

MAMMALIAN SPECIES COMPOSITION, DIVERSITY, AND SUCCESSION IN CONSERVATION RESERVE PROGRAM GRASSLANDS

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ABSTRACT—Species diversity and composition of small mammals were each compared between Conservation Reserve Program (CRP) grasslands and native shortgrass prairie on the Southern High Plains of Texas. Small mammals were livetrapped in all four seasons during a one-year interval at six CRP sites (1, 2, and 3 years of age) and two control sites. Two factors (vegetational heterogeneity and age of habitat) known to affect species diversity were analyzed by a variety of quantitative methods. No significant differences in mammalian diversity (Fisher's log series α) were found among sites, and diversity was not significantly correlated with vegetational heterogeneity or site age. Species composition (proportional density of species) was significantly different among all sites in each season. Regardless of season, a priori hierarchical comparisons revealed significant differences in the proportional abundances of species between all CRP sites as a group and in the control sites. The CRP grasslands simulate shortgrass prairies in species diversity, but not in species composition. Differences in species composition between CRP grasslands and shortgrass prairie may be a result of the lack of natural disturbances (i.e., grazing, fire) on the CRP grasslands.

Conservation efforts, such as reclamation or restoration, are frequently judged as to their success based on considerations of species diversity (including species richness and evenness) and species composition (relative abundance of each species). Diversity measures are used to gauge environmental disturbances and have emerged as widely-used criteria in the assessment of conservation potential and ecological value (Margules and Usher, 1981). In contrast, changes in species composition (succession) have been viewed as environmental indicators of stressed ecosystems (Rosenberg, 1976; Wu, 1982; Lovell et al., 1985), or as a result of release from perturbations (Beckwith, 1954; Hirth, 1959; Pearson, 1959; Moulton et al., 1981a; Huntly and Inouye, 1987). Whereas restoration implies the return of an area to its original state in terms of both structure and function, reclamation only imports that an area become usable again (Bradshaw, 1987). Consequently, the degree to which species diversity and composition are important depends upon the desired outcome of particular conservation efforts.

Contemporary views posit that species diversity is the product of several factors, with vegetational heterogeneity and length of time since last major perturbation among the most impor-

tant (Huston, 1979; Krebs, 1985). An increase in vegetational heterogeneity leads to a concomitant increase in animal species diversity (Kelting, 1954; Pielou, 1975; Grant et al., 1977; Huston, 1979; Moulton et al., 1981a; Moulton et al., 1981b; Navo and Fleharty, 1983; Krebs, 1985). For example, moderate grazing by cattle increases vegetational heterogeneity in shortgrass prairies (Kelting, 1954; Grant et al., 1982), and either increases or has little effect on mammalian species diversity (Moulton et al., 1981b; Grant et al., 1982). Vegetational heterogeneity increases diversity of food resources and microhabitats. The enhanced diversity of microhabitats and food resources (seeds, foliage, and invertebrates) should increase the diversity of consumer species because of a reduction in interspecific competition for food, resources, or microhabitats (Pielou, 1975; French et al., 1976; Grant and Birney, 1979).

Equally important, the length of time since last perturbation may affect species diversity. Results of such perturbations depend on their frequency, scale, and intensity (Pickett and White, 1985). Frequency includes how often the perturbation occurs and the predictability of the perturbation in time. Many environments exist in a state of nonequilibrium brought about through periodic

reductions in population density caused by density-independent perturbations, such as seasonality of rainfall and temperature (Krebs, 1985; Pickett and White, 1985). If a perturbation has an equal effect on all species, nonequilibrium states may occur and preclude competitive exclusion; consequently, species richness should increase with perturbation (Kelting, 1954; Paine, 1966; Pielou, 1975; Huston, 1979; Moulton et al., 1981b; Grant et al., 1982; Krebs, 1985). The age of a habitat (length of time since last perturbation) may result in either an increase or decrease in species richness (number of species present). Changes in vegetational composition over time (succession) may facilitate the immigration of other species hindered earlier by unfavorable physiognomic factors (Pimm, 1982). Concomitantly, perturbations may cause short-term, local extinctions of species. Given that the species composition of agricultural lands and grasslands are similar (Flehart and Navo, 1983; Navo and Flehart, 1983) the former result is the more likely.

Although mammalian facilitation of grassland succession is probably slight (MacMahon, 1981), trajectories of mammalian succession are, to some extent, a product of vegetational succession in grasslands. Nonetheless, changes in species composition of vegetation may not be as important to mammalian succession as are changes in vegetational structure (Egoscue, 1960; MacMahon, 1981; Kaufman et al., 1988).

The Conservation Reserve Program (CRP) was established by the United States Department of Agriculture in 1985 as a reclamation program. The primary objective is to conserve and improve soil and water resources by taking highly erodible land out of crop production, and establishing suitable vegetative cover in its place (Food Security Act of 1985). On the Southern High Plains of the Texas Panhandle, the native environment was shortgrass prairie (Stoddart et al., 1975). Through the CRP, and under the supervision of the State Soil Conservation Service, landowners have established grasslands, either of native or introduced grasses, on previous cropland. One year after planting, these sites are either sprayed with an herbicide or mowed to facilitate establishment of grasses. After establishment, no other maintenance is required, no grazing by domestic livestock or harvesting of vegetation is allowed, and the site must remain in the CRP for at least 10 years.

The principle objective of this study was to

determine how habitat created by establishment of CRP grasslands compared to habitat in a natural shortgrass prairie in terms of the composition and diversity of rodents. As a result of these comparisons, inferences can be made concerning the success of the CRP in establishing habitats for small rodents.

MATERIALS AND METHODS—Study Site—Research was conducted at eight sites that differed in management history. Six CRP sites (each approximately 800 m²) were sampled; two were seeded in 1987, two in 1988, and two in 1989. Maximum distance between sites was less than 30 km and each was adjacent to potential immigrant sources (Flehart and Navo, 1983; Navo and Flehart, 1983), such as other CRP sites, abandoned pastures, croplands of winter wheat, grain sorghum fields, or corn fields. No sites were completely surrounded by cotton fields or residential areas. All CRP sites were located on Amarillo soil associations in Hockley County, Texas (33°43'N, 102°18'W), and planted in weeping lovegrass (*Eragrostis curvula*), a stout, perennial bunchgrass native to Africa.

Two sites of natural shortgrass prairie, located at Muleshoe National Wildlife Refuge, Bailey County, Texas (34°14'N, 102°43'W), were used as controls (distances between CRP sites and the controls was approximately 56 km). This refuge, created in 1939, maintains one of the last shortgrass prairie environments on the Southern High Plains of Texas (McMahan et al., 1984). Dominant perennial grasses include buffalograss (*Buchloe dactyloides*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), and alkali sacaton (*Sporobolus airoides*). Other dominant vegetation includes mesquite (*Prosopis glandulosa*), broomweed (*Xanthocephalum dracunculoides*), and yucca (*Yucca louisianensis*). Moderate grazing by cattle is allowed on these grasslands from May through October. Both control sites were located on a combination of Berthoud-Mansker and Arch-Drake soil associations. Refuge lands themselves do not contain Amarillo soil associations, although they are surrounded by them. Neither control site had been grazed since 1988.

Experimental Design—In this study, the relation between alpha diversity (Whittaker, 1975) and factors known to affect mammalian species diversity (vegetational heterogeneity and age of the sites) were evaluated in CRP and native grasslands. Each site contained three transects that were sampled on consecutive days within each of four seasons (May, August, and November, 1990; February, 1991). Each transect comprised 50 Sherman live traps, set approximately 15 m apart and baited with oatmeal. During the February trapping period, 50 Museum Special snap traps were set in conjunction with, and at the same stations as, the Sherman traps, to obtain voucher specimens. Traps were set in the evening and checked just after sunrise

to prevent possible hyperthermia in the spring and summer; likewise, bedding material was added to the traps during the fall and winter to prevent possible hypothermia. No trapping was done for three days before or after a full moon (Carley et al., 1970), and trapping was interrupted for one day during August and for four days during February because of inclement weather. Within a site, transects were positioned approximately 200 m apart, either in a north-south or east-west direction (depending on the month), so that an 800-m² area was sampled eventually. Pairs of sites were trapped simultaneously, except during November, when the CRP sites were trapped three at a time and the control sites were trapped simultaneously. For each season, trapping of all eight sites was completed within a 10- to 17-day period.

Vegetational heterogeneity was estimated, during May 1991, using a variation of the step-point method (Evans and Love, 1957). Three transects were positioned approximately 200 m apart within each site. Along each transect, 100 sampling points were positioned approximately 7 m apart. At each point, the plant first contacted above ground by a thin rod running perpendicular to the sole of the sampler's boot was identified. Vegetational heterogeneity of each site was estimated by the Shannon-Wiener information index:

$$H' = -\sum(p_i \ln p_i),$$

where p_i is the proportion of all individuals represented by the i th species (Shannon and Weaver, 1949).

All rodents were ear-marked with a Sharpie® permanent marker to provide identification of previous captures within a season. This prevented duplication in the counting of individuals in the event of a recapture within a three-day trapping period. Sex, reproductive condition (position of testes or condition of vulva), weight, age (juvenile or adult), molt (presence or absence), and trap number were noted for each capture. All rodents captured in snap traps or found dead in live traps were kept as voucher specimens and are deposited in The Museum of Texas Tech University.

Sites also were ranked as to age. Age was considered to be the length of time since the last major anthropogenic perturbation. In the CRP sites, this time interval began with the planting of the weeping lovegrass and the concomitant cessation of agriculture. The age of the control sites was based upon the date of establishment of the Muleshoe National Wildlife Refuge.

Statistical Analysis—Fisher's log series α (Fisher et al., 1943) was used to calculate species diversity of rodents within each site during each season. This index is sensitive to both species richness and species evenness; depending upon the number of species and number of individuals, it ranges from zero to infinity. It is robust to deviations from a log-series distribution, and is a good discriminator between sites with little difference in diversity (Taylor, 1978). This index is also robust with respect to variation in total number of

sampled individuals (Kempton and Taylor, 1974; Magurran, 1988). The index (Taylor et al., 1976) is defined by:

$$\alpha = N(1 - x)/x,$$

where N is the total number of individuals and x may be estimated by an iterative procedure. More specifically, x is defined by a ratio of the total number of species to the total number of individuals and can be estimated from

$$S/N = [(1 - x)x^{-1}][-\ln(1 - x)]$$

where S is the total number of species and N is the total number of individuals. Diversity indices were considered statistically different if the 95% CI of α in two sites did not overlap.

Separate G-tests of independence (Program RXC: Two-way test of independence and homogeneity; Pimentel and Smith, 1990) were used to evaluate if the proportional representation of rodent species varied seasonally within sites of a particular age. William's correction factor (Williams, 1976) was employed as an adjustment for cells containing zeros. Because of the large number of empty cells within each contingency table, sites of the same age were combined, as well as certain species. Groups were formed primarily based upon taxonomic or ecological considerations. When possible, congeners were pooled into single categories (e.g., all *Peromyscus*, all *Reithrodontomys*). *Dipodomys* and *Chaetodipus* were combined into a single group because they are similar-sized heteromyids. The remaining taxa (*Mus*, *Onychomys*, *Perognathus*, and *Neotoma*) were combined into a single group solely for methodological reasons. Five groups of species resulted from the aforementioned combinations: (1) *Reithrodontomys* (includes *R. megalotis* and *R. montanus*), (2) *Sigmodon hispidus*, (3) *Dipodomys ordii* and *Chaetodipus hispidus*, (4) *Peromyscus* (includes *P. maniculatus* and *P. leucopus*), and (5) *Mus musculus*, *Onychomys leucogaster*, *Perognathus flavus*, and *Neotoma micropus*.

Hierarchical, pair-wise comparisons of proportional species abundances between site groups (first-year CRP, second-year CRP, third-year CRP, and control) were performed a priori using a variation of Upton's method (Upton, 1978) for the analysis of cross-tabulated data (Program RXC: Two-way test of independence and homogeneity; Pimentel and Smith, 1990). Each CRP site group was compared to the control site group, a posteriori (Program RXC: Two-way test of independence and homogeneity; Pimentel and Smith, 1990), holding comparison-wise error rate at 0.017 in order to maintain experiment-wise error rate at 0.05 (Sokal and Rohlf, 1981).

Three different measures of similarity (Jaccard, simple matching, cosine) were used to evaluate relationships among sites based upon rodent community composition and vegetation (Program PROXIMITIES, SPSS Inc., 1988). The three similarity indices vary in

TABLE 1—Fisher's log series α species diversity index ($\pm 95\%$ CI) for each site in each of four seasons (1 and 2 = first-year sites, 3 and 4 = second-year sites, 5 and 6 = third-year sites, 7 and 8 = control sites).

| Site | Species diversity | | | |
|----------------|-------------------|-------------------|-------------------|-------------------|
| | Spring | Summer | Fall | Winter |
| CRP | | | | |
| 1 | 0.856 \pm 1.210 | 1.662 \pm 1.487 | 2.906 \pm 2.373 | 1.753 \pm 1.431 |
| 2 | 1.687 \pm 1.509 | 1.922 \pm 1.719 | 2.212 \pm 1.978 | 1.596 \pm 1.428 |
| 3 | 1.662 \pm 1.487 | 2.342 \pm 1.913 | 2.019 \pm 1.806 | 1.439 \pm 1.287 |
| 4 | 0.729 \pm 0.841 | 1.465 \pm 1.310 | 0.939 \pm 1.084 | 1.766 \pm 1.442 |
| 5 | 2.293 \pm 2.051 | 3.184 \pm 3.184 | 2.906 \pm 2.373 | 0.856 \pm 1.211 |
| 6 | 1.871 \pm 1.871 | 3.218 \pm 2.878 | 1.744 \pm 2.013 | 1.359 \pm 1.569 |
| Control | | | | |
| 7 | 2.388 \pm 2.757 | 1.359 \pm 1.569 | 0.856 \pm 1.211 | 0.852 \pm 0.983 |
| 8 | 5.453 \pm 6.296 | 2.471 \pm 3.657 | 2.471 \pm 2.471 | 1.594 \pm 1.594 |

the degree to which they are sensitive to the abundance of species, or the manner in which shared species absences are considered in estimating similarity. The Jaccard and simple-matching indices are based upon presence-absence data, and do not consider the abundances of each species. The Jaccard index bases similarity on the proportion of shared species to the number of species in either site. The simple-matching index is similar, except that it considers shared absences of species when calculating similarity. In contrast, the cosine measure is a similarity index based upon distances derived from species abundance data. It places more importance on the proportion of species within sites and less importance on their absolute quantities. In each case, sites were subsequently clustered based upon UPGMA (unweighted pair-group method average) algorithm (Program CLUSTER, SPSS Inc., 1988), after the site-species similarity matrix was transformed to a dissimilarity matrix. For the purpose of the cluster analysis, a rodent species was considered present at a site if more than one individual of that species was captured during the one-year period. As a result, transient species were less likely to be considered as part of the community. Cluster analysis was also performed on the vegetational data, using the cosine similarity measure, in order to determine if groups of sites could be distinguished based on vegetation. The association between rodent species diversity and vegetational heterogeneity and site age was analyzed using Spearman's rho (Program NONPAR CORR; SPSS Inc., 1988). All correlations utilized rodent species diversity indices calculated for the summer in order to minimize variations in the number of species captured due to physiological responses to seasonal changes.

RESULTS—All species diversity indices were statistically indistinguishable, as their 95% CIs overlapped extensively in each season. Possibly,

this was a result of the large *SD* associated with indices based on small sample sizes. The smallest *SDs* occurred in the winter, which had the largest sample size because of the doubled trapping effort. However, differences in species diversity among sites were less in the winter than in any other season (Table 1).

Although no significant correlation existed between rodent species diversity and site age ($\rho = 0.195$, *d.f.* = 6, $P = 0.32$), differences were found in vegetational composition and structure. Vegetational heterogeneity varied between some sites within the same age groupings. The percentage of weeping lovegrass (*E. curvula*) at first-year sites ranged from 36 to 79%. At the site consisting of 36% lovegrass, 49% of the vegetation was forbs (21% fireweed, *Kochia scoparia*; 12% russian thistle, *Salsola iberica*; 16% other forbs). At each second-year site, 87% of the vegetation consisted of weeping lovegrass. The other 13%, at both sites, consisted of other grasses and forbs. Third-year sites ranged from 69–85% weeping lovegrass, with 4–11% yucca and 7–18% forbs.

The control sites were different from CRP sites because of their complement of native grasses and vegetation. The dominant grass on these two sites was blue grama, which composed 37–45% of the vegetation. Other grasses included alkali sacaton (4%), buffalograss (14%), and sideoats grama (3–8%). Forbs, mostly broomweed (16–24%), accounted for approximately 25% of the vegetation. Other vegetation included yucca (4%) and honey mesquite (7%).

Cluster analysis, based on vegetation, divided the sites into two distinct groups: the CRP sites

and the control sites (Fig. 1). The CRP sites were tightly grouped, with the exception of one first-year site, which was only 36% lovegrass. No significant correlation existed between rodent species diversity based on Fisher's log series α , and vegetational heterogeneity based on the Shannon-Wiener information index ($\rho = -0.238$, $d.f. = 6$, $P = 0.29$).

Eleven rodent species were captured during the 6,000 trap-nights (TN) of this study. Both species richness and the abundances of particular rodent species varied among seasons and sites (Table 2). One hundred fifty-seven rodents were captured in the spring (0.163/TN in CRP, 0.033/TN in control), 163 in the summer (0.163/TN in CRP, 0.053/TN in control), 123 in the fall (0.112/TN in CRP, 0.073/TN in control), and 248 in the winter (0.112/TN in CRP, 0.077/TN in control). Winter captures were greater as a result of using twice as many traps to sample each site (128 were captured in live traps, and 120 in snap traps). Of the 11 species encountered during the study, *N. micropus* was captured only once (in the winter). *Reithrodontomys megalotis* and *R. montanus*, as well as *P. maniculatus* and *P. leucopus*, could not be reliably distinguished based upon field characteristics; therefore, all *Reithrodontomys* were combined and considered as one entity in statistical analyses, as were all *Peromyscus*. Consequently, *Reithrodontomys* constituted the majority of captures in all seasons, ranging from 31% in the spring to 69% in the winter. The prevalence of other species varied according to the season. In particular, *S. hispidus* ranged from 5% in the winter to 25% in the spring; *M.*

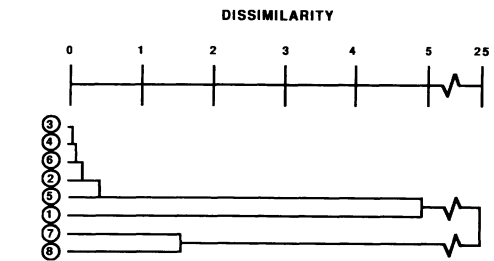


FIG. 1—The dendrogram represents relationships among sites based upon vegetational heterogeneity during the spring using cluster analysis (UPGMA) of the cosine similarity index. Numerical values to the left of the dendrogram indicate the identity of each field (1 and 2 = first-year sites; 3 and 4 = second-year sites; 5 and 6 = third-year sites; 7 and 8 = control sites). Scale above dendrogram indicates degree of dissimilarity, rescaled from zero (identical) to 25 (most dissimilar).

musculus from 5% in the winter to 15% in the spring; *Peromyscus* from 9% in the summer to 15% in the spring; *C. hispidus* from 3% in the winter to 28% in the summer; *O. leucogaster* from 3% in the summer to 6% in the spring; *D. ordii* from 2% in the fall to 4% in the winter; and *Perognathus flavus* from <1% in the spring to 6% in the fall.

The G-test for independence indicated a highly significant difference in the proportional abundance of rodent species among sites in each season (Table 3). A priori comparisons of sites revealed significant differences between the proportional abundances of species, at first- and second-year sites, during the spring, summer, and winter. Significant differences, in the spring and the winter,

TABLE 2—Number of individuals of each taxon of rodents captured in Conservation Reserve Program grasslands (first, second, and third year) and at Muleshoe National Wildlife Refuge (control) during each of four seasons (Sp = spring, Su = summer, F = fall, W = winter).

| Taxa | First year | | | | Second year | | | | Third year | | | | Control | | | |
|------------------------------|------------|----|----|----|-------------|----|----|----|------------|----|----|---|---------|----|----|----|
| | Sp | Su | F | W | Sp | Su | F | W | Sp | Su | F | W | Sp | Su | F | W |
| <i>Reithrodontomys</i> spp. | 6 | 11 | 18 | 59 | 26 | 32 | 28 | 69 | 12 | 5 | 10 | 9 | 5 | 8 | 12 | 33 |
| <i>Onychomys leucogaster</i> | 5 | 2 | 1 | 6 | 0 | 1 | 0 | 1 | 4 | 1 | 3 | 0 | 1 | 0 | 0 | 0 |
| <i>Sigmodon hispidus</i> | 2 | 1 | 5 | 2 | 25 | 15 | 5 | 9 | 12 | 5 | 3 | 1 | 0 | 0 | 0 | 0 |
| <i>Dipodomys ordii</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 2 | 9 | 0 | 1 | 0 | 1 |
| <i>Chaetodipus hispidus</i> | 3 | 25 | 5 | 5 | 1 | 12 | 1 | 2 | 1 | 6 | 0 | 0 | 3 | 2 | 1 | 0 |
| <i>Mus musculus</i> | 0 | 5 | 4 | 10 | 23 | 7 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| <i>Peromyscus</i> spp. | 22 | 9 | 3 | 4 | 1 | 2 | 5 | 11 | 0 | 0 | 0 | 0 | 1 | 5 | 7 | 10 |
| <i>Perognathus flavus</i> | 1 | 3 | 3 | 1 | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| <i>Neotoma micropus</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total taxa | 6 | 7 | 7 | 7 | 5 | 7 | 6 | 7 | 5 | 5 | 4 | 3 | 4 | 4 | 5 | 5 |

TABLE 3—Results of G -tests of independence comparing sites based upon rodent species abundances in each season. $df.$ = degrees of freedom, G = G statistic, and P = probability (NS, $P > 0.05$; *, $0.05 \geq P > 0.01$; **, $0.01 \geq P > 0.001$; ***, $P \leq 0.001$).

| Comparisons | $df.$ | G | P |
|--------------------------|-------|---------|-----|
| Spring | | | |
| Among sites | 12 | 105.339 | *** |
| A priori comparisons | | | |
| Year 1 vs. Year 2 | 4 | 59.867 | *** |
| Years 1 & 2 vs. Year 3 | 4 | 30.637 | *** |
| CRP vs. Control | 4 | 14.836 | *** |
| A posteriori comparisons | | | |
| Year 1 vs. Control | 4 | 14.625 | * |
| Year 2 vs. Control | 4 | 22.766 | * |
| Year 3 vs. Control | 3 | 10.897 | * |
| Summer | | | |
| Among sites | 12 | 57.676 | *** |
| A priori comparisons | | | |
| Year 1 vs. Year 2 | 4 | 33.117 | *** |
| Years 1 & 2 vs. Year 3 | 4 | 8.286 | NS |
| CRP vs. Control | 4 | 16.273 | ** |
| A posteriori comparisons | | | |
| Year 1 vs. Control | 4 | 13.097 | * |
| Year 2 vs. Control | 4 | 19.625 | * |
| Year 3 vs. Control | 4 | 18.642 | * |
| Fall | | | |
| Among sites | 12 | 22.237 | * |
| A priori comparisons | | | |
| Year 1 vs. Year 2 | 4 | 6.005 | NS |
| Years 1 & 2 vs. Year 3 | 4 | 3.636 | NS |
| CRP vs. Control | 4 | 12.597 | * |
| A posteriori comparisons | | | |
| Year 1 vs. Control | 4 | 11.750 | NS |
| Year 2 vs. Control | 4 | 7.702 | NS |
| Year 3 vs. Control | 4 | 14.186 | * |
| Winter | | | |
| Among sites | 12 | 63.093 | *** |
| A priori comparisons | | | |
| Year 1 vs. Year 2 | 4 | 16.799 | ** |
| Years 1 & 2 vs. Year 3 | 4 | 30.958 | *** |
| CRP vs. Control | 4 | 15.533 | ** |
| A posteriori comparisons | | | |
| Year 1 vs. Control | 4 | 16.495 | * |
| Year 2 vs. Control | 4 | 9.187 | NS |
| Year 3 vs. Control | 4 | 28.400 | * |

were also evident in the comparison of third-year sites with the group consisting of first- and second-year sites. Lack of significant differences in the fall may be a result of the relatively small number of individuals captured during that season. As a group, the CRP sites were significantly different from control sites in the proportional abundances of species in all seasons (Table 3).

The a posteriori comparisons of proportional species abundances in CRP sites and control sites showed significant differences in all seasons. Individually, site groups were significantly different from the control group in proportional abundances of rodents in both the spring and the summer. Only third-year sites were significantly different from control sites in the fall. Again, this

may be an artifact of the small sample size in that season. During the winter, both first- and third-year sites were significantly different from control sites, but second-year sites were not.

Cluster analysis, using rodent abundance data, showed no consistent groups of sites over the four seasons (e.g., first- and second-year sites were grouped together in the spring but not in the summer). This was probably related to unequal trapping success, based on the trapping interval for each site (3 days), and inconstancy of weather, that can affect the activity of rodents (Pearson, 1960; Jahoda, 1970; O'Farrell, 1974; Drickamer and Capone, 1977). Likewise, clustering based on presence-absence data showed no consistent agglomerations, with the exception of the third-year sites. Their similarity may be a product of their contiguity as well as their age.

In contrast, cluster analysis based on presence-absence data over the entire year (pooling seasons) indicated groupings that reflect age since incorporation into the CRP (Fig. 2). The Jaccard similarity index showed the CRP sites to be more similar to one another than to either of the control sites. Within the CRP sites, the third-year sites were more similar to one another than to the other sites. Although first- and second-year sites were consistently grouped together, clusters of sites of the same age did not occur within this group. In contrast, the simple-matching similarity index determined third-year sites to be more similar to the control sites than to other CRP sites.

Consensus analysis identified associations among sites which were the same, regardless of the similarity coefficient upon which the clustering was based. Three consensus groups were obtained from analyses based on Jaccard's and simple-matching coefficients (Greek letters in Fig. 2). Although component sites showed the same associations within consensus groups, the relationships among consensus groups differed, depending upon similarity coefficient. Consensus groups α and λ were more similar to each other than to consensus group δ in the analysis based on Jaccard's index (Fig. 2a), whereas consensus groups α and δ were more similar to each other than either was to consensus group λ in the analysis based upon simple-matching index (Fig. 2b).

DISCUSSION—Diversity measures are the most commonly used indicators of environmental well-being (Magurran, 1988), and species diversity and composition have long been the focal point

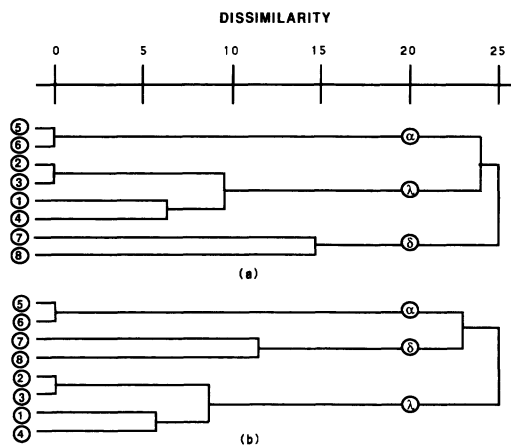


FIG. 2.—The dendrogram represents relationships among fields based upon cluster analysis of rodent species (UPGMA) Jaccard's similarity index (a) and simple-matching index (b). Numerical values to the left of the dendrogram indicate the identity of each site (1 and 2 = first-year sites; 3 and 4 = second-year sites; 5 and 6 = third-year sites; 7 and 8 = control sites). Scale above dendrogram indicates degree of dissimilarity, rescaled from zero (identical) to 25 (most dissimilar). Clusters, identified by Greek letters (α , λ , δ), represent consensus groups.

of restoration and reclamation efforts (Jordan et al., 1987). Whereas restoration programs strive to reconstruct an environment to its original form, both in structure and function (e.g., physiognomy, primary production), reclamation efforts usually focus on one or the other, or some part thereof. For example, the CRP in this area prevents soil erosion and water runoff by establishing grasslands. Many of these grasslands consist of introduced grasses that allow the CRP to accomplish its goals, but do not create the "native habitat" with respect to plant or animal species composition.

The extent to which a reclamation project is restorative to species diversity or composition may be extremely variable because both may be a result of many factors working in concert (Huston, 1979). Vegetational heterogeneity may increase rodent species diversity, whereas vegetational succession may decrease it. Site age may increase species composition as a result of the increased probability of immigration of new species over time. The degree to which a reclamation project will be restorative will depend on the intent of the reclamation project, and the extent that it affects the factors responsible for maintaining species diversity.

In this study, rodent species diversity was not significantly correlated with the vegetational heterogeneity of the sites or the age of the site. These results may be a result of the number of sampled sites ($n = 8$), rather than lack of real associations between these factors.

Vegetational heterogeneity may still be an important factor in determining rodent species diversity. Heterogeneity, based on vegetational structure rather than floral species composition, appears to be a determining factor in many grassland communities (Hansen and Warnock, 1978; Houtcooper, 1978; Huntly and Inouye, 1987; Kaufman et al., 1988; Fa et al., 1990). Some species appear to prefer habitats with vertical structuring (Box, 1959; Barry and Franq, 1980), whereas the presence of others seems to depend on the amount of cover in the overstory and on the ground (Goertz, 1964; Maxwell and Brown, 1968; Birney et al., 1976; Snyder and Best, 1988).

Successional changes in vegetational structure occurred in the CRP sites. First-year sites, on average, contained more bare ground and less cover than older sites. Consequently, fewer *S. hispidus* and more *Peromyscus* were captured in these sites. Also, *O. leucogaster* was more abundant in the first-year sites, possibly because of their preference for open sand in which to dust-bathe and the prevalence of insects therein (Egoscue, 1960).

Second-year sites were dense and almost homogeneous with lovegrass. *Sigmodon hispidus* and *Reithrodontomys* were found in greatest abundance in these sites. *Peromyscus* was present, but in lower numbers, as they prefer more open habitat with less litter (Kaufman et al., 1988). *Mus musculus* was found in both first- and second-year sites, but this was probably related to the proximity of the sites to human habitation rather than to the vegetational structure of the sites.

Third-year sites still contained dense lovegrass, but it occurred in clusters or bunches, interspersed with open spaces. *Sigmodon hispidus* and *Reithrodontomys* were present, but in lower numbers. *Dipodomys ordii* was present only in CRP sites in their third year. This species, along with the absence of *Peromyscus* and *M. musculus*, tended to segregate the third-year sites from other CRP sites, and group them more closely with the control sites, based upon simple matching similarity indices.

Control sites were conspicuous in the absence of *S. hispidus*, *O. leucogaster*, and *M. musculus*.

Although the absence of *O. leucogaster* cannot be explained easily, the lack of dense vegetation probably accounts for the absence of *S. hispidus*; the scarcity of human habitation on the Refuge probably limits the potential habitat for *M. musculus*. Only *Reithrodontomys* and *C. hispidus* were captured in all sites and appear to be grassland generalists.

CRP grasslands support as great a diversity of small mammals as do shortgrass prairie, at least within the first three years after establishment. The main differences between CRP grasslands and shortgrass prairie is in species composition and abundance. First- and second-year sites supported an average of six rodent species (disregarding *M. musculus*), whereas third-year sites and control sites harbor five. This short return time, in terms of species diversity, is to be expected in environments in which species have evolved around frequent (every 1–3 years), large-scale disturbances such as fire (Denslow, 1985; Loucks et al., 1985). The difference between third-year and control sites involved their complement of rodents. Third-year sites lacked *Peromyscus* and *Perognathus flavus*, whereas control sites lacked *O. leucogaster* and *S. hispidus*. Even though species composition may change from year to year with changes in vegetational structure, species diversity remains virtually the same. This same result was reported when comparing agricultural lands to relictual areas in Kansas (Flehart and Navo, 1983; Navo and Flehart, 1983). This suggests that species diversity may not be greatly affected by either agriculture or reclamation projects such as the CRP. This is to be expected in disturbance-mediated environments, such as grasslands, where both plant and animal species must be resilient to disturbances in order to persist. However, species composition may be highly dependent on specific physiognomic parameters that are not met in either agricultural sites or CRP grasslands. Species composition might be restored if grazing or fire-induced disturbances were allowed on the CRP grasslands, but either of these two events might be detrimental to the primary goals of the CRP, prevention of soil erosion and water runoff.

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