

U.S. Fish and Wildlife Service

Proceedings of the
Florida Scrub Symposium 2001

Orlando, Florida
June 5-7, 2001



Florida Jay
CORVUS FLORIDANUS. GILM.
Male, Female.
Revised from *Dicophrys virginiana*.

About the Cover:

This John James Audubon painting of the Florida scrub-jay (Florida jay) was done in the early 1820s. The persimmon in which the jays are perched was probably painted by Joseph Mason, one of Audubon's apprentices during the time Audubon was in Louisiana. The jays may have been painted in New Orleans (from a caged pair being held as pets). Audubon wrote, "Their cage was usually opened after dinner, when both immediately flew upon the table, fed on the almonds that were given them and drank claret diluted with water." (Peterson and Peterson 1981).

References:

Peterson, R.T. and V.M. Peterson. 1981. Audubon's Birds of America, The Audubon Society Baby Elephant Folio. Artabras Book, Distributed by Harrison House.



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U.S. DEPARTMENT OF THE INTERIOR
Gale Norton, Secretary

U.S. FISH AND WILDLIFE SERVICE
Marshall Jones, Acting Director

July 2001

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PREFACE

The Florida Scrub Symposium 2001 was the first of what I hope will be a continuous forum for the exchange of information among scrub scientists, consultants, NGO representatives, and people who appreciate the beauty of Florida scrub habitat. With the help of a few key individuals, this first attempt was a great success, attended by around 200 people.

This proceedings document was pulled together in an attempt to disseminate information as rapidly as possible, not only for use by the folks who attended the symposium, but also by those who could not. You will note that all the abstracts (as they appeared in the Program brochure) are printed for the papers actually presented at the symposium. In addition, when an extended abstract was received from the author, it was printed immediately following. You may also note that in one case (Schultz et al.), while the paper could not be presented at the symposium because of a last-minute scheduling conflict, both the regular and extended abstracts are presented in an effort to share the information which would have been presented in Orlando.

I would like to thank everyone who made this first symposium a reality: **Eric Menges** (Archbold Biological Station) for general guidance from start to finish, including input on program content and layout advice on publications; **Dave Breininger** (Dynamac Corporation) for periodic sanity checks and the loan of a book on how to set up scientific meetings; **Mary Huffman, Walt Thomson, Ted Stevens** (The Nature Conservancy) for setting up and running the scrub management workshop session of the symposium; and **Jim Yawn** (Walt Disney Imagineering) for sponsoring one of the morning coffee breaks and freeing up some of my budget for other uses.

I would also like to thank all of the session chairs: **Terry Doonan** (Florida Fish and Wildlife Conservation Commission); **Donna Oddy** (Dynamac Corporation); **Laurie MacDonald** (Defenders of Wildlife); **Mike Jennings** (U.S. Fish and Wildlife Service); **Jennifer McMurtray** (Defenders of Wildlife); **Anne Cox** (Florida Division of Forestry); and **Kathy O'Reilly-Doyle** (U.S. Fish and Wildlife Service). They all kept everything running on time so we could get our relaxation between sessions.

The Audio-Visual operators kept operations running extremely smoothly, juggling computers with Powerpoint among the slide presentations. Thanks go to **Miles Meyer, Annie Dziergowski, and Jane Monaghan** (U.S. Fish and Wildlife Service), and **Alexandra Collazos** (Southwest Florida Water Management District). The help with registration was provided by the Ridge Rangers, a volunteer group sponsored by The Nature Conservancy. We all appreciate what this group does for the good of the Lake Wales Ridge scrub.

Thanks also to all the contributing presenters and authors. Without your hard work, the symposium could not have been the success that it was. I personally learned more than I could have ever dreamed from your input. And last, but not least, thanks should go to each of the attendees for sharing close quarters without much fuss and for being attentive and responsive to each of the speakers.

I look forward to the next scrub symposium, roughly scheduled for about two years down the road. I hope that we can all work together to improve upon this first attempt and continue to build the partnerships that are so essential to recovery of the scrub ecosystem.

Dawn Zattau, Symposium Chair

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CHAPTER 1

FLORIDA SCRUB-JAY

Metapopulation Viability Analysis of the Florida Scrub-Jay

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Abstract. A 1992-1993 statewide survey of the Florida Scrub-Jay (*Aphelocoma coerulescens*) and jay habitat was used as input to a spatially-explicit individual-based model to estimate the viability of 21 demographically isolated jay metapopulations around the state. Key questions addressed by this project include: How viable are existing populations of scrub-jays if no more land is acquired, and how much improvement in viability is possible if additional habitat is protected? Simulations were run for different reserve design scenarios that represented a minimal configuration which included only currently protected habitat (as of 1999); additional scenarios included a maximal configuration protecting all known populations (excluding "suburban" jays). Three measures of viability — extinction and quasi-extinction probabilities, and risk of population decline — were used to rank the vulnerability and potential for improvement for each metapopulation under alternative reserve design configurations. Only 3 of 21 metapopulations scored high for all measures of viability without further habitat acquisition. Fourteen of 21 metapopulations were highly vulnerable to quasi-extinction at currently protected levels; of these, the risk of quasi-extinction could be greatly reduced for 7 metapopulations, moderately reduced for 4 metapopulations, and 3 metapopulations were at great risk of extinction even if all remaining habitat were acquired. For the remaining 4 metapopulations, the risk of quasi-extinction was low to moderate at currently protected levels; additional acquisitions improved all measures of viability. These modeling results suggest that jays can be preserved throughout much of their current geographic range, provided land acquisition is sufficient and habitat is properly restored.

Florida's only endemic bird species, the Federally threatened Florida Scrub-Jay (*Aphelocoma coerulescens*), is rapidly declining throughout most of its range. Formerly occurring in 39 counties of peninsular Florida, the Florida Scrub-Jay has been extirpated from 9 counties, its existence is very precarious in 6 other counties, and declines of 50% or more have been recently documented in key portions of its range (Woolfenden and Fitzpatrick 1996). Humans are directly responsible for these dramatic losses through suppression of natural fires and destruction or degradation of jay habitat. Even on protected lands, jays have declined due to inadequate habitat management.

In response to this continuing decline in jay populations, efforts at habitat management on protected lands are increasing, and land acquisition programs are gradually adding more jay populations to the network of protected areas. A 1992-1993 statewide mapping project (SMP) provided a detailed overview of most of the scrub-jay's population (Fitzpatrick et al. 1994). This survey showed that the spatial distribution of jays throughout the state was quite variable, consisting of many small and some large populations with varying degrees of isolation. This variability in spatial structure undoubtedly has strong effects on the ability of jays to persist within different landscapes, and makes it difficult

to decide which jay populations are adequately protected, and where further land acquisition should be directed.

Ascertaining which jay populations have the greatest need for land acquisition is further complicated by the fact that currently protected lands have not been properly managed, and could support more jays if restored to optimal conditions. If stronger mandates to restore habitat in these protected areas are implemented and jay populations recover to normal densities, how viable would jay populations be, with and without further land acquisition? Which patches should have the highest priority for acquisition?

These questions were investigated using a spatially-explicit, individual-based population model developed specifically for the Florida Scrub-Jay. This model incorporates demographic stochasticity, environmental stochasticity, epidemics, and many details of jay biology. The model simulates jay population dynamics on realistic landscapes developed from satellite imagery and aerial photographs. Actual jay territory locations from the 1992-1993 survey were imported into the model and overlaid on the habitat data. Additional jays were added to many simulations to represent increased jay densities associated with habitat restoration in protected areas.

The statewide population of jays was divided into 21 metapopulations thought to be demographically isolated from each other (see Stith et al. 1996). A series

of simulations were run for each metapopulation based on different reserve design scenarios. These scenarios ranged from a minimal configuration consisting of only currently protected patches (no acquisition option), to a maximal configuration consisting of all significant patches (complete acquisition option). For all simulations, the assumption was made that all protected areas were restored and properly managed, and that jays had demographic performance and densities typical of high quality habitat. These assumptions should be viewed as optimistic. Jays outside of protected areas were assumed to have poor demographic performance typical of suburban areas.

The output from the simulation runs included estimates of extinction, quasi-extinction (probability of falling below 10 pairs), and percent population decline. Comparisons of these results provided the basis for ranking the vulnerability of different metapopulations around the state. Metapopulations were ranked in terms of vulnerability assuming no further acquisition, and in terms of potential for improvement through acquiring all unprotected habitat.

Only 3 of 21 metapopulations scored high for all measures of viability without further habitat acquisition. Fourteen of 21 metapopulations were highly vulnerable to quasi-extinction at currently protected levels; of these, the risk of quasi-extinction could be greatly reduced for 7 metapopulations, moderately reduced for 4 metapopulations, and 3 metapopulations were at great risk of extinction even if all remaining habitat were acquired. For the remaining 4 metapopulations, the risk of quasi-extinction was low to moderate at currently protected levels; additional acquisitions improved all measures of viability. See Stith 1999 for further details.

These modeling results suggest that jays could be preserved throughout much of their geographic range, given adequate land acquisition and proper habitat restoration and management. However, habitat losses and fire suppression have continued since the 1992-1993 survey, undoubtedly leading to further population declines. Scrub has proven difficult to manage and restore, and model assumptions about maintaining all publicly owned scrub in optimal habitat are clearly overly optimistic. New findings suggest that future modeling efforts also should include deleterious effects of road mortality and relatively low-density housing.

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Demography of Florida Scrub-Jays in a Suburban Matrix: Implications for Reserve Design and Spatially-Explicit Modeling

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Abstract. Fewer than 4,000 breeding pairs of Florida Scrub-Jays occur throughout their range, a decline of over 90% from estimated historical numbers. Many of these jays occur in habitats degraded by fire suppression, but these habitats can be restored via application of prescribed fire. However, over 30% of extant scrub-jays occupy scrub patches in a suburban matrix, for which little amelioration exists. Urbanization has multiple impacts on the demography of scrub-jays. Juvenile recruitment is reduced through increased nestling brood reduction and increased post-fledging mortality. Although many birds begin breeding at an earlier age, survival of both non-breeding and breeding adults is lower than that of jays in unimpacted scrubs. Stochastic individual population models developed using these demographic data suggest suburban jay populations are demographic sinks, in which mortality exceeds recruitment. Surprisingly, the strength of these effects was independent of the density of human residences within suburbs; jays in low-density suburbs suffered as much as jays in high-density suburbs. This suggests that urbanization has a negative effect on scrub-jays in preserves that are adjacent to suburbs. Modeling suggests that these effects may be strong enough to turn demographic sources into demographic sinks, but these effects vary depending on the size of the jay population within the preserve and the proportion of jays within the preserve which suffer the affects of urbanization. These data suggest that the matrix habitats surrounding scrub preserves may have a profound impact on the long-term viability of scrub-jay populations.

Fire and Florida Scrub-Jay Source-Sink Dynamics in Mesic Flatwoods

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Abstract. Natural resource applications frequently use xeric oak scrub as a primary habitat requirement and exclude secondary habitats not dominated by scrub oaks on well-drained soils. Using 12 years of demography and dispersal data, we investigated source-sink population dynamics within a site dominated by mesic flatwoods with different arrangements of scrub oak. We found that source-sink distributions varied with oak cover, fire patterns, and scrub-jay population density. Xeric scrub was usually a source except during periods of high immigration pressure or extensive recent fire (<3 years since fire). Areas with low scrub oak cover (<15% cover) were almost always sinks, if they were not associated with oak patches of optimal height (120-170 cm) greater than 1.0 acre in size. Areas of moderate oak cover (15-50%), not on well-drained soils, had average reproductive success rates that were approximately equal to mortality rates. Related studies show that areas with low scrub oak cover are often occupied if they are within average dispersal distance of xeric scrub. Areas with moderate scrub oak cover are usually occupied, except where they are dominated by tall shrubs (> 300 cm) or have a dense tree canopy. Therefore, secondary habitats contribute significantly to Florida scrub-jay populations. Based on extensive habitat mapping specific to Florida scrub jays, we estimate that at least half of the Florida scrub-jay population along the central Atlantic coast uses secondary habitat. These areas are not distinguished as suitable habitat in most landcover and natural community classifications so that potential habitat can be greatly underestimated.

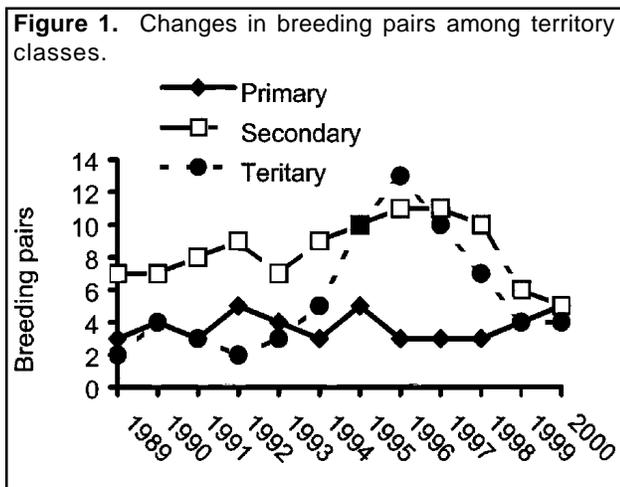
We studied source-sink dynamics among three categories of scrub oak ridges in a frequently burned landscape that lacked large (> 0.4 ha) patches of tall shrubs (>170 cm). Because frequent fires are essential for recovery, we also investigated the minimum area of optimal oak (120 cm-170 cm) needed for reproduction to exceed mortality, assuming the remaining landscape is short (< 120 cm). Florida scrub-jays have poor demographic success when fire frequencies are reduced (Woolfenden and Fitzpatrick 1984, 1991; Breininger et al. 1998, 1999) and restoration of infrequently burned

areas is expensive and experimental (Schmalzer and Boyle 1998). Fire frequencies of only every 8-20 years in some Atlantic coast scrubs can result in a loss of openings and interspersions of tall shrubs and dense trees that are difficult to reverse (Breininger et al. 1998, Duncan et al. 1999). Habitats with these characteristics have high extinction risk (Breininger et al. 1999).

Our study occurred from 1989-2000 at Tel-4 on Kennedy Space Center/Merritt Island National Wildlife Refuge. Oak scrub occurred on the ridges, and marshes occurred in the troughs with mesic flatwoods

dominating intermediate areas. We used a habitat map that distinguished all oak scrub patches >20 m² (Breininger et al. 1995; Duncan et al. 1995, 1999). Oak scrub located on well-drained soils was designated as primary ridge. Within poorly drained soils, secondary ridges were oak patches >0.4 ha and tertiary ridges were <0.4 ha. Primary territories included primary ridges, secondary territories included secondary but not primary ridges, and tertiary territories lacked primary and secondary ridges.

We mapped all fires between 1979-2000 (1985, 1987, 1992 and 1998). We used fire boundaries to map habitat suitability because time-since-fire is a useful indicator of shrub height at our site (Duncan et al. 1995). We overlaid fires and habitat to develop a map of optimal oak for every year. We designated optimal oak (120-170 cm) as patches that had not burned for 10



years but had burned before 20 years (Breininger et al. 1998, in press). This relationship was based on long-term studies of vegetation dynamics (Schmalzer and Hinkle 1992) and was identical to other independent descriptions of optimal habitat (Fitzpatrick et al. 1991). Hereafter, we emphasize scrub height and not time-since-fire. We recommend the use of structural habitat features (i.e., height, openings) for identifying habitat suitability and not time-since-fire because of variability in shrub height recovery from fire (Breininger et al. in press).

We used colorbanding methods established by Woolfenden and Fitzpatrick (1984). We censused monthly and searched for emigrants annually. We mapped territory boundaries during April and May and monitored almost every nest attempt. We defined demographic performance as yearling production mi-

nus breeder mortality to summarize habitat-specific demographic success (Breininger et al. 1995, 1998; Duncan et al. 1995). This was an indicator of source-sink patterns because one-year-olds breed if they have opportunity (Breininger 1999). We tested for density dependent reductions in demographic performance by performing Pearson product-moment correlations using the annual number of breeding pairs.

Territory boundaries were digitized as ARC/INFO polygon files. These were intersected with habitat layers to determine the area of suitable habitat, oak scrub, and optimal oak within territories. We used the area of suitable habitats, excluding marshes, forests, and concrete, to describe territory sizes to be consistent with Woolfenden and Fitzpatrick (1984). We used linear and quadratic regressions to estimate how much optimal oak (120-170 cm) was needed in a territory for yearling production to

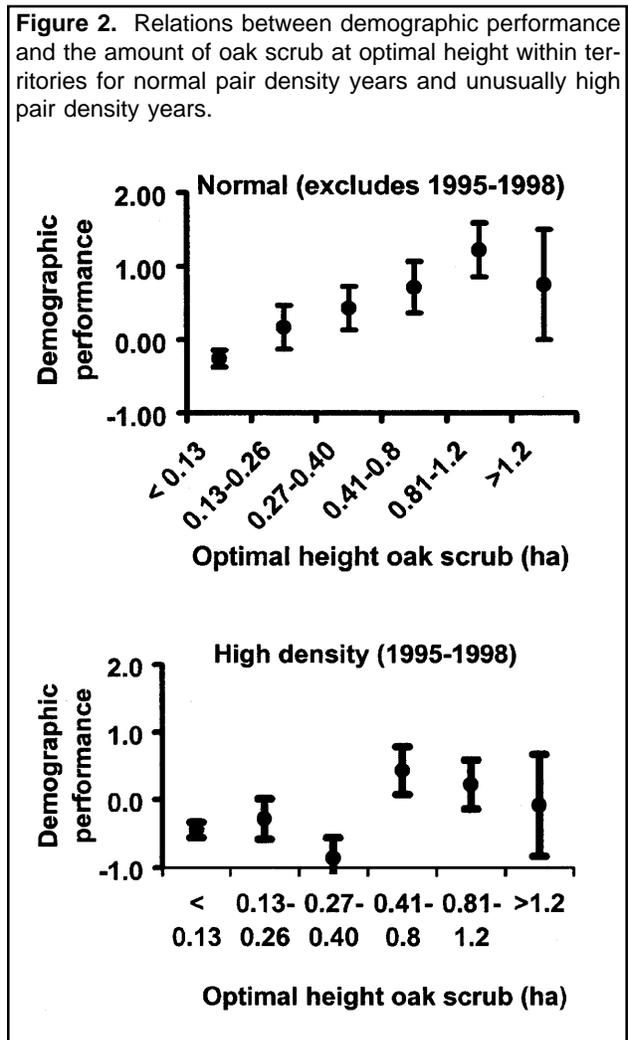


Table 1. Florida scrub-jay habitat characteristics and demography.

	Type of territory			Influence of height	
	Primary	Secondary	Tertiary	Optimal	Short
Territory size (ha)	8.33 (0.77)	8.18 (0.48)	9.74 (1.12)	8.26 (0.45)	8.52 (0.52)
Demographic performance	0.22 (0.18)	0.06 (0.12)	-0.39 (0.09)	0.23 (0.11)	-0.33 (0.08)
Fledglings/pair	1.95 (0.23)	1.22 (0.22)	1.28 (0.27)	1.49 (0.25)	1.33 (0.26)
Yearlings/pair	0.57 (0.13)	0.53 (0.11)	0.28 (0.07)	0.78 (0.13)	0.30 (0.05)
Breeder survival	0.83 (0.04)	0.78 (0.02)	0.68 (0.04)	0.85 (0.03)	0.71 (0.02)
Fledgling survival	0.38 (0.10)	0.36 (0.06)	0.24 (0.06)	0.49 (0.06)	0.23 (0.03)

Notes: Entries are means of annual means with 1 SE in parentheses. Optimal height category included primary, secondary, or tertiary territories that had >0.13 ha optimal oak (120-170 cm tall). Short included territories that had primary, secondary, and tertiary territories with <0.13 ha optimal oak.

equal or exceed breeder mortality. We used the area of optimal oak within territories as the independent variable and demographic performance as the dependent variable. The value on the x axis where demographic performance was zero was used to distinguish “short” and “optimal oak” territories. “Short” territories had too little oak so that mortality exceeded reproduction (demographic performance < 0), and “optimal” territories had enough oak at optimal height so that reproduction equaled or exceeded mortality (demographic performance > 0). We performed these analyses by lumping annual values for periods that included normal pair densities.

Oak scrub comprised only 11% of the study area even though most of the site was occupied by scrub-jays. The area optimal oak was greatest during 1996 and 1997. Most breeding population size changes occurred because the number of tertiary territories increased when immigration was high due to adjacent fires and losses of suburban habitat (Figure 1). The minimum amount of optimal oak needed for reproductive success to equal mortality during years without high pair densities (i.e., excluding 1995-1998) was 0.13 ha/territory based on a quadratic regression ($r^2 = .20$, $df = 113$, $p < 0.001$). The quadratic model might have explained more variance than the linear model because Florida scrub-jays need open sandy areas that are associated with recent fires in oak scrub (Schmalzer and Hinkle 1992, Breininger et al. 1995, in press). We found that 0.4-1.2 ha of optimal oak/territory resulted in the greatest demographic performance, even during high pair density years (Figure 2). Because ecosystems differ, the amount of optimal oak scrub requires study across the species range.

Primary territories were usually sources because recruitment exceeded mortality and emigration exceeded immigration (Table 1). Secondary territories were usually sources when enough oak was at optimal height (>0.13 ha/territory) and when population densities were not too high (<5 pairs/40 ha). Most secondary territories were pseudo-sinks (mortality temporarily exceeded reproduction) during high population densities. Correlations coefficients between pair density and demographic performance were -0.31 ($p = 0.331$) and -0.70 ($p = 0.012$) respectively for primary and secondary territories. Not all, but most, tertiary territories were sinks because mortality exceeded recruitment and immigration exceeded emigration. Because demographic performance in tertiary territories was not correlated with population density ($r = 0.18$, $p = 0.587$), many tertiary territories were true sinks. Fledgling production was low when population densities were great. Nearly all scrub temporarily occurred as a sink depending on fires, which produced shifting mosaics of optimal and suboptimal habitat. Habitat influenced demographic performance most because breeder survival differed among habitat types. Year-round territoriality, philopatry, and low dispersal propensities of Florida scrub-jays provided the asymmetric constraints on dispersal and habitat availability needed for source-sink dynamics. We observed movements from sinks to sources suggesting that these dynamics could be an evolutionary stable strategy. These source-sink dynamics do not explain movements among habitat fragments (Thaxton and Hingtgen 1996, Breininger 1999, Bowman pers. comm.). However, these dynamics are important within contiguous reserves because net reproduction must equal or exceed net mortality if there is little immigration.

Annual mean territory sizes did not vary among habitat types (Table 1). Oak scrub averaged 88% of the suitable habitat within primary territories, 60% of the suitable habitat within secondary territories, and 15% of the suitable habitat within tertiary territories. Oak at optimal height averaged 29% of the oak scrub in primary territories, 18% of the oak scrub in secondary territories, and 17% of the oak scrub in tertiary territories. Few natal dispersals occurred beyond the widths of three territories. All (n=26) one-year-olds hatched in primary territories delayed breeding for one year. Two of 46 one-year-olds hatched in secondary territories delayed breeding for one year. Four of 14 one-year-olds hatched in tertiary territories delayed breeding for one year. Pairs that included two experienced breeders had greater demographic performance than pairs that included at least one novice breeder. Except for fledgling survival, the presence of nonbreeders had no or little enhancement on demographic performance.

Pine flatwoods should be inspected for imbedded patches of oak scrub because suitable Florida scrub-jay habitat is not restricted to oak scrub. Secondary ridges could sustain themselves and most tertiary ridges had mortality that only slightly exceeded recruitment. Because of low dispersal propensities, tertiary habitat should be adjacent to primary or secondary ridges. Modeling results show that sinks can contribute to population stability by making populations larger (Howe et al. 1991, Pulliam 1998). We have many examples where flatwoods having secondary and tertiary scrub make local populations larger and more contiguous than possible by primary scrub alone (Breininger, Elseroad, Legare, Oddy, Toland unpublished data). For example, if we assume an average of 10 ha territories, mainland metapopulations in Brevard and Indian River Counties have enough habitat for 380 pairs, but secondary and tertiary scrub could provide habitat for another 525 pairs.

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Status of the Florida Scrub-Jay at Cedar Key Scrub State Reserve and Vicinity

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Abstract. We monitored the Florida scrub-jay (*Aphelocoma coerulescens*) population in and around Cedar Key Scrub State Reserve (CKSSR) in western Levy County, Florida, during the 2000 breeding season. These scrub-jays constitute the northernmost population of the species on Florida's Gulf Coast. Nineteen different Florida scrub-jays were observed during the course of the study. Of those, 15 were members of 4 resident family groups. Only one of these family groups (Group 1) was resident within the Reserve. Our results indicate that three resident scrub-jay family groups (Groups 4, 5, and 8) abandoned their territories since the previous population survey was concluded in August 1998 by the Florida Department of Environmental Protection. In addition, individual jays disappeared from two other locations where family groups may have been established (Groups 6 and 10). We did not observe scrub-jay families colonizing new areas where they had not previously been documented during 1997-1998. Our observation of 4 transient individuals suggests that undetected scrub-jay groups might be resident in scrub patches on surrounding properties that were not surveyed. However, we suspect that additional jays would be few in numbers given the survey effort expended in this and previous studies and the fragmented, overgrown nature of the scrub. This scrub-jay population is now at a critical juncture, having declined from an estimated 100 individuals as recently as 1982 to fewer than two dozen individuals in 2000. Immediate management attention is needed to increase the viability of this unstable population. Acquisition of additional scrub habitat is necessary because most of the high-quality scrub that exists in the region lies outside of CKSSR boundaries. Survey records indicate that the largest historical concentration of scrub-jays occurred along County Road 347 immediately north of the Reserve.

CHAPTER 2 FIRE MANAGEMENT AND ECOLOGY

Spatial Fire Behavior Modeling: Simulating Past and Present Fire Spread Distributions Along the East Coast of Central Florida

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Abstract. Fire has historically been an important ecological factor in maintaining southern vegetation. Humans have altered natural fire regimes by fragmenting fuels, introducing exotic species, and suppressing fires. Little is known about how these alterations affect spatial fire spread and its behavior through time. To quantify the difference between historic and current fire spread distributions, we used ARC/INFO and the FARSITE fire spread model. We held all variables constant with the exception of the fuel models representing different time periods. Fires during the early 1900s burned freely across the landscape, while current fires are much smaller and restricted by human-created barriers.

Abstract

Fire has historically been an important ecological factor maintaining southeastern vegetation. Humans have altered natural fire regimes by fragmenting fuels, introducing exotic species, and suppressing fires. Little is known about how these alterations affect spatial fire spread and its behavior through time. To quantify the difference between historic and current fire spread distributions, we used ARC/INFO and the FARSITE fire spread model. We held all variables constant with exception of the fuel models representing different time periods. Fires during the early 1900s burned freely across the landscape, while current fires are much smaller, restricted by human-created barriers.

Introduction

Florida scrub and flatwoods communities are dependent on, and adapted to, frequent fire (Abrahamson 1984, Myers 1990). Historically frequent fires were ignited by growing season lightning strikes, maintaining vegetation composition and structure (Robbins and Myers 1989, Duncan et al. 1999). Human influences such as fire suppression, fragmentation, and proliferation of exotic vegetation have greatly altered fuels disrupting natural fire regimes (Duncan et al. 1999, Myers and White 1987).

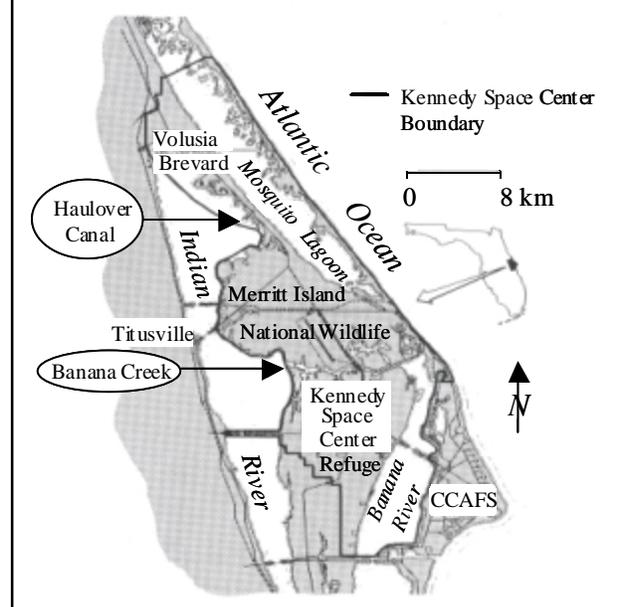
To understand the effects of anthropogenic change on spatial fire behavior, we modeled historic and current fire spread across Kennedy Space Center (KSC)/Merritt Island National Wildlife Refuge (MINWR), Florida. During the modeling we held all variables constant with exception of the fuels, which represented different time periods. This approach

isolated the differences between natural and anthropogenic fuel conditions providing valuable perspective on baseline burning conditions for land managers.

Study Site

KSC/MINWR comprises 57,000 ha in Brevard and Volusia counties located along the east coast of central Florida (Figure 1). KSC/MINWR occupies a barrier island complex comprised of a diverse assemblage of fire-adapted terrestrial vegetative communities. Upland

Figure 1. The geographic location of Kennedy Space Center on the east coast of Florida. Haulover Canal separated the north and central region while Banana Creek separated the central and southern regions.



xeric sites are dominated by oak scrub vegetation (*Quercus* spp.), while mesic sites are dominated by flatwoods (e.g., *Serenoa repens*, *Lyonia* spp., *Ilex* sp., and overstory of *Pinus elliotii*) (Schmalzer and Hinkle 1992). Because the landscape is comprised of relict dunes forming ridge swale topography, there are interleaving swale marshes and hammocks on hydric soils between the xeric ridges. The swales are dominated by *Spartina bakeri* and *Andropogon* spp. while the hardwood hammocks are dominated by *Quercus virginiana* and *Quercus laurifolia* that have a structure that is much less flammable than surrounding communities.

Methods

We used the Fire Area Simulation model (FARSITE) version 3.0 (SEM 2001) for all spatial fire modeling with input directly from ARC/INFO GRID software (ESRI 2001). We were interested in anthropogenic features and their impact on fire so we modeled the landscape at 10 meter resolution to include linear features created by man. To increase modeling efficiency at this resolution, we split the study area into north, central, and south regions by using natural geographic barriers to fire.

We converted 1920, 1943, and 1990 landcover maps (Duncan et al. 2000, Duncan et al. 2001 in review) into fuel models by assigning each landcover type to a BEHAVE fire model class (FARSITE online documentation). Freshwater marshes were assigned to Fire Behavior Model 1 (Anderson 1982). Disturbed freshwater marshes were assigned to Fire Behavior Model 2, while oak scrub and flatwoods communities were assigned to Fire Behavior Model 7. Hammocks, mixed hardwoods, and wetland hardwoods were assigned to Fire Behavior Model 8 and categories associated with water were assigned to Fire Behavior Model 98. The fuel models were then converted to grid coverages for input into FARSITE.

To complete the spatial data requirements for the model, we created an elevation grid, a slope grid, an aspect grid, and a canopy coverage grid. The elevation grid was given an elevation of three meters for the entire study site, while the slope and aspect layers were assigned a value of zero degrees. The north and south canopy coverage layers were generated with model 1 having 7% canopy coverage, model 2 and model 7 having 15%

canopy coverage and model 8 having 100%, and model 98 having no canopy coverage. The central region of KSC/MINWR is dominated by scrub vegetation communities with very little pine canopy so the canopy cover values were 3%, 7%, 100%, and 0%, respectively.

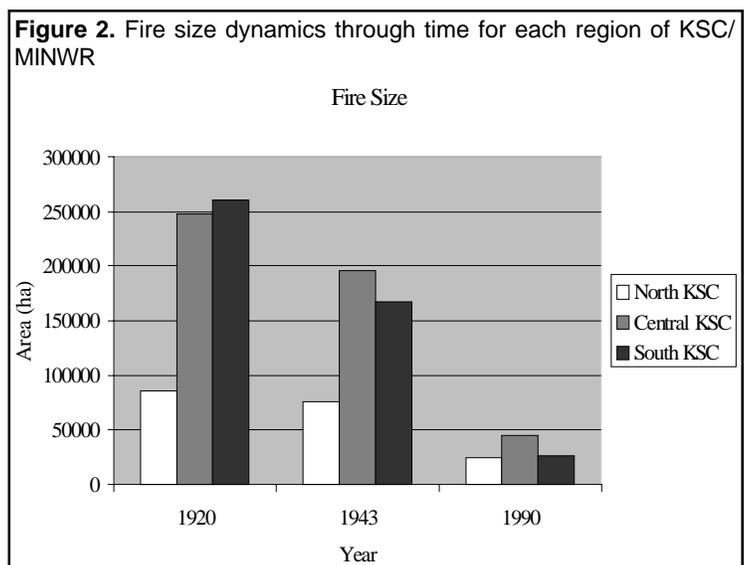
Meteorological inputs were gathered using KSC's network of meteorologic towers and collection sites. We selected July 20th through 27th 1999 for our modeling window, because it was representative of typical meteorologic conditions during the summer when lightning strike probabilities were high. The model requires daily inputs for precipitation, hour of minimum temperature, hour of maximum temperature, minimum temperature, maximum temperature, minimum humidity, maximum humidity, and elevation of meteorological collection site.

Wind data are required on an hourly basis with wind speed, wind direction, and cloud cover data all being required by the model. The last remaining required input to the model is initial fuel moistures. These are input in percent for each fuel model as 1-hour fuel moistures, 10-hour, 100-hour, live herbaceous, and live woody fuels.

We selected our ignition point for a simulated lightning strike and began our fire simulations. We held the location of ignition and all model inputs constant with exception of the fuel models represented different time periods and varying levels of anthropogenic disturbance of fuels.

Results

The largest simulated fires occurred in 1920 and fires became smaller for each successive modeling date



(Figure 2). The largest decreases in fire size occurred between 1943 and 1990 for all regions of study. In the northern region, 85,151 hectares burned in 1920 with 88% (75,535 ha) of that burning in 1943 and 28% (24,579 ha) burning in 1990. In the central region, 247,769 hectares burned in 1920 with 78% (195,592 ha) of that burning in 1943 and 18% (45,328 ha) burning in 1990. In the southern region, 260,672 hectares burned in 1920 with 64% (167,380 ha) of that burning in 1943 and 10% (26,314 ha) burning in 1990.

The extents of the simulated fires have become much more restricted through time (Figure 3). In 1943 and 1990, fires followed anthropogenic features on their boundaries, particularly in the south and central regions.

Discussion and Conclusions

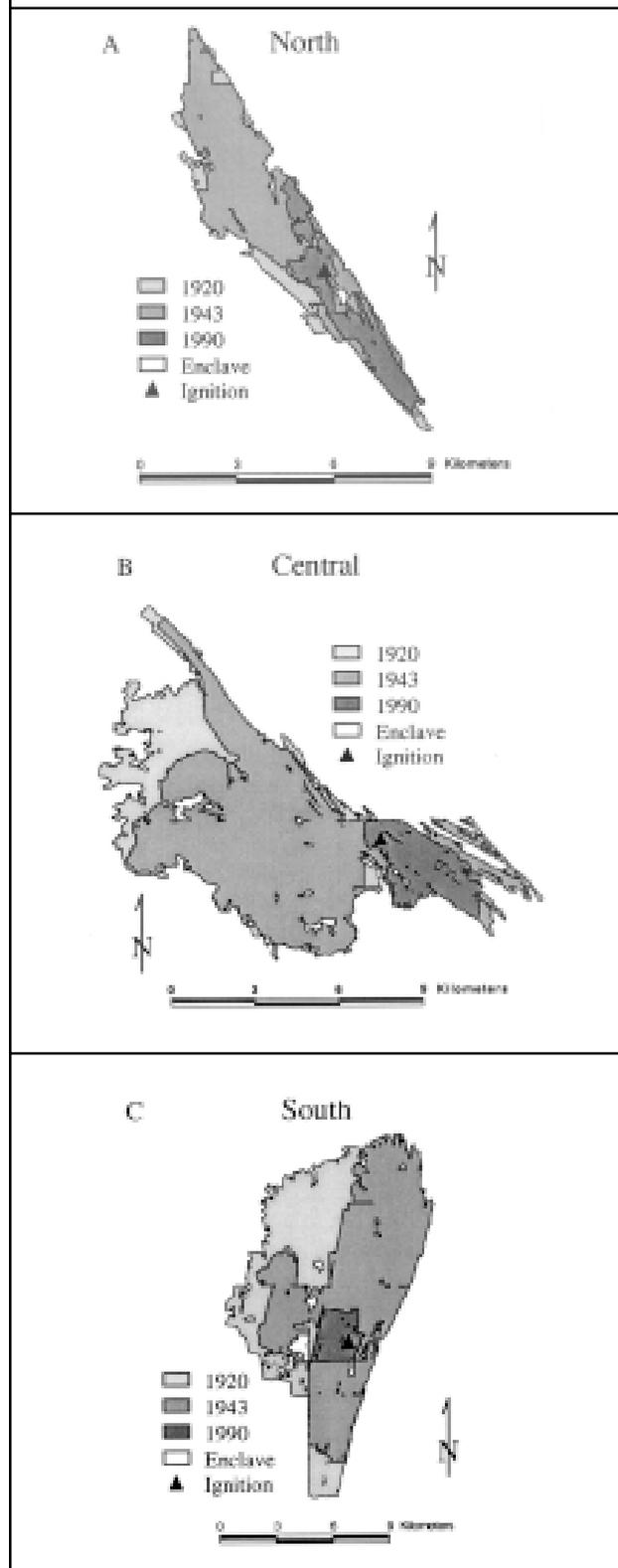
Anthropogenic influences have affected scrub and flatwoods fuel continuities and flammability, causing a reduction in fire extent. The simulations show that in 1920, fires would burn until the fuels were either exhausted or meteorologic conditions became unfavorable. In 1943, fires began to be confined by anthropogenic features on the landscape and were even more restricted by these features in 1990. Fragmentation, however, is not the only anthropogenic obstacle for fire. Past fire suppression policies have altered landcover and hence fuels, in several ways. The absence of fire in this fire maintained ecosystem has allowed scrub to grow to unnatural heights, excluding fire in all but the most extreme meteorologic conditions. Exotic and hardwood species invasion of swale marshes have increased with fire suppression policies, reducing flammability across the KSC/MINWR landscape. For a more complete discussion of anthropogenic impacts on the KSC/MINWR landscape, see Duncan et al. (1999).

The results presented here help to quantify anthropogenic effects on fire behavior. The fires simulated on the relatively natural 1920 landscape burned freely until fuels or meteorologic condition became unfavorable. The 1943 and 1990 simulations show that fires have become much less governed by natural variables, such as fuels and meteorologic conditions, but rather by human imposed barriers.

Acknowledgements

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Figure 3. The extent of simulated fires for 1920, 1943, and 1990 by KSC/MINWR region. The ignition locations are indicated for the northern (A), central (B), and southern (C) regions.



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Fire, Habitat Connectivity, and Patch Size: Key Considerations in the Management of Scrub for Lizards

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Abstract. We examined the effects of habitat quality and landscape structure on the Florida scrub lizard (*Sceloporus woodi*) at Avon Park Air Force Range using three approaches — demographic field studies with mark-recapture, habitat modeling using GIS techniques, and an assessment of regional population dynamics with simulation modeling. This research demonstrates that the distribution and population persistence of the Florida scrub lizard are highly dependent upon habitat quality, particularly open habitat maintained by fire, and landscape structure (e.g., adequate patch sizes and connectivity). Scrub lizards occurred in only 25% of the 132 scrub patches on Avon Park Air Force Range and the Arbuckle Tract of the Lake Wales State Forest. Lizards were absent from scrub patches overgrown with vegetation, and densities were highest in areas with greater than 30% bare sand. These field data, as well as models of regional population dynamics support the importance of fire in maintaining suitable habitat for scrub lizards. Lizards also were absent from isolated patches of scrub. The poor dispersal ability of scrub lizards, which was demonstrated with field experiments and distribution data, makes populations of this species especially vulnerable to habitat fragmentation. Because of their low dispersal ability through dense habitat, the spatial arrangement of prescribed fires also is likely to be critical for scrub lizards. Our understanding of the relationship between scrub lizards and fire could be greatly enhanced by linking “on the ground” management with monitoring of lizard populations in an adaptive management context.

We examined the effects of habitat quality and landscape structure on the Florida scrub lizard (*Sceloporus woodi*) at Avon Park Air Force Range and the neighboring Arbuckle Tract of the Lake Wales State Forest using three approaches — demographic field studies, habitat modeling, and an assessment of regional population dynamics with simulation modeling (Branch et al. 1999). Demographic data were obtained from mark-recapture of lizards on trapping grids (1-ha grids, 100 pitfall traps per grid) in 8 scrub patches that ranged in size from 8.5 to 278 ha. Grids were surveyed for one week each month from January 1995 - July 1996, and June - July 1997. The dispersal potential of scrub lizards was examined by observing the movement patterns of marked juvenile lizards and the distribution of patches occupied by scrub lizards. In addition, to obtain an index of the ability of lizards to move through different habitats, lizard movements were examined in experimental enclosures in habitats ranging from open scrub to dense vegetation dominated by wire grass (*Aristida stricta*). The habitat model combined field censuses and remote sensing. First, we delineated all potentially suitable habitat patches on aerial photographs and thoroughly surveyed those patches for scrub lizard occupancy. In order to analyze the landscape at a spatial scale relevant to scrub lizards, we delineated regional clusters of patches using an estimate of the maximum dispersal distance of scrub lizards (750 m,

see below). Using GIS, we generated a dispersal buffer of 750 m around each scrub patch and grouped scrub patches with overlapping buffers into clusters. This buffering approach resulted in five distinct clusters of patches on Avon Park Air Force Range and one cluster on the Arbuckle Tract. Habitat conditions of each patch and landscape characteristics were measured using remote sensing and GIS techniques. We then constructed and tested a multifactor habitat model that described the distribution pattern of scrub lizards and identified key characteristics affecting this distribution. The model was tested by applying it to two study areas that were not used to develop the model, including one cluster of scrub patches on Avon Park Air Force Range and the scrub on the Arbuckle Tract. Simulation models to project population trajectories for lizards under different habitat conditions were developed using field demographic data and assessment of changes in habitat post-fire from a series of aerial photographs that spanned 6 decades. We used a stage matrix approach and the software program RAMAS/Metapop for simulations (Akçakaya 1994).

Our research demonstrates that the distribution and population persistence of the Florida scrub lizard are highly dependent upon habitat quality, particularly open habitat maintained by fire, and landscape structure, including adequate patch sizes and connectivity. Scrub lizards occurred in only 25% of the 132 scrub patches

on Avon Park Air Force Range and the Arbuckle Tract of the Lake Wales State Forest, even though our habitat analysis indicated that many of these patches contained suitable habitat (Hokit et al. 1999). Scrub lizards were restricted to 3 of the 5 clusters of scrub patches on Avon Park Air Force Range and the single cluster on Arbuckle Tract. Lizards were absent from small scrub patches, patches overgrown with vegetation, and isolated patches.

Within the three occupied clusters of patches on Avon Park Air Force Range, we found scrub lizards in 92% of the patches with an area greater than 50 ha ($n = 13$) and in only 18% of the patches less than 10 ha in size ($n = 50$). Our demographic studies provide evidence that the inability of scrub lizards to persist in small areas of good habitat is not due solely to random processes such as demographic or environmental stochasticity. Mark-recapture data show that the abundance, survival, and recruitment of scrub lizards are higher in large patches than in small patches of similar habitat quality (Branch et al. 1999). A variety of mechanisms may contribute to these patterns. For example, compared to large patches, small patches have higher perimeter-to-area ratio that could lead to edge effects such as increased predation rates. The mechanisms responsible for differences in these demographic parameters have not been identified, and need to be investigated. If differences in demography with patch size are related edge effects, patch shape, as well as patch size, must be considered in management.

Demographic data, as well as models of regional population dynamics, support the importance of fire in maintaining suitable habitat for scrub lizards. Under natural conditions large, open areas in scrub are created and maintained by fire. Lizard densities were highest in areas with greater than 30% bare sand. Numerical simulation models indicated that the proportion of patches occupied by scrub lizards on Avon Park Air Force Range should remain relatively constant if current habitat conditions prevail, but patch occupancy declines rapidly if the amount of bare sand declines with vegetation succession (e.g., due to fire suppression) or habitat patches are removed (Hokit et al. 2001). Our regional population models also suggest that the distribution of scrub lizards on Avon Park Air Force Range fits a "mainland-island" model of metapopulations. Under this scenario, large patches function as sources of immigrants to smaller, extinction-prone patches. Thus, maintenance of high quality habitat in the large, "mainland" patches is especially

critical to maintaining the overall metapopulation. Environmental stochasticity (e.g., droughts or excessively wet conditions during the reproductive season) and autocorrelation of environmental factors also may influence the dynamics of regional populations. These factors were not incorporated into our models because their effects on scrub lizards are not known. Long-term monitoring is needed to investigate these factors. Until such data are available and incorporated into models, quantitative predictions about persistence of lizards under current habitat conditions on Avon Park Air Force Range should be interpreted with caution.

Landscape connectivity is another key variable for the persistence of scrub lizards (Hokit et al. 1999, Tiebout and Anderson 1997). Lizards were absent from patches of scrub isolated by unsuitable habitat. In experimental exclosures, lizards moved significantly farther in open scrub habitat than in medium or high density vegetation. The maximum gap between scrub patches occupied by scrub lizards was 750 m, and the proportion of patches that were occupied by scrub lizards declined sharply when the gap between patches exceeded 200 m. Of the 277 juvenile lizards marked to assess dispersal distances within a scrub patch, 71 were recaptured. Most lizards moved less than 100 m, and the maximum distance moved was 330 m. No inter-patch dispersal was documented. These data suggest that patches separated by as little as 750 m are beyond the normal dispersal abilities of scrub lizards unless patches are connected by suitable habitat, and that dispersal is highly restricted between patches that are separated by as little as a few hundred meters.

The links between patch size and demography in scrub lizards, and their poor dispersal ability, make populations of this species especially vulnerable to habitat fragmentation and loss of "stepping stone" patches or other forms of connectivity with habitat degradation. Because of their low dispersal ability through dense habitat, the spatial arrangement of prescribed fires is likely to be critical for scrub lizards. Long-term management plans at the landscape scale are most appropriate for addressing issues of habitat connectivity, as well as habitat quality, for scrub lizards. Tiebout and Anderson (1997) suggest that in Ocala National Forest, where lizards are dependent on scrub patches opened by logging, landscape connectivity may be accomplished by designing timber harvest schemes that result in juxtaposition of young seral patches and maturing stands so that lizards can move to open patches

as the maturing stands become inhospitable. Similar mosaics created with fire are appropriate for management of relative large scrub patches in landscapes like Avon Park Air Force Range. In landscapes where scrub is highly fragmented into very small patches surrounded by inhospitable habitats (e.g., urban development) maintenance or restoration of habitat connectivity may be impossible. Management options may be limited to enhancement of population persistence within patches by maintaining high-quality habitat.

Currently, the development of models of scrub lizard populations and management recommendations are outpacing field data for validating models and evaluating recommendations. Our understanding of the relationship between scrub lizards, fire, and landscape dynamics could be greatly enhanced by linking "on the ground" scrub management with landscape-level monitoring of lizard populations in an adaptive management context. For example, currently there are no empirical data on the response of scrub lizards to fire. From a number of perspectives, the Florida scrub lizard is an ideal species for examining a large range of problems common to other scrub organisms. First, the life history traits of the scrub lizard (e.g., low vagility, short life span, etc.), and the scale of its response to landscape structure, contrast sharply with those of the Florida scrub-jay (*Aphelocoma coerulescens*), the species that has served as a basis for much of the scrub management. Second, many life history traits of this species, including low vagility, and the conservation issues promulgated by this low vagility (e.g., restricted ability to colonize empty patches) are common to other poorly studied scrub species. Because the Florida scrub lizard is highly conspicuous and relatively easy to observe, capture, and mark in large numbers, studies of this species can provide large amounts of information for management that are difficult, if not impossible, to obtain for many scrub species (e.g., the sand skink, *Neoseps reynoldsi*) which face similar problems. A thorough understanding of scrub lizard

populations, at the patch and landscape scales, could substantially broaden the perspective for scrub management.

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Response of the Threatened Sand Skink (*Neoseps reynoldsi*) to Controlled Burning and Clear-Cutting in Florida Sand Pine Scrub Habitat

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Abstract. Florida scrub habitat is highly endangered because of high demand for land for agriculture and real estate. Maintenance of remaining patches of Florida scrub habitat requires active management. We experimentally investigated the effects of clear-cutting and burning on sand skink populations in three patches of sand pine scrub. Each patch included a clear-cut plot, a burned plot, and an undisturbed plot. The responses of sand skink populations were monitored over a five-year period immediately following clear-cutting and burning. Initially sand skink captures in the burned and clear-cut plots were lower than in the undisturbed plots. Over the five-year period, sand skink captures significantly increased in the clear-cut plots. No clear trend occurred in the burned plots, although fluctuations from year to year were significant. Significant differences among sites indicated that an interaction between microhabitat variables and treatment also existed. Several microhabitat variables were correlated with sand skink activity. Analysis of the distribution of individuals also indicated that sand skink distribution was clumped, especially near the centers of the three scrub patches.

Florida scrub habitat is highly endangered because of high demand for land for agriculture and real estate. Maintenance of remaining patches of Florida scrub habitat requires active management. We experimentally investigated the effects of clear-cutting and burning on sand skink populations in three patches of sand pine scrub. Each patch included a clear-cut plot, a burned plot, and an undisturbed plot. The responses of sand skink populations were monitored over a five-year period immediately following clear-cutting and burning. Initially sand skink captures in the burned and clear-cut plots were lower than in the undisturbed plots. Over the five-year period, sand skink captures significantly increased in the clear-cut plots. No clear trend occurred in the burned plots, although fluctuations from year to year were significant. Significant differences among sites indicated that an interaction between microhabitat variables and treatment also existed.

An analysis of the spatial distribution of sand skinks within the scrub sites indicated that there was an edge effect on the isolated sites. Sand skinks were more likely to be found in the center of the sites than along edges bordering non-scrub habitat. This edge effect extended into the site to 50 meters on one site and 40 meters on the other. Several microhabitat features measured were significantly different between the edges and middle of these two sites. The middle of the scrub sites were characterized by shorter mean understory vegetation height, lower litter depth, higher percent bare ground, and lower soil compaction (penetration resistance). All of these microhabitat features

work together to enable the sand skink to thermoregulate. The vegetation present and exposed bare ground provide opportunities for thermoregulation, and the loose soils may serve as a buffer against the summer heat as well as facilitate less energetically expensive movement through the sand. Sand skink activity was found in this study to be strongly negatively correlated with soil compaction. Large amounts of understory vegetation have been found to be negatively correlated with the presence of termites, a food source for the sand skinks (Collazos 1998). However, Collazos (1998) also found that sand skink density was positively correlated with canopy density, which indicates that sand skinks may not do well in areas recently clear-cut or burned.

Areas set aside for conservation must take into consideration the negative effects of non-scrub edge on the distribution of sand skinks. A fifty meter buffer along any non-scrub edge should be subtracted from the total area of the preserve to calculate the area potentially available to the sand skinks. The center area must also contain substantial amounts of those microhabitat features found in areas with the highest sand skink occupation, such as relatively short understory vegetation, low amounts of litter, high percent bare ground, and low soil compaction.

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Scrub Management in Brevard County: Planes, Cranes and Scrub-Jays

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Abstract. Most of the sand pine and oak scrub in Brevard County has been fire suppressed for the past 50 years, resulting in a predominance of mature scrub communities throughout the County. Land managers are therefore faced with the difficult challenges of preserving suites of scrub-inhabiting species that require the low vegetation characteristics of young scrub. Prescribed fire is one of the tools utilized to alter scrub habitat, but the drastic fire behavior of mature scrub communities often prohibits use of this tool without some form of mechanical preparation beforehand. Unfortunately, mechanical preparation can be prohibitively expensive. One solution is to seek partners who can bring both management skills and funding dollars to the table in order to achieve the desired results. An example of this cooperation is ongoing at the Valkaria Airport, in south Brevard County. This airport has considerable mature sand pine/oak scrub onsite, as well as Florida scrub-jays. It is also located between two conservation areas that contain scrub-jay territories, which makes proper management of the airport's scrub integral to preventing habitat and population fragmentation. The scrub habitat within the Valkaria Airport also poses line-of-sight problems for airplanes that utilize the runways. In order to reduce the vegetation height the airport received funding from the Florida Department of Transportation to mechanically cut the scrub. Since the airport's needed management would also serve to benefit the scrub-jays, the Brevard County Office of Natural Resources was asked to write a scrub management plan for the airport. This plan outlined specific actions and procedures that would guide the scrub management. Once the mechanical treatment was completed, a prescribed fire was successfully performed. A combination of cooperative management actions has successfully satisfied both the airport's safety regulations and scrub-jay habitat requirements. Additional scrub management is scheduled for this year.

Developing Methods for Measuring Fire Intensity: Insights from a Mow and Burn Experiment

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Abstract. Fire is essential to ecosystems worldwide. Fire effects may vary with small-scale heterogeneity in intensity (temperature achieved and residence time), and such patchiness can affect the subsequent establishment of plant species. Unfortunately, the different methods of estimating fire intensity are not always congruent (e.g., Perez and Moreno 1998). Dataloggers collect precise, detailed information, but can only be deployed in a limited area due to expense and difficulty of installation. Pyrometers (metal tags with paints that melt at given temperatures) and calorimeters (aluminum cans with water that evaporates) are cheaper and more efficient but less accurate. In June 1999 we deployed dataloggers, pyrometers, and calorimeters in several areas of a mow and burn vs. burn-only experiment at Lake Apthorpe Scrub. Trends in fire intensity were congruent among thermocouples, calorimeters, and, to a lesser extent, pyrometers. Dataloggers provided detailed information about fire behavior on a local scale, but the alternative methods better described burn heterogeneity throughout treatment areas. Calorimeters did not match thermocouple rankings of fuel types; this may be an artifact of small samples and the lack of replication within thermocouple data. Indeed, substantial within-sample variability for calorimeters placed along transects and clustered at thermocouples suggest heterogeneity at multiple scales, emphasizing the need for flexibility in dispersing sample points. Pyrometers both under- and over-estimated maximum temperatures: the construction of the units may have played a role. We plan to refine our techniques in prescribed burns scheduled for spring 2001 at Archbold Biological Station, Lake Placid Scrub, and Gould Road Scrub.

CHAPTER 3 MANAGEMENT

Effects of Prescribed Management of the Four-Petal Pawpaw *Asimina tetramera* Small (Annonaceae), an Endangered Species in Florida Scrub

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Abstract. Mechanical cutting and fire in combination were used to test the flowering and fruiting response of *Asimina tetramera* to various management techniques in sand pine scrub habitat. This federally endangered species, limited to two counties in southeastern Florida, showed reduced flowering and fruiting under a closed canopy of sand pine (*Pinus clausa*). The results of this 1994-1996 study show that significantly higher percentages of plants flowered in the BURN and CUT&BURN treatments one year post-treatment than in the MULCHED, HAND-CUT and the CONTROL. Weighted least squares analysis for number of plants that set fruit showed a significant difference among years, but there was no difference among treatments. This study shows that flowering and fruiting can be stimulated by burning a mature habitat in the spring with no loss of individual plants. Habitat management will be required at some point for the remaining populations of *A. tetramera* in the small scrub habitats on the Atlantic Coastal Ridge. The life history traits are just now being examined for *A. tetramera*. Critical life history stages may be seed dispersal and germination, and burning frequency may affect recruitment.

Scrub Restoration on Kennedy Space Center/Merritt Island National Wildlife Refuge, 1992-2000

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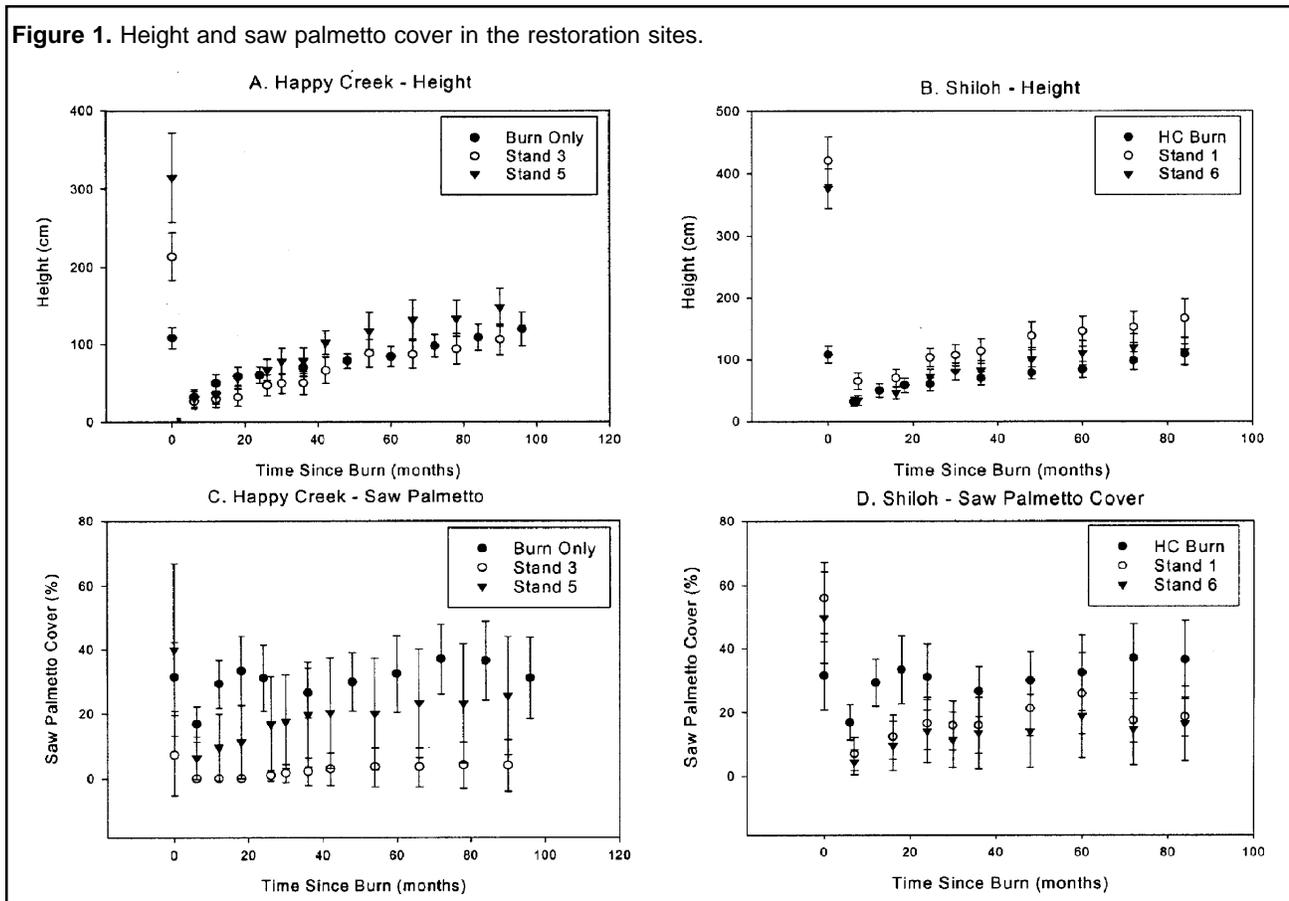
Abstract. Kennedy Space Center (NASA) and Merritt Island National Wildlife Refuge (USFWS) have collaborated in scrub restoration and monitoring since 1992. Scrub restoration is directed towards improving habitat conditions for the Florida scrub-jay. Fire suppression (1962-1981) and landscape fragmentation allowed some scrub to reach size structure that was fire resistant under prescribed burning conditions. Mechanical treatment combined with prescribed burning has been used to restore vegetation structure that could then be maintained by prescribed burning. Mechanical equipment and techniques used have included V-blade, K-G blade, Brown tree-cutter, Kendall tree-cutter, and roller-chopper. Vegetation monitoring has been conducted using permanent 15 m transects established before treatment and sampled periodically after cutting and burning. With careful application, all these techniques can produce acceptable vegetation recovery. All mechanical treatments cause some decline in saw palmetto cover. Saw palmetto is the most flammable element in scrub of Merritt Island, and excessive loss can reduce the ability to burn the scrub in the future. Height growth rates of long-unburned scrub vary and often exceed that of regularly burned scrub by 50% or more. These growth rates suggest that restored scrub may have to be burned on relatively short intervals during a restoration period. Where fuels are uniform, regrowth may be dense with no persisting openings, important to scrub-jays. Piled fuels produce local hot spots that kill the roots and rhizomes of sprouting species. Such openings close slowly from ingrowth of oaks and ericads with opening area declining by about 50% in seven years.

Kennedy Space Center (KSC/NASA) and Merritt Island National Wildlife Refuge (MINWR/USFWS) have collaborated in scrub restoration and monitoring since 1992. Scrub restoration is directed towards improving habitat conditions for the Florida Scrub-Jay (*Aphelocoma coerulescens*). KSC/MINWR supports a core Scrub-Jay population important to the species survival. Fire suppression (1962-1981) and landscape fragmentation allowed some scrub to reach size structure that was fire resistant under prescribed burning conditions. Unburned scrub

becomes unsuitable as Scrub-Jay habitat, and demographic success declines even if the habitat is still occupied (Breininger et al. in press).

Areas for restoration were selected that had the potential to be optimal habitat but could not be restored by prescribed burning alone (Schmalzer et al. 1994). Mechanical treatment combined with prescribed burning was used to restore vegetation structure that could then be maintained by prescribed burning. Mechanical equipment and techniques used have included Brown

Figure 1. Height and saw palmetto cover in the restoration sites.



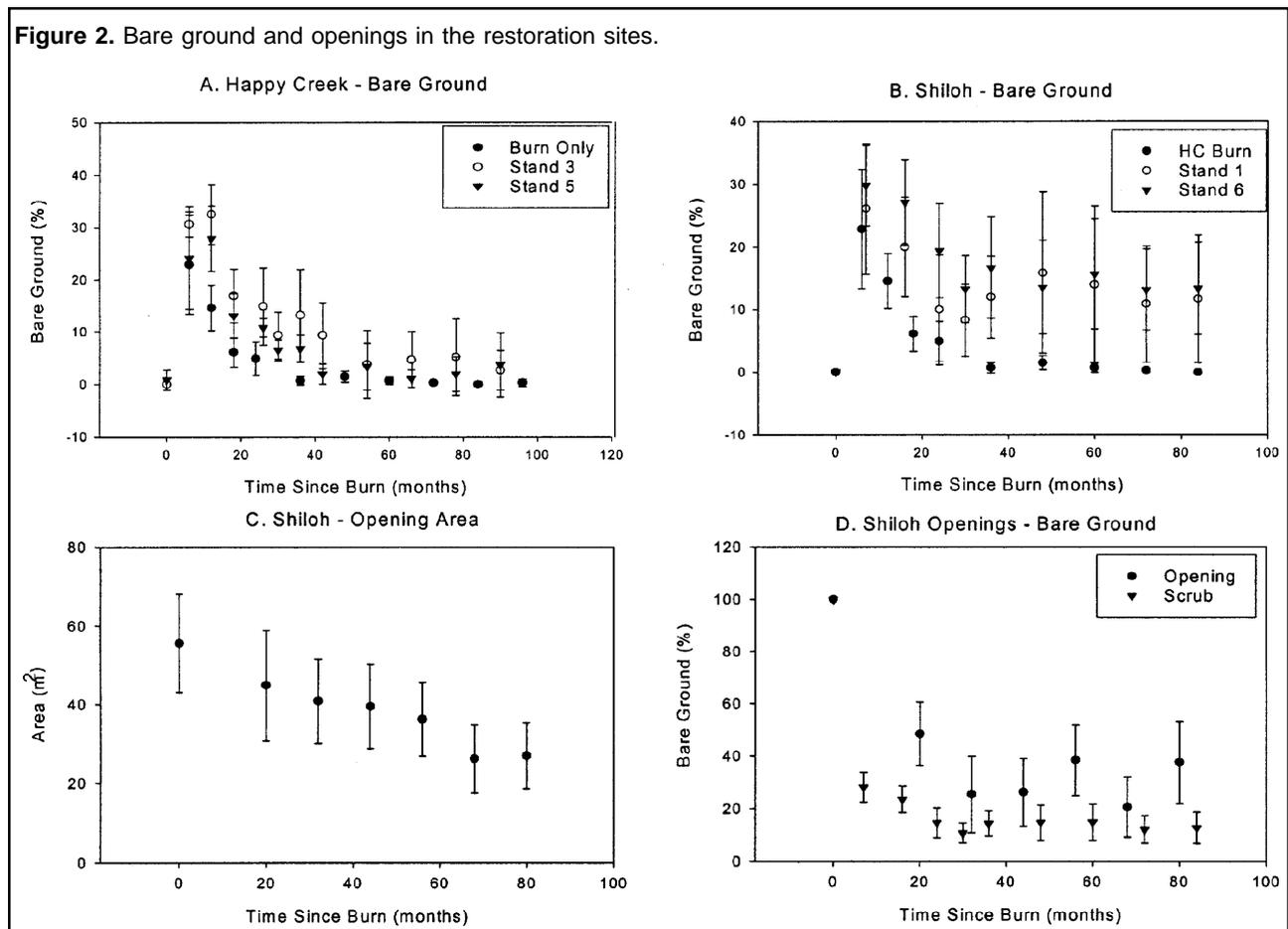
tree-cutter, V-blade, K-G blade, Kendall tree-cutter, and roller-chopper. Sites have been burned within ca. six months of cutting. Vegetation monitoring has been conducted using permanent 15 m transects established before treatment and sampled periodically after cutting and burning. In this paper, we review vegetation responses to combinations of mechanical treatment and prescribed burning. We focus on the Happy Creek and Shiloh sites that were treated first and have the longest-term data.

In Happy Creek, mechanical treatment began in August 1992 and was completed in January 1993. For most of the Happy Creek restoration sites, a modified Brown tree cutter, mounted on a Ford 9030 Versatile tractor, was used. Modifications to the tree cutter allowed it to be mounted in front of the tractor instead of being pulled; also, a push bar was added. Production rates of 1-1.5 ha/day could be achieved where there was a high proportion of saw palmetto and the scrub oaks were < 10 cm in diameter at ground level. Where scrub oaks were denser, or where the scrub oaks were 10-15 cm in diameter, rates could be as low as 0.5 ha/day. The Brown cutter caused almost no soil

disturbance and produced a good fuel bed for prescribed burning. Three prescribed burns were conducted in February 1993 to burn these sites. These burns were relatively complete with over 90% of the one and ten hour time lag fuels consumed in the flaming stage of the fire. Where possible, the heavier fuels were allowed to burn down as much as possible resulting in over 70% of the 100-hour fuels and 40 to 50% of the larger fuels being consumed.

Cutting of the scrub vegetation at the Shiloh site began in late January 1993 and was completed by the end of March 1993. The scrub oak stems at the Shiloh site were too large (12-20 cm diameter at ground level) to use either the Brown tree cutter or the roller chopper. A V-blade mounted on the D-6 was used in 95% of the cutting operation, and the remaining 5% was cut with chain saws. Production rates varied widely depending on the density of the scrub oaks and their size, but an average rate was 1 ha/day. The resulting fuel bed was composed of nearly intact oak trees laid on the ground. The percentage of heavy fuels was quite high, and the fuel bed was discontinuous. Because of the size of the fuels they were left scattered to cure,

Figure 2. Bare ground and openings in the restoration sites.



and then piled to enhance complete burning. The two sites were burned on November 1 and 5, 1993.

Fire behavior and percent of area burned were very different on the two burn days. This can be attributed to differences in both the fuel beds and weather conditions. In the northern section (Stand 1), the fuel bed was discontinuous after the cutting and piling, limiting the spread of the fire. In addition, fuel moisture was fairly high (15% at 1120, fuel moisture sticks) further reducing fire intensity. As a result only 60 to 70% of the area was burned. The southern section (Stand 6) had a more continuous fuel bed, with a larger component of fine fuels, allowing the fire to spread more evenly over the site. In addition, fuel moisture was lower (13.5% at 1045). This combination of conditions significantly increased fire behavior, and about 95% of the area burned. On both days, all of the slash piles burned to white ash.

We compared the responses of scrub vegetation to mechanical treatment and burning to burning only using data from transects (N=8) in scrub in Happy Creek that burned in 1986 and were sampled at least

annually thereafter (Schmalzer and Hinkle 1992). Scrub height in restoration stands in Happy Creek (Stand 3, N=5; Stand 5, N=7) and Shiloh (Stand 1, N=10; Stand 6, N=10) exceeded considerably the height of periodically burned scrub before treatment (Fig. 1A, 1B). Height growth of cut and burned scrub equaled or exceeded, sometimes by 50% or more that of scrub burned without mechanical treatment (Fig. 1A, 1B). Regrowth of oaks and ericads was similar between cut/burned and burned only stands (data not shown). Mechanical treatment reduced saw palmetto cover (Fig. 1C, 1D). In burned stands, saw palmetto cover returned to preburn values within one year and remained at that level. Saw palmetto cover in cut/burned stands was still reduced 7-8 years postburn (Fig. 1C, 1D).

The amount of bare ground in scrub declined to minimal amounts in a few years after burning where there was no mechanical treatment (Fig. 2A, see also Schmalzer and Hinkle 1992). Bare ground in the Happy Creek restoration sites also declined to low levels within a few years postburn (Fig. 2A), although not as rapidly as uncut scrub. The Shiloh site (Fig. 2B) has retained

more bare ground. Two factors contribute to this. First, the V-blade treatment caused more soil disturbance and direct mortality of oaks and saw palmetto than the Brown cutter. Second, burning piled fuels produced hot spots that killed roots and rhizomes of sprouting species (oaks, ericads, saw palmetto). We monitored a sample (N=12) of openings caused by burned piles. Openings closed slowly by oaks and ericads spreading into the openings from the perimeter; opening area declined by about 50% in seven years (Fig. 2C). Few woody species established by seed in the interior of the openings. Herbaceous species and bare ground were most common in openings (data not shown). Transects in the openings retained much more bare ground than transects in the scrub matrix (Fig. 2D).

With careful application, all these techniques can produce acceptable vegetation recovery. All mechanical treatments cause some decline in saw palmetto cover. Saw palmetto is the most flammable element in scrub of Merritt Island, and excessive loss can reduce the ability to burn the scrub in the future. Lack of fuel continuity can result in fires no longer spreading through sites, degrading habitat quality (Breininger and Schmalzer 1990). The growth rates of long-unburned scrub after restoration suggest that restored scrub may have to be burned on relatively short intervals during a restoration period. Thus, it is critical to retain the ability to burn scrub frequently. In the historic landscape, openings in scrub were common, but they disappeared during decades of fire suppression, and prescribed burning has not reestablished openings in many landscapes (Duncan et al. 1999). Where fuels are uniform, regrowth may be dense with no persisting openings. Piled

fuels produce local hot spots that kill the roots and rhizomes of sprouting species. These openings close slowly from in growth of oaks and ericads. Such strategies should be used with care, because it is also important that the scrub matrix burn in order to top-kill shrubs, reduce litter and duff, and volatilize and recycle nutrients.

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The Evolution of Ocala National Forest's Current Sand Pine Scrub Management Program

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Abstract. We summarized the events that have led to and shaped the current sand pine scrub management program in Ocala National Forest. Ocala National Forest has a land use history that has been documented for almost 100 years, from the original land surveys and classification, through the advent of sand pine silviculture, to the present day efforts of ecosystem management. The events from proclamation as a National Forest through the present have shaped our current land management practices. We offer this history to provide other land managers useful insights to scrub management.

Introduction

Natural areas have become so fragmented that they are incapable of being perpetuated only through the natural processes, yet to manage these ecosystems land managers must mimic the environmental disturbances that are now missing. While we can learn of the forces that once shaped the lands we manage through understanding the geology of the landscape and biology of the flora and fauna, we can use the local history of the land to understand events that were specific to the geographic location of the particular ecosystems we manage. Because the largest area of sand pine scrub in the world, the Big Scrub, has been under long-term federal ownership, we have a documented history of the environmental and human activities in the sand pine scrub for the past century. This history provides managers with examples of what has been attempted and accomplished in the past, what is being tried now, and what we yet have to learn.

The Unmanaged Scrub

In 1908, President Theodore Roosevelt proclaimed 202,081 acres in Marion and Lake Counties Florida to be the Florida National Forest. This land had never been bought or sold. Rather, it was platted land that was never homesteaded and remained unclaimed. In 1916, W.F. Hill produced a Land Classification report for the U.S. Forest Service (USFS). He documented that "Great Scrub," which he described as a "great sand-waste area", comprised 98% of what was then the Ocala National Forest (ONF). Around this time, the logging of cypress was in full swing, many former flatwoods areas were in agriculture, and pines other than sand pine were being cut wherever they occurred. However, the Ocala scrub was not considered a commodity producing landscape. Hill wrote that the "worthless nature of the loose, sandy soil of the scrub has been well established" and while "all the longleaf pine

had been turpented and a large percent logged...the inferior grade of the sand pine timber of the scrub area...has not been looked upon by the sawmill operator as a profitable field of investment." A pattern of public use was already well established before the government acquired the land. While no one inhabited, logged or farmed the scrub, residents of the more fertile lands surrounding the Big Scrub used it for its meat-producing capabilities. Free-ranging swine were kept in the scrub, where they fed on an abundance of acorns and palmetto, and were harvested like game animals with packs of dogs. Cattle were grazed on the prairies dotting the scrub during the cooler months, and were moved to the flatwoods every summer to escape the scrub's searing heat. The public was already accustomed to unrestricted accessibility, as documented by Hill: "Camping parties in large numbers are annually attracted to these woods and waters during hunting and fishing seasons...no restrictions were placed upon the use of the land for camping places, it being the custom to make camp wherever an opportunity presented..."

Hill commented on the depletion of the yellow pine species and predicted that sand pine would someday be used for paneling, paper, and crates. He recommended protecting the scrub from fire to protect the timber that would someday have commercial value. Hill's prediction was accurate, but it would be several decades before sand pine would become a major commodity.

Hill observed that the sand pine scrub was a fire-dependent community. He noted that, "...fires swept over the landscape in irregular intervals, about once in the lifetime of a sand pine." He remarked that areas that were not burned had sand pines that were 40 to 50 years old. Hill described the opening of the serotinous cones on the dead trees, the prolific seeding of the sand pine, and how rapidly the new trees grew and reestablished following the fires. While he described the areas that burned as being large he did not provide

any information on the size of the fires, only that the sand pine “burns very readily” and “all vegetation in the path of the fire ... (is) killed.”

The comments of H.J. Webber, a botanist who classified scrub ecosystems in the 1890s, supported Hill’s observations of a long fire cycle. Webber returned to ONF in 1932 and remarked how the great expanses of mature sand pine forest that were there 40 years before, were reduced to fragmented strands in a landscape dominated by scrub oak and young pines (Webber 1935). Severe droughts in the 1920s created conditions that made the scrub easily ignited (Hough 1972) and produced the open scrub described by Webber.

Three years after Webber described the fire fighting association of scrub vegetation, the fastest spreading fire in U. S. history occurred in the ONF. The Big Scrub Fire of 1935 started from a burning stump in muck farmlands at the southwest corner of the forest. The crowning fire ran to Lake George then turned to the southeast in response to a wind shift. In 4 hours, the fire ran 36 miles and burned 35,000 acres. It was not slowed by the 300-foot wide firebreaks that had been placed at 3-mile intervals across the scrub. John W. Cooper (undated), former ONF Ranger, reported that every tree in the fire’s path had been killed except for a few scattered islands of green trees. Despite the wildfires in the 1920s, the sand pine had reached sufficient height by 1935 to support a widespread crown fire.

Management of Sand Pine

In the 1920s, the USFS experimented with planting more valuable pine species in the scrub because sand pine had little commercial value. These projects failed because the scrub was too dry to support longleaf pines and slash pines. In 1932, a method of making good sulfate pulp from sand pine was discovered, and in 1938 the USFS proposed to harvest 22,000 cords from ONF. The first sand pine harvest was in 1940, and it took 6 more years for the Forest to reach its goal of 22,000 cords (only ~1,000 ac.). Between 1940 and 1953, a total of 200,000 cords (avg. ~ 700 ac./yr.) of sand pine were harvested. These low harvest levels may have reflected the low amount of mature forest that was harvestable due to the fires of the 1920s and 1930s. Also, the USFS had not yet figured out a method of regenerating the sand pine after an area was harvested.

Foresters in ONF experimented with methods of regenerating sand pine during the 1940s, which laid the groundwork for formal studies conducted from 1949-1956

(Cooper et al. 1959). The scrub presented many problems not seen before in other pine ecosystems. Here was an ecosystem that naturally regenerated after intensely hot fires burned off the shrub layer, killed the mature pines, and caused the pine cones to open and release seed. How could this process be mimicked after the sand pine was harvested? Prescribed fire was tested as a site preparation method during this time. But because the cones lay on the ground following timber harvests, the fire consumed the cones instead of just opening them. At this point, artificial seeding methods were developed. The USFS developed a method of extracting sand pine seeds by baking the cones to a temperature that opened the cone without burning them. Various methods of direct seeding, including aerial seeding, broadcast seeding, and Bracke seeding, were used in the 1960s-1980s until a customized seeder was developed specifically for use in scrub in the late 1980s. The formal and informal studies that the USFS conducted during this time produced the current system of using clearcutting, followed by preparing the site with a scarification method, and either seeding the site mechanically or timing the timber harvest to occur between late summer and early fall to allow natural seeding from the scattered pine cones that remained after the timber harvest.

By the 1960s, the sand pine that regenerated after the big wildfires of the 1920s and 1930s was old enough to harvest, and the demand for pulp was increasing. The ONF increased its timber production and clearcut large blocks of sand pine scrub up to 320 acres. From the process that triggered the National Forest Management Act of 1976, it became clear that the public disliked seeing large, open, square clearcuts. ONF made its cuts smaller, about 50 acres, made the shapes of the stands more intricate, and no longer harvested adjacent to stands of young scrub. This type of timber management was not only more visually pleasing to the public, but also produced numerous small stands with lots of edge, which benefited game species. Land managers believed they were improving conditions for wildlife while improving aesthetics.

Changing Emphasis

When the Florida scrub-jay was listed as Threatened in 1987 and the U.S. Fish and Wildlife Service (USFWS) started to draft a recovery plan, it became obvious that the ONF had a key role to play. At the same time, the National Forests in Florida were

developing a new Forest Plan, and Chief Jack Ward Thomas had directed the USFS to manage land in accordance with ecosystem processes such as fire. The ONF worked with the USFWS, other agencies, and the public, including scientists, resource managers, and conservationists, to identify gaps in agency knowledge and management direction.

In response to the concerns and information gathered from natural resource professionals and advocates, ONF began increasing the sizes of its sand pine stands to benefit scrub-jays, and is maintaining sand pine harvest levels at a rate that will prevent habitat "bottle-necks" from occurring. Because the scientific community expressed concerns that harvesting all stands at 40-50 years may cause a loss of biodiversity, 5% of sand pine scrub is now retained as older age classes. Natural regeneration is used more often as a seeding method, and patchy or low stocking densities of sand pine are acceptable now, whereas such conditions would have required rechopping and reseeded in the past.

At the recommendation of members of the research community, for every 24 acres that are chopped, 1 acre is left unchopped to provide denser patches of scrub for scrub-jay nesting. It has not been determined yet whether jays prefer these nest areas, but unchopped areas have not proved to be successful in attracting jays to stands any earlier. Placing clearcuts next to stands occupied by jays appears to be more effective. The presence of suitable scrub-jay habitat, particularly stands that are occupied by scrub-jays, is now used to determine where future sand pine harvests will occur. The cuts are planned to create a stair-step of different aged scrub; the goal is to provide a constant supply of suitable habitat. Further, the ONF is taking 2,000 contiguous acres of scrub out of timber production as a "Scrub-jay Management Area." Once the existing timber is harvested, the stands in this area will not be seeded with sand pine, and they will be treated with prescribed fire on a 10-20 year rotation. In addition, the scrub in the wilderness areas and the bombing range (~ 10,000 ac.) are being converted to, and maintained as, young scrub through prescribed fire.

Incorporating New Findings

The ONF has been a partner or supporter of several ecological studies in the scrub, and continually incorporates the results of these and other studies into its land management. Greenberg (1993) found no differences in the vegetation, bird communities, and

reptile communities of burned, logged and naturally regenerated sand pine scrub versus clearcut, chopped and seeded sand pine scrub within the short term scope of her study. Because Greenberg's study did not incorporate a stand-replacement fire, the ONF burned a stand of mature sand pine for the first time in 1993 as an additional comparison. The results of how the animal communities responded are still forthcoming, but it is recognized that there may be other differences in biotic and abiotic responses. The ONF now uses stand-replacing fire in the wilderness areas that contain scrub, and in the bombing range.

R. Anderson and H. Tiebout have been studying scrub lizards and 6-lined racerunners for 10 years in the ONF: Their work shows that sites prepared by chopping supported significantly more lizards than those prepared by burning (Anderson, pers. comm.). Baldwin (1999) suggests that burning may reduce external parasite loads on lizards, and therefore it is possible that burning in combination with chopping may improve fitness and survival of lizard populations in the scrub. Anderson and Tiebout have also documented that scrub is suitable for scrub lizards for a relatively short interval (3-5 years after regeneration), and because scrub lizards are poor immigrants, adjacency of suitable habitat or connectedness by short sand roads is essential to maintaining abundant lizard populations in scrub (Anderson, pers. comm.).

The Florida Fish and Wildlife Conservation Commission has completed the first 2 years of an ongoing black bear study in the ONF. Research indicates that the ONF bears have significantly smaller home ranges than usual, possibly due to the diversity and abundance of food available (Walt McCown, FWC, pers. comm.). The study also shows that bears prefer to cross roads in areas where the scrub is thick and tend to avoid crossing where there are younger stands of scrub; this information may be used to manage the land to channel bears to cross roads at more desirable locations (e.g., future underpasses). Half of the females in the study denned in mature sand pine scrub, rather than flatwoods or swamps that were thought to be typical for Florida black bears. Before this finding, mature sand pine scrub was considered to have little value for any state or federally listed species.

The USFS recognizes that there are still many gaps in understanding the scrub, and the management of ONF's scrub will continue to evolve as new information and techniques become available. As there is much

to be learned about the relationship of scrub-jays and silvicultural practices, ONF now has a biologist working full time on a 4-year scrub-jay demographic project. The ONF will apply the results of this project towards improving current methods of providing habitat for scrub-jays.

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CHAPTER 4 WILDLIFE

Monitoring Amphibian Movements During Mechanical Treatment of Scrub

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Abstract. Spear's Scrub is a 290-acre sand pine scrub community located at Rock Springs Run State Reserve. On October 4, 2000, the Wekiva Basin GEPark, in partnership with the Florida Division of Forestry, signed a timber harvest contract with a private company. The company was contracted to remove large sand pines that would make burning more difficult. The purpose of this timbering contract was to: (1) restore the scrub habitat for nearby families of scrub-jays; and (2) to make the habitat suitable for prescribed burns. One complication of mechanical treatment is its effect on wildlife. There is a population of striped newts (*Notophthalmus perstriatus*) that occurs at Spear's Scrub and could be impacted by the timbering project. In order to protect the population and the ponds they depend on, the park has established buffer zones where no trees will be cut. Inside this buffer zone a 500' drift fence with pit fall traps has been established to determine the movements of amphibians and reptiles around the breeding ponds before, during, and after the timbering. The methods used in this study will be explained and data gathered will be summarized. Future mechanical treatments will be detailed as well as any burn operations that may take place.

The Wekiva Basin GEPark is over 42,000 acres located north of Orlando, Florida. Included in Wekiva Basin GEPark are Wekiwa Springs State Park (WSSP), Rock Springs Run State Reserve (RSR), and Lower Wekiva River Preserve State Park (LWR). Through interagency efforts between Department of Environmental Protection and Division of Forestry the park has made strides to restore Spear's Scrub, a 290-acre portion of sand pine (*Pinus clausa*) scrub at RSR, in order to restore Florida scrub-jay (*Aphelocoma coerulescens*) habitat. The Florida scrub-jay was documented at Spear's Scrub 15 years ago (Cox 1984) but has not been documented at Spear's Scrub since then.

Judging from core samples that were taken from sand pines, Spear's Scrub has not been burned in over 100 years (Parks Small, pers. comm.). Previous park managers have identified the need to burn the area; however, the complex fire behavior required for a successful burn has been a major deterrent. In addition to Florida scrub-jays, gopher frogs (*Rana capito*), Florida mice (*Podomys floridanus*), and the Florida black bear (*Ursus americanus*) have all been documented from Spear's Scrub.

The steps involved in restoring Spear's Scrub include: (1) manual removal of rusty lyonia (*Lyonia ferruginea*) at ground level; (2) removal of sand pines by a contracted timber company; (3) if necessary, chopping or mowing of remaining shrubs; and (4) burning. To date the merchantable rusty lyonia has been

removed and a timber contract has been established. Revenue from these activities will go directly towards the restoration and monitoring of Spear's Scrub.

The purpose of this study was to monitor amphibian movements [especially the striped newt (*Notophthalmus perstriatus*)] before, during, and after the mechanical restoration of Spear's Scrub. During mechanical treatment, large pieces of equipment will be used to remove mature sand pine. Monitoring was initiated to determine whether artificial treatment had a negative impact on amphibians. Because Spear's Scrub contains several ephemeral ponds that many amphibians use for breeding, a pond buffer zone was created. The entire buffer zone includes approximately 30 acres of scrub habitat around several of the sink-hole depression ponds. Since little is known regarding the life history of the striped newt in sand pine scrub, the size of the buffer was varied around two of the ponds to provide for differing levels of potential protection. A third pond was not buffered. Prescribed fire will be used to restore the buffer zone.

In January 2001, a 500-foot drift fence with 40 pitfall traps was installed around one of the ephemeral ponds located within Spear's Scrub. The fence partially encircles the pond to trap amphibians moving in and out during breeding events.

From January to June 2001, a total of 563 captures have been made. A total of nine species of amphibians and eight species of reptiles have been

captured. To date, southern toads (*Bufo terrestris*) have made up 75 percent of the total captures (426/563).

Unfortunately, no striped newts have been captured at the pond since they were found there in the mid 1990s. The newt's absence may be caused by the extreme drought that has developed in Central Florida since 1998. Preliminary findings from this study suggest that the striped newt population at Spear's Scrub is a relatively small one. If the population still exists, it would be one of the southern-most colonies in the range.

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Translocation Success of the Threatened Sand Skink, *Neoseps reynoldsi*

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Abstract. Relocation of populations from one area to another is widely used as a last ditch effort to preserve populations that would otherwise be extirpated by development. The primary purpose of this study was to examine the success of translocated populations of the small fossorial sand skink, *Neoseps reynoldsi*, on two restored scrub sites. Persistence, recruitment, and survival were compared to those of a nearby population for 6 years. Our results suggest that after 6 years, the translocated population on one site has not established a self-sustaining population, but the translocated population on the second site has. The factors affecting the differences in success between these two populations include site location, habitat suitability, and initial propagule size. We also examined dispersal capabilities of the sand skink because natural colonization into restored areas is dependent on its ability to disperse. The sand skink has been thought to have low vagility, but our results suggest that its dispersal capabilities have been underestimated. The tendency to disperse varies among individuals. Some adult individuals moved long distances (greater than 140 m) while other adults moved only short distances within distinct home ranges. Our results indicate that populations of this threatened species could be established in restored habitat or fragments that are close to intact scrub, but it may not be easily established in restored patches or fragments that are isolated.

Neoseps reynoldsi Stejneger, the sand skink, is a small fossorial sand-swimming lizard restricted to xeric sand pine scrub habitat found along the Lake Wales ridge and other associated ridges in central Florida. In 1987, the sand skink was listed under the Endangered Species Act of 1973 as threatened (USFWS 1987). An immediate threat to sand skink recovery is habitat loss. Scrub habitat is quickly being replaced by increasing development in central Florida, thus further restricting the distribution of the sand skink. Over two-thirds of scrub habitat on the central Florida ridges has been replaced by agriculture and development (Peroni and Abrahamson 1985; Christman 1988). Other anthropogenic forces, such as fire suppression and habitat fragmentation also threaten the future of scrub (Menges

1999). In the remaining scrub habitat fragments, changes in canopy cover and vegetation in overgrown scrub may create unfavorable patches for many species. The remaining small fragments are no longer self-maintaining ecosystems (Myers 1990). Intensive effective management and restoration practices may be required to prevent extirpation of those species restricted to scrub habitats (Hokit et al. 1999). Another management technique is population translocation. Relocation of populations from one area to another is widely used as a "last ditch effort" to preserve populations that would otherwise be extirpated by development (Dodd and Siegel 1991; Platenburg and Griffiths 1999; Fischer and Lindenmayer 2000). The primary purpose of this

Figure 1. Number of individual sand skinks captured per year on Site 1, 1995-2000.

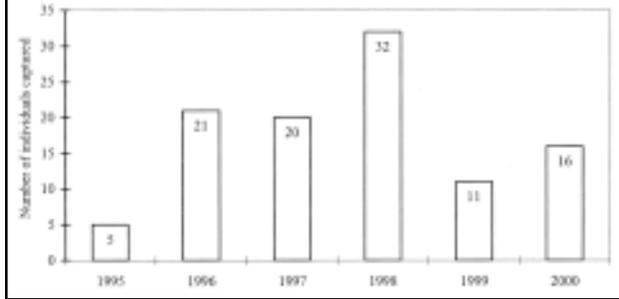
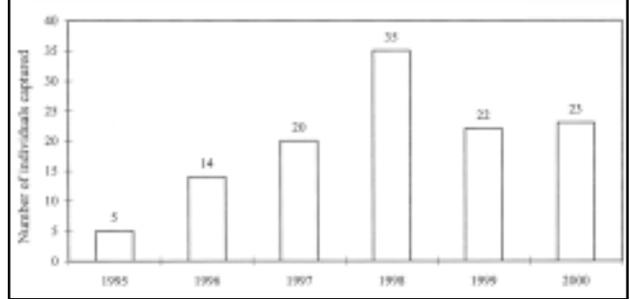


Figure 2. Number of individual sand skinks captured per year on Site 2, 1995-2000.

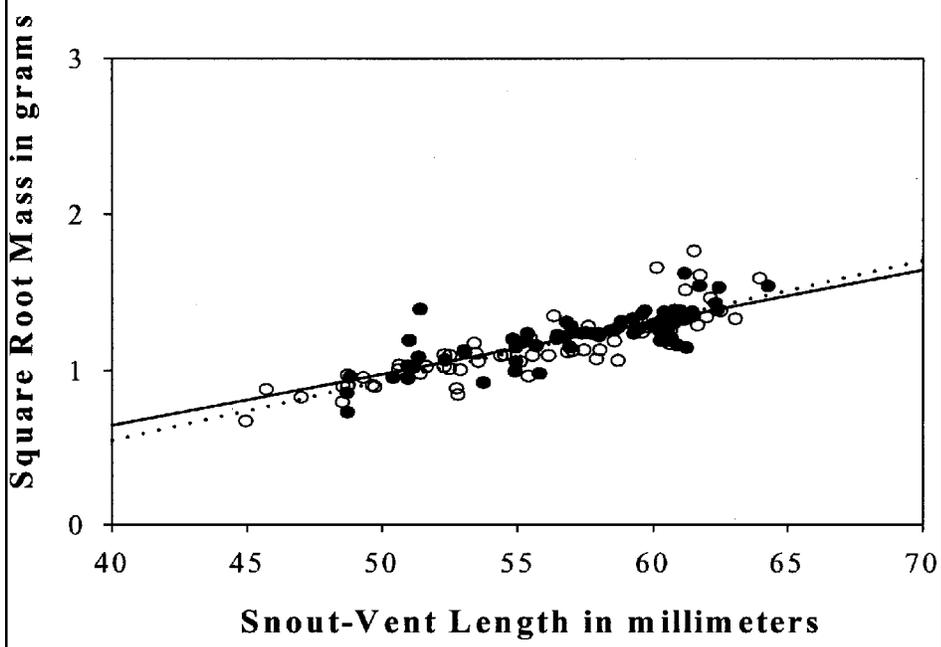


study was to examine the success of translocated populations of the sand skink on two restored scrub sites.

In 1994, 154 sand skinks were released at equal densities in a uniform pattern on two scrub restoration sites. Both scrub restoration sites are contiguous with the Lake Wales Ridge in Orange County, Florida. Prior to restoration, Site 1 (5.46 ha) was an abandoned citrus grove, which had succeeded into an old field community. Site 1 was considered a habitat island. All sides of this created upland are surrounded by mesic habitat and wetland, making it inaccessible to sand skinks. Site 2 (3.44 ha) was an abandoned improved pasture. Site 2 abuts a managed intact scrub on two sides. The translocated populations were monitored from February-May in 1995-2000.

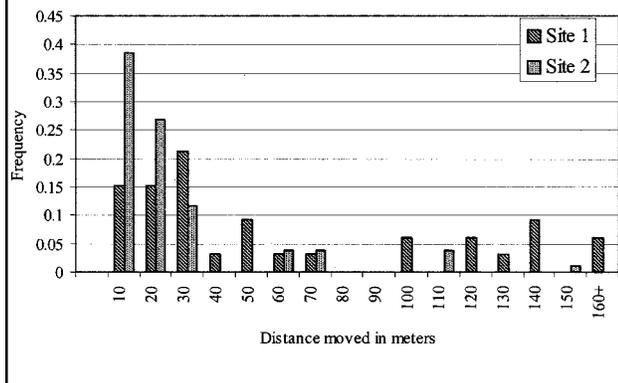
Our results indicate that after 6 years, the translocated sand skink populations have persisted on both sites (Figures 1 and 2). In most years, juveniles were captured, indicating reproduction has occurred during our study. Although both sites were originally stocked at the same density, fewer individuals have been caught on Site 1 than on Site 2 in the last two years of the study. To determine whether this difference was predictive of a long-term difference in translocation success, body condition (mass to snout-vent length) was used to compare possible differences in health of sand skinks within sites across years, and between sites. Differences in body condition for each site between years were assessed comparing regression lines of mass to snout-vent length on each site. The slopes of the lines for total individuals captured (1996-2000) were different ($p < 0.001$), indicating that individuals grew in mass per unit snout-vent length faster on Site 2 than Site 1 (Figure 3). Because numbers of individuals dropped in the last few years of sampling, this difference between sites may have been caused by individuals captured in 1998-2000. We used a subset of data (1998-2000) to examine whether a difference in these years was creating the difference across all years. Regression lines from 1998-2000 were not significantly different. Body condition was then compared between sites for the years 1996-1997. The difference between slopes of

Figure 3. Relationship between SVL and mass for both sites 1996-2000. The solid line and filled circles indicate Site 1. The dotted line and unfilled circles indicate Site 2. Regression line for Site 1: $Y = 0.691 + 0.334X$. Regression line for Site 2: $Y = -1.006 + 0.0387X$. Slopes are significantly different ($p < 0.001$).



of the lines for total individuals captured (1996-2000) were different ($p < 0.001$), indicating that individuals grew in mass per unit snout-vent length faster on Site 2 than Site 1 (Figure 3). Because numbers of individuals dropped in the last few years of sampling, this difference between sites may have been caused by individuals captured in 1998-2000. We used a subset of data (1998-2000) to examine whether a difference in these years was creating the difference across all years. Regression lines from 1998-2000 were not significantly different. Body condition was then compared between sites for the years 1996-1997. The difference between slopes of

Figure 4. Comparison of frequency distribution of distance moved by an individual between Sites 1 and 2. Frequency distributions are significantly different between sites (Kolmogorov-Smirnov 2-sample test, $P < 0.05$).



the regression lines for Site 1 and Site 2 were significantly different between sites ($p < 0.001$). This difference in slope in 1996-97 indicates that in the first few years of this study Site 1 individuals were not gaining mass per unit snout-vent length as quickly as individuals on Site 2. The difference in mass growth per unit length between sites may indicate that Site 1, the isolated site, may not be as suitable for the sand skink as Site 2, which abuts an intact scrub.

We examined dispersal capabilities of the sand skink because natural colonization into restored areas is dependent on its ability to disperse. The sand skink has been thought to have low vagility (Branch et al. 1999), but our results suggest that its dispersal capabilities have been underestimated. The tendency to disperse varies among individuals. Some adult individuals moved long distances (greater than 150 meters). Additionally, individuals tended to move longer distances on Site 1 than on Site 2 (Figure 4). If habitat quality is worse on Site 1 than Site 2, as suggested by the difference in body condition, then it may be that individuals are moving in search of better habitat more often on Site 1 than Site 2. Similarly, Mushinsky and McCoy (1994) found that gopher tortoises (*Gopherus polyphemus*) on habitat islands relocate burrows more often than those found on larger continuous patches.

In conclusion, our results suggest that sand skink translocation can result in populations that persist for at least six years after translocation. Habitat suitability may contribute to whether or not translocated populations persist longer than our study. Also, our results indicate that populations of this threatened species could be established in restored habitat or fragments that are close to intact scrub, but it may not be easily established in restored patches or fragments that are isolated.

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Habitat Characteristics Affecting Use By Florida Mouse (*Podomys floridanus*) Populations and Implications for Scrub Management

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Abstract. The Florida mouse, *Podomys floridanus*, is endemic to sites supporting xeric, fire-dependent communities in peninsular Florida. Scrub communities have been considered primary habitats for *Podomys*, whose distribution is limited in part by a dependence upon gopher tortoise (*Gopherus polyphemus*) burrows, used as sites for its burrows and nests. It has been suggested that habitat structure is an important determinant of habitat suitability for *Podomys*. Although habitat structure and food availability may be linked, habitat suitability may be more dependent upon the availability of food resources. The availability of acorns is likely to be an important determinant of habitat quality for *Podomys*. A diversity of other plant species, especially ground cover species, also may provide important food resources. Sites where habitat structure has been altered by human activities provide an opportunity to evaluate effects of resource abundance on habitat use by *Podomys*. Standard small-mammal live-trapping surveys were conducted on sites in north Florida supporting a range of habitats including oak-dominated scrub, scrubby flatwoods, and pine-oak sandhill. Numbers of *Podomys* were higher on some scrub sites and not correlated with numbers of active tortoise burrows. The capture rate and number of *Podomys* on a mowed sandhill site were similar to levels recorded from some scrub sites. On more typical sandhill sites, numbers of *Podomys* varied with shrub and groundcover diversity. Results indicate management activities increasing plant species diversity or, in sandhill areas, numbers of oaks, may increase *Podomys* numbers. These factors should be considered when developing restoration and ecosystem management plans.

Bug's Eye View of Florida Scrub Biogeography

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Abstract. Animals and plants distribute themselves in the landscape according to their habitat needs and dispersal abilities. The species that are the fussiest about their habitat requirements are not necessarily the best dispersers— in fact, the opposite often seems to be true. The dispersal abilities of insects seem to be influenced by such factors as the long-term persistence of the habitat, and the trouble and expense of (as it were) maintaining a functional airplane in the garage for an organism that walks to work. Scrub insects, because of their diversity of species and lifestyles, help us isolate the factors involved in habitat specificity and endemism. Insects can also reveal previously unknown areas of endemism. They can test our ethics and commitment to the preservation of species, and make us think more deeply about management and restoration of scrub areas.

CHAPTER 5 PLANT DEMOGRAPHY

Comparative Ecology of Florida Scrub Plants

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Abstract. Although all Florida scrub plants have to deal with such ecological realities as harsh soils and intense fires, they exhibit a variety of ecological, demographic, and genetic patterns. Specialization for yellow sands, white sands, or xeric sands occurs in various species, although many scrub plants occur across many soil types. Species differ in microhabitat specialization within soil types, some preferring gaps (scrub balms, also many herbs in rosemary scrub) or recently burned areas (Carter's mustard) or long-unburned areas (ground lichens). Rooting depths vary from shallow (Florida rosemary, palmettos, some herbs) to deep (oaks, other herbs) and this affects species' responses to drought. Most dominants of Florida scrub are long-lived, demographically stable, resprouting shrubs such as clonal oaks, lyonias, and palmettos. Subshrubs and herbs have a variety of life history strategies with respect to fire, including strong resprouting (scrub buckwheat), weak resprouting (scrub blazing star), clonal spread (Chapman's goldenrod), obligate seeding from a seed bank (scrub hypericum), or dispersal from unburned patches (jointweeds). Resprouters may flower immediately postfire (e.g., Chapman's goldenrod) or several years later (e.g., palafoxia, oaks). Most resprouters are also long-lived plants with stable population dynamics and may harbor more genetic diversity than demographically volatile, short-lived, reseeding herbs and subshrubs. However, considerable variation in demographic details exists even within species with similar overall life history traits, leading, for example, to differences in optimal fire return intervals even among rosemary scrub gap specialists. Diversity in postfire recovery modes and flowering patterns, and flexibility within many species, suggests that the fire regime under which these plants evolved includes variation in fire return interval, burn patchiness, and fire intensity. To maintain biodiversity and diversity of functional groups, land managers need to avoid uniform prescriptions and provide spatial and temporal heterogeneity in the fire regime.

Although all Florida scrub plants have to deal with such ecological realities as harsh soils and intense fires, they exhibit a variety of ecological, demographic, and genetic patterns. In this review, I summarize ecological research on Florida scrub plants, with a focus on the work of Archbold Biological Station's Plant Ecology Lab on Lake Wales Ridge endemics.

Florida scrub soils are sands with very low water holding capacities, rapid drainage, and low levels of plant nutrients. They include white sands that often support rosemary scrub, and yellow sands that can support sandhill or scrub. Less excessively well-drained sands have gray horizons and often support scrubby flatwoods. These scrubby flatwoods soils are closer to the water table than true white or yellow sands. The two xeric soil groups are very similar, although xeric white sands may have slightly lower levels of some nutrients than yellow sands.

Preferences for yellow sands (e.g., *Quercus myrtifolia*, myrtle oak, on the Lake Wales Ridge), white sands (e.g., *Ceratiola ericoides*, Florida rosemary), or gray and white sands (e.g., *Q. inopina*, Archbold oak) occur in some scrub dominants, although many scrub plants (e.g., *Q. geminata*, sand live oak) occur in similar proportions across many soil types. The same is true of Florida scrub endemics, which include yellow

sand specialists (e.g., *Dicerandra* spp., scrub mints), white sand specialists (e.g., *Hypericum cumulicola*, Highlands scrub hypericum), and endemics that are soil generalists (e.g., *Nolina brittoniana*, scrub beargrass). More work is needed on Florida scrub soils and their relationships to vegetation.

Species differ in microhabitat specialization within soil types, some preferring gaps (*Dicerandra* spp., also many herbs in rosemary scrub such as *Eryngium cuneifolium*, wedge-leaved button snakeroot) or recently burned areas (*Warea carteri*, Carter's mustard) or long-unburned areas (*Cladonia* spp., ground lichens). Gap specialists may be restricted there by reduced competition, reduced allelopathy, facilitation by soil crusts, adaptation to greater moisture in gaps, or a combination of these and other factors. Poor dispersal in many species may reinforce spatial patterns and create post-fire distributions that reflect conditions before the burn.

Most insect-pollinated Florida scrub plants are serviced by abundant, strong-flying generalist insects. Others are primarily pollinated by a single abundant strong-flying generalist (e.g., *Dicerandra frutescens* by a bee-fly) or by a dependable group of traplining insects (e.g., *Hypericum cumulicola* by solitary bees). In these studied species, there is little evidence that

pollinator service generally limits fecundity or demography. However, long-unburned sites often support sparser plant populations, and the combination of changed habitat structure and low plant density may reduce pollinator efficiency and thus plant fecundity.

Several studies of genetic variation in Florida scrub plants (mainly endemics) have recently been completed. They show that levels of genetic variation are often lower than in comparable groups, although the restricted *Polygonella* spp. (wireweeds) showed high genetic variation relative to widespread relatives. Although levels of genetic variation are low, there seems generally little evidence that genetic factors are playing a primary role in endangerment. An exception is *Ziziphus celata* (Florida Ziziphus), where few genotypes exist and cross-incompatibility among many genotypes may be eliminating seed production in most of the wild populations.

Most dominants of Florida scrub are long-lived, demographically stable, resprouting shrubs such as clonal oaks (*Quercus* spp.), lyonias (*Lyonia* spp.), and palmettos (*Serenoa repens* and *Sabal etonia*). The rapid post-fire recovery in the cover of dominant shrubs is an important characteristic of Florida scrub and key to its management for many organisms. Exceptions include sand pine (*Pinus clausa*) and Florida rosemary, which recover from persistent seed banks in the canopy and soil respectively. Areas dominated by Florida rosemary in particular stay open for far longer than oak dominated areas. Sub-shrubs and herbs have a wider variety of life history strategies with respect to fire, including strong resprouting (*Eriogonum longifolium* var. *gnaphalifolium*, scrub buckwheat), weak resprouting (*Liatris ohlingerae*, scrub blazing star), clonal spread (*Solidago odora* var. *chapmanii*, Chapman's goldenrod), obligate seeding from a seed bank (*Hypericum cumulicola*, scrub hypericum), or dispersal from unburned patches (*Polygonella* spp., wireweeds). Resprouters may flower immediately postfire (e.g., *Liatris* spp.) or several years later (e.g., *Palafoxia feayi*, oaks). Most resprouters are also long-lived plants with stable population dynamics and may harbor more genetic diversity than demographically volatile, short-lived, reseeding herbs and subshrubs.

Many of the obligate seeding species maintain persistent seed banks in the soil. High germination and survival post-fire translates to rapid population increases within the years or decades after fire, before declines in population size begin with habitat closure. These

seeders are especially prominent in rosemary scrub, where the seed bank has considerable overlap with the vegetation. In flatwoods and sandhill, the seedbank is dominated by weedy species and most plants in the undisturbed community persist through fires by resprouting. Scrubby flatwoods life histories are intermediate, with mainly resprouters but a guild of gap specialists, some of which maintain soil seed banks.

However, considerable variation in demographic details exists even within species with similar overall life history traits. For example, resprouting rates among Florida scrub plants varies continuously, from strong resprouters (oaks, *Nolina brittoniana*) to intermediate resprouters (e.g., *Liatris ohlingerae* with about 1/2 resprouting), to weak resprouters (e.g., *Garberia fruticosa* with about 1/4 resprouting) to species that never resprout when burned (*Polygonella* spp.). Likewise, there are considerable differences in optimal fire return intervals even among rosemary scrub gap specialists. For example, *Eryngium cuneifolium* requires fires about every 15 years whereas *Hypericum cumulicola* requires fires about every 30 years to avoid extinction of individual populations.

Fire return intervals of longer than 25 years will certainly threaten the most sensitive post-fire specialists in Florida scrub. Fires more frequent than every 10 years may eliminate Florida rosemary or sand pine before they build up a seed bank. The more open, xeric patches of scrub where Florida rosemary dominates are unlikely to burn more frequently than once per 10 years. The dominant resprouters such as oaks and palmettos are probably resilient to fire over a much larger range of fire return intervals. For some species, such as the endangered perforate lichen *Cladonia perforata*, we still do not understand what fire management is appropriate. But, given the evolutionary history of fire in Florida scrub, it is unlikely that periodic fires will harm any scrub plant species.

Fire intensity effects are poorly known in scrub. Intense fires kill more pine trees than less-intense fires. Rarely, a fire will be so intense in natural scrub to completely kill oaks and palmettos. However, it may be possible to pile fuels in such a way that inter-shrub gaps can be created to restore overgrown scrub. Variation in fire intensity, including unburned patches, will probably be beneficial to the greatest number of scrub plants, including those that are killed by fire but lack

seed banks (e.g., *Polygonella* spp.) and thus must disperse into burned areas from unburned patches.

There is great interest in the use of fire surrogates and pretreatments for fire in vegetation management. Much of this interest is driven by management for a single species: the Florida scrub-jay. However, single species management is probably always a mistake, and we need to evaluate the effects of any management treatment on a range of organisms and processes.

Logging, mowing, roller chopping, and similar treatments are being used to reduce the height of scrub vegetation (a surrogate for burning) and to provide more dependable conditions for burning (as a pretreatment for burning). Some monitoring of effects is being conducted, but more detailed studies are essential. Logging experiments at Ocala National Forest, published by Greenberg and colleagues in a series of papers, provide useful information but could not include a fire-only, unsalvaged treatment. Therefore, departures caused by the use of logging equipment, such as weedy species increases and soil compaction, could not be analyzed.

We hypothesize that mowing or logging, as surrogates will result in a lower number of seedlings of scrub endemics postfire because thatch remaining after the treatment may inhibit seedling emergence. We predict

that mowing or logging, as a pretreatment will result in similar conditions to fire only. However, we expect that there will be reduced variation in fire intensity that may have subtle effects on vegetation recovery. We are evaluating these hypotheses in several experiments in collaboration with the Division of Forestry, the Florida Fish and Wildlife Conservation Commission, the U.S. Fish and Wildlife Service, and The Nature Conservancy.

Small-scale vegetation clipping and litter removal may be an option in intensively managed plant species that would benefit from such treatments. For *Eriogonum longifolium* var. *gnaphalifolium*, clipping individual plants stimulated flowering in much the same way as fire. Litter removal around plants stimulated seedling recruitment, as did fire.

Diversity in postfire recovery modes and flowering patterns, and flexibility within many species, suggests that the fire regime under which these plants evolved includes variation in fire return interval, burn patchiness, and fire intensity. To maintain biodiversity and diversity of functional groups, land managers need to avoid uniform prescriptions and provide spatial and temporal heterogeneity in the fire regime (pyrodiversity).

Population Viability of *Eryngium cuneifolium* in Florida Scrub Under Different Fire Regimes

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Abstract. We modeled demography of *Eryngium cuneifolium*, a Florida scrub endemic. Using 10 annual censuses (1990-1999) of 11 populations at Archbold Biological Station, we built 54 matrices representing different time-since-fire and evaluated twelve fecundity and seed bank scenarios. The stochastic simulation program DISTPROJ was used to obtain estimates of extinction probability under different regular fire intervals. The scenario with high seed bank survival (0.5) and low germination rates (0-0.4) was the best predictor of observed years of peak plant number (8) and aboveground disappearance (30-34). Time-since-fire had major effects on demography. Survival of seedling cohorts recruiting shortly after fire was greater than for later cohorts. Finite rates of increase were > 1 only during the first decade postfire, and decreased with time-since-fire. Elasticities for survival increased with time-since-fire, while other elasticities decreased. Our results indicated that frequent fires with return intervals of 15 years or less are necessary for *E. cuneifolium* persistence. Since rosemary scrub may burn less often, local extinctions and metapopulation dynamics may be the norm for this species. Other rosemary scrub specialists (e.g., *Hypericum cumulicola*) thrive with less frequent fires. Therefore, we suggest that variation in fire regimes will allow co-existence and hedge against local extinctions.

Population Dynamics of the Scrub Lupine and Some Management Implications

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Abstract. Individually marked plants on three soil types in Orange and Polk Counties were counted each month for the last four years. Records for one site extended to 10 years. Recruitment, survival, and reproduction varied among the sites. Up to five generations of lupines may comprise a local population. The major source of mortality for plants more than a year old was a pathogen that caused wilt. However, survival of seedlings was severely impacted by atypical rainfall patterns experienced between 1998 and 2001. Seed banks appeared to be critical to the local success of the scrub lupine. Certain animals may be important as dispersal agents of the seeds. Management of the Lake McLeod Unit of the Lake Wales Ridge National Wildlife Refuge will become critical in the near future as it is the only public site with a relatively stable population of the scrub lupine. Some management options will be outlined.

Effect of Small-Scale Gap Disturbance on the Recruitment of Florida Scrub Herbs

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Abstract. Fires in Florida scrub are large-scale disturbances creating gaps in the shrub matrix. Gaps are often important microhabitats for recruitment of herbaceous plants. Spontaneous seedling recruitment, and survival and recruitment from sown seeds of 7 scrub herbs in natural, artificial aboveground, and artificial belowground gaps were studied. In rosemary scrub and scrubby flatwoods, aboveground gaps were created by clipping vegetation, and belowground gaps were created by removing shrub roots and rhizomes. Soil moisture, soil temperatures, root water retention, and light availability in these gaps were measured. The effect of rainfall intensities on seedling recruitment of each species in the field and lab were tested. Droughts in 2000 and 2001 suppressed natural seedling recruitment. In 2001, watering treatments increased recruitment in gaps and in the lab experiment. Over half of all gaps were colonized; mostly watered belowground gaps in scrubby flatwoods. Overall seedling recruitment in gaps was very low. Spontaneous seedling recruitment was more abundant than recruitment of sown species. Seedlings of locally common gap specialists were most abundant, followed by locally rare gap specialists and generalists. Gap types did not generally differ in abiotic characteristics, suggesting similar recruitment opportunities. Because many gap specialists are endangered plants, understanding how disturbances create microsites for regeneration is critical for conservation of the Florida scrub ecosystem. Recruitment in artificial gaps suggests mechanical treatment could be a potential substitute for fire management, when fire is impossible.

Fires in Florida scrub are large-scale disturbances creating gaps in the shrub matrix and maintaining recruitment of many scrub species through gap dynamics. Gaps also can appear in the scrub also after artificial disturbances, such as periodical road disking or mechanical treatments employed when fire is impossible. Gaps are aboveground openings in the matrix, and in rosemary scrub they extend from one rosemary canopy to the other. However, rosemary roots grow into aboveground gaps, meaning belowground gaps may be smaller than aboveground gaps. Belowground gaps may be also present along roads. Gaps are often important microhabitats for many endangered and endemic Florida scrub herbs, and the patterns of seedling

recruitment in gaps can be driven by several factors, such as conditions in gap microsites or the weather.

I studied seedling recruitment and survival in gaps after fire and after mechanical disturbance, and I explored conditions in gaps to determine if they are favorable microsites for seedling recruitment. I tested the importance of water for seedlings during periods of drought in the scrub.

In a field experiment in two scrub habitats, rosemary scrub and scrubby flatwoods, I created artificial aboveground gaps by clipping all aboveground vegetation. Artificial belowground gaps were made by clipping all shrubs aboveground and removing shrub roots and rhizomes to a depth of 30 cm. Artificial gaps were

round with a diameter corresponding to the median gap diameter of natural gaps in the scrub. In rosemary scrub the gap diameter was 2.5 m and in scrubby flatwoods it was 2 m. I established gaps in January 2000, and added 20 seeds of 6 herb species to the gaps. I monitored seedling recruitment monthly until April 2000. Since the drought in 2000 suppressed germination in the experiment, I performed a watering treatment with half of the gaps watered with approximately 2.5 mm of water twice a week and the other half of gaps left as non-watered control. I watered gaps beginning in December 2000 and added 30 more seeds of each species into each gap. I monitored seedling recruitment and survival weekly until February 2001. In the experiment I examined recruitment of narrowly endemic gap specialists, *Eryngium cuneifolium* and *Hypericum cumulicola*, endemic gap specialists locally abundant in the scrub, *Paronychia chartacea* (added in 2001) and *Polygonella basiramia*. I also used widespread gap specialists, *Balduina angustifolia* and *Lechea deckertii* (which recruited spontaneously), and a guild of gap generalists represented *Liatris ohlingerae* and *Palafoxia feayi*.

In July 2000 and February 2001, I explored microsites for seedling recruitment and survival, and measured soil moisture in gaps, water retained in roots, and light levels in gaps.

In addition to the field watering treatment in December 2000 through March 2001, I conducted an outdoor watering experiment on potted seeds of *Balduina*, *Eryngium*, *Hypericum*, *Paronychia*, *Polygonella*, and *Palafoxia*. Pots were watered with the same amount of water used in the field watering treatment in three frequencies. Pots received water once every two weeks, once per week or twice per week.

In 2000, no seedlings were recruited in the entire field experiment. In 2001, 53.3% of all gaps were colonized and the total number of 544 seedlings recruited in gaps. The seedling recruitment in gaps strongly responded to watering. Average seedling numbers were significantly higher in watered gaps ($p = 0.016$) and recruitment was more frequent (85.1% of all colonized gaps) compared to 14.9% of non-watered gaps with recruitment. Both rosemary scrub and scrubby flatwoods gaps were colonized. Recruitment occurred more frequently in scrubby flatwoods gaps (59.5% of all colonized gaps); however, seedling numbers in these gaps were not significantly different from rosemary gaps. No significant differences in number of

seedlings were found among gap types, but belowground gaps were colonized most frequently (43% of all colonized gaps) and also had the highest seedling numbers, followed by natural gaps (30% colonized gaps) and aboveground gaps (27% gaps colonized).

Spontaneous seedling recruitment was significantly more abundant than recruitment from sown seeds ($p < 0.001$), but was represented by only one species (*Lechea deckertii*). Thus sown species recruited more frequently: 51.7% of all colonized gaps compared to 26.5% of gaps colonized by *Lechea*. Seedling recruitment in the guild of widespread gap specialists was most abundant and frequent; species in this guild occurred in 78.7% of all colonized gaps. Endemic species, locally abundant gap specialists and generalists, each recruited in 30% of gaps, and narrowly endemic species were the least frequent (6.3% of colonized gaps).

Spontaneously recruited *Lechea deckertii* was the most abundant species in the whole study. *Balduina angustifolia* occurred in 44.7% of colonized gaps and was the most abundant of the sown species. Seedlings of *Hypericum cumulicola* were never observed. Survival of seedlings ranged from 30% to 70%, with a species mean of about 50%. However, most of the seedlings survived only in watered gaps.

Seedling recruitment could have been affected by abiotic factors in gaps. Artificial gaps had higher percent soil water than natural gaps and random points in the matrix ($p = 0.026$). Water available for seedlings can become unavailable when roots are present in gaps. Percent water in roots was in average 50 times greater than percent water in soil. Removal of roots from gaps could increase soil water available for seedlings. Higher values of soil moisture in artificial belowground gaps together with abundant seedling recruitment, supports this hypothesis. Belowground gaps received significantly lower light levels compared to natural and aboveground gaps ($p = 0.012$). The combination of higher soil moisture and shading may have provided favorable microsites for seedling recruitment in these gaps.

In the pot watering experiment, *Polygonella basiramia* recruited in all watering frequencies. However seedlings survived only with frequent watering. For the other species, seedlings occurred only with frequent watering, but in very low numbers.

In conclusion, the drought in 2000 and 2001 was the most important factor affecting seedling recruitment in gaps. The potential effects of small-scale gap disturbance on the field seedling recruitment were

overshadowed by the weather. Supplemental watering increased recruitment and survival of seedlings during drought periods in the scrub. Weather may be affecting population dynamics of many Florida scrub herbs among years. Gap effects may differ in non-drought years, but periodic droughts are normal in the Florida scrub.

Seedlings of scrub herbs have the opportunity to recruit in gaps both in rosemary scrub and scrubby flatwoods. Species recruited most frequently in artificial belowground gaps. This result supports observations of high population densities of some scrub herbs such as *Polygonella basiramia* and *Balduina angustifolia* along roads, which are arguably

belowground gaps. Abiotic conditions in gaps were not pronouncedly different in belowground gaps compared to other gap types. Slightly higher soil moisture levels and lower light levels may have contributed to the observed recruitment patterns. Investigation of belowground gaps may help to explain the distribution of Florida scrub species.

Research in artificial gaps determined that mechanical treatments could potentially substitute for fire in small-scale conservation projects, by providing regeneration opportunities for some scrub herbs when prescribed fire is impossible.

Gapology in the Florida Scrub: Incorporating Spatial and Demographic Approaches

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Abstract. Gaps in dominant vegetation are important microhabitats for myriad Florida scrub plants. Gapology is our attempt to integrate spatially explicit data on gaps with the demography of many scrub plants. We define gaps as openings among dominant shrubs (e.g., oaks, rosemary) that may have bare sand, lichens, herbs, or shrub stems less than 50 cm tall. We are locating and measuring thousands of gaps using GPS and ground measurements. In five years, we will re-census these gaps, and derive estimates of gap demography such as “death” of small gaps, shrinkage in gap size, and coalescence and creation of gaps after fires. A number of demographic projects are utilizing this common gapology framework. We are: (1) comparing the importance of gap size on the demography of two Florida scrub endemic plants primarily restricted to gaps in rosemary scrub (*Polygonella basiramia* and *Lechea cernua*) with the demography of two widespread, less specialized congeners; (2) examining the effects of experimental aboveground vs. belowground gaps on seedling recruitment, in rosemary scrub and scrubby flatwoods; (3) using both gap and habitat patch scales to develop a spatially explicit metapopulation model for *P. basiramia*, including measures of subpopulation growth, extinction, and colonization rates, genetic structure, spatial structure, patterns of gene flow, dispersal, and habitat patch quality; (4) examining source-sink dynamics in a population of *Dicerandra christmanii*; and (5) tracking fire-induced temporal and spatial shifts in genetic structure of *Hypericum cumulicola* in a burn unit in which all xeric gaps have been mapped and measured. Our gapology approach integrates spatial and demographic data at population and metapopulation scales to increase our understanding of the ecology and management of Florida scrub plants.

Many Florida scrub plants, including at least six endemics, are found primarily in areas of bare sand, or gaps in the dominant vegetation. The dynamics of these ecologically important gaps in space and time likely affect the population dynamics of the plants that depend on them for habitat. Gapology is our attempt to apply a standardized protocol across studies (examples below) for the characterization and measurement of gaps. The goal of gapology is to link fire models and spatially explicit gap dynamic models to models of the demography and population dynamics of scrub plants.

We define gaps as openings in the matrix of dominant shrubs, usually Florida rosemary (*Ceratiola ericoides*), oaks (*Quercus* spp.), or palmettos (*Serenoa repens* and *Sabal etonia*). Gaps occur in a variety of Florida scrub habitats including the rosemary phase of sand pine scrub (rosemary scrub) and scrubby flatwoods. Gaps can include bare sand, ground lichens, litter, herbs, and/or small woody plants. The boundaries of gaps are delineated by shrubs > 50 cm tall. Small interruptions of < 1 m in the shrub boundary are ignored. Trees (*Pinus elliottii* and *Pinus clausa*) are

not considered to define a gap if the canopy is > 50 cm off the ground. "Islands" of tall shrubs at least 1 m in diameter x 50 cm high are measured and subtracted from the total gap area. Once delineated, we map the edges of gaps with a Global Positioning System (GPS). Finally, we calculate gap area with ArcInfo or ArcView or by direct measurement with tapes for gaps that we estimate are less than approximately 5 m² in area.

Spatial Genetic Structure of Highlands Scrub *Hypericum* Before and After Fire (Menges and Pedro F. Quintana-Ascencio)

Because many scrub plants are found mainly in gaps, gapology will structure not only demographic movements but also the distribution of genetic variation in space. We are examining spatial structure in isozyme variation in *Hypericum cumulicola* in a study at Archbold Biological Station. In a single burn unit, we have identified and mapped 171 gaps, of which 58 support plants. In collaboration with Rebecca Dolan of Butler University, we have determined isozyme genotypes on all 841 plants (1026 samples) in this area at four enzyme loci. We detected one allele previously unsampled in a range-wide survey. Before fire *H. cumulicola* was very rarely found in gaps of < 23 m² and found in all gaps > 210 m². The study site was burned by a wildfire in February 2001. We will sample the new plants recruiting from the soil seed bank following this fire. We will then be able to analyze the distribution of gene frequencies before and after the fire and look for shifts in gene distribution and in the spatial patterns of genetic diversity at a small scale.

Source-Sink Dynamics in *Dicerandra christmanii* (Menges)

At Flamingo Villas (USFWS), we have surveyed all gaps in two areas adjacent to a large firelane population of *Dicerandra christmanii*, an endangered Lake Wales Ridge endemic. Currently, most of the gaps do not have any *D. christmanii* individuals. We will document colonization events into unoccupied gaps, which we hypothesize, are most likely from the firelane source or nearby, occupied gaps. Within the firelane and each occupied gap, we have marked and measured each individual and are conducting a full suite of demographic analyses. We will be able to test the effects of source gap demography on colonization potential. After several years, one of the scrub patches will be burned. All aboveground individuals will be killed in fires, but recovery of the

population from a soil seedbank or from dispersal is likely. We will examine postfire recolonization in formerly occupied and unoccupied gaps as a function of gap size, former occupancy, former fecundity, and position of the gap relative to other occupied gaps. Future demographic rates will be compared to gap size and characteristics.

When Is a Gap Not a Gap? (Petr $\bar{\text{D}}$)

Although aboveground gaps, as we defined them, are easy to identify, belowground gaps (without roots) may be smaller than aboveground gaps but are important as well. Florida rosemary roots can extend over a meter into aboveground gaps. In my master's research, I created gaps aboveground (by clipping vegetation) and belowground (by removing roots and rhizomes). I am monitoring natural seedling recruitment and recruitment from seeds of six Florida scrub species placed into the gaps. I am also studying natural gaps as a comparison (Petr $\bar{\text{D}}$ this volume).

Gap Size Effects on the Demography of *Polygonella* and *Lechea* (Maliakal)

As part of my doctoral dissertation research, I am characterizing the effects of time-since-fire and gap size on the demography of two Florida scrub plants, *Polygonella basiramia* and *Lechea cernua*. Both of these endemic species are predominantly restricted to open sand gaps in rosemary scrub. *P. basiramia* and *L. cernua* have congeners that are more broadly distributed and occur in a wider range of habitats, *P. robusta* and *L. deckertii*. I will compare the demography of *P. basiramia* and *L. cernua* with these habitat-generalist species that co-occur in rosemary-scrub in addition to occurring throughout Florida in sandy habitats such as sandhill, oak-scrub, and scrubby-flatwoods. I am currently collecting data on the growth, survival, and reproduction of individuals of each species in relation to time-since-fire and size of open sand gaps that can be used to determine what conditions are most favorable for persistence of each species. In addition, I am conducting experiments to determine how the growth and survival of seedlings of each species are affected by competition from Florida rosemary (*Ceratiola ericoides*) or presence of ground lichens (*Cladonia spp.*) and litter. Preliminary data suggest that densities of *L. cernua*, *P. basiramia*, and *P. robusta* are higher in large gaps, whereas density of *L. deckertii* is lower in large gaps.

Gap-Mediated Metapopulation Dynamics of *Polygonella basiramia* (Boyle)

The objectives of my doctoral thesis are to characterize metapopulation structure and dynamics of *P. basiramia* and develop management and monitoring protocols to expedite this species' recovery. I am developing a spatially-explicit model simulating metapopulation dynamics by measuring the effects of gap area and isolation on colonization, growth, and extinction rates and on genetic (AFLP) structure, spatial structure, and patterns of gene flow of *P. basiramia* in a network of 1,226 gaps in 19 rosemary patches. In addition, I will examine seed dispersal and postfire recruitment. I will also determine if predictions of metapopulation lifetime and viability differ between ecological and genetic models. I will simulate metapopulation dynamics at two spatial scales: between rosemary balds and within balds (between gaps), in order to estimate which combinations of population and patch densities and proximity best allow for the persistence of *P. basiramia*. Over the first two seasons of this study I observed extinctions of subpopulations in 62 gaps (6%) while 28 other gaps (3%) were colonized, confirming subpopulation turnover at this scale.

Demography of Gaps: Long-Term Mapping and Measurement (ABS Plant Lab)

Although gap presence and gap size are important to many scrub plants, we do not really know when and how

gaps are formed, how fast they shrink, or when they disappear. We have begun a long-term study of gap demography in which we will characterize thousands of gaps across many studies during the next 2-3 years and follow changes in gap size, shape, and landscape position.

By using GPS to measure gap locations, sizes, and shapes, we are able to directly measure the demography of gaps. As shrubs expand between fires, gaps will shrink in size and eventually "die" when they get too small for gap-specialists. With fire, we expect to see coalescence of small gaps into large open areas. Measuring gap demography and its effects on plant species demography will help us better understand the dynamics of rare Florida scrub plants and, ultimately, make more spatially detailed management decisions.

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Integrating Sandhill Restoration with an Experimental Introduction of Florida Ziziphus (*Ziziphus celata*)

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Abstract. Restoration of fire-suppressed scrub and sandhill, and maintenance of healthy populations of their endemic plants continue to be challenges for land managers. We are using field experiments to address the recovery needs of a federally listed endangered plant and to investigate the restoration dynamics of a long unburned sandhill (the USFWS's Carter Creek Tract). Recovery of the narrowly endemic shrub Florida ziziphus (*Ziziphus celata*) requires its introduction to protected habitats. Few studies have investigated the restoration requirements of Lake Wales Ridge sandhill or the fire ecology of its component species. We are proposing an experimental introduction of Florida ziziphus to the Carter Creek Tract integrated with research on the effects of fire and mechanical pre-treatments on long unburned sandhill vegetation. Twelve large treatment blocks will be randomly assigned to one of three treatments: mechanical removal of the subcanopy followed by prescribed burning, burning only, and an untreated control. We will examine establishment success of known seed and seedling genotypes of Florida ziziphus in relation to treatments and microsites. We also will study demographic responses of naturally occurring individuals of other listed plants (e.g., *Prunus geniculata*, *Polygala lewtonii*). Within 120 community plots, we will monitor structural and compositional changes, including pine survival, oak canopy dynamics, and wiregrass cover changes. Our goals are the establishment of a demographically and genetically viable population of Florida ziziphus, insight into its microsite requirements, and the development of practical management tactics for restoring vegetation structure in sandhill.

Two of the challenges faced by resource managers of Florida's xeric uplands are the restoration of fire-suppressed ecosystems and the recovery and maintenance of healthy populations of endemic species. Few studies have investigated the restoration needs of Lake Wales Ridge sandhill or the fire ecology of its component species. This project combines sandhill restoration studies and an experimental introduction of a rare sandhill endemic, Florida ziziphus (*Ziziphus celata*).

Sandhills were once the dominant forest type on the southeastern coastal plain and the second most extensive ecosystem in Florida (2.789 million ha) (Cox et al. 1994). Pre-settlement yellow sand habitats comprised about 87% (255,707 ha) of the 292,645 ha of xeric upland habitats on the Lake Wales Ridge. While not all yellow sand habitats are sandhills—yellow sands also support some types of oak scrub—sandhills occurred along the full extent of the Lake Wales Ridge. Today, only ~15% of the Lake Wales Ridge xeric upland landscape remains. Moreover, there has been a disproportionate loss of yellow sand ecosystems—partly at least because they were favored by the citrus industry. While 61% of white and gray sand habitats—rosemary and oak scrub and scrubby flatwoods—has survived, only 10% of yellow sand ecosystems is extant.

Historically, Lake Wales Ridge sandhills were characterized by an open canopy of longleaf (*Pinus palustris*) or South Florida slash (*Pinus elliottii* var. *densa*) pine, a groundcover dominated by wiregrass (*Aristida beyrichiana*) and other graminoids, high herb

diversity, and by frequent (2-8 yrs) low intensity fire. However, most remaining sandhills are degraded due to logging and decades of fire suppression. Long-unburned sandhills often develop subcanopies of turkey (*Quercus laevis*) and scrub (*Quercus* spp.) oaks (Menges et al. 1993). As these oak subcanopies increase, wiregrass cover declines, interrupting the coverage of fine fuels and making fires patchy and less effective in maintaining the open character and high herb diversity of the sandhill community (Menges 1999).

Restoration of fire-suppressed sandhills requires the reduction of the oak subcanopy to increase light levels and promote wiregrass cover which provides the fine fuels needed to support frequent fire. Increase in fire frequency, in turn, maintains the open character of sandhill and promotes high herb biodiversity. Faced with managing oak-dominated sandhills, fire managers have experimented with mechanical pre-treatments to reduce oak cover, while increasing fuels available to a surface fire. However, these practices have not yet been systematically evaluated in Lake Wales Ridge sandhills. Relevant concerns include the effects of mechanical treatments on pine recruitment, wiregrass cover, and the abundance of listed and indicator sandhill species.

About half of the 22 federally-listed "scrub" plants also occur in sandhills, some preferentially. Scrub plum (*Prunus geniculata*), scrub beargrass (*Nolina brittoniana*) and scrub morning-glory (*Bonamia grandiflora*) occur on both white and yellow sands, while scrub buckwheat (*Eriogonum longifolium* var.

gnaphalifolium) and Lewton's polygala (*Polygala lewtonii*) occur almost exclusively on yellow sands, mainly in sandhills. Relatively few studies have focused on the recovery needs of these sandhill endemics.

One of the rarest and most endangered of the Lake Wales Ridge sandhill endemics is Florida ziziphus (*Ziziphus celata* Judd and D. Hall [Rhamnaceae]), a xeromorphic clonal shrub. Habitat loss and fragmentation have reduced Florida ziziphus to six remnant populations, four of which are found in pastures. However, several lines of evidence indicate that it is a sandhill species: it is known only from yellow sand sites, it appears to be shade-intolerant, it seems to need frequent fire, and both of the remnant natural populations are in sandhill habitats. In addition to the in situ populations, an ex situ population in the Center for Plant Conservation National Collection at Bok Tower Gardens has been maintained for several years. The ex situ population is important because it brings together genotypes from all in situ populations and it is the only sexually reproductive population.

The endangerment of Florida ziziphus is due largely to the genetic consequences of the loss and fragmentation of its habitat. Analyses of allozyme (Godt et al. 1997) and molecular (Weekley et al. in prep.) data concur that the overall adult population comprises only 11 genotypes and that at least half of the remnant populations are uniclinal. Florida ziziphus is self-incompatible (Weekley and Race 2001), and most of the 11 genotypes are also cross-incompatible, owing most likely to the sharing of self-incompatibility (SI) alleles (Weekley et al. in prep.). There may be as few as three SI alleles and two SI mating types among the adult population. Because of high levels of seed abortion and the production of seedless fruits (parthenocarpy), only 20-25% of fruits contains germinable seeds. Thus low genetic diversity and high levels of sterility complicate recovery efforts. Recovery of Florida ziziphus requires the creation of sexually viable populations through the genetic enhancement of existing sterile populations and the establishment of new populations (USFWS 1999).

This project integrates an experimental introduction of Florida ziziphus with an investigation of the restoration dynamics of a long-unburned Lake Wales Ridge sandhill. Our objectives are (1) to assess the community response and the responses of endemic or indicator species to two sandhill restoration techniques; and (2) to establish an experimental population of Florida ziziphus in appropriate protected habitat. The two

restoration techniques are prescribed fire (1) with; and (2) without a mechanical pre-treatment (felling by chain saws) to remove the oak subcanopy (stems between 3 and 8m in height). We will evaluate the effects of these treatments on several key aspects of sandhill vegetation structure (longleaf pine density and recruitment, density of hardwood trees, wiregrass cover, herb diversity and richness) and on the demography of listed and indicator plant species. We will also evaluate the effects of microsite variables (canopy opening, fire intensity, wiregrass cover, and litter cover) and the merits of different translocation techniques (outplanting seedlings vs. sowing seeds) on the establishment of an experimental population of Florida ziziphus.

This project is being conducted at the Carter Creek tract of the US Fish and Wildlife Services' Lake Wales Ridge National Wildlife Refuge. The ~40 ha study site consists of fire-suppressed sandhill dominated by a subcanopy of turkey oak and sand live oak (*Q. geminata*) with scattered patches of dense scrub oaks and a sparse cover of wiregrass. We divided the study area into 12 treatment blocks and assigned each block to one of three treatments: (1) subcanopy removal followed by burning; (2) burning only; and (3) an untreated control. Thus each treatment will have four replicates. Treatment blocks were assigned randomly, but stratified by community traits. Within each treatment block we established six randomly-located circular macroplots (78.5m²)—72 macroplots in all.

We marked the center of each 5m radius macroplot with an aluminum stake and mapped its location with a GPS. Within the macroplot we recorded all vascular plants and terrestrial lichens observed and counted canopy trees—pines and oaks > 8m in height—and subcanopy trees (mostly oaks) between 3 and 8m in height. We used 4m x 1m belt transects along the four cardinal radii to count stems in the shrub layer (oaks, other hardwoods, and palmettos between 0.5m and 3m in height), and we used eight 0.25m radius quadrats to sample the herb layer and the groundcover (stems < 0.5m in height and litter, lichen and bare sand cover).

The macroplots also provide focal points for the transplanting of Florida ziziphus seedlings and seeds. In each macroplot, we will transplant four seedlings propagated at Bok Tower Gardens in yellow sands collected from the introduction site. Seedlings are being genotyped using the RAPD (random amplified polymorphic DNA) technique at the USDA Forest Service Genetics Lab in Mississippi to maximize the likelihood

that cross-compatible mating types will be transplanted to the same macroplots. Forty seeds collected from open-pollinated fruits in the Bok Tower Gardens' ex situ population will also be planted in each macroplot. Twenty seeds will be protected and twenty seeds unprotected from herbivores by wire mesh cages.

Fire intensity during the prescribed burn will be monitored using data-loggers with thermocouples, pyrometers (temperature-sensitive paints on copper tags), and calorimeters (pre-weighed cans with water).

Within the 72 macroplots, we recorded ~ 80 plant species (including ~10 federally or state listed species). Oaks dominated all strata below the sparse longleaf pine canopy (less than two pines per ha). About 40% of subcanopy stems were turkey oaks and a little over 50% were sand live oaks, with myrtle oaks (*Q. myrtifolia*) making up most of the remainder. In the shrub layer, myrtle oak was dominant with about 36% of the stems, followed by sand live oak (25%) and the two palmetto species (*Serenoa repens* and *Sabal etonia*) which together made up about 25% of stems; other hardwoods accounted for the remaining 15%. The herb layer comprised four components: graminoids; shrub seedlings and root shoots; herbs; and others. Overall, 70% of the non-graminoids were shrub seedlings or root shoots (70% oaks, 28% palmettos). Among herbs and others, ~60% of the stems were accounted for by a woody subshrub, gopher apple (*Licania michauxii*), with smaller numbers of herbs (e.g., *Stipulicida setacea*, *Liatris tenuifolia*, *Tephrosia chrysophylla*). Leaf litter accounted for 94% of the groundcover and bare sand for < 6%. Total herb cover was about 8%; graminoid cover alone accounted for almost 2%, about the same as lichen cover.

With high values for subcanopy and shrub layer oak cover and low values for wiregrass cover, the physiognomy of the study site conformed to expectations for a long unburned sandhill community. Post-treatment data will be collected at the end of the first full growing season following the prescribed burn and in subsequent years to evaluate treatment effects on community structure and species composition. We are also tracking the demographic responses and fire ecology of selected endemics and indicator species. For example, to compare the demographics of scrub plum, Lewton's polygala, and scrub buckwheat under the three treatments, we tagged hundreds of plants and collected pre-treatment data on plant size and reproductive activity; to

investigate the microhabitat preferences and (anticipated) postburn recruitment of Lewton's polygala, we will compare pre-and post-treatment cover within quadrats occupied by polygala to randomly-located quadrats lacking polygala.

Translocation of Florida ziziphus will occur as soon as possible following the prescribed burn. Sown seeds and transplanted seedlings will be monitored monthly to record germination, survival, growth and (eventually) reproductive activity. Results of the experimental introduction will provide insight into the microhabitat needs of Florida ziziphus, the relative merits of translocation techniques (sown seeds vs. transplanted seedlings) and guidelines for future introductions.

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CHAPTER 6 PLANT ECOLOGY

Water Use of Eleven Species in the Florida Scrub

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Abstract. This study examines how efficient eleven species in fire-maintained scrub are in their water-use and whether land management practices have an effect on a species' water-use efficiency. The land management practices include scrub that has been subject to prescribed burning, mechanical treatment and prescribed burning, and fire-suppression. Instantaneous water-use efficiency (photosynthesis/conductance) was calculated from light response curves measured for three individuals of each species. An integrated measure of water-use efficiency was also determined for each species. It was found that higher water-use efficiency occurred as a consequence of higher photosynthesis and not decreased stomatal conductance. In fire maintained scrub, the most water-use efficient species comprise the evergreen oaks *Quercus geminata*, *Quercus chapmanii*, *Quercus myrtifolia*, along with the vines *Galactia elliotii* and *Smilax auriculata*. *Ximenia americana*, a parasitic plant, was the least water-use efficient. In general species responded similarly between the three different land management practices: fire maintained, mechanically treated, and fire-suppressed scrub. Five of the eleven species did exhibit significant differences in water-use efficiency between plots. However in most cases only one of the nine plots differed, with no trends being evident among the species.

Introduction and Methods

Florida scrub is a relict ecosystem confined to the droughty and nutrient poor soils of Florida's inland sand ridges and coastal dunes. Due to the xeric nature of scrub, a plant's ability to conserve water may enhance its survival. However a plant conserves water at the expense of gaining carbon, so a balance must be achieved. The objectives of this study are twofold: (1) to determine if dominant scrub species differ in their ability to balance carbon gain and water loss; and (2) to determine if different management treatments affect a species' water use.

This study was conducted at the Kennedy Space

Center (KSC), Merritt Island National Wildlife Refuge (MINWR) on the central Atlantic Coast of Florida. KSC/MINWR contains 1559.2 ha of scrub habitat, the majority (909.2 ha) of which is Oak and Oak-Saw Palmetto Scrub (Schmalzer et al. 1999). Prescribed burning on KSC/MINWR was initiated in the 1980s after twenty years of fire suppression. Restoration of scrub that includes prescribed burning as well as mechanical treatment followed by prescribed burning began in 1992.

Three sites were established on KSC/MINWR in locations where fire suppressed scrub, mechanically treated and burned scrub, and burned scrub occurred in close proximity (Camera Pad Site 28°37.676'N; 80°39.305'W; Kennedy Parkway 28°36.957'N; 80°40.826'W; Happy Creek 28°37.983'N; 80°39.904'W). Plots 30m x 30m were set up in each of the three management treatments for all sites. The eleven most dominant scrub species present in these plots were identified and chosen for inclusion in sampling. Among the dominant species were four evergreen trees (*Quercus chapmanii*, *Quercus geminata*, *Quercus myrtifolia*, and *Myrica cerifera*), four evergreen shrubs (*Lyonia ferruginea*, *Lyonia lucida*, *Vaccinium myrsinites*, and *Ximenia americana*), two vines (*Galactia elliotii* and *Smilax auriculata*), and *Serenoa repens*.

Predawn and midday water potentials were taken using a pressure chamber (PMS Instruments) on three individuals from a subset of six woody species (*Quercus*

Figure 1. Water potentials for six woody species taken at the Camera pad burn plot on 06/15/00. quch = *Quercus chapmanii*, quge = *Quercus geminata*, qumy = *Quercus myrtifolia*, lyfe = *Lyonia ferruginea*, lylu = *Lyonia lucida*, xiam = *Ximenia americana*

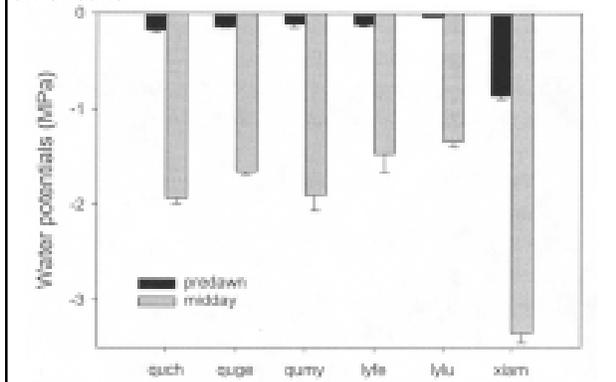


Table 1. Comparison of the dominant scrub species ability to balance carbon gain and water loss.

	Species	A _{max}	A/g	δ ¹³ C
Group 1	<i>Galactia elliotii</i> <i>Quercus chapmanii</i> <i>Quercus geminata</i> <i>Quercus myrtifolia</i>	High (>16 μmols CO ₂ m ² s ⁻¹)	High (60 μmols CO ₂ /mols H ₂ O)	High (>-28.5)
Group 2	<i>Lyonia lucida</i> <i>Serenoa repens</i> <i>Smilax auriculata</i> <i>Myrica cerifera</i> <i>Vaccinium myrsinites</i>	Intermediate (12-16 μmols CO ₂ m ² s ⁻¹)	Intermediate (35-60 μmols CO ₂ /mols H ₂ O)	Intermediate – High (>-31.0)
Group 3	<i>Ximenia americana</i>	Low (>12 μmols CO ₂ m ² s ⁻¹)	Low (<20 μmols CO ₂ /mols H ₂ O)	Low (<-31.0)

chapmanii, *Quercus geminata*, *Quercus myrtifolia*, *Lyonia ferruginea*, *Lyonia lucida*, and *Ximenia americana*) to determine the water status of the plants. Photosynthetic light response curves were measured on three individuals for each species at a plot using the Li-Cor 6400 (Lincoln, NE) portable photosynthesis system. The light response curve provided photosynthesis at light saturation (A_{max}) and conductance at light saturation (g_{max}). These values were used to calculate the instantaneous water-use efficiency (WUE), or the amount of carbon dioxide fixed per amount of water lost:

$$WUE = A_{max}/g_{max} \quad (eq. 1)$$

Mature foliage samples from three individuals of each species at a plot were collected, dried, and ground for carbon isotope (δ¹³C) analysis. These samples were analyzed on a light stable isotope mass spectrometer (EPA, Corvallis, OR).

$$\delta^{13}C_{plant} = \delta^{13}C_{air} - a - (b-a) C_i / C_a \quad (eq. 2)$$

where a is the diffusion of CO₂ in air (4.4 ppm), b is the discrimination of RuBP carboxylase for ¹²CO₂ (30 ppm), C_a is ambient CO₂ concentration, and C_i is internal CO₂ concentration. The carbon isotope ratio (δ¹³C) values provide an integrated measure of water-use efficiency (C_i ~ g/A).

Results and Discussion

The predawn water potentials were close to zero MPa, with the exception of the parasitic *X. americana* which had a predawn water potential close to -1.0 MPa (Fig. 1). This indicates that the plants had adequate exposure to water either in the soil or the ground water. The midday water

potentials were around -1.5 MPa for the shrubs *L. ferruginea* and *L. lucida* and -2.0 MPa for the evergreen oaks (Fig. 1). *X. americana* had a more negative midday potential (<-3.0 MPa), suggesting that it can function at a more negative potential than the other species. The plants are experiencing water stress as seen by the large difference between predawn and midday potentials along with midday stomatal closure (data not shown). Since the predawn potentials indicate that the plants have access to adequate water, the stress is from loss of water through high transpiration most likely due to a high vapor pressure deficit.

Dominant scrub species were found to differ in their ability to balance carbon gain and water loss (Table 1, Fig. 2 and 3). The evergreen oaks (*Q. chapmanii*, *Q. geminata*, *Q. myrtifolia*) and the vine *G. elliotii* are the most water-use efficient of the eleven species studied, whereas *X. americana* is the least water-use efficient.

There were some differences in species ranking between the instantaneous WUE and the integrated WUE (δ¹³C), most notably *S. repens* and *L. lucida* (Fig. 2 and 3). This is not surprising since instantaneous WUE can vary greatly as environ-

Table 2. Plot correlations for δ¹³C. CP = Camera pad, KP = Kennedy Parkway, HC = Happy Creek, b = burned scrub, fs = fire suppressed, mt = mechanically treated.

	CPb	CPfs	CPmt	HCb	HCfs	KPb	KPfs	KPmt
CPb	-----		0.901**	0.829**		0.902*	0.0942**	0.953**
CPfs		-----	0.836*		0.969*			0.891*
CPmt	0.901**	0.836*	-----	0.861**	0.881*			0.937**
HCb	0.829**		0.861**	-----			0.853*	0.922**
HCfs		0.969*	0.881*		-----			
KPb	0.902*					-----		0.866*
KPfs	0.942**			0.853*			-----	0.925**
KPmt	0.953**	0.891*	0.937**	0.922**		0.866*	0.925**	-----

Figure 2. Instantaneous water-use efficiency as a function of maximum photosynthesis at light saturation (A_{max}). A_{max} explained 46.1% of the variation in WUE ($p=0.022$).

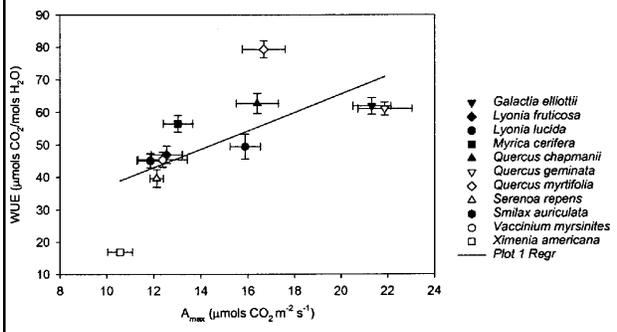


Figure 3. $\delta^{13}C$ as a function of maximum photosynthesis at light saturation (A_{max}). A_{max} explained 31.5% of the variation in $\delta^{13}C$ ($p=0.091$).

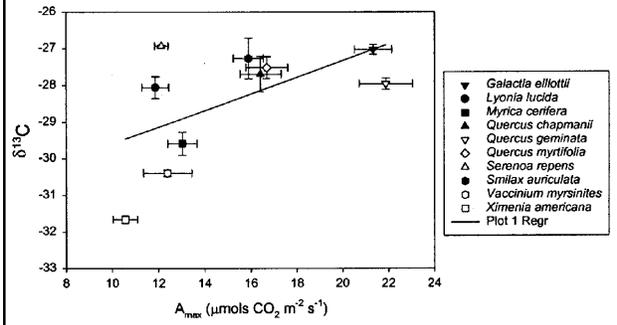
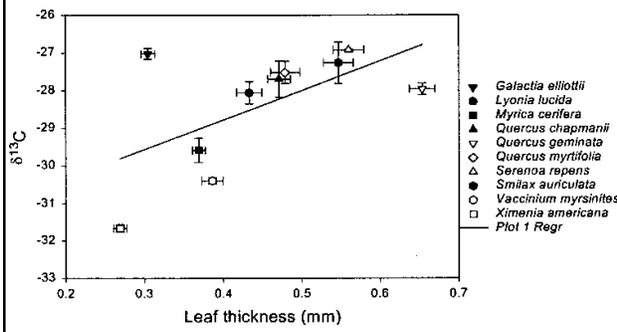


Figure 4. $\delta^{13}C$ as a function of leaf thickness. Leaf thickness explained 31.9% of the variation in $\delta^{13}C$ ($p=0.089$).



m e n t a l conditions change. However over a season WUE should be relatively constant for a species, because the seasonal mean is based on the stomata being fully open since when the stomata are closed photosynthesis is negligible (Jones 1992). Even with these differences, both instantaneous WUE (Fig. 2) and integrated WUE (Fig. 3) are positively correlated with photosynthesis at light saturation (A_{max}). Since all species, with the exception of *X. americana*, have a similar range of conductance, high water-use efficiency is a consequence of

higher photosynthesis and not decreased stomatal conductance.

Integrated WUE ($\delta^{13}C$) is also correlated to leaf thickness (Fig. 4). Those species with thicker leaves tend to be more WUE than species with thinner leaves. The leaves of xerophytic plants tend to have adaptations for conserving water and dealing with high light. These adaptations may include decreased surface area, increased mesophyll concentration, and thicker cuticles.

In general species responded similarly between the three different land management practices: burned scrub, mechanically treated scrub, and fire suppressed scrub. Five of the eleven species (*G. elliptica*, *M. cerifera*, *Q. chapmanii*, *Q. myrtifolia*, and *V. myrsinites*) did exhibit significant differences in integrated water-use efficiency ($\delta^{13}C$) between plots. However in most cases only one of the nine plots significantly differed from the other plots. No trends were evident in determining which plot differed. For example, for *G. elliptica* the Happy Creek fire suppressed site differed from the remaining plots, while for *Q. myrtifolia* the Kennedy Parkway burn plot differed.

Trends were evident when plots were correlated for $\delta^{13}C$ of all species (Table 2). The fire suppressed plots generally did not correlate well with the other plots. The Kennedy Parkway burn plot, which was the most recently burned plot (<12 months since burn), did not correlate well with the other plots. However, there is good agreement in integrated WUE ($\delta^{13}C$) between scrub that has been subject to only prescribed burning and mechanically treated and burned scrub.

The function of balancing carbon gain with water loss did not vary greatly for a species between scrub that was restored using only fire and scrub that was mechanically treated. However fire suppression did have an effect on the functioning of the scrub species, with species in general becoming less water-use efficient in long unburned scrub. Thus the use of mechanical treatment for restoration of scrub at KSC/MINWR appears not to negatively impact a species water use.

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Effects of Hurricane Irene on Mature Sand Pine Scrub in Southeast Florida

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Abstract. The effects of Hurricane Irene on mature sand pine scrub were analyzed in Jonathan Dickinson State Park, Hobe Sound, Florida. Hurricane Irene impacted the southeast coast of Florida on October 15, 1999, with winds > 45 km/hr. Damage from the storm resulted in a loss of 16.2% of the standing trees. Sand pine density decreased from 192 trees/ha to 161 trees/ha after this storm. Bole-snapped trees accounted for the majority of the damage suffered during the hurricane, averaging 24.6 trees/ha. Sand pine regeneration was detected in only 23.7% of the plots and typically was < 3 trees. Additionally, we discovered that an average of 28.7 dead trees/ha existed prior to Hurricane Irene. Following Irene, the live to dead tree ratio was 2.8 to 1.0. Average age of live and Irene-killed sand pines was 51 (n = 38; S.E. = 1.49) and 49 (n = 38; S.E. = 1.28) years, respectively. Using a 1-tailed, paired t-test, no significant difference was detected between the ages of live and Irene-killed sand pines ($t_{37} = 1.69$; $P = 0.15$). One-way analysis of variance comparing plot elevations to the density of live trees ($F_{2,38} = 1.86$, $P = 0.17$), bole-snapped trees ($F_{2,38} = 0.39$, $P = 0.68$), and pre-Irene dead trees ($F_{2,38} = 1.09$, $P = 0.35$) revealed no significant difference for elevation as a proximate cause in the loss of sand pines to high intensity winds from Irene or other factors. Based on these results and wind conditions, hurricane damage in sand pine scrub appears to be limited to tracts of older sand pines and occurs randomly within a stand.

We examined the effects of Hurricane Irene on mature sand pine scrub in Jonathan Dickinson State Park (JDSP), Hobe Sound, Florida. JDSP is located in Martin County (27°00' N; 80°06' W) and represents the largest remaining tract of contiguous scrub in southeast Florida. Hurricane Irene crossed the southern peninsula of Florida from the Gulf of Mexico and began to turn north on October 15, 1999 as it neared the east coast. Winds from Hurricane Irene caused considerable damage to mature stands of sand pine in JDSP. Irene was classified as a Category I Hurricane. Sustained winds from Irene were ca. 120 km/hr as it moved northward from Palm Beach County through Martin County (NOAA 1999).

Mature tracts of sand pine scrub were sampled using the variable radius plot method and a wedge prism (BAF 10). Sampling was conducted systematically along a transect line running south to north through the center of the study area. Plots (n = 38) were located 48.2 m apart at a random distance (3.4 – 30.0 m) to the east or west of the transect line. All sand pines, live and dead, within the variable plots were characterized using a diameter tape (d.b.h.) and 10-factor prism (density and basal area). Average canopy height in each plot was determined using a clinometer. Trees were classified as live, bole snapped (dead), uprooted (dead), downfall mortality (dead), limb damage to > 25% of canopy (live), pre-Irene unknown dead, and post-Irene unknown dead. In each plot, the nearest live and Irene-killed sand pines were cored to examine

the age of the plot. Ages of live and Irene-killed trees were downloaded into Quattro spreadsheets and analyzed using 1-tailed, paired t-tests.

The center of each plot was recorded with a geographical positioning system (Trimble Navigator TDC1) and downloaded into ArcView[®] Geographic Information Systems to examine topographical differences among plots. Plots were characterized as having elevations of 4.3 – 8.5 m, 8.6 – 10.7 m, and 10.8 – 12.5 m. This delineation allowed for the examination of differences among plot elevations for live trees/ha, bole snapped trees/ha, and dead (pre-Irene, unknown) trees/ha using one-way analysis of variance.

Canopy height in the study site averaged 15.4 m (S.E. = 0.3; n = 37; min. = 10.4 m; max. = 18.9 m). Mean d.b.h. was 27.0 cm for live sand pines, 27.3 cm for bole snapped sand pines, 30.8 cm for uprooted sand pines, 27.7 cm for dead (post-Irene, unknown) sand pines, and 19.4 cm for dead (pre-Irene, unknown) sand pines. Average age of live and Irene-killed sand pines was 51 (n = 38; S.E. = 1.49; min. = 21; max. = 61) and 49 (n = 38; S.E. = 1.28; min. = 23; max. = 62) years of age, respectively. No significant difference was detected between the ages of live and Irene-killed sand pines (n = 38; p = 0.15).

Prior to Hurricane Irene, the density of live and dead trees/ha was calculated to be 192 and 29, respectively, with a live to dead tree ratio of ca. 6.5:1.0. Directly after Hurricane Irene, our data indicate that the number of live trees decreased to 161/ha while the

number of dead trees increased to 58/ha with a 2.8:1.0 ratio of live to dead trees. High intensity winds from Irene resulted in the loss of 14.1% of the live trees within the study area in addition to increasing the number of dead trees within the study area by 50%. Post-storm analysis indicated that the canopy composition of sand pine was reduced to 161 live trees/ha, 29 dead (pre-Irene, unknown) trees/ha, 24 bole snapped trees/ha, 4 dead (post-Irene, unknown) trees/ha, and 3 uprooted trees/ha. Bole snapped trees accounted for the majority of tree mortality caused by Hurricane Irene.

Prior to Hurricane Irene, the basal area (BA) for live and dead trees per ha was estimated to be 4.5 and 0.3 m², respectively. Directly after Hurricane Irene, live tree BA/ha decreased to 3.7 m² while BA/ha for dead trees increased to 1.1 m² (e.g., 0.34 m²/ha dead trees pre-Irene and 0.79 m²/ha dead trees post-Irene). High intensity winds from Irene resulted in the loss of 0.67 m²/ha of BA for living trees within our study area.

Wind damage from Irene within the study area was patchy in distribution. No distinctive pattern of damage or mortality to sand pines was detected. Typically, clumps of bole-snapped sand pines were scattered randomly throughout the study area. Overall, 63.2% (n = 24) of the plots we examined contained dead trees. Our results indicate that 44.7% (n = 17) of the study plots experienced direct damage from Irene, while 26.3% (n = 10) of the study area exhibited signs of mortality prior to Irene. Only 7.9% (n = 3) of the plots exhibited signs of damage from Hurricane Irene and prior to Irene. Even with the breakup of the canopy in mature sand pine from past wind disturbances or other events, we observed little regeneration of sand pines within our plots. Young sand pines < 5.1 cm were observed in the close vicinity of 23.7% (n = 9) of the plots, but never accounted for > 3 trees in each plot. No large-scale regeneration was observed in the study area.

Structurally, sand pines in the 20.4 – 25.4 cm d.b.h. class accounted for 30.8% of all living sand pines. Trees between 15.3 - 30.5 cm in d.b.h. accounted for 88.6% of the mortality suffered from Irene. Sand pines within the 15.3 – 25.4 cm d.b.h. range accounted for the highest number of bole snapped trees / ha. Uprooted trees were rare but primarily occurred in the d.b.h. classes > 25.4 cm. Dead (pre-Irene, unknown) sand pines were most commonly observed in d.b.h. classes ranging from 5.2 – 20.3 cm. Major limb damage and downfall

mortality accounted for the least damage from Hurricane Irene. Uprooted trees and trees killed by downfall accounted for 9.0% and 1.2% of the remainder of damage caused by Irene, respectively.

Elevation differences within the study site revealed no significant effect on the number of live and dead trees within the study area. One-way analysis of variance comparing plot elevations to live tree density (F = 1.86; P = 0.17), bole snapped density (F = 0.39; P = 0.68), and pre-Irene dead trees (F = 1.09; F = 0.35) revealed no significant differences. The mean density of live trees/ha was highest at the intermediate elevation (8.6-10.7 m), while the mean density of bole snapped trees was recorded at the lowest elevation (4.3-8.5 m). In addition, the mean density of pre-Irene dead trees was greatest at the highest elevation (10.8-12.5 m). We detected no obvious pattern in the damage caused by Hurricane Irene to mature sand pines at different topographic ranges.

Our results indicate that canopy breakup in mature sand pines in southeast Florida begins at ca. 40 years of age and that scrub succeeds into an evergreen shrub oak community. Along the southeast coast of Florida, high intensity wind events from tropical storms and hurricanes act to accelerate this successional sequence. Observations in nearby sand pine scrub < 25 years old revealed no loss of sand pines from Hurricane Irene. Many of the live and dead trees we aged exhibited signs of heart rot. Tropical storms and hurricanes, combined with heart rot and nutrient poor soils, appear to shorten the life expectancy of coastal sand pines compared to tracts of mature sand pine communities in the interior portion of peninsula Florida. We discovered that high intensity wind events in mature sand pine scrub can result in the loss of > 10% of the living trees, per episodic event, in addition to ca. 2-3% annual mortality from other factors. Our study suggests that as sand pines increase in age, there is a gradual decrease in the density of mature sand pines from various types of disturbances and patchy regeneration.

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Stem Turnover in the Clonal Scrub Oak, *Quercus inopina*, From South-Central Florida

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Abstract. To determine stem longevity, the perimeters of fifty-six stem clusters at nodes on the rhizomes of *Quercus inopina* were outlined with wire flags in four scrub stands at Archbold Biological Station in south-central Florida. Stems in each cluster were identified with sequentially numbered tags. The four stands consisted of adjacent *Quercus inopina*-dominated and *Ceratiola ericoides*-dominated stands at two sites: one long-unburned (>41 years) and one burned 4 yrs previously. Height growth and survival of 429 stems were followed for 9 to 10 yrs, along with that of any new stem sprouts appearing within the perimeters of the marked clusters during this time period. Between 80 and 90% of the initially tagged oak stems died within 10 yrs. These were replaced by new stem sprouts such that the total number of stems at the marked clusters either remained roughly the same (long-unburned stands) or increased (recently burned stands). Median life span of stems was between 3 and 6 yrs. Such rapid stem turnover, combined with its leaf morphology, make *Q. inopina* vulnerable to being shaded out by competing species. Increased drought stress in winter, compared to more northern and coastal scrubs, may contribute to its success on the Lake Wales Ridge of Florida by slowing the growth of competing shrubs.

Rare Plant Species and High Quality Natural Communities of Twenty-Six CARL Sites in the Lake Wales Ridge Ecosystem

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Abstract. The Lake Wales Ridge contains an extremely high concentration of listed plant and animal taxa. Its best remaining habitat has been designated for protection as the Lake Wales Ridge Ecosystem (LWRE) Project by the Conservation And Recreational Lands (CARL) program of Florida Department of Environmental Protection. These disjunct remnants of primarily scrub and sandhill natural communities are all that remain due to development for residential, agriculture, or other uses. Ecological surveys were conducted on twenty-six of the LWRE CARL sites by the Florida Natural Areas Inventory in Lake, Osceola, Polk, and Highlands counties during the period from October 1997 to November 1998. Data were collected on the current status of 34 listed plant species and their natural communities, with incidental observations on 15 listed animal species. Descriptions for each site discuss natural community conditions, observed species populations, and recommendations on management and acquisition.

The United States Fish and Wildlife Service (USFWS) provided funding to the Florida Natural Areas Inventory (FNAI) to conduct ecological surveys of twenty-nine Conservation and Recreation Lands (CARL) sites on the Lake Wales Ridge. These sites in Lake, Osceola, Polk, and Highlands counties, Florida, are designated as the Lake Wales Ridge Ecosystem (LWRE) project by the CARL Program of the Florida Department of Environmental Protection. Field surveys were conducted to provide current information on listed plant species and their natural communities. Data were also gathered on listed animal species that were incidentally observed during the survey. The FNAI statewide database was used to map, store, retrieve, and analyze the data and combine them with historical information. Results of this survey were

designed to facilitate management and guide future acquisitions at each site.

Twenty-six of the LWRE sites were surveyed during the period from October 1997 to November 1998. The surveys were conducted over a one year period so that each species could be observed during their optimal season (each site had at least one spring and one fall visit). We were unable gain access to the Ridge Scrub and McJunkin Ranch sites, and the Highlands Park Estates site was deemed too developed to warrant a survey. Information for each surveyed site is summarized in the text of the report, including descriptions of the site and natural communities, observed listed species, and recommendations on management and acquisition. Data on 34 plant and 15 animal rare or listed taxa were collected and updated in the FNAI database, with every site containing multiple listed

Table 1. Element rank, status, and occurrence data for 34 rare plant species found on 26 Lake Wales Ridge Ecosystem (LWRE) sites. All FNAI Element Occurrence Record (EOR) data are current as of September 1999.

Rare Plant Species	FNAI Global/State Rank	Federal/State Legal Status	EORs in FL	# (%) EORs on managed areas	EORs on LWRE sites	LWRE sites with species
<i>Asclepias curtissii</i>	G3/S3	N/LE	141	60 (43%)	28	17
<i>Bonamia grandiflora</i>	G3/S3	LT/LE	95	30 (32%)	25	14
<i>Calamintha ashei</i>	G3/S3	N/LT	73	31 (42%)	20	11
<i>Chionanthus pygmaeus</i>	G3/S3	LE/LE	56	17 (30%)	18	10
<i>Cladonia perforata</i>	G1/S1	LE/LE	26	17 (65%)	1	1
<i>Clitoria fragrans</i>	G3/S3	LT/LE	68	32 (47%)	18	12
<i>Conradina brevifolia</i>	G2Q/S2	LE/LE	35	10 (29%)	9	3
<i>Crotalaria avonensis</i>	G1/S1	LE/LE	4	2 (50%)	2	2
<i>Dicerandra christmanii</i>	G1/S1	LE/LE	6	2 (33%)	4	2
<i>Dicerandra frutescens</i>	G1/S1	LE/LE	12	3 (25%)	2	2
<i>Eriogonum longifolium</i> var. <i>gnaphalifolium</i>	G4T3/S3	LT/LE	101	57 (56%)	17	12
<i>Eryngium cuneifolium</i>	G1/S1	LE/LE	20	8 (40%)	5	3
<i>Gymnopogon chapmanianus</i>	G3/S3	N/N	31	22 (71%)	2	2
<i>Hypericum cumulicola</i>	G2/S2	LE/LE	76	32 (42%)	24	10
<i>Hypericum edisonianum</i>	G2/S2	N/LE	25	11 (44%)	2	2
<i>Ilex opaca</i> var. <i>arenicola</i>	G5T3/S3	N/N	110	41 (37%)	35	16
<i>Illicium parviflorum</i>	G2/S2	N/LE	20	16 (80%)	2	1
<i>Lechea cernua</i>	G3/S3	N/LT	164	52 (32%)	24	10
<i>Lechea divaricata</i>	G2/S2	N/LE	13	8 (62%)	2	1
<i>Liatris ohlingerae</i>	G3/S3	LE/LE	107	39 (36%)	34	15
<i>Lupinus westianus</i> var. <i>aridorum</i>	G2T1/S1	LE/LE	43	5 (17%)	3	2
<i>Nolina brittoniana</i>	G2/S2	LE/LE	95	30 (32%)	36	22
<i>Panicum abscissum</i>	G3/S3	N/LE	62	47 (76%)	11	8
<i>Paronychia chartacea</i> ssp. <i>chartacea</i>	G3T3/S3	LT/LE	141	55 (39%)	43	19
<i>Persea humilis</i>	G3/S3	N/N	243	79 (33%)	41	21
<i>Polygala lewtonii</i>	G2/S2	LE/LE	39	16 (41%)	12	10
<i>Polygonella basiramia</i>	G3/S3	LE/LE	142	61 (43%)	42	17
<i>Polygonella myriophylla</i>	G3/S3	LE/LE	124	38 (31%)	44	16
<i>Prunus geniculata</i>	G2G3/S2S3	LE/LE	114	35 (31%)	34	21
<i>Salix floridana</i>	G2/S2	N/LE	14	9 (64%)	1	1
<i>Schizachyrium niveum</i>	G1/S1	N/LE	48	17 (35%)	18	10
<i>Stylisma abdita</i>	G2G3/S2S3	N/LE	41	13 (32%)	10	9
<i>Warea amplexifolia</i>	G1/S1	LE/LE	21	3 (14%)	6	6
<i>Warea carteri</i>	G1G2/S1S2	LE/LE	36	25 (69%)	8	5

species. Field data also included species lists of all plants identified for each natural community. More than 870 Element Occurrences (EOs) for rare plants and animals and exemplary natural communities were documented on LWRE sites; additional EOs were documented from adjacent areas recommended for addition to the CARL sites. EO Records are included as appendices to the report.

The importance of the LWRE to rare plant conservation in Florida—and globally—cannot be overstated. Table 1 presents the number of occurrences of 34 rare plant taxa found on LWRE and compares it with the total number in Florida. Protected populations of rare species are represented by the number of occurrences on managed areas. Table 2 provides a matrix that allows the reader to determine how many EOs of each rare plant taxa occur at each site. The distribution of taxa along the Ridge can be seen as the sites are arranged in a generally north to south order. These data may be used to help prioritize site acquisition based on plant protection needs.

Acquisition of LWRE sites is absolutely critical to the survival of some species, such as *Crotalaria avonensis* and *Dicerandra christmanii*. For another 18 species, the LWRE sites support between 25-50% of all known populations. Some taxa, such as *Polygonella basiramia* and *Polygonella myriophylla*, are shown by these results to be relatively secure. *Ziziphus celata*, critically imperiled, was not found on the LWRE sites.

FNAI recommends that *Hypericum edisonianum* and *Schizachyrium niveum*, both with low numbers of occurrences and few protected populations, be proposed for federal listing. *Liatris ohlingerae* is currently listed by USFWS as Endangered. It is found at more than 100 locations on the Lake Wales Ridge, with 39 populations occurring on 15 different managed areas. FNAI recommends down-listing this species to Threatened. *Paronychia chartacea ssp. chartacea* is currently listed by USFWS as Threatened. It is found

at over 140 locations in central Florida; 55 of these populations are on at least 16 different managed areas. This subspecies is more abundant and secure than previously believed. FNAI recommends that this subspecies be considered for de-listing. *Polygonella basiramia* and *Polygonella myriophylla* are listed as Endangered by USFWS. FNAI recommends that both species be down-listed to Threatened. Both are found at well over 100 locations, with 43% and 31%, respectively, occurring on managed areas. Many of the unprotected populations occur on LWRE sites which are candidates for acquisition. *Prunus geniculata* is listed as Endangered by USFWS. It occurs at 114 locations, with 35 of these on managed areas. An additional 35 occurrences are found on unprotected LWRE sites which may be acquired. FNAI recommends down-listing this species to Threatened.

As a result of the data gathered during this survey, FNAI made the following changes in its tracking list and to the global and state ranks of the following species: *Asclepias curtissii*-removed from tracking list; *Cladonia perforata*- changed ranks from G1/S1 to G2/S2; *Ilex opaca var. arenicola*- removed from tracking list; *Lechea cernua*- removed from tracking list; *Nolina brittoniana*- changed ranks from G2/S2 to G3/S3; *Persea humilis*- removed from tracking list; *Prunus geniculata*- changed ranks from G2G3/S2S3 to G3/S3; *Stylisma abdita*- changed ranks from G2G3/S2S3 to G2/S2; *Warea carteri*- changed ranks from G1G2/S1S2 to G2/S2.

Numerous surveys have been carried out on the LWRE by biologists from FNAI, The Nature Conservancy, and government and private research institutions over the last two decades. This survey is another building block in our growing knowledge of the Lake Wales Ridge Ecosystem. Much more information will be discovered as each site is more intensively surveyed. We still have a long way to go in learning about what is on the Lake Wales Ridge and how to best manage for it.

Table 2. Number of FNAI Element Occurrence Records for 34 rare plant species found on 26 Lake Wales Ridge Ecosystem sites (data are current as of September 1999). Sites are arranged from north to south.

LWRE SITES <i>Plant species</i>	Sugar loaf Mtn	Fern dale Ridge	Castle Hill	Flat Lake	Schofield Sandhill	Lake Daven port	Horse Creek Scrub	Lake Blue	Eagle Lake	Lake McLeod	Mtn Lake Cutoff	Hespe rides	Lake Walk in Water	Sunra yHick ory L	Trout Lake	Avon Park Lakes	Silver Lake	Carter Creek	Fla mingo Villas	Hen scratch Jack Cr	Lake Ap thorpe	Holmes Ave	Sun 'n Lakes South	Lake June West	High lands Ridge	Gould Road	Total EORs
<i>Asclepias curtissii</i>							2	1	1	1		2		3	1	1	3	4	1	2	1	1		1	2	1	28
<i>Bonamia grandiflora</i>		1		1			2	2		1	1	3	4	3	1	1		2	2		1						25
<i>Calamintha ashei</i>												1		4		1	2	1		1	1	1		2	5	1	20
<i>Chionanthus pygmaeus</i>		1					2		1			1	2	4		1	2	3	1								18
<i>Cladonia perforata</i>																1											1
<i>Clitoria fragrans</i>				1				1			1	2	3	1	1	1		3	1		2	1					18
<i>Conradina brevifolia</i>														4		1	4										9
<i>Crotalaria avonensis</i>																1		1									2
<i>Dicerandra christmanii</i>																		1	3								4
<i>Dicerandra frutescens</i>							1																1				2
<i>Eriogonum longifolium</i> <i>var. gnaphalifolium</i>	1	1	1	1		1	1					1	3			1		3	2		1						17
<i>Eryngium cuneifolium</i>																					3	1				1	5
<i>Gymnopogon chapmanianus</i>							1					1															2
<i>Hypericum cumulicola</i>														2	1	1	3	4			4	1		2	5	1	24
<i>Hypericum edisonianum</i>																						1	1				2
<i>Ilex opaca var.</i> <i>arenicola</i>							2	1		1		4	2	4		1	4	3		2	3	1	1	3	2	1	35
<i>Illicium parviflorum</i>							2																				2
<i>Lechea cernua</i>						1		2	1	1				2			2			5		1		3	6		24
<i>Lechea divaricata</i>																				2							2
<i>Liatris ohlingeriae</i>								2				3		4	1	1	2	2	1	4	2	2	1	3	5	1	34
<i>Lupinus westianus var.</i> <i>aridorum</i>									2	1																	3
<i>Nolina brittoniana</i>	1	1	1			1	1	2	1	1	1	4	3	4	1	1	1	4		1	2	1		1	2	1	36
<i>Panicum abscissum</i>												2		1	1	1		2		1	2	1					11
<i>Paronychia chartacea</i> <i>ssp. chartacea</i>		1			1	1	2	2		1	1	3		5		1	2	2	2	5	4	2		3	4	1	43

LWRE SITES Plant species	Sugar loaf Mtn	Fem dale Ridge	Castle Hill	Flat Lake	Schofield Sandhill	Lake Davenport	Horse Creek Scrub	Lake Blue	Eagle Lake	Lake McLeod	Min Lake Cutoff	Hespe rides	Lake Walk Water	Sunra Hick ory L.	Troat Lake	Avon Park Lakes	Silver Lake	Carter Creek	Villas Cr.	Hen Jack Cr.	Lake Ap thorpe	Holmes Ave	Sun 'n Lakes South	Lake Jame West	High lands Ridge	Gould Road	Total EORs
<i>Persea humilis</i>					1		2	2	1	1	1	3	4	4	1	1	2	3	2	1	3	1	1	3	3	1	41
<i>Polygala lewtonii</i>	1	1	1	1	1	1	1					1	3														12
<i>Polygonella basiramia</i>								2	1	1	1	4		4	1	1	4	3		5	4	2	1	3	4	1	42
<i>Polygonella myrtophylla</i>								2		1		5		5	1	1	4	3	2	5	3	1		3	6	1	44
<i>Prunus gemiculata</i>										1		4	3	3	1	1	1	4	1	2	2	1		2		1	34
<i>Salix floridana</i>																											1
<i>Schizachyrium niveum</i>											1	2		2	1		3			2	1	1		4	1	18	
<i>Stylisma abditia</i>										1	1	1	1	1	1	1	2							1		10	
<i>Warea amplexifolia</i>																											6
<i>Warea carteri</i>													2														8
Total plant EORs by site	5	10	5	6	5	7	23	20	8	12	8	47	30	60	13	20	36	56	18	38	39	20	6	29	49	13	583

CHAPTER 7 PROGRAMS AND POLICY

Natural Areas Training Academy

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Abstract. The Natural Areas Training Academy offers training workshops that provide managers with up-to-date skills and information to help them manage Florida's natural areas to ensure protection over the long-term. This presentation will focus on the Academy's Certificate in Natural Areas Management as well as other products currently in development.

The Natural Areas Training Academy was created by The Nature Conservancy in partnership with Valencia Community College and the University of Florida, Institute for Food and Agricultural Sciences (IFAS). Representatives from several state and county land management agencies serve on an advisory committee to ensure relevance and quality in the Academy's programs. The Certificate in Natural Areas Management program provides the basic, practical skills needed to effectively manage Florida's natural areas. The program consists of five workshops designed and delivered by a team of experienced public and private natural areas managers. All five workshops emphasize current conservation management practices and hands-on learning. Upon completion of the five workshops the certificate is conferred by IFAS, Center for Natural Resources.

A total of 139 participants, representing a diversity of public agencies and private companies, completed the workshops up to May 2001. Eight participants had satisfied all requirements to earn the Certificate in Natural Areas Management. Two of these "graduates" work for the Florida Department of Environmental Protection, four for County land management agencies, one for an environmental consulting firm and one is a private land owner. Interest in the academy is high as measured by both inquiries for further information and the number of participants who have expressed their commitment to complete the Certificate series next year.

The academy will enter its second year with one major change to the Certificate program: the requirement for fire training will be achieved by completing Introduction to Fire Effects. This will allow staff to provide participants with a superior level of training about fire ecology rather than just basic crew training.

The other four certificate workshops will be modified to varying degrees to account for some excellent evaluative comments made by participants. The most dramatic of these will be the lengthening of the workshop titled Achieving Ecosystem Management Through Interagency Teamwork from two days to three.

The participants in the workshops represented the following public and private entities:

- State agencies - 6
- Federal agency - 1
- County agencies - 9
- Private companies - 9
- Private land owners - 3
- City parks and recreation program - 1
- State universities - 3
- Soil and water conservation district - 1

Instructors involved in the workshops represented the following organizations:

- The Nature Conservancy - 20
- University of Florida - 5
- University of Central Florida - 2
- Department of Environmental Protection - 4
- Florida Division of Forestry - 2
- Archbold Biological Station - 3
- Brevard County Parks - 1
- Orange County - 1
- Hubbs Sea World Institute - 1
- South Florida Water Management District - 1
- St. John's River Water Management District - 1

For more information about the academy go to www.cnr.ifas.ufl.edu/programs and click on the academy icon.

Fire in Florida's Ecosystem

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Abstract. The preservation of scrub communities around Florida not only hinges on protection and acquisition but also on continued prescribed fire management supported by an educated public. "Fire in Florida's Ecosystems" is one such education program that is teaching Floridians about fire. "Fire in Florida's Ecosystems" is a program being funded by the Florida Division of Forestry that will, over the next two years, train educators in Florida about fire and its benefits along with distributing instructional materials for classroom implementation. The training has been tailored for different ecosystems, including scrub, and trainees have had the opportunity to visit scrub to see first-hand the benefits of fire. During the presentation, data will be presented about the changes in knowledge and attitudes of trainees as a result of the training. In addition, "Fire in Florida's Ecosystem" materials will be displayed and demonstrated.

The Florida Scrub-Jay Fire Strike Team: Working Together to Burn the Overgrown Scrub

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Abstract. The Florida Scrub-Jay Fire Strike Team is a short-term emergency effort to reduce the backlog of unburned scrub that threatens the survival of the Florida scrub-jay and 23 other federally listed species. The five-year goal of the team is to assist managers of public and private conservation land to conduct 150 prescribed burns in overgrown uplands in Polk, Highlands and Brevard Counties. Two of the state's largest concentrations of Florida scrub-jays occur in these counties. A benefit of prescribed burning hazardous scrub fuels is improving public safety in the wildland-urban interface. The Fire Strike Team serves as a mobile, supplemental resource to agency fire managers who plan and boss the burns on their properties. The team moves from site to site as weather and site readiness permit. The team consists of two professional fire staff and a coordinator from The Nature Conservancy and four seasonal fire crew members. The team is outfitted with two Type 6 wildland fire engines and one outfitted ATV. To date, land managers from eight organizations have requested the team's assistance in burning 74 burn units on 27 scrub sites, encompassing 11,235 acres. Extended drought has hampered prescribed burning during the first two years, but 18 prescribed burns have been accomplished. When the team cannot burn, it serves as a hand crew to assist managers with fireline preparation and removal of woody cover, in preparation for later prescribed burning. In periods of extreme fire danger, the team has assisted the Division of Forestry with wildfire suppression. Led by the U.S. Fish and Wildlife Service, seven funding partners have supported the Fire Strike Team. Wildfire suppression activities were funded separately by the Division of Forestry. The team's work is guided by an interagency steering committee, consisting of 14 experts in fire management, Florida scrub-jays, and scrub conservation.

Fish and Wildlife Service Landowner Incentives Programs

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Abstract. The Fish and Wildlife Service currently has 7 partnership programs providing matching federal funds for various conservation efforts. Development and implementation of Candidate Conservation and Safe Harbor Agreements, habitat acquisition associated with Habitat Conservation Plans, habitat acquisition for recovery of federally listed species, and conservation incentives for private landowners are emphasized within these programs. A total of about \$68 million is available nationally on a competitive basis for these programs in FY 2000-01.

The Endangered Species Act (ESA) of 1973 mandates the U.S. Fish and Wildlife Service to list, protect, and recover species. Until recently, protection of threatened and endangered species, relied heavily on enforcement under section 9 of the ESA by the Fish and Wildlife Service. Over the years, this regulatory tactic has resulted in increasing public resentment and a corresponding mistrust by the public for the Service. Thus, conservation of federally listed species by regulation has become politically unfavorable and increasingly difficult.

In recent years, it has become evident that the conservation and recovery of federally listed species must rely, in part, on private landowners since many threatened, endangered and other rare species occupy habitat on private lands. Without landowner participation in conservation efforts, the long-term prognosis for many federally listed species is not good.

To encourage private landowner participation in listed species conservation, the Service has initiated several programs that provide for greater regulatory flexibility and certainty. These programs also offer financial incentives to encourage private landowner-based conservation efforts. Currently, the Service offers seven conservation programs for willing private landowners. Five of these programs are funded through grants to States and Territories who in turn provide the funds to private landowners. These include Safe Harbor, Candidate Conservation, Recovery Land Acquisition, Habitat Conservation Plan, and Habitat Conservation Plan Land Acquisition grant programs. The Endangered Species Landowner Incentives and Partners for Fish and Wildlife programs offer competitive matching funding opportunities to private landowners. These two grant programs are funded directly by the Service. Each of the seven conservation grant programs employs a different conservation tactic, addresses

different categories of listed species and/or funds varying conservation strategies. These are summarized below.

Safe Harbor

The Safe Harbor program relies on voluntary commitments of private landowners to implement conservation actions for listed or candidate species on their properties. A Safe Harbor Agreement is mutually agreed to by both the landowner and the Service for a specified period of time during which the landowner implements their prescribed conservation actions. In return for their commitment to conduct these conservation measures, the Service provides landowners assurances that no new additional regulatory burden will be realized in the future. Importantly, the landowners retain responsibility for any species or habitat present at the time they entered the Safe Harbor Agreement. Additional habitat or individual animals resulting from the landowners conservation actions may be taken at the termination of the Safe Harbor Agreement with no additional regulatory burden. Matching funding is available to assist landowners in developing and implementing Safe Harbor Agreements. Local, County, and State government grant applications are also considered under this program. In fiscal year 2000-01, \$5 million were available nationally under the Safe Harbor grant program.

Candidate Conservation

The Candidate Conservation program is similar to the Safe Harbor program except that only species that are candidates or proposed to be federally listed are covered by this program. The Candidate Conservation program seeks to conserve candidate and proposed species on private lands so that the need to list them as threatened or endangered in the future can be avoided. Generally, large-scale or umbrella agreements are sought that programmatically cover a large number of

landowners. Like Safe Harbor, funding is available for the development and implementation of Candidate Conservation Agreements. Local, County, and State government grant applications are also considered under this program. In fiscal year 2000-01, \$5 million were available nationally under the Candidate Conservation grant program.

Recovery Land Acquisition

This program provides matching funds to private landowners to protect habitat for federally listed species. Grants target habitat acquisition needs addressed in approved recovery plans. Local, County, and State government grant applications are also considered under this program. In fiscal year 2000-01, \$11 million were available nationally under the Recovery Land Acquisition grant program.

Habitat Conservation Plan

Landowners considering the development of a Habitat Conservation Plan under section 10 of the Endangered Species Act may apply for matching funds to assist in the planning, development, and implementation of the Plan. Local, County, and State government grant applications are also considered under this program. During fiscal year 2000-01, \$7 million were available nationally.

Habitat Conservation Plan Land Acquisition

Landowners who develop Habitat Conservation Plans as part of the Endangered Species Act section 10 permitting process can apply for grants to purchase habitat for threatened and endangered species covered under the section 10 permit. Funding under this program is intended to augment mitigation provided by the landowner and cannot be used as a source of money to meet the mitigation needs of the permit. Local, County, and State government grant applications are also considered under this program. During fiscal year 2000-01, \$40 million were available nationally under the Habitat Conservation Plan Land Acquisition grant program.

Endangered Species Landowner Incentives

The Landowner Incentives program provides matching funding for a wide variety of conservation efforts undertaken by private landowners. Actions that conserve listed, proposed, candidate species, and species that are likely to become candidates in the near future are emphasized under this grant program.

Local, County, and State government grant applications are not considered under this program. During fiscal year 2000-01, \$4.025 million were available nationally under the Endangered Species Landowner Incentives grant program.

Partners for Fish and Wildlife

This well established grant program provides funds to landowners to conserve federal trust resources, which include threatened and endangered species and migratory birds. Matching grants are typically provided for the enhancement and restoration of habitat for these species. Funds are also provided for the enhancement and restoration of wetlands. Local, County, and State government grant applications are considered under this program, but private landowners are emphasized. During fiscal year 2000-01, the Partners for Fish and Wildlife program in Florida provided \$251,000 for 24 conservation projects.

The prognosis for the Fish and Wildlife Service's landowner incentives programs is not certain. The changing political atmosphere has created uncertainty regarding the future of several of these grant programs. While we are generally optimistic that the new administration will be supportive of efforts to include the private sector in our conservation efforts, we do not know exactly which programs will be emphasized. Preliminary indications are that the Endangered Species Landowner Incentives program will not be continued in fiscal year 2001-02, but the conservation intent and funding for that program are expected to be transferred to an undefined new program. Similarly, it appears that the Safe Harbor and Candidate Conservation grant programs will not be funded in fiscal year 2001-02, but the program structure for these two will remain in place should future funding become available.

The success of the Service's conservation incentives programs will be dependent to a large extent on the acceptance and demand for these programs by private landowners. Large-scale conservation programs previously instituted by the Natural Resource Conservation Service (NRCS) through the Farm Bill show just how well Federal grant programs can work towards achieving conservation. While the NRCS example tells us that agricultural activities and conservation work well together, only time will tell whether conservation through the Service's incentives programs will become institutionalized.

The assistance of local, County, State, and private institutions can help ensure the success of these programs. As partners, government agencies and NGOs can assist by providing information about the incentives programs, help landowners understand these programs, provide technical assistance, and either directly or indirectly partner with landowners to help them achieve their conservation goals.

For further information about the Fish and Wildlife Service's Conservation Incentives Programs in the panhandle please contact our Panama City Field Office at 850-769-0552, in central and northcentral Florida contact staff in our Jacksonville Field Office at 904-232-2580, or in south Florida at our South Florida Field Office at 561-562-3909.

Reclassifications and Delistings Under the Endangered Species Act

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Abstract. The Endangered Species Act requires us to identify specific threats to animals and plants through its listing process, then remedy those specific threats through its recovery process. When threats are reduced, we are expected to reclassify species using exactly the same criteria as were used to judge that they qualified for listing. The Fish and Wildlife Service had a more active listing program in Florida during the 1980s than nearly anywhere else in the country. Since then, Florida's massive land acquisition programs and other conservation measures have improved the status of some species so that at least a few can now be considered for reclassification. Examples include *Paronychia chartacea*, *Polygonella myriophylla*, and *Polygonella basiramia* from the Lake Wales Ridge.

Key Idea

Ideally, species listed under the Endangered Species Act recover from the threats that caused their listing, and can be delisted.

Listing and Delisting: The Law

Section 4 of the Endangered Species Act (Act) requires us to identify specific threats to animal and plant species that could eventually result in their extinction. Species qualify for listing under the Act's five factors:

1. The present or threatened destruction, modification, or curtailment of its habitat or range;
2. overutilization for commercial, recreational, scientific, or educational purposes;
3. disease or predation;
4. the inadequacy of existing regulatory mechanisms;
5. other natural or manmade factors affecting its continued existence.

A species cannot be listed merely for having a limited distribution. The Act's listing process is about identifying threats; the recovery process is about reversing them.

When threats are reduced or controlled, the Act requires us to reclassify species using exactly the same criteria as were used to judge that they qualified for listing. Because the U.S. Fish and Wildlife Service

(Service) had a more active listing program in Florida during the 1980s than nearly anywhere else in the country, and because Florida has had the largest land acquisition program in the country, it's now possible to consider a few species for reclassification—adding to the trickle of species proposed for reclassification elsewhere in the country. Examples include *Paronychia chartacea*, *Polygonella myriophylla*, and *Polygonella basiramia* from the Lake Wales Ridge (albeit little information exists on the life history of *P. myriophylla*).

The Endangered Species Act's standards for listing species as endangered or threatened were designed to recognize conservation problems while they are still manageable and can be remedied through the Act's recovery planning process. Because listing is threat-based, it is typically much simpler to demonstrate threats to an entire ecosystem or geographic area (like the Lake Wales Ridge) than to elucidate the particular problems affecting individual species. For example, massive loss of scrub vegetation was easy to demonstrate, while threats to individual species resulting from changes in fire regime were not.

How Listing is Done

The process of listing species under the Endangered Species Act has become more complex in the

past decade. Apart from difficulties caused by limited funding and the setting of priorities by court order or lawsuit settlement (which in effect diverted most resources to the Pacific Coast), we are now expected to determine critical habitat for most species. This creates an expectation that we will have very good information on a species' distribution and habitat requirements. And critical habitat determinations include a detailed economic assessment that, it appears, will now include an assessment of the economic effects of all anticipated Endangered Species Act consultations on Federally-permitted projects within critical habitat, whether or not the consultations were triggered by the area being critical habitat or by the species being listed (which is normally the case).

The prelude to listing is usually for a species to become a "candidate." The process for making a species a candidate is straightforward. A field office submits what amounts to a short version of a listing proposal, laying out the threats, in a memorandum to be signed by the Director of the Service.

Congress, through the appropriations process, has shown interest in conserving candidates in hopes that listings can be forestalled. One of our biggest challenges has been to make use of these funds, basically for quick fixes to conservation problems. In terms of getting conservation funds from the Federal government, it's almost as good for a species to be a candidate as to be listed. Maybe better. Our only candidate on the Lake Wales Ridge is the Highlands tiger beetle (*Cicindela highlandensis*), an inhabitant of more or less bare sand. Fortunately, tiger beetles are charismatic insects, "the butterflies of the beetle world," and experience gained from conserving coastal tiger beetles is applicable to this species, whose habitat requirements and distribution are reasonably well understood, making it an excellent example of a conservable candidate.

Recovery

Because listing and designation of critical habitat under the Endangered Species Act is intended not to be permanent (at least for many species), a major purpose of recovery planning is to arrange permanent protection for listed species. As a corollary, one of the most important parts of recovery planning is to provide measurable, scientifically-based criteria for a species to qualify for reclassification from endangered to threatened, or from threatened to unlisted.

The Act requires recovery plans to provide:

- "site specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species"
- "objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this section, that the species be removed from the list;" and
- "... estimates of time and cost."

Establishing recovery criteria can be difficult (how do you determine how many tiger beetles are enough, when populations are prone to boom and bust?). But the Fish and Wildlife and National Marine Fisheries Services have been preparing recovery plans for over twenty years, and it has usually proven possible to establish useful criteria. The step in setting criteria is to review the threats that caused the species to be listed, and to determine how those threats will be reversed. Second, serious new threats may emerge while a species on a Federal list. For example, when the Florida scrub-jay was listed, no one realized how difficult its recovery would be. In such a case, recovery plans must be revised. The second step in establishing recovery criteria is to determine whether populations or habitats must be stabilized or restored, how much restoration is enough, and how you ensure that you have enough. In a few cases, like *Eryngium cuneifolium*, reclassification criteria can be based on excellent demographic data. But not every species can be the subject of such intensive research. The setting of recovery criteria can be a first step toward determining what recovery measures, and what monitoring data, are most important. And perhaps most important, recovery criteria must be written to fit the Act's requirements for reclassifying species.

Review and Reclassification

The Act requires that we review listed species at least once every five years to determine which should be removed from the list, changed from endangered to threatened, or changed from threatened to endangered. These reviews have been carried out in a low-key manner. While the usual route to reclassification or delisting is fulfillment of recovery-plan criteria, the Act says nothing about such changes in status being based

on recovery plan criteria. It simply requires that the Service will

“conduct, at least once every five years, a review of all species included in a list which is published pursuant to paragraph (1) and which is in effect at the time of such review; and determine on the basis of such review whether any such species should be removed from such list; be changed in status from an endangered species to a threatened species; or be changed in status from a threatened species to an endangered species.”

Species are reviewed using the same five factors for which species qualify for listing. The Endangered Species Act’s criterion for reclassifications and delistings can be phrased as:

“if the species were not currently listed, would we move toward listing it, based on the existing situation?”

The best way to conduct such a review is to consult biological and other experts who are members of recovery teams or who have contributed to setting recovery criteria, which in turn ought to fit the Act’s reclassification requirement, but there are sometimes glitches. We are beginning to have helpful precedents. In delisting the bald eagle, the Service relied on several regional recovery plans. In general, recovery criteria had been met, but the plan for the southwestern United States, where there are few bald eagles, lacked recovery criteria. Delisting is going ahead despite this omission.

The Service’s reclassification and delisting proposals have almost exactly the same format as listing proposals. They provide background information, summarize the five threats, and are published in the Federal Register, the government’s daily publication of legal notices (which is now available on the Web).

The Fish and Wildlife Service in Florida had the most active listing program in the country during the 1980s, so we are ahead of the rest of the country (especially the West Coast) in recovery planning and, to some extent, in arranging for conservation measures. And Florida had the most active land acquisition program in the country. So as a result, we may lead the country in downlistings and possibly delistings.

After Delisting, Monitoring

Once species are recovered and have been delisted, the Endangered Species Act requires that they be monitored for not less than 5 years. This

requirement was added the last time the Act was amended, to encourage delistings by providing for insurance against mistakes. This requirement means that when a species is delisted, a monitoring plan must be ready and the resources available for carrying it out. Ironically, this is more attention than many listed species get.

Potential Reclassifications of Scrub Plants

Several Lake Wales Ridge plants are early candidates for reclassification or delisting. The ones under the jurisdiction of the Vero Beach field office are:

Paronychia chartacea ssp. *chartacea*
(threatened)

Polygonella basiramia (endangered)

Polygonella myriophylla (endangered)

Example: *Paronychia chartacea*

Paronychia chartacea ssp. *minima*, a small “whitlow-wort” that grows on bare, sunny sand was listed basically because of fear that its habitat was being destroyed.

Today, this species is covered by the massive South Florida Multi-Species Recovery Plan (MSRP), which addresses threats due to habitat (mis) management as well as direct habitat loss. Its recovery criteria state that “*Paronychia chartacea* may be delisted when

- “enough demographic data are available to determine the appropriate number of self-sustaining populations and sites needed to assure 95 percent probability of persistence for 100 years;
- when these sites, within the historic range of *P. chartacea*, are adequately protected from habitat loss, degradation, and fragmentation;
- when these sites are managed to maintain the rosemary phase of xeric oak scrub communities to support *P. chartacea*; and
- when monitoring programs demonstrate that these sites support the appropriate number of self-sustaining populations, and those populations are stable throughout the historic range of the species.” [bullets added]

The recovery criteria are backed up by recovery tasks to “conduct research on life history characteristics of *P. chartacea*” and to “monitor populations of *P. chartacea*” so as to “detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.” The tasks

also call for germ plasm conservation as an *ex situ* conservation measure, and habitat-level recovery tasks call for performing prescribed fires and restoring natural fire regimes. The tasks have not been assigned priorities because the Implementation Plan is not yet developed.

The MSRP emphasizes that “the species’ tendency to colonize disturbed areas along easily accessible State road cuts and rights of way can result in over-estimation of the species abundance and health. On publicly managed lands, we caution against using species presence or abundance in altered habitats as the benchmark with which management decisions are made. Instead, management decisions should be made that maintain or enhance the dynamic diversity of Florida’s scrub vegetation.” This is an important concern, and one that has been raised with respect to other plants, such as the San Francisco lessingia, a coastal dune species. Its draft plan emphasizes restoration of natural disturbance dynamics and firmly discourages artificial pumping up of population sizes through mechanical disturbance.

The MSRP’s recovery criteria are far more cautious than those of its immediate predecessor, the Recovery Plan for 19 Florida Scrub and High Pineland Plant Species (1996), which stated that “the first edition of this recovery plan [1990] called for delisting this species when it is protected at 10 sites, including at least one in Orange and/or Osceola Counties and at least three each in Polk and Highlands counties. These criteria are likely to be substantially exceeded as recovery measures are implemented for the other species.” Reasons for the criteria were: “this is one of the most widely-distributed of the listed scrub species, and it is usually abundant in disturbed areas such as fire lanes. Enough sites are protected or nearing protection

(including one small privately-owned site in Orange County), that the delisting process can be started as soon as land acquisition is complete and prescribed fire plans are implemented. This plant is so abundant that demographic monitoring is not needed. . . . [one biologist] notes that until land acquisition programs were implemented, this plant was genuinely threatened and that conserving its habitat has been a difficult and worthwhile enterprise.”

This is a striking example of how different individuals or teams can view conservation situations differently.

At the present time, the Service is finishing the MSRP. An important portion of this document, its implementation schedule, has not yet been prepared. The schedule coordinates the various species and habitat-level tasks, prioritizes them, and estimates costs. In that the MSRP was prepared under tight time constraints and it tended to apply the same recovery tasks to each species, we are hoping that the implementation schedule, by setting priorities, will streamline the MSRP’s text and provide a coordinated agenda for recovery of dry upland species from Polk County southward, and especially to ensure that the ecosystems they depend on are acquired and appropriately managed. While the challenges of managing conservation lands and their species are formidable, we should not minimize the accomplishments of the past 15 years, and we need to move from seeing conservation of these lands as mainly an “endangered species” problem to more of a “natural areas management problem” with a substantial endangered species component.

*While I have endeavored to present the Service’s policies accurately, this discussion is not an official statement of Service policy.

The Evolution of Habitat Conservation Planning

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Abstract. The development of habitat conservation planning in its current form began in 1982 with the amendment of Section 10 of the Endangered Species Act (ESA). The initial HCPs developed under Section 10 focused on the resolution of conflicts between the conservation needs of one or a few listed species and the implementation of other ongoing land uses. These planning efforts were successful in the sense that they led to approval of Section 10(a)(1)(B) permits and resulted in conservation of habitat for the species and a reduction of the constraints that the occurrence of the species had put on the development process. Although single species HCPs were generally successful, the participants on all sides of the issue recognized the need to deal with the next species in line. The approach adopted in Clark County, Nevada, is an example of ecosystem-based conservation utilizing single species tools. The Clark County Multiple Species Habitat Conservation Plan (MSHCP) was the outgrowth of a single species plan for the Mojave Desert Tortoise (the Desert Conservation Plan or DCP). Building on the DCP, the MSHCP provides conservation measures by species, by ecosystem, and by land manager. Building on lessons learned from previous HCPs, planning efforts underway in Pima County, Arizona, and Riverside County, California, are taking biological conservation planning forward to the next logical level, the incorporation of endangered species issues and ecosystem concerns into comprehensive land use planning. Pima County's Sonoran Desert Conservation Plan (SDCP) integrates biological resource goals and objectives with planning for cultural resources, ranching, parks and open space, and balances them with the land use and infrastructure needs of the rapidly growing greater Tucson communities.

Potential Uses of Safe Harbor Agreements in the Florida Scrub

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Abstract. Endangered species "safe harbor" agreements are a relatively new conservation tool under which private and other non-federal landowners can restore or enhance habitat for endangered species without incurring new regulatory constraints on future uses of the restored property or imposing such constraints on neighboring properties. Such agreements are currently being used to promote voluntary landowner cooperation with conservation efforts for the red-cockaded woodpecker, Attwater's prairie-chicken, northern aplomado falcon, and other federally listed species. This paper provides an overview of what safe harbor agreements are and how they function, illustrating both with examples from around the country. The paper also explores the potential use of safe harbor agreements to aid the Florida scrub-jay and other scrub-associated species, while preserving long-term options for participating landowners and neighboring property owners.

Endangered species "safe harbor" agreements represent a new approach to the conservation of endangered species on private and other non-federal land. They attempt to enlist the cooperation of landowners in actively managing land to improve conditions for rare species by removing the Endangered Species Act's unintended disincentive against such beneficial practices. This paper first explains what safe harbor agreements are and how they work, then provides examples of several such agreements currently in effect. It concludes with a discussion of potential uses of this new conservation tool in the Florida scrub system.

It would be useful to begin with a short definition of what safe harbor agreements are. In short, they are voluntary agreements between a landowner and the U.S. Fish and Wildlife Service (or, in some cases, a governmental or non-governmental intermediary)

under which the landowner commits to carry out specific management activities for an agreed-upon period of time for the benefit of one or more endangered or threatened wildlife species. In return for the landowner's commitment, the government gives him or her an assurance that no new or additional Endangered Species Act restrictions on the use of the property will be imposed as a result of the landowner's success in restoring or increasing listed species on his or her land. Safe harbor agreements do not eliminate or reduce any land use restrictions that may already be applicable to the property as a result of endangered species already on or near it at the time the agreement is signed (those restrictions are reflected in the "baseline" responsibilities set forth in the agreement). Defined in this way, it is easy to perceive the essential difference between safe harbor agreements and

habitat conservation plans (or HCPs). HCPs are legally required of persons who are planning to carry out some action that will harm one or more individuals of a listed species that is currently present, and are undertaken for the purpose of mitigating that harm. Safe harbor agreements, in contrast, are truly voluntary undertakings by landowners whose immediate purpose is to do something beneficial for an endangered species that may or may not already be present. The agreement effectively preserves the option for the landowner of removing the improvement in the future, should he or she choose to do so.

A brief review of some of the safe harbor agreements approved to date illustrates the range of possibilities. The safe harbor idea was born in the Sandhills region of North Carolina, an area with extensive longleaf pine tracts capable of supporting endangered red-cockaded woodpeckers. The problem that safe harbor agreements were intended to address in the Sandhills was fairly straightforward. Because the U.S. Fish and Wildlife Service interprets the Endangered Species Act to require landowners with an active cluster of red-cockaded woodpeckers on their land to preserve an extensive area of forest proximate to each cluster, forest landowners generally have a clear economic incentive to manage their land so as to keep woodpeckers away from it, rather than to attract woodpeckers to it. Because the red-cockaded woodpecker is part of a fire-adapted ecosystem, active habitat management through prescribed burning or other activities mimicking the effects of fire is needed to create and maintain conditions conducive to woodpecker use. In addition, because the woodpecker in the Sandhills is constrained by the availability of cavities (which it can only excavate in very old pines), active management that places artificial cavities in suitably sized trees can speed the growth of the population. Because of the high opportunity costs associated with having woodpeckers on your property, however, many landowners were reluctant or unwilling to implement such active management activities.

Safe harbor agreements changed that. By assuring participating landowners that their beneficial management practices would not increase restrictions on their land, even if new groups of woodpeckers took up residence there, safe harbor agreements effectively eliminated the opportunity costs associated with having an endangered species increase in numbers on one's property. The response of landowners to this new approach was remarkably positive. In North Carolina, 52

landowners have enrolled over 35,000 acres of land in safe harbor agreements. Meanwhile, a similar safe harbor effort in South Carolina has netted 48 landowners and 143,000 acres thus far. There is good potential to enroll even larger acreages in Georgia, where yet another safe harbor program has been launched within the past year.

Though red-cockaded woodpeckers were the first species to benefit from safe harbor agreements, others have done so as well. In southern Texas, The Peregrine Fund had for many years asked the owners of large ranches for permission to use their ranches as release sites for the northern aplomado falcon, America's rarest falcon. With but a single exception, permission was denied. The ranchers insisted they bore no malice toward the falcon; indeed, they said they would welcome it were it not for the fact that the falcon's presence might restrict the use of their land. When the Peregrine Fund heard about the Sandhills safe harbor program, it decided to go back to the same ranchers and ask again. This time, because of the protection against land use restrictions that safe harbor agreements offered, many landowners agreed to let the Fund use their land. Today, nearly 1.5 million acres of privately owned rangeland in south Texas are enrolled in the safe harbor program administered by The Peregrine Fund. More importantly, 19 of the first 30 nesting pairs of northern aplomado falcons to be established in the United States in many decades were established on safe harbor properties.

Elsewhere in Texas, some 17 different landowners are restoring coastal prairie habitat on over 50,000 acres of privately owned rangeland under a safe harbor program administered by the local resource conservation district. The effort includes prescribed burning, removal of aggressive non-native woody species such as Chinese tallow and McCartney rose, and planting of native grasses. If all works as planned, this restoration effort will not only improve forage for cattle, but create high quality habitat for the highly endangered Attwater's prairie-chicken. Whether these recently initiated efforts will come too late to stave off the extinction of a bird whose numbers in the wild have declined from nearly 2,500 to only about 50 in the last quarter century remains to be seen. What is clear at this point, however, is that the safe harbor assurances have made it possible for local landowners to become enthusiastic partners in an effort to save an endangered species on their own land.

There are still other safe harbor agreements for still other species in other places. They all have certain basic features in common. First, each agreement commits a landowner to undertake some clearly specified conservation action. Without a specific commitment from the landowner, there is no assurance with respect to future regulatory restrictions. In most of the examples cited above, the landowner actually enters into his agreement not with the Fish and Wildlife Service, but with an intermediary that has taken on the responsibility of administering a safe harbor program in an area. In the case of the northern aplomado falcon example above, The Peregrine Fund holds a permit from the Fish and Wildlife Service to enter into subsidiary agreements with individual landowners in certain Texas counties. The individual landowners receive the benefit of The Peregrine Fund's permit (i.e., the assurances with respect to future restrictions) through "certificates of inclusion" (essentially, sub-permits) issued by the Fund. Similarly, in the case of the South Carolina and Georgia statewide safe harbor agreements for the red-cockaded woodpecker, individual landowners enter into agreements with departments of natural resources in those states, each of which holds a "master" permit from the Fish and Wildlife Service. This programmatic approach to safe harbor agreements has several practical advantages. First, it makes it possible for state agencies and even private conservation organizations to supplement the limited resources of the Fish and Wildlife Service in seeking out and working with landowners. Since some landowners are wary of dealing directly with the federal government, using an intermediary expands the universe of potential participants. This programmatic approach also avoids the needless expense and delay of going through the permitting process anew each time another landowner elects to take part in the program.

Although programmatic approaches to safe harbor have obvious advantages, individual landowners can enter into such agreements directly with the U.S. Fish and Wildlife Service. Two such agreements are currently pending in Hawaii, where private landowners have committed to conservation actions benefiting the Hawaiian goose (or nene) and Hawaiian duck (or koloa).

Another indispensable element of every safe harbor agreement is a specification of the landowner's "baseline" responsibilities. As noted earlier, safe harbor agreements do not relieve landowners from any restrictions already applicable to their property as a

result of the Endangered Species Act. They do, however, require that those existing restrictions be clearly expressed in the agreement. In some cases, this is relatively straightforward, particularly when the Fish and Wildlife Service has already developed quantitative guidelines specifying how much of what quality of habitat must be protected in order to avoid taking a protected animal. In most cases, such guidelines do not already exist, and the task of specifying the baseline restrictions is more challenging. In every case, however, the task is fundamentally the same: specify what restrictions on land use apply to the property as a result of current levels of utilization thereof by endangered species. If the Fish and Wildlife Service finds this difficult to do, that fact ought to create some sympathy for the plight of the landowner who, lacking the specialized expertise of the Service, only wants to know what he can or cannot do on his property.

Safe harbor agreements always allow a landowner to take endangered species in the course of land use activities carried out after the landowner's conservation commitments have been fulfilled, provided only that the landowner's actions have improved conditions on the property above baseline conditions. In many cases, the landowner will be required to give advance notice before carrying out activities likely to take such species, in order that efforts to rescue and relocate them can be undertaken. In some cases, the conservation measures required by an agreement may have the potential to take individual protected animals (such as, for example, prescribed burning that incidentally takes some Karner blue butterflies in the course of improving habitat conditions for the species). Permits issued in conjunction with safe harbor permits can authorize this type of incidental taking as well, provided only that the overall impact of the effort will be to produce a net conservation benefit for the species.

Finally, in the absence of safe harbor agreements, conservation actions that result in endangered species utilizing areas where they do not currently occur could potentially result in restrictions on ongoing actions nearby, such as the use of pesticides in nearby agricultural fields, or timber harvest in watersheds where endangered fish are reintroduced pursuant to safe harbor agreements. Very often the landowners who wish to enter into safe harbor agreements have less interest in being able to "return to baseline" in the future (they often have no intention of doing so) than in knowing that their voluntary conservation actions will not result

in restrictions on their ongoing activities. Thus, for a safe harbor program to appeal to landowners, it must address this possibility as well. Again, so long as any incidental taking does not reduce conditions below their baseline levels, foreseeable incidental take of this sort can also be authorized. The mechanism for authorizing such take can either be the safe harbor permit itself or the "incidental take statement" portion of the biological opinion done in conjunction with that permit.

Finally, landowners considering positive management to benefit endangered species may be concerned about the consequences of doing so not only for themselves, but for their neighbors as well. This is especially the case when the Fish and Wildlife Service interprets the Endangered Species Act to impose habitat maintenance obligations on land within a specified distance of a nest site. If an endangered species establishes a nest site on a safe harbor property, but near the boundary with another property, the effect of the Service's general interpretation may to impose restrictions on the neighbor, while relieving the safe harbor landowner from any restrictions. Such possibilities could dissuade many landowners from entering into agreements that would protect themselves, but encumber their neighbors. In recognition of this fact, the national safe harbor policy adopted by the Fish and Wildlife Service on June 19, 1999, seeks to avoid impositions on neighboring property owners as much as possible. In this one instance, a neighboring property owner can secure the same rights as a safe harbor participant simply by signing an agreement that establishes a baseline and allows an opportunity to rescue and relocate animals at risk of being incidentally taken.

To date, no safe harbor agreements have been done in the Florida scrub system. However, certain similarities between the scrub system and other systems where safe harbor agreements have been used suggest that such agreements could serve useful purposes in the scrub system. In particular, just as forest habitats where red-cockaded woodpeckers occur naturally required frequent fire in order to continue to provide suitable habitat for the woodpecker, so is fire needed in the scrub system to provide habitat for the Florida scrub-jay and other scrub-associated species. Without fire or other active management to set back overly mature scrub habitats, the patchy open character of scrub habitat will give way to a dense and closed habitat inhospitable to many scrub-associated species.

One noteworthy difference between the longleaf ecosystem and the scrub system, however, is that there may be economic benefits to a landowner from actively managing a longleaf tract with prescribed burning, whereas in the scrub system there is unlikely to be any economic reason for a landowner to burn a tract of scrub (except possibly to reduce the fire hazard to nearby properties). Hence, unless someone else is willing to bear the cost of management, there may be relatively few scrub landowners interested in safe harbor arrangements.

Nonetheless, there are at least a few potential safe harbor scenarios worth exploring. First, public bodies such as water management districts may own land with significant scrub restoration potential. The willingness of such public bodies to aggressively restore or enhance scrub may be constrained by at least two factors. First, it may have long-term plans to use the site for some other purpose, such as a reservoir. Its willingness to actively manage scrub habitat now may depend upon securing an assurance that such management will not complicate the task of building the reservoir later. A safe harbor agreement can provide that assurance, thus removing an obstacle to restoration.

A further obstacle may stem from concerns about impacting neighboring landowners. Successful restoration on the water management district's property may create source habitat for scrub-jays, some of which could disperse to adjoining lands. That possibility could be an important consideration for a public agency mindful of the importance of maintaining good relations with its neighbors. Again, safe harbor offers a means of addressing those concerns, allowing the water management district to aggressively carry out restoration activities without burdening its neighbors with unwanted land use restrictions.

Yet another potential safe harbor scenario arises from the fact that certain privately owned tracts have been targeted for eventual public acquisition, but the acquisition may be many years off in the future. If, in the meantime, conservation interests were willing to foot the bill for active management, owners of the land targeted for eventual acquisition could consent to having that management done now, with the assurance provided by a safe harbor agreement that the effect of the management will not be to constrain the use of the land in the event that the anticipated acquisition never occurs.

There is at least one scenario under which a private landowner might undertake restoration under a

safe harbor agreement in the hope of securing a financial benefit from having done so in the future. To the extent that a private landowner successfully restores habitat under a safe harbor agreement and attracts scrub-jays or other endangered species to it, he may have a right (the right to bring that property back to baseline conditions) that can be sold as mitigation for development in scrub habitat elsewhere. That is, a landowner who initially restores habitat under a safe harbor agreement may later decide that he is willing to give up his safe harbor right if he is paid for doing so.

Thus, what started out as purely a safe harbor effort can become a conservation banking enterprise, thus making the landowner's investment in conservation a potentially profitable venture.

There are doubtless other potential uses for safe harbor agreements in Florida's scrub ecosystem. Such agreements, flexibly and creatively used, have proven to be helpful in furthering the conservation of imperiled species in other systems. With similar creativity, they may be able to contribute something of value to the conservation of the Florida scrub system as well.