

**New Mexico DEPARTMENT OF GAME AND FISH
SHARE-WITH-WILDLIFE –FINAL REPORT JUNE 2006**

**INFLUENCE OF LANDSCAPE AND WITHIN-PATCH CHARACTERISTICS ON AVIAN
COMMUNITY DYNAMICS IN CHIHUAHUAN DESERT GRASSLANDS**

Principal Investigator: Martha Desmond, Department of Fishery and Wildlife
Sciences, New Mexico State University, Las Cruces, NM 88007

Research Assistant: Sofia Agudelo, Department of Fishery and Wildlife
Sciences, New Mexico State University, Las Cruces, NM 88007

INTRODUCTION:

In North America, grassland bird populations are exhibiting greater population declines than any other avian assemblage (Knopf 1994, Peterjohn et al. 1995, Peterjohn and Sauer 1999, Vickery et al. 1999, Askins 2000). Causes of declines are mainly speculation but have been attributed to habitat loss and fragmentation due to agricultural activities, urban expansion, livestock grazing, shrub encroachment, and pesticide use (Rappole and McDonald 1994, DeGraaf and Rappole 1995, Sherry and Holmes 1995, Sherry and Holmes 1996, Latta and Baltz 1997, Weltzin et al. 1997, Johnson and Igl 2001). Fragmentation of grasslands has been identified as a critical factor affecting breeding grassland bird populations. Johnson and Temple (1990) found that Grasshopper sparrows (*Ammodramus savannarum*) and Western Meadowlarks (*Sturnella neglecta*) were more likely to nest in large grassland fragments and that predation rates were lower in such fragments compared to smaller patches. Bollinger and Gavin (2004) found that Bobolinks (*Dolichonyx oryzivorus*) rarely nested near edges and edge avoidance was related to a pattern of area sensitivity.

The majority of research on grassland species has focused on the breeding season with many of these studies being conducted in the eastern United States (Askins 1995, Hunter et al 2001, Norment 2002, Rodewald and Brittingham 2002). Little is known about the effects of fragmentation during winter and migration. During the non-breeding period, birds may have a wider tolerance of habitat associations. For example, Hutto (1985) found many migrant species in western Mexico broadened their habitat use in the non-breeding period to agricultural hedgerows and had broader distributions than resident species. Wunderle (1999) found that species richness of migratory birds in Dominican shade coffee plantations unlike resident species was not correlated with vegetation variables suggesting less specific habitat associations. Seasonal changes in habitat use during stopover in Pennsylvania led Yahner (1993) to hypothesize that birds may be less sensitive to fragmentation during migration.

During migration, birds do not have the opportunity to search for the most suitable stopover habitat and may be forced to use sub-optimal sites (Moore et al. 1990). However, settlement at a stopover site must be driven by some bio-ecological clues, and habitat selection during stopover should be related to the intrinsic suitability of the habitat (Moore and Simmons 1992, Kelly et al 1999), extrinsic landscape factors (Dooley and Bowers 1998) or a combination of the two.

The Southwestern United States is an important region for migratory and wintering grassland and shrub-adapted birds. In this region, large expanses of native perennial grasslands have been lost to shrub encroachment (Buffington and Herbel 1965, Brown 1982, Kerley and Whitford 2000, Saab et al. 1995). While patches of intact grassland persist, these grasslands are fragmented and degraded with many experiencing various levels of shrub encroachment (Bahre and Shelton 1993). In the northern Chihuahuan Desert, the percentage

of land area of the Jornada del Muerto Basin classified as grassland declined 60% between 1858 and 1970 (Gibbens and Beck 1988). Gibbens and Beck linked the loss of grassland with a 40% increase in honey mesquite (*Prosopis glandulosa*) cover. Today, greater than 50% of this area is dominated by honey mesquite (Whitford 2002). Remaining grassland remnants are fragmented with varying levels of isolation and shrub encroachment (Reynolds et al 1999). The affect of this habitat conversion on non-breeding passerines is not well understood. Pidgeon et al. (2000) suggests that a substantial turnover in the breeding avian community of the Chihuahuan Desert has occurred over the past 150 years.

A large body of literature has addressed abiotic factors associated with desertification and vegetation responses; however, little research has addressed the response of vertebrates to the desertification process. Whitford (2000) reported an increase in rodent abundance in shrub encroached systems in the Chihuahuan Desert. Similarly, avian species richness and abundances were higher in the desertified habitats due to species with affiliations with shrub and grassland habitats occupying these sites (Whitford 1997). While some grassland species may persist in these degraded grasslands, Pidgeon et al. (2000) found breeding grassland obligates did not occupy degraded sites in southcentral New Mexico. Other studies have shown that fragmentation results in a change in avian community composition, due to increased presence of generalist species and the loss of area sensitive or specialist species (Bierregaard and Stoufer 1997, Ribic and Sample 2001, Jones and Bock 2002, Roesnblatt et al. 1999). The influence of the fragmentation and degradation of Chihuahuan Desert grasslands on the winter grassland bird community is not well understood. Winter bird community structure in these remnant grasslands will be potentially influenced by a reduction in available habitat, degree of isolation, edge effects and grassland degradation (With et al. 1999, Wenny et al.1998).

In this study we are examining how fragmentation of Chihuahuan Desert grasslands and shrub encroachment into remaining fragments, with its subsequent reduction and alteration of vegetation cover and structure, influences site occupancy by various grassland- and shrub-adapted species during the non breeding season at both local and landscape scales. At the local scale, we hypothesized vegetative structure and composition in a patch will influence avian community composition. Specifically, we predicted: 1) heterogeneous grasslands will support more diverse bird communities than homogeneous grasslands, 2) grassland patches with moderate and high shrub encroachment will contain a shrub-adapted avian community whereas patches with little or no shrub encroachment will be dominated by grassland specie and 3) avian abundance and community composition will differ among grassland types.

At the landscape scale we hypothesized avian composition and abundance within a grassland patch will be influenced by the size, shape and degree of isolation of the patch. We predicted that: 1) grassland bird abundance will be positively correlated with patch size, amount of grassland habitat within a 1500 m radius and will be inversely related to the distance to the nearest grassland patch and the edge to area ratio of the patch, 2) the abundance and composition of shrub-adapted birds will not be relate to patch size, shape or isolation and 3) edge habitats within grassland patches will have an avian composition representative of the adjacent habitat whereas the avian community within interior grassland patches will be specific to that patch type.

STUDY AREA AND METHODS

Study Area - Research was conducted on the Jornada Experimental Range (JER) and adjacent Chihuahuan Desert Rangeland Research Center (CDRRC) between October 2003 and May 2006; this is a report of the 2005-2006 non-breeding season. Together the study

area comprises a block of 104,166 ha located at the northern edge of the Chihuahuan Desert, in South-central New Mexico, USA. The predominant vegetation types are representative of the Jornada del Muerto Basin: black grama (*Bouteloua eriopoda*), tobosa (*Pleurapis mutica*) and dropseed spp (*Sporobolus spp.*) grasslands, creosote bush (*Larrea tridentata*), honey mesquite (*Prosopis glandulosa*), tarbush shrub lands (*Flourensia cernua*) and playa, dominated by a variety of grasses in periodically flooded areas (Schlesinger 1994, Dick-Peddie 1993).

The climate in south-central New Mexico is variable, with hot summers and mild winters. The elevation of the study area is approximately 1186 m. The average maximum temperature in June is 36°C; temperatures are coldest in January, with an average maximum of 13°C. Mean annual precipitation is 23 cm, with 52% of the annual total occurring between July and September and comes in the form of intense monsoonal thunderstorms that are highly localized however, on a regional basis late summer precipitation is more predictable than winter. Winter precipitation is characterized by low-intensity rainfall covering wide areas; total winter precipitation can vary dramatically between years.

Landscape Analysis - Coverage maps of the JER and the CDRRC with distribution and location of different grassland patches were used to select grassland fragments of tobosa, black grama and dropseed species as study sites. Patch selection was based on grassland type, topography (Renfrew and Ribic 2002), size, nearest neighbor distance and shape, (With and Crist 1995).

Patch sizes ranged from 6.18 ha to 684 ha. Twenty seven grassland patches, nine each of black grama, tobosa and dropseed species were selected for this study. All transects were centrally located using the center of the grassland by identifying GPS coordinates as the reference point. When possible, contiguous 1000 m permanent transects were located within each grassland fragment and marked at 100m intervals. Due to fragment shape, some transects (n = 12) were divided into two or three segments, spaced by a minimum of 60 m (Whitmore 1979).

For each transect, we recorded a series of patch and landscape level factors. Arc View 3.2 Software was used to determine the area and perimeter of each grassland patch. To account for edge effects, we calculated the shape (edge to area ratio) and the length of disjunct edge types (Winter et al. 2000). We differentiated between two edge types, shrubland edge and grassland edge, based on GIS coverage maps. Nearest grassland fragment and amount of grass cover within 1500m from the fragment edge were used as indicators of patch isolation. These metrics are shown in Table 1.

Along each transect, we sampled ten 100 m vegetation transects placed systematically across the 1000 m transect. Every 25 m along the vegetation transect, data was collected on floristic structure and vegetation composition, for a total of 30 sampling points per site. Percent canopy cover and percent cover of grass, forbs and woody vegetation were determined using a Daubenmire frame (1959). In the far right corner of each Daubenmire frame, a visual obstruction reading was taken at 4m from a Robel pole at a height of 1m (Robel et al. 1970). Random and maximum grass heights within 1 m of the far left corner of the frame were also recorded. The number of shrubs within 3 m of each avian transect was counted and identified.

Avian Surveys - Birds were surveyed along each of the 27 1000 m transects three times during the fall and spring migration (September 1- October 10 and 1 April to 10 May) and four times over the winter period (15 November to 10 March). A minimum of three days were spaced between surveys of the same patch. Censuses were conducted within four hours after sunrise (Kirkpatrick et al. 2002). All birds were counted and identified within 30m on each side of the transect. In addition, data was collected on bird location, strata, activity and perpendicular distance to the transect (using a hypsometer). Birds flying over or detected

outside the transect were not included in the analyses. Observers were careful to note the position and movement of birds to avoid double sampling. Surveys were not conducted during precipitation and winds speed exceeding 20 km/h (Gutzwiller and Barrow 2002).

Statistical Analyses - All landscape level and within patch predictor variables were tested for normality and homogeneity of variance prior the analysis. We used a nonparametric approach to our analyses since assumptions could not be met. Seasonal sample sizes by bird species and transects were small and sparse, making predictive analyses difficult, therefore, species were grouped into shrubland-adapted and grassland-adapted assemblages. Bird abundance, species richness and Shannon Weaver diversity indices (Zar 1999) were calculated at the transect level for each avian guild.

We used multiple regression analyses of *a priori* models (Table 2) to examine the relationship between avian abundance at the guild level with local and landscape scale factors. These models represented hypotheses based on previous knowledge of habitat selection by wintering grassland birds and the specific hypotheses of this study (Burnham and Anderson 2002). The number of parameters allowed in each model was limited by the sample size of $n = 27$ and did not exceed 5. Only 2 way interaction terms were included. Dummy variables were used to test for effects due to grassland type and transect type. The variables included in the analyses were: 1) percent of grass cover; 2) heterogeneity index of percent canopy cover (*sensu* Rotenberry and Wiens 1990); 3) random height; 4) area of the grassland patch; 5) percent of grass cover within 1500m from the grassland edge; 6) transect type; 7) grassland type 8) abundance of invasive shrubs. None of these variables were found to be correlated (Pearson $r < 0.70$)

A Poisson distribution was used to assess model fit because the data was non-normally distributed. An information-theoretic approach was used to select the top models from the set of all *a priori* models. Model selection was conducted using Akaike's Information Criterion (QAIC) with a correction for small sample size (QAIC_c) (Burnham and Anderson 2002) using Proc GLM (SAS INSTITUTE 1990). The model with the lowest QAIC_c is considered the best approximating model and models within 1-2 QAIC_c were considered competing models and within 4 QAIC_c when variables were nested (Anderson et al. 2001). We also calculated model selection uncertainty in terms of Akaike weights which indicate the likelihood of a given model. Because we were interested in assessing the relative importance of variables, we report sums of Akaike weights across the top five models for important variables or suites of important variables (Anderson et al. 2001).

Poisson distribution was used to assess model fit based on de DEV/DF value (Littell et al 2002, Davis et al. 2004). A variable was considered significant based on the change in deviance associated with dropping that variable. I continued to add and delete variables until this procedure resulted in a model that had the lowest deviation value (Davies and Margules 1998). A model containing only main effects of all variables included in the analysis was used as the global model (Anderson et al. 2001). Candidate models were evaluated using model weight (w_i), Likelihood (LogL) and Δ QAIC_c. We report only the most parsimonious models, which are those with the lowest QAIC_c. The relative variable importance of the predictor variables across the models considered was also calculated. Software SAS (SAS Institute 1990) was used for the analyses.

RESULTS:

Bird Surveys - A total of 83 species were recorded on plots during the 2005-2006 nonbreeding period; 68 species in the fall ($n = 68$), 39 species in the winter and 54 species in the spring. Species abundance, richness and diversity were highest during migration and substantially lower during the winter period (Table 3). There was a consistent higher abundance of shrub-adapted species on grassland fragments compared to grassland-adapted

species (Table 3). Similar to other years, fall migration had higher abundance and diversity compared to spring. Within season in the 2005-2006 non-breeding period no differences were observed in species abundances, richness or diversity among the three grassland types.

Sage Sparrows (*Amphispiza belli*) were the dominant winter resident. Other species abundant during the winter period were Horned Larks (*Eremophila alpestris*), Lark Buntings (*Calamospiza melanocorys*), Chipping (*Spizella passerina*) and Brewer's (*Spizella breweri*) Sparrows. Horned Larks and Black-Throated Sparrows (*Amphispiza bilineata*) were the dominant species during fall migration. Other abundant species during this period included Meadowlarks (*Sturnella* spp.), Lark Buntings, and Sage, Vesper (*Pooecetes gramineus*), Black-throated, Chipping, and Brewers Sparrows (Table 4). During spring migration Black-throated Sparrows and Lark Buntings were the dominant species with Horned Larks, House Finches (*Carpodacus mexicanus*) and White Crowned Sparrows (*Zonotrichia leucophrys*) also in abundance (Table 4). Most species were rarely observed over the course of the study (Table 4). Due to the low number of observations, species were grouped into grassland- and shrub-adapted guilds by season (Table 4).

Landscape and local associations - Poisson regression models included local and landscape scale variables for grassland and shrub-adapted guilds separately. We report the top five models for each of the two guilds among seasons (Tables 5)

Grassland bird guild. The percent grass cover was the most important variable consistently influencing grassland bird abundance during the fall and spring migration periods. This variable appeared in the top 5 models for both fall and spring migration positively influencing grassland bird abundance. Grass height was also important during migration, negatively influencing grassland bird abundance in the fall and positively influencing abundance in the spring (Table 5). This difference was likely a result of differences in the grassland guild composition between the two seasons. The interaction of patch size (area) and shrubs positively influenced grassland bird abundance during migration. During migration, shrub abundance negatively influenced grassland bird abundance. The top 4 models for both fall and spring migration were considered competing models ($QAIC \leq 3$). During the winter period, no individual variable had a strong influence of the abundance of grassland birds possibly a result of low numbers and different habitat associations for Horned Larks and Meadowlarks, the two most abundant winter species in the grassland guild. All models were competing (Table 5).

Shrubland guild. Invasive shrubs was the most consistent variable influencing shrub-adapted bird abundance during fall and spring migration. This variable alone was in one of the top 5 models for fall migration and 4 of the top 5 models for spring migration. Shrub abundance also interacted with patch size to positively influence the abundance of shrub-adapted birds in 2 of the top 5 models for fall migration and one of the top 5 models for spring migration. Grass height negatively influenced shrub-adapted bird abundance in the fall and positively influenced abundance in the spring, likely a result of changes in community composition. During the winter period grass cover and grass height were the most consistent variables influencing the abundance of shrub-adapted birds. Grass cover was present in each of the top 5 models negatively influencing shrub-adapted bird abundance and grass height was present in all of the top 5 models positively influencing shrub-adapted bird abundance. Both shrub abundance and patch size were present in 2 of the top 5 models positively influencing the abundance of shrub-adapted birds.

Our fitted models show that the response is more complex than the main effects of single variables. This was especially true when patch size (area) interacted with shrub abundance. This interaction played an important role as a predictor of avian abundance, and was present in models for both grassland and shrub-adapted birds.

No relationships were found ($P > 0.05$) between measures of avian abundance, shrub-adapted bird abundance, grassland-adapted bird abundance, species richness or species diversity and the relative density of invasive shrubs.

DISCUSSION:

Avian abundance, diversity and species richness, in general, were substantially higher in the 2005-2006 non-breeding period than observed over the preceding two non-breeding periods; with observed differences in abundance orders of magnitude higher than previous years. Significant spring and summer rains resulted in an excellent seed crop during the spring and summer of 2005 (for forbs in the spring and grasses in the late summer) which likely contributed to observed increases in avian abundance and diversity. As in previous years, abundance, diversity and richness were highest during fall migration, suggesting the desert grasslands of the southwest are an important corridor for grassland- and shrub-adapted passerines. This was most notable for migratory granivores, including Horned Larks, Meadowlarks, Savannah Sparrows, Vesper Sparrows, Brewer's Sparrows, Black throated Sparrows, House Finches, Lark Buntings, Sage Sparrows, and White Crowned Sparrows. Loggerhead Shrikes were also more abundant this year. Year round resident species were found in lower numbers similar to past years. Similar to other years, species composition overlapped substantially among the three grassland types with no differences in abundance among grassland types detected in any season indicating the dominant grassland type does not appear to influence abundance or diversity possibly because a large component of diet is forb seeds. Alternatively an interaction with invasive shrubs may have masked any relationship. Also interesting is the consistent lower abundance of grassland-adapted birds compared to shrub-adapted birds on plots and the absence or low abundance of true grassland obligate species. This suggests that patches are either too fragmented or too degraded to be of value to most grassland obligate species. It was, however, interesting to note the higher abundance of Meadowlarks and Savannah and Vesper Sparrows this past year compared to previous years.

As in previous years, Sage Sparrows were the dominant winter resident, with abundance being much higher this past winter compared to the previous two winters. Interestingly, unlike previous winters, our study plots were important migratory pathways for this species, especially during fall migration. This suggests larger numbers of Sage Sparrows were present in the southern end of their winter range this past winter. The consistent dominance of this species on plots each winter while other species are more variable suggests that this species is better adapted at locating seeds under variable conditions. Smaller flock sizes for this species may also contribute to its ability to persist at sites during dry years. The low numbers during spring migration suggests that Sage Sparrows depart early for breeding grounds.

Greater flexibility in habitat selection has been observed among some members of the grassland assemblage. Based on results of our previous research and that of others, we classified lark buntings and Loggerhead Shrikes in the shrub assemblage for the nonbreeding period. Assemblage classifications have been previously based on habitat affiliations during the breeding period. Other studies have also found these species to be strongly associated with shrubs during the non-breeding period (Lima 1990; Lima and Valone 1991; Niemela 2001; Desmond 2004). Lark buntings in this study were found exclusively on mesquite-encroached plots. Interestingly, we observed some Grasshopper Sparrows, Savannah Sparrows, Vesper Sparrows, and Meadowlarks on mesquite-encroached plots indicating these species will use grassland patches interspersed with shrubs. However, the relative importance of these patches compared to extensive grasslands was not clear due to the low number of observations and differences in survivorship are not understood.

Unlike the 2004-2005 non breeding season we did not observe a linear relationship between species richness and abundance and invasive shrub encroachment. The variable relationships of community composition and abundance of invasive shrubs among years suggests this is strongly dependent on species present and that some species, including shrub-adapted species may have a threshold tolerance of shrub encroachment. Other studies on breeding passerines in the southwest have found that avian abundance and richness were higher in desert and mesquite-encroached grasslands in southern New Mexico and southeast Arizona (Whitford 1997; Lloyd et al. 1998; Pidgeon et al. 2001). Whitford (1997) suggested that higher avian diversity on desertified sites was a result of breeding grassland species persisting at sites despite shrub encroachment, while shrub-adapted species colonized sites.

Within grassland patches, the percent grass cover had the strongest impact on the relative abundance of grassland birds. Grass cover on transects ranged from 8 to 44%, substantially more than previous drier years. The increase in grass cover, along with increased seed production may have strongly influenced occupancy of plots by both grassland- and shrub-adapted birds. Loss of perennial grass cover is part of the desertification process (Buffington and Herbel 1965, Kerely and Whitford 2000) and likely interacts with shrub abundance on plots. A threshold level of cover may be necessary for some species to occupy a plot and along with summer precipitation, is an indicator of seed production. Interesting, invasive shrubs did not have as strong of a relationship (negative) with grassland bird abundance as in previous years, possibly because of the ability of Horned Larks, Meadowlarks and Vesper Sparrows to tolerate some level of shrub encroachment.

Grass height was also an important variable influencing the abundance of grassland birds, however observed relationships were not consistent among seasons. The negative relationship observed in the fall was likely a result of Horned Lark abundance. Horned Larks were the most abundant species during fall migration and were common with number substantially higher than previous years. This is a species that is commonly associated with grazed grasslands (Niemela 2002, Desmond 2004) and this relationship likely contributed to the negative association with grass height in the fall. The positive relationship in the spring is likely related to lower numbers of Horned Larks on plots.

At the landscape scale, area interacting with invasive shrub encroachment was the most important variable positively influencing the abundance of grassland and shrub species suggesting that larger patches with lower shrub encroachment were preferred by both guilds. Within a desertified landscape, larger grassland patches are likely easier for birds to locate both during winter and migration. However, grass dominated patches with higher levels of shrub encroachment may not be perceived as grassland patches. Small isolated grassland patches with little or no shrub encroachment appear to be of little value to grassland-adapted birds during the nonbreeding period. Some individual bird species may also exhibit area sensitivity on wintering grounds. Identifying area requirements and minimum patch sizes for individual grassland species is an important and on-going objective of this project. However, data at the individual species level will have to be pooled over multiple years to have sufficient sample sizes to adequately address this question.

For shrub-adapted birds, within-patch variables with a strong influence on relative abundance of shrub-adapted birds included the abundance of invasive shrubs and percent grass cover. Interestingly, this year invasive shrub consistently had a positive influence on shrub-adapted bird abundance. In previous years this relationship has been variable and is likely related to changes in species composition among years. The variability observed among years may indicate that some shrub-adapted species have a threshold level of shrub-encroachment that is suitable for occupancy, and above and below this level their populations may be negatively impacted. Many shrub-adapted species are declining and the influence of desertification across the landscape in the desert southwest may play a key role in population

declines. These shrub encroached landscapes may not provide all of the essential resources for these species.

As in previous years, grass cover negatively influenced abundance of shrub-adapted birds. This relationship may be a function of the desertification process. Desertified habitats have higher shrub abundance and lower grass coverage (Kerely and Whitford 2000). In previous years, the shrub-adapted assemblage has exhibited strong associations with grassland type with tobosa and black grama grasslands supporting the highest relative abundance of shrub-adapted birds. This relationship was not apparent during 2005-2006 nonbreeding period and may be a result of higher seed production and increased grass cover across plots. This was apparent in both winters despite the change in community composition between years.

Similar to our predictions, the shrub-adapted assemblage was strongly influenced by local scale factors but not landscape scale variables, with the exception of the interaction between patch size and shrub encroachment. The lack of a strong landscape effect may be a result of the large areas of shrub-encroached habitats occurring across the study area, however, in the future this needs to be examined more closely for individual species. Many shrub-adapted species are exhibiting population declines and the abundance and condition of common species across a gradient of desertification should be examined.

Contrary to our prediction, the grassland assemblage did not exhibit consistent positive associations with the cover of tobosa or grama grasses, grassland types typical of the Chihuahuan Desert or shrub encroachment. This was likely a result several factors. The paucity of grassland obligate species observed throughout this study certainly played a role. Obligate grassland species such as, Baird, grasshopper, and savannah sparrows, chestnut-collared longspurs and Sprague's pipits, were either absent or present in low numbers. We need to better understand patch selection of grassland obligate species including minimum patch size suitable for occupation and threshold levels of mesquite encroachment that render a patch unsuitable. The expansion of mesquite may contribute to increases in local avian diversity and richness but more importantly contributes to local and regional losses of grassland obligate species and an overall reduction in diversity.

During the 2005-2006 non-breeding period we observed an impressive diversity and abundance of grassland- and shrub-adapted birds on our plots. This was especially true during fall migration. This data indicates that when conditions are appropriate (ie conditions that result in high seed production) desert grasslands of the southwest are important wintering and migratory grounds for declining grassland- and shrub-adapted species. The fragmentation and degradation of sites, however, has impacted community composition with few grassland obligate species utilizing sites. Key variables influencing the grassland guild were the percent grass cover, grass height and the interaction of patch size with shrub density. Key variables influencing the shrub-adapted guild included shrub density, grass cover, grass height, and the interaction of shrub density with patch size.

LITERATURE CITED

- Askins, R.A. 2000. Restoring North America's birds. Yale University Press. USA.
- Anderson, D. R., W. A. Link, D. H. Johnson and K. P. Burnham. 2001. Suggestions for presenting the results of data analyses. *Journal of Wildlife Management* 65:373-378.
- Bahre, C.J. and M.L. Sheton. 1993. Historic vegetation change, mesquite increases and climate in southeastern Arizona. *Journal of Biogeography*. Vol. 20:489-504.
- Bierregaard, R.O. and P. Stouffer. 1997. Understory birds and dynamic habitat mosaics in Amazonian Rainforests. In: Laurance, W.F. and O. Bierregaaran. *Tropical Forest Remnants*. University of Chicago Press. USA.

- Brown, D. 1982. Biotic communities of the America Southwest United States and Mexico. *Desert Plants*. Vol. 4:123-179.
- Buffington, L.C. and C.H. Herbel. 1965. Vegetational changes on a semidesert grassland range from 1858 to 1963. *Ecological Monographs*. 35: 139-164.
- Burnham, K. P., and D. R. Anderson. 2002. *Model selection and multi-model inference*. Springer-Verlag, Inc., New York, NY.
- Davis, S.K, D.C. Duncan and M. Skeel. 1999. Distribution and habitat associations of three endemic grassland songbirds in southern Saskatchewan. *Wilson Bulletin*. Vol. 111:389-396.
- Daubenmire, R. F. 1964. A canopy coverage method of vegetational analysis. *Northwest Science*, 33:43-64.
- Davis, S. K. 2004. Area Sensitivity in grassland passerines: Effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in Southern Saskatchewan. *Auk* 121(4):1130-1145.
- DeGraaf, R. and J.H. Rappole. 1995. *Neotropical Migratory birds*. Cornell University Press. Ithaca, NY.
- Desmond, M. J. 2004. Effects of grazing practices and fossorial rodents on a winter avian community in Chihuahua, Mexico. *Biological Conservation*, 116:235-242.
- Desmond, M. J., K. E. Young, B. Thompson, R. Valdez and A. Lafon-Terrazas. *In Press*. Avian diversity and conservation in Chihuahuan Desert grasslands of Northern Mexico: Case studies of passerine and raptor communities in Chihuahua. In: Carton, J-L. E., and G. Ceballos (Eds.), *Biodiversity, ecosystems, and conservation in northern Mexico*. Oxford University Press, New York, NY.
- Dick-Peddie, W. A. 1993. *New Mexico vegetation, past, present and future*. University of New Mexico Press, Albuquerque, NM.
- Donovan, T.E. and R.H. Lamberson. 2001. Area sensitive distributions counteract negative effects of habitat fragmentation on breeding birds. *Ecology*. Vol. 82(4): 1170-1179.
- Dos Anjos, L. and R. Bocon. 1999. Bird communities in natural forest patches in southern Brazil. *Wilson Bulletin*. Vol. 111(3): 397-414.
- Gibbens, R.P. and R.F. Beck. 1988. Changes in grass basal area and forb densities over a 64-year period on grassland types of the Jornada Experimental Range. *Journal of range management*. Vol. 41:186-192.
- Gibbens, R.P., J.M. Tromble, J.T. Hennesy and M. Cardenas. 1983. Soil movement in mesquite dune lands and former grass grasslands of southern New Mexico from 1933 to 1980. *Journal of Range Management*. Vol. 36:145-148.
- Gordon, C.B. 2000. Movement patterns of wintering grassland sparrows in Arizona. *The Auk*. Vol. 117(3): 748-759.
- Grzybowski, J.A. 1983. Patterns of space use in grassland bird communities during winter. *Wilson Bulletin*. Vol. 95(4): 591-602.
- Gutzwiller, K.J. and W.C. Barrow. 2002. Does bird community structure vary with landscape patchiness? A Chihuahuan desert perspective. *Oikos*. Vol. 98: 284-298
- Herbel, C., F. Ares and R. Wright. 1972. Drought effects on a semi desert grassland range. *Ecology*. Vol. 53(6): 1084-1093.
- Herkert, J.R. 1994. The effects of habitat fragmentation on midwestern grassland bird communities. *Ecological Applications*. Vol. 4(3): 461-471.
- Hunter, C., D.A. Buehler, R.A. Canterbury, J.L. Confer and P.B. Hamel. 2001. Conservation of disturbance dependent birds in Eastern North America. *Wildlife Society Bulletin*. Vol. 29(2): 440-455.
- Hutto, R.L. 1985. Seasonal changes in the habitat distribution of transient insectivorous birds in southeastern Arizona: Competition mediated? *The Auk*. Vol. 102:120-132.

- Hutto, R.L. 1987. A description of mixed species insectivorous bird flocks in western Mexico. *The Condor*. Vol. 89:282-292.
- Igl, L.D. and B.M. Ballard. 1999. Habitat associations of migrating and over wintering grassland birds in southern Texas. *The Condor*. Vol. 101: 771-782.
- Jeger, E.J. 1957. *The North American Deserts*. Stanford University Press, USA.
- Johnston, M.C. 1963. Past and present grassland of southern Texas and northeastern Mexico. *Ecology*. Vol. 44: 456-466.
- Johnson, D.H. and L.D. Igl. 2001. Area requirements of grassland birds: A regional perspective. *The Auk*. Vol. 118(1): 24-34
- Kelly, J., R. Smith, D. Finch, F. Moore and W. Yang. 1999. Influence of summer biogeography on Wood Warbler stopover abundance. *The Condor*. Vol. 101: 76-85.
- Kerley, G. H., and W. G. Whitford. 2000. Impact of grazing and desertification in the Chihuahuan Desert: plant communities, granivores, and granivory. *American Midland Naturalist* 144:78-91.
- Kirkpatrick, C., S. DeStephano, R.W. Mannan and J. Lloyd. 2002. Trends in abundance of grassland birds following a spring prescribed burn in Southern Arizona. *The Southwestern Naturalist*. Vol. 47(2): 282-292.
- Knopf, F.L. and F.B. Samson. 1994. Scale perspectives on avian diversity in western riparian ecosystems. *Conservation Biology*. Vol. 8: 669-676.
- Latta, S.C. and M.E. Baltz. 1997. Population limitation in Neotropical migratory birds: Comments on Rappole and McDonalds. *The Auk*. Vol. 114: 754-762.
- Lima, S. L. 1990. Protective cover and the use of space: different strategies in finches. *Oikos*, 58:151-158.
- Lima, S.L. and T.J. Valone. 1991. Predators and avian community organization: An experiment in a semi desert grassland. *Oecologia*. Vol.86: 105-112.
- Lloyd, J. R. Mannan, S. DeStefano and C. Kirkpatrick. 1998. The effects of Mesquite invasion on a Southwestern Arizona grassland bird community. *Wilson Bulletin*. Vol. 110(3): 403-408.
- Moore, F.R., P. Kerlinger and T.R. Simons. 1990. Stopover on a gulf coast barrier island by spring trans gulf migrants. *Wilson Bulletin*. Vol. 102(3): 487-500.
- Moore, F.R. and T.R. Simmons. 1992. Habitat suitability and stopover ecology of Neotropical landbird migrants. In: *Ecology and Conservation of Neotropical Migrant Landbirds*. Hagan and Johnston Eds. Smithsonian Institution Press. Washington, USA.
- Niemela, S. A. 2002. Influences of habitat heterogeneity and seed distribution on a Chihuahuan Desert Avifauna. Thesis, New Mexico State University, Las Cruces, New Mexico, USA.
- Norment, C. 2002. On Grassland bird conservation in the Northeast. *The Auk*. Vol. 119: 271-279.
- Peterjohn, B.G. and J.R. Sauer. 1999. Population status of North American grassland birds from the North American breeding bird survey, 1966-1996. *Studies in Avian Biology*. Vol. 19: 27-44.
- Peterjohn, B.G., J.R. Sauer and Ch.S. Robbins. 1995. Population trends from the North American Breeding Bird Survey. In: *Martin and Finch Eds. Oxford University Press, New York*.
- Pidgeon, A. M., N. E. Mathews, R. Benoit, and E. V. Nordheim. 2001. Response of avian communities to historic habitat change in the Northern Chihuahuan Desert. *Conser. Biol.*, 15:1772-1788.
- Pulliam, H.R. and G.S. Mills. 1977. The use of space by wintering sparrows. *Ecology*. Vol. 58: 1393-1399.

- Pulliam, H.R. 1985. Foraging efficiency, resource partitioning and the coexistence of sparrow species. *Ecology*. Vol. 66(5): 1820-1836.
- Pulliam, H.R. and J.B Dunning. 1987. The influence of food supply on local density and diversity of sparrows. *Ecology*. Vol. 68(4): 1009-1014.
- Raitt R.J. and S.L. Pimm. 1976. Dynamics of bird communities in the Chihuahuan desert, New Mexico. *The Condor*. Vol. 78: 427-442.
- Rappole, J.H. and M.V. McDonald. 1994. Cause and effect in population declines of migratory birds. *The Auk*. Vol. 111(3): 652-660.
- Renfrew, R.B. and C.A. Ribic. 2002. Influence of topography on density of grassland passerines in pastures. *The American Midland Naturalist*. Vol. 147: 315-325.
- Ribic, C.A. and D.W. Sample. 2001. Associations of grassland birds with landscape factors in southern Wisconsin. *The American Midland Naturalist*. Vol. 146: 105-121.
- Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. *Journal of Range Management*. 23:295-297.
- Rodewald, P.G. and M.C. Brittingham. 2002. Habitat use and behaviour of mixed species land bird flocks during fall migration. *The Wilson Bulletin*. Vol. 114: 87-98.
- Rosenblatt, D.L., E.J. Heske, S.L. Nelson and D.M. Barber. 1999. Forest fragments in east-central Illinois: Islands or habitat patches for mammals? *The American Midland Naturalist*. Vol. 141: 115-123.
- Saab, V.A., C.E. Bock, T.D. Rich and D.S. Dobkin. 1995. Livestock grazing effects in western North America. In: Martin and Finch Eds. Oxford University Press, New York.
- SAS Institute.. 1990. SAS/STAT user's guide. Version 6. 4th ed. SAS Institute, Inc. Cary, NC.
- Schlesinger, W.H.; J.F. Reynolds, G.L. Cunningham, L.F. Hueneke, W.M. Jarrell, R.A. Virginia and W. Whitford. 1990. Biological feedbacks in global desertification. *Science*. Vol. 247: 1043-1048.
- Schlesinger, W.H. 1994. Long term ecological studies in the Chihuahuan Desert. The Jornada LTER-III Consortium, Duke University.
- Sherry, T.W. and R.T. Holmes. 1995. Summer vs. winter limitation of populations: What are the issues and what is the evidence? In: Martin and Finch Eds. Oxford University Press, New York.
- Sherry, T.W. and R.T. Holmes. 1996. Winter habitat quality, population limitation and conservation of Neotropical-Nearctic migrant birds. *Ecology*. Vol. 77(1): 36-48.
- Vickery, P.D., P.L. Tubarro, J.M. Cardoso da Silva, B.G. Peterjohn, J.R. Herkert and R.B. Cavalcanti. 1999. Conservation of grassland birds in the western hemisphere. *Studies in Avian Biology*. Vol. 19: 2-26.
- Weltzin, J., S. Archer and R. Heitschmidt. 1997. Small mammal regulation of vegetation structure in a temperate savanna. *Ecology*. Vol. 78(30): 751-763.
- Wenny, D., R. Clawson, J. Faaborg and S. Sheriff. 1993. Population density, habitat selection and minimum area requirements of three forest interior warblers in central Missouri. *The Condor*. Vol. 95: 968-979.
- Whitford, W.G. 1997. Desertification and animal biodiversity in the desert grasslands of North America. *Journal of Arid Environments*. Vol. 37: 709-720.
- Whitford, W.G. 2002. *Ecology of desert systems*. Elsevier Science Ltd. London, UK.
- Whitmore, R.C. 1979. Temporal variation in the selected habitats of a guild of Grassland Sparrows. *Wilson Bulletin*. Vol. 91(4): 592-598.
- Winter, M., D. Johnson and J. Faaborg. 2000. Evidence for edge effects on multiple levels in tallgrass prairie. *The Condor*. Vol. 102: 256-266

- With, K.A. and T. Crist. 1995. Critical thresholds in species responses to landscapes structures. *Ecology*. Vol. 76(8): 2446-2459.
- Yahner, R.H. 1993. Effects of long term forest clear cutting on wintering and breeding birds. *Wilson Bulletin*. Vol. 105(2): 239-255.
- Zar, J. H. 1999. *Biostatistical Analysis*. 4th Edition. Prentice-Hall, Inc., Upper Saddle River, NJ. 931 pp.

TABLE 1. Landscape metrics computed by grassland type and size class using Arc View 3.2 for the 27 grassland patches. Shape (edge to area ratio), length of disjunct edge types (shrubland edge and grassland edge), nearest grassland fragment and amount of grass cover within 1500m from the fragment edge are the variables included.

Dominant grass spp.	Size category	Area (ha)	Perimeter (m)	Shape(m)	%Grass edge	%Shrub edge	%Grass within 1500m	Nearest Neighbor (m)	# of patches per class
Black grama	Large	370.77	10550.70	345.17	11.87	75.84	15.58	122.00	3.00
	Medium	166.52	6531.09	251.84	28.26	64.24	18.26	35.67	3.00
	Small	28.65	2434.34	106.57	19.75	80.25	25.73	35.67	3.00
Dropseed	Large	311.72	10947.69	260.29	45.00	53.51	34.01	0.00	3.00
	Medium	54.81	3361.13	159.38	17.18	70.86	6.43	231.00	2.00
Tobosa	Small	13.65	1956.60	72.51	69.14	30.86	21.59	214.50	4.00
	Large	124.82	6310.15	197.81	20.68	79.32	10.52	220.00	2.00
Tobosa	Medium	59.76	4852.04	128.15	18.09	65.21	20.32	32.75	4.00
	Small	18.42	1988.05	85.62	0.00	100.00	10.29	360.67	3.00

TABLE 2. Apriori models examined in relation to relative avian abundance for the grassland- and shrub-adapted avian guilds during the 2005-2006 non-breeding period.

Avian Guild	Apriori Models
<i>Shrubland Bird Guild</i>	Invasive Shrubs Invasive Shrubs, Grass Cover Invasive Shrubs, Transect type, Grass Cover Invasive Shrubs, Heterogeneity Index, Grass Cover Grass type, Grass Cover Invasive Shrubs, Grass type, Grass Cover Invasive Shrubs, Grass type, Grass Cover, Heterogeneity Index Invasive Shrubs, Grass type, Area Invasive Shrubs, Grass Cover*Invasive Shrubs Heterogeneity Index , Grass Cover*Heterogeneity Index Grass type, Invasive Shrubs, Invasive Shrubs*Grass type Grass type, Invasive Shrubs, Invasive Shrubs*Grass Cover Grass type, Invasive Shrubs, Grass type*Heterogeneity Index Grass type, Area, Grass Cover, Area*Invasive Shrubs Transect type, %Grass Cover*Area
<i>Grassland Bird Guild</i>	Invasive Shrubs Invasive Shrubs, Grass Cover Invasive Shrubs, Grass Cover, Area Invasive Shrubs, Grass Cover, Area, Buffer Invasive Shrubs, Grass Cover, Area, Buffer, Random height Area, Invasive Shrubs Area, Buffer, Invasive Shrubs Grass Cover, Random Height, Area Invasive Shrubs, Area, Grass Cover*Random Height Invasive Shrubs, Area, Buffer, Grass Cover*Random Height Area, Invasive Shrubs, Area*Buffer Area, Grass Cover*Buffer Area, Invasive Shrubs, Buffer, Grass Cover*Buffer Invasive Shrubs, Area*Buffer Invasive Shrubs, Grass Cover*Buffer

TABLE 3. A comparison of mean avian abundance, abundance of grassland species, abundance of shrub-adapted species, species richness and avian diversity by season for fall 2005, winter 2005-2006, and spring 2006.

Variable	Fall 2005	Winter 2005-06	Spring 2006
Abundance	14.8	7.5	9.8
Grassland Guild Abundance	5.0	1.4	1.3
Shrubland Guild Abundance	9.8	6.1	8.4
Richness	9.4	5.5	7.7
Diversity	0.2	0.2	0.1

TABLE 4. Birds included in the Shrub-adapted and Grassland guilds. Classification was based on BBS database, Igl and Ballard 1999, Mendez 1997, Niemela and Desmond *in press* and Simberloff and Dayan 1991). Density estimates (#birds/ha) are given for each species.

Common name	Scientific name	Fall	Winter	Spring
		2005	2005-6	2006
Grassland Guild				
American Kestrel	<i>Falco sparverius</i>	0.03	NP	0/02
Bairds Sparrow	<i>Ammodramus bairdii</i>	<0.01	NP	<0.01
Burrowing Owl	<i>Athene cunicularia</i>	<0.01	<0.01	<0.01
Ferruginous Hawk	<i>Buteo regalis</i>	<0.01	NP	NP
Grasshopper Sparrow	<i>Ammodramus savaanarum</i>	<0.01	<0.01	NP
Horned Lark	<i>Eremophila alpestris</i>	1.28	0.32	0.31
Meadowlark	<i>Sturnella sp.</i>	0.30	0.17	0.12
Northern harrier	<i>Cyrcus cyaneus</i>	<0.01	<0.01	<0.01
Prairie Falcon	<i>Falco mexicanus</i>	<0.01	NP	<0.01
Says Phoebe	<i>Sayornis saya</i>	<0.01	<0.01	<0.01
Savannah Sparrow	<i>Passerculus sandwichensis</i>	0.30	0.02	0.04
Swainson's Hawks	<i>Bueto swainsoni</i>	<0.01	NP	<0.01
Vesper Sparrow	<i>Poecetetes gramineus</i>	0.46	0.06	0.03
Shrub-adapted guild				
Ash throated flycatcher	<i>Myracus cinerascens</i>	<0.01	NP	0.07
Black chinned Hummingbird	<i>Archilocus alexandri</i>	<0.01	NP	<0.01
Bewicks Wren	<i>Thryomanes bewickii</i>	<0.01	NP	<0.01
Brown headed Cowbird	<i>Molothrus ater</i>	<0.01	<0.01	<0.01
Brewer's Sparrow	<i>Spizella breweri</i>	0.4	0.30	0.28
Black tailed Gnatcatcher	<i>Poliopitila melanura</i>	<0.01	0.03	NP
Blue Gray Gnatcatcher		0.1	NP	NP
Black chinned Sparrow	<i>Spizella atrogularis</i>	<0.01	<0.01	NP
Black throated Sparrow	<i>Amphispiza bilineata</i>	0.92	0.16	0.53
Cactus Wren	<i>Campylorhynchus brunneicapillus</i>	0.16	0.03	0.07
Canyon Towhee	<i>Pipilo fuscus</i>	<0.01	NP	NP
Cassin's Kingbird		NP	NP	0.05
Curve billed Thrasher	<i>Toxostoma curvirostreae</i>	<0.01	<0.01	<0.01
Chihuahuan Raven	<i>Corvus cryptoleucus</i>	<0.01	<0.01	<0.01
Chipping Sparrow	<i>Spizella passerine</i>	0.62	0.52	0.08
Common Raven	<i>Corvus corax</i>	<0.01	<0.01	<0.01
Crissal Thrasher	<i>Toxostoma crissale</i>	<0.01	<0.01	<0.01
Gambells Quail	<i>Callipepla gambelii</i>	<0.01	<0.01	<0.01

Green Tailed Towhee	<i>Pipilo chlorurus</i>	<0.01	NP	NP
House Finch	<i>Carpodacus mexicanus</i>	0.63	0.20	0.36
House Sparrow	<i>Psere domesticus</i>	NP	<0.01	NP
Lark Bunting	<i>Calamospiza melanocorys</i>	0.56	0.45	0.58
Lark Sparrow	<i>Chondestes grammacus</i>	<0.01	NP	<0.01
Ladder backed Woodpecker	<i>Picoides scalaris</i>	0.04	0.01	0.02
Lesser Nighthawk	<i>Chordeles major</i>	NP	NP	NP
Loggerhead Shrike	<i>Lanius ludovicianus</i>	0.16	0.05	0.10
Mourning Dove	<i>Zenaida macroura</i>	0.20	0.10	0.20
Northern Mockingbird	<i>Mimus polyglottos</i>	<0.01	NP	<0.01
Pyrrhuloxia	<i>Cardinalis sinuatus</i>	<0.01	NP	<0.01
Red tailed Hawk	<i>Buteo jamaicensis</i>	<0.01	<0.01	<0.01
Sage Sparrow	<i>Amphispiza belli</i>	0.68	0.70	0.07
Sage Thrasher	<i>Oreoscoptes montanus</i>	<0.01	NP	<0.01
Scotts Oriole	<i>Icterus parisorum</i>	NP	NP	0.03
Scaled Quail	<i>Callipepla squamata</i>	0.10	NP	0.05
Sharp-shinned Hawk	<i>Accipiter striatus</i>	NP	NP	<0.01
Verdin	<i>Auriparus flaviceps</i>	<0.01	<0.01	<0.01
White crowned Sparrow	<i>Zonotrichia leucophrys</i>	0.24	0.20	0.32
Western Kingbird	<i>Tyrannus verticalis</i>	NP	NP	0.11
Yellow Warbler		0.03	<0.01	NP

* = Species present in at least 15% of the transects

NP=Not present

TABLE 5. Five best fit *a priori* models (lowest QAICc value) for the fall 2005, winter 2005-2006 and spring 2006. Explanatory variables are: dummy variables gdum1, gdum2 (Grassland type), transect type (Core and Edge), heterogeneity index, % grass cover, random height, buffer type, invshrubs (number of invasive shrubs), grassland patch size. Sample size $n = 27$.

Model Parameters	K	QAIC _c	ΔQAIC _c	Wi
Grass-adapted Guild				
Fall 2005				
Grass Cov (+), Grass Ht (-)	2	-168.12	0.00	0.20
Grass Cov (+), Grass Ht (-), Shrubs (-)	3	-166.67	1.45	0.20
Grass Cov (+), Grass Ht (-), Shrub*Area (+)	3	-166.49	1.62	0.20
Grass Cov (+), Shrub*Area (+), Buffer (-)	3	-166.38	1.74	0.20
Grass Cov (+), Grass Ht (-), Area (-)Shrub*Area(+), Shrubs (-), Buffer (-)	6	-160.71	7.40	0.20
Spring 2006				
Grass Cov (+), Grass Ht(+), Buffer (+), Area (-)	4	-44.20	0.00	0.21
Grass Cov (+), Shrub*Area (-), Buffer (+)	3	-44.08	0.13	0.20
Grass Cov (+), Grass Ht (+)	2	-43.52	0.69	0.19
Grass Cov (+), Grass Ht (+), Shrubs (-)	3	-42.24	1.97	0.19
Grass Cov (+), Grass Ht (+), Shrubs*Area (+), Shrubs (-), Area (-), Buffer (+)	6	-38.22	5.98	0.21
Winter 2005-2006				
Shrubs (+)	1	-24.52	0.00	0.20
Shrubs*Area (+)	1	-24.21	0.31	0.20
Area (-), Shrubs (+)	2	-22.33	2.19	0.20
Area (-), Buffer (-)	2	-22.15	2.37	0.20
Grass Cov (+), Grass Ht (-)	2	-21.89	2.63	0.20
Shrub-adapted Guild				
Fall 2005				
Shrub*Area (+)	1	-183.08	0.00	0.20
Shrubs (+)	1	-182.24	0.84	0.20
Grass Cov (-), Grass Ht (-)	1	-180.87	2.21	0.20
Shrub*Area (+), Buffer (-)	2	-180.86	2.22	0.20
Grass Ht (-), Shrub*Area (+), Area (-)	3	-178.89	4.19	0.20

Table 5 (Cont.)

Spring 2006				
Shrubs (+)	1	-149.03	0.00	0.20
Shrubs (+), Area (-)	2	-146.88	2.15	0.20
Shrubs (+), Grass Cov (-), Grass Ht (+)	3	-144.82	4.21	0.20
Grass Ht (+), Shrub*Area (+), Area (-)	3	-144.40	4.64	0.20
Shrubs (+), Grass Cov (-), Grass Ht (+), Area (-)	4	-142.23	6.80	0.20
Winter 2005-2006				
Grass Cov (-), Grass Ht (+)	2	-125.17	0.00	0.20
Grass Cov (-), Grass Ht (+), Shrub*Area (+)	3	-123.62	1.55	0.20
Grass Cov (-), Grass Ht (+), Shrubs (+)	3	-123.48	1.69	0.20
Grass Cov (-), Grass Ht (+), Shrubs (+), Area (+)	4	-121.04	4.13	0.20
Grass Cov (-), Grass Ht (+), Area (+), Buffer (-)	4	-120.11	5.06	0.20
