was derived from the native habitat and multiplied on Sudan grass nurse cultures in the greenhouse. Seedlings were grown first in the greenhouse for two months and then hardened in full sun for one month before being planted in native rear dune habitat at Bill Baggs State Recreation Area on 20 September 2001 (under Fla. Dept. of Environmental Protection, Div. of Recreation & Parks research permit No. 5-01-39).

Three plots, each with 35 plants were set up in a random 3 block design for the 4 treatments (27 total replicates per treatment). After outplanting, these plants were watered weekly for 3 weeks and thereafter left unmanaged. Some plants were initially lost due to disturbance by raccoons and perhaps rabbits. Significant differences (at 0.05 level) were determined by Pearson Chi-Square (suning SPSS).

Results

The four-month-old seedlings varied in size at the time of outplanting from largest to smallest in the following order: +Fert **>** +Fert + AMF **>** +AMF-Fert **>** -AMF-Fert. Heavy rains occurred after the watering period and most plants seemed well established and a few were flowering when first surveyed on 10 December 2001 (after 11.5 wk). Unfertilized seedlings had a significantly higher mortality than fertilized. AMF increased survivorship for unfertilized plants. The best survivorship occurred in unfertilized and non-AMF plants. Survivorship was determined again at the end of the rainy season (after 45 wk on 31 December 2002) and in the second dry season (after 82 wk on 18 April 2003). Most plants had evidence of flowering and fruit production.

Table 4.3.1.**1** Survivorship of seedlings at Bill Baggs.

Number of plants Dead/Alive at three times after outplanting

	AMF inoculum					
Fertilizer	**Present**			**Absent**		
Week	11.5	45	82	11.5	45	82
Present	2/29	3/29	4/27	1/14	1/14	1/14
Absent	15/35	25/10	26/8	7/17	22/2	22/2

Fertilizer had a significant positive effect on survival for plants both with AMF and without after 11.5 and 45 wk. However, after 82 wk, there was no difference between mycorrhizal and non-mycorrhizal plants that had fertilizer.

Table 4.3.1.**2** Survivorship as percentage alive after 82 weeks.

	With AMF	**Without AMF**
With Fertilizer	87.1	93.3
Without Fertilizer	25.7	8.3

The difference in survivorship for unfertilized plants was not significant. The greatest mortality occurred in unfertilized and non-AMF plants.

Conclusions

The results are hard to interpret because survivorship is correlated to plant size, and the largest plants were those fertilized. However, if fertilizer was not used, AMF improved both plant size and survivorship. Thus, if fertilization is not recommended for these natural sites because of fear of eutrophication (especially phosphorus pollution), then AMF inoculation of nursery stock will improve plant growth, both in the nursery (Fisher & Jayachandran 2002) and in the field as noted above.

Output 4.3.2 Effects of environmental gradients within the coastal dune on survivorship of outplantings – Samuel J. Wright

Outplanting (September 2001) update

Habitat fragmentation, plant competition, and effects of large-scale natural disturbances (e.g. hurricanes) have become threats to South Florida's native flora. With approximately 700 wild individuals remaining it is essential to establish self-sustaining populations using (re) introduction as a means to recovery. We conducted an outplanting study to increase the previously introduced population size at Bill Baggs State Park. In addition the outplanting was designed to test the influence of environmental gradients (salt spray, sand accretion and distance from ocean) from the coast inland on *J. reclinata* growth and survival. Establishing a population at Bill Baggs, from seed collected at Crandon Park nearby, would serve as a backup for the Crandon site, the largest remaining site supporting *J. reclinata.* Results from this study could assist in designing the methods and site selection for future out-planting efforts.

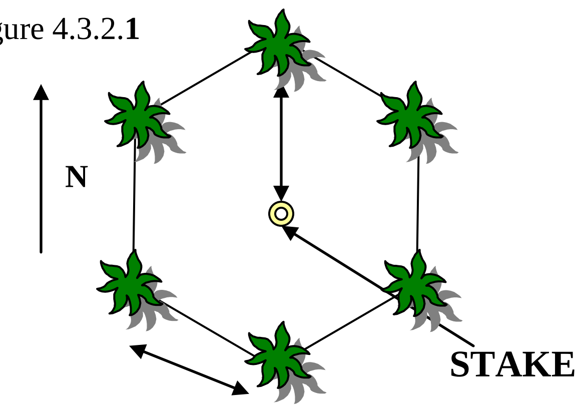
Methods

Plant material used for the outplanting was germinated from wild seed collected from six tagged and mapped plants at Crandon Park. Seeds were collected on April 20, 2000 and May 24, 2000. Collected seeds were primarily used for seed germination experiments (Output 4.2). When the

the seed germination experiment was terminated, plants were added to the *ex-situ* collection. Seedlings were transplanted to 1-gallon pots and grown in full sun.

On September 21, 2001, 90 *Jacquemontia reclinata* were outplanted at Bill Baggs State Park (Appendix A29-31). Of the 90 plants, 15 each came from six separate accession numbers or origins. *Jacquemontia reclinata* individuals were planted in three randomly selected parallel transects that ran east to west from the ocean. The first transect was located 6m from the beginning of the coastal dune vegetation or possible high tide mark. Each transect consisted of five 3x8m permanent plots separated by 12m. Each plot contained six plants originating from six separate accessions. Placement of each accession within the plot was selected randomly without replacement. A stake was inserted into the ground to determine the center of the plot. A meter stick was used to measure .95 meters north from the stake then each plant was planted clockwise in a hexagon one meter from each other and .95 meters from the center (Figure 4.3.2.**1**). The planting spacing design was utilized to minimize edge effects for all of the plants and it was believed to provide sufficient space for subsequent growth.

Figure 4.3.2.**1**

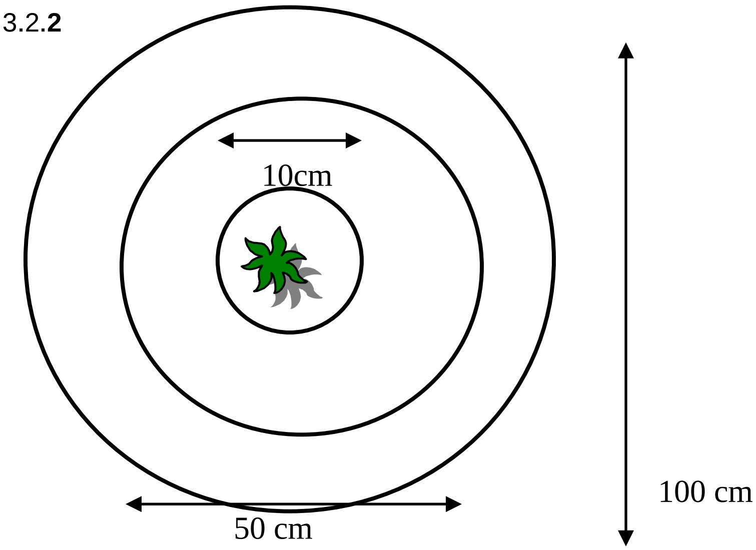


After installation all plants were watered with 1 gallon of water per individual. The amount of rain and soil moisture were monitored and plants were watered as needed. Plants received their second watering five days later on September 26, 2001. Due to the 8.5" of rainfall (South Florida Water Management District rain fall gauge) the Key Biscayne and Miami Beach areas received over the next month, additional watering was not necessary.

Vegetation, salt spray and sand accretion were sampled to test the relationship of these factors and gradients to plant survival and growth. Sampling followed the same protocol as described in the methods section of the environmental gradient and associated vegetation study (Output 1.2). Survival of plants associated with distance from the ocean was also explored.

An initial base count of stems was documented on October 3, 2001 to quantify size of *J. reclinata* upon planting. Numbers of stems were counted using circular rings of three different diameters: 10cm, 50cm, and 100cm (Figure 4.3.2.**2**). Rings were constructed of a flexible polyurethane tube for each diameter. The ring was then centered over the plant and any stem that touch the ring was counted and the procedure was repeated for the other diameters. To quantify health and growth of each plant, stems were counted approximately every three months for one year. Table 4.3.2.**1** lists the types of data collected at each plot and the date samples were collected.

Figure 4.3.2.**2**



Statistical Analysis

Growth and survival of transplants in each transect were analyzed using Kruskal-Wallis tests across replicates and distance from ocean separately. Because sample size was small, a significance level of $p = 0.1$ was accepted.

Results

Observations and occurrences

One year following transplanting, 65 of the original 90 plants have survived—a 72% survival rate (Table 4.3.2.**3**). Distance and location significantly correlated with salt conductivity, and significantly influenced growth rate of *J. reclinata,* but not survival (Table 4.3.2.**4**, Growth Distance KW = 8.4, $p = 0.08$; Growth Location KW = 8.4, $p = 0.08$; Survival Distance KW = 3.79, $p = 0.4$, Survival Location KW =3.79, $p = 0.4$).

Although survival was not significantly affected by distance and location, there were patterns in mortality that we observed. Of the 25 that have not survived, 20 are located in the extreme front or back plots. Herbivory was believed to be the primary cause of mortality for the plants in the back plots (1E, 2J, 3O). All back plots were observed to experience varying levels of herbivory when monitored on October 10, 2001. Detached stems have angle cuts indicative of rodent incisor-like teeth perhaps marsh rabbits (*Sylvilagus palustris*). Rabbit herbivory has been shown to affect the survival, growth rate and reproduction timing of native coastal plants (Fox and Palisan 1997). Rabbit dropping were observed next to plants and *S. palustris* are known to exist at Bill Baggs (Wright per. observation, Golden per. communication)

Mortality of plants within the front plots is believed to be attributed to location, which exposed plants to extreme environmental conditions. The monitoring period in October observed stressed (wilting, brown leaves) plants within front plots 2F and 3K. Both plots are located close to the ocean and are susceptible to salt spray, wind and extreme high tides. A surge from the previous night's storm caused the high tide line to reach beyond the beginning of the foredune vegetation. Front plots were inundated with seawater likely leading to the stressed out condition of the plants.

Areas in the vicinity of plots 2F and 3K experienced extreme erosion and flooding caused by Hurricane Michelle on November 5, 2001. The storm surge resulted in approximately a .6m elevational loss of foredune substrate, while exposing roots of *Uniola paniculata* and *Ipomoea* *pes-caprae ssp. brasiliensis*. All but two of the plants within the plots were buried in 3cm to 10cm of sand. Buried plants were monitored thereafter for emergence and have yet to appear.

Plants species and mean % coverage documented during vegetation sampling are reported in Table 4.3.2.**2** by plot location. Also reported by plot location within the table are average woody height, total quantity of natives and exotics, and % coverage of bareground and life forms.

Previous outplanting (June 1997) update

Bill Baggs State Recreation Area conducted a outplanting of 93 *J. reclinata* plants in June 1997. The plants were donated from Fairchild Tropical Garden, which germinated the plants in their greenhouse from seed collected from wild populations at Crandon Park. Plants were monitored the first month after planting and every six months thereafter. Plants were last monitored in February 2003 and of the original 93 plants outplanted only 8 remain (8 % survival rate). The remaining plants have been observed to flower, fruit and seed through the year (Wright per. observation, Golden and Duquesnel 2002)

Conclusions

Our preliminary studies suggest that future reintroductions should occur in the range of 19-45 meters from the ocean.

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Table 4.3.2.**1**. Type of data collected and date sampled for Bill Baggs outplanting.

Type	**Installation**	**Sampling / monitoring dates**
Outplanting stem count	September 21, 2001	October 2, November 16, 2001; January 4, March 26 (just presence/absence), April 5, July 3, September 24, 2002
Vegetation	na	February 19 and 21, 2002
Salt spray	February 12, and June 04, 2002	April 23, July 03, August 1, and September 5, 2002
Sand accretion	February 12, 2002	March 12, June 20, and September 17, 2002

Table 4.3.2.**2**. Vegetation characteristics of Bill Baggs outplanting plots located at various distances from the high tide line. Species cover reported as % mean cover.

6 meters from high tide mark		**18 meters from high tide mark**		**30 meters from high tide mark**	
Species	**Cover**	**Species**	**Cover**	**Species**	**Cover**
Uniola paniculata	34.3	*Uniola paniculata*	30.8	*Uniola paniculata*	9.3
Iva imbricata	9.3	*Suriana maritima*	5.8	*Saltgrass complex*	3.8
Panicum amarum	6.8	*Crotalaria pumila*	3.8	*Lantana involucrata*	3.7
Canavalia rosea	3.5	*Helianthus debilis*	3.8	*Crotalaria pumila*	3.0
Croton punctatus	2.0	*Coccoloba uvifera*	3.5	*Eustachys petraea*	3.0
Chamaesyce mesembrianthemifolia	1.3	*Trichostema dichotomum*	2.3	*Dactyloctenium aegyptium*	2.3
Saltgrass complex	1.3	*Croton punctatus*	2.3	*Trichostema dichotomum*	2.0
Sesuvium portulacastrum	1.0	*Croton glandulosus*	1.7	*Chamaecrista nictitans var. aspera*	2.0
Cakile lanceolata	1.0	*Alternanthera flavescens*	1.7	*Cnidoscolus stimulosus*	1.7
Chamaesyce ssp.	0.7	*Iva imbricata*	1.3	*Alternanthera flavescens*	1.7
Polygala grandiflora	0.3	*Lantana involucrata*	1.0	*Helianthus debilis*	1.7
Helianthus debilis	0.3	*Passiflora suberosa*	1.0	*Ambrosia artemisiifolia*	1.3
Dactyloctenium aegyptium	0.3	*Smilax auriculata*	1.0	*Lantana cf. camara*	1.0
		Cnidoscolus stimulosus	1.0	*Polygala grandiflora*	1.0
		Saltgrass complex	1.0	*Galactia volubilis*	0.7
		Panicum amarum	1.0	*Croton punctatus*	0.3
		Lantana cf. camara	0.7	*Iva imbricata*	0.3
		Galactia volubilis	0.7	*Suriana maritima*	0.3
		Chamaesyce ssp.	0.7	*Canavalia rosea*	0.3
		Commelina erecta	0.7	*Chamaesyce ssp.*	0.3
		Canavalia rosea	0.5	*Croton glandulosus*	0.3
		Dactyloctenium aegyptium	0.3	*Physalis walteri*	0.3
		Physalis walteri	0.3	*Polypremum procumbens*	0.3
				Fimbristylis cymosa	0.3
Average plants per plot	7.7	Average plants per plot	15.3	Average plants per plot	16.0
Total native species	12	Total native species	21	Total native species	21
Total exotic species	1	Total exotic species	2	Total exotic species	3
% Bareground	39.2	% Bareground	24.2	% Bareground	39.2
% Woody species cover	8.7	% Woody species cover	13.2	% Woody species cover	4.5
% Vine species cover	3.2	% Vine species cover	3.2	% Vine species cover	0.7
% Forb species cover	5.3	% Forb species cover	17.5	% Forb species cover	14.2
% Graminoid species cover	39.2	% Graminoid species cover	30.8	% Graminoid species cover	24.2
Average woody height	0.6	Average woody height	0.6	Average woody height	0.6

Table 4.3.2.**2** cont. Vegetation characteristics of outplanted Bill Baggs study

42 meters from high tide mark		**60 meters from high tide mark**	
Species	**Cover**	**Species**	**Cover**
Coccoloba uvifera	7.8	*Coccoloba uvifera*	25.2
Suriana maritima	5.8	*Lantana involucrata*	10.7
Panicum amarum	5.8	*Crotalaria pumila*	6.2
Eustachys petraea	3.8	*Caesalpinia bonduc*	5.8
Lantana involucrata	3.2	*Chamaesyce ssp.*	4.3
Trichostema dichotomum	3.0	*Metopium toxiferum*	2.8
Uniola paniculata	2.5	*Lantana cf. camara*	2.3
Helianthus debilis	2.3	*Trichostema dichotomum*	1.7
Crotalaria pumila	2.3	*Helianthus debilis*	1.7
Lantana cf. camara	1.7	*Passiflora suberosa*	1.3
Alternanthera flavescens	1.7	*Catharanthus roseus*	1.0
Cnidoscolus stimulosus	1.7	*Hymenocallis latifolia*	0.7
Dactyloctenium aegyptium	1.3	*Alternanthera flavescens*	0.7
Chamaecrista nictitans var. aspera	1.3	*Croton punctatus*	0.7
Randia aculeata	1.0	*Eustachys petraea*	0.7
Croton glandulosus	1.0	*Physalis walteri*	0.7
Chamaesyce ssp.	1.0	*Cnidoscolus stimulosus*	0.7
Polygala grandiflora	1.0	*Croton glandulosus*	0.7
Croton punctatus	1.0	*Colubrina asiatica*	0.3
Saltgrass complex	1.0	*Randia aculeata*	0.3
Iva imbricata	1.0	*Galactia volubilis*	0.3
Echites umbellata	0.7	*Sabal palmetto*	0.3
Galactia volubilis	0.3	*Echites umbellata*	0.3
Passiflora suberosa	0.3	*Polygala grandiflora*	0.3
Smilax auriculata	0.3	*Saltgrass complex*	0.3
Ambrosia artemisiifolia	0.3	*Yucca aloifolia*	0.3
Commelina erecta	0.3	*Parthenocissus quinquefolia*	0.3
Catharanthus roseus	0.3		
Caesalpinia bonduc	0.3		
Verbesina virginica	0.3		
Commelina erecta	0.3		
Argusia gnaphalodes	0.3		
Stenotaphrum secundatum	0.3		
Average plants per plot	20.7	Average plants per plot	16.3
Total native species	29	Total native species	24
Total exotic species	4	Total exotic species	3
% Bareground	30.8	% Bareground	24.2
% Woody species cover	17.5	% Woody species cover	45.8
% Vine species cover	1.7	% Vine species cover	1.7
% Forb species cover	17.5	% Forb species cover	9.3
% Graminoid species cover	20.8	% Graminoid species cover	0.7
Average woody height	1.3	Average woody height	>2

Table 4.3.2.**3** Proportion of *J. reclinata* transplants surviving at varying distances from the ocean.

	Distance from Ocean (m)				
Replicate	**58**	**45**	**32**	**19**	**6**
1	0	100	100	100	100
2	100	66	83	83	0
3	50	100	100	100	0

Table 4.3.2.**4** Mean growth of *J. reclinata* in replicate at varying distances from the ocean.

	Distance from Ocean (m)				
Replicate	**58**	**45**	**32**	**19**	**6**
1	0	540	553	3770	2105
2	0	4012	1217	458	950
3	340	291	3225	4100	487

Output 5 Information on *J. reclinata* organized and accessible through GIS – Hannah Thornton

Output 5.1 Create GIS coverages of remote sensed imagery, vegetation types, habitat data, land ownership, roads, streets, buildings, foot trails, management units and site features.

Detailed reference maps were created for all known *J. reclinata* populations, including outplanted populations at Red Reef Park and Bill Baggs State Park, and the recently rediscovered natural population at Atlantic Dunes Park (Appendix A). Coverages were created for individual plant locations, as well as for contextual data like footpaths, trails, boardwalks, roads, fences, park entrances, lifeguard towers, recreation facilities, parking lots and nearby buildings. Coverages were also created for less permanent site features like, irrigation pipes, stakes, signs and surrounding vegetation, especially if that vegetation limited the growth of *J. reclinata* populations. New coverages have been created containing data pertinent to ongoing studies (e.g. locations of rain and temperature gauges, permanent vegetation sampling plots and new trail markers). Coverages for vegetation types present at each of the sites were created by digitizing habitat types from aerial photographs and groundtruthing as outlined in Output 1.4.

Output 5.2 Develop GIS linked databases for *ex situ*, wild and outplanted *J. reclinata* populations.

As maps have been created for wild and outplanted *J. reclinata* populations, information regarding *J. reclinata* individuals (i.e. plant locations, ID numbers and *ex situ* accession numbers of outplanted individuals) and regarding *J. reclinata* sites (i.e. species lists and habitat types) has been organized in the GIS database at FTG. This information is linked to the GIS coverages incorporated in the population and vegetation maps and can be accessed or queried through this visual framework.

Output 5.3 Establish GCPs at all sites, georeference site imagery and groundtruth imagery

See Output 1.1.

Output 5.4 Create ArcView user interface to query GIS coverages, databases and display info as standardized maps, reports and graphs.

ArcView interfaces have been created for eight wild populations and two outplanted populations of *J. reclinata*. Current interfaces contain detailed location maps (Appendix A), detailed maps of vegetation community structure (Appendix A), georeferenced aerial photographs and the various databases described in Output 5.2.

Output 6 Efficient project management and information distribution

Output 6.1 Host and facilitate land manager meeting to discuss habitat management opportunities and constraints – Hannah Thornton

Communication between land managers and researchers has been essential to the completion of this project. On April 27th, 2001, FTG researchers organized a meeting of 20 project collaborators, including land managers, biologists and naturalists from Miami-Dade County, Broward County, Palm Beach County, the State of Florida, and the City of Boca Raton, and researchers from Fairchild Tropical Garden and Florida International University. This group identified specific research opportunities, as well as resource availability and management issues at each *J. reclinata* site. This information was incorporated into site-specific management recommendations (Output 6.3.2), and protocols for monitoring (Output 6.3.3) and outplanting (Output 6.3.4) *J. reclinata* populations. Based on communication at this meeting, three additional populations of *J. reclinata* were relocated (populations at Atlantic Dunes Park in the city of Delray, Lake Worth Inlet in the town of Palm Beach and on private property in Hillsboro Beach).

Output 6.1.1. Compiling the history of *J. reclinata* conservation – Hannah Thornton

The research team at FTG pursued a number of methods to compile the conservation and management history of *J. reclinata*. Information regarding the historical distribution of *J. reclinata*, the connectedness of past populations and past outplantings of this species has informed natural history descriptions of current *J. reclinata* populations. Such information has also been useful in selecting sites for future outplantings and interpreting research results. We recognized three main methods to gather historical information regarding *J. reclinata*: 1) searches of written records regarding the species, 2) examination of historical photographs, including aerial photographs, and 3) interviews with researchers and naturalists who have had been associated with the species in recent years.

Searches of files at Fairchild Tropical Garden, contact with the Florida Natural Areas Inventory, and communications with Land Managers produced 50 references relevant to *J. reclinata* or coastal conservation (see Bibliography below). Aerial photographs of select *J. reclinata* sites were acquired from the National Oceanic and Atmospheric Administration for multiple years (Table 6.1a.**1**). Searches at the Boca Raton Historical Society, the Florida State Archive, and the Historical Museum of South Florida produced forty-seven historical photographs of the south Florida coastline dating from 1927. Interviews were conducted with eight individuals identified as directly involved with conservation of *J. reclinata* (Paul Davis, Janice Duquesnel, George Gann, Tiffany Troxler Gann, Liz Golden, Christopher Kernan, Ginny Powell and Steve Woodmansee). The above data will be stored at FTG for future use.

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Table 6.1.**1**. Aerial photographs of *J. reclinata* sites acquired from the National Oceanic and Atmospheric Administration.

Site	**Years of Aerial Photo Coverage**
Carlin Park	1999, 1988, 1970, 1959, 1945
Loggerhead Park	1999, 1971, 1959, 1945
South Beach Park	1999, 1987, 1962, 1945
Hugh Taylor Birch State Park	1999, 1987, 1972, 1959, 1945
Crandon Park	1999, 1992, 1971, 1960, 1959, 1945

Output 6.2 Involve land managers in designing and implementing field work – Samuel J. Wright

Collaborative outplanting of *J. reclinata*

On March 28, 2002, FTG researchers worked together with land manager Steve Bass (Gumbo Limbo Nature Center) and Boca High School students to remove *Schinus terebinthifolius* from a designated coastal dune restoration site. The site chosen for restoration was an exotic dominated 10 x 20m section on the leeward side of the permanent dune in the northern section of Red Reef Park, Boca Raton. The area was replanted with common, native coastal species such as *Distichlis spicata, Licania michauxiia*, *Spartina patens*, and *Helianthus debilis.*

Restoring this portion of the coastal dune presented an opportunity to outplant *J. reclinata.* On May 25, 2002 local Boy Scout Troop 333 removed the remaining *S. terebinthifolius* from the section previously mentioned as well as a smaller (4 x 9m) adjacent area. After a brief discussion of the background, history and the ecological importance of *J. reclinata*, scouts were given one plant each to plant haphazardly within the cleared dune. Eighteen tagged plants were outplanted originating from three separate accessions (parent plants). Material used for the outplanting was germinated from seeds collected from local Boca Raton populations.

The outplanting was revisited on February 06, 2003 for the monitoring of plant survival and health. Of the 18 outplanted individuals, 15 are still alive and thriving (growth, flowering, and fruiting). For easy relocation a 45cm long ½" PVC was installed into the ground adjacent to each plant. Attached to the top of each PVC pipe is a numbered metal tag used for identification. Using the PVC for relocation and identification of plants is an alternative to the previous method (Output 1.1) of attaching a tag with steel wire to the rootstock. We feel the new method is less invasive to the plants. While using the later method plants have been semi-excavated in order to locate lost tags, which could cause stress within the plants.

GPS points were also recorded for each plant. In the GIS lab all data were downloaded into Pathfinder Office, examined, and then exported in ArcView shapefile format. A map documenting plant location and ID number within the outplanting has been creating using Arcview GIS version 3.2. (Appendix A32 and A33).

While the survival rate of the outplanting is outstanding, its prolonged success cannot be accomplished without continual monitoring of the outplanting and maintenance of the area. FTG researchers will continue to monitor the health of the outplanting and keep park officials informed of the augmented population. We advise that park personnel monitor the growth of the planted *Helianthus debilis*, which has begun to dominate (Wright per. observation) some areas of the open restored dune.

Output 6.3 Distribute information on *J. reclinata* as GIS coverages, GIS databases, GIS management models and out-of-habitat propagation protocols – Hannah Thornton and Samuel Wright

Output 6.3.1. Distribute information on *J. reclinata* as GIS coverages and GIS databases.

As detailed in Outputs 1 and 5 a GIS containing information regarding various aspects of this project has been created and will be maintained at Fairchild Tropical Garden. This GIS is meant to serve as a source for information regarding *J. reclinata* and the sites where it occurs. Because maintaining and using such a GIS requires highly specialized equipment, it is not feasible to distribute digital copies of GIS coverages and GIS data to collaborators. This information is included in this report as tables, figures and maps. Digital information can be provided to interested parties on a case by case basis.

Output 6.3.2. Distribute information on *Jacquemontia reclinata* as management models: Site-specific recommendations for management of *J. reclinata* populations.

Introduction

We make the following recommendations based on our research results and field observations. Order of recommendation does connote priority; however, all recommendations are considered important for the preservation of this species. Management goals are the same for all sites, actions and the subsequent comments are site-specific. Some goals may require frequent action (e.g. removal of invasive grasses) and monitoring (Goal 2) should dictate this frequency. We encourage the modification of these recommendations following an adaptive management model, based on the beneficial or deleterious results of implementing these actions. Fairchild Tropical Garden agrees to provide stock for outplantings.

Associated documents are: Monitoring Protocol (Output 6.3.3), Outplanting Protocol (Output 6.3.4), Population Maps and Vegetation Maps (Appendix A). Park managers/biologists/significant contacts are listed, along with their agency, after park names. See Table 1.**1** for contact information.

Table 6.3.2.1 *Atlantic Dunes Park (Joe Weldon, City of Delray)*

General Notes

- Nearest wild populations are Lake Worth Inlet (Paul Davis, Palm Beach County Environmental Resource Management) to the north and Red Reef/South Beach Parks (Steve Bass, City of Boca Raton) to the south.
- Augmentation is especially recommended for the *J. reclinata* population at Atlantic Dunes Park because of reduced genetic diversity and small population size (Output 2.1).
- The population at South Beach Park is the best source for seed to use in augmentations at Atlantic Dunes Park (Output 2.4).

Goal 1. Maintain the health of the current *J. reclinata* population.

Action: Use the provided GIS maps of the *J. reclinata* population to increase awareness about the location of individuals and to rally support for their protection.

- → On visits to the park, we have moved large piles of plant debris from the largest patch of *J. reclinata* (patch 1, see population map). As *J. reclinata* requires high amounts of sunlight for growth and survival, individuals could easily die underneath such debris piles.

Action: Protect *J. reclinata* patches from encroachment by larger shrubs by cutting back shrubs along the edges of patches.

- → Shrub cover may be reduced by various means; however, we recommend this action be completed with the removal of dead plant matter.
- → Plants located in patches 3 and 4 (see population map) are in danger of being shaded out by surrounding shrubs. Thinning/cutting back vegetation along the edges of these patches will improve the health of these plants.

Goal 2. Monitor growth and dieback within the current *Jacquemontia reclinata* population.

Action: Observe/measure the health of the *J. reclinata* population according to the Monitoring Protocol in Output 6.3.4.We recommend monitoring, at least, on an annual basis.

- → Because of the density of rootstocks in patch 1, we recommend using the patch-size methods outlined in Output 6.3.4 to monitor this population. Counts of individuals could be used to monitor plants in patches 2, 3 and 4.

Action: Monitor, on a frequent basis, the response of the population to management.

Action: Conduct occasional surveys of coastal strand habitat throughout the park to record the appearance of new *J. reclinata* patches.

Goal 3. Remove/continue efforts to remove exotic species and native pest plant species throughout Atlantic Dunes Park.

Action: Remove *Rhynchelytrum repens* (Rose natalgrass) from patch 1.

- → Because *J. reclinata* plants are intertwined with *R. repens*, we recommend hand removal of *R. repens*, taking care not to damage *J. reclinata* plants or dislodge rootstocks.

Action: Remove *Schinus terebinthifolius* (Brazilian pepper) and cut back *Caesalpinia bondoc* (Nickerbean) in patches 3 and 4 (see population map).

- → Shrub cover may be reduced by various means; however we recommend the action be completed with removal of dead plant matter.

Goal 4. Maintain vegetation cover throughout *J. reclinata* patches as close as possible to the following guidelines: 10% bare ground, 75% open canopy and relatively equal proportions of vines, herbs, and grasses.

Action: Reduce cover of *Vitus rotundifolia* (Muscadine) in patch 1.

- → Because *J. reclinata* plants are intertwined with *V. rotundifolia*, we recommend hand removal of this species, taking care not to damage *J. reclinata* plants or dislodge rootstocks.
- → Grasses and vines are dominating within patch 1, creating an almost impenetrable mat of vegetation and leaving very little bare ground. Even though it is native, Muscadine cover should be reduced to open the area for herbs and other vines. Removal of Rose natalgrass will also help restore ratios of vines, herbs, grasses and bare ground in this area.

Action: Remove/cut back larger shrubs throughout patches 1 – 4 as indicated under Goal 1.

Goal 5. Increase the numbers of *J. reclinata* at Atlantic Dunes Park.

Action: Establish new sub-population(s) where possible.

- → Follow Seed Germination and Outplanting Protocols provided in Output 3.5 and Output 6.3.4.
- → The easternmost dune area may be an effective site for outplanting.
- → In order to increase genetic diversity within the Atlantic Dunes population, plants grown from seed collected in South Beach Park should be used for outplanting (Output 2.4).

Action: Monitor newly established populations as indicated in the Outplanting Protocol in Output 6.3.4.

Table 6.3.2.2 *Carlin Park (Paul Davis, Palm Beach County Environmental Resource Management)*

General Notes

- We endorse existing activities to preserve the *Jacquemontia reclinata* population at Carlin Park. Without past efforts and attention, this population might not exist.
- Carlin Park is the northernmost population of *J. reclinata*. Stock from Carlin Park could be used to re-establish populations of *J. reclinata* in Coral Cove Park to the north; however, due to the reduced genetic diversity evident in this population, any outplanting using stock from Carlin Park should also include stock from the population at South Beach Park (Steve Bass, City of Boca Raton) (Output 2.4).
- Nearest wild population is Loggerhead Park (Greg Atkinson, Palm Beach County Parks and Recreation; Paul Davis, Palm Beach Country Environmental Resource Management) to the south.
- Augmentation is especially recommended for the *J. reclinata* population at Carlin Park because of reduced genetic diversity and small population size (Output 2.1).
- The population at South Beach Park is the best source for seed to use in augmentations at Carlin Park.

Goal 1. Maintain the health of the current *J. reclinata* population.

Action: Protect *J. reclinata* patches from encroachment by larger shrubs by cutting back shrubs along the edges of patches.

- → Shrub cover may be reduced by various means; however, we recommend the action be completed with removal of dead plant matter.
- → Remove the leading edge of *Dalbergia ecastophyllum* (Coin vine) and the entire patch of the exotic *Scaevola sericea* (Beach napuka) to the north of the population. These two species have already covered many individuals of *J. reclinata*.
- → Action: Cut back *Coccoloba uvifera* (Sea Grape) where it contacts the current population as well as west of the open area adjacent to the largest patch of *J. reclinata* (see population map).

Action: Use the provided GIS maps of the *J. reclinata* population to increase awareness about the location of individuals and to rally support for their protection.

Goal 2. Monitor growth and dieback within the current *J. reclinata* population.

Action: Observe/measure the health of the *Jacquemontia reclinata* population according to the Monitoring Protocol in Output 6.3.3.We recommend monitoring, at least, on an annual basis.

- → Dune sands shift within the Carlin Park population more than within any other population; therefore, we recommend using the patch-size methods outlined in Output 6.3.3 to monitor this population. Given the length of the largest patch of *J. reclinata* individuals, it may be helpful to divide the patch into two sections.

Action: Monitor, on a frequent basis, the response of the population to management.

Action: Conduct occasional surveys of coastal strand habitat throughout the park to record the appearance of new *J. reclinata* patches.

- → Monitor especially the area surrounding the westernmost individuals (see population map). On our most recent site visit, we were unable to relocate these individuals; however they may come back after Sea grape is cut back.

Goal 3. Remove/continue efforts to remove exotic species and native pest plant species throughout Carlin Park.

We applaud the efforts of Palm Beach County in removing *Casuarina equisetifolia* and restoring native vegetation in the western area of Carlin Park.

Action: Remove *Scaevola sericea* as indicated under Goal 1.

Goal 4. Maintain vegetation cover throughout *J. reclinata* patches as close as possible to the following guidelines: 10% bare ground, 75% open canopy and relatively equal proportions of vines, herbs, and grasses.

Action: Maintain current vegetation cover in the area west of the foredune.

Goal 5. Increase the numbers of *J. reclinata* at Carlin Park.

Action: Establish new sub-population(s) where possible.

- → Follow Seed Germination and Outplanting Protocols provided in Outputs 3.5 and 6.3.4.
- → The strand area directly between the two patches of *J. reclinata* individuals (see population map) may be an effective site for outplanting.
- → The area that was recently cleared and restored, west of the current population, may also be an effective site for outplanting.
- → Additional subpopulations could be created within the open dune faces south of current population.
- → In order to increase genetic diversity within the Carlin Park population, plants grown from seed collected from South Beach Park should be used for augmentation (Output 2.4). Additional stock for outplantings could be grown from seeds collected from Loggerhead Park (Greg Atkinson, Paul Davis, Palm Beach County Environmental Resource Management) or Red Reef Park (Steve Bass, City of Boca Raton).

Action: Monitor newly established populations as indicated in the Outplanting Protocol in Output 6.3.4.

Table 6.3.2.3 ***Crandon Park (Ernie Lynk, Miami-Dade County Parks and Recreation)***

General Notes

- We endorse existing activities to preserve the *Jacquemontia reclinata* population at Crandon Park. Without past efforts and attention, this population might not exist.
- Nearest wild population is Hugh Taylor Birch State Park (Jim Gibson, State of Florida Department of Recreation and Parks) to the north. An outplanted population exists at Bill Baggs State Park (Liz Golden, State of Florida Department of Recreation and Parks) to the south. Stock from Crandon Park was used in the outplanting at Bill Baggs.
- Crandon Park has high genetic diversity and is a good source of stock for outplantings or augmentations within Miami-Dade and southern Broward County, especially at Virginia Key (Juan Fernandez, City of Miami).

Goal 1. Maintain health of current *J. reclinata* population.

Action: Use the provided GIS maps of the *J. reclinata* population to increase awareness about the location of individuals, and to rally support for their protection.

Action: Protect *J. reclinata* patches from encroachment by larger shrubs by cutting back shrubs along the edges of patches.

- → Shrub cover may be reduced by various means; however, we recommend the action be completed with removal of dead plant matter.
- → We have noticed problems with *Coccoloba uvifera* (Sea grape) and *Dalbergia ecastolphyllum* (Coin vine) encroaching on edges of patches throughout Crandon Park.

Action: Protect *J. reclinata* patches from trampling.

- → Continue efforts to control public access to the Bear Cut natural area. The current fencing and signage seem to be effective—the many small foot trails that once crisscrossed the park are filling in nicely.
- → As possible, monitor old footpaths for infiltration of invasive species.

Goal 2. Monitor growth and dieback of current *J. reclinata* population.

Action: Observe/measure the health of the *J. reclinata* population according to the Monitoring Protocol in Output 6.3.3.We recommend monitoring, at least, on an annual basis.

- → Because the Bear Cut Natural Area is so large and supports such a large population of *J. reclinata*, we recommend using the patch-size methods outlined in Output 6.3.3 to monitor at this site.
- → Monitoring is especially important at Bear Cut because the coastal strand habitat is more dynamic here than at any other park. Consequently, patches of *J. reclinata* are more likely to appear and disappear over the course of a season.

Action: Monitor, on a frequent basis, the response of the population to management.

Action: Conduct occasional surveys of coastal strand habitat throughout the park to record the appearance of new *J. reclinata* patches.

Goal 3. Remove/continue efforts to remove exotic species and native pest plant species throughout Crandon Park.

Action: Continue removal of invasive exotic and native pest plant species especially *Dactyloctenium aegyptium* (Durban crowfoot grass), *Rhyncoletrum repens* (Rose natalgrass), *Caesalpinia bondoc* (Nickerbean), and *Dalbergia ecastolphyllum* (Coin vine).

- → Shrub cover may be reduced by various means; however, we recommend the action be completed with removal of dead plant matter.
- → Monitoring of patches following herbicide and removal may be important to help test this management technique. Monitoring could include recording the (re)growth of *J. reclinata*, or other endangered/indicator species, recording the growth of target invasive species, and recording the growth of native species.

Goal 4. Maintain vegetation cover throughout *J. reclinata* patches as close as possible to the following guidelines: 10% bare ground, 75% open canopy and relatively equal proportions of vines, herbs and grasses.

Action: Monitor aggressive native vines (e.g. *Smilax auriculata, Parthenocissus quinqefolia*) in vicinity of *J. reclinata* and *Zanthoxylum coriaceum*, and remove vines as needed.

Action: As possible, experiment with fire as a method of maintaining openness.

Goal 5. Increase the numbers of *J. reclinata* at Crandon Park.

Action: Establish new sub-population(s) where possible.

- → Follow Seed Germination and Outplanting Protocols provided in Outputs 3.5 and 6.3.4.

Action: Monitor newly established populations as indicated in the Outplanting Protocol in Output 6.3.4.

Table 6.3.2.4 *Hugh Taylor Birch State Park (Jim Gibson, State of Florida Department of Recreation and Parks)*

General Notes

- We endorse existing activities to preserve the *Jacquemontia reclinata* population at Hugh Taylor Birch. Without past efforts and attention, this population might not exist.
- Hugh Taylor Birch represents the only wild population of *J. reclinata* on public land in Broward County. This population is also genetically very distinct from all other wild populations. Preservation of this population is essential to preservation of the full range of genetic diversity within *J. reclinata*.
- Nearest wild populations in public ownership are Crandon Park (Ernie Lynk, Miami-Dade County Parks and Recreation) to the south and South Inlet Park (Paul Davis, Ginny Powell, Palm Beach County Environmental Resource Management) to the north. The population on private land in Hillsboro Beach (Gretel McCausland, Carol Morgenstern, Broward County Parks and Recreation) is nearest population to the north.
- Although the population at Hugh Taylor Birch State Park is the only *J. reclinata* population on public land in Broward County, we do not recommend using this population as a source for outplanting stock (Output 2.4). Similarly, any outplantings pursued within Hugh Taylor Birch State Park should use plants grown from seed collected within this population.

Goal 1. Maintain the health of the current *J. reclinata* population.

Action: Use the provided GIS maps of the *J. reclinata* population to increase awareness about the location of individuals, and to rally support for their protection.

Action: Limit weed whacking along the very eastern edge of the protected area adjacent to the parking lot (see population map).

- → Many *J. reclinata* individuals grow along this edge, and are subject to frequent trampling and weed whacking. Their growth and reproduction may be compromised.

Action: Expand protected area 4 – 5 feet beyond current boundaries in order to encompass individuals growing along edge of parking lot.

Action: Remove *Stenotaphrum secondatum* (St. Augustine grass) along the edge of the parking lot to prevent competition with *J. reclinata*.

- → Because of the proximity of St. Augustine grass to *J. reclinata* individuals, we recommend continuous hand removal of this species.

Goal 2. Monitor growth and dieback within the current *J. reclinata* population.

Action: Observe/measure the health of the *J. reclinata* population according to the Monitoring Protocol in Output 6.3.3. We recommend monitoring, at least, on an annual basis.

- → Because of the density of rootstocks in the center of the population, we recommend using the patch-size methods outlined in Output 6.3.3 to monitor at Hugh Taylor Birch State Park. Counts of individuals could be used to monitor plants in the northern and southern parts of the population.
- → Monitoring is especially important at Hugh Taylor Birch, because the habitat here is very dynamic. Consequently, patches of J. reclinata are more likely to appear and disappear over the course of a season.

Action: Monitor, on a frequent basis, the response of the population to management.

Action: Conduct occasional surveys of coastal strand habitat throughout the park to record the appearance of new *J. reclinata* patches.

Goal 3. Remove/continue efforts to remove exotic species and native pest plant species throughout Hugh Taylor Birch State Park.

We applaud the efforts of the park staff in removing exotics, especially *Casuarina equisetifolia*, and restoring native vegetation throughout the northwestern area of Hugh Taylor Birch State Park.

Action: Remove exotic invasive species from the area containing the *J. reclinata* individuals, especially, *Abrus precatorius* (Rosary pea), *Wedelia trilobata* (Creeping wedelia), and *Schinus terebinthefolius* (Brazilian pepper).

- → Shrub cover may be reduced by various means; however we recommend the action be completed with removal of dead plant matter.

Goal 4. Maintain vegetation cover throughout *J. reclinata* patches as close as possible to the following guidelines: 10% bare ground, 75% open canopy and relatively equal proportions of vines, herbs, and grasses.

Action: Continue efforts to control the growth of large shrubs and trees surrounding, and throughout, patches of *J. reclinata* individuals.

- → Following typical patterns of succession, since this area is located west of existing maritime hammock, it has the potential to shift to a maritime hammock community. Jim Higgins regularly removed saplings of hammock species (like *Simarouba glauca*, and *Bursera simarouba*) to maintain an open, heterogeneous landscape.

Goal 5. Increase the numbers of *J. reclinata* at Hugh Taylor Birch State Park.

Action: Establish new sub-population(s) where possible.

- → Follow Seed Germination and Outplanting Protocols provided in Outputs 3.5 and 6.3.4.
- → The easternmost dune area may be an effective site for outplanting (see Goal 6, below).
- → Because of the unique genetic identity of this population, outplantings at Hugh Taylor Birch State Park should be completed only using plants grown from seed collected from the Hugh Taylor Birch population.

Action: Monitor newly established populations as indicated in the Outplanting Protocol in Output 6.3.4.

Goal 6. Increase the amount of coastal dune/coastal strand habitat throughout Hugh Taylor Birch State Park.

Action: Remove small ($30m^2$) portions of the *Coccoloba uvifera* hammock west of A1A.

- → Portions of this hammock contain *Schinus terebinthefolius* and *Scaveola sericea*. These species could be removed to open areas for outplantings of *Jacquemontia reclinata* and other coastal dune/strand species (see Appendix A pg. A37)
- → Maintain vegetation cover in such restored areas according to proportions listed in Goal 4.

Table 6.3.2.5 ***Loggerhead Park (Greg Atkinson, Palm Beach County Parks and Recreation; Paul Davis, Palm Beach County Environmental Resource Management)***

General Notes

- Nearest wild populations are Lake Worth Inlet (Paul Davis, Palm Beach County Environmental Resource Management) to the south and Carlin Park (Paul Davis, Palm Beach County Environmental Resource Management) to the north.
- Augmentation is especially recommended for the *J. reclinata* population at Loggerhead Park because of the extremely low population size. Although the population still shows high genetic diversity, it seems that most of this diversity is contributed by just a single individual (Output 2.1).
- Preservation of this population is essential to preserve the full range of genetic diversity within *J. reclinata*.
- The population at South Beach Park is the best source for seed to use in augmentations at this site.

Goal 1. Maintain the health of the current *J. reclinata* population.

Action: Use the provided GIS maps of the *J. reclinata* population to increase awareness about the location of individuals, and to rally support for their protection.

Action: Place a permanent fence between the path and the area containing *J. reclinata* in order to prevent passersby from trampling existing plants.

→ Plants in this area grow almost directly along the pavement of the path. If possible, the park may want to consider reducing the width of the path near the plants in order to accommodate the fence.

Action: Protect *J. reclinata* patches from encroachment by larger shrubs by cutting back shrubs along the edges of patches.

→ Shrub cover may be reduced by various means; however we recommend the action be completed with the removal of dead plant matter.

→ Since FTG began research in this park, the six westernmost individuals seem to have died back. We believe this dieback to be the result of overcrowding throughout the area containing *J. reclinata* individuals. There is good chance that these individuals may come back after cover is reduced.

Goal 2. Monitor growth and dieback within the current *J. reclinata* population.

Action: Observe/measure the health of the *J. reclinata* population according to the Monitoring Protocol in Output 6.3.3. Because of the size of this population, we recommend monitoring on a bi-annual basis.

→ Because of the size of the Loggerhead Park population, and the importance of each individual within the population, we recommend monitoring at the level of individual rootstocks as described in Output 6.3.3.

Action: Monitor, on a frequent basis, the response of the population to management.

→ This kind of monitoring will be especially important at Loggerhead Park in order to record the reappearance of lost individuals.

Action: Conduct occasional surveys of coastal strand habitat throughout the park to record the appearance of new *J. reclinata* patches.

Goal 3. Remove/continue efforts to remove exotic species and native pest plant species throughout Loggerhead Park.

We applaud the efforts of Palm Beach County in removing exotics, especially *Schinus terebinthifolius* at Loggerhead Park.

Goal 4. Maintain vegetation cover throughout *J. reclinata* patches as close as possible to the following guidelines: 10% bare ground, 75% open canopy and relatively equal proportions of vines, herbs, and grasses.

Action: Reduce cover/remove individuals of *Quercus geminata, Agave sp., and Serenoa repens* throughout the area surrounding the *J. reclinata* individuals.

- → Because *J. reclinata* plants are intertwined with many individuals of these species, we recommend CAREFUL removal of target species, taking care not to trample *J. reclinata* plants or dislodge rootstocks.
- → Loggerhead Park represents a beautiful example of dense coastal scrub habitat; however, maintaining openness throughout the area surrounding the *J. reclinata* individuals is essential to the survival of this population.

Action: Reduce cover of *Cassytha filiformis* throughout the area surrounding *J. reclinata* individuals.

Goal 5. Increase the numbers of *J. reclinata* at Loggerhead Park.

Action: Establish new sub-population(s) where possible.

- → Follow Seed Germination and Outplanting Protocols provided in Output 3.5 and 6.3.4.
- → The newly cleared area just east of the current population might be an effective site for outplanting; however, this area is a depression and if water collects here, it may be too moist for *J. reclinata.*
- → Juno Dunes Natural Area to the north of Loggerhead Park may also present effective outplanting sites (see Restoration Plan, Output 1.5).
- → In order to increase/maintain genetic diversity within the Loggerhead Park population, plants grown from seed collected in South Beach Park should be used for outplanting.

Action: Monitor newly established populations as indicated in the Outplanting Protocol in Output 6.3.4.

Table 6.3.2.6 *Red Reef Park (Steve Bass, City of Boca Raton)*

General Notes

- We endorse existing activities to preserve the *Jacquemontia reclinata* population at Red Reef Park. Without past efforts and attention, this population might not exist.
- Nearest populations are South Beach Park (Steve Bass, City of Boca Raton) to the south and Atlantic Dunes Park (Joe Weldon, City of Delray) to the north.
- The population at Red Reef Park is a good source for stock to be used in outplantings throughout Palm Beach County, especially at Spanish River Park. In general, the population at South Beach Park is a better source for stock; however, stock from the Red Reef Park population can be added to an outplanting to increase genetic diversity of the founding population (Output 2.**4**).
- If augmenting the population at Red Reef Park, a mix of stock from Red Reef and South Beach Parks should be used.

Goal 1. Maintain the health of the current *J. reclinata* population.

Action: Use the provided GIS maps of the *J. reclinata* population to increase awareness about the location of individuals and to rally support for their protection.

Action: Protect *J. reclinata* patches from encroachment by larger shrubs by cutting back shrubs along the edges of patches.

→ Individuals in patch 1 (see map) are in danger of being over grown by *Coccoloba uvifera* (Sea grape) encroaching from the edges of the patch.

Action: Remove shrubby vegetation and open the dune area east of the *J. reclinata* individuals in patch 2 (see population map).

→ These individuals are in danger of being lost to over crowding by sea grape and grasses. Careful opening of this area may promote the growth and expansion of this subpopulation.

Goal 1A. Maintain the health of recently outplanted *J. reclinata* individuals.

Action: Monitor and limit the growth of associated native species (like *Helianthus debilis*). Avoid allowing a single species to become the dominant cover in this area.

Action: Continue efforts to remove exotic invasive species from the revegetated area, especially *Momordica charantia* (Bitter melon) and *Rheo spathacea* (Oyster plant).

Action: Monitor health and survival of outplanted *J. reclinata* individuals.

Goal 2. Monitor growth and dieback within current *J. reclinata* population.

Action: Observe/measure the health of the *J. reclinata* population according to the Monitoring Protocol in Output 6.3.3.We recommend monitoring, at least, on an annual basis.

→ Because of the density of rootstocks in patch 1, we recommend using the patch-size methods outlined in Output 6.3.3 to monitor in Red Reef Park. Counts of individuals could be used to monitor plants in patches 2 and 3.

Action: Monitor, on a frequent basis, the response of the population to management.

Action: Conduct occasional surveys of coastal strand habitat throughout the park to record the appearance of new *J. reclinata* patches.

- → The southern coastal strand area should be especially monitored as the heterogeneous vegetation coverage here could provide appropriate microhabitats for *J. reclinata* seed germination.

Goal 3. Remove/continue efforts to remove exotic species and native pest plant species throughout Red Reef Park.

We applaud the efforts of the City of Boca Raton in removing exotics, especially *Schinus terebinthifolius,* from Red Reef Park.

Action: Begin removing *Scaevola sericea* (Beach napuka) where it occurs.

- → Shrub cover may be reduced by various means; however we recommend the action be completed with removal of dead plant matter.
- → *S. sericea* occurs frequently along the dune face.

Action: Continue efforts to remove *Schinus terebinthifolius* (Brazilian pepper) where appropriate.

- → Shrub cover may be reduced by various means; however we recommend the action be completed with removal of dead plant matter.
- → Removal of *S. terebinthifolius* along the dune ridge and from the dune faces may open appropriate areas for *J. reclinata* outplantings.

Goal 4. Maintain vegetation cover throughout *J. reclinata* patches as close as possible to the following guidelines: 10% bare ground, 75% open canopy and relatively equal proportions of vines, herbs, and grasses.

Action: Thin graminoids within the largest patch of *J. reclinata*, concentrating especially on the southern half of the patch.

- → Because *J. reclinata* plants are intertwined with graminoids throughout this patch, we recommend hand removal of these species, taking care not to damage *J. reclinata* plants or dislodge rootstocks.
- → Grasses are beginning to dominate within this patch. In some areas, they are beginning to create an almost impenetrable mat of vegetation, leaving very little bare ground.
- → The healthiest individuals within this patch are located along the eastern edge where bare sand is still visible.

Action: Remove/cut back larger shrubs throughout the southernmost area containing *J. reclinata*.

- → It is especially important to maintain openness throughout this area, as it is the best patch of coastal strand in the park.
- → Shrub cover may be reduced by various means; however we recommend the action be completed with removal of dead plant matter.

Action: As possible, experiment with fire as a method of maintaining openness.

Goal 5. Increase the numbers of *J. reclinata* at Red Reef Park.

Action: Establish new sub-population(s) where possible.

- → Follow Seed Germination and Outplanting Protocols provided in Output 3.5 and Output 6.3.4.
- → New dune openings may be effective sites for outplantings.
- → Plants grown from seeds collected from the Red Reef and South Beach Park populations are the best stock to use for outplantings within Red Reef Park.

Action: Monitor newly established populations as indicated in the Outplanting Protocol in Output 6.3.4.

Goal 6. Increase the amount of coastal dune/coastal strand habitat throughout Red Reef Park.

Action: Continue efforts to remove pieces of the dense shrubby vegetation along the dune face.

- → Maintain vegetation cover in such restored areas according to proportions listed in Goal 4.

Table 6.3.2.7 *South Beach Park (Steve Bass, City of Boca Raton)*

General Notes

- We endorse existing activities to preserve the *Jacquemontia reclinata* population at South Beach Park. Without past efforts and attention, this population might not exist.
- Nearest populations are South Inlet Park (Paul Davis, Ginny Powell, Palm Beach County Environmental Resource Management) to the south and Red Reef Park (Steve Bass, City of Boca Raton) to the north.
- The population at South Beach Park is the best source for outplanting stock to be used throughout Palm Beach County and southern Broward County (Output 2.4).

Goal 1. Maintain the health of the current *J. reclinata* population.

Action: Use the provided GIS maps of the *J. reclinata* population to increase awareness about the location of individuals and to rally support for their protection.

Action: Protect *J. reclinata* patches from encroachment by larger shrubs by cutting back shrubs along the edges of patches.

- → Regularly cut back sea grape along the edges of dune openings to prevent encroachment.
- → Remove, especially, the dense herbaceous vegetation east of the recently installed paved trail south of the golf course.
- → Cut back with care—many individuals have rootstocks and large portions of stems underneath the edge vegetation.

Goal 2. Monitor growth and dieback of the current *J. reclinata* population.

Action: Observe/measure the health of the *J. reclinata* population according to the Monitoring Protocol in Output 6.3.3.We recommend monitoring at least on an annual basis.

- → Because of the density of rootstocks in all patches of *J. reclinata* at South Beach Park, and because of the density of ground cover within some of the dune openings, we recommend using the patch-size methods outlined in Output 6.3.3 to monitor at this site.
- → Because some dune openings have a large area, it may be necessary to separate them into quadrats for the purposes of monitoring.

Action: Monitor, on a frequent basis, the response of the population to management actions.

Action: Conduct occasional surveys of coastal strand habitat throughout the park to record the appearance of new *J. reclinata* patches.

Goal 3. Remove/continue efforts to remove exotic species and native pest plant species throughout South Beach Park.

We applaud the efforts of the City of Boca Raton in removing exotics, especially *Schinus terebinthifolius,* from South Beach Park.

Action: Continue efforts to remove established *Schinus terebinthifolius* (Brazilian pepper) where appropriate.

Action: Remove seedlings of *S. terebinthifolius* and *Casuarina equisetifolia* as they appear.

Goal 4. Maintain vegetation cover throughout *Jacquemontia reclinata* patches as close as possible to the following guidelines: 10% bare ground, 75% open canopy and relatively equal proportions of vines, herbs, and grasses.

Action: Maintain low cover within dune openings. Avoid allowing a single species to become the dominant cover in a single opening.

- → Cut back/remove thick shrubby species throughout openings.
- → Because *J. reclinata* plants are frequently intertwined with the low-growing species within these openings, we recommend very careful removal/reduction of cover of target species. Take care not to damage *J. reclinata* plants or dislodge rootstocks.

Action: Remove/cut back larger shrubs throughout the blowouts.

- → Shrub cover may be reduced by various means; however we recommend the action be completed with removal of dead plant matter.

Action: As possible, experiment with fire as a method of maintaining openness.

Goal 5. Increase the numbers of *J. reclinata* at South Beach Park.

Action: Establish new sub-population(s) where possible.

- → Follow Seed Germination and Outplanting Protocols provided in Outputs 3.5 and 6.3.4.
- → New dune openings may be effective sites for outplantings.
- → Plants grown from seeds collected within the South Beach Park population are the best stock to use for outplantings within South Beach Park.

Action: Monitor newly established populations as indicated in the Outplanting Protocol in Output 6.3.4.

Goal 6. Increase the amount of coastal dune/coastal strand habitat throughout South Beach Park.

Action: Continue efforts to remove some of the dense shrubby vegetation along the dune face, including *Coccoloba uvifera* (Sea grape) and *Serenoa repens* (saw palmetto).

- → Maintain vegetation cover in such restored areas according to proportions listed in Goal 4.

Table 6.3.2.8 ***South Inlet Park (Paul Davis, Ginny Powell, Palm Beach County, Environmental Resource Management)***

General Notes

- We endorse existing activities to preserve the *Jacquemontia reclinata* population at South Inlet Park. Without past efforts and attention, this population might not exist.
- Nearest wild populations are Hugh Taylor Birch State Park (Jim Gibson, State of Florida Department of Recreation and Parks) to the south and South Beach Park (Steve Bass, City of Boca Raton) to the north.
- Augmentation is especially recommended for the *J. reclinata* population at South Inlet Park because of reduced genetic diversity and small population size (see Output 2.4).
- The population at South Beach Park is the best source for seed to use in augmentations at this site.

Goal 1. Maintain the health of the current *J. reclinata* population.

Action: Use the provided GIS maps of the *J. reclinata* population to increase awareness about the location of individuals, and to rally support for their protection.

→ In our experience, lifeguards at this park are especially dedicated to protecting the dune habitat. Perhaps they could be recruited as volunteer monitors for the South Inlet Park population.

Action: Continue efforts to limit public access to dune areas.

→ Specific attention should be paid to the path behind the guard house (at the park entrance), which leads directly to *J. reclinata* population. This path has been used to varying degrees throughout the course of our research at South Inlet Park. We have observed some trampling of the population. Perhaps a small fence could be installed, or guards could be especially watchful.

Action: Protect *J. reclinata* patches from encroachment by larger shrubs by cutting back *Coccoloba uvifera* (Sea Grape) along the edges of the patch.

→ Shrub cover may be reduced by various means; however we recommend the action be completed with removal of dead plant matter.

→ Many individuals have rootstocks and large portions of stems underneath the leading edges of the sea grape within this patch. All vegetation should be removed with extreme care.

Goal 2. Monitor growth and dieback within current *J. reclinata* population.

Action: Observe/measure the health of the *J. reclinata* population according to the Monitoring Protocol in Output 6.3.3.We recommend monitoring, at least, on an annual basis.

→ Given the small size of the population at South Inlet Park, it may be possible to monitor the health of this population by revisiting individual, tagged rootstocks. However, dense grass cover may force observers to use the patch-size method described in the Monitoring Protocol in Output 6.3.3.

Action: Monitor, on a frequent basis, the response of the population to management.

Action: Conduct occasional surveys of coastal strand habitat throughout the park to record the appearance of new *J. reclinata* patches.

→ Monitor especially the area to the east of the current population.

Goal 3. Remove/continue efforts to remove exotic species and native pest plant species throughout South Inlet Park.

Goal 4. Maintain vegetation cover throughout *J. reclinata* patches as close as possible to the following guidelines: 10% bare ground, 75% open canopy and relatively equal proportions of vines, herbs and grasses.

Action: Remove/reduce cover of graminoids throughout the *J. reclinata* patch at South Inlet Park.

- → *Panicum amarum* (Bitter panicum) has begun to dominate this patch, and may be shading-out *J. reclinata* individuals.
- → Because *J. reclinata* stems are intertwined with the stems of *P. amarum*, we recommend careful hand removal of this species.

Goal 5. Increase the numbers of *J. reclinata* at South Inlet Park.

Action: Establish new sub-population(s) where possible.

- → Follow Seed Germination and Outplanting Protocols provided in Ouputs 3.5 and 6.3.4.
- → The area directly east of the current *J. reclinata* patch may be an effective site for outplanting.
- → The open strand area north of the population (but west of tall sea grape) may also be an effective outplanting site.
- → *J. reclinata* individuals could also be installed throughout the recently restored dune areas.
- → In order to increase genetic diversity and population size within this population, plants grown from seed collected from South Beach Park should be used for augmentations within South Inlet Park. Additional stock for outplantings could be grown from seeds collected from Red Reef Park (Steve Bass, City of Boca Raton). (Output 2.4)

Action: Monitor newly established populations as indicated in the Outplanting Protocol in Output 6.3.4.

Goal 6. Increase the amount of coastal dune/coastal strand habitat throughout South Beach Park.

We applaud the efforts of Palm Beach County in restoring coastal dune areas within South Inlet Park.

Output 6.3.3. Distribute information on *Jacquemontia reclinata* as management models: Protocol(s) for monitoring populations

Overall Monitoring Goal: To detect (at least) a 25% reduction in population size with 95% confidence.

Sub-Goals: To detect, document and mark recruitment (new seedlings).
To record the growth of new seedlings.
To observe the causes of diebacks (especially overgrowth by exotic-invasive or native pest-plant species).

Action: Contact USFWS should a severe (25% or greater) reduction in population size be observed.

Introduction

Over the last thirty years, the occurrence of *J. reclinata* has been chronicled primarily through anecdotal monitoring. Without these efforts, local extirpations might have gone unnoticed, and small, but lingering, populations might not have been recorded. The results of these monitoring efforts provided the basis for species listing in 1993.

Now that a framework for management of this species has been established, it is important to move from irregular monitoring of species presence/absence to regular monitoring of the size of individual populations. Consistent monitoring is essential to measuring the success of augmentations and outplantings and to detecting dieback and impending extirpation. In short, consistent monitoring of individual populations is essential to preservation of this species.

Given its importance, we emphasize that regular monitoring of population size should be pursued by any means possible. Each wild population of *J. reclinata* is physically unique, and each managing agency has its own unique capabilities and limitations. In light of these differences, we do not wish to mandate a specific monitoring protocol. We do not wish monitoring efforts to be impeded by inappropriate or unreasonable suggestions. Instead, we wish to create guidelines that individual agencies can modify and shape into site-specific, logistically feasible protocols.

Regardless of monitoring method or final protocol, two elements are very important: consistency and sustainability. Monitoring methods should be clear enough that they can be effectively repeated by different observers, especially during times of staff turnover, and realistic enough that the task can be completed on schedule. We encourage the use of protocols that can be implemented easily by volunteers or other collaborators. This can include protocols that use categories to classify the size of *J. reclinata* patches, as long as those categories are not subjective (i.e. they are specific m^2 measurements, as opposed to percentages). We especially encourage the use of protocols that are not so labor intensive as to cause an agency to abandon monitoring efforts, or to wish they could abandon monitoring efforts! We believe these suggestions will help increase confidence in estimates of population size.

Suggested methods to monitor individual populations of *Jacquemontia reclinata*

Counting individual rootstocks. In this method, individual rootstocks are relocated on an annual or semi-annual basis using the site-specific GIS population maps provided in this report. Observers can record presence/absence (death), approximate size, and even numbers of flowers or fruits of an individual plant. This method may be appropriate for populations of smaller sizes (Loggerhead Park, South Inlet Park); however, we do not recommend this method for large populations. Locating individual rootstocks can be time consuming and difficult, especially where surrounding vegetation is thick or sands are particularly shifty (Carlin Park). In the course of our research, we have had difficulties relocating identification tags, and we generally find this method ineffective for monitoring dense populations. Additionally, calculating approximate change in population size becomes increasingly time-intensive as the quantity of data increases.

Relative Patch Size. For larger populations, a more practical method may be to monitor the relative size of patches of *J. reclinata*. In some sites, the species occurs as groupings of individuals nestled between larger shrubs or dense vegetation. These groupings could be considered patches (see Pascarella, Output 3.4.2), and population size and health could be assessed by monitoring the size and health of these patches. Because the number of individuals within each patch varies considerably, we caution against monitoring at the coarse scale of patch presence or absence—the loss of a single patch could mean the loss of many individuals. Patches can be located using the GIS population maps included in this report. If this method is employed, we recommend permanently marking/identifying each patch, perhaps with rebar, so that they can be revisited with ease.

Patch size could be measured in a number of ways:

1) Measurements in 2 – 4 cardinal directions from the center to the edges of the patch using a meter tape. The center of the patch should be permanently marked; directions measured should be consistent; and, the "edge" of the patch should be clearly defined.

2) Visual estimation according to pre-set categories (e.g. $5m^2$, $10m^2$, etc). Using a meter-square as a reference can help keep estimations consistent between observers. These estimations are probably most accurate when made on a finer scale (for instance, less than $15m^2$).

3) Estimation from photographs of patches. This seems like the least reliable methods of assessing patch size; however, with care, it could be implemented effectively. We include it primarily to emphasize the idea that the method (as long as it is consistent and reliable) is less important than completion of the task.

Output 6.3.4. Distributing information on *Jacquemontia reclinata* as management models: Protocols for outplanting *J. reclinata* individuals.

General Recommendations

- Outplantings of adult plants grown from seed seem to be more successful than outplantings of plants grown from cuttings and outplantings of seeds.
- Planting during the height of the rainy season (August and September) can greatly reduce the amount of necessary watering and increase the survivorship of outplants.
- *J. reclinata* outplants at Bill Baggs State Park showed highest survival rates in mid-dune area, that is, from the lee side of the fore dune to the beginning of scrub vegetation.
- The ideal site has an open canopy, sandy substrate (low organic matter, detritus), moderate (25 – 50%) low shrub cover, and less than 25% bare ground.
- These are some of the (native) species that most commonly occur with *J. reclinata*: *Cnidoscolus stimulosus, Commelina erecta, Galactia volubilis, Bidens alba, Polygala grandiflora, Ipomoea indica, Pithecellobium keyense, Randia aculeata, and Trema micrantha.*
- If *J. reclinata* is planted as part of a dune restoration, we recommend including the species named above; HOWEVER, plants acquired from nurseries may be hardier than plants of *J. reclinata*, and may out-compete newly planted *J. reclinata* individuals. Neighboring plants should be removed if they begin to shade/crowd out *J. reclinata*. Avoid planting many individuals of the same species.
- Planting *J. reclinata* individuals in clusters (see design for our outplanting study Output 4.3.2 above) may minimize deleterious edge effects. Plants should be at least 1m apart.
- *J. reclinata* has proven difficult to maintain in an *ex situ* setting. We recommend germinating seeds and growing plants for outplanting purposes ONLY.
- The number of individual plants and genets included in an outplanting depends on many factors: size of site, availability of source plants/seed, and ability to germinate seed and

raise plants. We recommend making outplantings as large as possible, ideally including at least 50 individuals, and as diverse as possible, ideally taking seed from at least ¼ as many maternal plants as will be included in the outplanting.

- We've found that fertilization more than replaces the effect of mycorrhiza on seedling growth. In a single experiment, fertilized potted seedlings had better outplanting survival than unfertilized and mycorrhizal plants. A combination of low levels of fertilizer plus mycorrhizal inoculation would be beneficial if introduction of phosphorus or fertilizers to the site are a concern. Inoculation with mycorrhiza is definitely recommended if propagules are planted in sites previously devoid of native vegetation (a natural source of mycorrhizal inoculation).

Protocols

Preparing Stock Plants

1. Select source populations for seed as recommended in Output 2.1.
2. Store or germinate seeds following protocols in Output 3.5.
3. Maintain plants in shade for up to one month after germination.
4. After one month, move plants to full sun, and maintain in full sun until outplanting.
5. Water 1 gal. every other day
6. Fertilize with Florikan ® (Nutricote, Sarasota, FL) slow-release fertilizer, 10% N 10% P 17% K.
7. It is not clear whether inoculating nursery plants with arbuscular mycorrhizae will improve outplanting success (see General Recommendations above). All propagules planted in a natural site should become colonized with mycorrhiza from adjacent vegetation within a few months. For planting at non-vegetated restoration sites, inoculate nursery plants with arbuscular mycorrhizae. Develop inoculum by growing Sudan grass for several months in a pot of native soil with roots of local plants, the source of native arbuscular mycorrhizae. Inoculum per nursery pot of *J. reclinata* = 1 Tsp. Soil + chopped sudan grass roots.
8. Outplant after first flowering (3 – 4 months). Plants should be at least 1 gallon size to ensure proper establishment of root structure.
9. Reduce water to every third day one month before outplanting.

Preparing Outplanting Site

Site preparation will vary depending on current vegetation type (see Output 1.5). Sites that are monocultures of exotic species should be cleared entirely—branches, dead plant material and other trash resulting from destruction of exotics should also be removed. In sites that already contain majority native coastal dune vegetation, shrubby cover (plants above 1m in height) should be reduced to approximately 25% throughout areas where *J. reclinata* will be outplanted. Additionally, small areas on the ground should be cleared of detritus where individual *J. reclinata* plants will be installed. Necessary arrangements should be made for watering. Outplanting locations should be marked with rebar, or another form of permanent identification. If possible, GPS coordinates of outplanted individuals should be recorded.

Installing *J. reclinata* individuals

1. Install outplants within 30 – 150m from the high tide line.
2. Plant individuals in clusters, with approximately 1m between each plant. If possible, follow Output 4.3.**2**.
3. Directly after installation, apply 1 gallon of water to each plant.
4. Water plants daily (1 gallon/plant) for the first week, and then only as needed.
5. Monitor rainfall and adjust watering regime accordingly (if outplanting is followed by a period of intense rainfall, further watering may not be necessary at all).

Monitoring Outplanted Individuals

1. Revisit each plant on a monthly basis for the first 6 months, and then biannually after that.
2. Record status (alive/dead), approximate size and approximate amount of flowering or fruiting for each individual outplant.

3. Monitor growth of surrounding vegetation, and cut back/remove plants that are encroaching on *J. reclinata* individuals.
4. Report health of outplanting to USFWS on an annual basis.

Appendix A: Associated Maps—Table of Contents

Maps of Wild Populations

Maps of Outplanted Populations