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Responses of small rodents to habitat restoration and management for the imperiled Florida Scrub-Jay

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ABSTRACT

Debate about the relative merits of single-species management versus more comprehensive approaches has intensified in recent years. In east-central Florida, USA, land managers use prescribed burns and mechanical cutting to manage and restore scrub habitat to benefit the imperiled Florida Scrub-Jay (*Aphelocoma coerulescens*). However, these land-management techniques may affect non-target taxa, especially the threatened southeastern beach mouse (*Peromyscus polionotus niveiventris*). We evaluated the collateral effects of single-species land management by trapping *P. p. niveiventris* and other small rodents in eighteen land-management compartments at Cape Canaveral Air Force Station, Florida during 2004–2005. Compartments were managed using either prescribed burns ($N = 5$), mechanical cutting ($N = 6$), checkerboarding (cut and uncut lanes alternating and overlapping, followed by a prescribed burn, $N = 4$) or left unburned and uncut for >50 year ($N = 3$). *P. p. niveiventris* was significantly more abundant in compartments managed with prescribed burns (mean ± SE: 4.2 ± 0.7 individuals/transect) than those managed with cutting alone (1.0 ± 0.3) or not managed for >50 y (0.2 ± 0.1 individuals/transect). In contrast, the cotton mouse (*Peromyscus gossypinus*) tended to be more abundant in compartments managed with mechanical cutting alone (2.6 ± 0.4 individuals/transect) compared to the other three management strategies (prescribed burns; 1.5 ± 0.4; checkerboarding, 1.1 ± 0.3; not managed, 1.6 ± 0.4 individuals/transect) but these differences were not statistically significant. Abundances of *P. p. niveiventris* and Florida Scrub-Jay breeding groups were positively correlated ($r = 0.655$), suggesting that both listed species benefit from similar management techniques. Thus, the mosaic of burned and cut patches used to improve habitat for the Florida Scrub-Jay also benefits an endemic, non-target species. Single-species management may benefit multiple species when restoration improves their shared habitat, which in this case is an endangered, fire-dependent ecosystem: Florida scrub.

1. Introduction

Habitat loss or modification is the major threat to most of the world's threatened and endangered species (Kerr and Currie, 1995; Fischer and Lindenmayer, 2007), so management to restore and improve habitat quality is of great conservation importance. Several short cuts have been proposed to prevent further loss of biodiversity, including single-species approaches that focus on one surrogate species (umbrella species) whose habitat requirements are believed to encapsulate those of additional species (Lambeck, 1997; Seddon and Leech, 2008). Flagship species such as elephants and grizzly bears are charismatic species used to raise conservation awareness, action, and funding at a global scale (Caro and O' Doherty, 1999). An alternative approach emphasizes keystone species such as the gray wolf, whose effect within its ecosystem is disproportionately large in relation to its abundance (Wilmers et al., 2003).

Single-species management has been criticized because it cannot be conducted fast enough to deal with the urgency of threats, consumes disproportionate funding, and does not provide whole-landscape solutions to conservation problems (Franklin, 1993; Hobbs, 1994; Walker, 1995; Roemer and Wayne, 2003). Consequently, critics have called for approaches that consider higher organizational levels, such as ecosystems and landscapes (Noss, 1987; Gosselink et al., 1990). In addition, we lack basic ecological information and the natural and monetary resources to manage individually every species that needs protection (Simberloff, 1998). Nevertheless, conservation based on single species likely will remain important to inventory, monitoring, and assessment efforts because it is straightforward and easier to evaluate than managing complex ecosystems (Noss, 1990; Rubinoff, 2001).

Here, we evaluate the utility of the single-species approach in a region high in biological diversity (Dobson et al., 1997; Breininger

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et al., 1998), coastal east-central Florida, USA. Rapidly expanding human population growth in this region drastically reduced Florida scrub, which is an endangered, fire-dependent ecosystem (Myers, 1990; Noss et al., 1997). Quality of remaining habitat patches also declined; they typically are fragmented, isolated and overgrown because of fire suppression (Myers, 1990). A number of threatened and endangered plant and animal species inhabit scrub communities (Christman and Judd, 1990; Stout and Marion, 1993; Stout, 2001) and management of remaining scrub is critical to their survival (Schmalzer et al., 2003). Consequently, remnant patches of coastal scrub are managed with prescribed fire and fuel-thinning techniques to improve habitat quality for the few remaining large populations of Florida Scrub-Jay (*Aphelocoma coerulescens*; Breininger et al., 2002). The Florida Scrub-Jay was classified as threatened under the US Endangered Species Act in 1987. This imperiled bird is considered a good indicator of scrub quality (Breininger et al., 2006) and high densities indicate well-managed scrub habitat, which is assumed to benefit other scrub-dependent species (Duncan et al., 1999). The focal species we studied, the threatened southeastern beach mouse (*Peromyscus polionotus niveiventris*; US Fish and Wildlife Service, 1993), co-inhabits scrub areas managed for the Florida Scrub-Jay; if the umbrella species concept is effective, prescribed fire and mechanical manipulations also should improve habitat for this and other sympatric species (e.g., other rodents, indigo snake (*Drymarchon couperi*) and gopher tortoise (*Gopherus polyphemus*)). Assessing this assumption is critical to validating the surrogate species concept as a method to protect biological diversity and evaluate management practices (Niemi and McDonald, 2004; Stewart et al., 2005).

How land-management practices designed to benefit Florida Scrub-Jays affect small mammal populations is unclear; therefore, we examined responses of small mammal populations to four options: prescribed burning, fuel reduction, checkerboarding (a combination of cutting and burning) and cessation of these practices within coastal scrub (fire suppression). Our objectives were to examine effects of land management treatments on the relative abundance and condition of *P. p. niveiventris*, *Peromyscus gossypinus* (cotton mice), and *Sigmodon hispidus* (cotton rats), and to determine whether management for the Florida Scrub-Jay benefits its sympatric small mammal assemblage.

2. Materials and methods

2.1. Study area

We conducted our study on Cape Canaveral (28°38′N, 80°42′W), part of a barrier island complex that includes Merritt Island, Merritt Island National Wildlife Refuge, Kennedy Space Center and Cape Canaveral Air Force Station (CCAFS). The area is within a biogeographic transition zone where floral and faunal assemblages derived from temperate Carolinian and subtropical Caribbean biotic provinces merge (DeFreese, 1995). Its biodiversity results from local juxtaposition of many types of upland and wetland habitats and from large numbers of migratory birds (Breininger and Smith, 1990). The dominant scrub type is oak-saw palmetto, which is characterized by myrtle oak (*Quercus myrtifolia*), sand live oak (*Quercus geminata*), Chapman oak (*Quercus chapmanii*), saw palmetto (*Serenoa repens*) and ericaceous shrubs (e.g., *Lyonia* spp.; Schmalzer and Hinkle, 1992).

Cape Canaveral is about 6475 ha (Fig. 1), and coastal strand and coastal scrub are its dominant vegetation types, with oak scrub further inland (Schmalzer et al., 1999). Development on CCAFS since the 1950s, including industrial facilities and infrastructure to support launch operations, resulted in substantial removal of scrub habitat. Most remaining scrub was unburned for 50 y and uninterrupted growth resulted in a closed canopy dominated by oaks (*Quercus* spp.) and a shrub layer dominated by saw palmetto (Schmalzer et al., 1999; Duncan et al., 1999).

To facilitate restoration and management, scrub at CCAFS was organized into several management compartments divided by fire breaks, power lines, service roads and canals. Compartments varied in size and stage of vegetation recovery. The ideal land management strategy was mechanical cutting of overgrown scrub, followed by a prescribed burn (Schmalzer and Boyle, 1998; Schmalzer and Adrian, 2001) but managers could not always conduct burns due to other constraints (e.g., Air Force base policy, smoke-sensitive space equipment, and proximity to launch pads). Instead, mechanical treatments were applied more frequently without the benefits of conflagration (Fig. 1).

2.2. Study species

Populations of old-field mice (*Peromyscus polionotus*) confined to beach dune and coastal scrub are collectively known as beach mice (Rave and Holler, 1992). *P. p. niveiventris* formerly occurred along 281 km of Florida's east coast, but its range is now restricted to small isolated populations and it was listed as threatened in 1989 (US Fish and Wildlife Service, 1989). The largest extant and most genetically diverse population is on our CCAFS study site (Degner et al., 2007).

Cotton mice (*P. gossypinus*) and cotton rats (*S. hispidus*) are common in many habitat types in the southeastern United States (Layne, 1974). Both species are considered generalists but differ in the way they use habitat. *P. gossypinus* exploits many microhabitats and are abundant in clearcuts and areas with abundant downed woody debris (Loeb, 1999). *S. hispidus* prefers grassland and old-field habitats (Cameron and Spencer, 1981).

2.3. Sampling

We assessed responses of small mammals to mechanical cutting and burning of coastal scrub in eighteen land-management compartments located throughout CCAFS (Fig. 1). We selected compartments based on land-management activities: five compartments were prescribed burned recently (range: 1–5 y), six were recently cut (1 y) and four were checkerboarded (cut and then prescribed burned; 1 y). We also selected three compartments that had not been cut or burned for 50+ years, to serve as fire-suppressed controls (Fig. 1). Management compartments averaged 31.7 ha (±6.5 SE), with no difference in size among treatments ($F_{3,14} = 0.71$, $P = 0.56$).

We maintained one transect line in each compartment from October 2004 to July 2005. Transect lines consisted of ten large Sherman live traps (7.6 × 8.9 × 22.9 cm; H.B. Sherman Traps Inc., Tallahassee, FL) spaced 15 m apart and positioned toward the center of each compartment to minimize edge effects. We surveyed compartments three times each season: spring (March–May), summer (June–August), fall (September–November), and winter (December–February). Live traps were pre-baited approximately two weeks before trapping commenced and trapping was conducted at biweekly intervals. Traps were opened late in the afternoon, baited with sunflower seeds and checked the following morning. All small mammals captured were marked with a numbered ear tag, identified to species, sexed and checked for reproductive condition. We also determined age class (juvenile, subadult or adult) by pelage coloration, and mass (Layne, 1968) using a spring scale accurate to the nearest 0.5 g. We followed guidelines on trapping and handling small mammals by the American Society of Mammalogists (Gannon et al., 2007) and IACUC project #03-13 issued to I.J. Stout at the University of Central Florida. We also followed Florida Fish and Wildlife Conservation Commis-

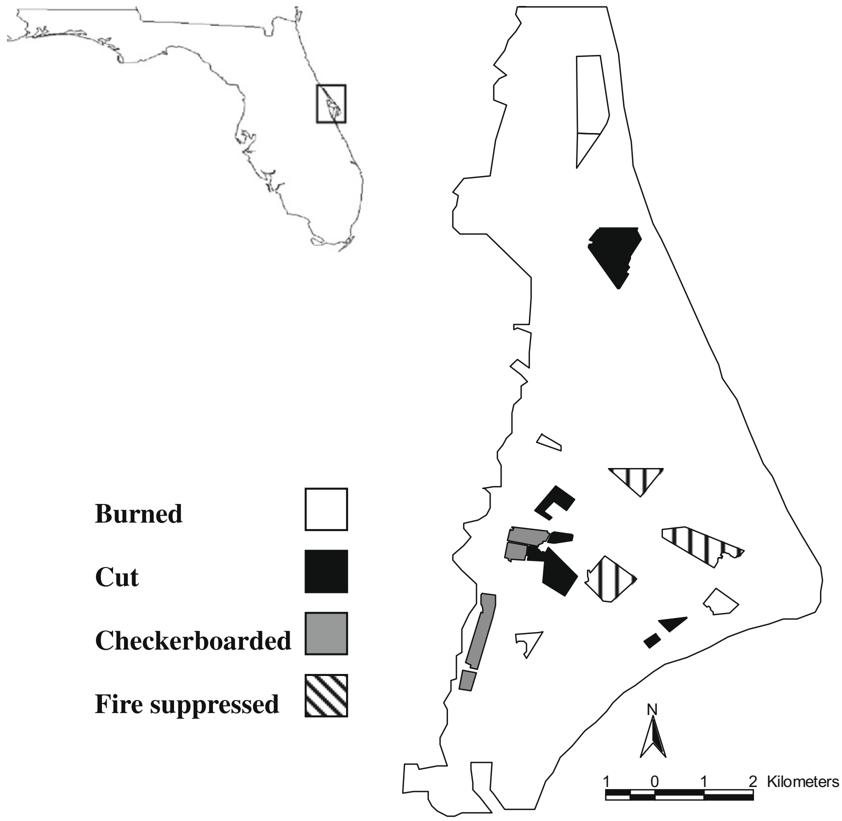

Fig. 1. Location of study compartments on Cape Canaveral Air Force Station, Florida, USA.

sion's (FFWCC) small mammal trapping protocol, and conducted all live trapping under state permit issued to I.J. Stout (Permit No. WV0316). All captured small mammals were released at the point of capture.

We used the number of Florida Scrub-Jay breeding groups to evaluate the relationship between the target of scrub restoration and *P. p. niveiventris*. Nesting data were collected by independent researchers (Stevens and Knight, 2004) during the 2003–2004 field seasons by censusing all CCAFS habitat suitable for Florida Scrub-Jay using playbacks of their vocalizations. We used these data conservatively with an understanding of limitations imposed by our post hoc analysis.

2.4. Analysis

We used Repeated Measures Analysis of Variance (RM-ANOVA; Crowder and Hand, 1990; Green, 1993) to test for differences among management types in mean number of small mammals and mean body mass. We used number of initial captures within each trapping period to reflect population size because it performs as well or better than closed population-estimation techniques when sample sizes are low or animals are not captured at all locations (Slade and Blair, 2000; Orrock and Danielson, 2005). Season was the repeated measure and management type was the between-subject variable in RM-ANOVA models, which were performed separately for *P. p. niveiventris* and *P. gossypinus*. We used Tukey's HSD to compare all possible contrasts and logarithmic transformations to improve homogeneity of variance. We constructed 2×4 contingency tables to evaluate reproductive parameters and a *G*-test to assess differences in observed frequencies of male and female mice in reproductive condition among land management types and seasons (Fowler et al., 2000).

To evaluate the efficacy of land-management techniques on the two listed species, we used Spearman's rank correlation to explore relationships between the number of Florida Scrub-Jay breeding groups and total number of first captures of *P. p. niveiventris* cohabiting compartments. We also fit a general linear model with a binomial error to the number of breeding groups and examined variation among management types. All analyses were conducted using SPSS 11.5 (SPSS Inc., Chicago, Illinois) with $\alpha = 0.05$. Results are expressed as the untransformed mean ± 1 SE unless otherwise indicated.

3. Results

We trapped 146 individual *P. p. niveiventris* (315 total captures), 130 *P. gossypinus* (300 total captures) and 32 *S. hispidus* (39 total captures). *P. p. niveiventris* and *P. gossypinus* were abundant during all seasons, while *S. hispidus* was captured sporadically and dropped from further analysis. The only other species captured in our traps was *Spilogale putorius* (eastern spotted skunk, 13 total captures). All of these species are native to east-central Florida.

3.1. Southeastern beach mouse (P. p. niveiventris)

Mean number of *P.p. niveiventris* differed significantly among management types ($F_{3,14} = 4.79$, $P = 0.017$). The mean number trapped in burned compartments (4.1 ± 0.7 individuals/transect) was significantly greater than in cut (1.0 ± 0.3) and fire-suppressed compartments (0.2 ± 0.1, Fig. 2). The number of *P. p. niveiventris* captured varied seasonally (RM-ANOVA, $F_{3,42} = 6.18$, $P = 0.001$), with peaks in winter (3.0 ± 0.8) and spring (2.2 ± 0.6) and lows in fall (1.8 ± 0.5) and summer (1.1 ± 0.3). Seasonal patterns were most pronounced in burned and checker boarded compartments (significant interaction term in RM-ANOVA: $F_{9,42} = 4.02$, $P = 0.001$; Fig. 3). Similar results were obtained when total captures (i.e., including animals captured more than once) were analyzed.

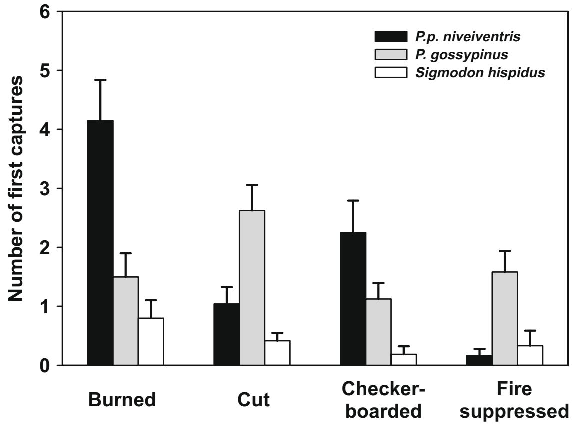

Fig. 2. Mean (±1 SE) number of first-time captures of *Peromyscus polionotus niveiventris*, *Peromyscus gossypinus* and *Sigmodon hispidus* in Florida scrub under different treatments. Rodents were sampled during 2004–2005 at Cape Canaveral Air Force Station, Florida, USA.

In small rodent populations, reduced body mass and reproductive condition often are associated with stressful environments or very high population densities (Desy and Batzli, 1989; Wauters et al., 2007). Management type did not affect mean body mass of *P. p. niveiventris*, ($F_{3,14} = 2.19$, $P = 0.13$) nor was the interaction between management type and season significant ($F_{9,42} = 1.80$, $P = 0.090$). Instead, mean body mass of *P. p. niveiventris* differed significantly among seasons ($F_{3,42} = 19.11$, $P = 0.001$), with the highest mean values in fall (15.9 ± 0.4 g) and spring (15.7 ± 0.4 g). The frequency of males and females in breeding condition did not vary among land management types (both $G < 1.54$, df = 3, $P > 0.05$). In contrast, females were in breeding condition most frequently in fall ($G = 8.15$, df = 3, $P < 0.05$), while male reproductive condition was independent of season ($G = 4.75$, df = 3, $P > 0.05$).

3.2. Cotton mouse (*P. gossypinus*)

Mean number of *P. gossypinus* did not differ significantly among land management type ($F_{3,14} = 1.53$, $P = 0.25$; Fig. 2) nor was the interaction between management type and season significant ($F_{9,42} = 1.15$, $P = 0.35$). However, mean number captured differed significantly among seasons ($F_{3,42} = 7.20$, $P = 0.001$), with higher numbers in winter (2.5 ± 0.6 individuals/transect) and fewest in summer (1.4 ± 0.3 individuals/transect). Mean body mass of *P. gossypinus* varied seasonally (RM-ANOVA, $F_{3,42} = 8.48$, $P = 0.001$), with the largest body mass recorded in fall (25.5 ± 0.8 g) and lowest in summer (21.4 ± 0.7 g). Mean body mass was independent of management type ($F_{3,14} = 2.36$, $P = 0.12$) and the management type × season interaction ($F_{9,42} = 1.60$, $P = 0.15$).

Reproductive condition of *P. gossypinus* did not differ among land management type for either males ($G = 1.76$, df = 3, $P > 0.05$) or females ($G = 4.64$, df = 3, $P > 0.05$). Reproductive condition of females did not differ among seasons ($G = 6.58$, df = 3, $P > 0.05$) but all males captured in summer were non-reproductive ($G = 17.89$, df = 3, $P < 0.05$).

3.3. Florida Scrub-Jay (*A. coerulescens*)

The total number of Florida Scrub-Jay breeding pairs was greater in burned ($n = 22$) than in cut ($n = 12$), checkerboarded ($n = 13$), or fire-suppressed ($n = 0$) compartments (Stevens and Knight, 2004). This pattern was supported by our maximum likelihood modeling approach: mean number of breeding groups (and 95% confidence intervals) were: burned 4.4 (0.8–8.0), cut 2.0 (0.2–3.8), checkerboarded 3.3 (0.5–6.0), and fire-suppressed 0.0 (0.0–0.0). Similarly, the total number of first captures of *P. p. niveiventris* was highest in burned ($n = 83$) and checkerboarded ($n = 36$), intermediate in cut ($n = 25$) and extremely low in fire suppressed ($n = 2$) compartments. Consequently, number of Florida Scrub-Jay breeding pairs were positively correlated among compartments with abundance of *P. p. niveiventris* (Spearman's correlation, $r = 0.655$, $P = 0.003$, Fig. 4) but uncorrelated with abundances of *P. gossypinus* ($r = 0.041$, $P = 0.87$).

4. Discussion and conclusions

Interruption of natural fire regimes and ecosystem fragmentation contribute greatly to habitat degradation, thereby necessitating active management to conserve threatened and endangered species (Saunders et al., 1991; Menges and Hawkes, 1998; Duncan et al., 1999). At the same time, limited budgets force conservation biologists to prioritize interventions and seek practical short-cuts for identifying useful management techniques. The single-species management approach presumes that many species within a community benefit from land-management activities targeting an

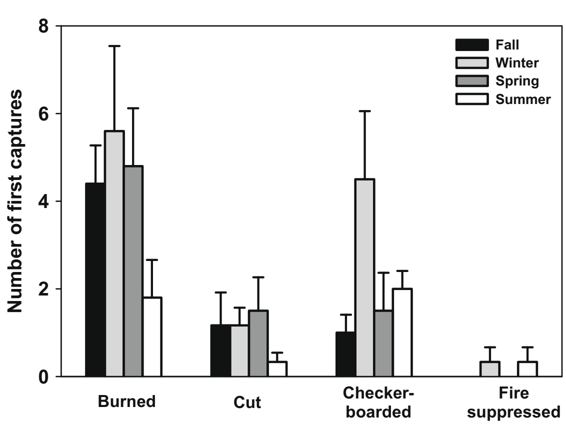

Fig. 3. Seasonal variation in mean (±1 SE) number of first-time captures of *Peromyscus polionotus niveiventris* in habitats under different treatments at Cape Canaveral Air Force Station, Florida, USA.

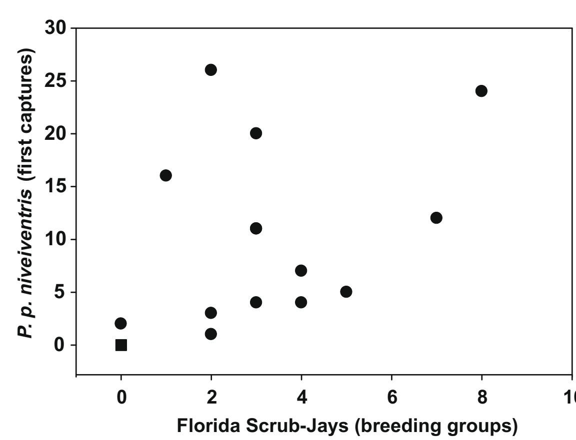

Fig. 4. Relationship between the number of Florida Scrub-Jay breeding groups and first-time captures of *Peromyscus polionotus niveiventris* in management compartments at Cape Canaveral Air Force Station, Florida. Data on Florida Scrub-Jay breeding groups are from Stevens and Knight (2004). Square symbol represents five compartments.

indicator, sentinel or umbrella species (Lambeck, 1997). However, support is limited for the efficiency of conservation measures based on umbrella species in some applications (Bifolchi and Lode, 2005; Rowland et al., 2006). Our results suggest that land-management activities at CCAFS designed to enhance populations of the threatened Florida Scrub-Jay also benefit the threatened *P. p. niveiventris*, and have no effect on two common small mammal species.

P. p. niveiventris were significantly more abundant in compartments that were prescribed burned, demonstrating that populations responded positively to this treatment. Mechanical manipulation (i.e., checkerboarding) of previously burned scrub also had a positive influence on their abundance, especially compared to fire-suppressed compartments where only two *P. p. niveiventris* were ever caught. These two management activities clearly benefited Florida Scrub-Jay breeding groups, which were more abundant in compartments managed with prescribed fires and checkerboarding than in fire-suppressed compartments. Consistent application of prescribed burns is imperative to maintain habitats preferred by these two federally-listed species.

The strong, positive correlation ($r = 0.65$) between abundance of *P. p. niveiventris* and Florida Scrub-Jay breeding groups is further evidence of the mutual benefits derived from actively managing scrub. Prescribed burning at CCAFS creates heterogeneous habitat and season of burning in oak/saw palmetto scrub does not appear to be a management issue (Foster and Schmalzer, 2003). Regardless of season of burn, bare ground is lost within one year. Elsewhere *Peromyscus polionotus* is associated with open habitats (Davenport, 1964; Wolfe and Rogers, 1969) and presumably exploits habitat mosaics created by land use changes and fire. In our study, *P. p. niveiventris* was most abundant in burned compartments in fall and winter, suggesting that it used patches of exposed soil created by fires. Cutting and burning Florida scrub also benefits the Florida Scrub-Jay because these management techniques create habitat conditions beneficial to jays; 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 cut-burned ($n = 5$). However, the number of fledglings ($n = 15$) was greatest in cut compartments, which suggests that the current mixed strategy of cutting, burning or checkerboarding compartments may be preferable to use of a single technique.

We found *P. p. niveiventris* is not confined to the sea oats–dune system on CCAFS. Instead, we trapped *P. p. niveiventris* in densely-vegetated sites up to 3–4 km inland, indicating that it tolerates various vegetation structures. Extine and Stout (1987) reported similar results on CCAFS, and mainland populations of *P. p. subgriseus* inhabiting scrub can also tolerate closed habitats (Packer and Layne, 1990). However, we did not find resident *P. p. niveiventris* in matrix habitat that was fire suppressed for more than 50 y. Therefore, treatment of scrub with fire or mechanical removal is critical for the long-term viability of *P. p. niveiventris* on CCAFS.

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. Downed woody debris from logging activities create complex habitats that *P. gossypinus* exploits. We did not quantify structural changes to vegetation caused by management treatments, but the downed trees and brush piles created from cutting scrub created habitat favorable to *P. gossypinus*. In general, medium-sized *Peromyscus* spp. (i.e., 17–46 g) increase in abundance after clearcutting (Kirkland, 1990; Sullivan et al., 1999). Absence of a treatment effect, however, indicates that the current land-management techniques are not important factors governing the distribution and abundance of *P. gossypinus* populations in our study site. Similar to *P. p. niveiventris*, we found no indication that land-management practices affected *P. gossypinus* body mass or reproductive condition.

Because abundance of small mammals alone is not necessarily a complete indicator of habitat quality (Van Horne, 1983), we also examined patterns of reproductive condition and body mass. We found no association between the number of male and female *P. p. niveiventris* in reproductive condition and land management technique. Instead, reproductive activity in *P. p. niveiventris* was seasonal. The number of female *P. p. niveiventris* in reproductive condition was particularly high in the fall, when 90% (10/11) of females had developed mammaries. Fall and spring are peak breeding periods for beach mice (Blair, 1951), but *P. p. niveiventris* can breed year round. Changes in habitat structure caused by land-management techniques also had no effect on body mass of *P. p. niveiventris*, suggesting that higher densities in burned compartments did not increase intraspecific competition. *P. p. niveiventris* is an omnivorous rodent that exploits a wide range of food sources at our study site (Keserauskis, 2007).

Our results support the umbrella species concept, but not in an unqualified manner; the work of Fleishman et al. (2001) predicted mixed success in selecting umbrella species to protect areas of high conservation value. Broadening the sentinel or indicator species approach at CCAFS to include additional scrub species with larger home ranges (e.g., eastern indigo snake) and longer lifespans (e.g., gopher tortoise) may suggest additional improvements to management techniques. Experimentally testing the effects of alternative management techniques is an adaptive strategy that managers and conservation biologists should use to recover *P. p. niveiventris*, the Florida Scrub-Jay and other endangered taxa at CCAFS. Finally, our study showed that *P. p. niveiventris*, a federally listed threatened species, inhabits scrub areas not currently recognized as critical beach mouse habitat. Land managers throughout the southeastern US should maintain and restore such potential beach mouse habitats.

5. Conservation implications

Restoration and management goals for remnant patches of coastal scrub and oak/palmetto scrub at Cape Canaveral Air Force Station are to create large areas of habitat optimal for the Florida Scrub-Jay, which is an indicator of well-managed scrub (Breininger et al., 2006). This "coarse filter" approach protects the whole scrub community or ecosystem without attention to other sympatric taxa. Using a single focal species for biodiversity conservation and management has been criticized because it is improbable that requirements of a single species can encompass those of an entire community (Andelman and Fagan, 2000). However, current management of Florida coastal scrub that mimics a natural ecosystem process – wildfire – improves habitat for both the Florida Scrub-Jay and the threatened *P. p. niveiventris*. Therefore, prescribed burning is preferable as a conservation tool over mechanical cutting of scrub that previously has been cut and burned.

However, prescribed burning alone may be insufficient to address conservation needs of other listed taxa on CCAFS. For example, on public lands elsewhere in Florida, *Gopherus polyphemus* appears to have declined despite aggressive prescribed burning (McCoy et al., 2006). Therefore, a long-term monitoring program that includes multiple species should be established because it combines the management simplicity of umbrella species with the effectiveness of ecosystem-level management (Lambeck, 1997). A long-term, multi-species monitoring program will allow land managers to understand the ecological effects of restoration and management treatments over time, ameliorate concerns over seasonal fluctuations in populations of short-lived species such as beach mice and Florida Scrub-Jays, and reduce uncertainties about management practices at the local scale.

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