BIRD DIVERSITY AND HABITAT AFFINITY ON A CENTRAL TEXAS RANCH

THESIS

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Bird diversity and abundance are indicators of the health of habitats. Due to declining numbers of avian species and an increased awareness of the importance and economic benefits of birds, new attention has been directed toward understanding birds. Knowledge of bird diversity, abundance, and utilization of habitats is imperative for maintaining and/or enhancing these species. The Point Count technique was used in 5 habitat types (Live Oak Woodland, Riparian Forest, Mesquite Savannah, Live Oak Savannah, and Juniper-Live Oak Woodland) representative of the Freeman Ranch, a heavily grazed ranch in Hays County, Texas. Baseline abundance and diversity data for birds were lacking for the ranch. A total of 600 Point Counts documented the presence of 8,381 individuals and 85 bird species on the ranch. In order to assess the vegetative composition in each of the 5 habitat types, the line intercept method and the vegetation profile board were used to calculate woody species composition and visual obstruction, respectively, in both horizontal and

vertical strata of habitats. Avian and vegetative diversity in each habitat were determined by Brillouin's Index (H) of diversity. A 2-way ANOVA was calculated using H for bird diversity per habitat per season to determine how birds utilize each habitat throughout the year. A significant statistical difference was found in avian species both among seasons and among habitats. The Live Oak Woodland and the Riparian Forest habitats were most diverse areas overall for bird species due to a dense canopy and heterogeneous vegetative structure. Special attention was given to nonresident summer breeders and winter residents and neither showed a statistical difference in habitat utilization. However, in post hoc testing of winter resident diversity, the Riparian forest was more highly selected for by some bird species. Although the ranch rated "poor" in terms of vegetation due to the lack of climax species, the endangered Golden-checked Warbler was recorded in the Juniper-Live Oak Woodland, an otherwise low-rated habitat in terms of diversity. It is recommended that Point Count studies be repeated in future years to ascertain trends in avian populations, so that the avifauna of the ranch can be managed.

CHAPTER 1

INTRODUCTION

Human actions have had unprecedented effects on wildlife and wildlife habitats. To conserve biological resources and diversity, an understanding of the influence habitat components have on the distribution and abundance of wildlife is essential (Flather and Sauer, 1996). The physical structure and biotic composition of habitats are of major importance for avian species in selecting suitable habitats to provide nesting and foraging sites (Cody, 1985). Many bird species, especially Neotropical migrants, have particular habitat requirements and are more sensitive to landscape structure than permanent residents (Flather and Sauer, 1996). Neotropical migrants are more abundant in habitats that contain less edge, larger patches, wetlands, and more continuous canopy.

The abundance, species richness, and composition of bird communities within a region are affected by habitat patch size, type and amount of edge, the quality and quantity of resources, human impact on resources, and natural disturbances (Best et al., 1995). When suitable habitats are scarce, the density and success of breeding birds declines (Brooks and Davis, 1987; Smith et al., 1999).

In recent years, awareness of the ecological and economic importance of birds has increased. There is concern for many species due to declining numbers (Robbins et al., 1989). Possible reasons for the decline in bird populations are habitat fragmentation, nest parasitism, and loss of quality habitat (Ralph et al., 1993).

The quality and availability of suitable habitat are reduced for birds by habitat fragmentation (Sherry and Holmes, 1996). Habitat fragmentation creates discontinuous pieces of land where pristine forests, grasslands, or marshes once existed. Development, subdivision of large tracts of land, roads, boundary fences, utility easements, and agricultural practices contribute to fragmentation and habitat loss (Damude and Bender, 1999). Many migrant bird species that breed in the United States are extremely sensitive to fragmentation (Hagan et al., 1997).

Habitat fragmentation, that creates an edge effect with an increase in the proportion of habitat edge compared to habitat interior, increases the vulnerability of some avian species to predators and nest parasites, such as the Brown-headed Cowbird, that thrive in edge habitats (Campbell, 1995). With little energy expenditure, cowbirds can lay up to 40 eggs per season. This ability of high egg production greatly reducing the fitness of parasitized birds. An increase in edge caused by fragmentation alters habitat patches and often decreases nest success through predation on nests and adult birds (Smith et al., 1999).

The spatial distribution and grain or scale of habitat patches influence species richness, diversity, and the ability of different species of birds to coexist

in an area. Small-scale patchiness increases species richness (Roth, 1976). Levin and Culver (1971) and Horn and MacArthur (1972) concluded that mosaics of partially isolated patches of habitat encouraged the coexistence of a variety of avian species. However, habitats with large-scale patchiness may cause disproportionate abundance among species and contribute to declines in species richness and species diversity (Rotenberry, 1978; Anderson and Gutzwiller, 1996).

The spatial arrangement of a habitat affects the distribution of bird species (Best et al., 1995). Best et al. (1995) found heterogeneous landscapes created by the juxtaposition of various habitat types and the presence of corridors that facilitate movement between habitat patches positively affected the abundance, composition, and species richness of avian populations. Thus, large-scale monocultures and homogeneous landscapes as produced by suburbanization and crop production result in lower biodiversity.

Habitat destruction and loss due to changing land use practices profoundly affect wildlife and are the primary causes for population declines among bird species (Smith et al., 1999; Sherry and Holmes, 1996). Changing land use practices include: converting naturally complex wildlife habitats into simpler agricultural land, housing and retail development, and recreational areas. As the human population continues to increase, more and more wildlife species are forced out of appropriate habitats and are unable to adapt to the rapidly changing conditions.

Vegetation and Habitat Selection

The structure and species composition of the vegetation in an area support specific wildlife species (Simpson et al., 1996). Determining the vegetation composition of an ecosystem is an essential step to effectively manage wildlife. The vegetative structure of an area also can influence habitat selection of mobile animals, such as birds, by providing an abundance of prey and/or protection from predators. Foraging, nesting, and reproduction often are more successful in certain vegetative types (Parrish, 1995). In general, bird diversity increases with the number of vertical foliage layers (MacArthur and MacArthur, 1961). Thus, investigation of the vegetative strata of a habitat is important to evaluate habitat suitability. For example, avian species often are more abundant in specific tree types because of the structure created by the tree and its foliage. Migratory birds are particularly discriminating with regards to vegetative structure and are sensitive to alterations to their habitat.

Migratory species are impacted by decreasing habitat quality and quantity in their summer and winter ranges. Neotropical birds are undergoing widespread declines in numbers due to changing land use practices on their breeding grounds (Flather and Sauer, 1996). Flather and Sauer (1996) found that Neotropical migrants were more sensitive to habitat structure than Temperate migrants or permanent residents. In areas with great amounts of continuous forest and wetland habitats and less edge habitats, there is a higher abundance of Neotropical migrants. In addition, permanent resident bird species showed

less correlation between the structure of the landscape and abundance. Temperate migrants had less of an association with the size and number of forest habitats and were more associated with habitat diversity and presence or absence of edge.

Neotropical migrants rely on the quality and quantity of summer breeding habitats to support the annual recruitment into the population by providing food, shelter, and nesting sites. Conservation plans designed for migrant bird species should concentrate on retaining natural habitats as well as high-quality managed areas in both their winter and summer ranges (Sherry and Holmes, 1996).

Wintering migrant birds are most susceptible to threats to self-maintenance. Self- maintenance includes competition with conspecifics and co-occurring species, predation, disease, and food resource availability. Food resource availability may be the most critical of these ecological factors affecting subsistence of migrant songbirds and winter survival (Sherry and Holmes, 1996).

Destruction or alteration of natural habitats reduces the carrying capacity of habitats in the winter. This creates increased competition for food for migrants and an increase in mortality because of the extra energy expended searching for suitable habitat. Site fidelity is seen in many bird species (Sherry and Holmes, 1996) and should be recognized and understood by wildlife managers. The propensity of individuals to return to familiar locations despite declining quality may exacerbate the impact of habitat destruction and changing land use on migrant birds.

Birds as Habitat Quality Indicators

The number of bird species and their populations can function as an indicator of the health of habitats. Species richness may be the most straightforward index of habitat quality (Sherry and Holmes, 1996). Thus, the more bird species occupying a particular habitat, the more diverse and healthy the habitat is assumed to be.

High quality habitat provides ecological requirements for a broad array of bird species, both specialists and generalists. High habitat quality also supports bird species that depend on that habitat during periods of stress (Karr and Freemark, 1983). A healthy, well-managed environment is capable of supporting not only a variety of bird species, but also an array of other wildlife.

Research Objectives

Distribution and abundance data for birds is one of the first steps in developing a database for conservation and management of an area. Baseline data such as relative abundance, diversity, and habitat affinity may be used to determine the status of bird populations. These baseline data can be used to establish trends in populations and to design management plans.

The objectives of this project were 1) to establish a baseline inventory of the birds on a central Texas ranch, 2) to determine habitat specificity with respect to groups of birds (year-round residents, winter migrants, and summer breeders), and 3) to determine relationships between bird diversity and the quality of available habitat on the ranch.

CHAPTER 2

MATERIALS AND METHODS

Study Site

The study was conducted on the Freeman Ranch, a 1,700 ha tract, located 4.8 km west of San Marcos in Hays County, Texas (N 29°56'18" W 98°00'29") (Fig. 1). The ranch is located on the eastern edge of the Edwards Plateau Ecological Region and has been managed by the Southwest Texas State University Agriculture Department since 1984. The topography of the ranch is rocky to rolling hills with elevations varying from 204 to 287m. The intermittent Sink Creek is the only major drainage system on the ranch. Two soil types are found predominantly on the ranch, Rumple-Comfort and Comfort-Rock outcrop (USDA Soil Conservation Service, 1984).

Barnes et al. (2000) determined the most common woody plant species on the Freeman Ranch were live oak (*Quercus fusiformis*), mesquite (*Prosopis glandulosa*), Ashe juniper (*Juniperus ashei*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis* sp.), Texas persimmon (*Diospyrus texana*), and greenbriar (*Smilax bona-nox*). Important grasses included Texas wintergrass (*Stipa leucotricha*), Texas grama (*Bouteloua rigidiseta*), King Ranch bluestem (*Bothriochloa ischaemum*), and common curlymesquite (*Hilaria*

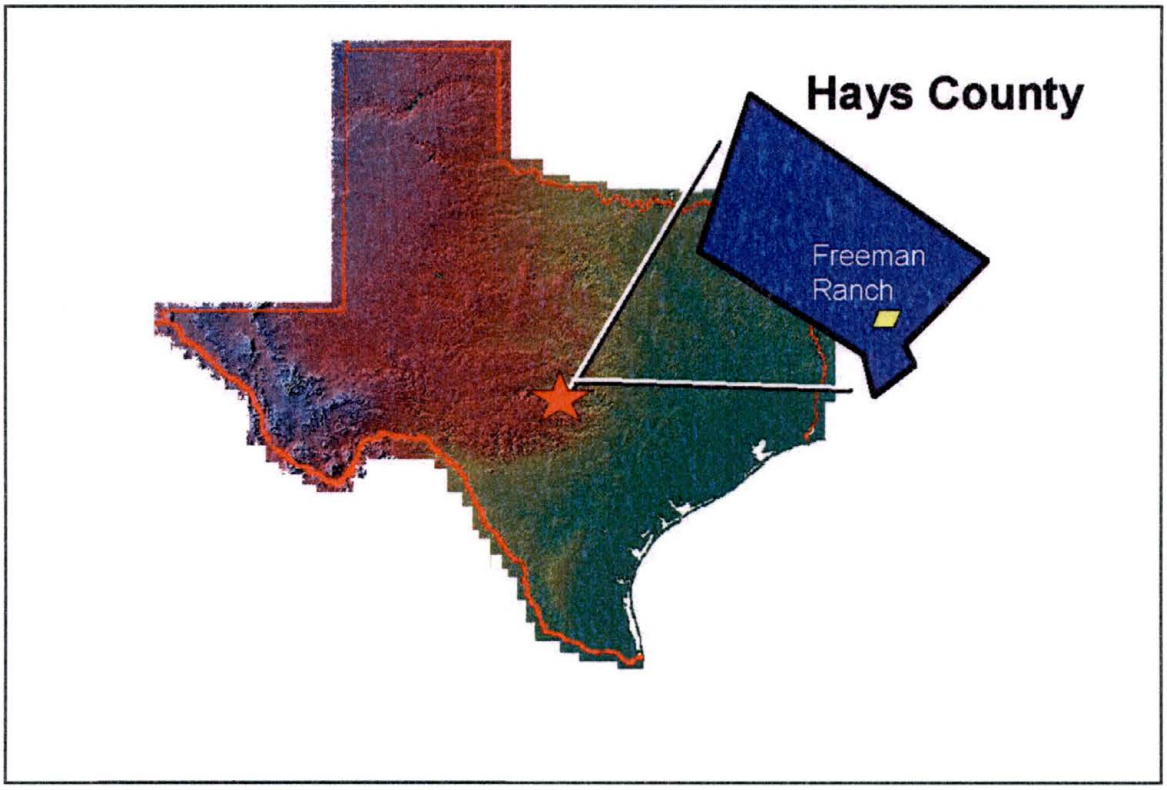

Fig 1. Location of Freeman Ranch in Hays County, Texas.

belangeri). Upon completing a vegetative study of the Freeman Ranch, Barnes et al. (2000) concluded that the ranch rated "poor", according to the USDA Soil Conservation Service guidelines, because less than 25% of the climax community was reported by the current plant community. The primary contributing factor to the poor status of the plant community was over grazing.

Selected Habitat Types within the Ranch

Five distinct vegetation types, representative of the ranch, were defined and located using visual field surveys and digital orthophoto quarter quadrangles (DOQQs). These five sites were quantified and labeled according to dominant woody vegetation as follows: Live Oak Savannah (LOS), Live Oak Woodland (LOW), Mesquite Savannah (MS), Riparian (RIP), and Ashe Juniper-Live Oak Forest (JOF). Two ponds, Crawford and Laguna, provided sites for incidental sightings for birds. It is noteworthy that the only habitat type on the ranch not impacted by grazing cattle was the LOW in which grazing had ceased three years prior to this study (Becker, 1998). Within each habitat type, data on bird abundance and diversity were collected using the Point Count technique.

The Point Count technique involves recording all birds seen and heard at a predetermined location and is the most efficient and data-rich method for gathering baseline data for long-term monitoring of population trends in bird species (Robbins et al., 1989; Simpson et al., 1996). This technique also allows comparison of bird species richness and species diversity in different types of habitats (Ralph et al., 1993; Wolf et al., 1995). The Point Count method often is

preferred to nest-site searches due to the disturbance to breeding birds and possible decrease in fitness that nest searches may inflict (Rangen et al., 2000).

Permanent stations (27 total: 5 within each of the five vegetation types and 1 at each pond) were established at which to conduct Point Counts. All stations were located at a distance of approximately 250 meters apart (Ralph et al., 1995) within a vegetation type. Point Count stations were permanently marked with flagging and/or T-posts. Each station was georeferenced using the Global Positioning System (GPS) and overlaid on a map of the Freeman Ranch using the Geographic Information System (GIS) software ArcView (Environmental Systems Research Institute Inc., 380 New York Street Redlands, CA 92373) (Fig. 2). Excluding the Point Counts at the ponds, which were not included in statistical calculations due to nonsystematic collection of this data, 600 Point Counts were conducted.

The study was conducted from October 1997 through October 1998. Data were collected between sunrise and 10:30 a.m. Counts were not performed in inclement weather or wind speeds in excess of 24 km/hr due to bird inactivity and the inability to hear birds under high wind conditions. A time of 12 mins. at each of the five stations within a vegetation type constituted a Point Count (Savard and Hooper, 1995). The first 3 mins. allowed birds to adjust to the disturbance created by the observer entering their habitat. The following 9 mins. were divided into 3-min. increments with the recording of all bird species seen or heard. To decrease the likelihood of counting birds more than once per visit, a digital compass was used to record the location of each bird. Other pertinent

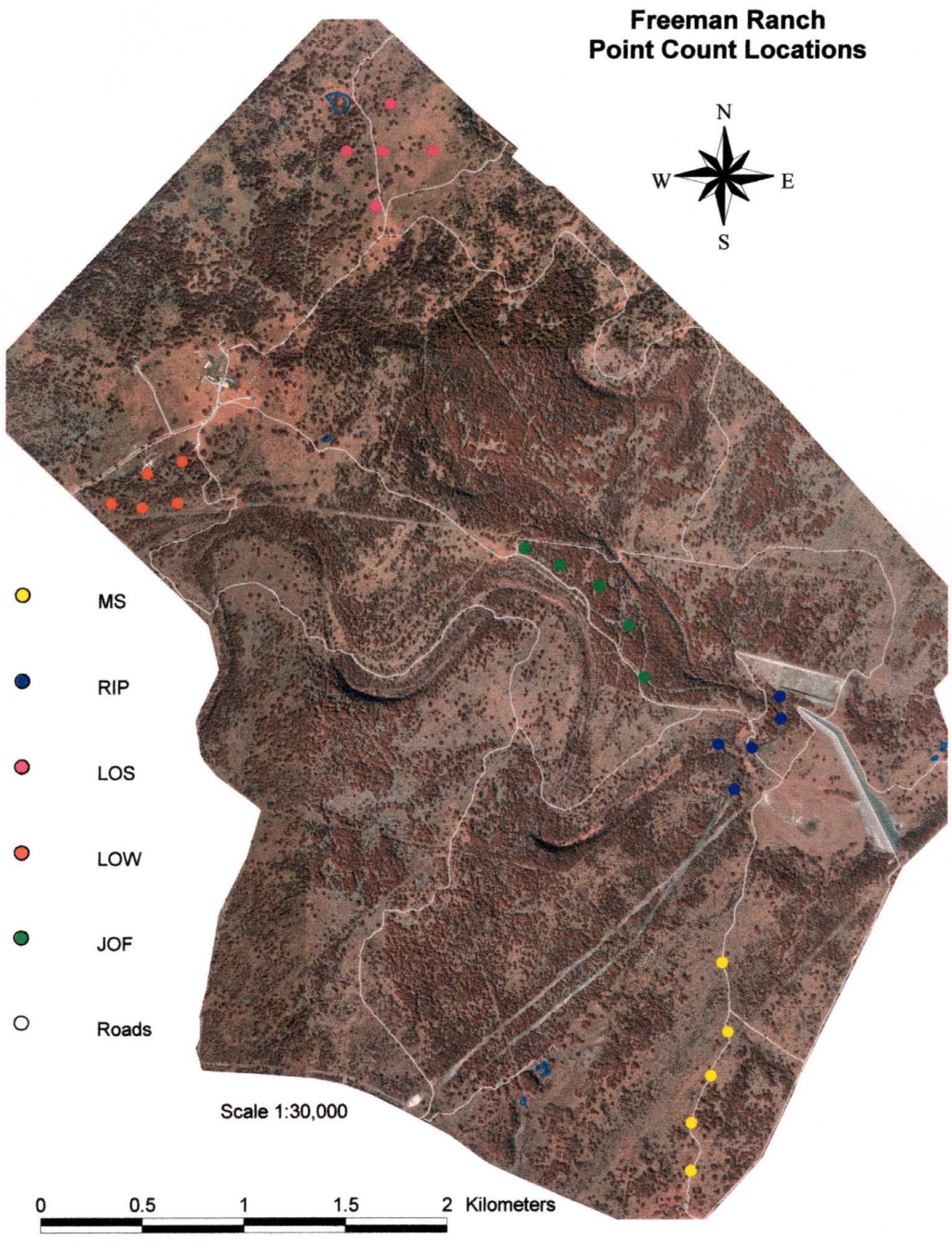

Fig 2. Locations of Point Counts (25) in the five habitat types representative of Freeman Ranch.

data, such as air temperature, relative humidity, wind speed, and sunrise time, were noted.

Bird Species and Diversity

Using Point Count data, species richness and abundance were calculated for each of the 5 habitat types for each season. Brillouin's Index (H) of diversity was selected as the statistical method for determining species diversity for each habitat type (Krebs, 1989). Brillouin's Index was calculated using Kreb's Ecological Methodology computer software program DIVERS (Krebs, 1988). The 5 Point Count stations within each habitat were totaled to calculate H in order to compare avian diversity across the ranch throughout the year. This resulted in a total of 100 diversity indices for the ranch by combining data for each Point Count station by season (20 for each habitat - 5 for each station in the 4 seasons). The diversity indices were then compared by a 2-way ANOVA, using "StatView" computer software, to determine if a significant difference existed in the utilization of bird species by habitat and/or by season.

Brillouin's Index is a more appropriate choice to measure diversity than the conventional Shannon-Wiener Index because the total number of species within each habitat types was unknown. The Shannon-Wiener Index is best used when a large number of random samples are drawn from a large habitat where the total number of species present is known (Krebs, 1989). Brillouin's Index of diversity is prone to underestimate the diversity. However, large sample sizes (such as in this study) reduce this bias (Zar, 1996).

Finally, to differentiate among birds encountered on the Freeman Ranch, the species were assigned to the following status categories: permanent residents (birds on the ranch year-round), summer breeders (birds on the ranch in the summer to breed and subsequently leave the area after breeding season), and winter residents (birds on the ranch only in the winter). The summer and winter residents were segregated by their occurrence in a habitat in one of two designated seasons.

Brillouin's Index (H) of diversity was calculated for these summer and winter migrants to determine if these species made differential use of a particular habitat type. If so, these areas were be assumed to be important to these migrants. In the calculation of H for summer and winter migrants, if a Point Count station recorded only one species, H was assigned the value zero, the lowest value H may possess. These diversity indices were then entered into a 1-way ANOVA to determine if there was a significant difference in the avian diversity for summer and winter residents throughout the 5 habitat types. Fisher's Protected Least Significant Difference was used in post hoc testing to further search for significant differences in habitat utilization by these non-resident bird species.

Vegetation Sampling

Managing habitats for maximum bird diversity requires an understanding of how the structure of a particular habitat affects the diversity of birds occupying the area and whether bird species utilize one type of habitat more readily than another. Cover and structure of the woody vegetation within a habitat are

components relating to diversity and use by birds. Detailed information on woody vegetation on the Freeman Ranch was collected from March through May 1998.

Cover is a fundamental component of habitat and vertical and horizontal vegetation cover are the two integral components for determining vegetative structure (Nudds, 1977). The vertical structure of vegetation is assumed to be the primary factor in habitat selection for birds (Karr and Freemark, 1983). The vegetation profile board (VPB) has proven useful in identifying structural differences in the vegetative structure of habitats used by birds (MacArthur and MacArthur, 1961). The VPB data also permits statistical comparisons of vegetative structure among habitats in one season and within the same habitat in different seasons (Nudds, 1977).

The VPB (Mitchell and Hughes, 1995) was used to measure the vertical structure of the vegetation on the Freeman Ranch. The VPB was divided into 5, 0.5 m segments for a total board height of 2.5 m. Measurements were taken in four cardinal directions, with the T-post or flagging as the center point, at each of the 25 Point Count stations. A total of 20 sampling points were recorded in each of the 5 habitat types. These data were analyzed by calculating the percent visual obstruction of the vertical strata of the vegetation and visual obstruction was assigned to one of five classes: 0-20% = 1, 21-40% = 2, 41-60% = 3, 61-80% = 4, and 81-100% = 5 (Nudds, 1997). The frequency (0-20) distribution of cover classes was recorded. The average visual obstruction was calculated from midpoint percent covers (10, 30, 50, 70, and 90%) multiplied by the frequency distribution of cover classes and divided by 20 (the total number of obstruction

measurements recorded per habitat type).

The horizontal configuration of vegetation affects canopy closure as well as foliage availability and quality. In addition, horizontal structure, like vertical structure, affects microclimate parameters, such as temperature and humidity, beneath the canopy (Halls, 1973). Horizontal vegetative structure was analyzed using the line-intercept method (Higgins et al., 1996). From these data, the relative density, percent cover, relative cover, frequency, relative frequency, dominance (m^2 canopy/ha), and the relative importance value (RIV) of woody vegetation in the five habitat types were calculated (Cox, 1996). This information was used to classify the 5 habitat types, determine the dominant woody species, and calculate the diversity of the vegetation.

CHAPTER 3

RESULTS

Avian Diversity

A total of 600 Point Counts at 25 permanent Point Count stations on the Freeman Ranch produced records for 8,381 individuals of 85 bird species (Appendix 1). In addition to these species, mist netting at 3 locations (2 ponds and the LOW) increased the total number of species on the ranch to 110 (Appendix 1).

Table 1 shows the number of individual birds recorded and the species richness in each of the 5 habitat types. Brillouin's Index (H) of diversity for each habitat by season is seen in Table 2. The 2-way ANOVA run on these 100 H indices showed a significant difference among seasons ($P = <.0001$) and among habitats ($P = <.0001$), as well as between habitats in different seasons ($P = <.0001$). The interaction between bird diversity in the different habitats throughout the year was plotted (Fig. 3).

Table 1 Total number of individual birds recorded during Point Counts and the species richness of the five habitats selected on Freeman Ranch as well as the total ranch

Habitat	Number of Individuals	Species Richness
LOS	1715	53
LOW	2027	50
MS	1837	48
RIP	1546	48
JOF	1256	44
Total Ranch	8381	85

Table 2 Mean Brillouin's Index (H) of diversity of bird species found in each habitat type throughout each season and the year (Appendix 4)

Habitat	Spring	Summer	Fall	Winter	Year
LOS	3.007	3.087	2.984	2.624	4.008
LOW	3.060	3.395	3.312	2.880	4.211
MS	3.202	3.304	2.546	2.840	4.020
RIP	3.143	3.074	2.909	3.196	4.134
JOF	2.926	3.015	2.849	2.532	3.805

The LOW contained the greatest number of birds (n = 2027) (Table 1) and ranked highest in avian diversity (H = 4.211) of the five habitat types on Freeman Ranch (Table 2). This habitat was intensely used by birds in summer (H = 3.395) and fall (H = 3.312) (Fig. 3), more than any other habitat type on the ranch. Furthermore, the LOW's winter and spring bird diversity ranked second and third, respectively, among the habitats.

The RIP ranked second overall in avian diversity (H = 4.134) for the year (Table 2). This habitat had the highest winter avian diversity (H = 3.196) of all habitat types (Fig. 3), surpassing the LOW. The RIP's spring bird diversity ranked second (H = 3.143) and this habitat's summer and fall diversity ranked third when compared to the other 4 habitat types.

Over the year, the LOS ranked fourth in avian diversity (H = 4.008) relative to the other habitat types (Table 2). By season, the LOS's highest diversity rank (H = 2.984), second, occurred during the fall. Furthermore, this habitat had the highest species richness (n = 53) for the year and ranked third in abundance (n = 1715) (Table 1).

The MS ranked second in abundance (n = 1837) of birds, however, it tied for fourth in species richness (n = 48) among habitats. This habitat had high avian diversity (H = 3.304) in the summer, ranking second due to the addition of summer breeding species (n = 8); the same number of summer species that were found in the RIP. The MS's high avian diversity (H = 3.304) in summer is comparable to that of the LOW (H = 3.395) (Fig. 3). After the summer breeders left the MS, bird diversity declined substantially in fall (H = 2.546) (Fig 3).

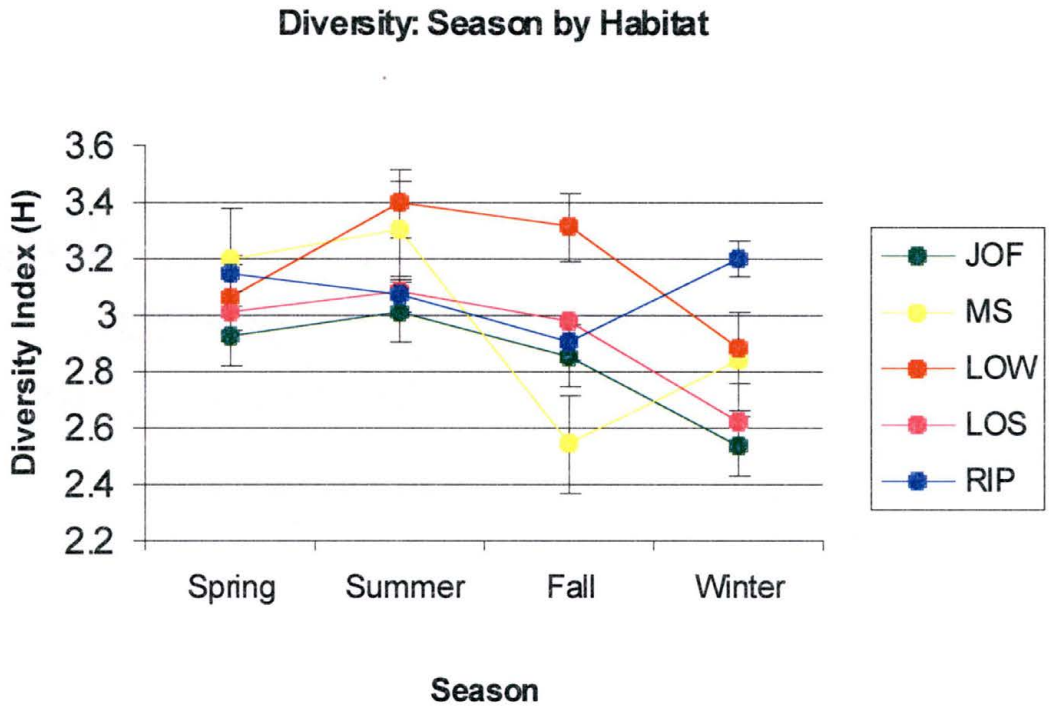

Fig. 3. Bird diversity for the five habitat types on Freeman Ranch through four seasons. Diversities represent the mean diversities per habitat per season as calculated using Brillouin's Index (H) of diversity; ± 1SE.

However, diversity in the MS rebounded slightly (H = 2.840) to rank third in winter, comparable to the LOW (H = 2.880).

The JOF had the fewest individuals (n = 1256) and the lowest species richness (n = 44) of all habitats on the ranch (Table 1). In addition, this habitat ranked fifth overall in avian diversity (H = 3.805) compared to other habitat types for the year (Table 2). When broken into seasons, JOF ranked last each season, with the exception of the fall when it ranked fourth.

Migrant Summer Breeders and Winter Residents

Twenty-five diversity values were calculated for summer breeders and winter residents using Brillouin's Index (H) for each point within each of the five habitat types (Appendix 5). No significant difference was seen in summer breeders among habitats (P = 0.7136) (Fig. 4).

Similarly, the winter resident bird diversity did not show a significant difference (P = 0.0823) (Fig. 5). However, the RIP's winter residents' diversity was marginally significant compared to 2 other habitat types in post hoc testing using Fisher's Protected Least Significant Difference for diversity. When compared to the JOF (P = 0.0114) and LOS (P = 0.0360), the RIP showed a significant difference in utilization by winter residents.

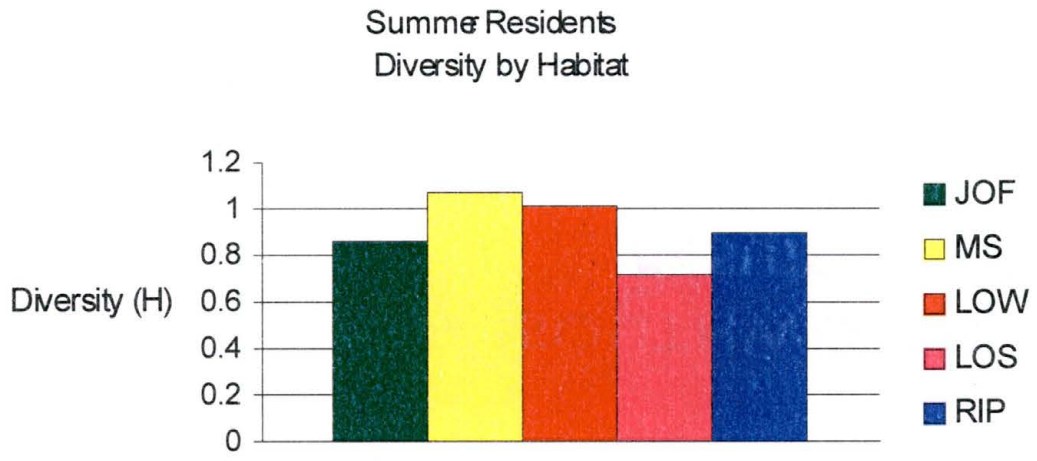

Fig. 4. Bird diversity of summer breeders for the 5 habitat types on Freeman Ranch. Brillouin's Index (H) was used to calculate diversity.

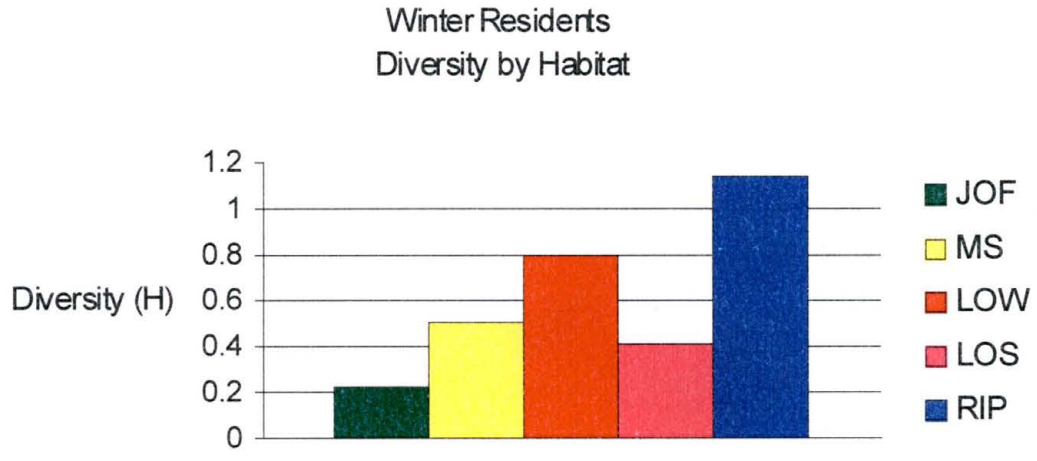

Fig. 5. Bird diversity of winter residents for the 5 habitat types on Freeman Ranch. Brillouin's Index (H) was used to calculate diversity.

Vegetation Results

The RIP (Table 3; Appendix 2d) had the greatest percent total canopy cover (144.8%) of the habitat types on the ranch, dominated by Ashe juniper, cedar elm, and live oak. The understory was primarily composed of Texas persimmon and green briar. Other woody plant species of the understory included Mustang grape (*Vitis mustangensis*), elbow bush (*Forestiera pubescens*), and walnut saplings (*Juglans* sp.). The RIP also had the highest diversity of woody plants (H = 3.502) and the highest species richness of woody vegetation (*n* = 25).

Table 3 Species richness, total number of individuals, total percent canopy cover (% cover), Brillouin's Index of diversity (H) for the woody plants in the five habitat types on Freeman Ranch

Habitat	Species richness	# Individuals	% cover	H
LOS	15	137	53.9	3.144
LOW	15	260	125.4	3.246
MS	16	121	59.8	3.193
RIP	25	296	144.8	3.502
JOF	11	167	121.2	1.871

The LOW (Table 3; Appendix 2a) had a total percent canopy cover of 125.4%, representing the second highest canopy cover on the ranch. The LOW was dominated by live oak. Ashe juniper was also frequently found in this area. The understory in this habitat was composed of green briar, Texas persimmon, and elbow bush. The LOW had a species richness of 15 and was the only area

of the ranch with restricted grazing by livestock. The Brillouin Index (H) of diversity for the LOW was 3.246 and ranked second among habitat types.

The MS (Table 3; Appendix 2c), had approximately one-half the percent total canopy cover (59.8%) of the LOW. The plant community was dominated by mesquite and hackberry. The understory in this habitat type included Texas persimmon, green briar, prickly pear (*Opuntia engelmannii*), agarita (*Berberis trifoliolata*), and tasajillo (*Opuntia leptocaulis*), which created a thorn/shrub environment. The MS ranked third in diversity (H = 3.193) and had the greatest species richness (n = 16) of woody plants.

The LOS (Table 3; Appendix 2b), had the least total canopy cover (53.9%) on the Freeman Ranch. This habitat type was dominated by live oak and mesquite. The understory was primarily composed of green briar and Texas persimmon saplings. The clumps or mottes of woody vegetation were scattered throughout a short-grass savannah. The diversity of plant species (H = 3.144) ranked second only to the JOF for the lowest plant diversity. The species richness for woody plants in the LOS was 15.

The JOF (Table 3; Appendix 2e) had a total percent canopy cover of 121.2%, ranking third among the habitats. It was dominated by Ashe juniper and live oak. Cedar elm was also present in this habitat. The understory in this habitat was comprised of prickly pear, Texas persimmon, and green briar. Much of the ground under the Ashe junipers was layered with needles creating an acidic soil environment that is inhospitable to many plant species. Although the

JOF had a large total canopy cover, it ranked last among the habitat types in woody plant diversity (H = 1.871) and species richness (*n* =11).

When comparing the average visual obstruction in the habitat types, the JOF had the highest average visual obstruction (56.8%) (Table 4; Fig. 6). The average visual obstruction of the JOF exemplified dense (51-64%) vertical foliage. Although the total average visual obstruction was closest to that of the RIP and LOW, relying solely on these numeric comparisons would not have been prudent.

Table 4 Average visual obstruction at five height increments for the understory in the five habitat types representative of Freeman Ranch Average visual obstruction seen here resulted from the calculation of midpoint % covers (10, 30, 50, 70, and 90%) multiplied by the frequency distribution cover classes (0-20) and divided by 20 (the total number of measurements recorded in each habitat type) (Appendix 3) The mean visual obstruction (Mean VisObstr) for each habitat is also shown for general comparison

Habitat	0.0–0.5 m	0.5–1.0 m	1.0–1.5 m	1.5–2.0 m	2.0–2.5 m	Mean VisObstr
LOS	34%	26%	27%	26%	25%	27.6%
LOW	63%	50%	45%	40%	38%	47.2%
MS	47%	29%	27%	23%	22%	29.6%
RIP	63%	46%	55%	46%	51%	52.2%
JOF	64%	51%	57%	54%	58%	56.8%

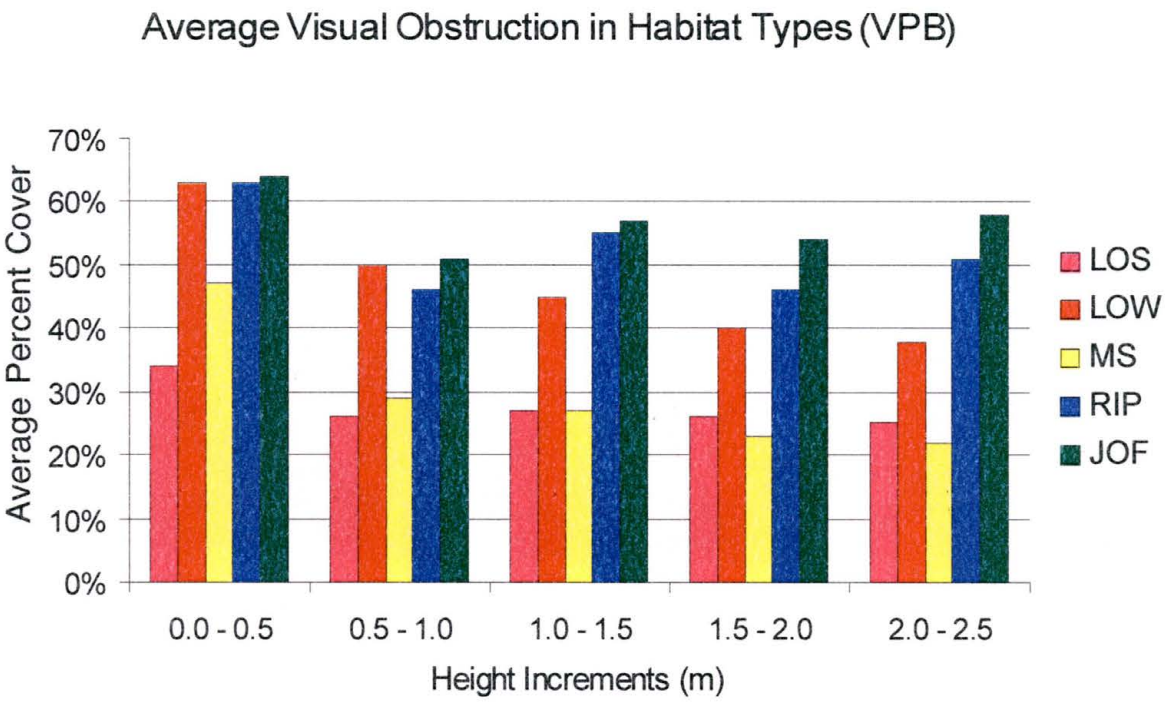

Fig. 6. Average visual obstruction at five height increments for the understory in the five habitat types representative of Freeman Ranch (Table 4; Appendix 3).

The JOF ranked last in woody plant species diversity as well as woody plant species richness when compared to the other 4 habitats on Freeman Ranch. In the JOF, visual obstruction was the highest in the 0.0-0.5 m (64%) and 2.0-2.5 m (58%) of the VPB (Table 4). The areas of low grassland patches juxtaposed to the dense cover created by Ashe juniper and live oak accounted for these numbers. The JOF showed high visual obstruction throughout the vertical strata, but again this was primarily due to the presence of a near monoculture of Ashe juniper.

The RIP ranked second (52.2%) in overall visual obstruction (Table 4). This habitat exhibited vegetative structure at all levels from the ground up. The vertical foliage was dense (46-63%) and was continuous from the base of Sink Creek, which winds throughout this habitat, to the steep limestone cliffs found in a large percent of the RIP. In Fig. 6, the average percent coverage of the RIP revealed a consistently dense vertical stratum. The norm was a pattern similar to that of the LOW (Fig. 6), however, in the RIP branches and foliage were denser throughout the understory and canopy.

The LOW had a total average visual obstruction of 47.2% and was similar to the RIP in terms of dense foliage structure throughout the vertical strata of the vegetation. Upon visual observation, the LOW appeared to be a thick shrubland with little open space and this was confirmed by these results. The LOW showed the highest visual obstruction (63%) in the lowest level of the VPB (0.0-0.5m) and dense vegetation remained relatively high as the height of measurements increased to 2.5 m. This indicated a thick understory at all vertical strata in the LOW.

The LOS had the greatest visual obstruction (34%) at the 0.0-0.5 m increment of the VPB, which is characteristic of a savannah. The majority of the habitat had oak mottes scattered throughout this area. The mid-vegetative strata of this habitat was sparse (Fig. 6).

Finally, the MS possessed the lowest (27.6%) average visual obstruction of all habitat types (Fig. 6). This habitat had a dense, low understory with the greatest visual obstruction at the 0.0-0.5 m level of the VPB. This type of vertical

strata was due to the thorny, smaller plants such as mesquite, prickly pear, and tasajillo. Although this habitat was dense in its understory, the general appearance of habitat type was rather open.

Commonalties of Bird Species and Vegetation Among Habitat Types

Several bird species were recorded in most if not all habitat types. Several plant species dominated the majority of the 5 habitat types. Twenty-six bird species occurred in all 5 habitats on Freeman Ranch throughout the year (Table 5). Nineteen bird species were classified as year-round residents, 4 as summer breeders and 3 as winter residents.

Table 5 Common bird species recorded during point counts in each of the 5 habitat types over the course of a year The status categories for birds were: Year-round residents (R), Summer breeders (S), and Winter residents (W)

Birds recorded in all 5 habitat types on Freeman Ranch	
Northern Cardinal (R)	Turkey Vulture (R)
Carolina Chickadee (R)	Black Vulture (R)
Tufted Titmouse (R)	Brown-headed Cowbird (R)
Bewick's Wren (R)	Blue-gray Gnatcatcher (R)
Carolina Wren (R)	Morning Dove (R)
Eastern Phoebe (R)	Inca Dove (R)
Great-tailed Grackle (R)	Rufous-sided Towhee (W)
Scrub Jay (R)	White-throated Sparrow (W)
Northern Mockingbird (R)	Ruby-crowned Kinglet (W)
Blue Jay (R)	Yellow-billed Cuckoo (S)
Ladder-back Woodpecker (R)	White-eyed Vireo (S)
Northern Bobwhite (R)	Painted Bunting (S)
Field Sparrow (R)	Sissor-tailed Flycatcher (S)

The tree species comprising the canopy cover in each of the 5 habitat types were markedly similar. Hackberry, Ashe juniper, live oak, and cedar elm occurred in varying percentages in all habitat types (Appendix 2). Mesquite was found in all habitat types with the exception of the JOF. The Spanish oak (*Quercus buckleyi*) was found exclusively in the RIP's canopy.

The woody shrubs, vines, and/or succulents that comprised the understory in each of the 5 habitat types were dominated by Texas persimmon and green briar in all but the JOF where prickly pear replaced green briar in dominance. Agarita was also found in each habitat type with the exception of the JOF. Elbow bush was encountered in every habitat. The JOF, LOS and MS habitats all had prickly pear as one of the top five dominant plants found in the understory. In the MS and the LOS, tasajillo was in the top 5 dominant understory plant species. Both these savannahs had prickly pear where cows had easy access to grass and forbs and over-grazing had occurred. The RIP had several understory plant species that were not found in any other habitat and walnut and mustang grape were of the 5 dominant species in this habitat.

CHAPTER 4

DISCUSSION

Avian Diversity by Habitat

The LOW had the highest overall bird diversity and surpassed all habitat types in the number of birds. This habitat was by far the most diverse of all areas studied on Freeman Ranch. By season, the LOW showed the highest avian diversity, when compared to other habitats, for both summer and fall. When solely examining summer breeders, the LOW supported the greatest number of birds. Such summer breeders as the Yellow-billed Cuckoo, White-eyed Vireo, and Painted Bunting contributed to the LOW's high diversity during summer. In winter, the LOW ranked second in bird diversity with dominant winter residents such as the Rufous-sided Towhee, Ruby-crowned Kinglet, White-throated Sparrow, Spotted Towhee, and House Wren contributing to the LOW's high winter resident numbers.

Upon initial observation in the field, the LOW was perceived to be a dense thicket with little open space in the vegetation. This was confirmed by examining the average visual obstruction (Fig. 6) created by the vertical strata of the vegetation in this habitat. The level of the VPB closest to the ground revealed

the most visual obstruction and this trend (> 40% average cover) continued up through 1.5 m and 2.5 m heights. These vertical strata exemplified thick understory in the majority of the LOW that may provide nest sites and protection for birds as well as continually dense foliage layers throughout the canopy.

The LOW ranked second in the total canopy cover recorded for a habitat type. This nearly continuous canopy may result in increased protection from predators such as hawks and more uniform temperatures hospitable to bird and plant species alike. The combination of dense understory and extensive canopy cover may provide greater numbers of suitable nest sites and foraging areas for birds. Also, the LOW ranked second in vegetative diversity on the ranch. The heterogeneous landscape in this habitat type seemed to appeal to birds throughout the year. The lack of grazing by livestock may also add to the inclination of birds to reside here by adding to the diverse vegetative structure. Overall, this habitat was an excellent area for birds as indicated by the diversity indices, species richness, and overall abundance.

The RIP had high use by birds on the Freeman Ranch. This habitat ranked second in total species diversity for the year. Surprisingly, the RIP ranked fourth overall in species richness. This peculiarity may be accounted for by the migratory nature of summer breeders and winter residents. Such transient winter species as the Rufous-sided Towhee, Ruby-crowned Kinglet, American Goldfinch, White-throated Sparrow, Lincoln Sparrow, and Savannah Sparrow found a hospitable home here in the winter, creating the highest diversity of all habitats in the winter. Another reason for the high winter bird

diversity may be due to the consistently higher cover values for the vertical strata in this habitat. The heterogeneous vegetative structure found throughout the strata in this habitat offers cover, nest sites, and foraging which attracts a diversity of bird species. This habitat type also had the highest woody plant species diversity. The RIP showed the greatest total percent canopy cover of any of the 5 habitats on the ranch. The canopy cover of live-oaks (nearly evergreen – leaves persist throughout the winter and fall off in the early spring) and Ashe junipers (evergreens) would provide protection from inclement weather. Also found in the RIP were cedar elms, which are one of the first species to lose its leaves in the winter and one of the first trees to bud in the spring.

Riparian areas are habitats with unique features because they are ecotones between upland and aquatic habitats (Murray and Stauffer, 1995). Water may or may not be present, as is the ephemeral nature of the Freeman Ranch's Sink Creek. Research has shown that riparian habitats support more avian species and a greater abundance of birds than adjacent habitats (Smith, 1977; Dickson 1978; Stauffer and Best, 1980). These studies, like the present one, were conducted in a riparian area that possessed an obvious change between riparian and adjacent zones. Some studies conducted in areas where forested habitats occurred continuously from riparian to upland zones did not demonstrate an increase in diversity (Murray and Stauffer, 1995).

The RIP on Freeman Ranch, which encompassed the two predominant soil types present on the ranch as well as Orif soils which were only found in this

habitat, was the site where Sink Creek's tributaries merged and was adjacent to a dam that created an abrupt shift in the forested riparian area. Typically, soil in riparian areas enable more plants to grow faster than in drier upland areas. Thus, higher plant diversity is found which enables more wildlife diversity (Murray and Shauffer, 1995).

Although the MS ranked third in bird diversity, this habitat had identical avian species richness as the RIP. Although a diversity of birds inhabits this area, their numbers are fewer than that of the RIP. By season, the MS's avian diversity ranked second only to the LOW in the summer. Similar to the LOW, the MS attracts such summer breeders as the Yellow-billed Cuckoo, White-eyed Vireo, and Painted Bunting; however, an additional tenant, the Scissor-tailed Flycatcher, flourished in the open landscape created by the short grassland.

Although ranchers consider mesquite, as found in the MS, a nuisance because of the tree's increased abundance, the plant provides valuable forage for livestock and wildlife as well as shelter for forbs and grasses (Tull and Miller, 1991). The mesquite trees, agarita, tasajillo, and prickly pear provide shelter from the weather, protection from predators, and nesting sites for birds as well as other wildlife. The thorny nature of this environment is also a deterrent for livestock grazing except under harsh environmental conditions, such as drought, when food is scarce.

The bird diversity in the MS radically declines in the fall, resulting in the lowest diversity of all 5 habitats. This is most likely due to the large number (n=8) of summer breeding species migrating from this habitat at this time of the year.

Also, the low vegetative diversity and the second lowest overall canopy coverage and vertical visual obscurity may make this area less hospitable in the cooler months when protection from winds and predators is minimal and food is scarce.

The LOS exhibited the second lowest overall avian diversity throughout the year and the second lowest avian diversity for each season (Table 2). The trend in bird diversity for the LOS exhibited a noticeable decline in the fall and winter and was slightly more accommodating to bird species in the summer. The reason for this may be that the short grasslands composing the majority of this area provide little habitat value to bird species in general, supplying little food or nest sites except within the oak mottes scattered throughout the habitat.

The greatest number of sightings of Northern Mockingbirds (422) was recorded in the LOS. This area may be conducive for this species due to the openness and perches available for display, especially during the breeding season, when the highest number of sightings (152) occurred.

The LOS's short grass savannah may provide some concealment for other bird species, however overall it did not appear to be a highly desirable habitat for birds. The LOS also had the lowest percent total canopy cover of all habitats on the ranch. Based on seasonal avian diversity, winter residents were under represented in this habitat and the lack of overstory may have been a factor. Also, the LOS had the lowest visual obstruction in all vertical strata of the vegetation.

The LOS had the largest number (13) of winter migrant species, although these were consistently single recordings. The proximity of the Laguna, a

constant water supply for all wildlife as well as cattle, may have been a lure for these birds and could account for some of these unique occurrences. Although summer breeders, such as the Yellow-billed Cuckoo and Painted Bunting were recorded in this area, migrants were found much more abundant in other habitat types.

The JOF as a whole was the least used habitat on the ranch with the lowest species richness and species diversity when compared to the other 4 habitats on the Freeman Ranch. Although this area had the third greatest total canopy cover of habitats, this was due primarily to the near monoculture of Ashe juniper. Although Ashe juniper stands are rather dense, they do not provide a rich food base for birds or the vegetative diversity proven advantageous for avian species. Ashe junipers are essentially devoid of any vegetation beneath the trees and the needles covering the ground provide a negligible amount of cover for birds. Recall that it is not the total visual obstruction, but rather the increasing number of vertical foliage layers that tend to support higher bird diversity. The vertical vegetative structure in the JOF from understory plants was practically nonexistent and this habitat's overall plant diversity was by far the lowest. Avian species diversity by season for the JOF was the lowest of all habitats during spring, summer, and winter. The seasonal trend in bird diversity, while consistently lower, followed that of the LOS, another habitat with low diversity.

Habitat loss due to land use practices is a gradual process. In Texas, an increase in Ashe Juniper density per hectar has progressively occurred on rangelands. The expansion of Ashe juniper has been accompanied by a

reduction in the numbers of hardwood trees due to the practices of fire suppression and overgrazing. Monocultures of Ashe juniper do not support a high diversity of bird species. Even the endangered Golden-cheeked Warbler, a species dependent upon Ashe Junipers, is more abundant in areas with less than 100% Ashe juniper. Woodlands with a combination of Ashe juniper and hardwoods located in relatively moist areas are not only prime habitat for Golden-cheeked Warblers, but the nearly continuous (50-100%) canopy cover of trees is also important for deer, turkey, songbirds, and other wildlife because of the vegetative and topographical diversity and proximity to a water source (Campbell, 1995).

Although the JOF was not preferred habitat as a whole, Scrub Jays were recorded more often in this habitat than in any other habitat on the ranch. Scrub Jays' breeding and nest sites often occur in Ashe junipers. More importantly, the Golden-checked Warbler (GCW) was recorded on a spring Point Count near a draw in the JOF. GCWs were also heard on two other occasions in the same area. GCWs breed almost exclusively in Ashe juniper woodlands on the Edwards Plateau in Texas. The area along the draw on Freeman Ranch has old growth Ashe juniper with striping bark that is used by GCWs for building their nests. Although these numbers are not outstanding, the endangered bird was present and follow-up searches are recommended during the spring to determine if GCWs are breeding in this area.

Migrant Summer Breeders and Winter Residents

When analyzing whether summer breeders and winter residents appeared to utilize any particular habitat over another, no significant statistical difference was found overall in species diversity for these two groups by habitat type (Figs. 4 and 5). Interestingly, two migratory species were found in all habitats. For the summer breeders, the Yellow-billed Cuckoo and Painted Bunting were recorded throughout the ranch during Point Counts. Similarly, the Rufous-sided Towhee and the Ruby-crowned Kinglet were detected in all habitat types during winter.

Although overall no significant statistical difference was detected in migratory bird habitat utilization, it was found in post hoc testing that winter residents do prefer the RIP compared with two of the other habitat types (Fig. 5). This indicates a selection for the RIP in winter by some birds.

Management Implications

After studying Freeman Ranch's bird diversity and abundance and usage of different habitat types, a management strategy for maintaining and/or improving areas of interest can be designed. The recognition of economic value derived from birds has encouraged ranchers and landowners to pursue non-traditional means of generating income from their land. The development of birding opportunities and nature tourism to supplement ranching income is a relatively new concept.

With the passage of the Endangered Species Act in 1973, many landowners began to view the presence of rare species as a threat to the rights

of private ownership (Scott et al., 1996). However, a diversity of birds and the presence of rare, threatened, and endangered avian species on a ranch can be a positive factor in attracting birders, photographers, and nature tourists. Biologists, landowners, and birders are recognizing that the presence of these species indicate that the habitat is experiencing excellent management and conservation. The encouragement of such superior management and conservation programs is desirable if high bird diversity and numbers are to be maintained. An important piece of this process is providing an economic incentive to the landowner through increased income opportunities from birding and ecotourism.

When studying each of the five habitat types on the ranch, the LOW appears to be the primary area in which such ecotourism would be feasible. In addition, the SWT Wildlife Society created the Nature Trail in this area. The Nature Trail is used to educate people about the flora and fauna on the ranch and is accessible to the public. Because the LOW presently has the greatest avian diversity and abundance on the ranch, continued conservation of this area is highly recommended. A bird check list, resulting from this study, will be provided to the ranch for disbursement to the public upon visiting the Nature Trail in hopes of stimulating interest in the bird species that inhabit this area.

An intensive study of the LOW habitat during migration is needed to assess which migrant birds depend on this habitat. These unique bird species would further attract birders that would generate income for the ranch with tours conducted by the SWT Wildlife Biology students. Also, the high usage of this

area by summer breeders should be monitored in order to maintain the floral characteristics of this habitat and its avian species.

The LOS habitat and JOF appear to be the least used habitats by birds on the ranch. However, the endangered Golden-cheeked Warbler found in the JOF should be monitored during breeding season to determine if there are significant breeding pairs using this area. If so, old growth Ashe juniper trees should be left in place and other smaller Ashe junipers, if desired, should be judicially culled to enhance the habitat for these endangered birds. These felled trees could be left as brush piles that provide habitat and cover for birds and other wildlife. Responsible land stewardship could enhance this habitat and these birds would attract avid birders that would contribute to ecotourism.

The MS, like the LOW habitat, was heavily uses by summer residents. The thorny structure of the vegetation may have provided protection for birds and their nests. This habitat should be monitored to ensure that nests are not unduly disturbed during the breeding season.

The RIP should be monitored to ensure that this unique habitat is not degraded. In this area, as well as throughout the ranch, dead trees (or "snags") should be left standing. Snags provide excellent food sources and shelter for many birds.

Overall, the Freeman Ranch has the potential to sustain and encourage a variety of bird species as well as other wildlife. Continued bird surveys every 2-5 years would allow trends in bird species diversity and abundance to be monitored. These data would enable the ranch to make adjustments in the

management plan, if necessary, to ensure a continued improvement in the condition of the land. Such improvements would not only benefit the existing wildlife, but also enhance the land for other wildlife. It is the privilege and responsibility of all landowners to strike a balance between himself and the land and animals which now or once inhabited it. This not only benefits the present, but also is our obligation to future generations.

APPENDICES

Appendix 1: Bird species lists
Appendix 1a: Bird species list (by habitat)

LOW = Live Oak Woodland, RIP = Riparian Forest, MS = Mesquite Savannah, LOS = Live Oak Savannah, JOF = Ashe Juniper-Live Oak Woodland

M = Migrant passing through W = Winter resident * = caught during mist netting / banded

X = Recorded on Point Counts S = Summer breeder

R = Year-round resident I = Incidental sighting not on Point Counts

			LOW	RIP	MS	LOS	JOF
FAMILY PODICIPEDIDAE							
Pied-billed Grebe	*Podilymbus podiceps*	I					
FAMILY PHALACROCORACIDAE							
Double-crested Cormorant	*Phalacrocorax auritus*	I					
FAMILY ARDEIDAE							
Great Blue Heron	*Ardea herodias*	R				X	
Great Egret	*Casmerodius albus*	R					X
Little Blue Heron	*Egretta caerulea*	I					
Green-backed Heron	*Butorides striatus*	I					
FAMILY ANATIDAE							
SUBFAMILY ANATINAE							
Northern Shoveler	*Anas clypeata*	I					
Gadwall	*A. strepera*	I					
American Wigeon	*A. americana*	W				X	
FAMILY CATHARTIDAE							
Black Vulture	*Coragyps atratus*	R	X	X	X	X	X
Turkey Vulture	*Cathartes aura*	R	X	X	X	X	X

Appendix 1a cont.			LOW	RIP	MS	LOS	JOF
FAMILY ACCIPITRIDAE							
SUBFAMILY ACCIPITRINAE							
Northern Harrier	*Circus cyaneus*	W	X			X	
Sharp-shinned Hawk	*Accipiter striatus*	I					
Cooper's Hawk	*A. cooperii*	R	X				
Red-shouldered Hawk	*Buteo lineatus*	R		X	X		
White-tailed Hawk	*B. albicaudatus*	I					
Red-tailed Hawk	*B. jamaicensis*	R	X		X		
FAMILY FALCONIDAE							
Crested Caracara	*Polyborus plancus*	R	X	X	X	X	
American Kestrel	*Falco sparverius*	W	X			X	
FAMILY PHASIANIDAE							
SUBFAMILY MELEAGRIDINAE							
Wild Turkey	*Meleagris gallopavo*	R	X	X		X	X
SUBFAMILY ODONTOPHORINAE							
* Northern Bobwhite	*Colinus virginianus*	R	X	X	X	X	X
FAMILY RALLIDAE							
SUBFAMILY RALLINAE							
Sora	*Porzana carolina*	I					
American Coot	*Fulica americana*	I					
FAMILY GRUIDAE							
SUBFAMILY GRUINAE							
Sandhill Crane	*Grus canadensis*	W			X		
FAMILY CHARADRIIDAE							
SUBFAMILY CHARADRIINAE							
Killdeer	*Charadrius vociferus*	R	X	X		X	X
FAMILY SCOLOPACIDAE							
SUBFAMILY SCOLOPACINAE							
Greater Yellowlegs	*Tringa melanoleuca*	I					
Lesser Yellowlegs	*T. flavipes*	I					
Spotted Sandpiper	*Actinis macularia*	I					
Common Snipe	*Gallinago gallinago*	I					

Appendix 1a cont.			LOW	RIP	MS	LOS	JOF
FAMILY COLUMBIDAE							
Rock Dove	*Columbia livia*	R			X		
Mourning Dove	*Zenaida macroura*	R	X	X	X	X	X
Inca Dove	*Columbina inca*	R	X	X	X	X	X
* Common Ground-Dove	*C. passerina*	R	X		X	X	X
FAMILY CUCULIDAE							
SUBFAMILY COCCYZINAE							
* Yellow-billed Cuckoo	*Coccyzus americanus*	S	X	X	X	X	X
SUBFAMILY NEOMORPHINAE							
Greater Roadrunner	*Geococcyx californianus*	R		X	X		X
FAMILY STRIGIDAE							
Eastern Screech-Owl	*Otus asio*	R					X
Great Horned Owl	*Bubo virginianus*	I					
Barred Owl	*Strix varia*	I					
FAMILY CAPRIMULGIDAE							
SUBFAMILY CHORDEILINAE							
Common Nighthawk	*Chordeiles minor*	I					
SUBFAMILY CAPRIMULGINAE							
Chuck-will's-widow	*Caprimulgus carolinensis*	I					
FAMILY TROCHILIDAE							
Ruby-throated Hummingbird	*Archilochus colubris*	S			X		
Black-chinned Hummingbird	*A. alexandri*	I					
FAMILY ALCEDINIDAE							
SUBFAMILY CERLYINAE							
Belted Kingfisher	*Ceryle alcyon*	I					
FAMILY PICIDAE							
SUBFAMILY PICINAE							
Golden-fronted Woodpecker	*Melanerpes aurifrons*	R		X			
Red-bellied Woodpecker	*M. carolinus*	R	X	X	X	X	

Appendix 1a cont.			LOW	RIP	MS	LOS	JOF
SUBFAMILY PICINAE cont.							
Ladder-backed Woodpecker	*Picoides scalaris*	R	X	X	X	X	X
Downy Woodpecker	*P. pubescens*	R					X
FAMILY TYRANNIDAE							
SUBFAMILY FLUVICOLINAE							
Acadian Flycatcher	*Empidonax virescens*	S		X			
* Eastern Phoebe	*Sayornis phoebe*	R	X	X	X	X	X
SUBFAMILY TYRANNINAE							
Great Crested Flycatcher	*Myiarchus crinitus*	I					
Western Kingbird	*Tyrannus verticalis*	S		X			
Scissor-tailed Flycatcher	*T. forficatus*	S	X	X	X	X	X
FAMILY HIRUNDINIDAE							
SUBFAMILY HIRUNDININAE							
Purple Martin	*Progne subis*	S					X
Cliff Swallow	*Hirundo pyrrhonota*	I					
Cave Swallow	*H. fulva*	I					
Barn Swallow	*H. rustica*	S	X	X	X		X
FAMILY CORVIDAE							
Blue Jay	*Cyanocitta cristata*	R	X	X	X	X	X
Scrub Jay	*Aphelocoma coerulescens*	R		X	X	X	X
American Crow	*Corvus brachyrhynchos*	R		X	X	X	X
FAMILY PARIDAE							
* Carolina Chickadee	*Parus carolinensis*	R	X	X	X	X	X
* Tufted Titmouse	*P. bicolor*	R	X	X	X	X	X
FAMILY REMIZIDAE							
* Verdin	*Auriparus flaviceps*	R	X		X		
FAMILY TROGLODYTIDAE							
Canyon Wren	*Catherpes mexicanus*	I					
Carolina Wren	*Thryothorus ludovicianus*	R	X	X	X	X	X
* Bewick's Wren	*Thryomanes bewickii*	R	X	X	X	X	X

Appendix 1a cont.			LOW	RIP	MS	LOS	JOF
FAMILY TROGLODYTIDAE	cont.						
* Bewick's Wren	*Thryomanes bewickii*	R	X	X	X	X	X
House Wren	*Troglodytes aedon*	W	X				X
Marsh Wren	*Cistothorus palustris*	I					
FAMILY MUSCICAPIDAE							
SUBFAMILY SYLVIINAE							
* Ruby-crowned Kinglet	*Regulus calendula*	W	X	X	X	X	X
Blue-gray Gnatcatcher	*Polioptila caerulea*	R	X	X	X	X	X
SUBFAMILY TURDINAE							
* Eastern Bluebird	*Sialia sialis*	R		X			X
* Gray-cheeked Thrush	*Catharus minimus*	I					
American Robin	*Turdus migratorius*	R		X	X	X	X
FAMILY MIMIDAE							
* Gray Catbird	*Dumetella carolinensis*	I					
* Northern Mockingbird	*Mimus polyglottos*	R	X	X	X	X	X
Brown Thrasher	*Toxostoma rufum*	I					
FAMILY BOMBYCILLIDAE							
Cedar Waxwing	*Bombycilla cedrorum*	W		X			X
FAMILY LANIIDAE							
SUBFAMILY LANIINAE							
Loggerhead Shrike	*Lanius ludovicianus*	R				X	X
FAMILY STURNIDAE							
SUBFAMILY STURNINAE							
European Starling	*Sturnus vulgaris*	R	X			X	X
FAMILY VIREONIDAE							
SUBFAMILY VIREONINAE							
* White-eyed Vireo	*Vireo griseus*	S	X	X	X	X	X
Bell's Vireo	*V. bellii*	I					
Red-eyed Vireo	*V. olivaceus*	S			X		
FAMILY EMBERIZIDAE							
SUBFAMILY PARULINAE							
* Orange-crowned Warbler	*Vermivora celata*	I					

	Appendix 1a cont.			LOW	RIP	MS	LOS	JOF
	SUBFAM PARULINAE cont.							
*	Nashville Warbler	*V. ruficapilla*	M					X
*	Yellow Warbler	*Dendroica petechia*	I					
	Golden-cheeked Warbler	*D. Chrysoparia*	S					X
	Yellow-rumped Warbler	*D. Coronata* (Myrtle)	I					
*	Black-and-white Warbler	*Mniotilta varia*	M	X	X			
	Northern Waterthrush	*Seiurus noveboracensis*	I					
	Common Yellowthroat	*Geothlypis trichas*	I					
	Wilson's Warbler	*Wilsonia pusilla*	I					
	SUBFAMILY THRAUPINAE							
	Summer Tanager	*Piranga rubra*	S				X	
	SUBFAMILY CARDINALINAE							
*	Northern Cardinal	*Cardinalis cardinalis*	R	X	X	X	X	X
*	Pyrrhuloxia	*C. sinuatus*	I					
	Black-headed Grosbeak	*Pheucticus melanocephalus*	I					
	Painted Bunting	*Passerina ciris*	S	X	X	X	X	X
	SUBFAMILY EMBERIZINAE							
	Eastern Towhee	*Pipilo erythrophthalmus*	W	X	X	X	X	X
*	Spotted Towhee	*P. maculatus*	W			X	X	
*	Rufous-crowned Sparrow	*Aimophila ruficeps*	R	X				X
*	Chipping Sparrow	*Spizella passerina*	R	X		X		
*	Clay-colored Sparrow	*S. pallida*	I					
*	Field Sparrow	*S. pusilla*	R	X	X	X	X	X
*	Vesper Sparrow	*Pooecetes gramineus*	W	X			X	
*	Lark Sparrow	*Chondestes grammacus*	R			X	X	X
*	Savannah Sparrow	*Passerculus sandwichensis* (W)					X	
*	Grasshopper Sparrow	*Ammodramus savannarum*	S			X		
	Le Conte's Sparrow	*A. leconteii*	I					
*	Fox Sparrow	*Passerella iliaca*	I					
	Song Sparrow	*Melospiza melodia*	I					
*	Lincoln's Sparrow	*M. lincolnii*	W	X		X		

Appendix 1a cont.			LOW	RIP	MS	LOS	JOF
SUBFAM. EMBERIZINAE							
White-throated Sparrow	*Zonotrichia albicollis*	W	X	X	X	X	X
* White-crowned Sparrow	*Z. leucophrys*	I					
Harris' Sparrow	*Z. querula*	W				X	
SUBFAMILY ICTERINAE							
Red-winged Blackbird	*Agelaius phoeniceus*	S		X		X	
Eastern Meadowlark	*Sturnella magna*	R	X			X	
Western Meadowlark	*S. neglecta*	W		X		X	
Great-tailed Grackle	*Quiscalus mexicanus*	R	X	X	X	X	X
Brown-headed Cowbird	*Molothrus ater*	R	X	X	X	X	X
Northern Oriole (Baltimore)	*Icterus galbula*	I					
FAMILY FRINGILLIDAE							
SUBFAMILY CARDUELINAE							
Purple Finch	*Carpodacus purpureus*	M				X	
* House Finch	*C. mexicanus*	R	X	X	X	X	
Lesser Goldfinch	*Carduelis psaltria*	R		X	X		
American Goldfinch	*C. tristis*	W	X	X		X	X
FAMILY PASSERIDAE							
House Sparrow	*Passer domesticus*	R	X				

Appendix 1b: Bird Species List (by season)

LOW = Live Oak Woodland, RIP = Riparian Forest, MS = Mesquite Savannah, LOS = Live Oak Savannah,
JOF = Ashe Juniper-Live Oak Woodland
M = Migrant passing through
X = Recorded on point count W = Winter Resident I = Incidental siting not on point count
R = Year-round Resident S = Summer breeder * = caught during mistnetting / banded

			Spring	Summer	Fall	Winter
FAMILY PODICIPEDIDAE						
Pied-billed Grebe	*Podilymbus podiceps*	I				
FAMILY PHALACROCORACIDAE						
Double-crested Cormorant	*Phalacrocorax auritus*	I				
FAMILY ARDEIDAE						
Great Blue Heron	*Ardea herodias*	R		X		
Great Egret	*Casmerodius albus*	R	X			
Little Blue Heron	*Egretta caerulea*	I				
Green-backed Heron	*Butorides striatus*	I				
FAMILY ANATIDAE						
SUBFAMILY ANATINAE						
Northern Shoveler	*Anas clypeata*	I				
Gadwall	*A. strepera*	I				
American Wigeon	*A. americana*	W	X			X
FAMILY CATHARTIDAE						
Black Vulture	*Coragyps atratus*	R	X	X	X	X
Turkey Vulture	*Cathartes aura*	R	X	X	X	X
FAMILY ACCIPITRIDAE						
SUBFAMILY ACCIPITRINAE						
Northern Harrier	*Circus cyaneus*	W	X		X	
Sharp-shinned Hawk	*Accipiter striatus*	I				
Cooper's Hawk	*A. cooperii*	R			X	
Red-shouldered Hawk	*Buteo lineatus*	R	X	X	X	
White-tailed Hawk	*B. albicaudatus*	I				
Red-tailed Hawk	*B. jamaicensis*	R	X	X	X	

Appendix 1b cont.			Spring	Summer	Fall	Winter
FAMILY FALCONIDAE						
Crested Caracara	*Polyborus plancus*	R	X	X	X	X
American Kestrel	*Falco sparverius*	W	X		X	
FAMILY PHASIANIDAE						
SUBFAMILY MELEAGRIDINAE						
Wild Turkey	*Meleagris gallopavo*	R	X	X	X	X
SUBFAMILY ODONTOPHORINAE						
* Northern Bobwhite	*Colinus virginianus*	R	X	X	X	
FAMILY RALLIDAE						
SUBFAMILY RALLINAE						
Sora	*Porzana carolina*	I				
American Coot	*Fulica americana*	I				
FAMILY GRUIDAE						
SUBFAMILY GRUINAE						
Sandhill Crane	*Grus canadensis*	W	X		X	X
FAMILY CHARADRIIDAE						
SUBFAMILY CHARADRIINAE						
Killdeer	*Charadrius vociferus*	R	X	X	X	X
FAMILY SCOLOPACIDAE						
SUBFAMILY SCOLOPACINAE						
Greater Yellowlegs	*Tringa melanoleuca*	I				
Lesser Yellowlegs	*T. flavipes*	I				
Spotted Sandpiper	*Actinis macularia*	I				
Common Snipe	*Gallinago gallinago*	I				
FAMILY COLUMBIDAE						
Rock Dove	*Columbia livia*	R		X		
Mourning Dove	*Zenaida macroura*	R	X	X	X	X
Inca Dove	*Columbina inca*	R	X	X	X	
* Common Ground-Dove	*C. passerina*	R	X	X	X	

Appendix 1b cont.			Spring	Summer	Fall	Winter
FAMILY CUCULIDAE						
SUBFAMILY COCCYZINAE						
* Yellow-billed Cuckoo	*Coccyzus americanus*	S	X	X		
SUBFAMILY NEOMORPHINAE						
Greater Roadrunner	*Geococcyx californianus*	R	X	X	X	
FAMILY STRIGIDAE						
Eastern Screech-Owl	*Otus asio*	R		X		
Great Horned Owl	*Bubo virginianus*	I				
Barred Owl	*Strix varia*	I				
FAMILY CAPRIMULGIDAE						
SUBFAMILY CHORDEILINAE						
Common Nighthawk	*Chordeiles minor*	I				
SUBFAMILY CAPRIMULGINAE						
Chuck-will's-widow	*Caprimulgus carolinensis*	I				
FAMILY TROCHILIDAE						
Ruby-throated Hummingbird	*Archilochus colubris*	S		X	X	
Black-chinned Hummingbird	*A. alexandri*	I				
FAMILY ALCEDINIDAE						
SUBFAMILY CERLYINAE						
Belted Kingfisher	*Ceryle alcyon*	I				
FAMILY PICIDAE						
SUBFAMILY PICINAE						
Golden-fronted Woodpecker	*Melanerpes aurifrons*	R		X		
Red-bellied Woodpecker	*M. carolinus*	R		X	X	X
Ladder-backed Woodpecker	*Picoides scalaris*	R	X	X	X	X
Downy Woodpecker	*P. pubescens*	R			X	X
FAMILY TYRANNIDAE						
SUBFAMILY FLUVICOLINAE						
Acadian Flycatcher	*Empidonax virescens*	S		X	X	
* Eastern Phoebe	*Sayornis phoebe*	R	X	X	X	X

Appendix 1b cont.			Spring	Summer	Fall	Winter
SUBFAMILY TYRANNINAE						
Great Crested Flycatcher	*Myiarchus crinitus*	I				
Western Kingbird	*Tyrannus verticalis*	S	X			
Scissor-tailed Flycatcher	*T. forficatus*	S	X	X	X	
FAMILY HIRUNDINIDAE						
SUBFAMILY HIRUNDININAE						
Purple Martin	*Progne subis*	S	X			
Cliff Swallow	*Hirundo pyrrhonota*	I				
Cave Swallow	*H. fulva*	I				
Barn Swallow	*H. rustica*	S	X	X		
FAMILY CORVIDAE						
Blue Jay	*Cyanocitta cristata*	R	X	X	X	X
Scrub Jay	*Aphelocoma coerulescens*	R	X	X	X	X
American Crow	*Corvus brachyrhynchos*	R	X	X		X
FAMILY PARIDAE						
* Carolina Chickadee	*Parus carolinensis*	R	X	X	X	X
* Tufted Titmouse	*P. bicolor*	R	X	X	X	X
FAMILY REMIZIDAE						
* Verdin	*Auriparus flaviceps*	R	X	X		
FAMILY TROGLODYTIDAE						
Canyon Wren	*Catherpes mexicanus*	I				
Carolina Wren	*Thryothorus ludovicianus*	R	X	X	X	X
* Bewick's Wren	*Thryomanes bewickii*	R	X	X	X	X
House Wren	*Troglodytes aedon*	W		X		
Marsh Wren	*Cistothorus palustris*	I				
FAMILY MUSCICAPIDAE						
SUBFAMILY SYLVIINAE						
* Ruby-crowned Kinglet	*Regulus calendula*	W	X		X	X
Blue-gray Gnatcatcher	*Polioptila caerulea*	R	X	X	X	X

Appendix 1b cont.			Spring	Summer	Fall	Winter
SUBFAMILY TURDINAE						
* Eastern Bluebird	*Sialia sialis*	R			X	X
* Gray-cheeked Thrush	*Catharus minimus*	I				
American Robin	*Turdus migratorius*	R	X		X	X
FAMILY MIMIDAE						
* Gray Catbird	*Dumetella carolinensis*	I				
* Northern Mockingbird	*Mimus polyglottos*	R	X	X	X	X
Brown Thrasher	*Toxostoma rufum*	I				
FAMILY BOMBYCILLIDAE						
Cedar Waxwing	*Bombycilla cedrorum*	W	X			X
FAMILY LANIIDAE						
SUBFAMILY LANIINAE						
Loggerhead Shrike	*Lanius ludovicianus*	R	X		X	
FAMILY STURNIDAE						
SUBFAMILY STURNINAE						
European Starling	*Sturnus vulgaris*	R	X	X		X
FAMILY VIREONIDAE						
SUBFAMILY VIREONINAE						
* White-eyed Vireo	*Vireo griseus*	S	X	X	X	
Bell's Vireo	*V. bellii*	I				
Red-eyed Vireo	*V. olivaceus*	S		X		
FAMILY EMBERIZIDAE						
SUBFAMILY PARULINAE						
* Orange-crowned Warbler	*Vermivora celata*	I				
* Nashville Warbler	*V. ruficapilla*	M	X			
* Yellow Warbler	*Dendroica petechia*	I				
Golden-cheeked Warbler	*D. Chrysoparia*	S	X			
Yellow-rumped Warbler	*D. Coronata* (Myrtle)	I				
* Black-and-white Warbler	*Mniotilta varia*	M	X		X	
Northern Waterthrush	*Seiurus noveboracensis*	I				
Common Yellowthroat	*Geothlypis trichas*	I				
Wilson's Warbler	*Wilsonia pusilla*	I				

	Appendix 1b cont.			Spring	Summer	Fall	Winter
	SUBFAMILY THRAUPINAE						
	Summer Tanager	*Piranga rubra*	S	X			
	SUBFAMILY CARDINALINAE						
*	Northern Cardinal	*Cardinalis cardinalis*	R	X	X	X	X
*	Pyrrhuloxia	*C. sinuatus*	I				
	Black-headed Grosbeak	*Pheucticus melanocephalus*	I				
	Painted Bunting	*Passerina ciris*	S	X	X		
	SUBFAMILY EMBERIZINAE						
	Eastern Towhee	*Pipilo erythrophthalmus*	W	X	X	X	X
*	Spotted Towhee	*P. maculatus*	W			X	X
*	Rufous-crowned Sparrow	*Aimophila ruficeps*	R	X	X	X	
*	Chipping Sparrow	*Spizella passerina*	R	X			X
*	Clay-colored Sparrow	*S. pallida*	I				
*	Field Sparrow	*S. pusilla*	R	X	X		X
*	Vesper Sparrow	*Pooecetes gramineus*	W	X			X
*	Lark Sparrow	*Chondestes grammacus*	R	X	X	X	
*	Savannah Sparrow	*Passerculus sandwichensis*	(W)				X
*	Grasshopper Sparrow	*Ammodramus savannarum*	S	X	X		
	Le Conte's Sparrow	*A. leconteii*	I				
*	Fox Sparrow	*Passerella iliaca*	I				
	Song Sparrow	*Melospiza melodia*	I			X	
*	Lincoln's Sparrow	*M. lincolnii*	W	X			X
*	White-throated Sparrow	*Zonotrichia albicollis*	W	X		X	X
*	White-crowned Sparrow	*Z. leucophrys*	I				
	Harris' Sparrow	*Z. querula*	W	X			
	SUBFAMILY ICTERINAE						
	Red-winged Blackbird	*Agelaius phoeniceus*	S	X			X
	Eastern Meadowlark	*Sturnella magna*	R			X	
	Western Meadowlark	*S. neglecta*	W	X			X
	Great-tailed Grackle	*Quiscalus mexicanus*	R	X	X	X	X
	Brown-headed Cowbird	*Molothrus ater*	R	X	X	X	X
	Northern Oriole (Baltimore)	*Icterus galbula*	I				

Appendix 1b cont.			Spring	Summer	Fall	Winter
FAMILY FRINGILLIDAE						
SUBFAMILY CARDUELINAE						
Purple Finch	*Carpodacus purpureus*	M	X			
* House Finch	*C. mexicanus*	R	X	X	X	X
Lesser Goldfinch	*Carduelis psaltria*	R	X			X
American Goldfinch	*C. tristis*	W	X			X
FAMILY PASSERIDAE						
House Sparrow	*Passer domesticus*	R		X		

Appendix 2: Vegetation Results: line intercept resultant calculations

Appendix 2a. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and importance values for woody vegetation in the **LOW** habitat type at Freeman Ranch, March to May, 1998 (Becker, 1998).

SPECIES	Relative Density	Percent Cover %	Dominance (m2/ha)	Relative Cover %	Percent Frequency %	Relative Frequency %	RIV %
TREES							
Celtis sp.	0.069	3.5	3788.8	2.8	40.0	7.8	5.8
Juniperus ashei	0.100	15.5	16705.2	12.4	48.0	9.4	10.6
Prosopis glandulosa	0.004	2.4	2540.2	1.9	4.0	0.8	1.0
Quercus fusiformis	0.119	45.5	48953.2	36.3	68.0	13.3	20.5
Ulmus crassifolia	0.065	3.6	3918.0	2.9	28.0	5.5	5.0
SHRUBS AND VINES							
Berberis sp.	0.054	5.0	5381.8	4.0	40 0	7.8	5.7
Bumelia lanuginosa	0.038	1.4	1463.9	1.1	20.0	3.9	2.9
Diospyrus texana	0.123	14.8	15973.3	11.8	64.0	12.5	12.2
Forestiera pubescens	0.050	8.7	9342.9	6.9	28.0	5.5	5.8
Parthenocissus quinquefolia	0.046	1.7	1851.4	1.4	24.0	4.7	3.6
Rubus trivialis	0.065	1.6	1722.2	1.3	36.0	7.0	4.9
Smilax bona-nox	0.235	19.5	21010.7	15.6	88.0	17.2	18.7
Toxicodendren radicans	0.008	0.1	86.1	0.1	8.0	1.6	0.8
Vitis sp.	0.008	1.1	1205.5	0.9	12.0	2.3	1.3
Yucca rupicola	0.015	0.9	990.3	0.7	4.0	0.8	1.0
Total	1.000	12.5	134933.4	100	512	100	100

Appendix 2b. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and importance values for woody vegetation in the **LOS** habitat type at Freeman Ranch, March to May, 1998 (Becker, 1998).

SPECIES	Relative Density	Percent Cover %	Dominance (m2/ha)	Relative Cover %	Percent Frequency %	Relative Frequency %	RIV %
TREES							
Celtis sp.	0.036	0.3	344.4	0.6	20.0	7.2	3.8
Juniperus ashei	0.073	4.9	5295.7	9.1	12.0	4.3	6.9
Prosopis glandulosa	0.029	7.2	7706.8	13.3	24.0	8.7	8.3
Quercus fusiformis	0.051	10.8	11667.8	20.1	16.0	5.8	10.3
Ulmus crassifolia	0.007	1.2	1291.6	2.2	8.0	2.9	2.0
SHRUBS AND VINES							
Berberis sp.	0.058	2.2	2325.0	4.0	20.0	7.2	5.7
Diospyrus texana	0.109	7.6	8223.4	14.2	32.0	11.6	12.2
Eysenhardtia texanna	0.007	0.4	387.5	0.7	4.0	1.4	0.9
Opuntia engelmannii	0.029	1.8	1937.5	3 3	12.0	4.3	3.5
O. leptocaulis	0.051	1.9	2066.6	3.6	20.0	7.2	5.3
Forestiera pubescens	0.051	1.7	1851.4	3.2	12.0	4.3	4.2
Parthenocissus Quinquefolia	0.109	2.6	2841.6	4.9	24.0	8.7	8.2
Rubus trivialis	0.080	1.5	1593.0	2.7	16.0	5.8	5.5
Smilax bona-nox	0.277	9.0	9687.3	16.7	48.0	17.4	20.6
Vitis sp.	0.029	0.7	775.0	1.3	8.0	2.9	2.4
Total	1.000	53.9	57994.7	100	276	100	100

Appendix 2c. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and importance values for woody vegetation in the **MS** habitat type at Freeman Ranch, March to May, 1998 (Becker, 1998).

Species	Relative Density	Percent Cover %	Dominance (m2/ha)	Relative Cover %	Percent Frequency %	Relative Frequency %	RIV %
TREES							
Celtis sp.	0.107	10.8	11581.7	18.0	44.0	13.3	14.0
Juniperus ashei	0.050	3.9	4219.4	6.6	20.0	6.0	5.8
Prosopis glandulosa	0.132	13.8	14810.8	23.0	48.0	14.5	16.9
Quercus fusiformis	0.008	1.6	1722.2	2.7	4.0	1.2	1.6
Ulmus crassifolia	0.091	3.3	3573.5	5.6	28.0	8.4	7.7
SHRUBS AND VINES							
Acacia farnesiana	0.008	0.6	645.8	1.0	4.0	1.2	1.0
Berberis sp.	0.074	4.2	4563.8	7.1	24.0	7.2	7.3
Bumelia lanuginosa	0.017	0.2	258.3	0.4	8.0	2.4	1.5
Cercis canadenisis	0.008	0.1	86.1	0.1	4.0	1.2	0.7
Colubrina texensis	0.008	0.2	258.3	0.4	4.0	1.2	0.8
Condalia hookeri	0.017	1.0	1119.4	1.7	8.0	2.4	1.9
Diospyrus texana	0.132	6.5	6974.9	10.8	28.0	8.4	10.8
Forestiera pubescens	0.050	1.2	1334.7	2.1	16.0	4.8	4.0
Opuntia engelmannii	0.182	4.7	5037.4	7.8	44.0	13.3	13.1
O. leptocaulis	0.041	2.0	2109.7	3.3	16.0	4.8	4.1
Smilax bona-nox	0.074	5.6	6070.7	9.4	32.0	9.6	8.8
Total	1.000	59.8	64366.8	100	332	100	100

Appendix 2d. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and importance values for woody vegetation in the **RIP** habitat type at Freeman Ranch, March to May, 1998 (Becker, 1998).

TREES	**Rel.Den.**	**% Cover**	**Dom.**	**Rel % Cv**	**% Freq**	**Rel % Frq**	RIV %
Celtis sp.	0.047	5.8	6242.9	4.0	40.0	7.4	5.4
Juniperus ashei	0.189	30.0	32334.1	20.8	64.0	11.8	17.1
Prosopis glandulosa	0.017	2.3	2454.1	1.6	8.0	1.5	1.6
Quercus fusiformis	0.034	27.4	29449.4	18.9	40.0	7.4	9.9
Q. buckleyi	0.030	3.0	3229.1	2.1	12.0	2.2	2.4
Ulmus crassifolia	0.149	28.4	30568.8	19.6	68.0	12.5	15.7
SHRUBS AND VINES							
Baccharis neglecta	0.003	0.2	258.3	0.2	4.0	0.7	0.4
Berberis sp.	0.010	0.5	559.7	0.4	8.0	1.5	0.9
Bernardia myricifolia	0.007	0.3	344.4	0.2	8.0	1.5	0.8
Bumelia lanuginosa	0.003	0.1	86.1	0.1	4.0	0.7	0.4
Ehretia anacua	0.003	0.4	473.6	0.3	4.0	0.7	0.5
Diospyrus texana	0.088	12.2	13174.7	8.5	44.0	8.1	8.4
Forestiera pubescens	0.047	4.0	4262.4	2.7	20.0	3.7	3.7
Ilex decidua	0.020	2.0	2195.8	1.4	24.0	4.4	2.6
I. vomitoria	0.003	0.2	172.2	0.1	4.0	0.7	0.4
Juglans sp.	0.014	3.8	4047.1	2.6	16.0	2.9	2.3
Mimosa borealis	0.003	0.4	387.5	0.2	4.0	0.7	0.4
Opuntia engelmannii	0.007	0.6	602.8	0.4	4.0	0.7	0.6
O. leptocaulis	0.010	0.4	387.5	0.2	12.0	2.2	1.2
Parthenocissus quinquefolia	0.014	0.4	473.6	0.3	12.0	2.2	1.3
Ptelea trifoliata	0 003	0.0	43.1	0.0	4.0	0.7	0.4
Rubus trivialis	0.061	1.6	1765.2	1.1	36.0	6.6	4.6
Smilax bona-nox	0.166	10.5	11323.4	7.3	60.0	11.0	11.6
Ungnadia speciosa	0.030	2.8	3013.8	1.9	16.0	2.9	2.6
Vitis sp.	0.041	7.4	7965.1	5.1	28.0	5.1	4.8
Total	1.000	144.8	155815.0	100	544	100	100

Appendix 2e. Species composition, percent cover, dominance, relative cover, percent frequency, relative frequency and importance values for woody vegetation in the **JOF** habitat type at Freeman Ranch, March to May, 1998 (Becker, 1998).

SPECIES	Relative Density	Percent Cover %	Dominance (m2/ha)	Relative Cover %	Percent Frequency %	Relative Frequency %	RIV %
TREES							
Celtis sp.	0.012	1.8	1894.4	1.5	8.0	3.3	2.0
Juniperus ashei	0.581	62.4	67208.4	51.5	84.0	35.0	48.2
Quercus fusiformis	0.186	39.6	42581.1	32.7	64.0	26.7	26.0
Ulmus crassifolia	0.042	8.8	9472.0	7.3	20.0	8.3	6.6
SHRUBS AND VINES							
Condalia hookeri	0.006	0.0	43.1	0.0	4.0	1.7	0.8
Diospyrus texana	0.030	2.6	2841.6	2.2	12.0	5.0	3.4
Forestiera pubescens	0.006	0.4	387.5	0.3	4.0	1.7	0.9
Opuntia engelmannii	0.066	3.8	4133.3	3.2	16.0	6.7	5.5
O. leptocaulis	0.006	0.1	129.2	0.1	4.0	1.7	0.8
Smilax bona-nox	0.060	1.4	1506.9	1.2	20.0	8.3	5.2
Yucca rupicola	0.006	0.2	215.3	0.2	4.0	1.7	0.8
Total	1.000	121.2	130412.7	100	240	100	100

Appendix 3. Frequency distribution of cover classes (1 = 0 – 20%, 2 = 21 – 40%, 3 = 41 – 60%, 4 = 61- 80%, 5 = 81 – 100%) for five 0.5m height increments of the vegetation profile board to determine vertical cover in the five habitats (Becker, 1998).

		Height (m)					
Habitat type	**Class**	0.0 - 0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	0.0 - 2.5
	1	12	14	13	15	15	69
	2	2	2	3	0	1	8
LOS	3	1	1	1	2	0	5
	4	0	0	0	0	2	2
	5	5	3	3	3	2	16
	1	5	8	11	12	13	49
	2	2	1	0	0	0	3
LOW	3	0	2	0	1	0	3
	4	1	1	1	0	0	3
	5	12	8	8	7	7	42
	1	8	11	14	14	14	61
	2	2	4	1	1	2	10
MS	3	1	2	1	4	3	11
	4	3	1	2	0	0	6
	5	6	2	2	1	1	12
	1	3	5	4	8	7	27
	2	2	6	3	1	2	14
RIP	3	3	2	3	2	1	11
	4	3	2	4	5	3	17
	5	9	5	6	4	7	31
	1	5	6	7	8	7	33
	2	0	3	0	0	1	4
JOF	3	2	2	1	1	0	6
	4	2	2	3	2	1	10
	5	11	7	9	9	11	47

Appendix 4. Brillouin's Index (H) of diversity values for 2-way ANOVA.

Habitat	Season	H
LOW	Spring	3.237
LOW	Spring	2.466
LOW	Spring	3.173
LOW	Spring	3.22
LOW	Spring	3.206
LOW	Summer	3.419
LOW	Summer	3.541
LOW	Summer	3.389
LOW	Summer	3.314
LOW	Summer	3.313
LOW	Fall	3.439
LOW	Fall	3.136
LOW	Fall	3.419
LOW	Fall	3.408
LOW	Fall	3.156
LOW	Winter	2.683
LOW	Winter	2.788
LOW	Winter	3.041
LOW	Winter	2.989
LOW	Winter	2.901
LOS	Spring	3.071
LOS	Spring	3.031
LOS	Spring	3.094
LOS	Spring	2.949
LOS	Spring	2.892
LOS	Summer	3.228
LOS	Summer	3.085
LOS	Summer	3
LOS	Summer	2.906
LOS	Summer	3.218
LOS	Fall	3.176
LOS	Fall	2.889
LOS	Fall	2.764
LOS	Fall	2.912
LOS	Fall	3.178
LOS	Winter	2.558
LOS	Winter	2.838
LOS	Winter	2.491
LOS	Winter	2.802
LOS	Winter	2.43
JOF	Spring	3.046
JOF	Spring	2.767
JOF	Spring	3.067

Habitat	Season	H
JOF	Spring	2.862
JOF	Spring	2.887
JOF	Summer	3.122
JOF	Summer	3.205
JOF	Summer	3.018
JOF	Summer	2.786
JOF	Summer	2.946
JOF	Fall	2.808
JOF	Fall	2.966
JOF	Fall	2.792
JOF	Fall	2.703
JOF	Fall	2.978
JOF	Winter	2.999
JOF	Winter	2.476
JOF	Winter	2.278
JOF	Winter	2.264
JOF	Winter	2.641
MS	Spring	3.261
MS	Spring	2.955
MS	Spring	3.205
MS	Spring	3.333
MS	Spring	3.258
MS	Summer	3.227
MS	Summer	3.418
MS	Summer	3.153
MS	Summer	3.424
MS	Summer	3.296
MS	Fall	2.645
MS	Fall	2.722
MS	Fall	2.475
MS	Fall	2.546
MS	Fall	2.342
MS	Winter	2.774
MS	Winter	2.8
MS	Winter	2.819
MS	Winter	2.873
MS	Winter	2.933
RIP	Spring	3.2
RIP	Spring	3.446
RIP	Spring	3.087
RIP	Spring	3.078
RIP	Spring	2.905
RIP	Summer	2.942

Appendix 4 cont.

Habitat	Season	H
RIP	Summer	3.37
RIP	Summer	2.934
RIP	Summer	2.842
RIP	Summer	3.284
RIP	Fall	3.055
RIP	Fall	2.994
RIP	Fall	2.816
RIP	Fall	2.869
RIP	Fall	2.813
RIP	Winter	3.42
RIP	Winter	3.225
RIP	Winter	2.849
RIP	Winter	3.113
RIP	Winter	3.375

Appendix 5: Brillouin's Indices (H) of diversity used in 1-way ANOVA for winter residents and summer breeders.

SUMMER :

Habitat	Point	Diversity (H)
LOW	1	1.445
LOW	2	1.445
LOW	3	0.000
LOW	4	1.563
LOW	5	0.601
LOS	1	0.601
LOS	2	0.720
LOS	3	0.528
LOS	4	0.802
LOS	5	0.959
JOF	1	1.445
JOF	2	1.251
JOF	3	0.464
JOF	4	0.726
JOF	5	0.431
MS	1	1.030
MS	2	1.292
MS	3	1.204
MS	4	0.913
MS	5	0.942
RIP	1	0.375
RIP	2	1.425
RIP	3	1.016
RIP	4	0.726
RIP	5	0.932

Appendix 5 cont.

WINTER :

Habitat	Point	Diversity (H)
LOW	1	0.710
LOW	2	1.141
LOW	3	0.959
LOW	4	0.000
LOW	5	1.214
LOS	1	0.000
LOS	2	0.664
LOS	3	0.401
LOS	4	0.464
LOS	5	0.500
JOF	1	1.146
JOF	2	0.000
JOF	3	0.000
JOF	4	0.000
JOF	5	0.000
MS	1	0.000
MS	2	0.332
MS	3	0.959
MS	4	1.227
MS	5	0.000
RIP	1	1.371
RIP	2	1.445
RIP	3	0.000
RIP	4	1.130
RIP	5	1.761

LITERATURE CITED

ANDERSON, SH. AND K.J. GUTZWELLER. 1996. Habitat evaluation methods. *In* pp 592-606, Research and Management Techniques for Wildlife and Habitats, (T. A. Bookhout, ed.). Wildlife Society, Bethesda, Maryland. 740 pp.

BARNES, P.W., S.-Y. LIANG, K.E. JESSUP, L.E. RUISECO, P. L. PHILLIPS, AND S.J. REAGAN. 2000. Soils, topography, and vegetation of the Freeman Ranch. Freeman Ranch Publication Series No. 1-2000. Southwest Texas State University Press, San Marcos, Texas. 31 pp.

BECKER, H.M. 1998. Small rodent diversity and habitat utilization of heavily grazed shortgrass rangeland of the Edwards Plateau. Thesis, Southwest Texas State University, San Marcos, Texas.

BEST, L.B., K.E. FREEMARK, J.J. DINSMORE, AND M. CAMP. 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. American Naturalist 134(1):1-29.

BROOKS, R.P. AND W.J. DAVIS. 1987. Habitat selection by breeding Belted Kingfishers (*Ceryle alcyon*). American Midland Naturalist 117(1):63-70.

CAMPBELL, L. 1995. Endangered and threatened animals of Texas. Texas Parks and Wildlife Press. 130 pp.

CODY, M.L. ed. 1985. Habitat selection in birds. Academic Press, New York, New York. 558 pp.

COX, G.W. 1996. Laboratory Manual of General Ecology. Wm. C. Brown Publishers, Dubuque, Iowa. 278 pp.

DAMUDE, N. AND K.C. BENDER. 1999. Texas wildscapes: gardening for wildlife. Texas Parks and Wildlife Press. 387 pp.

DICKSON, J.G. 1978. Forest bird communities of the bottomland hardwoods. *In* R.M. DeGraaf, Technical Coordinating Proceedings Workshop, Management of Southern forests for nongame birds. U.S. Forest Service General Technical Report SE – 14.

FLATHER, C.H. AND J.R. SAUER. 1996. Using landscape ecology to test hypotheses about large-scale abundance patterns in migratory birds. Ecology 77(1):28-35.

HAGAN, J.M., P.S. MCKINLEY, A.L. MEEHAN, AND S.L. GROVE. 1997. Diversity and abundance of landbirds in a Northeastern industrial forest. Journal of Wildlife Management 61(3):718-735.

HALLS, L.K. 1973. Deer browse growth reduced in pine overstory. Procedings of the Southeastern Association. Game and Fish Commissioners 27:304-306.

HIGGINS, K.F., J.L. OLDEINEYER, K.J. JENKINS, G.K. CLAMBEY, AND R.F. HARLOW. 1996. Vegetation sampling and measurement. Pages 567-591 *In* Research and Management Techniques for Wildlife and Habitats (T.A. Bookhout, ed.). The Wildlife Society, Bethesda, Maryland.

HORN, H.S. AND R.H. MACARTHUR. 1972. Competition among fugitive species in a harlequin environment. Ecology 53:749-752.

KARR, J.R. AND K.E. FREEMARK. 1983. Habitat selection and environmental gradients:dynamics in the "stable" Tropics. Ecology 64(6):1481-1494.

KREBS, C.J. 1988. Fortran programs for Ecological Methodology. Harper and Row, New York, New York. 156 pp.

_____. 1989. Ecological Methodology. Harper and Row, New York, New York, 654 pp.

LEVIN, R. AND D. CULVER. 1971. Regional coexistence of species and competition between rare species. Proceedings of the National Academy of Science of the USA 68:1246-1248.

MACARTHUR, R.H. AND J.M. MACARTHUR. 1961. On bird species diversity. Ecology 42:594-598.

MITCHELL, W.A. AND H.G. HUGHES. 1995. Visual obstruction: Section 6.2.6, U.S. Army Corps of Engineers, Wildlife Resources Management Manual. Technical Report EL-95-23, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. 16 pp.

MURRAY, N.L. AND D.F. STAUFFER. 1995. Nongame bird use of habitat in Central Appalachian riparian forests. Journal of Wildlife Management 59(1):78-87.

NUDDS, T.D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113-117.

PARRISH, J.D. 1995. Effects of needle architecture on warbler habitat selection in a coastal spruce forest. Ecology 76(6):1813-1820.

RALPH, C.J., G. GEUPEL, AND P. PYLE. 1993. Handbook of field methods for monitoring landbirds. Technical Report PSW-GTR-144. Albany, California: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 41 pp.

_____, J.R. SAUER, AND S. DROEGE. 1995. Monitoring bird populations by point counts. General Technical Report PSW-GTR-149. Albany, California: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 187 pp.

RANGEN, S.A., K.A. HOBSON, AND R.G. CLARK. 2000. A comparison of density and reproductive indices of songbirds in young and old boreal forest. Wildlife Society Bulletin 28(1):110-118.

ROBINS, C.S., J.R. SAUER, R. GREENBERG, AND S. DROEGE. 1989. Population declines in North American birds that migrate to the Neotropics. Proceedings of the National Academy of Sciences (USA) 86:7658-7662.

ROTENBERRY, J.T. 1978. Components of avian diversity along a multifactorial climate gradient. Ecology 59:693-699.

ROTH, R.R. 1976. Spatial heterogeneity and bird species diversity. Ecology 57:773-782.

SAVARD, J.L. AND T.D. HOOPER. 1995. Influence of survey length and radius size on grassland bird surveys by point counts at Williams Lake, British Columbia. Pages 57-62 *In* Monitoring Bird Populations by Point Counts. USDA Forest Service General Technical Report PSW-GTR-149.

SCOTT, J.M., S.A. TEMPLE, D.L. HARLOW, AND M.L. SHAFFER. 1996. Restoration and management of endangered species. Pages 531-539 *In* Research and Management Techniques for Wildlife and Habitats (T.A. Bookhout, ed.). The Wildlife Society, Bethesda, Maryland.

SHERRY, T.W. AND R.T. HOLMES. 1996. Winter habitat quality, population limitation, and conservation of Neotropical-Nearctic migrant birds. Ecology 77(1):36-48.

SIMPSON, B., D. FRELS, T. LAWYER, T. MERENDINO, E. MYERS, C. RUTHVEN, S. SOROLA, AND M. WAGNER. 1996. Baseline inventory and monitoring procedures on Texas Parks and Wildlife Department lands. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas. 81 pp.

SMITH, K.G. 1977. Distribution of summer birds along a forest moisture gradient in an Ozark watershed. Ecology 58:810-819. *In* N.L. Murray and D.F. Stauffer. 1995. Nongame bird use of habitats in Central Appalachian riparian forests. Journal of Wildlife Management 59(1):78-87.

SMITH, S.A., S.J. STEWART, AND J.E. GATES. 1999. Home ranges, habitat selection, and mortality of Ring-necked Pheasants (*Phasianus colchicus*) in North-Central Maryland. American Midland Naturalist 141:185-197.

STAUFFER, D.F. AND L.B. BEST. 1980. Habitat selection by birds of riparian communities evaluating effects of habitat alterations. Journal of Wildlife Management 11:1-15 *In* N. L. Murray, D.F. Stauffer. 1995. Nongame bird use of habitats in Central Appalachian riparian forests. Journal of Wildlife Management 59(1):78-87.

TULL, D. AND G.O. MILLER. 1991. A field guide to wildflowers, trees, and shrubs of Texas. Texas Monthly Field Guide Series. Gulf Publishing Company, Houston, Texas. 344 pp.

USDA Soil Conservation Service. 1984. Soil Survey of Comal and Hays Counties, Texas. United States Department of Agriculture, Soil Conservation Service, Washington, D.C. 136 pp.

WOLF, A.T., R.W. HOWE, AND G.J. DAVIS. 1995. Detectability of forest birds from stationary point counts in Northern Wisconsin. *In* Monitoring Bird Populations by Point Counts. USDA Forest Service. General Technical Report PSW-GTR-149. pp. 19-23.

ZAR, J.H. 1996. Biostatistical Analysis. Prentice Hall, Upper Saddle River, New Jersey. 662 pp.

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