Population Demography of the Fragrant Prickly-Apple Cactus (*Harrisia fragrans*)

Final Report

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Abstract

The fragrant prickly-apple cactus, *Harrisia fragrans*, is an endemic shrubby cactus listed as endangered by the U.S. Fish and Wildlife Service and the State of Florida. Its current distribution is limited to the Savannas Preserve State Park and surrounding private parcels, an area approximately 10 miles long by 0.5 miles wide. A previous study indicated that the population was rapidly declining and would possibly go extinct within 30 years; however, a recent study indicates that the population was in fact stable. The goals of this study were to continue to monitor three colonies of *H. fragrans* at the Savannas Preserve State Park and to conduct more thorough investigations of the processes that influence mortality and recruitment. Data was collected from 1,025 plants during three sampling periods in April, July, and November 2005 to estimate mortality, fruit and flower production, average number of stems, and average total plant length at the three subpopulations. Mortality was extremely high with 56% of *H. fragrans* individuals dead after a series of three strong hurricanes in 2004 and 2005. Site A had significantly lower flower and fruit production, mean number of stems/plant, and total plant length than at the other two sites, but had higher recruitment and overall number of plants than sites B and C. Site A, unlike the other two, is dominated by an exotic pest plant, *Callitris glaucophylla*, which, may be impacting the population through a change in microhabitat.

Introduction

The fragrant prickly-apple cactus, *Harrisia fragrans* Small ex Britton & Rose, is a shrubby cactus endemic to Florida, which is listed as endangered by the U.S. Fish and Wildlife Service and the State of Florida. Today, all known occurrences of *H. fragrans* are in southeastern St. Lucie County (Rae 1995; FNAI 1997). According to Small (1933), this species was historically found in hammocks on high sand dunes, kitchen middens, and coquina ledges; although he may have mistaken the similar *H. simpsonii* for *H. fragrans* in some cases. The Institute for Regional Conservation (IRC) reported *H. fragrans* as being frequent at Savannas Preserve State Park (SPSP; Bradley et al. 1999), based on surveys conducted between 1998 and 2002.

Two demographic studies of *H. fragrans* have been conducted previously. The first, by Rae and Ebert (2002) studied the population dynamics of two subpopulations in and around SPSP between 1988 and 1996. Their results indicated a serious decline (55.3% - 59.8%) over the eight year study and predicted the eventual extinction of *H. fragrans*. The second study, conducted by The Institute for Regional Conservation (IRC) between 1999 and 2002 (Bradley et al. 2002), encompassed monitoring the entire SPSP *H. fragrans* population, including Rae & Ebert's (2002) subpopulations. IRC found the population to be stable, contradicting Rae's results. Bradley et al. (2002) also discovered that approximately 10% of *H. fragrans* plants died each year, while another 10% recruited. Because of the high, yearly turnover rate of plants, a negative change in any ecological process that affects mortality or recruitment could result in a substantial decline of *H. fragrans*.

Despite the significant progress towards understanding the biology of *H. fragrans*, there are still many unanswered questions that need to be addressed. First, we still do not have a good idea of the long-term population trend of *H. fragrans*. Rae and Ebert's (2002) study suggested population decline, while Bradley et al.'s (2002) suggested relatively little population growth. Second, the relative importance of sexual and asexual reproduction is still unknown. While, Bradley et al.'s study showed that sexual reproduction is more frequent and sexually derived recruits have greater survival, the exact contribution of asexually derived recruits to population dynamics can not be determined without an appropriately constructed matrix model. Third, it is unknown whether *H. fragrans* has any long-term seed dormancy. It is important to consider the role of seed dormancy in population dynamics since it can buffer populations from environmental variation. Fourth, we do not yet know what processes are contributing to plant mortality. Although several different sources of mortality have been observed, their contribution to population dynamics has not been quantified. Lastly, much of the Savannas PSP was historically dominated by *Pinus clausa* communities. With the exception of a dozen plants, *H. fragrans* does not occur in remnant *P. clausa* stands. Since *P. clausa* communities may be the dominant successional habitat of the Savannas PSP, managers need to determine why *H. fragrans* is not abundant in that habitat. Understanding these aspects of the species will enable us to recommend management strategies for the species and the habitats in which it occurs. The goal of this project is to continue monitoring the population status of *H. fragrans* in SPSP, and to conduct more thorough investigations of the processes that influence mortality and recruitment using matrix population models.

Methods

<u>Study Site</u>. *Harrisia fragrans* is presently known from a 10 miles by 0.5 miles section of the Atlantic Coastal Ridge between the cities of Ft. Pierce and Jensen Beach, between the Indian River and a large swale known as the Savannas (Figure 1). Most of the undeveloped area in this region is now located within the Savannas Preserve State Park (SPSP). This section of the Atlantic Coastal Ridge is transected by the Florida East Coast (FEC) Railway from north to south. The SPSP, and the bulk of the *H. fragrans* population, is on the west side of these tracks. To the east of the tracks, extensive development has occurred and little is in public ownership. An undetermined number of *H. fragrans* occur on private lands east of the tracks. *H. fragrans* is found on St. Lucie sand with 0-8% slopes, at elevations between approximately 8 to12 meters (Watts & Stankey 1980). The area receives 140 cm rainfall/year, with about 62% occurring from June to October (Watts & Stankey 1980).

Before human alteration, the vegetation along the ridge was primarily scrub, dominated by a sand pine (*Pinus clausa*) canopy with an understory of *Quercus* spp., *Ceratiola ericoides*, *Carya floridana*, and *Ximenia americana*, and a sparse forb layer. Xeric hammocks were located primarily on the slopes of the ridge and were dominated by *Quercus* spp., *Carya floridana, Ximenia americana,* and *Sideroxylon tenax*. Much of this scrub community is intact along the western edge of the ridge, although those on the eastern edge have been mostly developed. Extensive clearing for pineapple farms occurred from the 19th century through the 1920s (Watts & Stankey 1980; Rae & Ebert 2002). This farming included the use of fertilizers (Watts & Stankey 1980) that may have altered soil properties. Little scrub has regenerated in areas previously farmed; these areas are now dominated by fields of *Aristida gyrans* and *Polygonella robusta*, open sand, isolated or clumped *Sabal palmetto* stands associated with vines (especially *Smilax auriculata*) and stands of *Quercus* spp. and *Carya floridana.*

H. fragrans rarely occupies areas of *Pinus clausa* scrub that do remain at SPSP. We have found that the species is intolerant of fire, an important component of the scrub ecosystem. It is likely that plants were formerly restricted to the eastern and western edges of this ridge in areas of xeric to mesic hammock where fires rarely occur. *H. fragrans* frequently grows along the edges of *Sabal palmetto* or *Quercus* stands or in the shade beneath them; plants are rarely found in open sun. Given, its current distribution, *H. fragrans* may have colonized abandoned pineapple plantations in areas where plants did not formerly occur.

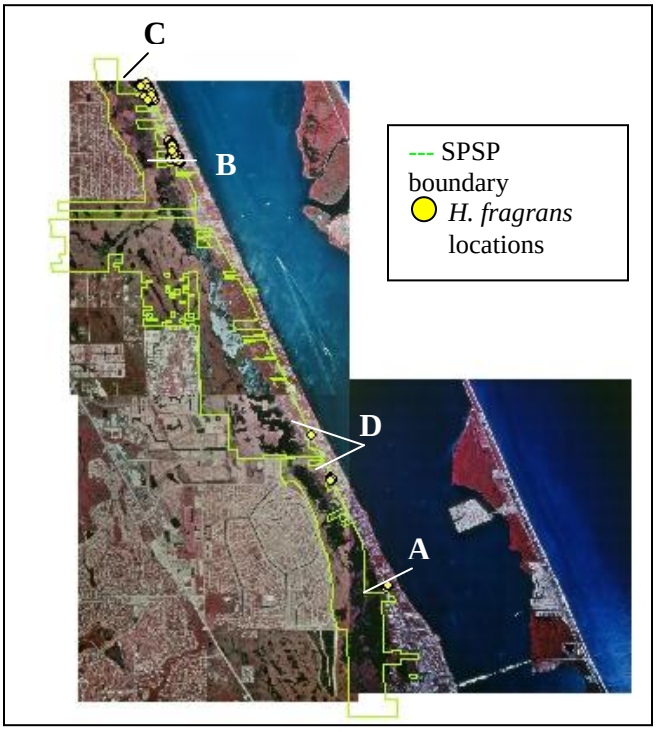

Figure 1. Study Sites (A, B, C, and D) for *Harrisia fragrans* at Savannas Preserve State Park (SPSP).

Study Species. *H. fragrans* is a columnar cactus with multiple stems reaching up to 4 meters. Stems may measure up to 5 cm in diameter and are armed with gray spines approximately 2-4 cm long. Branches arise from both the base of the plant and laterally from other stems. White to pink fragrant flowers that are ca. 20 cm long open at night and are presumably moth pollinated (Ted Fleming pers. comm.). The red fruits are globose and 5-6 cm in diameter and can contain 700-1,400 seeds (Rae 1995). Plants may live at least 17 years, as we have monitored plants that were tagged by John Rae in 1988. Few interactions with animals have been observed. A scale insect, *Diaspis echinocati* (Diaspididae) is frequently observed on plants. Birds, gopher tortoises, and raccoons may play a role in dispersal, although this has not been observed.

Sampling. Three subpopulations (Figure 1, A, B, and C) from Bradley et al. (2002) were chosen to represent the range of habitat types where H. fragrans occurs. Populations began with approximately 300 plants each. In November of 2005, subpopulations were intensively sampled as in Bradley et al. (2002). Status of each plant was noted as alive or dead. Plants were noted as dead if they possessed no green or yellow parts. Total plant length and number of stem tips was measured for all plants. Tags and GPS locations were updated, if necessary. New plants were tagged and GPS coordinates were recorded using a Trimble GPS unit which is accurate within a few centimeters. Microhabitat (sun, partial-shade and shade) and reproductive output (number of flowers and fruits) was also recorded. After intensive searching, those which could not be located using maps and the Trimble GPS unit were recorded as dead. Furthermore, intensive searches for new seedling recruits were conducted by devoting four person hours to searching per subpopulation. Searching efforts were focused in soil duff in partial and shady microhabitats. Sources of plant mortality were identified whenever possible for each plant.

In addition, subpopulations were resurveyed at 4 month intervals to measure reproduction and mortality. The number of flowers and fruits were counted in April 2005 and July 2005 to obtain more accurate estimates of yearly reproductive output. Data were collected only for adult plants which were measured at 2 cm or higher in stem length during the last census (January 2004), with the assumption that plants measuring less than 2 cm would not produce fruits or flowers. Plants were sampled at three sites (Figure 1, A, B, and C). Status of each plant was noted as alive or dead. Plants were noted as dead if they possessed no green or yellow parts. After intensive searching, those which could not be located using maps and the Trimble GPS unit were recorded as missing and probably dead.

Plants from Rae and Ebert's study (2002) that are still alive, regardless of whether they are in one of our three subpopulations (Figure 1, A, B, C, and D), will be monitored annually (November 2005) to estimate the maximum life-span of *H. fragrans*. This represents approximately an additional 24 plants.

In November 2005, nine fruits (700-1400 seeds in each fruit; 3 fruits per subpopulation) were collected to establish seed dormancy experiments in each subpopulation. Fifty seeds were placed in fine mesh bags and buried in the soil in seedling arrays. Each seedling array (3 per subpopulation and one in each microhabitat) contains nine bags. Bags will be sampled three times a year, starting in spring 2006, to test for seed viability using seed germination trials in order to estimate seed dormancy over a three-year period. An initial 450 seeds (9 arrays X 50 seeds each) in November 2005 was given to Fairchild Tropical Botanical Garden to establish baseline germination rates for this cohort of seeds.

Seed germination experiments were initiated to accurately estimate the probability of seedling recruitment and early seedling survival under field conditions. In November 2005, six fruits (2 per subpopulation) were collected to establish seed germination experiments in each subpopulation. Fifty seeds were spread across a small area in each habitat (25 cm X 25 cm) and covered with a mesh box to protect from disturbance. Nine of these germination boxes were established in each subpopulation, three per microhabitat type (sun, partial-shade and shade). Boxes were placed in discrete locations. Seedlings will be tagged and their fates followed quarterly beginning in spring 2006. Germination and survival data from these experiments will be used to parameterize matrix models. These field germination experiments are not being conducted to augment the population of *H. fragrans* at SPSP. Any recruits will be destroyed at the end of the study.

To determine whether *H. fragrans* is unable to establish in *Pinus clausa* communities due to relative poor germination and early survival rates, an additional set of field germination experiments will be established in *P. clausa* communities. In November 2005, nine germination boxes (three per microhabitat type) were established in a *P. clausa* stand. Seeds for this study were obtained from the same mixture of seeds used above.

Germination and dormancy studies were initiated in November of 2005 instead of in April 2005 as planned because no ripe fruit were available until then.

Analyses. Mean number of flowers and fruit per site was calculated by dividing the # flowers (or fruit)/# live plants. Mean number of stems and total plant length were calculated by dividing the # of stems (or total plant length)/# live plants. Mortality was calculated by dividing the # dead or missing plants/# live adult plants. A One-Way ANOVA (Analysis of Variance) was used to test for differences between number of flowers and fruit by sampling period and by site and to tests for differences in average number of stems and total plant length between sites.

Results

Long Term Monitoring. In November 2005 we collected data on 1,025 plants in three subpopulations. Of the 1,054 plants, 565 were alive, with 488 plants having died since the last sampling (December 2003/January 2004) or were missing and probably dead. Plants occurred over a wide range of microhabitats varying from full sun to almost full shade. Plants were located in areas composed of mostly native vegetation to areas dominated by invasive exotic species such as *Schinus terebinthifolius* and *Callitris glaucophylla*. In some cases, plants were covered by vine blankets of *Smilax auriculata* and/or the invasive exotic *Abrus precatorius*.

The total number of *H. fragrans* plants at all subpopulations decreased dramatically from the previous census. There were previously 428 plants in subpopulation A, but only 168 were found alive during the present census for a total of 260 or 60.75% plants lost. Subpopulation B lost 104 plants, from 251 to147 (41.43%) and subpopulation C lost 124 plants, from 267 to 143 (46.44%) in this census. In addition to losses, subpopulation A had the highest number of new plants (56), subpopulation B had 16, and subpopulation C had 36 new recruits.

A summary of average number of stems and total plant length are given in Table 1. Site A had significantly lower average number of stems than either Site B (Figure 2; $p=0.020$) or Site C ($p=0.005$) and average total plant length (Figure 3; B and C: $p<0.001$) than both Sites B and C which did not differ from each other statistically (Avg. #stems: $p=0.934$, Avg. total plant length: $p=0.389$).

Study Site	Average # Stems/Plant	Average Total Plant Length (cm)	Range (cm)
A	2.63	60.01	1 - 569
B	3.61	148.12	2 - 1172
C	3.75	175.06	3 - 1856

Table 1. Description of the average total plant length and average number of stem tips of *Harrisia fragrans* at three sites in Savannas Preserve State Park in 2005.

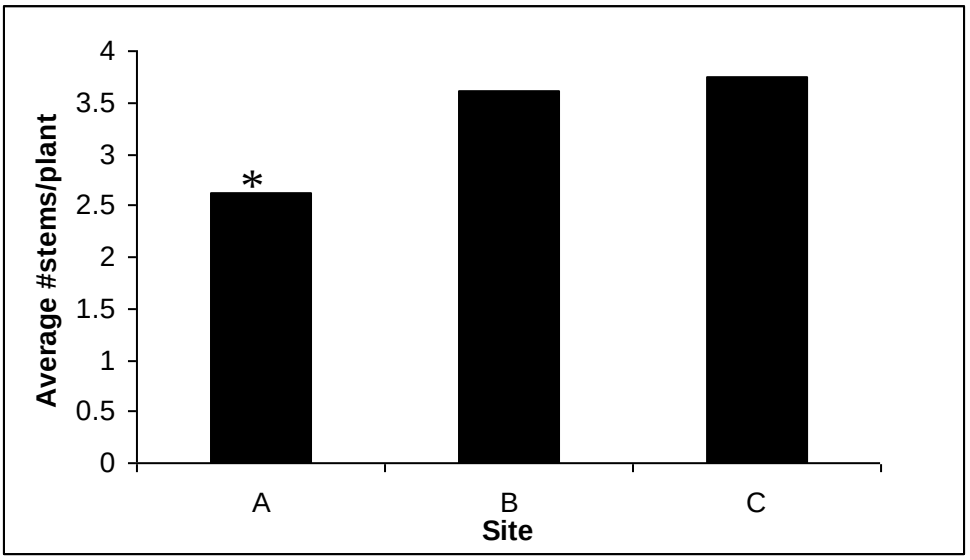

Figure 2. Average number of stems per *Harrisia fragrans* at three sites in Savannas Preserve State Park in 2005. * denotes significant differences.

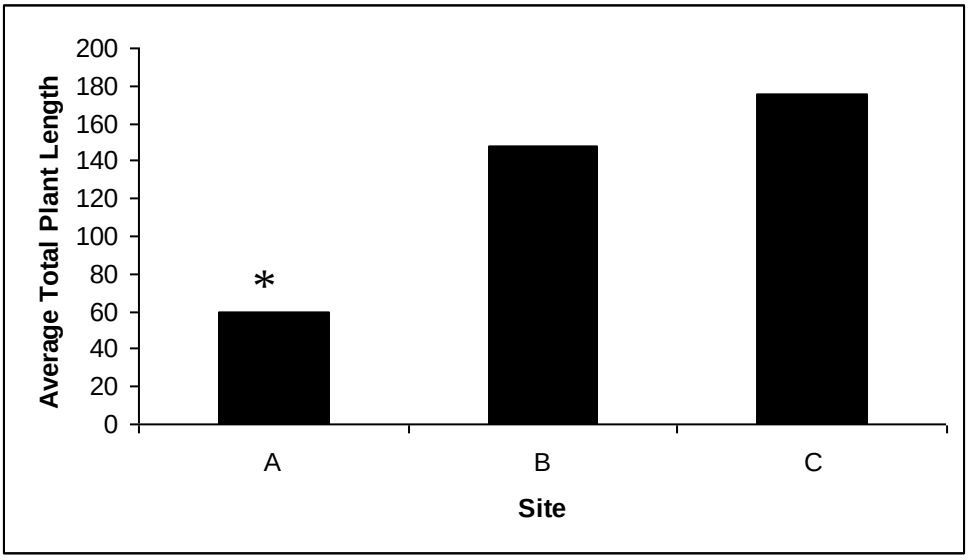

Figure 3. Average total plant length of *Harrisia fragrans* at three sites in Savannas Preserve State Park in 2005. * denotes significant differences.

Quarterly Reproductive Monitoring. A summary of reproductive data collected can be found in Table 2. Site A had significantly lower fruit and flower production than either Site B (Figure 4; Fruit: $p<0.001$, Flower: $p=0.042$) or Site C (Fruit: $p=0.024$, Flower: $p=0.015$). There was no significant difference in flower or fruit production between Sites B and C (Fruit: $p=0.314$, Flower: $p=0.947$). July had significantly higher fruit production (Figure 5; April: $p<0.001$, November: $p<0.001$), however there was no difference in production between April and November ($p=0.271$). Flower production was highest in April (July: $p<0.001$, November: $p<0.001$) and there was no difference in number of flowers in July and November ($p=0.705$).

	April 2005			July 2005			November 2005		
Study Site	# Alive	#fruit	#flowers	# Alive	#fruit	#flowers	# Alive	#fruit	#flowers
A	180	6	79	201	50	17	217	23	0
B	130	13	202	148	165	9	158	55	0
C	141	7	221	153	137	23	176	38	7

Table 2. Description of the reproductive characteristics and status of *Harrisia fragrans* at three sites in Savannas Preserve State Park in 2005.

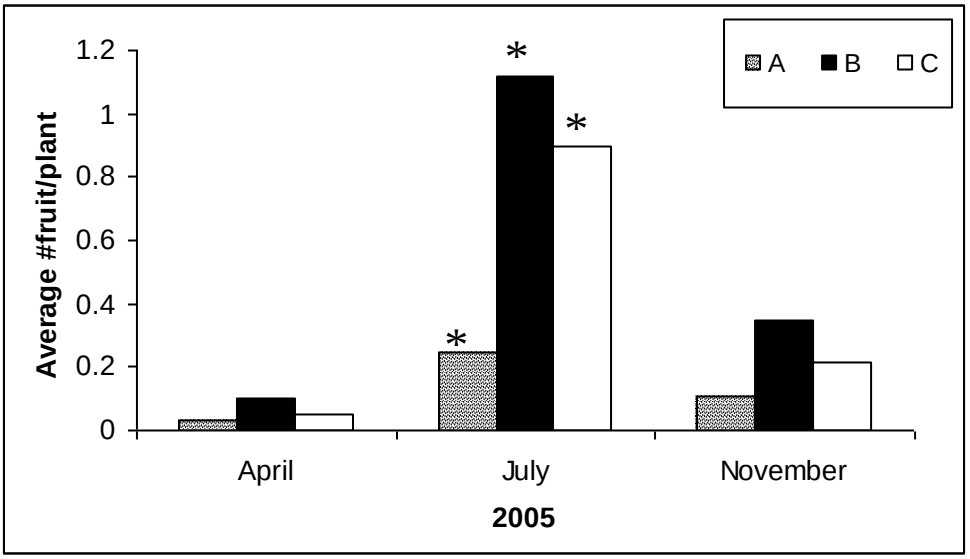

Figure 4. Average number of *Harrisia fragrans* fruit at three sites in Savannas Preserve State Park in 2005. * denotes significant differences.

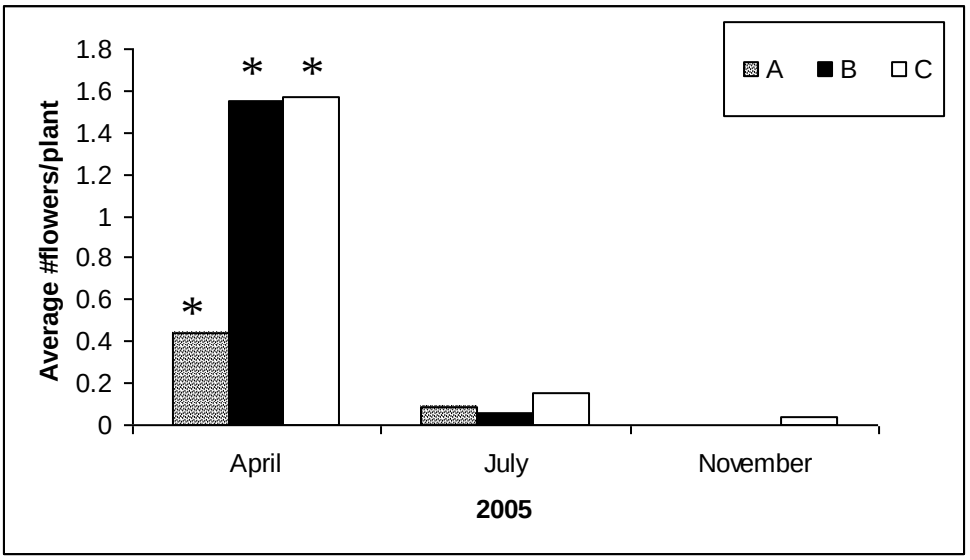

Figure 5. Average number of *Harrisia fragrans* flowers at three sites in Savannas Preserve State Park in 2005. * denotes significant differences.

From 1999 to 2002, Bradley et al. (2002) monitored all *H. fragrans* individuals in SPSP. In 2003/2004 we began to limit our monitoring efforts to the 3 subpopulations A, B, and C. Fruit and flower production were also studied during Bradley et al.'s (2002) earlier efforts. Figure 6 illustrates flower and fruit production in November of each year for six years.

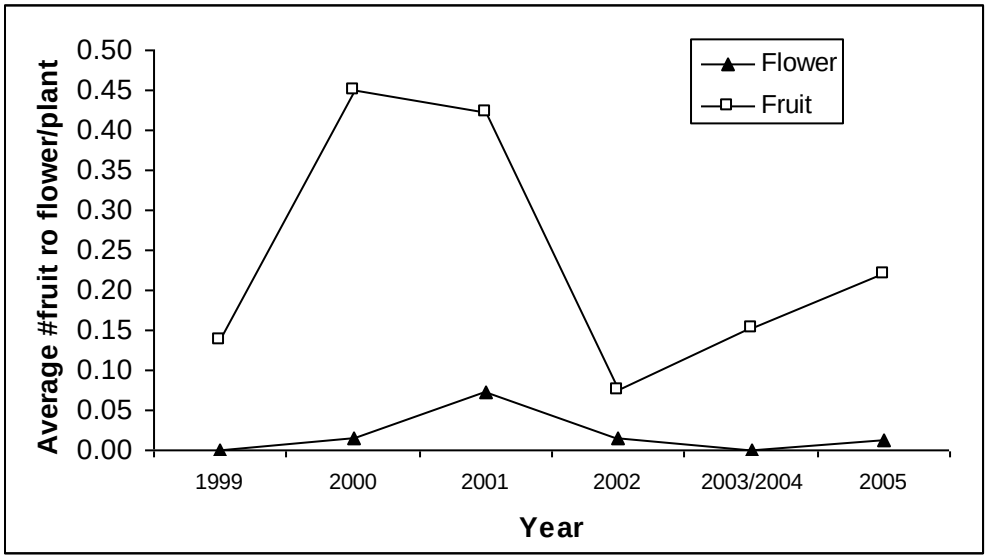

Figure 6. Average number of fruits and flowers in November per *Harrisia fragrans* at Savannas Preserve State Park from 1999 to 2005.

Discussion

In September 2004 two hurricanes made direct hits on Savannas Preserve State Park (SPSP). On September 4th, Hurricane Frances made landfall at Sewell's Point just south of the Savannas as a Category 2 hurricane. On September 25th, Hurricane Jeanne made landfall on Hutchinson Island just offshore of the Savannas as a Category 3 hurricane. In addition, on October 24, 2005, Hurricane Wilma hit about 15 miles south of SPSP as a strong Category 2 storm with winds exceeding 105 mph. Hurricane categories are described using the Saffir-Simpson hurricane scale.

Overall, the hurricanes appear to have had a negative effect on most *H. fragrans* individuals. Plants lost occasional stems, but typically only if they were taller and had many branches. Plants that did topple over or that lost stems were showing new growth, with new stems appearing at the base of the plants in many cases. Yet, the main impacts were made on surrounding vegetation and not directly on *H. fragrans*. Much of this surrounding vegetation, however, was defoliated, had shed many branches, fallen over, and some were entirely uprooted. This debris has thus covered up many plants of *H. fragrans*.

These conditions may explain the extremely high mortality rate at all three sites. We were also unable to relocate many of the plants, possibly because they were buried under vegetation or sand from the storms and are dead. Although a very thorough search was conducted for the missing plants, most were not found and are presumed dead. While it may first appear that hurricane activity negatively impacts *H. fragrans* through loss of adult and juvenile plants, the change in habitat by hurricane activity through increase in light gaps and leaf litter may help reproductive potential by exposing mature plants to sunlight, stimulating flowering activity, and aid seed germination. Dormant *H. fragrans* seeds may be able to buffer populations from environmental variation due to hurricanes.

Hurricane Irene, a Category 1 storm, crossed over SPSP in 2000. This hurricane had little if any impact on the population. Stronger hurricanes appear to have a stronger impact on the *H. fragrans* population at SPSP. Higher winds of Category 2 and 3 storms can create considerable damage to shrubbery and trees with foliage blown off trees and large trees blown down.

Flower and fruit production appear to be highly seasonal with peak flower production during the months of April and May and fruit production in the fall (Figures 2 and 3). Rae (1995) reported two peaks in flowering, one from April to May and a second in October. Although, our results do not indicate a second peak in October/November, Hurricane Wilma in October may have influenced flower productivity. *H. fragrans* at sites B and C contained significantly higher number of flowers and fruits and average number of stems and average total plant length than at Site A.

Exotic pest plants are commonly observed in association with *H. fragrans*. Rae (1995) found that the exotic tree *Schinus terebinthifolius* was one of four species most likely to be found in association with the cactus. The authors have also observed severe infestations of the exotic vine *Abrus precatorius*, exotic succulent herbs *Kalanchoe pinnata* and *K. tubiflora*, and the exotic tree *Callitris glaucophylla*. The removal of these species should be a high priority.

Site A is located at the southern portion SPSP and is situated in a habitat dominated by the exotic tree, *C. glaucophylla*, not found at the other two sites. Competition (direct or indirect) with exotic pest plants such as *C. glaucophylla* may be impacting the population's growth and reproductive potential. Although mortality is highest at this site, so is recruitment. *C. glaucophylla* is an extremely fragile plant which under hurricane force winds, is easily broken compared to other native plants found at SPSP such as oaks and palms. In addition to higher tree fall, which may explain this site's higher mortality rate, this species also provides deeper leaf litter and more shade than the other two sites. This high duff layer and increased shade may be altering this species preferred microhabitat, and in turn impact this subpopulation. Our seed germination and dormancy experiments will be able to shed some light on this issue.

Acknowledgements

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