RESPONSE BY TWO ENDANGERED PINE ROCKLAND PLANTS TO MECHANICAL VEGETATION THINNING TREATMENT IN THE LOWER FLORIDA KEYS

Kate Guerena Watts, Wildlife Biologist
Florida Keys National Wildlife Refuges Complex
28950 Watson Boulevard, Big Pine Key, FL 33043, USA

INTRODUCTION

Pine rocklands are a globally endangered ecosystem found only in the Lower Florida Keys, Everglades National Park, and in scattered parcels in Miami-Dade County. They are limited to less than 3 percent of their original extent due to conversion to other land uses, significant ecological degradation and destruction (Noss et al. 1995). Pine rocklands consist of an open canopy of slash pines with patchy understory and groundcover layers. The south Florida slash pine (*Pinus ellioti* var. *densa*) and palms (*Coccothrinax argentata, Thrinax morrisii, Thrinax radiata*, and *Serenoa repens*) are fire-adapted and dependent on periodic fires for their long-term persistence (Snyder et al. 1990). Sub-canopy layers include a diverse assemblage of tropical and temperate shrubs, palms, grasses, and herbs (Folk 1991). Pine rocklands occur at an elevation of 3 to 8 feet above mean sea level and are usually underlain by a freshwater lens.

Pine rocklands found on Big Pine Key have the highest plant diversity of all plant communities in the Florida Keys. Over 240 species of plants have been identified in the pine rocklands of South Florida and the Lower Keys. This community contains 14 herbs endemic to South Florida, 5 of which occur only in the Lower Keys (Avery and Loope 1980). Common plants associated with pine rocklands include long-stalked stopper, blackbead, Keys thatch palm, silver palm, and locustberry. Pine rocklands contain significant freshwater resources, including widespread freshwater solution holes and marshes that are important to wildlife.

Four pine rockland plant species were newly listed under the Endangered Species Act in 2016, including Big Pine partridge pea (*Chamaecrista lineata keyensis*), wedge spurge (*Chamaesyce deltoidea serpyllum*), sand flax (*Linum arenicola*) and Blodgett's silverbush (*Argythamnia blodgettii*), joining other listed plants found in pine rocklands. Within pine rockland habitats, Big Pine partridge pea is associated with areas that have few hardwoods, and overstory palms are abundant (Bradley and Gann 1999). Partridge pea plants are often found in a clumped distribution surrounded by large areas of bare, open rock that do not support plant growth. Wedge spurge is similarly associated with areas of relatively higher elevation, extensive exposed rock substrate, where the understory is open, hardwood and palm density is low, and native herbaceous species cover and richness are high (Bradley and Saha 2009, Ross and Ruiz 1996, Bradley 2006). The decline in Big Pine partridge pea and wedge spurge can be largely

attributed to loss of pine rocklands habitat to development and modification of this habitat due to inadequate fire management. Folk 1991 estimated that pine rocklands historically covered 2,592 ac, about 44 percent of Big Pine Key. Pine rocklands now cover approximately 1,438 ac of Big Pine Key, 56 percent of the historical estimate by Folk (Bradley 2006). Hurricanes and associated storm surges have also impacted population levels.

Pine rocklands are dependent on fire to maintain the diverse assemblage of plants. Radiocarbon dating on soil samples taken from two water holes on Big Pine Key reveal repeated, local fires during the past ca. 450–500 years, documenting the long importance of fire in the Florida Keys' pine rocklands (Horn 2008). Pine rocklands historically burned once or twice every decade (Hofstetter 1974). Fire frequency has been shown to be an important parameter affecting the abundance and diversity of endemic herbs and the vegetation structure of pine rocklands (Lui et al. 2005, Bradley and Saha 2009). In the absence of fire, pine rocklands will succeed to hardwood hammock approximately within a 50-year-timeframe (Dickson 1955).

Implementing prescribed fire has become increasingly challenging on Big Pine Key, due to human development of adjacent land and the wildland-urban interface in which the pine rockland resides. Wildfire suppression has been identified as a primary cause of the local extirpation of the Florida leafwing butterfly (*Anaea troglodyta*), as well as the severe decline of the Bartram's scrub-hairstreak butterfly (*Strymon acis bartrami*). Due to increased fuel loading stemming from wildfire suppression, fuel reduction efforts through mechanical vegetation removal are necessary in many areas of Big Pine Key in order to minimize the risk of catastrophic wildfire or escaping prescribed fire.

Previous research has shown that mechanical vegetation thinning treatments have benefitted other partridge pea species in the pine rocklands of Miami-Dade County (Maschinski et al. 2005). In an effort to document the effects of habitat management treatments on listed plant species abundance, the primary objective of this project was to measure the response to mechanical treatments by Big Pine partridge pea, wedge spurge, sand flax, and Blodgett's silverbush – four federally endangered plant species found in varying degrees in the pine rockland ecosystem.

STUDY AREA

Three locations were selected for study areas within pine rockland habitat at National Key Deer Refuge on Big Pine Key (Figure 1), and named Units A, B and C. Descriptive information about each study area can be found in Table 1. Each study area was divided into two segments, including a control and a treatment segment.

METHODS

Habitat management treatment

Mechanical treatments were conducted using a skidsteer and forestry/mulching attachment during the late summer of 2015. Heavy equipment operators used a free motion mosaic pattern to treat 40-50% of the unit in order to mimic the effects of a natural lightning fire disturbance event. Mechanical treatments were aimed at the removal of late successional tree and shrub species, including poisonwood and Keys thatch palm. Locations of occupied habitat for Bartram's scrub-hairstreak were avoided to minimize impacts to the host plant. Slash pine trees were avoided whenever possible during treatments, and downed tree and shrub branches were mulched or removed to minimize the production of additional ladder fuels. Mulch produced during the treatments remained on the ground.

Treatment monitoring

Within three treatment and control units, a subset of 135 x 2.5m radius plots were selected on Big Pine Key as part of a separate project to restore pine rocklands using mechanical treatments (USFWS 2014), and measure the response of pineland croton to those treatments (Henry 2017). The number of individual plants of Big Pine partridge pea, wedge spurge, sand flax and Blodgett's silverbush were counted just prior to treatment, and then repeated at intervals of 3, 12 and 24 months after treatment. Due to the number of plants present within any individual plot (sometimes exceeding 100+), plant tags were not used to measure survival or recruitment. Vegetation cover classes were also collected using the Daubenmire method (1959). Mean percent change in plant counts and cover classes were calculated and tested for differences between treatment and control for each species using a one-way analysis of variance. All data analyses were conducted in R version 3.2.4.

RESULTS

Big Pine Partridge Pea (*Chamaecrista lineata keyensis*)

Effect of mulching treatment

Mean percent change in Big Pine partridge pea plant counts between pre-treatment monitoring and fall 2015, summer 2016 and summer 2017 for both treatment and control plots can be found in Table 2. Within three months after treatment, the percent change in the number of Big Pine partridge pea plants significantly increased in treatment vs. control plots (Figure 2 and Table 2; FF(1,134)=4.66, p=0.03259). After one year, the percent change in the number of Big Pine partridge pea plants was not significantly different between treatment and control plots (F(1,134)=2.19, p=0.14117). After two years, the percent change in the number of partridge pea plants significantly increased in treatment vs. control plots (F(1,134)=3.921, p=0.04973). Due to the low frequency of plots with partridge pea plants detected, the sample sizes were too small to test for Unit effect.

Wedge Spurge (*Chamaesyce deltoidea serpyllum*)

Mean percent change in wedge spurge plant counts between pre-treatment monitoring and fall 2015, summer 2016 and summer 2017 for both treatment and control plots can be found in Figure 3 and Table 3. No significant difference was found between treatment and control units throughout the study. Within three months after treatment, the percent change in the number of wedge spurge plants was not significantly increased in treatment vs. control plots (Figure 3; $F(1,134)=0.05$, $p=0.85$). After one year, the percent change in the number of wedge spurge was not significantly different between treatment and control plots ($F(1,134)=0.39$, $p=0.534$). After two years, the percent change in the number of wedge spurge plants did not significantly increase in mowed vs. control plots ($F(1,134)=3.03$, $p=0.084$). Due to the low frequency of plots with wedge spurge plants detected, the sample sizes were too small to test for Unit effect.

Sand flax (*Linum arenicola*) and Blodgett's silverbush (*Argythamnia blodgettii*)

There were only 12 detections of sand flax within one plot during the summer of 2017, and no detections of Blodgett's silverbush within the study plots; therefore, the sample sizes for these species were too small to measure response.

Changes in Vegetation Cover Classes

Pine cover was significantly increased in treatment vs. control units between summer 2015-summer 2017 (Table 4; $F(1,134)=7.538$, $p=0.007$). Palm cover was not significantly increased in treatment vs. control units ($F(1,134)=0.937$, $p=0.334$). Shrub cover was not significantly increased in treatment vs. control units ($F(1,134)=0.316$, $p=0.574$). Grass cover was not increased in treatment vs. control units ($F(1,134)=1.002$, $p=0.318$).

DISCUSSION/MANAGEMENT IMPLICATIONS

Pine rockland plant species depend upon periodic fire to open the palm and shrub canopy to sunlight, recycling nutrients back into the soil, and potentially increase germination rates of fire-dependent species (Sah et al. 2010). Mechanical vegetation thinning treatments were used in this project in an effort to reduce fuel loads in preparation for prescribed fire, and to improve conditions for small flowering plants, grasses and shrubs by providing increased access to sunlight. Plant response by Big Pine partridge pea was positive when compared to no action over the two years of the study. Big Pine partridge pea displayed an initial pulse of germination within one year of the treatment, but the increase in plant counts lessened in the second year. Several factors may have played a role in the study-wide decline in plant counts during this time, including a change in precipitation, background plant senescence and/or mortality, or other unknown factors. Wedge spurge did not show a statistically significant response to the treatment; however, several treatment and control plots exhibited increases in plant counts of over 200% during the study. This exponential growth may highlight additional variables involved in the observed plant response. The mechanical thinning treatment may not physically

affect wedge spurge plants due to the short stature of the plant and barren rocky locations in which it resides. Plant response would have been primarily due to opening the vegetative canopy during the mosaic mechanical treatment, rather than the additional mowing/mulching effect to which the partridge pea was subjected.

There were few flowering herbs found in plots within Unit A during the study, which is likely due to the lack of wildfire or prescribed burning within the last 60 years (Fire history found in Table 1). Fire frequency has been linked to herbaceous plant diversity in the pine rocklands (Lui et al. 2005, Bradley and Saha 2009). Because of the length of time since the last fire, it is likely that additional seed bank restoration efforts are necessary in this area to increase cover of herb species. Recent efforts have been initiated at National Key Deer Refuge to restore the seed bank for pineland croton within Unit A through local propagation and planting. Prescribed fire is also planned within this unit when conditions allow. Seed bank restorations for other listed plant species should be considered as part of a strategic prescribed fire habitat restoration program.

Big Pine partridge pea and wedge spurge were most commonly found in Unit B throughout the study, which is potentially due to the more frequent, but still low, fire frequency. The last fires within the unit were in 2001, which is still far beyond the fire frequency objectives for habitat management. Further research on the use of mechanical treatments combined with prescribed fire are needed to evaluate the germination and survival rates of herbaceous plants in units with a history of varying fire frequency from both habitat restoration and management perspectives.

There was an initial concern about the quantity of vegetative mulch that was produced by the mechanical treatment and remained in the units, and the potential for this mulch to shadow germinating plants or increase ground fuels. This concern was alleviated as the mulch quickly decomposed, leaving little trace of mulch by the second year. Summer rainfall and the hot, humid climate accelerated decomposition during the project, and Big Pine partridge pea plants were documented germinating and flowering through the mulch layer within three months of treatment. This mulch layer may serve to provide insulation from extreme summer heat and increase humidity for young plants as they emerge. A small human-caused wildfire was started on the edge of a mechanically treated segment of Unit A within one year of treatment. Even though this unit had not experienced fire in the last 60 years, it is likely that the reduction of fuel loading associated with the mechanical treatment allowed this wildfire to be quickly extinguished by the local fire department without allowing flames to reach the tree canopy. Further research may be necessary to measure the impacts of residual mulch on fire behavior, and on the response by other plant species as the mulch layer breaks down.

There was also an initial concern that mechanical treatments would provide an opening for exotic plants to invade the study units. However, throughout the project, only one Australian pine tree (*Casuarina* spp.) was found in a treatment unit. Because this plant had a diameter at

breast height (dbh) of >1" when found one year after the treatment in Unit C, we assumed that the plant was present prior to the initial treatment. We quickly treated this plant with herbicide to prevent any further spread, and monitored the area for new seedlings for the duration of the study.

This project documented increased plant counts of Big Pine partridge pea and no detectable plant response from wedge spurge when mechanical vegetation thinning treatments were applied. We recommend that this technique be considered as a tool in reducing fuel loading in pine rocklands of the Lower Florida Keys. As seen in this study, mechanical treatments can reduce the risk of catastrophic wildfire and allow for increased control of prescribed burns, while benefitting a federally-endangered plant species. Other concurrent research has documented that this tool provides a short-term net benefit for pineland croton (Henry 2017), the host plant for Bartram's scrub-hairstreak and Florida leafwing butterflies – two lepidopteran species that are federally endangered and highly imperiled. Longer term research is needed to monitor the plant response beyond 2 years, and identify the most effective mechanical and fire treatment schedule for increasing herbaceous plant diversity in the pine rocklands. Further research is encouraged to better understand how this restoration/management tool can be used as a surrogate for prescribed fire in human developed areas where burning is inappropriate. A thorough understanding of the changes in soil nutrient levels, vegetative structure and diversity, and other effects will inform management decisions on the expanded use of this tool as a surrogate.

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Figure 1. Map of three study areas measuring plant response to mechanical treatments on Big Pine Key, FL.

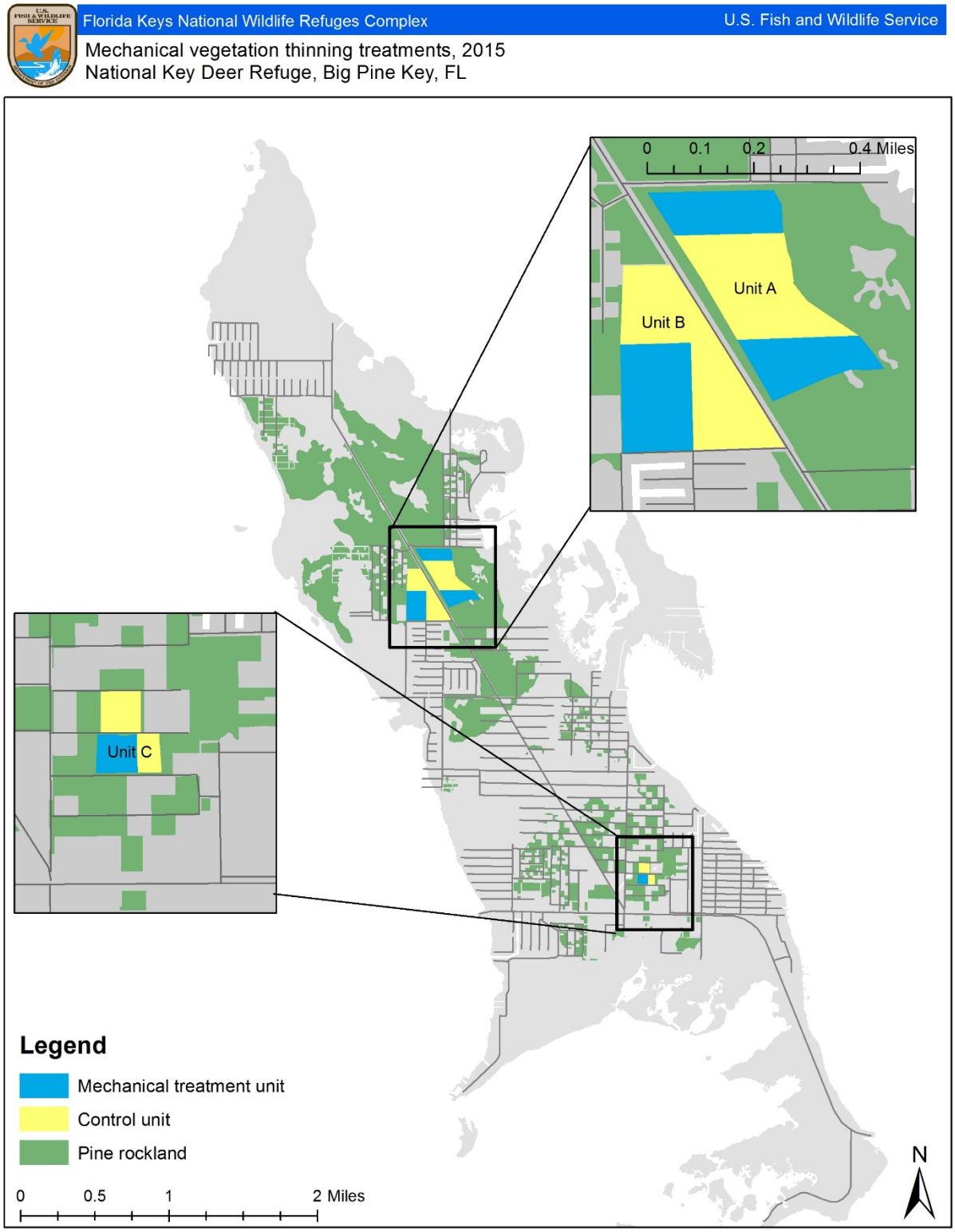

Figure 2. Response by Big Pine partridge pea (*Chamaecrista lineata keyensis*) to mechanical treatment and control units after 3 months, 1 year, and 2 years.

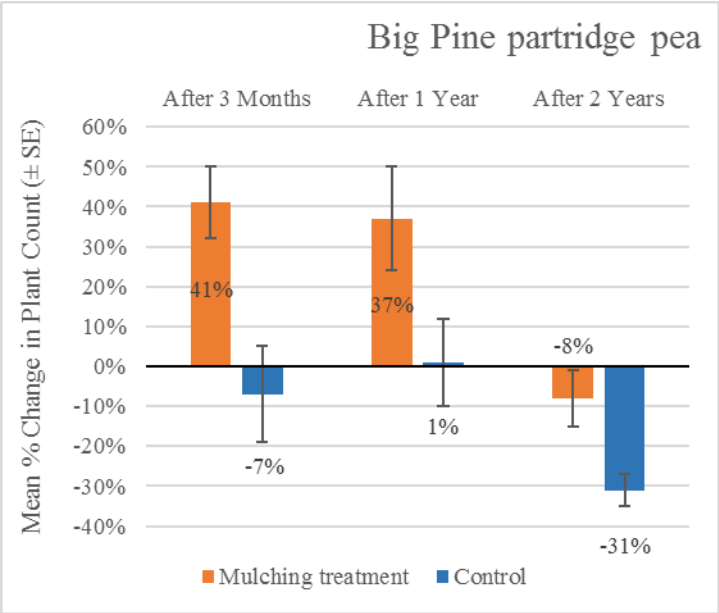

Figure 3. Response by wedge spurge (*Chamaesyce deltoidea serpyllum*) to mechanical treatment and control after 3 months, 1 year, and 2 years.

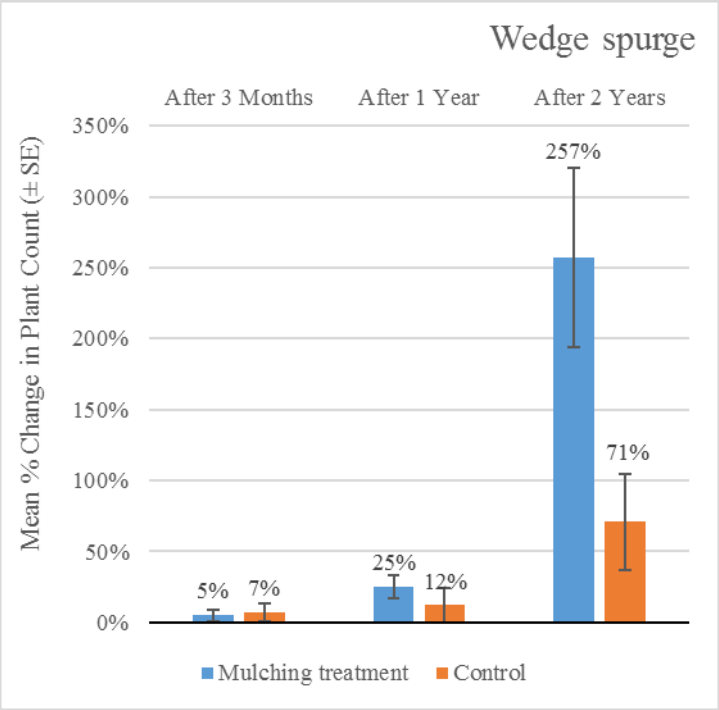

Figure 4. Photos of study areas prior to and after mechanical treatments.

Untreated pine rockland, Control Unit B (Summer 2015)

Immediately after mechanical treatment, Treatment Unit A (Summer 2015)

Three months after treatment, Treatment Unit C (Fall 2015)

One year post-treatment, Treatment Unit B (Summer 2016)

One year post-treatment, Treatment Unit B (Summer 2016)

One year post-treatment, Treatment Unit B (Summer 2016)

One year post-treatment, Treatment Unit C (Summer 2016)

Two years post-treatment, Treatment Unit B (Summer 2017)	Two years post-treatment, Treatment Unit B (Summer 2017)

Table 1. Descriptive statistics of the three study areas on Big Pine Key, FL.

Characteristic	**Unit A**	**Unit B**	**Unit C**
Area (ha)	20	18	4
Number of Plots (Control/Treatment)	38	52	45
Year of Last Fire (Wildfire or Prescribed Burn)	Prior to compiled records (50+ years ago)	2001 (Rx; Part of unit)	2010 (Rx; Part of unit), 2015 (Wildfire; Part of unit)
Mean # Big Pine partridge pea plants counted per plot prior to treatment	0.88	21.10	1.70
Mean # wedge spurge plants counted per plot prior to treatment	0.50	13.29	0.20

Table 2. Mean % change in plant count of Big Pine partridge pea (*Chamaecrista lineata keyensis*) within survey plots in treatment and control units from August 2015 to August 2017 on National Key Deer Refuge on Big Pine Key, Florida.

Big Pine Partridge Pea					
(Treatment in summer 2015)		Mulching treatment		Control	
	Relative timeframe	Mean Δ count	SE	Mean Δ count	SE
Fall 2015	After 3 Months	41%	9%	-7%	12%
Summer 2016	After 1 Year	37%	13%	1%	11%
Summer 2017	After 2 Years	-8%	7%	-31%	4%

Table 3. Mean % change in plant count of wedge spurge (*Chamaesyce deltoidea serpyllum*) within survey plots in treatment and control units from August 2017 to November 2017 on National Key Deer Refuge in Big Pine Key, Florida.

Wedge Spurge					
(Treatment in summer 2015)		Mulching treatment		Control	
	Relative timeframe	Mean Δ count	SE	Mean Δ count	SE
Fall 2015	After 3 Months	5%	4%	7%	6%
Summer 2016	After 1 Year	25%	8%	12%	12%
Summer 2017	After 2 Years	257%	63%	71%	34%

Table 4. Percent cover by cover class within survey plots in treatment and control units in Big Pine Key, Florida.

	Pine		Palm		Grass		Shrub	
CONTROL	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Summer 2015	16.87	2.26	30.02	2.94	8.45	1.49	27.53	2.45
Summer 2016	16.97	2.40	33.15	3.03	6.46	1.11	26.51	2.61
Summer 2017	18.74	2.29	33.13	2.51	17.21	2.23	29.31	1.80
Fall 2017	6.25	0.98	20.44	2.23	5.12	0.85	19.97	1.71
TREATMENT	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Summer 2015	10.15	1.42	21.26	2.05	5.51	0.92	17.79	1.77
Summer 2016	11.07	1.54	17.17	2.13	3.70	0.67	15.51	1.76
Summer 2017	23.20	2.58	28.83	2.34	17.65	2.15	23.93	1.71
Fall 2017	6.30	0.99	12.10	1.27	4.75	0.72	14.45	1.28