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ABSTRACT: We studied the effects of cutting Ashe juniper (*Juniperus ashei* Bucholz) woodlands on populations of small mammals at Friedrich Wilderness Park, north of San Antonio, Texas. Three patches of juniper ranging from 1.8 ha to 2.4 ha were cut to provide habitat for endangered black-capped vireos (*Vireo atricapillus* Woodhouse). We trapped small mammals along transects placed in the treated patches and in untreated areas of the park from October 1995 to May 1996 and again from October 1996 to March 1997. Three species of small mammals were trapped, but *Peromyscus pectoralis* Osgood (white-ankled mouse) was the most common species captured. *Peromyscus pectoralis* was more abundant in the treated patches in which the juniper had been removed. Trapping success in the three treated areas was consistently higher (average of 12%) than in the untreated Ashe juniper woodlands (average of 3%). Mice that colonized treated patches survived longer than mice in control areas. Each year the number of *P. pectoralis* increased during the winter and spring, with juveniles accounting for up to 32% of captures. The management of habitat for an endangered species, such as the black-capped vireo, enhanced the biodiversity of small mammals in this study.

Index terms: black capped vireo, endangered species management, *Peromyscus,* small mammal populations, Texas hill country, *Vireo atricapillus*

INTRODUCTION

An environment that provides a mosaic of resources, such as patches of habitat at different successional stages, sustains a greater number of species than homogeneous environments sustain (World Resources Institute 1992). The loss of patches of different successional stages is thus a contributing factor in loss of biodiversity (Huston 1994). Prior to European settlement, the Edwards Plateau of Texas consisted of areas of open savanna and grassland, a habitat maintained by naturally occurring fires (Fonteyn et al. 1988, Diamond et al. 1995). The Edwards Plateau is subject to summers of intense heat and long drought periods, and is susceptible to fires ignited by lightning. However, since around 1850, the suppression of anthropogenic and natural fires has eliminated patches of early successional habitat and transformed this region into woodlands (Fonteyn et al. 1988, Smeins and Merrill 1988) dominated by Ashe juniper (*Juniperus ashei* Bucholz) (Diamond et al. 1995). The loss of open savanna areas to mature juniper woodlands has impacted many species, most notably the black-capped vireo (*Vireo atricapillus* Woodhouse) (Graber 1961, Grzybowski et al. 1994), a federally listed endangered species. Clearing and controlled burning of woodland habitats have been used to produce patches of suitable habitat for this species (O'Neal et al. 1996). The effects of such manipulations on other faunal elements are not well understood. Our objective was to monitor the effects of cutting patches of Ashe juniper woodlands on the resident small mammal biodiversity.

STUDY AREA

We conducted research at the Friedrich Wilderness Park, a natural area located in northwest San Antonio, Bexar County, Texas. Friedrich Park, founded in 1979, is about 94 ha in size. The park is located in the southeastern part of the Edwards Plateau in the Balcones Canyonlands. The habitat of this region is characterized as woodland and forest vegetation (Riskind and Diamond 1988). Our study area was on south- and west-facing slopes dominated by Ashe juniper, Texas oak (*Quercus texana* Buck.), and Plateau live oak (*Quercus fusiformis* Small). Historically, two endangered bird species, the golden-cheeked warbler (*Dendroica chrysoparia* Sclater and Salvin) and the black-capped vireo, nested in Friedrich Park. No black-capped vireos nest in the park at present due to the lack of suitable nesting habitat. San Antonio City Public Service (CPS) became interested in constructing a radio tower in endangered species habitat near Friedrich Park. In a mitigation agreement with the U.S. Fish and Wildlife Service and Friedrich Park officials, CPS agreed to manage appropriate areas of the park for the black-capped vireo.

The black-capped vireo is a habitat specialist that prefers isolated oaks arranged in small clumps, interspersed with a layer of shrubs that provide cover near the ground (Graber 1961, Grzybowski et al. 1994). In the northern part of the species' geographic range, males prefer territories in dense, deciduous shrubs comprised mostly of oaks. But on the Edwards Plateau, juniper shrubs are also used (Grzybowski et al. 1994). To manage habitat for black-capped vireos, CPS personnel used chain saws to cut Ashe junipers, leaving clumps of oak trees standing. The cut junipers were left on the ground in an attempt to prevent white-tailed deer (*Odocoileus virginianus* Boddaert) from foraging on deciduous shrubs. One area, area 2 (2.8 ha), was treated in spring 1995. Area 1 (2.4 ha) and area 3 (1.8 ha) were cut in spring 1996.

METHODS

During the first year of our study when only treated area 2 had been managed, we trapped along three transects located in the treated patch (transects E, D, J; Figure 1) and two control transects located north of the treated area (both at F; Fig. 1). Ashe junipers were cut in treated area 1 and area 3 in the spring 1996. Mice were initially trapped on two transects in each of these treated areas (transects A, B, D, E, G, and H; Figure 1), on a new control transect (C: Figure 1), and on only one of the control transects at F. In January 1997 we added two additional transects: I in treated area 1, and J in treated area 2.

We trapped one night each month from October 1995 to May 1996. We trapped three to four times a month from October 1996 to March 1997. We did not trap during summer months due to the abundance of red imported fire ants (*Solenopsis invicta* Buren), which forage at night (Smith et al. 1990) and are drawn to bait in traps. This can result in the mortality of captured rodents (Masser and Grant 1986), as well as decreased trapping success.

Mice were trapped along transects of 10 stations spaced 10 m apart. Two traps were set at each station for a total of 20 traps on each transect. We used Sherman Live traps (8 cm x 9 cm x 23.5 cm) baited with rolled oats. Traps were set in the late afternoon and checked the next morning at sunrise. For each capture we recorded the species, age, breeding status, weight, and sex. Davis and Schmidly (1994) was used to identify species. The age was determined by the color of the pelage. Gray mice were recorded as "juveniles," completely brown mice as "mature" adults, and mice with a mix of gray and brown were recorded as "subadults." Pregnant, lactating, or perforate vulva females and males with descended testes were considered to be breeding. Each new capture was ear-tagged with an aluminum, numbered tag. All individuals were released near the station. Four mice found dead in traps were prepared as voucher specimens and deposited in the teaching collection of the Biology Department of Trinity University (San Antonio, Texas).

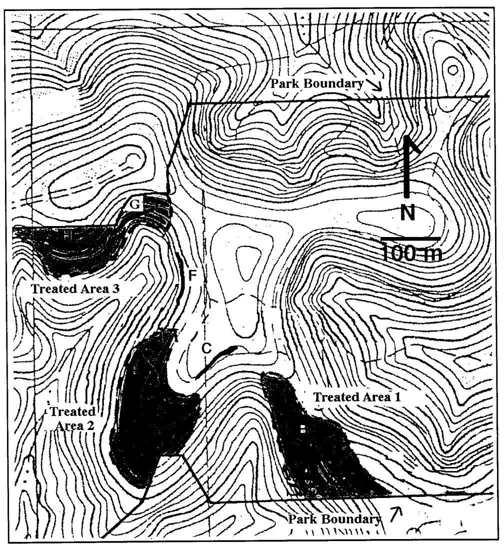

Figure 1. Topographic map of a portion of Friedrich Wilderness Park, Bexar County, Texas. Treated areas in which Ashe junipers were cut are indicated by gray shaded areas. Live-trapping transects are indicated by thick lines and labeled A–H. Transects C and F were control transects.

To compare the number of rodents captured on control and treated transects, we calculated trapping success (the number of rodents captured divided by the number of traps set). We calculated the mean trapping success for two or three transects in each treated area and the mean trapping success for two controls. In the first year, the mean trapping success of the three treated areas was compared to the mean for control transects using a paired *t*-test. In the second year, a repeated measures analysis of variance was used to compare mean trapping success between the treated areas and the control transects. Trapping success data were square-root transformed prior to analysis.

Table 1. Capture results of all rodents during study on control and treatment transects in Friedrich Wilderness Park, Bexar County, Texas. "Number tagged" is the number of unique individuals captured. "Number captured" represents how many times the tagged mice were captured.

		Treatment Transects		Control Transects	
Scientific Name	Common Name	Number Tagged	Number Captured	Number Tagged	Number Captured
Peromyscus pectoralis	white-ankled mouse	96	228	10	10
Peromyscus leucopus	white-footed mouse	22	45	1	1
Sigmodon hispidus	hispid cotton rat	4	4	0	0
	Total	122	277	11	11

RESULTS

Of the 288 total captures, 82% were *Peromyscus pectoralis* Osgood (white-ankled mouse), 16% were *P. leucopus* Rafinesque (white-footed mouse), and 1% were *Sigmodon hispidus* Say and Ord (hispid cotton rat) (Table 1). There were no recaptures of *S. hispidus*, and only four *P. leucopus* were recaptured. In the second year, no *S. hispidus* and one *P. leucopus* were captured. Eleven rodents were ear-tagged in control areas and none were recaptured (Table 1).

The mean trapping success for all transects in each treated area ranged from 0% to 33% (Figure 2). The mean trapping success for treated area 2 was 16.2% ± 6.8%. In the second year, treated areas 1 and 3 averaged 8.1% ± 6.5% and 14.7% ± 8.3%, respectively. Trapping success peaked above 30% during January 1996 in treated area 2. Trapping success in treated areas 1 and 3 peaked at around 17% to 28% in March and April 1997. On control transects, many trapping sessions (6 of 19, 32%) resulted in no captures. The highest mean trapping success in control areas was 15% in March 1997. Mean trapping success on control areas during the study was 3.2% ± 2.8%.

In the first year, mean trapping success was greater in treated area 2 than on control transects ($t = -3.19$, $df = 5$, $p = 0.02$). Similarly, mean trapping success in the second year was greater in treatment areas compared to control transects ($F = 13.32$; $df = 5, 10$; $p < 0.01$). Mean monthly survivorship was 56% ± 10% for the study. The monthly survivorship on treated transects usually exceeded 50%, with a high of 83% in November 1995 and a low of 25% in November 1996. On control transects there were no recaptures.

We observed breeding mice in both treatment and control areas. The number of breeding individuals was greater than the number not breeding during each month of the study. The number of breeding individuals increased during winter months (December–January) and declined in the spring. In the second year of the study, reproduction by adults possibly contributed to the increase in juvenile and subadult mice captured in treated areas (Figure 3). Beginning in November 1996, there was an increase in mature, subadult, and juvenile individuals.

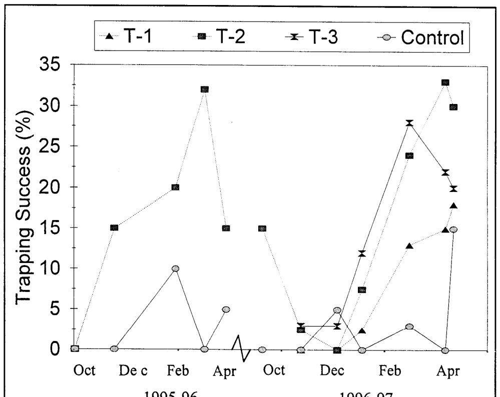

Figure 2. Mean trapping success (number captured/number traps set) for all rodent species at Friedrich Wilderness Park, Bexar County, Texas. Treated areas 1 and 3 were trapped only during the second year of the study. Two transects were trapped as control transects during both years of the study. T-1, T-2, T-3, and Control indicate treated areas 1, 2, 3, and control areas, respectively.

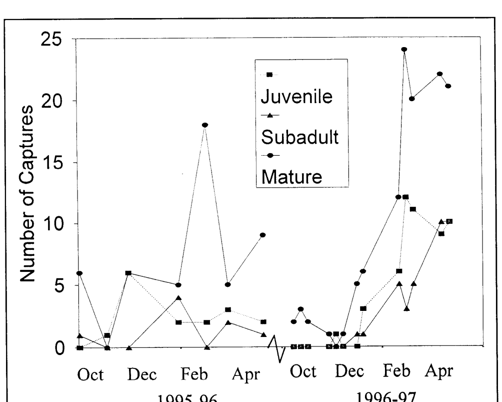

Figure 3. Age structure of all rodents captured on treated transects in Friedrich Wilderness Park, Bexar County, Texas. Age was based on pelage characteristics (see Methods).

On both control transects, a total of 11 mice were captured during the two years of this study. Of these, one was *P. leucopus*, and the remaining were *P. pectoralis*. These captures included 5 juveniles, 2 subadults, and 4 mature mice. Fifty percent of the mature and subadult rodents were in breeding condition.

DISCUSSION

Our results indicate the importance of maintaining different habitats. More rodents were caught in areas where Ashe junipers had been removed in order to benefit black-capped vireos than in uncut areas. Although we were unable to document dispersal into treated areas, we do know that mice in the treated areas survived and reproduced. The average number of mice known to survive from month to month in the treated areas was greater than 50%, while no mice were known to survive from month to month in the control areas.

Although the breeding season is thought to extend from at least March to October (Davis and Schmidly 1994), little is known about the breeding habits of *P. pectoralis*. Dalquest (1953) and Baker (1956) indicated that *P. pectoralis* breeds all year in some areas of Mexico. We trapped pregnant females from December to March, and a peak was evident in January and February. Although we did not trap during summer months, we suspect there is minimal breeding activity due to hot summer temperatures and the fact that fire ants, which prey upon juveniles in nests, are more active during the summer, particularly at night (Smith et al. 1990). The occurrence of reproductive activity by rodents at least indicates there are sufficient resources to support reproduction in the treated areas.

The higher abundance of small mammals in treated areas may be the result of changes in vegetation due to the cutting of the Ashe junipers. After cutting, there was an increase in the abundance of grasses, especially big bluestem (*Andropogon gerardii* Vitman) and little bluestem (*A. scoparius* Michx.), and *P. pectoralis* is known to feed on a variety of grass seeds (Schmidly 1974). In addition, the presence of the slash from the cut junipers increased the number of nesting sites and amount of shrub-level escape cover. *Peromyscus pectoralis* prefers limestone ledges and associated habitats (Baccus and Horton 1984, Etheredge et al. 1989, Mullican and Baccus 1990). Within these habitats, brushpiles and rocky ledges are preferred as escape cover from predators (Baccus and Horton 1984, Etheredge et al. 1989). In a study of *P. leucopus*, McMurry et al. (1996) induced early successional habitats with a treatment of herbicides. Peak abundance of *P. leucopus* was observed in these treated habitats due to increased forb growth and increased escape cover.

We did observe fewer species in year 2 compared to year 1. No *P. leucopus* and *S. hispidus* were captured in the second year, possibly because the treated areas were not suitable habitat. Cummings and Vessey (1994) found that *P. leucopus* will use nonwoodland habitats for dispersal routes, but they prefer wooded habitats (see also Yahner 1983). It is also possible that the drought conditions of 1996 (62% of average of 73 cm precipitation; National Weather Service data from San Antonio) had more of an effect on *S. hispidus* and *P. leucopus* than on *P. pectoralis*.

After we completed this study, a program of controlled burns was started that will entail burning approximately one-half of each treated area. This should further encourage growth of grasses, which should benefit small mammals that depend on grassy habitats. *Sigmodon hispidus*, for example, will likely increase because it is dependent on habitats with tall grass, which provides protection and an adequate food supply (Davis and Schmidly 1994). We plan to continue to monitor small mammal diversity following these controlled burns. At least in prairie ecosystems, *Peromyscus* species are known to benefit from periodic fires (Kaufman et al. 1983).

Our study has implications for management aimed at supporting a variety of habitats, and thus biodiversity, in the Texas Hill Country. The lack of habitat heterogeneity due to the dominance of Ashe juniper in woodlands can reduce small mammal diversity. Previous studies of small mammals have documented changes in species composition with successional woodland development (Mengak et al. 1989). Maximum diversity is achieved by maintaining all successional stages, a strategy which provides a variety of habitats. For example, Yahner (1992) reported that some populations of small mammals increased after forest fragmentation because particular microenvironments increased in abundance. Management for a particular endangered species, such as black-capped vireos in this study, can enhance biodiversity in general and deserves consideration in management plans for similar natural areas.

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Krista A. Schnepf and Jennifer A. Heselmeyer completed their undergraduate degrees in biology at Trinity University in 1997. Krista now works as an environmental specialist and ecologist for an environmental consulting firm in San Antonio, while Jennifer is completing an environmental internship for the National Audubon Society in Washington, D.C. David O. Ribble is an Associate Professor of Biology at Trinity University, where he teaches ecology, vertebrate zoology, and conservation biology. He divides his research efforts in mammalian ecology between San Antonio and northern New Mexico.

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