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RESPONSES OF SMALL RODENTS
TO RESTORATION AND MANAGEMENT TECHNIQUES OF FLORIDA SCRUB
AT CAPE CANAVERAL AIR FORCE STATION, FLORIDA

by

ALEXIS A. SUAZO
B.S. University of Central Florida, 2000

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Biology
in the College of Sciences
at the University of Central Florida
Orlando, Florida

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ABSTRACT

Proper habitat management is essential for the survival and reproduction of species, especially those listed under state or federal laws as endangered, threatened or of special concern, and those with small local populations. Land managers use a combination of mechanical cutting and prescribed burning to manage and restore degraded scrub habitat in east central Florida. This approach improves habitat for the endangered Florida scrub-jay (*Aphelocoma coerulescens*), but little is known about its effects on other taxa, especially the threatened southeastern beach mouse (*Peromyscus polionotus niveiventris*). This single species approach may not be beneficial to other taxa, and mechanical cutting and prescribed burning may have detrimental effects on *P. p. niveiventris*. To evaluate the effects of land management techniques on *P. p. niveiventris*, I live trapped populations at Cape Canaveral Air Force Station near Titusville, Florida during 2004-2005. I evaluated the relative abundance and related demographic parameters of small mammal populations trapped in compartments under different land management treatments, and investigated the relationship between Florida scrub-jay breeding groups using these compartments and abundance of southeastern beach mice. My results suggest that *P. p. niveiventris* responded positively to prescribed burning, while the cotton mouse (*P. gossypinus*) responded positively to the mechanical cutting. Reproduction and body mass of southeastern beach mice were similar across land management compartments. Abundance of Florida scrub-jay breeding groups and southeastern beach mice were positively correlated suggesting that both listed species benefited from the same land management

activities. A mosaic of burned and cut patches should be maintained to support small mammal diversity. In addition, adaptive management should be used at CCAFS to understand how small mammals, particularly the southeastern beach mouse, respond to land management activities.

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INTRODUCTION

Changing patterns of land use worldwide have resulted in the loss and fragmentation of natural habitats. These changes have altered community structure and landscape configuration and modified the rates and intensities of many natural processes essential for ecosystems to retain their integrity (Lambeck 1997). All ecosystems are currently being managed or will need some form of management in the future; science-based land management is essential for these efforts to be successful (Duncan et al. 1999). Land managers must determine strategies that best maintain biological diversity and biological processes within a specific habitat. Making such decisions is not easy; several shortcuts have been proposed whereby protecting single species also shelters others (Simberloff 1998). There has been considerable debate in the ecological literature about whether the requirements of single species should serve as the basis for defining conservation requirements or whether analysis of landscape patterns and processes should underpin conservation planning (Franklin 1993; Hansen et al. 1993; Orians 1993; Franklin 1994; Hobbs 1994; Tracy and Brussard 1994). Species-based approaches have been criticized because they do not provide whole-landscape solutions to conservation problems, cannot be conducted fast enough to deal with the urgency of threats, and consume a disproportionate amount of conservation funding (Franklin 1993; Hobbs 1994; Walker 1995; Roemer and Wayne 2003). Consequently, critics of single-species management have called for approaches that consider higher organizational levels, such as ecosystems and landscapes (Noss 1983; Noss and Harris 1986; Noss 1987; Gosselink et al. 1990). However, conservation based on single species likely will continue to be important foci of inventory, monitoring, and assessment efforts because managing single species is more straightforward and easier to evaluate than managing a

complex of amorphous, abstract ecosystems (Noss 1990; Rubinoff 2001). Furthermore, laws such as the U.S. Endangered Species Act (ESA) mandate species-level management (Noss 1990; Rubinoff 2001). Often the animals managed as single species are legislatively protected species, mostly vertebrates (Andelman and Fagan 2000).

My thesis research evaluated the effects of habitat restoration techniques based on a single species management philosophy on another federally listed species. Florida scrub is a rare and declining ecosystem (Myers 1990; Menges 1999) that often is managed to benefit the endangered Florida scrub-jay (*Aphelocoma coerulescens*), a scrub dependent species. Presence of the Florida scrub-jay is indicative of well managed scrub habitat, which is assumed to benefit other scrub dependent species (Duncan et al. 1999). Suitable Florida scrub-jay habitat consists of scrub vegetation dominated by oaks (*Quercus* sp.) with open sandy spaces, few or no trees, and shrub heights of 1 to 2 m (Westcott 1970; Breininger 1981; Cox 1984; Woolfenden and Fitzpatrick 1984). Florida scrub-jays are very habitat specific (Woolfenden and Fitzpatrick 1984) and the remaining patches of scrub along the central east coast of Florida are being managed exclusively to maintain suitable habitat for one of the three core populations of Florida scrub-jays (Stith et al. 1996). More than 50 % of this ecosystem has been lost to land use conversion (Fernald 1989; Bergen 1994), and remaining patches are typically fragmented, isolated and overgrown (Myers 1990). A number of threatened and endangered plant and animal species also inhabit scrub communities (Christman and Judd 1990; Stout and Marion 1993; Stout 2001), and management of remaining scrub is critical to the survival of these species (Schmalzer et al. 2003). Scrub communities are well adapted to fire and other natural disturbances (Abrahamson

1984; Myers 1990; Schmalzer and Hinkle 1992). In the absence of lightning ignited fires, prescribed burning is the primary management technique applied in scrub communities (Menges 1999). However, scrubs that have not been properly managed (e.g., lack of fire) may become fire resistant and require a combination of mechanical cutting and prescribed burning for restoration and management (Schmalzer and Boyle 1998; Schmalzer and Adrian 20001). Such management techniques have successfully restored long-unburned scrub vegetation to a habitat more suitable for scrub-dependent species (Schmalzer et al. 2003). However, the current focus of land managers is the Florida scrub-jay, and the consequences of scrub management and restoration for other species is poorly documented (Stevens and Knight 2004). Despite the frequency and importance of fire in managing habitats in the southeastern U. S., little is known about its effects on non-target species, especially small mammals (Arata 1959; Robbins and Myers 1992).

Beach mice are coastal subspecies of the old field mouse (*Peromyscus polionotus*), which is endemic to the southeastern coastal plain (Hall 1981). Beach mice inhabit coastal scrub (Blair 1951; Humphrey and Barbour 1981; Holliman 1983; Extine and Stout 1987; Rave and Holler 1992), and two extant sub-species, the Anastasia Island beach mouse (*P. p. phasma*) and the southeastern beach mouse (*P. p. niveiventris*), occur on the east coast of Florida. These sub-species are listed under the Endangered Species Act of 1973 as endangered and threatened, respectively (U.S. Fish and Wildlife Service 1993). Extensive coastal development has fragmented beach mouse habitat and left most remaining populations small and isolated (Oli et al. 2001).

Blair (1951) suggested that primary beach mouse habitat was the beach dune system where sea oats (*Uniola paniculata*) and open sandy patches were the main habitat. However, Stout (1979) captured *P. p. niveiventris* in areas (e.g., coastal scrub) more than 3 km inland from the primary beach dune system on Cape Canaveral. In the only published study of habitat selection by *P. p. niveiventris*, Extine and Stout (1987) suggested *P. p. niveiventris* preferred habitats interior to the beach dune system. However, interior habitat has been considered of lesser quality, and therefore, given little consideration when making management decisions about *P. p. niveiventris*. The lack of management planning to include other species is exemplified in the current management of scrub at Cape Canaveral Air Force Station, where scrub management focuses on the habitat needs of the Florida scrub-jay. However, Cape Canaveral Air Force Station harbors a suite of endangered and threatened species (Breininger et al. 1998), and it remains to be determined whether, when making land management decisions, managers should incorporate as many species as possible (i.e., they should follow a multi-species approach).

Florida scrub historically was maintained by intense fire (Schmalzer et al. 2003). Therefore, scrub endemics are assumed to have had the time to adapt to natural disturbances typical of their environment (Hunter 1993). Disturbance events such as naturally occurring fires (e.g., wildfires) or applied fires (e.g., prescribed burning) can affect some small mammal populations (Cook 1959; Harty et al. 1991). Fire (hereafter, prescribed burning) can affect small mammals directly or indirectly; an obvious direct effect is mortality (Harty et al. 1991). However, changes in small mammal abundance after fire are assumed to be caused by changes in

vegetation structure (Kaufman et al. 1983; Monamy and Fox 2000). For example, the deer mouse (*Peromyscus maniculatus*) responded positively to the mosaic created by prescribed burns on the Konza Prairie (Kaufman et al. 1983, 1990). These fires burned live and dead vegetation and created patches of exposed soil that *P. maniculatus* exploited (Kaufman et al. 1988). Based on long-term studies on fire and the responses of small mammals, *P. maniculatus* has been classified as a fire positive species: its abundance increases after fire (Kaufman et al. 1988). Responses of other small mammal species to fire are less well understood. For instance, *P. polionotus* has mixed responses to fire. Odum et al. (1973) reported low numbers after fire; while Boyer (1964) reported increased number of *P. polionotus* after fire, and Arata (1959) found a neutral response to fire: populations did not increase or decrease. The above studies explored how *P. polionotus* responded to fires in old-field and turkey-oak habitats, however empirical data on how *P. polionotus* responds to fires in the Florida scrub are lacking.

Clearcutting is often the first step taken to restore overgrown scrub, and such a strategy may alter small mammal population dynamics. Few studies have documented the effects of clearcutting on forest biota in general and small mammals in particular (Sullivan et al. 1999). Small mammal abundance tends to increase after clearcutting especially abundance of *Peromyscus* spp. (Kirkland 1990). For example, *P. maniculatus* preferred clearcut-burned sites in boreal forest harvested by clearcutting. Their density was higher on clearcut-burned sites than on forest and clearcut sites (Sullivan et al. 1999). In the southeastern United States, little attention has been given to the effects of clearcutting on small mammal communities (Constantine et al. 2004), but clearcutting can substantially change the structure of small mammal assemblages

(Kirkland 1990). For example, the cotton mouse (*P. gossypinus*), a common small mammal of southeastern habitats, was significantly more abundant in areas with substantial downed logs and branches (Loeb 1999).

My study evaluated responses of small mammals, particularly the southeastern beach mouse, to land-management techniques currently employed on Cape Canaveral Air Force Station. My data included the relative abundances of small mammal populations inhabiting patches of coastal scrub subjected to mechanical cutting and prescribed burning. My objectives were to quantify small mammal responses and related demographic parameters, and document whether management of Florida scrub-jay (i.e., single species) benefits small mammal populations.

METHODS

Study Area

Merritt Island is a complex barrier island that includes Cape Canaveral, Merritt Island National Wildlife Refuge, Kennedy Space Center and Cape Canaveral Air Force Station (Latitude 28.48 and Longitude 80.59). The area is a biogeographic transition zone with floral and faunal assemblages derived from temperate Carolinian and tropical subtropical Caribbean biotic provinces (DeFreese 1995). Its wildlife diversity results from many types of upland and wetland habitats and from a large number of migratory birds (Breininger and Smith 1990). A strip of coastal dune occurs adjacent to the Atlantic Ocean (Breininger et al. 1998), but scrub and pinelands are the dominant natural upland communities (Breininger et al. 1995) and the dominant scrub type is oak-saw palmetto. Dominant species include myrtle oak (*Quercus myrtifolia*), sand live oak (*Q. geminata*), Chapman oak (*Q. chapmanii*), saw palmetto (*Serenoa repens*), and ericaceous shrubs (e.g., *Lyonia* spp.) (Schmalzer and Hinkle 1992).

At Cape Canaveral Air Force Station, scrub has been divided into several management compartments to facilitate restoration and management. Land management compartments are divided by fire breaks, power lines, service roads and canals (Fig.1). Compartments vary in size and stage of vegetation recovery. Although the ideal land management strategy is to clearcut overgrown scrub and follow with a prescribed burn, managers cannot always conduct the burns necessary to keep up with the acreage of scrub cut. Prescribed burning occurs opportunistically due to non-ecological issues (e.g., Air Force base policy, smoke-sensitive space equipment, and location of launch pads), so mechanical treatments are applied more frequently.

Sampling

I assessed the responses of small mammals to current management techniques (Fig. 2) by collecting data on their abundance in 18 land management compartments located throughout Cape Canaveral Air Force Station (Fig. 1). I selected compartments based on land management activities: five compartments were recently prescribed burned, six compartments were recently cut, and four compartments were checkerboarded (i.e., cut and prescribed burned). I also selected three compartments without any management for at least 50 years as fire-suppressed controls (Table 1).

I set up one transect line in each compartment to estimate the relative abundance of small mammals. Transects were positioned toward the center of each compartment to minimize edge effects. Transects consisted of 10 large Sherman live traps (7.6 x 8.9 x 22.9 cm, H. B. Sherman Traps Inc., Tallahassee, Florida) spaced 15 m apart. I opened traps late in the afternoon, baited them with sunflower seeds, and checked for captures the following morning. All small mammals captured were marked with a numbered ear tag, identified to species, sexed, and checked for reproductive condition (male: testes descended into the scrotal sack (breeding) or abdominal (non-breeding); female: perforate or non-perforate vagina, lactating or not, enlarged mammarys or hair pulled away, and obviously pregnant). Age class (juvenile, subadult and adult) was determined by pelage coloration and mass (Layne 1968), which was obtained using a Pesola spring scale accurate to the nearest 0.5 g. I surveyed compartments three times each season (spring: March-May, summer: June-August, fall: September-November, winter: December-February). I pre-baited live traps approximately 2 weeks before trapping commenced, and

trapping periods were conducted at 2 week intervals. All captured small mammals were released at the point of capture.

I evaluated the relationship between Florida scrub-jay and small mammal abundance using Florida scrub-jay nesting data from land management compartments collected during 2004-2005 field seasons (Stevens and Knight 2004). These data were collected by censusing all suitable habitat for Florida scrub-jay on Cape Canaveral Air Force Station using playbacks of recorded Florida scrub-jay vocalizations (Stevens and Knight 2004). I followed guidelines on trapping methodology and handling of small mammals by the American Society of Mammalogists (1998) and IACUC project # 03-13 issued to the Department of Biology at the University of Central Florida. I also followed Florida Fish and Wildlife Conservation Commission's (FFWCC) small mammal trapping protocol, and conducted all live trapping under a permit issued to I. Jack Stout by FFWCC.

Data Analysis

I used Repeated Measures Analysis of Variance (RM-ANOVA) to test whether mean relative abundance of small mammals and body mass differed among management treatments. I calculated small mammal abundance as the number of first captures trapped during each trapping period, and used only the number of first captures of individuals in compartments to test for treatment and seasonal effects. I used time (seasons) as the repeated measure, and management treatment was the between-subject variable and input size (ha) of compartments as a covariate. The independent measure of analysis was mean small mammal relative abundance and body mass in burned (n = 5), cut (n = 6), checkerboard (n = 4), and fire-suppressed (n = 3)

management compartments. I performed RM-ANOVAs for southeastern beach mouse and cotton mice separately (Crowder and Hand 1990; Green 1993). When a significant effect was found, I performed a Bonferroni Multiple Comparison Tests to discern differences among means, and adjusted the degrees of freedom to meet the assumption of sphericity (Crowder and Hand 1990). I constructed 2 x 4 contingency tables to evaluate demographic parameters of reproduction for southeastern beach mice and cotton mice. I used a G-test to test for differences on the frequency of observed male and female beach mice in reproductive condition among land management treatments and seasons (Fowler et al., 2000).

I used Pearson correlations to explore relationships between Florida scrub-jay breeding groups and first captures of southeastern beach mice in surveyed compartments to demonstrate the efficacy of land management techniques on these two listed species. The data on Florida scrub-jay breeding groups did not meet the assumptions for parametric analysis; therefore, I used a Kruskal-Wallis test (Zar 1999) to examine mean differences among Florida scrub-jay breeding groups. The remaining data sets met assumptions for parametric analysis. I also present numeric data on Florida scrub-jay in land management compartments. All tests were considered significant if $P < 0.05$. Analyses were conducted using SPSS 11.5 (SPSS Inc., Chicago, Illinois). Results are expressed as mean \pm 1 SE unless otherwise indicated.

RESULTS

I captured three species of small mammals during the study southeastern beach mouse, cotton mouse, and cotton rat (*Sigmodon hispidus*). I trapped 146 individual southeastern beach mice (315 total captures), 130 cotton mice (300 total captures), and 33 cotton rats (39 total captures). The three species were captured in compartments under different management treatments, but their relative abundance varied by season (Fig.3) and land management practice (Fig. 4). *Peromyscus polionotus niveiventris* and *P. gossypinus* were relatively abundant during all seasons, while *S. hispidus* were seldom captured. Relative abundance of *P.p. niveiventris* and *P. gossypinus* varied among management treatments (Fig.4). Relative abundance of *P. p. niveiventris* appeared to be higher in compartments that were burned relative to other treatments, whereas the relative abundance of *P. gossypinus* appeared to be greater in compartments that were cut (Fig. 4).

Southeastern beach mice

Mean number of *P.p. niveiventris* captured at least once differed significantly among treatments with the mean number trapped in burned compartments significantly greater than fire suppressed. Mean number of first captures did not differ significantly between seasons, and the interaction between seasons x compartment size also was not significant (Table 2). However, the interaction between seasons x treatments was significant, (Table 2, Fig. 5). A significant treatment effect was found when recaptured animals were included in the analysis (RM-ANOVA, $F_{3, 13} = 3.82$, $P = 0.03$).

The mean body mass *P. p. niveiventris* did not differ among land management treatments ($F_{3,42} = 0.89$, $P = 0.45$, Fig. 6), and the interaction between treatment and season also was not significant ($F_{9,42} = 1.43$, $P = 0.20$, Fig.6). There were no significant differences in the frequency of male ($G = 1.538$, d. f. = 3, $P > 0.05$, Fig. 7) or female ($G = 2.224$, d. f. = 2, $P > 0.05$, Fig. 7) *P. p. niveiventris* in breeding condition among land management treatments. There was no significant difference in the frequency of male ($G = 4.753$, d. f. = 3, $P > 0.05$, Fig. 8) *P. p. niveiventris* in breeding condition among seasons, but the frequency of female ($G = 8.148$, d. f. = 3, $P < 0.05$) *P. p. niveiventris* in breeding condition among seasons was significantly different (Fig. 8 B). Numbers of females showing signs of being reproductive were highest during fall, but reproductive characters were dominant throughout the seasons.

Cotton mice

Mean number of first captures of *P. gossypinus* did not differ among land management treatments (RM-ANOVA, $F_{3,14} = 1.54$, $P = 0.24$), and no significant interactions were found between seasons and size of compartments (RM-ANOVA, $F_{3,39} = 0.54$, $P = 0.65$) or between treatments and seasons ($F_{9,39} = 1.58$, $P = 0.15$, Fig.9). Mean body mass of *P. gossypinus* did not differ significantly among land management treatments (RM-ANOVA, $F_{3,14} = 1.86$, $P = 0.18$, Fig. 10), and the interaction between treatment and season also was not significant (RM-ANOVA, $F_{5.3,24.9} = 1.89$, $P = 0.09$). No treatment effect was found when recaptured animals were part of the analysis (RM-ANOVA, $F_{3,13} = 2.59$, $P = 0.09$).

The frequency of male ($G = 1.758$, d. f. = 3, $P > 0.05$, Fig. 7) and female ($G = 4.644$, d. f. = 3, $P > 0.05$, Fig 7) *P. gossypinus* in breeding condition did not differ among land management

treatments, but there were significant differences in the frequency of male ($G = 17.886$, $d. f. = 3$, $P < 0.05$, Fig. 8 C) cotton mice in reproductive condition among seasons with all captured males non-reproductive in summer. Reproductive condition of females did not differ among seasons ($G = 6.578$, $d. f. = 3$, $P > 0.05$, Fig. 8).

Cotton rat

Mean relative abundance of *S. hispidus* appeared unaffected by management treatments, but low sample sizes of *S. hispidus* at some sites precluded statistical analysis. Mean body mass of male cotton rats was (122.6 ± 10.6 g) and (121.8 ± 8.3 g) for female cotton rats during the study, and no males were captured in checkerboarded compartments (Fig. 11). Most *S. hispidus* showed no signs of reproduction, 14 males had non-descended testes and only one had descended testes. A similar pattern was observed in female *S. hispidus*: 17 females were non-reproductive, while seven appeared reproductively active with enlarged mammarys.

Florida scrub-jays

Total number of Florida scrub-jay breeding pairs was relatively higher in burned ($n = 22$) than in cut ($n = 12$) or checkerboarded ($n = 13$) compartments, and no breeding activity was observed in fire suppressed compartments; however, no significant differences were found (Kruskal-Wallis test, $X^2 = 7.34$, $d. f. = 3$, $P = 0.06$). Total number of first captures of southeastern beach mice was highest in burned ($n = 83$) and extremely low in fire suppressed ($n = 2$) compartments, while the Florida scrub-jay did not use any of the fire suppressed compartments (Table 4). Moreover, the relationship between Florida scrub-jays breeding pairs

and southeastern beach mice were positively correlated (Pearson correlation, $r = 0.51$, $P < 0.05$, Fig. 12).

DISCUSSION

The Department of Defense is the second largest land steward in the United States and oversees 10.4 million ha, much of which is managed as wildlife habitat (Cohn 1996). Military bases support many listed species, and Cape Canaveral Air Force Station harbors four federally listed species and one species of special concern (Breininger et al. 1998). However, the presence or protection of habitat is insufficient to ensure survival of many species. The interruption of fire regimes and ecosystem fragmentation has contributed greatly to the ecological degradation of many habitats; therefore, active management of critical habitats and species is necessary.

Land management activities at Cape Canaveral Air Force Station influenced all three small mammal species. The threatened southeastern beach mouse was significantly more abundant in compartments that had been prescribed burned, regardless of compartment size, suggesting that populations responded positively to this treatment. Boyer (1964) found a similar response by *P. polionotus* to fire whereas Odum et al. (1973) found that their density remained low after fire, and Arata (1959) found no response in mainland Florida. The lack of agreement among these studies was likely the result of low treatment replications among sites. In this study, I used five burned replicates to test for fire effects on *P. p. niveiventris*. Therefore, the results are likely to indicate true responses to fire. Other small mammal species respond positively to fire. For example, relative abundance of deer mouse (*P. maniculatus*) increased after prescribed fires in tallgrass prairie in Kansas (Kaufman et al. 1988), and kangaroo rats (*Dipodomys* sp.) preferred microhabitats created by fire in southern Idaho (Halford 1981). *P.*

polionotus is associated with open spaces and perhaps could exploit the habitat mosaic created by fire.

Prescribed burning at Cape Canaveral Air Force Station created heterogeneous habitat conditions; winter and summer burns reduced plant cover by 40% and exposed 20% more soil (Foster and Schmalzer 2003). In my study, the number of *P. p. niveiventris* in burned compartments was numerically higher than in cut compartments in fall and winter, suggesting that *P. p. niveiventris* may use open patches of exposed soil created by fires. *P. polionotus* is thought to prefer structurally open ground sites (Davenport 1964). However, my study showed that *P. p. niveiventris* was not confined to the sea oats–dune system that presumably is its preferred habitat. Instead, I trapped *P. p. niveiventris* in densely vegetated sites more than 1.5 km inland, suggesting that it tolerates various vegetation structures. Extine and Stout (1987) reported that residents populations of *P. p. niveiventris* occupied closed habitats on Cape Canaveral Air Force Station; mainland populations of *P. p. subgriseus* inhabiting scrub habitat on the Archbold Biological Station can also tolerate closed habitats (Packer and Layne 1990). I could not demonstrate resident populations of *P. p. niveiventris* in matrix habitat that has been fire suppressed for more than 50 years. Therefore, treatment of the scrub habitat with fire or mechanical means remains as critical for the long-term viability of *P. p. niveiventris*.

Body mass of southeastern beach mice was not affected by land management treatments. Animals maintained their body mass within their range (10.0 to 17.0 g, Hall 1981) suggesting that food was available. Old-field mice are omnivores capable of ingesting very diverse food items (Gentry and Smith 1968). In dune habitat, beach mice food consumption was primarily

determined by seasonal changes in food availability (Moyers 1996). Data from management compartments are necessary to fully evaluate the effects of management practices on food availability to the small mammal assemblage.

Management treatments did not affect the number of male beach mice with descended testes, and most males were non-reproductive. Fall and spring have been reported as peak breeding periods for beach mice (Blair 1951), but male southeastern beach mice did not follow this reproductive pattern. Female southeastern beach mice, contrary to males, followed this seasonal pattern, and their reproductive condition differed among seasons. Numbers of female southeastern beach mice in reproductive condition were particularly high in the fall, when 90 % (10/11) of the females had developed mammarys. In burned compartments, the proportion of female southeastern beach mice showing signs of being reproductive was 57 % (21/37), while in cut compartments, 75 % (6/8) had developed mammarys. However, land management treatments did not have a significant effect on reproductive condition; nonetheless, future management plans should incorporate studies of reproductive performance to further evaluate whether land management activities improve the habitat of the small mammal assemblage.

Although not statistically significant, responses of *P. gossypinus* to mechanized cutting were similar to those reported by Loeb (1999), who found increased abundance in southeastern forest plots where downed woody debris was abundant relative to plots without debris. Downed woody debris from logging activities create complex habitats that *P. gossypinus* exploits. In addition, adult female *P. gossypinus* had greater survival and were more likely to be in reproductive condition (Loeb 1999).

I found no association between land management treatment and body mass and reproduction of small mammals, which suggests the land management treatments did not significantly improve the quality of the habitat. Nonetheless, it appears that cotton mice are responding positively to the cutting treatment, indicating that cutting improves its habitat, but this numeric response is not necessarily an indicator of habitat quality; instead reproductive activity should be used to evaluate habitat quality (Van Horne 1983). Therefore, a good understanding of the population dynamics and demographic parameters are essential to assess the quality of habitats in areas with different structural characteristics. I did not record quantitative data on vegetative structural changes that may have been created by the management treatments, but it appears that they created complex conditions (Fig. 2) favorable to *P. gossypinus*. McCay (2000) documented a variety of microhabitats utilized by *P. gossypinus*; 69% used stumps, 14 % were under upturned root boles, 7% were in shallow burrows not associated with woody debris, 6% were in brush piles, and 4% were under fallen logs. Thus, 100 of 108 microhabitat sites were associated with some form of woody debris.

I could not evaluate population trends of *Sigmodon hispidus* because few individuals were captured. In general, *S. hispidus* was less abundant than the other species throughout the study. They tended, however, to be relatively more abundant during summer in burned compartments. Their body mass in burned compartments was recorded well within the range for the species (110 to 225 g for males and 100 to 200 g for females, Chipman 1965). Typical habitat of *S. hispidus* is characterized by well-developed herbaceous ground cover and an open tree layer, although it also occurs in habitats ranging from sparsely vegetated dunes to dense mesic

forests (Cameron and Spencer 1981). *Sigmodon hispidus* usually nests on the ground in dense vegetation but may construct burrows (Shump 1978). *Sigmodon hispidus* responds to habitat changes in some situations. For example, relative abundance of *S. hispidus* in clearcuts is greater than in uncut forests in South Carolina (Constantine et al. 2004), and they respond positively to prescribed fires in eastern Kansas (Rehmeier et al. 2005).

My study compares small mammal populations in replicated burned, cut, burned–cut, and fire suppressed coastal scrub habitats in east central Florida. The number of replicates and temporal component included in the data set allow me to make strong inferences about responses of small mammals to land management techniques. However, it is possible that the variation in rodent captures among periods following land management activities may result from natural fluctuations or other factors confounded with compartment history. Periodic, cyclic fluctuations in abundance of some small mammal populations are common (Krebs 1966). Therefore, long-term field studies of these small mammal populations are essential for establishing general patterns of population abundance (Rehmeier et al. 2005). Short-term projects may allow detection of variability in abundance, but long-term ecological studies are necessary to investigate potential factors affecting variability (Matlack et al. 2002) and to help avoid erroneous conclusions about complex systems (Swihart and Slade 1990).

Results of my study can be used to aid in designing and implementing a long-term, science-based land management program that would favor multiple species. The goal for restoration and management of Florida scrub at Cape Canaveral Air Force Station is to create large areas of optimal habitat for the Florida scrub-jay, which is an indicator species for scrub

(Breininger et al., 2006). This “coarse filter” approach protects the whole scrub community or ecosystem without attention to other sympatric taxa. However, the indicator species approach has been criticized because there is no agreement on what the indicator is supposed to indicate and because it is difficult to know which is the best indicator species (Simberloff 1998). Several threatened and endangered species inhabit Florida scrub and a management approach that weighed the value of all species to the ecosystem would provide a better chance of conserving imperiled species and the habitats on which they depend. My study showed that *Peromyscus polionotus niveiventris*, a federally listed threatened species, inhabits scrub areas that are not recognized as beach mouse habitat. Going forward, land managers should take the steps necessary to manage such habitat as required by the Endangered Species Act. Conducting experimental tests of management practices is a science-based action that will contribute to recovery of *P. p. niveiventris* and other endangered taxa.

CONCLUSIONS

Results from my study suggest that responses of the small mammal species to land management activities are species-specific: southeastern beach mice positively responded to prescribed burning while cotton mice appeared to positively respond to mechanical cutting. I suggest that best management practices will maintain a mosaic of burned and cut compartments. This strategy will maintain small mammal species diversity and benefit the greatest mix of federally threatened species. Current land management techniques benefits the Florida scrub-jay, for example, the number of nesting pairs ($n = 16$) was numerically higher in compartments managed with fire than in compartments that were cut ($n = 7$) or checkerboarded ($n = 5$). However, number of fledglings ($n = 15$) was greatest in cut compartments. The southeastern beach mouse also favorably responded to the same management practices. Number of individual southeastern beach mice in burned compartments was significantly higher than in cut or fire suppressed treatments. Therefore, consistent application of prescribed burns is imperative to maintain habitat characteristics preferred by these two federally listed species. In addition, a long term small mammal study should be established to investigate temporal patterns and recovery mechanisms of small mammals to the land management treatments.

APPENDIX: FIGURES AND TABLES

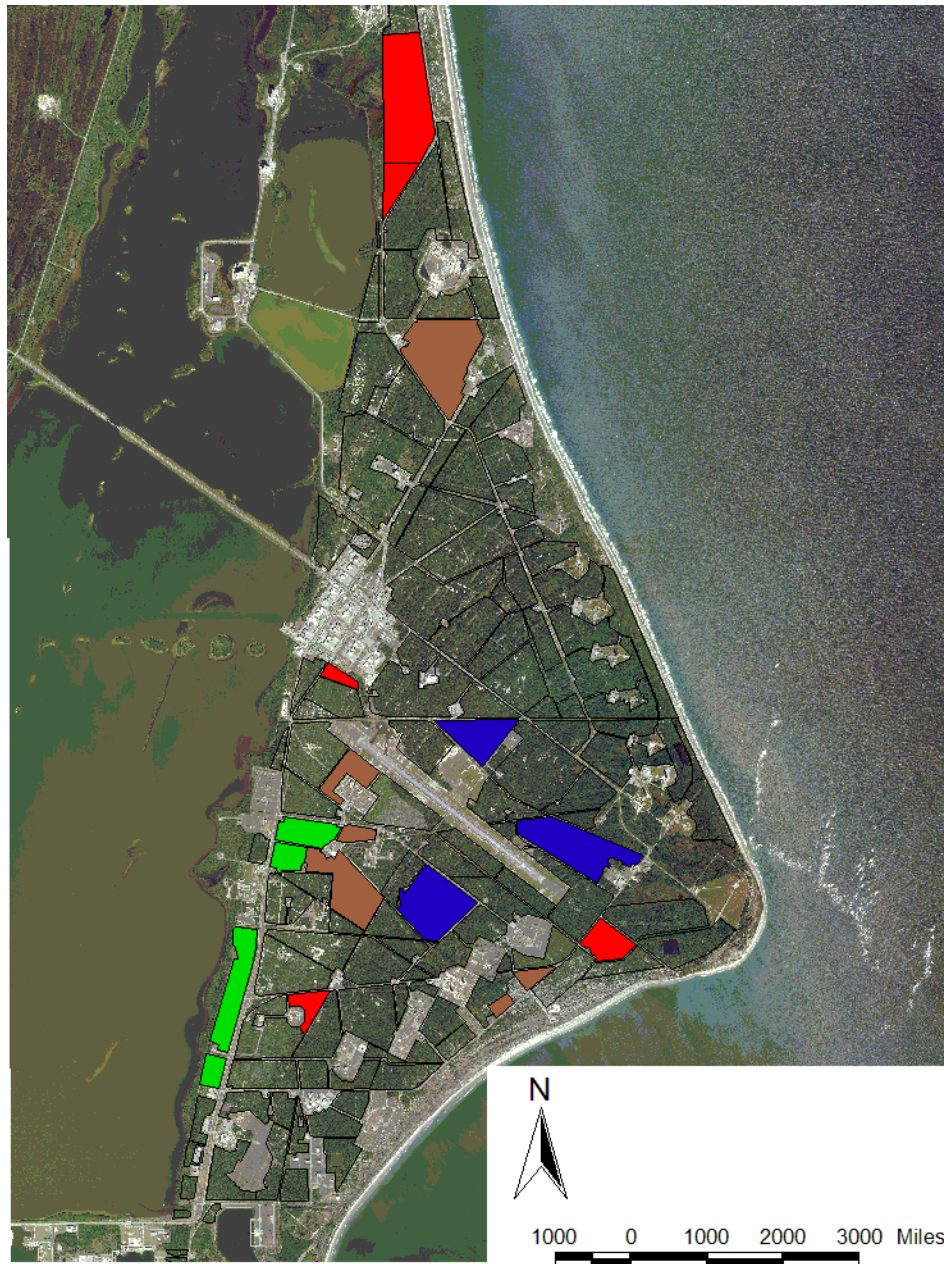


Figure 1— Location of burned (red), cut (brown), checkerboarded (green) and fire suppressed (blue) compartments used to evaluate rodent responses to land management strategies at CCAFS, FL.



Burned



Cut



Checkerboarded



Fire suppressed

Figure 2— Photos of study sites showing differences among land management treatments of Florida scrub at CCAFS, FL

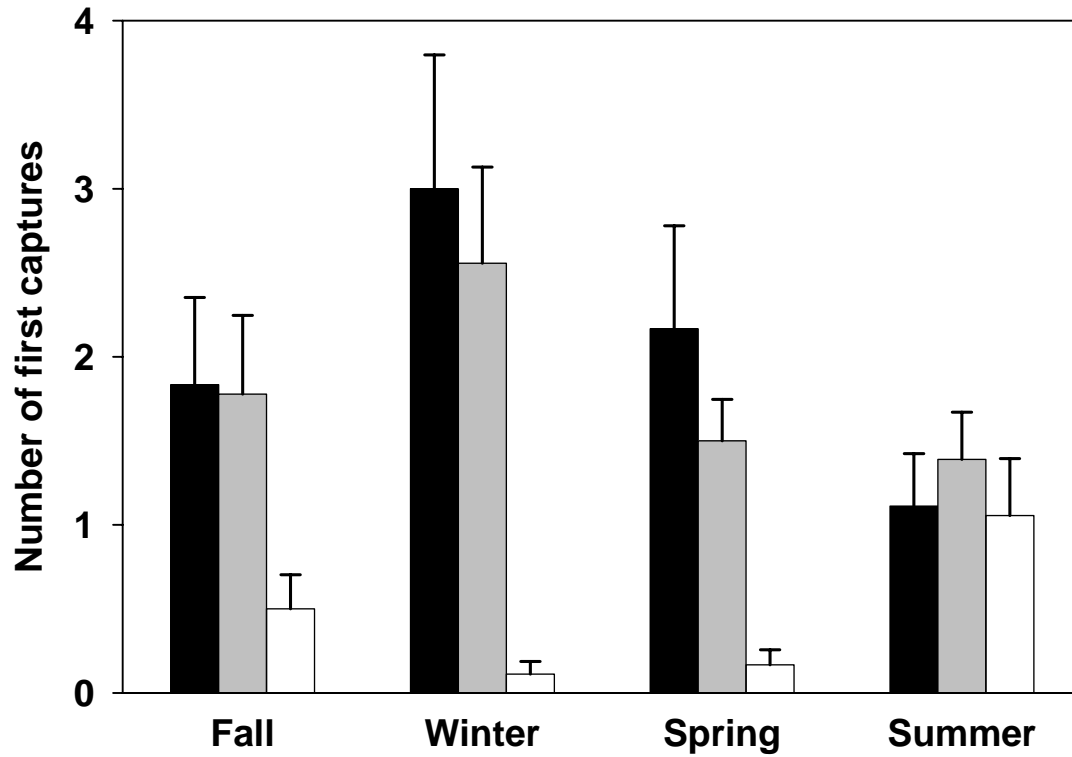


Figure 3— Mean (± 1 SE) number first-time (black) *Peromyscus polionotus niveiventris*, (gray) *P. gossypinus*, (white) *Sigmodon hispidus* captures during the 2004 – 2005 field season in Florida scrub land management compartments at Cape Canaveral Air Force Station, Titusville, Florida, USA.

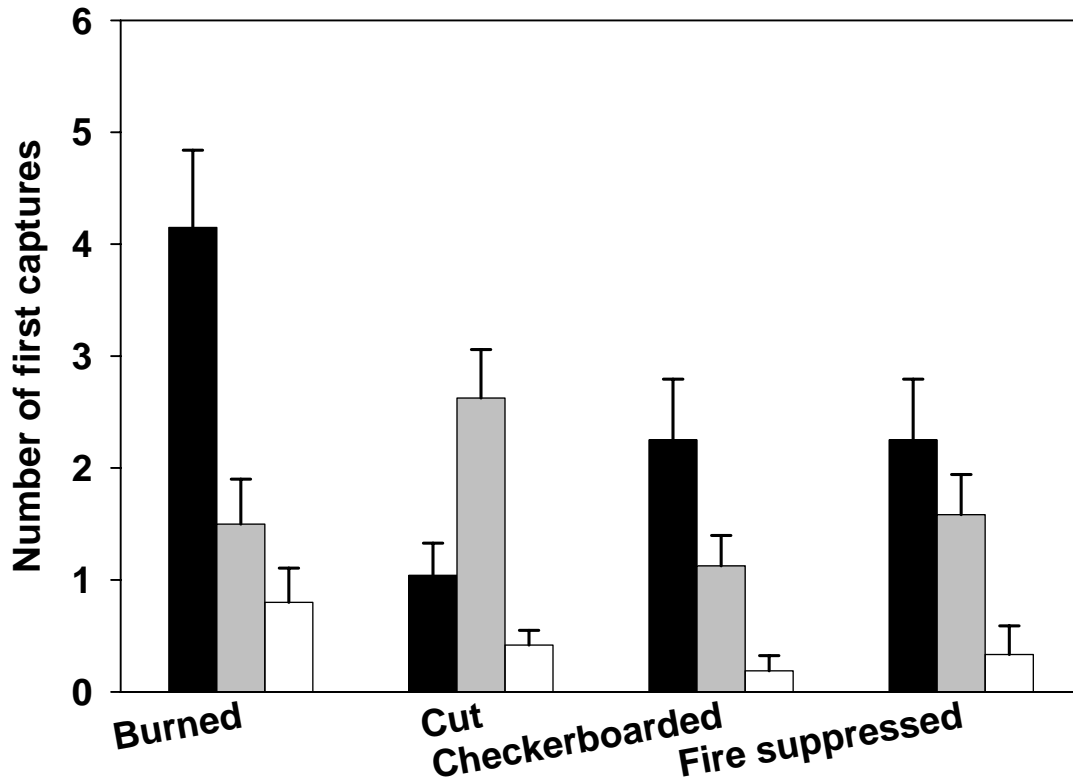


Figure 4— Mean (± 1 SE) number first-time (black) *P. p. niveiventris*, (gray) *P. gossypinus* and (white) *S. hispidus* captures in Florida scrub management compartments under different management strategies. Rodent populations were sampled during 2004-2005 field season at Cape Canaveral Air Force Station, Titusville, Florida, USA.

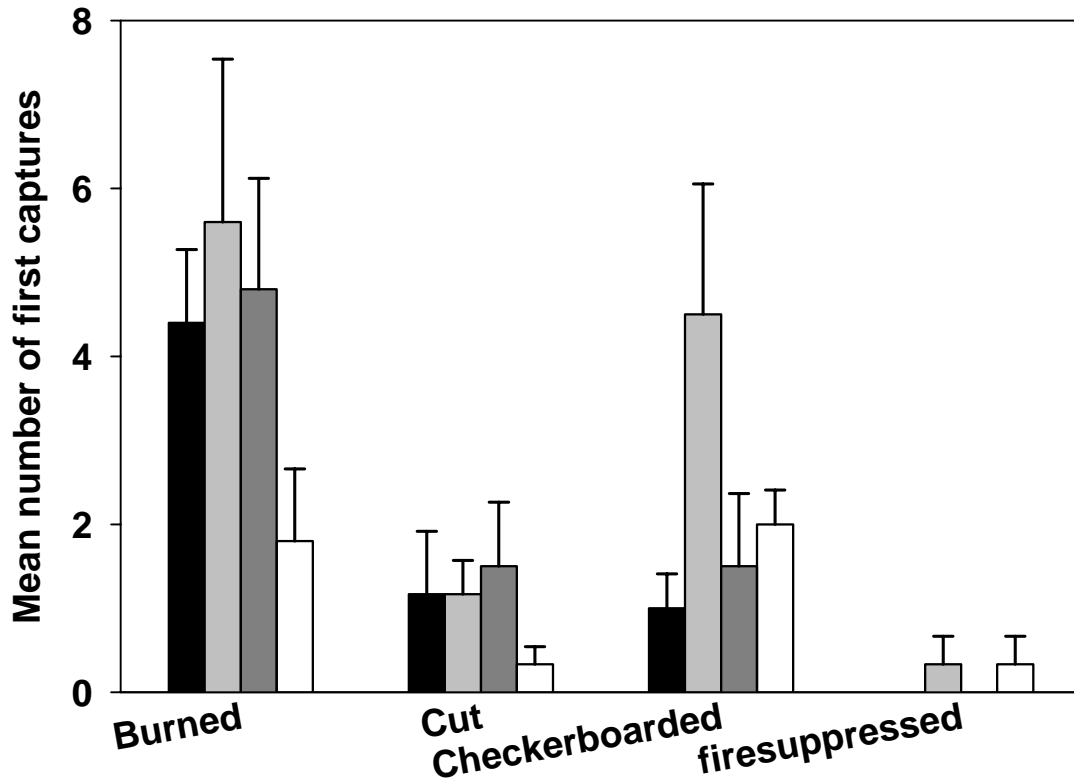


Figure 5— Mean (\pm 1 SE) number first-time *P. p. niveiventris* captures during (black bars) fall, (light gray bars) winter, (dark gray bars) spring and (white bars) summer in compartments under different management treatments at Cape Canaveral Air Force Station, Titusville, Florida, USA.

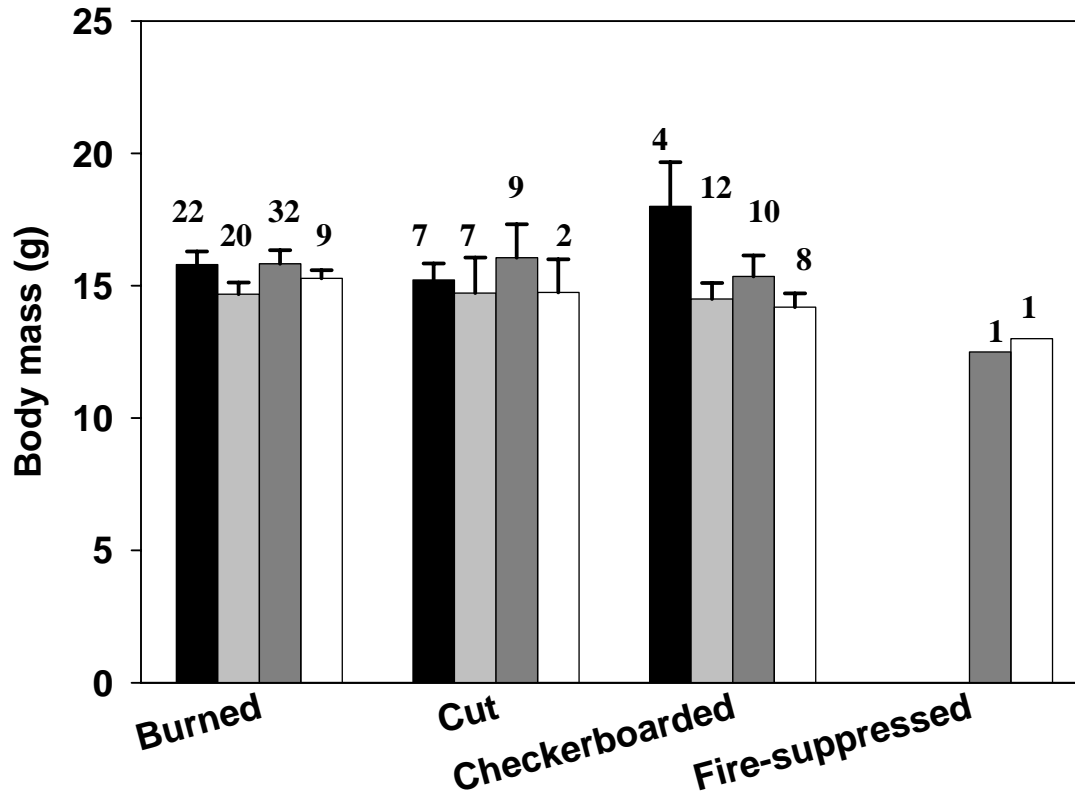


Figure 6—Mean (± 1 SE) body mass first-time *P. p. niveiventris* captures in land management compartments at Cape Canaveral Air Force Station during (black bars) fall, (light gray bars) winter, (dark gray bars), spring, and (white bars) summer. No *P. p. niveiventris* were live trapped in fire-suppressed compartments during fall and winter. Numbers above error bars are sample size.

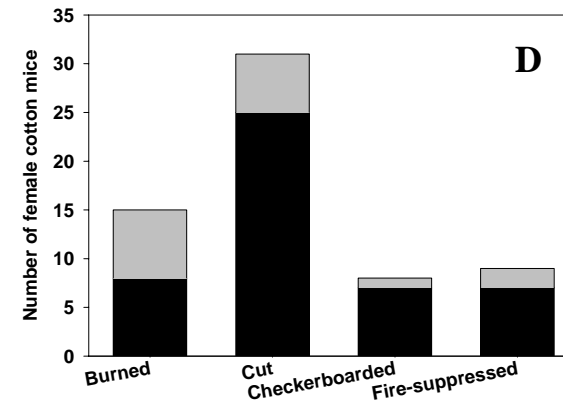
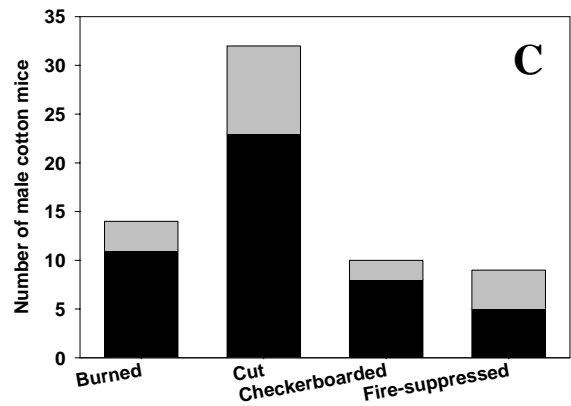
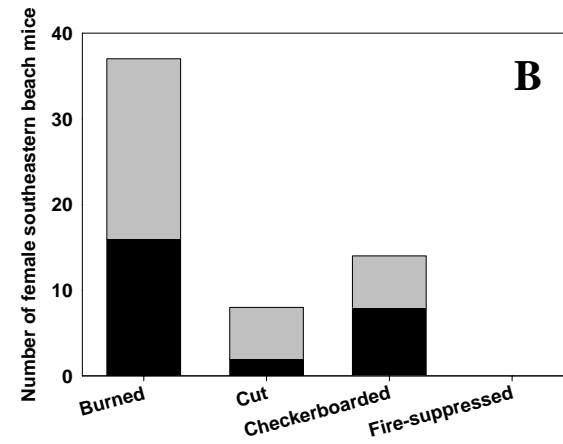
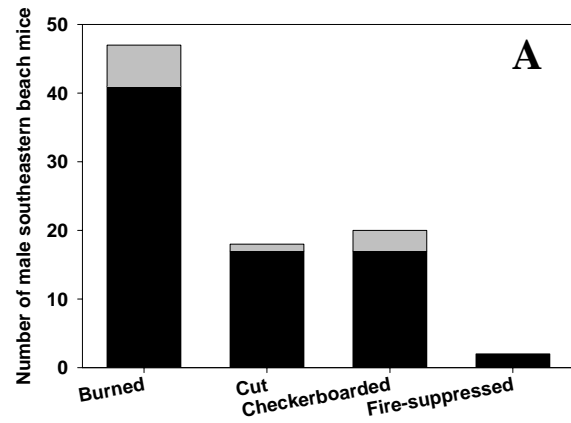


Figure 7—A) Males with descended (gray) and non-descended (black) testes and B) females *P. p. niveiventris* with developed mammarys and hair pulled away from mammarys (gray), and with no reproductive signs (black), and C) males with descended and non-descended testes and D) females *P. gossypinus* with developed mammarys and with no reproductive signs in land management compartments at Cape Canaveral Air Force Station, Florida during 2004-2005. No female *P. p. niveiventris* were trapped in fire-

suppressed compartments. Reproductive condition was independent of land management treatment. Data are number of first-time captures.

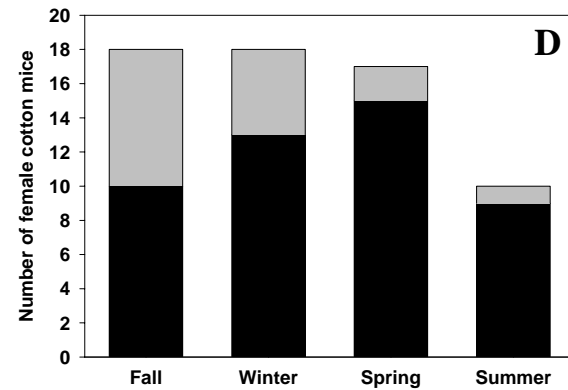
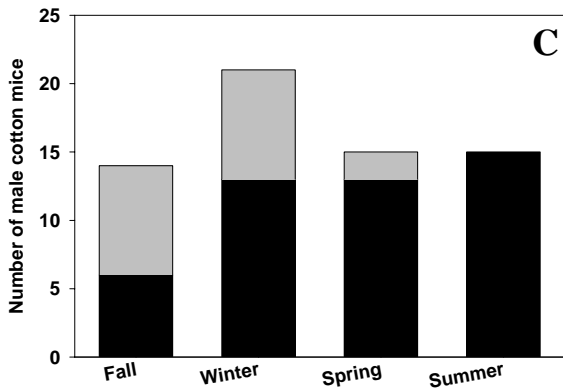
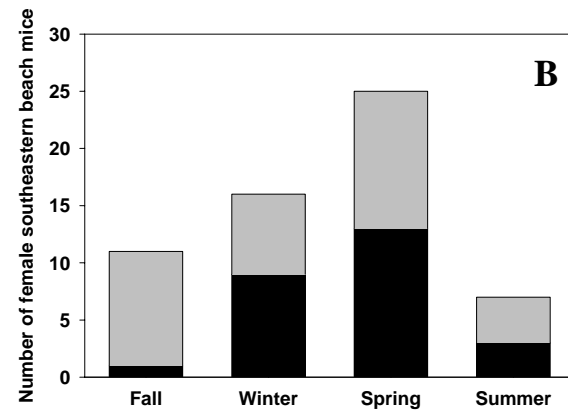
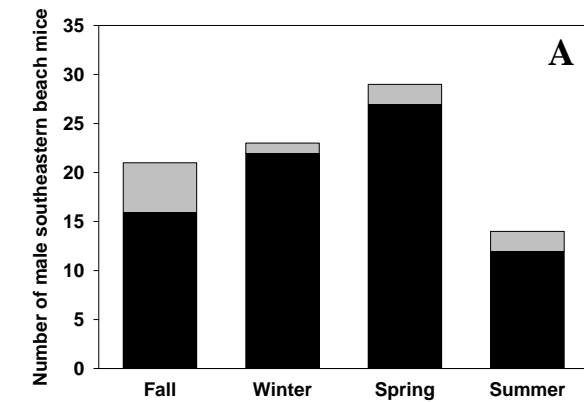


Figure 8—A) Males with descended (gray) and non-descended (black) testes and B) females *P. p. niveiventris* with developed mammarys and hair pulled away from mammarys (gray) and showing no signs of reproduction (black), and C) males with descended and non-descended testes and D) females *P. gossypinus* with developed mammarys and no signs of reproduction. Reproductive condition of female *P.p. niveiventris* and of male *P. gossypinus* differed among seasons. Data are number of first-time captures.

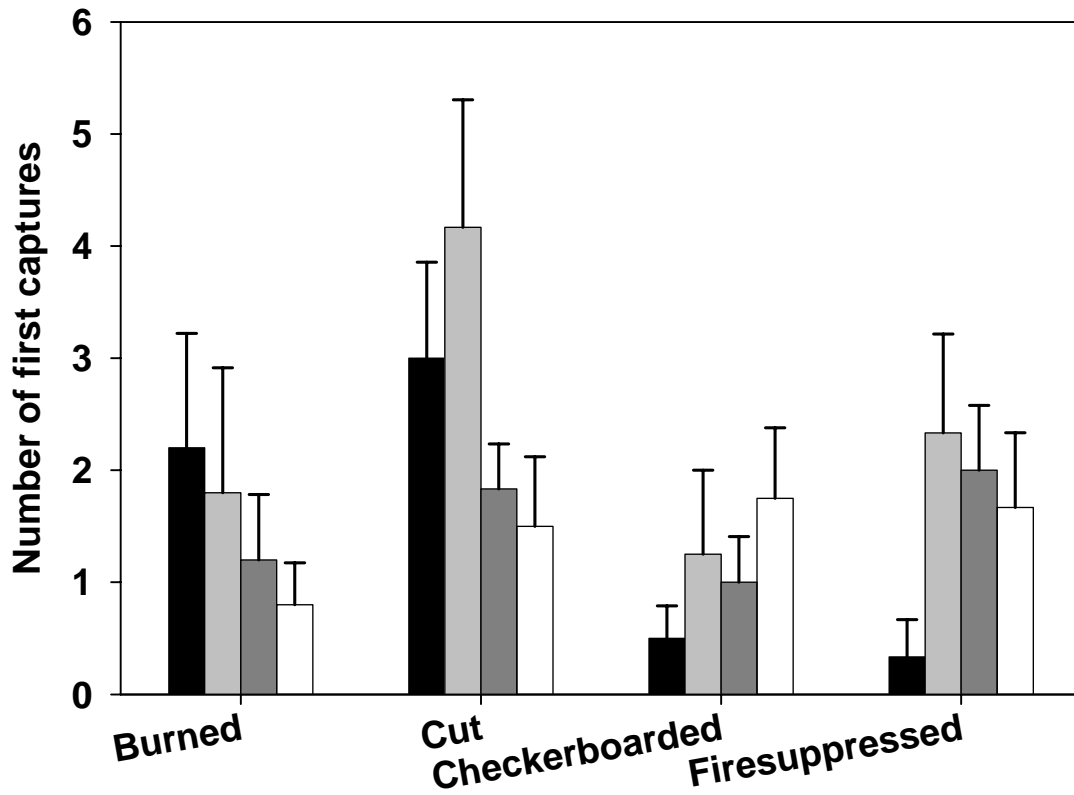


Figure 9— Mean (± 1 SE) number first-time *P. gossypinus* captures during (black bars) fall, (light gray bars) winter, (dark gray bars) spring and (white bars) summer in land management compartments at Cape Canaveral Air Force Station, Titusville, Florida, USA.

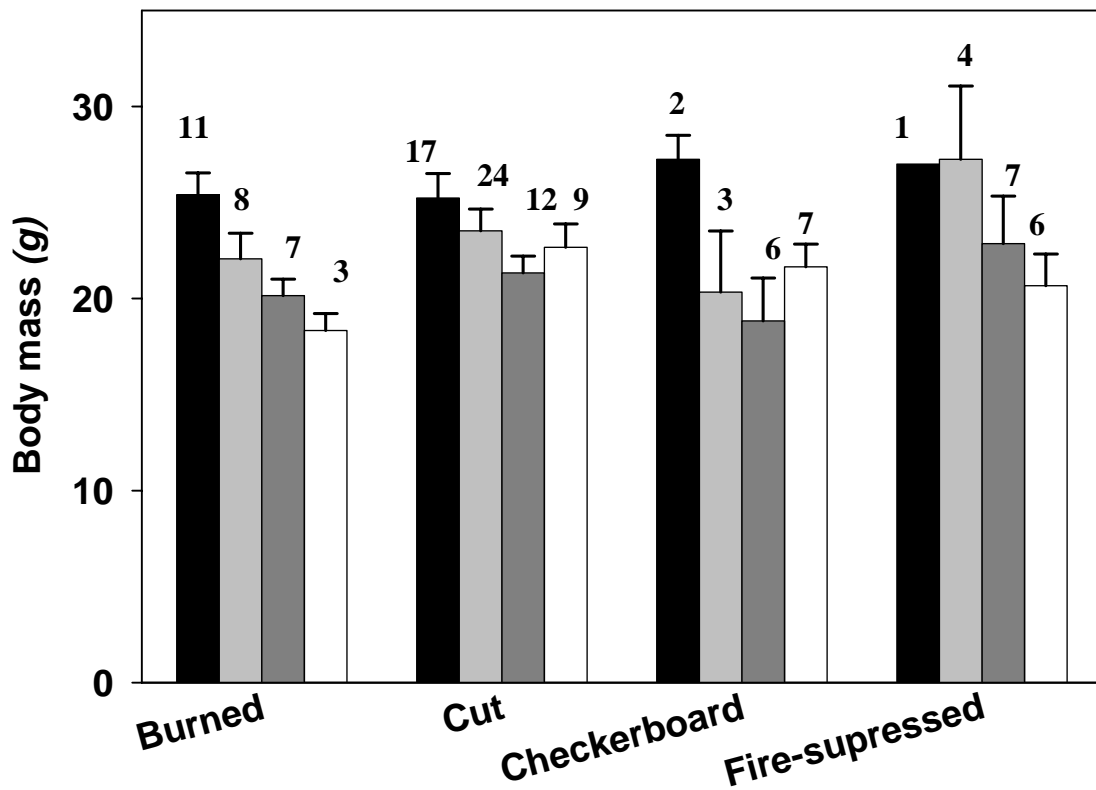


Figure 10— Mean ($\pm 1SE$) body mass first-time *P. gossypinus* captures in land management compartments during (black bars) fall, (light gray bars) winter, (dark gray bars), spring and (white bars) summer at Cape Canaveral Air Force Station, Florida. Sample sizes are shown above error bars.

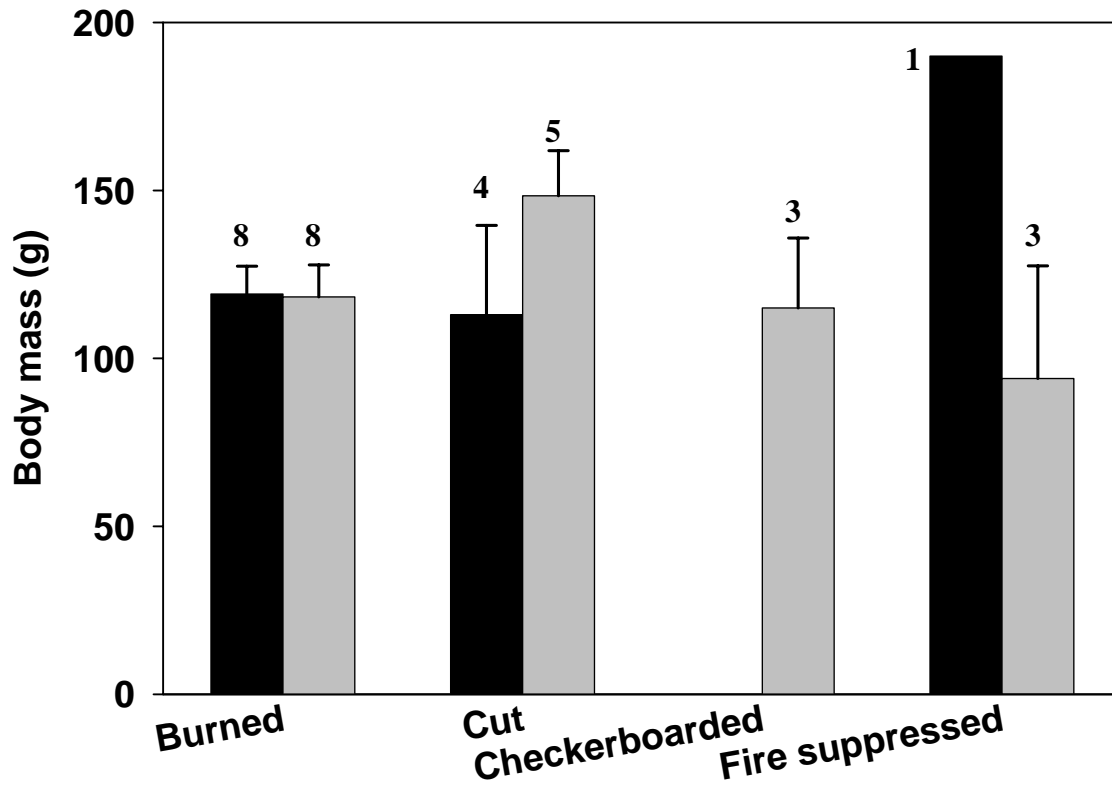


Figure 11— Mean (± 1 SE) body mass first-time male (black bars) and female (gray bars) cotton rat captures in land management compartments at Cape Canaveral Air Force Station, Florida. No male cotton rats were trapped in checkerboarded compartments. Sample sizes are shown above error bars.

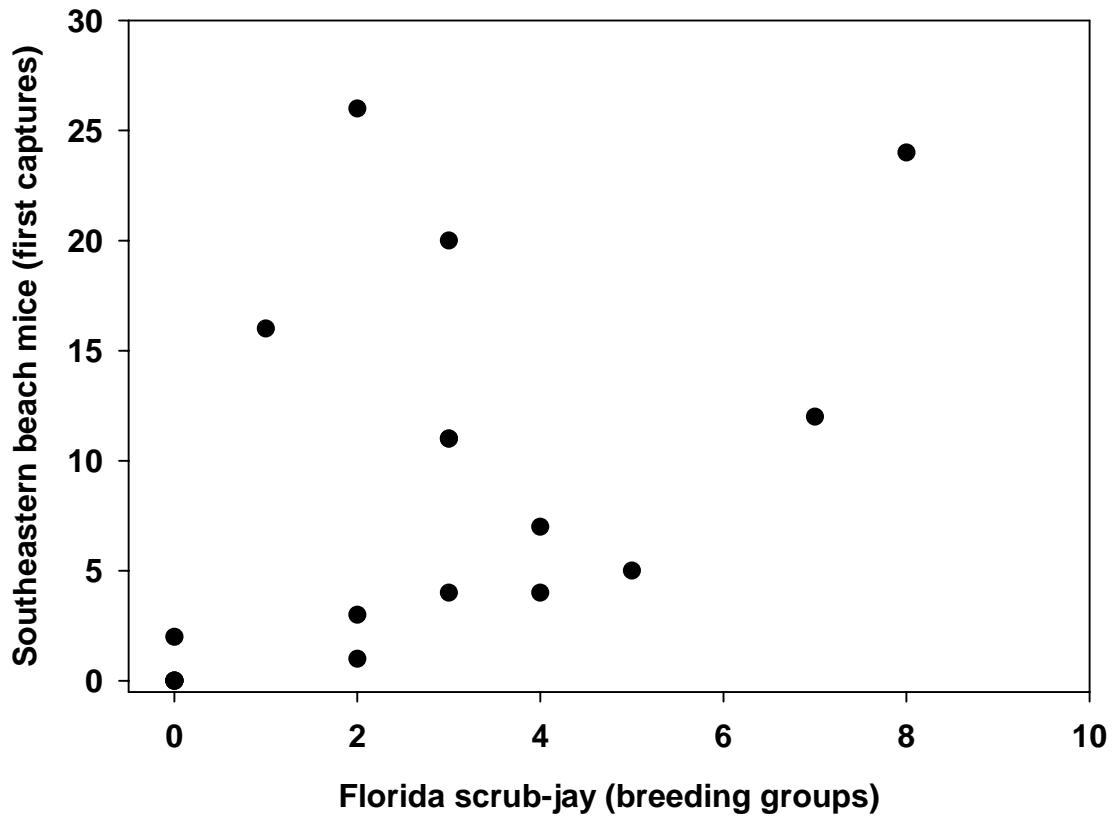


Figure 12— Pearson correlation between Florida scrub-jay breeding groups and first-time captures of southeastern beach mice in land management compartments during 2004 –2005 field season at Cape Canaveral Air Force Station, Florida.

Table 1. Area (ha) and time since treatment of land management compartments used to evaluate responses of the small rodent assemblage to management techniques at Cape Canaveral Air Force Station during 2004-2005.

Compartment	Area (ha)	Treatment	Years since treatment
4	93.1	Burned	1
7	15.4	Burned	1
37	7.7	Burned	5
87	23.1	Burned	2
115	12.5	Burned	3
13	84.4	Cut	1
48	19.8	Cut	1
67	8.1	Cut	1
79	48.6	Cut	1
102	8.0	Cut	1
104	5.2	Cut	1
69	24.7	Checkerboarded	1
81	13.4	Checkerboarded	1
101	40.5	Checkerboarded	1
118	9.7	Checkerboarded	1
55	34.7	Fire suppressed	50
70	64.9	Fire suppressed	50
77	57.1	Fire suppressed	50

Table 2. Results of RM-ANOVA on *Peromyscus polionotus niveiventris* relative abundance in scrub compartments under different management techniques at Cape Canaveral Air Force Station, Titusville, Florida, USA.

Source	<i>d. f.</i>	F	P
Within-subjects factors			
Season	3	0.91	0.44
Season x compartment size (ha)	3	0.79	0.50
Season x treatment	9	2.81	0.01
Error	39		
Between-subjects factors			
Compartment size (ha)	1	0.01	0.98
Land management treatment	3	4.33	0.02
Error	13		

Table 3. Abundances of Florida scrub-jay (*Aphelocoma coerulescens*) and southeastern beach mouse (*Peromyscus polionotus niveiventris*) on land management compartments during the 2004-2005 field season at Cape Canaveral Air Force Station, Florida. ¹Florida scrub-jay data are from Stevens and Knight 2003-2004 annual report. *Cut but unburned.

Compartment	¹ Florida scrub-jay groups using compartments						Southeastern beach mouse
	Area(ha) (burned)	2004 Census	Breeding Season	Nesting	Successful Groups	Fledging	Number of first-time captures
4	93(40)	10	8	8	0	0	24
7	15(15)	4	7	6	1	4	12
*13	84(0)	0	0	0	0	0	0
37	7(7)	2	3	1	1	2	20
*48	19(0)	1	3	3	3	11	4
55	34(0)	0	0	0	0	0	2
*67	8(0)	0	2	0	0	0	3
69	24(0)	2	3	1	0	0	11

¹Florida scrub-jay groups using compartments						Southeastern beach mouse	
Compartment	Area(ha)	2004	Breeding	Nesting	Successful	Fledging	Number of first-time
	(burned)	Census	Season		Groups		captures
*79	48(0)	0	0	0	0	0	0
81	13(0)	3	4	1	0	0	4
87	23(12)	1	2	1	1	3	26
101	12(0)	1	5	2	0	0	5
*102	4(0)	0	4	0	0	N/A	7
*104	6(0)	5	3	4	1	4	11
115	12(12)	0	2	0	0	0	1
118	9(0)	0	1	1	0	0	16

LIST OF REFERENCES

- Abrahamson, W. G. 1984. Post-fire recovery of Florida Lake Wales Ridge vegetation. *American Journal of Botany* 71:9-21.
- Andelman, S. J., and W. F. Fagan. 2000. Umbrellas and flagships: efficient conservation surrogates, or expensive mistakes? *Proceedings of the National Academy of Sciences of the United States of America* 97:5954-5959.
- Animal Care and Use Committee. 1998. Guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists. *Journal of Mammalogy* 79:1416-1431.
- Arata, A. A. 1959. Effects of burning on vegetation and rodent populations in a longleaf pine-turkey oak association in north central Florida. *Quarterly Journal Florida Academy of Sciences* 22:94-104.
- Bergen, S. 1994. Characterization of fragmentation in Florida scrub communities. M. S. Thesis. Florida Institute of Technology, Melbourne, Florida. 71 pp.
- Blair, W. F. 1951. Population structure, social behavior, and environmental relations in a natural population of the beach mouse (*Peromyscus polionotus leucocephalus*). *Contributions of the Laboratory of Vertebrate Biology, University of Michigan* 48: 1-47.
- Boyer, W. D. 1964. Longleaf seed losses to animals on burned seedbeds. United States Department Agriculture, Forest Service. *Restoration Notes SO-6*. 3 pp.

- Breininger, D. R. 1981. Habitat preferences of the Florida Scrub Jay (*Aphelocoma coerulescens* *coerulescens*) at Merritt Island National Wildlife Refuge, Florida. Master's thesis. Florida Institute of Technology, Melbourne, Florida, 159 pp.
- Breininger, D. R., M. J. Barkaszi, R. B. Smith, D. M. Oddy, and J. A. Provanha. 1998. Prioritizing wildlife taxa for biological diversity conservation at the local scale. *Environmental Management* 22:315-321.
- Breininger, D. R., V. L. Larson, B. A. Duncan, R. B. Smith, D. M. Oddy, and M. Goodchild. 1995. Landscape patterns in Florida scrub jay habitat preference and demography. *Conservation Biology* 9:1442-1453.
- Breininger, D. R., and R. B. Smith. 1990. Waterbird use of coastal impoundments and management implications in east-central Florida. *Wetlands* 10:223-241.
- Breininger, D. R., B. Toland, D. M. Oddy, and M. L. Legare. 2006. Landcover characterizations and Florida scrub-jay (*Aphelocoma coerulescens*) population dynamics. *Biological Conservation* 128:169-181.
- Cameron, G. N., and S. R. Spencer. 1981. *Sigmodon hispidus*. *Mammalian Species* 158:1-9.
- Chipman, R. K. 1965. Age determination of the cotton rat (*Sigmodon hispidus*). *Tulane Studies Zoological* 12:19-38.
- Christman, S. P., and W. S. Judd. 1990. Notes on plants endemic to Florida scrub. *Florida Scientist* 53:52-73.
- Cohn, J. P. 1996. New defenders of wildlife. *Bioscience* 46:11-14

- Constantine, N. L., T. A. Campbell, W. M. Baughman, T. B. Harrington, B. R. Chapman, and K. V. Miller. 2004. Effects of clearcutting with corridor retention on abundance, richness, and diversity of small mammals in the coastal plain of South Carolina, USA. *Forest Ecology and Management* 202:293-300.
- Cook, S. F., Jr. 1959. The effect of fire on a population of small rodents. *Ecology* 40:102-108.
- Cox, J. 1984. Distribution, habitat, and social organization of the Florida scrub jay, with a discussion of the evolution of cooperative breeding in new world jays. Ph.D. Dissertation. University of Florida, Gainesville, Florida. 259 pp.
- Crowder, M. J., and D. J. Hand. 1990. *Analysis of Repeated Measures*. Chapman and Hall, New York.
- Davenport, L. B., Jr. 1964. Structure of two *Peromyscus polionotus* populations in old-field ecosystems at the AEC Savannah River Plant. *Journal of Mammalogy* 45:95-113.
- DeFreese, D. E. 1995. Land acquisition: A tool for biological diversity protection in the Indian River Lagoon, Florida. *Bulletin of Marine Science* 57:14-27.
- Duncan, B. W., S. Boyle, D. R. Breininger, and P. A. Schmalzer. 1999. Coupling past management practice and historic landscape change on John F. Kennedy Space Center, Florida. *Landscape Ecology* 14:291-309.
- Extine, D. D., and I. J. Stout. 1987. Dispersion and habitat occupancy of the beach mouse, *Peromyscus polionotus niveiventris*. *Journal of Mammalogy* 68:297-304.

- Fernald, R. T. 1989. Coastal xeric scrub communities of the Treasure Coast Region, Florida. Nongame Wildlife Program Technical Report No. 6. Florida Game and Freshwater Fish Commission, Tallahassee. 113 pp.
- Foster, T. A., and P. A. Schmalzer. 2003. The effect of season of fire on the recovery of Florida scrub. In Proceeding of the Second International Wildland Fire Ecology and Fire Management Congress, American Meteorological Society, Published on CDROM and at www.ametsoc.org.
- Fowler, J., L. Cohen, and P. Jarvis. 2000. Practical Statistics for Field Biology. John Wiley and Sons, New York.
- Franklin, J. F. 1993. Preserving biodiversity: species, ecosystems or landscapes? Ecological Applications 3:202-205.
- Franklin, J. F. 1994. Preserving biodiversity: species in landscapes. Response to Tracy and Brussard, 1994. Ecological Applications 4:208-209.
- Gentry, J. B., and M. H. Smith. 1968. Food habits and burrow associates of *Peromyscus polionotus*. Journal of Mammalogy 49:562-565.
- Green, R. H. 1993. Application of repeated measures designs in environmental impact and monitoring studies. Austrian Journal of Ecology 18:81-98.
- Gosselink, J. G., G. P. Shaffer, L. C. Lee, D. M. Burdick, D. L. Childers, N. C. Leibowitz, S. C. Hamilton, R. Boumans, D. Cushman, S. Fields, M. Koch, and J. M. Visser. 1990. Landscape conservation in a forested wetland watershed. Bioscience 40:588-600.
- Hall, E. R. 1981. The Mammals of North America. John Wiley and Sons, New York.

- Halford, D. K. 1981. Repopulation and food habits of *Peromyscus maniculatus* on a burned sagebrush desert in southeastern Idaho. Northwest Science 55:44-49.
- Hansen, A. J., S. L. Garman, B. Marks, and D. L. Urban. 1993. An approach for managing vertebrate diversity across multiple-use landscapes. Ecological Applications 3:481-496.
- Harty, F. M., J. M. Ver Steeg, R. R. Heidorn, and L. Harty. 1991. Direct mortality and reappearance of small mammals in an Illinois grassland after a prescribed burn. Natural Areas Journal 11:114-118.
- Hobbs, R. J. 1994. Landscape ecology and conservation: moving from description to application. Pacific Conservation Biology 1:170-176.
- Holliman, D. C. 1983. Status and habitat of Alabama Gulf coast beach mice, *Peromyscus polionotus ammobates* and *P. p. trissyllepsis*. Northeast Gulf Science 6:121-129.
- Humphrey, S. J., and D. B. Barbour. 1981. Status and habitat of three subspecies of *Peromyscus polionotus* in Florida. Journal of Mammalogy 62:840-844.
- Hunter, M. L., Jr. 1993. Natural fire regimes as spatial models for managing boreal forests. Biological Conservation 65:115-120.
- Kaufman, D. W., E. J. Finck, and G. A. Kaufman. 1990. Small mammals and grassland fires. Pages 46-80 in S. L. Collins, and L. L. Wallace, editors. Fire in North American Tallgrass Prairies. University of Oklahoma Press, Norman, Oklahoma.
- Kaufman, D. W., G. A. Kaufman, and E. J. Finck. 1983. Effects of fire on rodents in tallgrass prairie of the Flint Hills region of eastern Kansas. Prairie Naturalist 15:49-56.

- Kaufman, D. W., S. K. Gurtz, and G. A. Kaufman. 1988. Movements of the deer mouse in response to prairie fire. *Prairie Naturalist* 20:225-229.
- Kaufman, G. A., D. W. Kaufman, and E. J. Finck. 1988. Influence of fire and topography on habitat selection by *Peromyscus maniculatus* and *Reithrodontomys megalotis* in ungrazed tallgrass prairie. *Journal of Mammalogy* 69:342-352.
- Kirkland, G. L., Jr. 1990. Patterns of initial small mammal community change after clearcutting of temperate North American forests. *Oikos* 59:313-320.
- Krebs, C. J. 1966. Demographic changes in fluctuating populations of *Microtus californicus*. *Ecological Monographs* 36:239-273.
- Lambeck, R. J. 1997. Focal species: A multi-species umbrella for nature conservation. *Conservation Biology* 11:849-856.
- Layne, J. N. 1968. Ontogeny. Pages 148-253 in J. A. King editor. *Biology of Peromyscus* (Rodentia). Special Publication 2, American Society of Mammalogists.
- Loeb, S. C. 1999. Responses of small mammals to coarse woody debris in a southeastern pine forest. *Journal of Mammalogy* 80:460-471.
- Matlack, R. S., D. W. Kaufman, G. A. Kaufman, and B. R. McMillan. 2002. Long-term variation in abundance of Elliot's short-tailed shrew (*Blarina hylophaga*) in tallgrass prairie. *Journal of Mammalogy* 83:280-289.
- McCay, T. S. 2000. Use of woody debris by cotton mice (*Peromyscus gossypinus*) in a southeastern pine forest. *Journal of Mammalogy* 81:527-535.

- Menges, E. S. 1999. Ecology and conservation of Florida scrub. Pages 7-22 in R. C. Anderson, J. S. Franlish, and J. M. Baskin, editors. Savannas, barrens, rock outcrop plant communities of North America. Cambridge University Press, New York.
- Monamy, V., and J. B. Fox. 2000. Small mammal succession is determined by vegetation density rather than time elapsed since disturbance. *Australian Ecology* 25:580-587.
- Moyers, J. E. 1996. Food habits of gulf coast subspecies of beach mice (*Peromyscus polionotus* spp.). Master thesis. Auburn University, Alabama, 83pp.
- Myers, R. L. 1990. Scrub and high pine. Pages 150-193 in R. L. Myers and J. J. Ewell, editors. Ecosystems of Florida. University of Central Florida Press, Orlando.
- Noss, R. F. 1983. A regional landscape approach to maintain biodiversity. *Bioscience* 33:700-706.
- Noss, R. F. 1987. From plant communities to landscape in conservation inventories: a look at The Nature Conservancy (USA). *Biological Conservation* 41:11-37.
- Noss, R. F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology* 4:355-364.
- Noss, R. F., and L. D. Harris. 1986. Nodes, networks and MUMs: preserving diversity at all scales. *Environmental Management* 10:299-309.
- Odum, E. P., S. E. Pomeroy, J. C. Dickinson, III, and K. Hutcheson. 1973. The effects of late winter litter burn on the composition, productivity and diversity of a 4-year old fallow-field in Georgia. Proceedings Annual Tall Timbers Fire Ecology Conference. Tallahassee, Florida. 13: 399-427.

- Oli, M. K., N. R. Holler, and M. C. Wooten. 2001. Viability analysis of endangered gulf coast beach mice (*Peromyscus polionotus*) populations. *Biological Conservation* 97:107-118.
- Orians, G. H. 1993. Endangered at what level? *Ecological Applications* 3:206-208.
- Packer, W. C., and J. N. Layne. 1990. Foraging site preferences and relative arboreality of small rodents in Florida. *American Midland Naturalist* 125:187-194.
- Rave, E. H., and N. R. Holler. 1992. Population dynamics of Alabama beach mice (*Peromyscus polionotus ammobates*) in south Alabama. *Journal of Mammalogy* 73:347-355.
- Rehmeier, R. L., G. A. Kaufman, D. W. Kaufman, and B. R. McMillan. 2005. Long-term study of abundance of the hispid cotton rat in native tallgrass prairie. *Journal of Mammalogy* 86:670-676.
- Roemer, G. W., and R. K. Wayne. 2003. Conservation in conflict: the tale of two endangered species. *Conservation Biology* 17:1251-1260.
- Robbins, L. E., and R. L. Myers. 1992. Seasonal effects of prescribed burning in Florida: a review. Miscellaneous Publication No. 8, Tall Timbers Research, Inc., Tallahassee, Florida.
- Rubinoff, D. 2001. Evaluating the California gnatcatcher as an umbrella species for conservation of southern California coastal scrub. *Conservation Biology* 15:1374-1383.
- Schmalzer, P. A., and F. W. Adrian. 2001. Scrub restoration on Kennedy Space Center / Merritt Island National Wildlife Refuge, 1992-200. Pages 17-20 in D. Zattau, editor. *Proceedings of the Florida Scrub Symposium 2001*. U. S. Fish and Wildlife Service. Jacksonville, Florida.

- Schmalzer, P. A., and S. R. Boyle. 1998. Restoring long-unburned oak-saw palmetto scrub requires mechanical cutting and prescribed burning (Florida). *Restoration and Management Notes* 16:96-97.
- Schmalzer, P. A., T. E. Foster, and F. W. Adrian. 2003. Responses of long-unburned scrub on the Merritt Island / Cape Canaveral barrier island complex to cutting and burning. In: *Proceedings of the Second International Wildland Fire Ecology and Fire Management Congress*, American Meteorological Society, Pulished on CDROM and at www.ametsoc.org.
- Schmalzer, P. A., and C. R. Hinkle. 1992. Species composition and structure of oak-saw palmetto scrub vegetation. *Castanea* 57:220-251.
- Shump, K. A., Jr. 1978. Ecological importance of nest construction in the hispid cotton rat (*Sigmodon hispidus*). *American Midland Naturalist* 100:103-115.
- Simberloff, D. 1998. Flagships, umbrellas, and keystone: Is single-species management passe' in the landscape era? *Biological Conservation* 83:247-257.
- Stevens, T., and G. Knight. 2004. Status and distribution of the Florida Scrub-Jay (*Aphelocoma coerulescens*) at Cape Canaveral Air Force Station, Florida. Annual Report 2003-2004.
- Stith, B. M., J. W. Fitzpatrick, G. E. Woolfenden, and B. Pranty. 1996. Classification and conservation of metapopulations: A case study of the Florida Scrub Jay. Pages 187-215 in D. R. McCullough, editor. *Metapopulations and Conservation*. Island Press, Washington, D. C.

- Stout, I. J. 1979. Efforts to inventory wildlife habitat: Progress toward a terrestrial ecosystem monitoring program for the U. S. space shuttle program. Transactions of the 44th North American Wildlife and Natural Resources Conference. Wildlife Management Institute, Washington, D. C.
- Stout, I. J. 2001. Rare plants of the Florida scrub. *Natural Areas Journal* 21:50-60.
- Stout, I. J., and W. R. Marion. 1993. Pine flatwoods and xeric pine forest of the southern (lower) coastal plain. Pages 373-446 *in* W. H. Martin, S. G. Boyce, and A. C. Echternacht, editors. *Biodiversity of the Southeastern United States Lowland Terrestrial Communities*. John Wiley and Sons, New York.
- Sullivan, T. P., R. A. Lautenschlager, and R. G. Wagner. 1999. Clearcutting and burning of northern spruce-fir forests: Implications for small mammal communities. *Journal of Applied Ecology* 36:327-344.
- Swihart, R. K., and N. A. Slade. 1990. Long-term dynamics of an early successional small mammal community. *American Midland Naturalist* 123:372-382.
- Tracy, C. R., and P. F. Brussard. 1994. Preserving biodiversity: species in landscapes. *Ecological Applications* 4:205-207.
- United States Fish and Wildlife Service. 1993. Recovery plan for the Anastasia Island and southeastern beach mouse. Atlanta, Georgia.
- Van Horne, B. 1983. Density as a misleading indicator of habitat quality. *Journal of Wildlife Management* 47:893-901.

Walker, B. H. 1995. Conserving biological diversity through ecosystem resilience. *Conservation Biology* 9:747-752.

Wescott, P. A. 1970. Ecology and behavior of the Florida scrub jay. Ph.D. Dissertation. University of Florida, Gainesville, 85 pp.

Wolfenden, G. E., and J. W. Fitzpatrick. 1984. The Florida scrub jay: demography of a cooperative-breeding bird. Princeton University Press. Princeton, New Jersey.

Zar, J. H. 1999. *Biostatistical Analysis*. Prentice Hall, New Jersey.