



Desertification and animal biodiversity in the desert grasslands of North America

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Studies of breeding birds and small mammals were conducted at a series of sites that form a gradient of severity of desertification. Desert grassland sites represented the least changed landscape units and mesquite coppice dunes represented the most severe degradation, an irreversibly degraded landscape unit. The hypothesis that desertification reduces species diversity was not supported by the data. Species richness and diversities (Shannon-Weaver H') of breeding birds were higher in the desertified areas than in the grassland with one exception. Data from a site dominated by the exotic African grass, *Eragrostis lehmanniana*, in south-eastern Arizona showed that breeding bird diversity was lower at that site than at a site in the same region that was dominated by native grasses. Species richness, diversity (H'), and abundance of small mammals were also higher in desertified areas than in desert grassland. Most grassland species of birds and mammals persist in the desertified habitats and species that are characteristic of shrublands colonize desertified desert grasslands. This accounts for the increases in species richness. However some species such as the banner-tailed kangaroo rat, *Dipodomys spectabilis*, are eliminated when grassland degrades to mesquite coppice dune or eroded creosotebush communities. These data suggest that other measures of faunal biodiversity such as *keystone species* may be better measures of the impact of desertification on animal biodiversity.

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Introduction

Desertification is widely recognized as a process that results in dramatic and frequently irreversible changes in the composition and cover of vegetation (Whitford, 1995). There are a few examples from arid/semi-arid regions where such changes in plant composition and cover have resulted in a loss in diversity of native animals (Jones, 1981; Jepson-Innes & Bock, 1989; Heske & Campbell, 1991). These limited studies

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support the common perception that large changes in composition and cover of vegetation result in reductions in floral and faunal diversity.

Many of the desert grasslands of North America have been converted to shrublands during the past 150 years (Buffington & Herbel 1965; Bahre & Shelton, 1993; Bahre, 1995; Whitford 1995). Soil loss and changes in soil properties have occurred with the changes in vegetation. Now the remaining desert grasslands exist as isolated patches within the shrublands. Not only is the desert grassland fragmented, the shrub communities that became established in former desert grasslands differ structurally and are dominated by different species. These shrub communities add to the fragmentation and fragmentation of habitats generally leads to reductions in species diversity.

As a result of these changes desert grasslands may represent the most endangered landscape type in North America. The former grasslands are now dominated by shrubs like creosotebush (*Larrea tridentata* (Sessé & Moç ex DC.) Coville) and mesquite (*Prosopis* spp.). In some areas, the soil from bare patches between shrubs has accumulated around the plants producing coppice dunes (Hennessy *et al.*, 1983). Restoration efforts have included the widespread seeding of exotic grasses such as Lehmann lovegrass (*Eragrostis lehmanniana* Nees). There are areas in south-eastern Arizona where *E. lehmanniana* has spread into areas where it was not seeded and now dominates the ground cover (Anable *et al.*, 1992). These large scale changes may result in equally dramatic changes in faunal biodiversity.

Biodiversity is often viewed as various measures of species diversity, but can include genetic diversity, and the structure of the communities and landscape units in which species occur. It has been argued that the diversity of functional groups *not* the diversity of species is the most important consideration in biodiversity, while others have argued that each species is important in the ecosystems in which they live and function (West, 1993). If desertification results in dramatic changes in the composition of the assemblages of species of various animals living in an altered landscape, those changes could have important ramifications for the long-term stability of the altered landscape and for the potential of restoration efforts. However, before we can examine the consequences of changes in biodiversity of animals resulting from desertification, we must document the changes in species richness and/or other measures of diversity. Here I examine the species composition, relative abundances, and diversity patterns of breeding birds and small mammals in a series of sites representing varying degrees of desertification. These data are compared with results of studies of ants and other insects in desertified and undegraded habitats.

Study sites

Most of the studies were conducted on the Jornada Experimental Range, located approximately 40 km north-east of Las Cruces, New Mexico. The Jornada Experimental Range was established as a research facility in 1912. Long-term records show that in 1858 good grass cover was present on more than 90% of the 58,492 ha surveyed. By 1963 less than 25% of the area had good grass cover and none of the remnant grassland was brush free (Buffington & Herbel, 1965). Data were also collected on the Chihuahuan Desert Rangeland Research Center which is adjacent to the Jornada Experimental Range and which has had a similar history of vegetation change.

Studies on avian diversity were also conducted on a native grassland site and a site dominated by Lehmann lovegrass, *E. lehmanniana*, on the Santa Rita Range Reserve and on the Empire Cienega Ranch. The Santa Rita, located 58 km south of Tucson, Arizona, was established in 1902. Changes in the type and amount of vegetation on the Santa Rita include marked reduction in the upland grasslands, increases in velvet

mesquite (*Prosopis velutina* Wootton) on the upland sites and vast areas where Lehmann lovegrass has replaced native grasses (Medina, 1996). The Empire Cienega Ranch is administered by the U. S. Bureau of Land Management as a working ranch to demonstrate land management practices. The Empire Cienega is located approximately 65 km south-east of Tucson, Arizona. Most of this ranch is a mesquite (*Prosopis velutina*)-bunch grass savanna. There are some areas where Lehmann lovegrass accounts for more than 50% of the grass cover.

Methods

Data on breeding birds were collected on 1-km transects in each of five habitats: black grama (*Bouteloua eriopoda* (Torr.) Torr.) grassland, tarbush (*Flourensia cernua* DC.)-burro grass (*Scleropogon brevifolius* Phil.) mosaic, creosotebush (*Larrea tridentata*) shrubland, shrubland bordering a grass covered ephemeral lake, and mesquite (*Prosopis glandulosa* Torr.) coppice dunes. These habitats represent a gradient of degradation from relatively undegraded (black grama grassland) to the extreme of desertification (mesquite coppice dunes) of south-western U.S. desert grassland. Birds were censused every 2 weeks for 5 consecutive years (1990–1994) by walking the 1-km transects and recording the distance to birds flushed or seen along the transect route (Bibby *et al.*, 1992).

In 1990, an intensive study of breeding birds at 15 sites was conducted by repeated visits to each site and recording territorial and nesting birds within a 100-m radius census area. Nest locations were mapped at each site. Each site was censused a minimum of six times during the breeding season. The sites were composed of three locations in each of the five habitats that were censused by the transects.

In 1994 additional data on breeding birds were collected from 100-m radius (3.1 ha) count circles by two observers (Bradford *et al.*, in press). A total of nine count circles with a minimum of 300 m between circle centers were censused in each of five habitats (black grama grassland, creosotebush shrubland, mesquite shrubland around an ephemeral lake, tarbush shrubland, and mesquite coppice dune). The nine count circles sampling protocol was used in native grass-velvet mesquite (*Prosopis velutina*) savanna and a Lehmann lovegrass-velvet mesquite savanna at the Santa Rita Range Reserve and Empire Cienega Ranch in Arizona.

Small mammals were censused using live traps baited with cracked sorghum. Each animal was identified to species and marked to allow identification as a recapture. We used the total number of individuals (counting recaptures only once) to obtain numbers of animals captured per unit effort. Each habitat was trapped for a minimum of 3 consecutive nights in June and October 1990. The habitats sampled were: a black-grama grass grazing exclosure, black grama grassland in a grazed paddock, two mesquite coppice dune sites, a mesquite sand site, two tarbush shrubland sites, and three creosotebush shrubland sites. Traps were placed on 7 × 7 m grids with 15 m trap spacing.

Results

Breeding birds

None of the grassland breeding bird species were restricted to the grassland habitat. The lowest breeding bird species richness was in the tarbush (*Flourensia cernua*) habitat (Table 1). Only three of the seven bird species that were reported as breeding in the grasslands in all years occurred in the tarbush habitat in all 5 years. Cassin's sparrow (*Aimophila cassinii*), which is listed as a grassland species (Ehrlich *et al.*, 1988), was

recorded in the tarbush habitat all 5 years but in the desert grassland habitat only 4 of the 5 years. There were eight species of breeding birds that were restricted to habitats that had a large shrub component (Table 1). The highest species richness was in the creosotebush shrubland where most of the grassland breeding bird species were recorded in more years than in the grassland habitat. The exceptions to this generalization were Cassin's sparrow and eastern meadowlark (*Sturnella magna*) both of which are considered grassland species (Ehrlich *et al.*, 1988).

The intensive study of nesting birds demonstrated that there is considerable variation in the number of bird species that nest within a 3 ha area among sites within the same habitat type (Fig. 1). At one of the mesquite sites, there were 10 species of birds that foraged within a site (i.e. a portion of their territory was included in the study area) but none of those species nested in the study area (Fig. 1). The sites centered on ephemeral lakes (playas) and in creosotebush shrubland had the highest average

Table 1. Number of years that a species was recorded on 1 km transects during the 5-year breeding bird censuses (1990–1994) in remnant black grama grassland and desertified shrublands

| Species | G | C | T | P | M |
|--|----|----|----|----|----|
| Ash-throated Flycatcher (<i>Myiarchus cinerascens</i>) | 3 | 5 | 1 | 5 | 2 |
| Black-chinned Hummingbird (<i>Archilochus alexandri</i>) | 1 | 3 | 2 | 1 | 0 |
| Brown-headed Cowbird (<i>Molothrus ater</i>) | 1 | 3 | 2 | 2 | 3 |
| Black-throated Sparrow (<i>Amphispiza bilineata</i>) | 5 | 5 | 5 | 5 | 5 |
| Blue Grosbeak (<i>Guiraca caerulea</i>) | 1 | 1 | 0 | 2 | 5 |
| Black-tailed Gnatcatcher (<i>Polioptila melanura</i>) | 0 | 0 | 0 | 1 | 3 |
| Bullock's Oriole (<i>Icterus galbula</i>) | 1 | 1 | 0 | 4 | 1 |
| Cactus Wren (<i>Campylorhynchus brunneicapillus</i>) | 3 | 5 | 2 | 4 | 4 |
| Cassin's Sparrow (<i>Aimophila cassinii</i>) | 4 | 2 | 5 | 5 | 2 |
| Chihuahuan Raven (<i>Corvus cryptoleucus</i>) | 2 | 2 | 1 | 3 | 4 |
| Crissal Thrasher (<i>Toxostoma crissale</i>) | 1 | 3 | 1 | 4 | 5 |
| Eastern Meadowlark (<i>Sturnella magna</i>) | 5 | 2 | 4 | 5 | 1 |
| Gambel Quail (<i>Callipepla gambelii</i>) | 0 | 2 | 0 | 0 | 0 |
| Greater Roadrunner (<i>Geococcyx californianus</i>) | 0 | 2 | 0 | 3 | 0 |
| Horned Lark (<i>Eremophila alpestris</i>) | 0 | 1 | 0 | 0 | 5 |
| House Finch (<i>Carpodacus mexicanus</i>) | 0 | 5 | 2 | 3 | 1 |
| Ladder-backed Woodpecker (<i>Picoides scalaris</i>) | 1 | 4 | 0 | 4 | 0 |
| Lesser Nighthawk (<i>Chordeiles acutipennis</i>) | 0 | 5 | 3 | 2 | 2 |
| Loggerhead Shrike (<i>Lanius ludovicianus</i>) | 5 | 4 | 4 | 3 | 5 |
| Mourning Dove (<i>Zenaidura macroura</i>) | 5 | 5 | 4 | 5 | 5 |
| Northern Mockingbird (<i>Mimus polyglottus</i>) | 5 | 3 | 5 | 5 | 5 |
| Pyrrhuloxia (<i>Cardinalis sinuatus</i>) | 3 | 5 | 0 | 5 | 2 |
| Scott's Oriole (<i>Icterus parisorum</i>) | 5 | 5 | 3 | 5 | 3 |
| Scaled Quail (<i>Callipepla squamata</i>) | 3 | 3 | 1 | 0 | 3 |
| Swainson's Hawk (<i>Buteo swainsoni</i>) | 2 | 4 | 2 | 0 | 4 |
| Verdin (<i>Auriparus flaviceps</i>) | 0 | 5 | 0 | 2 | 3 |
| Western Kingbird (<i>Tyrannus verticalis</i>) | 5 | 5 | 5 | 5 | 5 |
| Total number of species | 19 | 26 | 18 | 23 | 23 |
| Number species recorded all 5 years | 7 | 9 | 4 | 9 | 8 |

G=grassland; C=creosotebush piedmont slope; T=tarbush shrubland; P=mesquite fringe around an ephemeral lake; M=mesquite coppice dune.

number of nesting species (5). The mesquite shrublands had the lowest average number of nesting species (1.3) (Fig. 1). Species nesting at only one site were the curve-billed thrasher (*Toxostoma curvirostre*) at one of the ephemeral lake sites, pyrrhuloxia (*Cardinalis sinuatis*) at one of the creosotebush sites and Swainson's hawk (*Buteo swainsoni*) at one of the grassland sites. Black-throated sparrows (*Amphispiza bilineata*) nested in all of the shrubland habitats but did not nest in the grassland. Scott's oriole (*Icterus parisorum*) nested in all of the creosotebush sites, in two of the grassland sites and in one of the dry lake sites and one of the mesquite sites.

The pattern of species richness based on single date censuses on the Jornada Experimental Range was similar to that observed for the 5-year transect study (Fig. 2). Mean abundance and species richness was lowest in the grassland but the index of species diversity (H') was lowest in the tarbush habitat. Mean abundance was not very different among shrub-dominated habitats. Species richness was highest at the plots around the dry lake (Fig. 2). Occurrence of birds within sample plots was also lowest in the black grama grassland and highest in the dry lake sites. One species, horned lark (*Erimophila alpestris*), was found only in the tarbush habitat in only one of the plots. Several species were found only in the dense mesquite fringe around a grass covered ephemeral lake basin: Blue Grosbeak (*Guiraca caerulea*), Bullock's Oriole (*Icterus galbula*), Ladder-backed Woodpecker (*Picoides scalaris*), and Western Meadowlark (*Sturnella neglecta*).

Species richness was higher at the Santa Rita native grassland area than at any of the other study sites (Fig 2). Species richness, abundance, and diversity index were higher for breeding birds in the Santa Rita native grassland than in the Santa Rita Lehmann lovegrass area. However at the Empire Cienega Ranch sites, species richness was lower on the native grassland sites than on the Lehmann lovegrass sites (Fig. 2).

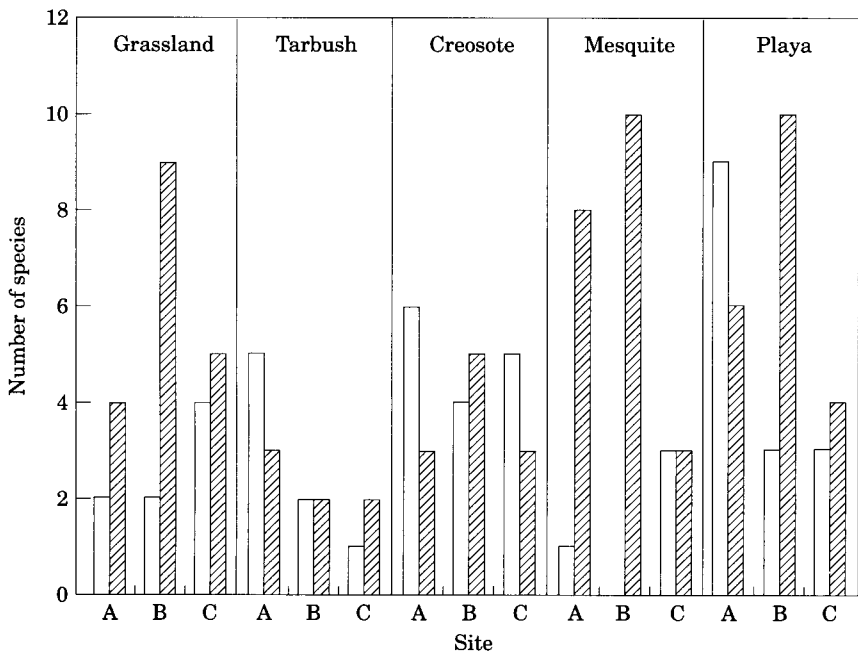


Figure 1. Number of bird species nesting (□) and/or foraging (▨) within a 100 m radius circle in a black grama grassland sites and several types of shrub dominated sites. A, B, and C refer to the sample sites within a habitat.

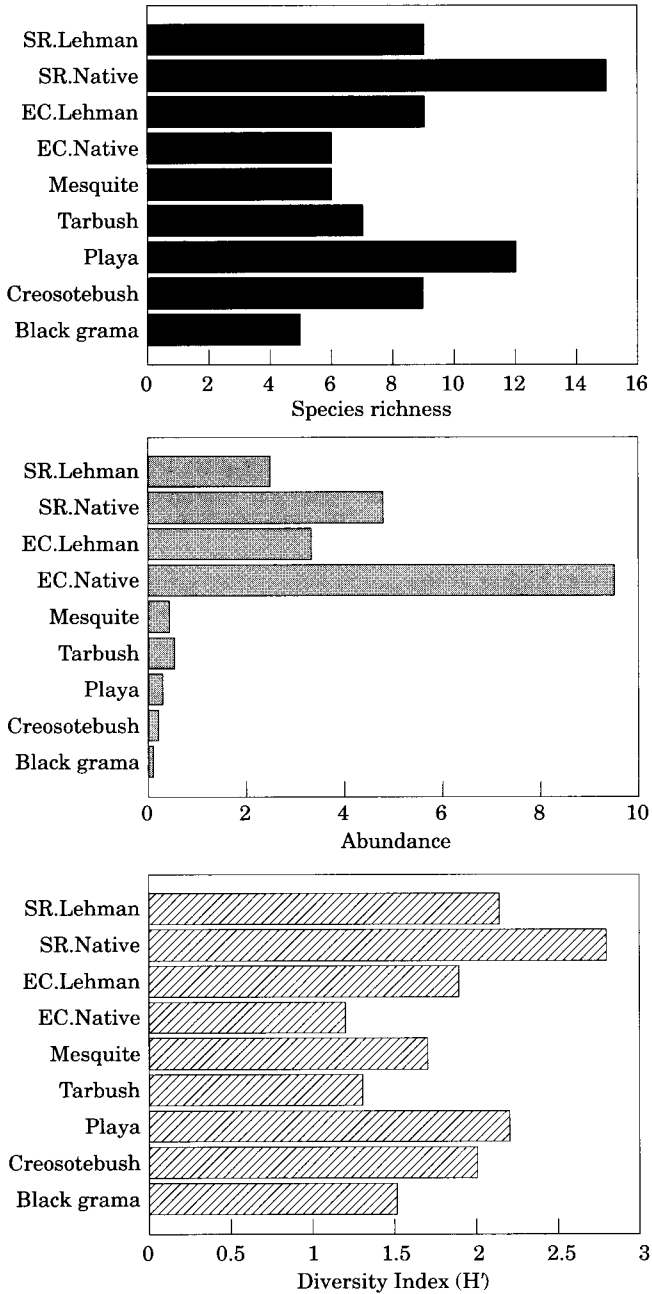


Figure 2. Species richness, abundance (No. km⁻²) and the Shannon-Weaver Diversity Index (H') for breeding birds censused in nine 100-m radius circles within each area. SR = Santa Rita and EC = Empire Cienega sites in south-eastern Arizona. Native and Lehmann refer to sites dominated by native grasses or by the African exotic, Lehmann lovegrass (*Eragrostis lehmanniana*), respectively. Playa refers to an ephemeral lake basin surrounded by dense mesquite (*Prosopis glandulosa*) and grass refers to a grassland dominated by black grama (*Bouteloua eriopoda*).

Small mammals

In the studies of sites on a desertification gradient, species richness and relative abundances of small mammals were lowest in grassland habitats and highest in creosotebush-dominated habitats (Table 2). Species richness and relative abundance were higher in mesquite coppice dune sites than in black grama grassland sites (Table 2). Small mammal communities on the Jornada had been studied in a series of mesquite coppice dune sites in comparison with a series of grassland (with varying cover of mesquite) sites (Alberico, 1978). In this comparison, both species richness and relative abundance were higher in the mesquite coppice dune sites (two way ANOVA, Fisher LSD method, $p < 0.05$). There was also an inverse relationship between grass cover and species richness and relative abundances of small mammals (Alberico, 1978) (Fig. 3).

Table 2. Relative abundances (number per 300 trap nights) and species richness of small mammals averaged for two black grama grassland sites (G), two tarbush sites (T), three creosotebush sites (C), and three mesquite sites (M)

| Species | G | T | C | M |
|---|-----|-----|------|-----|
| Desert Pocket Mouse (<i>Chaetodipus penicillatus</i>) | 0 | 0 | 1.3 | 0 |
| Merriams Kangaroo Rat (<i>Dipodomys merriami</i>) | 0 | 2.0 | 13.7 | 0 |
| Ord's Kangaroo Rat (<i>Dipodomys ordii</i>) | 0.5 | 0 | 0 | 6.0 |
| White-throated Woodrat (<i>Neotoma albigula</i>) | 0 | 0 | 0.3 | 0 |
| Southern Plains Woodrat (<i>Neotoma micropus</i>) | 0 | 0 | 0 | 0.3 |
| Northern Grasshopper Mouse (<i>Onychomys leucogaster</i>) | 0 | 0 | 0 | 0.6 |
| Silky Pocket Mouse (<i>Perognathus flavus</i>) | 0.5 | 0 | 0.3 | 0 |
| Western Harvest Mouse (<i>Reithrodontomys megalotis</i>) | 0 | 0.5 | 0 | 0.6 |
| Spotted Ground Squirrel (<i>Spermophilus spilsoma</i>) | 0.5 | 0 | 0.3 | 0 |
| Species richness (S) | 3 | 2 | 5 | 4 |

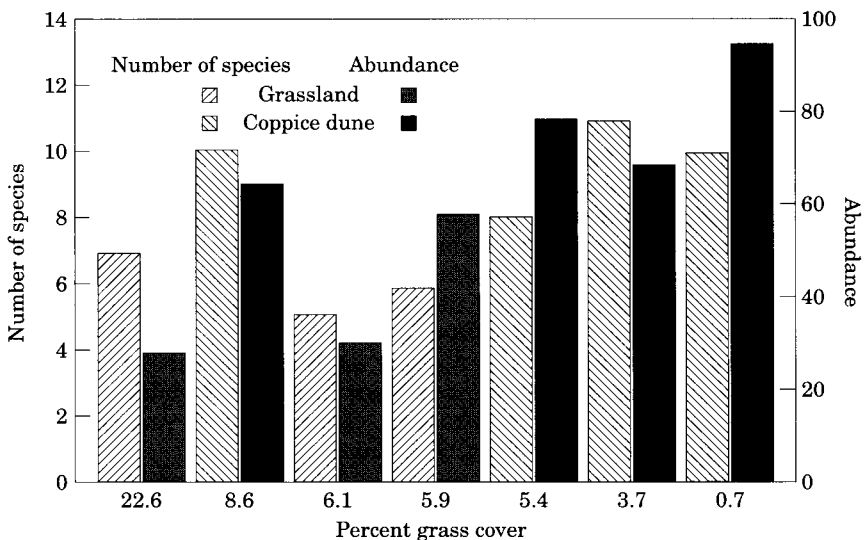


Figure 3. Number of species (species richness) and average abundance (number per 650 trap nights) of small mammals in several grassland and mesquite coppice dune sites with varying grass cover (data from Alberico, 1978).

Discussion

The data presented here suggest that degradation of North American desert grasslands has not resulted in reduction in species richness of breeding birds or of small mammals. A study of ant communities in desertified and remnant grasslands demonstrated that there were no differences in species richness, relative abundances and species composition (Whitford *et al.*, in press). While desertification has resulted in local extinctions of some species of plants e.g. black grama (*Bouteloua eriopoda*) in mesquite coppice dunes and creosotebush shrublands, the loss of this previously dominant plant species has not resulted in a decrease in species richness of breeding birds, small mammals or ants. Indeed, species richness and relative abundances of the species was frequently higher in the desertified habitats than in the remnant desert grasslands.

Habitat influences on avian species diversity are complex and involve more than the apparent good correlation with foliage height diversity (Wiens, 1989). There are correlations between plant species composition of habitats and bird communities (Tomoff, 1974; Wiens & Rotenberry, 1981; Rotenberry, 1985). Desertification in desert grasslands has affected both foliage height diversity and plant species composition of habitats. Small trees and shrubs completely dominate some areas that were desert grassland and in some areas a grass layer is completely absent. In other former desert grasslands the trees and shrubs are interspersed within the grassland forming a savanna-like landscape. These changes increase foliage height diversity in some areas and increase nesting sites in all areas (Naranjo & Raitt, 1993). However plant species composition may be more important than the structural feature of foliage height diversity. For example, western kingbirds and Scott's orioles nest in the inflorescence stalks of *Yucca elata* Engelm. plants that are greater than 2 m in height (Naranjo & Raitt, 1993; pers. comm.). Although *Y. elata* plants are a minor component of desert grasslands, they survive and continue to reproduce even in the most degraded mesquite coppice dune areas and creosotebush shrublands. However, the availability of inflorescence stalks as nesting sites is affected by the timing of livestock grazing in an area. Livestock eat all of the inflorescence stalks of *Y. elata* except for those on caudices that are too tall for the cattle to reach (Kerley *et al.*, 1993). Other plant species may be important as feeding sites for particular species of birds (e.g. black-throated sparrows gleaning insects from shrubs) or as nest sites.

Inter-annual variation in breeding bird species richness was probably related to variation in rainfall and phenologies of plants. During 4 years of breeding bird censuses, rainfall varied between 110 to 170% above the long-term average. In the other year of the study, the annual rainfall was only 60% of the long-term average and the rainfall during the bird breeding season was only 31% of the long-term average. Despite these drought conditions a number of species of breeding birds occurred at all of the sites. The comparisons of bird species that forage in an area with those species actually nesting in the area suggests another variable that contributes to inter-annual variation in species richness. Territory sizes vary with resource abundance (Wiens, 1989) and many of the birds recorded from the transects may not have been nesting within the area that was sampled. The transect method of censusing birds does not provide information on nest locations hence overestimates the abundance and diversity of breeding birds. As Wiens (1989) emphasized, census methods vary considerably in their reliability for interpreting community structure.

The comparisons of the single date censuses provided some valuable comparisons for evaluating the importance of vegetation structure and plant species composition for breeding bird diversity. The reduction in breeding bird species richness in the Santa Rita Lehmann lovegrass area was predicted for a habitat dominated by an exotic species. The higher breeding bird species richness in the Empire Cienega lovegrass area appeared to be attributable to one sample location that was within 200 m of a well

in an area with a dense stand of mesquite trees and a small cluster of introduced trees. At that sample point we recorded three species that were not recorded at any of the other sample locations. Of those species, brown headed cowbird (*Molothrus ater*) and house finch (*Carpodacus mexicanus*) are frequently found near human habitation and were probably present because of the water well and trees. Curve-billed thrashers (*Toxostoma curvirostre*) prefer sites with dense shrubs (Vander Wall & MacMahon, 1984; Narajano & Raitt, 1993). If those species are eliminated from consideration then the richness, diversity and abundance of breeding birds was higher in the Empire Cienega native grassland than in the lovegrass-dominated areas. At the Santa Rita location, the exotic Lehmann lovegrass formed a virtual monoculture which excluded other perennial grasses and annual forbs. At Empire Cienega, the Lehmann lovegrass areas had a mix of native grass species, forbs, and sub-shrubs. According to Bock *et al.* (1986), the spread of Lehmann lovegrass has had a negative effect on the species richness and abundance of indigenous animals. Lehmann lovegrass also has a competitive advantage over native grasses both because of its phenology and because cattle prefer to graze native species which allows lovegrass to increase during the summer growing season (Bahre, 1995). This exotic grass increases fire frequency and is predicted to continue to increase and dominate the desert grassland areas of North America (McClaran, 1995). This exotic grass species has a large negative effect on species richness and diversity of breeding birds. The negative effect of this exotic species is greater than the more dramatic changes in plant composition inherent in the shift from desert grassland to mesquite coppice dunes.

Desertification did not reduce either the species richness nor abundances of small mammals. In studies of small mammals in the Jornada Basin between 1960 and 1963, Wood (1969) reported that the black grama grasslands had the lowest mean rodent densities of any area and contained only six of the 12 species that were present in the other habitat types. In Wood's studies the highest species richness (11) was in an area dominated by annual weeds. A mesquite dune area and creosotebush area supported 10 species. Whitford (1976) reported 11 species of small mammals in a creosotebush-dominated area and 14 species in a mesquite, *Ephedra trifurca* Decne., *Yucca elata* area that was heavily grazed by domestic livestock. Data from Alberico (1978) showed that small mammal abundance and species richness were negatively correlated with perennial grass cover. The recent trapping studies are consistent with these earlier studies and support the conclusion that desertification does not have a negative effect on small mammal species richness and abundance. The data from these studies show that grassland species continue to inhabit the desertified areas and that additional species move into the 'degraded' habitats.

Shrubland small mammal species have expanded into desertified grassland fragments. Pairs of similar species now co-exist as potential competitors in desertified areas. The southern plains wood rat (*Neotoma micropus*), a grassland species, must compete with the white-throated wood rat (*Neotoma albigula*) for nest sites and food in the grassland-shrub mosaics and in coppice dune areas (Wright, 1973). In many creosotebush, mesquite and tarbush habitats, Ord's kangaroo rat (*Dipodomys ordii*), a grassland species, shares space with Merriam's kangaroo rat (*Dipodomys merriami*) (Whitford 1976; Whitford & Steinberger, 1989). Competition between such species pairs may eventually result in the local extinction of the 'grassland species'. However, results of long-term studies demonstrate that competition between such species is temporally episodic, occurring primarily during periods of adverse climate and limited food resources (Wright, 1973; Whitford & Steinberger, 1989). Thus it is likely that local extinction of one of the species will not occur for many decades. The assemblages of small mammals and birds that currently occupy desertified habitats are products of only a few decades of change. The desertified habitats, while superficially stable, are dynamic and continue to experience soil loss and vegetation change (Chew & Whitford, 1992). Considering the dynamic nature of desertified landscapes and the

changing environmental stressors that interact with drought and other natural disturbances, the animal communities in desertified desert grasslands in North America will probably be very different from those recorded in this study by the end of the twenty-first century.

One species of small mammal that has been adversely affected by desertification is the banner-tailed kangaroo rat, *Dipodomys spectabilis*. This species may be a keystone species in desert grassland ecosystems. *Dipodomys spectabilis* nest mounds produce water- and nutrient-rich patches in the desert grassland (Moroka *et al.*, 1982; Moorhead *et al.*, 1988; Mun & Whitford, 1990). *Dipodomys spectabilis* may also be responsible for harvesting flowering tillers of perennial grasses before the seeds are ripe thereby affecting the seed bank (Kerley *et al.*, 1997). There may be additional processes and functions that this species affects in desert grasslands which would contribute to its keystone status. This species is absent in most mesquite coppice dune areas and creosotebush shrublands. *Dipodomys spectabilis* is adversely affected by soil loss and in some grassland areas which have experienced soil loss the nest mounds of this species are covered with fragments of cemented calcium carbonate. Additional soil loss from these areas could eliminate *D. spectabilis* if the soil depth decreases below that required for the nest mound. However we need considerably more information in order to evaluate the implications of the loss of this potential keystone species for the long-term structure and ecosystem processes of the desertified ecosystems.

Evaluation of the impact of desertification on biodiversity of animals requires considerable information on the life history characteristics of the species and of their autecology (Hansen & Urban, 1992). Careful long-term studies of the natural histories of animal species has not been considered valuable science in the latter half of this century. With the growing concern about biodiversity (Wilson, 1992; Rosenzweig, 1995) we need to focus attention on natural histories of the organisms that remain in the decreasing undesertified patches and on those species that flourish in the desertified patches.

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