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Effects of fire on home range size, site fidelity and habitat associations of grassland birds overwintering in southeast Texas

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EFFECTS OF FIRE ON HOME RANGE SIZE, SITE FIDELITY AND HABITAT ASSOCIATIONS OF GRASSLAND BIRDS OVERWINTERING IN SOUTHEAST TEXAS

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DEDICATION

To my grandmother, Drusilla, for taking me to Colorado during my first year of college, where I returned to change my major to wildlife.

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TABLE OF CONTENTS

ABSTRACT

Understanding habitat affinities of wintering grassland birds is pertinent to their conservation. The objectives of this study were to evaluate the 1) effect burn history has on vegetation structure in coastal prairie; 2) habitat associations of the most common avian species; and, 3) home range size and site fidelity of Le Conte's Sparrow (LCSP). Data were collected on sites with 1-, 2- and 3-year burn histories during the winter of 2002 at Brazoria National Wildlife Refuge, Texas. Line transects were conducted to estimate bird abundance and vegetation measurements were recorded for herbaceous density, shrub density, and community type. Twenty-six Le Conte's Sparrows (*Ammodramus lecontii*) (LCSP) were radio-marked, in 1- and 2-year burn units, and located for approximately 10 days. One hectare plots on each burn unit were flush-netted once each month. Burn history was highly correlated with herbaceous vegetation and shrub density. LCSP were most common in areas of medium herbaceous density, low to medium litter densities, and areas with tall vegetation. LCSP also occurred in areas with low shrub densities, but abundance was significantly higher in areas with dwarf wax myrtle (*Morella cerifera*). Savannah Sparrows (*Passerculus sandwichensis*) were most often found in areas with low herbaceous and shrub densities. Sedge Wrens (*Cistothorus platensis*) (SEWR) were most common in areas with dense herbaceous vegetation, but showed no relationship to shrub density. SEWR were associated with areas where saltbush and tallow were present. Swamp Sparrows (*Melospiza georgiana*) were most common in areas of high shrub densities, but demonstrated no relationship to herbaceous vegetation densities. LCSP were sedentary during winter with a mean home range of 2.41 ha (72% < 1 ha) with a 50% probability, and 10.31 ha (44% < 1 ha and 55% < 1.5 ha) with a 95% probability. Home range size did not significantly differ between burn year ($p = 0.227$). LCSP appeared to exhibit a behavioral response to capture

(p < 0.001) with estimated capture probability of 0.462 and recapture probability of 0.056. Maintaining a mosaic of prairie, in three year burn rotations, and controlling woody invasives will provide sufficient overwintering habitat for SAVS, LCSP and SEWR.

INTRODUCTION

Declines of grassland bird populations have been more severe than any other group of birds in North America (Knopf 1994, Sauer et al. 1995). Declines have been attributed to degradation and loss of habitat on breeding and wintering grounds (Sherry and Holmes 1992, Rappole and McDonald 1994, Martin and Finch 1995, Arey et al. 1998). Conservation of remaining habitat is crucial for the preservation of these species. Without conserving their habitat, populations may eventually approach a threshold below which recovery is unlikely. A critical step to formulate management strategies is to examine habitat associations, and other aspects of their ecology such as movements and site fidelity.

Individual species are more common in areas with specific habitat characteristics, primarily related to vegetation structure (Walk and Warner 2000, Herkert 1994, George and McEwen 1992, Schramm et al.1984, Wiens and Rotenberry 1981, Rotenberry and Wiens 1980, Wiens 1969). Often, but not always, breeding and wintering habitats of birds are similar in structural characteristics. To conserve grassland birds, their habitat associations should be examined on both areas of their range. Most research on Le Conte's Sparrow (*Ammodramus leconteii*) and Sedge Wren (*Cistothorus platensis*) has focused on management of breeding grounds and breeding ecology (Madden et al. 1999, Igl and Johnson 1999, Cooper 1984). Little research has focused on winter resources, largely because these birds are difficult to study during this time of year due to their secretive behavior.

Within-season site fidelity is a common avian behavior, exhibited by many overwintering grassland birds (Gordon 2000). Familiarity with an area may increase an individuals ability to acquire resources and avoid predators. Conservation of wintering grounds for species exhibiting high site fidelity may increase overwinter survival and positively influence breeding

communities (Pulliam and Enders 1971, Fretwell 1972, Wiens 1974, Raitt and Pimm 1976, Grzybowski 1982).

The focal species of this study were birds that overwinter in coastal prairie. The coastal prairie is the southernmost unit of the tallgrass prairie ecosystem and is located along the northwestern Gulf of Mexico coast. This ecosystem is listed as “imperiled globally” by The Nature Conservancy and the Texas Natural Heritage Program lists it as ”critically imperiled” (Grace 2000). Over 2.4 million hectares of coastal prairie once ranged from southwest Louisiana to the lower Texas coast (Arey et al. 1998). Agriculture, fire-suppression, wetland draining, and urbanization are major contributors to coastal prairie loss. Less than one percent of the coastal prairie ecosystem now remains in relatively pristine condition (Diamond and Smeins 1984, Arey et al. 1998), making this habitat of critical importance for those species who rely on its persistence.

FIRE MANAGEMENT AND HABITAT ASSOCIATIONS OF OVERWINTERING GRASSLAND BIRDS IN COASTAL PRAIRIE

Population declines of grassland birds have been more severe than any other group of birds in North America (Knopf 1994, Sauer et al. 1995). Declines have been attributed to degradation and loss of habitat on breeding and wintering grounds (Sherry and Holmes 1992, Rappole and McDonald 1994, Martin and Finch 1995, Arey et al. 1998). Proper management of remaining habitat is crucial for the preservation of these species. Without proper management of their habitat, populations may eventually approach a threshold below which recovery is unlikely.

A critical first step to formulate habitat management techniques is to examine habitat associations. Individual species of grassland birds, along with birds in many other habitats, are more common in areas with specific habitat characteristics, usually associated with vegetation structure (Wiens 1969, Rotenberry and Wiens 1980, Wiens and Rotenberry 1981, George and McEwen 1992, Schramm et al. 1984, Herkert 1994, Walk and Warner 2000). Often, but not always, breeding and wintering grounds share similar structural characteristics. To best manage for grassland birds, their habitat associations should be examined on both areas of their range. Research on Le Conte's Sparrow (*Ammodramus leconteii*) and Sedge Wren (*Cistothorus platensis*) has focused on management of breeding habitat and breeding ecology (Cooper 1984, Igl and Johnson 1998, Madden et al. 1999). Little research has focused on winter resources, largely because they are difficult to study during this time of year due to their secretive behavior.

Coastal prairie is the southernmost unit of the tallgrass prairie ecosystem and is located along the northwestern coast of the Gulf of Mexico. This ecosystem is listed as "imperiled globally" by The Nature Conservancy, and the Texas Natural Heritage program lists it as 'critically imperiled' (Grace 2000). Over 2.4 million hectares of coastal prairie once ranged from southwest Louisiana to the lower Texas coast (Arey et al. 1998). Agriculture, fire-

suppression, wetland drainage, and urbanization are major contributors to coastal prairie loss. Less than one percent of the historic coastal prairie ecosystem now remains in relatively pristine condition (Diamond and Smeins 1984, Arey et al. 1998), so these remaining coastal prairie landscapes are vital for obligate prairie birds.

The coastal tallgrass prairie is home to Attwater's Prairie-Chicken (*Tympanuchus cupido attwateri*) and several other species that have been identified as high priority species in need of conservation attention by Partners in Flight (Carter et al.2000, Shackelford et al. 2001). Other high priority species that overwinter here include Le Conte's Sparrow (LCSP), Sedge Wren (SEWR), Sprague's Pipit (*Anthus spragueii*), Grasshopper Sparrow (*Ammodramus savannarum*), and Henslow's Sparrow (*Ammodramus henslowii*).

The focal species of this study overwinter in coastal prairie. The purpose was to improve our understanding of how overwintering grassland birds, specifically LCSP and SEWR, relate to fire management by examining the relationships between vegetation characteristics and time since last burn, with bird abundance. Swamp Sparrows (*Melospiza georgiana*) and Savannah Sparrows (*Passerculus sandwichensis*) were included in the study because they are abundant in the area. They are not considered priority species because their population numbers are stable (Sauer et al. 2004). As part of this study, I investigated the relative abundance of LCSP, SEWR, Savannah Sparrow (SAVS) and Swamp Sparrow (SWSP) in areas burned within the past 1, 2, or 3 years to examine the effect of fire on herbaceous and woody vegetation, and habitat associations of individual bird species. I expected the response of vegetation structure to be predictable based on time since burn, and that each bird species would be more abundant in areas with particular structural characteristics.

STUDY AREA AND METHODS

This study was conducted during the winter of 2002-03 at Hoskins Mound (upland coastal prairie), which is part of the Brazoria National Wildlife Refuge, Texas. This refuge is part of the Texas Mid-coast National Wildlife Refuge Complex and is located along the upper Texas Gulf Coast (Figure 1). Prior to purchase in 1990, the land was used for cattle and rice production, which contributed to the dissection of the refuge into numerous well-defined units or areas surrounded by fire breaks such as levees, roads and ditches. Units included were not grazed since 1990 (Grace and Allain personal communication). Dominant plant species in the units studied included little bluestem (*Schizachyrium scoparium*), broom sedge (*Schizachyrium virginicus*), cord grass (*Spartina patens*), switchgrass (*Panicum scoparium*), *Muhlenbergia expansa*, *Iva angustifolia*, *Tridens strictus*, *Dichanthelium* and sedges (*Cyperus* sp.) Saltbush (*Baccharis halemifolia*), a native and invasive shrub commonly found in coastal areas, occurred in scattered clumps throughout much of the refuge and dominated portions of many units included in this study. Other woody trees/vines species found on study sites included *Rubus* sp., Macartney rose (*Rosa bracteata*), wax myrtle (*Morella cerifera*), and Chinese tallow tree (*Triadeca sebifera*).

Approximately 3,200 hectares of Hoskins Mound is actively managed with prescribed burning. The burning program at Hoskins Mound was established in 1997, with an emphasis on growing season fires. In some areas, mowing and haying have also been employed for management. The management plan for Hoskins Mound seeks to achieve an average burn rotation of every 3 to 5 years, depending on site conditions and successional status. Typically, there is a substantial portion of the total refuge that is roughly in compliance with burn objectives as a result of their burn activities. However, weather conditions have significant influence on management's ability

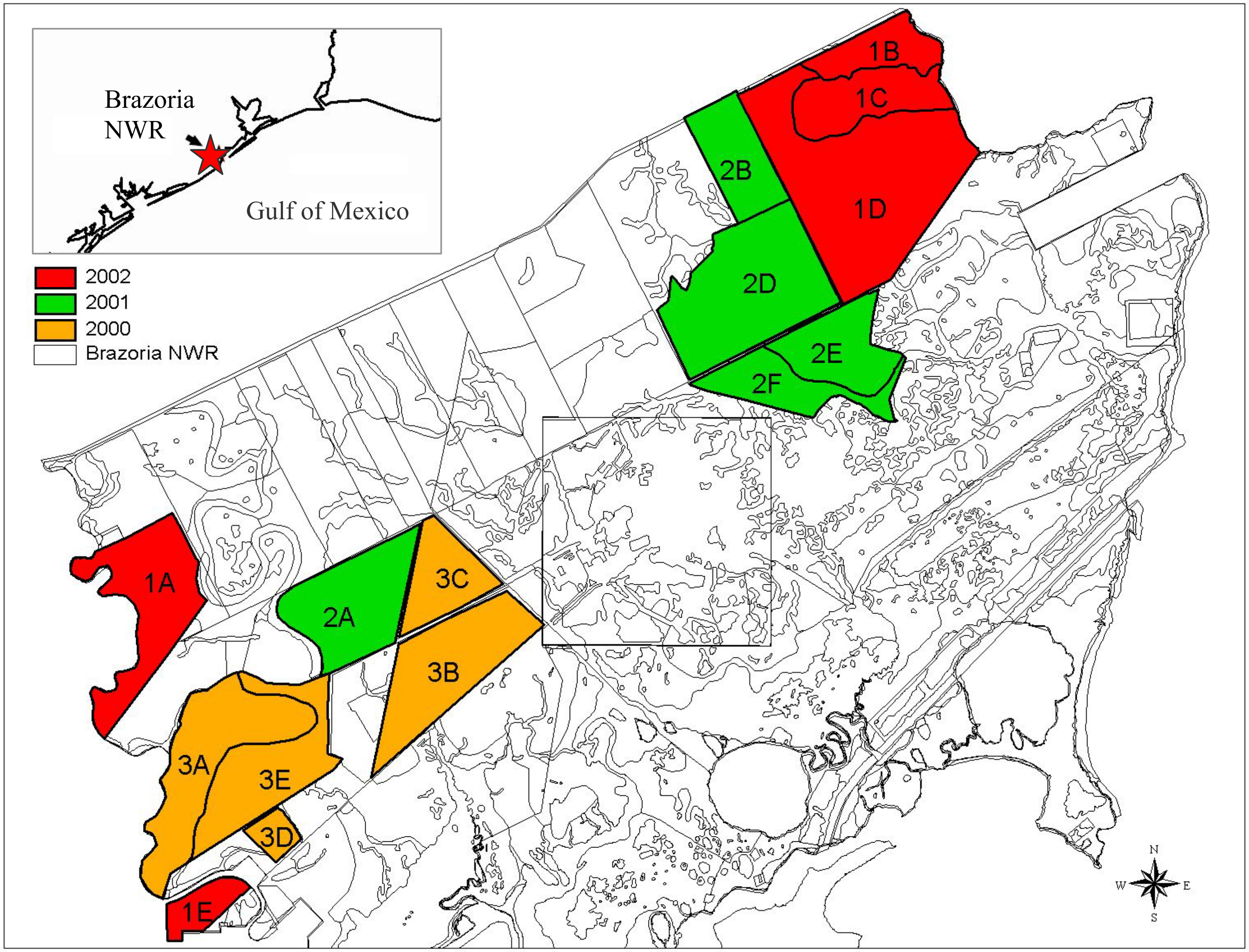

Figure 1. Map of Brazoria National Wildlife Refuge located along the upper Texas Gulf coast. Labeled polygons represent burn units included in study.

to implement annual burn plans completely and, as a result, there is a consistent shortfall in capacity to restore more badly degraded areas using frequent burning. The overall result is a management environment directed by general objectives and guided by periodic monitoring of habitat conditions.

Christmas Bird Counts conducted on Brazoria (Freeport) and/or San Bernard National Wildlife Refuge have been among the highest counts of LCSP and SEWR in the country (National Audubon Society 2002). This area provided an excellent opportunity to study their winter ecology and evaluate the implications of fire management for their habitat usage.

The study design called for the sampling of replicate burn units subjected to differing burn intervals. Sampled units were selected from those available using a completely randomized design. Each unit included in the study was burned within one, two or three years from the initiation of data collection. Units included were selected from all possible prairie units on Hoskins Mound. Fifteen burn units were sampled, with five replicates in each burn interval. Management units selected ranged in size from 40 ha to 520 ha. In each unit, four 300 m-long transects were surveyed for birds, and vegetation was sampled from 9 locations associated with each transect. Thus, a total of sixty line transects were surveyed and vegetation measurements were recorded from 540 locations.

Transects were randomly selected with the restriction that they be a minimum of 50 m apart and have a 50 m buffer zone from edges such as roads and firebreaks. Transects were surveyed in random order, and each sampled once. One transect from each burn treatment was surveyed on the same day (n = 3, 300 m transects per day), and they were sampled in random order.

Surveys

Line transect surveys of bird abundance were conducted based on a recently developed survey method specifically designed to survey grassland birds for a program called Project Prairie Birds (PPB) (Shackelford et al. 2001, Carrie et al. 2002). I modified the protocol to increase sampling effort by increasing transect length from 100 m up to 300 m with the criterion that each survey was to be completed in six minutes. Transect direction was from NE to SW, which was chosen because birds were more easily identified when the sun was behind the observer. Three people were involved; one observer standing between two "beaters". "Beaters" disturb vegetation with 3 m poles. Individuals were identified in flight because most are difficult to observe in grasslands, and usually do not perch, sing or call in winter. For each flushed bird, the perpendicular distance from the centerline was recorded. Surveys were conducted when weather conditions were not expected to impede our ability to detect birds (i.e. rain, fog, or wind speed ≥ 20 km/h) (Gabrey et al. 1999).

The probability of detecting an individual bird is expected to decrease as the distance from the observer increases, but the degree to which detectability decreases can be expected to vary for different species in different habitats (Selmi and Boulinier 2004, Slooten et al. 2004). Program DISTANCE (Thomas et al. 2004) attempts to improve over previous methods of estimating abundance by estimating and correcting for variable detection probabilities. DISTANCE also allows the incorporation of other covariates that might influence estimates of abundance.

Vegetation Measurements

Vegetation was sampled after bird surveys were completed each day. The structural characteristics of the habitat at Hoskins Mound can change appreciably over a 300 m distance.

Data were recorded and analyzed by breaking each 300 m transect into three 100 m transect links. Vegetation measurements were collected at nine random points along transect lines (three points per link) to facilitate comparisons between vegetation density and bird abundance.

Selection of habitat variables to measure was based on previous studies that have examined habitat associations with birds in similar environments. Height of herbaceous vegetation was measured by recording the tallest vegetation within 1m of each point from four cardinal directions (VEGHT). Herbaceous density was measured using a variation of the pole method (Plentovich et al. 1999) modified from Mills et al. (1989). The number of herbaceous contacts on a pole (~5cm in diameter) was recorded in five centimeter increments up to 20cm (sum 0-20cm = GRNDEN), and every 10 centimeters up to two meters (sum 0-200cm = VEGDEN). The maximum number of contacts for each increment was limited to 10. Community type was recorded for each link based on dominant plants; little bluestem (*Schizachyrium scoparium*), Gulf cordgrass (*Spartina patens*), and mix (*Schizachyrium s./Spartina p.*).

Woody vegetation density, primarily Saltbush, was measured using the point-centered quarter (PCQ) method (Cottam et al. 1953). From each sample point along transects, woody plant density was estimated by measuring the distance to the nearest woody plant in each cardinal direction. Each woody plant was placed into a size class according to height (e.g. 0-1.0 m, 1.01-2.0 m, 2.01-3.0 m, etc.). Woody plant density was calculated by squaring the mean distance (d) between sample points and individual shrub. Density was calculated dividing 1 by the squared mean distance using the formula

$$\text{density} = 1/d^2 .$$

Shrub data were recorded for all woody plants (DSHR), live Saltbush (DLS), and dead Saltbush (DDS).

Statistical Analyses

Bird Abundance

Data were collected using distance-sampling methods (Buckland et al. 2001). I modeled the probability of detection by measuring the distance each bird was observed from the centerline. A sufficient sample size (n ranged from 42 to 55) was obtained for four species: LCSP, SEWR, SAVS, and SWSP. Histograms were produced for each species to examine general patterns, obvious outliers, and potential problems with the data. Observations were not split by sex or age because this could not be determined during censusing. Detection curves and density estimates were generated using program DISTANCE (Thomas et al. 2004).

DISTANCE produces detection functions using two analysis engines, conventional distance sampling (CDS) and multiple covariate distance sampling (MCDS). Modeling functions comprise a key function and a series expansion. Four modeling functions were considered for CDS analyses (uniform; cosine, uniform; simple polynomial, half-normal; Hermite polynomial, hazard rate; and cosine), and three for MCDS analyses (half-normal; Hermite polynomial, half-normal; cosine, and hazard-rate; cosine). Curve suitability was evaluated both visually and based on measures of fit. When a suitable curve was not achieved from these standard functions, I used the hazard-rate; simple polynomial model to achieve a sufficient fit. Each function represents one of three main shapes of detection curves (Buckland et al. 2001). Options are relatively similar between each engine. The MCDS engine has fewer model options and allows the introduction of covariates (categorical or continuous) into analyses and constraints on monotonicity are not applied. Analyses were run without multipliers, and use

of adjustment terms and constraints on curve shape were used only if necessary. Prior to final truncation, intervals were manually selected as 8-1m intervals for G-O-F chi-square testing, which are the same intervals in which the data were recorded. Final truncation distances were determined to be the points where detection probability was at least 0.15, as suggested by Buckland et al. (2001).

Data were pooled across all burn units to produce an overall detection curve and density estimate separately for each species with a minimum of 40 observations prior to truncation (Buckland et al. 2001). Final truncation ranged from 4m to 6m (n from 39 to 51) from the transect line to produce a more accurate density estimate. Covariate analyses were performed under the MCDS analysis engine, covariates included; temperature (˚C), wind speed (km/h), and time. Each was analyzed separately to examine which, if any, affected detectability. Model selection was based upon best visual fit and lowest Akaike Information Criterion (AIC; Akaike 1973, Burnham and Anderson 1998) adjusted for small sample size bias (AICc). If a model including a covariate yielded a lower AICc value than the previously selected model, a second covariate would be added to the selected model with one covariate. This stepwise approach continued until AICc value increased (Marques and Buckland 2003). Adjustment terms were introduced sequentially within each model and were selected by the results from likelihood ratio tests with significance at $p = 0.15$. That means, if a model type with one adjustment term had a significantly better fit, a second test between model types with one and two adjustment terms was performed. Overall model selection was based on AICc and AICc weighted values. Models with the lowest ΔAICc are considered the most parsimonious fits of the data. AICc weighted values are derived from ΔAICc and represent the relative strength of each model (Burnham and Anderson 1998).

Most biological populations exhibit some degree of clumping; therefore variance was calculated empirically, which was a more conservative approach than Poisson estimation. Non-parametric bootstrapping methods were used to calculate variance only when constraints influenced the shape of the curve or the use of adjustment terms produced the best fit (Buckland et al. 2001).

Habitat conditions were observed to change appreciably from link to link; thus, aggregating the data at a higher level, such as the level of the whole transect or management unit, would not permit a detailed examination of bird-habitat relations. Producing density estimates for each transect link requires an exceedingly large sample size to produce realistic results at the link level. For these and other reasons (non-normality and nonlinearity of raw and distance corrected data), bird survey data were reduced to presence/absence (categorical) data at the scale of a transect link (100 m) to permit evaluations of habitat associations. For simplicity and allow for nonlinear relations to habitat characteristics, each continuous habitat variable was equally split into high, medium and low categories. All analyses were performed at the scale of a 100 m transect link ($n = 183$). Relationships between individual bird species and year since burn, density of herbaceous vegetation, density of shrubs, and plant community type were examined using a series of chi-square tests (PROC FREQ; SAS Institute 1999). Significance values were adjusted according to the Bonferroni rule where needed.

Curvilinear logistic regression was also used to examine each individual bird/habitat relationship (PROC LOGISTIC; SAS Institute 1999). Vegetation variables were transformed by subtracting each observation from its mean and dividing by the standard deviation to produce z transformed data. Bird observations were treated as categorical presence/absence variables.

Structural equation modeling (SEM) (Bollen 1989, McCune and Grace 2002, Pugesek et al. 2004) was used to examine relations between individual bird species and habitat conditions in a multivariate framework. The goal of the SEM analysis was to determine the degree to which the association of birds with different post-burn conditions can be explained by related habitat features. Figure 2 presents the conceptual model that was formulated to guide the analyses. Density of shrubs and density of herbaceous vegetation were hypothesized to be influenced by year since burn and to potentially influence the probability of occurrence for birds. Of particular interest was whether relationships between year since burn and bird occurrence can be explained by intervening effects of shrubs and herbaceous plants (indirect pathways), or whether additional influences (represented by a direct path from year since burn to bird occurrence) would be significant. Additionally, selective associations of birds with herbaceous community types dominated by *Schizachyrium scoparium*, *Spartina spartinae*, or a mixture of the two species were also considered.

Because the primary response variables, presence or absence of bird species in a transect link, are binary, SEM was performed in a categorical modeling mode using Mplus (Muthén and Muthén 2004). Using a probit response basis, the analysis can be interpreted as seeking to explain variations in the underlying probabilities of birds being found under various habitat conditions. To make the habitat condition variables more compatible with a categorical model, variables describing both shrub density and herbaceous vegetation density were categorized as high, medium and low according to number of observations. Thus, all predictor variables were represented by categorical dummy variables as follows: (1) year since burn was represented by three variables "burnyr1", "burnyr2", and "burnyr3", with each being a 0 if false and 1 if true; (2) density of shrubs was represented by three variables, "low", "medium" and "high" (3) density

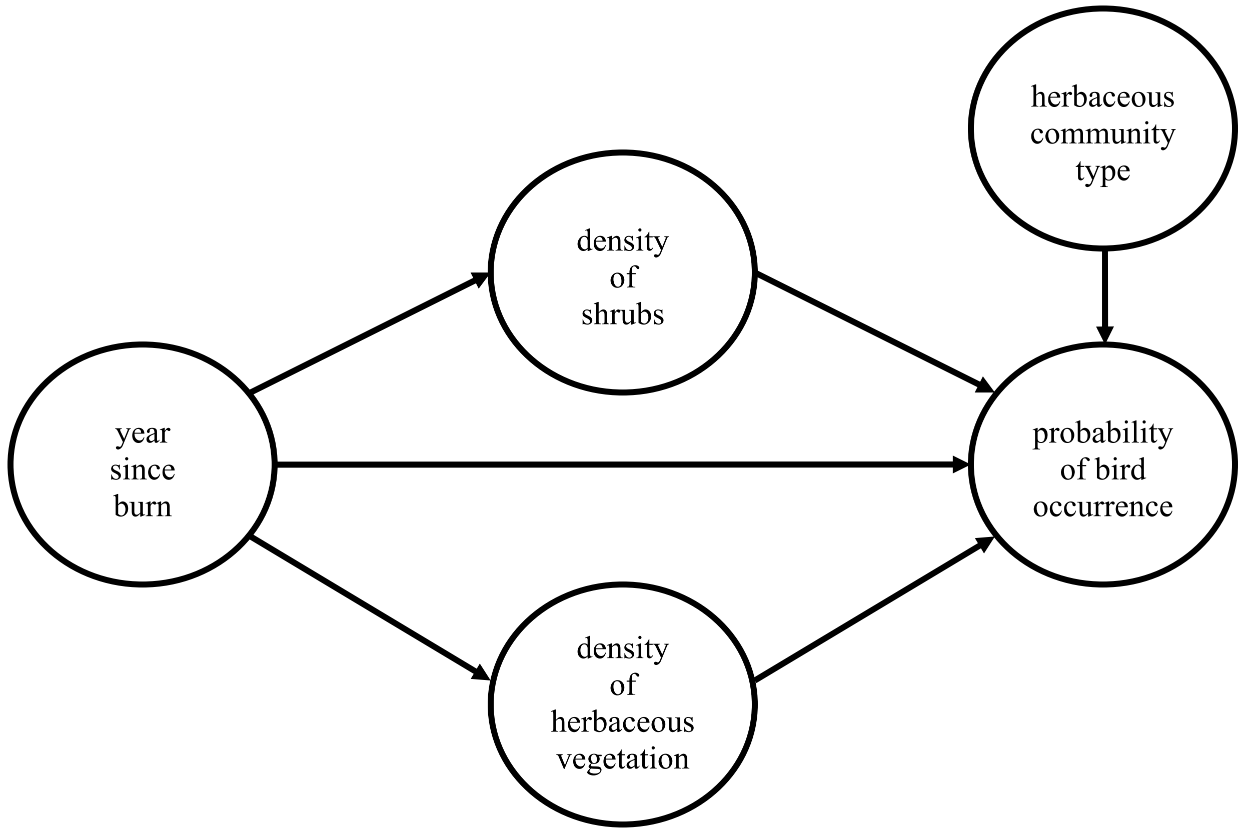

Figure 2. Conceptual (construct) model formulated to represent the theoretical relations of interest between the probabilities of bird occurrence and habitat conditions. The construct model was a precursor to the formulation of the structural equation model.

of herbaceous vegetation was also represented by “low”, “medium”, and “high”, and (4) community type was represented by three variables, “*Schizachryium*”, “*Spartina*”, and “mix”. As is standard in categorical modeling, one of the variables was always omitted to serve as the baseline condition.

Data were adjusted for the fact that samples were nested within burn units by using the “cluster” option in Mplus. This option accounts for non-independencies in the data by calculating adjusted standard errors and alternative tests of model fit that are robust to hierarchical sampling structure (Muthén and Satorra 1995). For all models (one for each of the four most common bird species), model fit was assessed using chi-squares calculated from a negative log likelihood fitting function. T-values and their associated p-values for individual parameters were also used in interpreting results. To aid with interpretation, composite variables (Heise 1972, Bollen and Lenox 1991) were included in models when the net effect of two, related and strongly intercorrelated variables occurred. Composites have the ability to represent the combined influence of two or more predictor variables on a response variable.

RESULTS

A total of 324 birds were observed during surveys and 22 species were observed throughout the study (Table 1). An average of 1.1 (SE ± 0.08) bird species were observed per transect, and an average of 5.3 (SE ± 0.43) species per unit. Species richness was not significantly different across burn years (df = 8, 1 vs. 2, t = -0.17, p = 0.871, 1 vs. 3, t = 0.30, p = 0.771, 2 vs. 3, t = 0.74, p = 0.481).

Histograms revealed that detectability decreased as distance from the centerline increased for all species except SAVS (Figure 3 and 4). The SAVS pattern suggested an observer-influenced response, with birds tending to move away from the observer prior to detection

(Figure 3b). I found that abundance curves could be produced that adjust for the presumed response to observer.

Six models were considered for estimating density of LCSP (n = 39). M_t (model including time of day as a covariate) had the largest affect on detectability with the lowest ΔAICc and highest AICc weighted value of 0.714 (vs. the next highest value of 0.265), strongly suggesting that it was the most parsimonious descriptor of variation in the data. I found that detectability increased as temperature increased. Probability of detecting an individual within 4 meters (truncation distance) was estimated to be 0.93 at 16˚C, 0.58 at 13˚C and 0.06 at 10˚C.

Four models were considered for SAVS (n = 49) and ΔAICc and AICc weighted values for all models were relatively similar. M (model without covariates) had the largest AICc weighted value of 0.394 and M_C [model including temperature (˚C) as covariate] and M_t had similar values of 0.222 and 0.220. M was selected as the best fit model for SAVS.

Four models were considered for SEWR (n = 46), with a fairly small ΔAICc across all models of 1.75. AICc weighted values for the first (M) and second (M_C) strongest model was 0.466 and 0.203. M_t, M_C, M_w [model including wind speed (km/h) as covariate] had fairly similar AICc weights suggesting they all affect detectability to the same degree.

Six models were considered for SWSP (n = 51). Of the models run with one covariate M_C was the best model with a ΔAICc 1.51 lower than the model excluding covariates. M_C was paired with a second covariate (M_{t+C} and M_{C+w}). M_{C+w} yielded a lower ΔAICc than M_C and an AICc weighted value of 0.380 (vs. 0.230 for M_C). M_{C+w} was selected as the best fit model, but AICc weights suggest that both M_{C+w} and M_C are reasonable fits, suggesting that wind speed had little affect on detection probability. Probability of detection increased as temperature increased and wind speed decreased. If wind speed was constant at 4 km/h, detection probability at 5 m

(truncation distance) increases from 0.11 at 11˚C to 0.64 at 14˚C, and if temperature was constant at 11˚C, detection probability decreases from 0.58 at 0 km/h to 0.09 at 4.2 km/h (Table 2).

Density estimates (D), estimated standard half-width (ESW) and detection probability (p-det) were reported for the best fit models (Table 3). ESW was a measurement of precision of the density estimate. The closer the ESW was to truncation distance, the greater precision of the density estimate. Constraints were not applied and adjustment terms were not necessary to produce the selected detection curves, therefore non-parametric bootstrapping methods were not necessary to estimate SE (Buckland 2001).

Density of LCSP was estimated to be 4.91 birds/ha (SE ± 1.49) with a 0.54 (SE ± 0.13) probability of detecting all individuals within survey area. ESW was 2.17 m (SE ± 0.51 m) with truncation at 4 m. Estimated density of SAVS was 2.87 birds/ha (SE ± 0.90) with a 0.78 (SE ± 0.11) probability of detecting all individuals within survey area. ESW was 4.66 m (SE ± 0.66 m) with truncation at 6 m. SEWR had an estimated density of 5.55 birds/ha (SE ± 1.97) with a 0.45 (SE ± 0.14) probability of detecting all individuals within survey area. Raw observations were truncated at 5 m and analyses produced an ESW of 2.27 m (SE ± 0.69 m). Estimated density of SWSP was 4.40 birds/ha (SE ± 1.48) with a 0.63 (SE ± 0.09) probability of detecting all individuals within the survey area. ESW was 3.16 m (SE ± 0.44 m) with truncation at 5 m.

Burn year had a significant relationship to every herbaceous and shrub variable recorded in the study. GRNDEN ($p < 0.0001$), VEGDEN ($p < 0.0001$), and VEGHT ($p < 0.0001$) all increase from low to high as time after burn increases. ALLSHR ($p < 0.0001$) and LBACC ($p < 0.0001$) increases from low to high, and DBACC ($p < 0.0001$) decreases from high to low as time since burn increases (Table 4).

Table 1. List of species observed throughout study.

Mottled Duck	*Anas fulvigula*
Northern Harrier	*Circus cyaneus*
White-tailed Hawk	*Buteo albicaudatus*
Sandhill Crane	*Grus canadensis*
Barn Owl	*Tyto alba*
Eastern Phoebe	*Sayornis phoebe*
Loggerhead Shrike	*Lanius ludovicianus*
Marsh Wren	*Cistothorus palustris*
Sedge Wren	*Cistothorus platensis*
American Robin	*Turdus migratorius*
Sprague's Pipit	*Anthus spragueii*
Yellow-rumped Warbler	*Dendroica coronata*
Common Yellowthroat	*Geothlypis trichas*
Grasshopper Sparrow	*Ammodramus savannarum*
Henslow's Sparrow	*Ammodramus henslowii*
Le Conte's Sparrow	*Ammodramus leconteii*
Savannah Sparrow	*Passerculus sandwichensis*
Lincoln's Sparrow	*Melospiza lincolnii*
Swamp Sparrow	*Melospiza georgiana*
Northern Cardinal	*Cardinalis cardinalis*
Eastern Meadowlark	*Sturnella magna*
Red-winged Blackbird	*Agelaius phoeniceus*

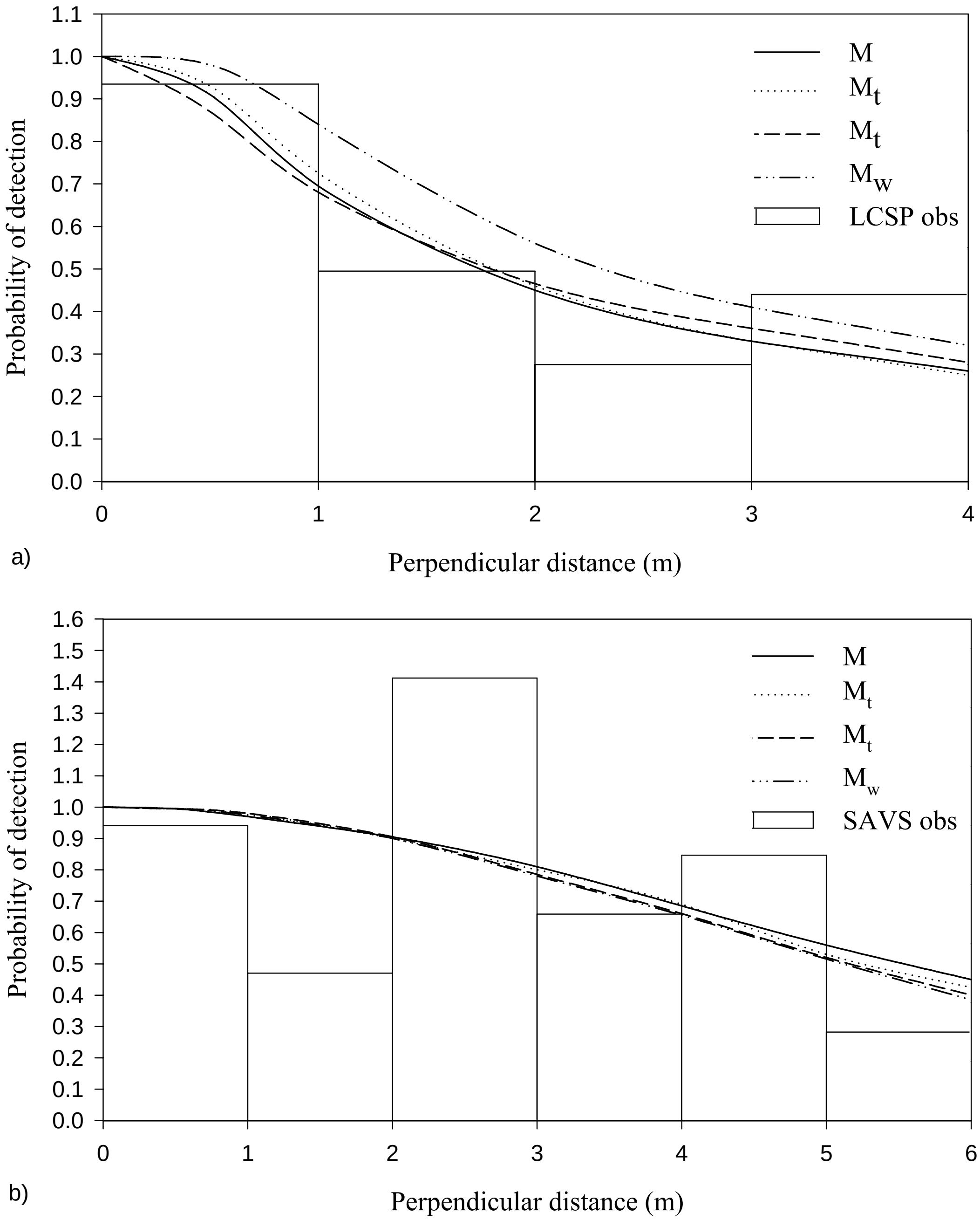

Figure 3. Detection curves of competing models for (a LCSP and (b SAVS. Curves compare influence of covariate on detection curve: M = no covariates, M_t = time of day, M_C = temperature and M_w = wind speed (km/h).

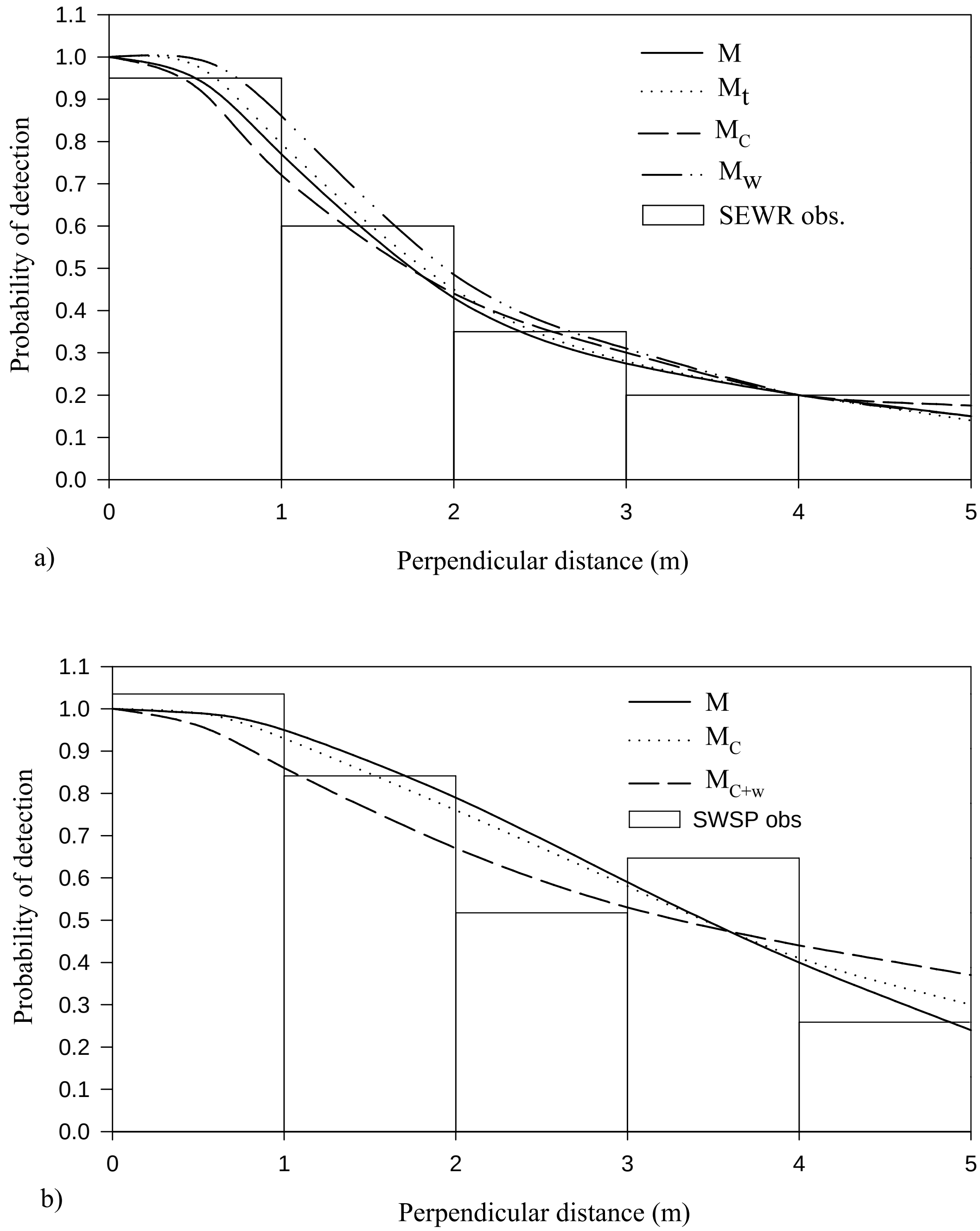

Figure 4. Detection curves of competing models for (a SEWR and (b SWSP. Curves compare influence of covariate on detection curve: M = no covariates, M_t = time of day, M_C = temperature, and M_w = wind speed.

Table 2. Model selection of DISTANCE results. Models with ΔAICc=0 are considered the most parsimonious fits of the data. AICc weighted values were derived from ΔAICc and represent the relative strength of each model.

Model[a]	Model[b]	ΔAICc	AICc weights
LCSP			
M_C	HN	0.00	0.714
M_{C+w}	HN	1.98	0.265
M_{C+t}	HZ	8.19	0.012
M	HZ	9.86	0.005
M_t	HZ	12.08	0.001
M_w	HZ	12.59	0.001
SAVS			
M	HN	0.00	0.394
M_C	HC	1.15	0.222
M_t	HN	1.16	0.220
M_w	HN	1.75	0.164
SEWR			
M	HR	0.00	0.466
M_C	HR	1.66	0.203
M_t	HR	1.79	0.190
M_w	HR	2.39	0.141
SWSP			
M_{C+w}	HN	0.00	0.380
M_C	HN	1.00	0.230
M	HN	1.51	0.178
M_{C+t}	HN	3.17	0.078
M_t	HN	3.39	0.070
M_w	HN	3.56	0.064

[a] Models compared are testing for effects on detectability that include: C = temperature (˚C), w = wind speed (km/h), and t = time.
[b] Models were selected within DISTANCE by best visual fit and low AICc value. No adjustment terms were necessary to produce the selected models (description of methods to select adjustment terms are found in text). Models include HN (half-normal: Hermite polynomial), HC (half-normal: cosine), HZ (hazard-rate: cosine), HR (hazard-rate: simple polynomial, UC (Uniform: cosine), US (Uniform: simple polynomial).

Table 3. DISTANCE results from the best fit model for each species. Results include: sample size (n) following final truncation, density estimate (D = number of birds/hectare), estimated standard half-width (ESW), and probability of detection (p-det).

Species / Model[a]	n[b]	D	SE(D)	ESW[c]	SE(ESW)	p-det[d]	SE(p-det)
LCSP / M_C	39	4.91	1.49	2.17	0.51	0.54	0.13
SAVS / M	49	2.87	0.90	4.66	0.66	0.78	0.11
SEWR / M	46	5.55	1.97	2.27	0.69	0.45	0.14
SWSP / M_{C+w}	51	4.40	1.48	3.16	0.44	0.63	0.09

[a] Models testing for effects on detectability include: C = temperature (˚C), w = wind speed (km/h), and t = time.
[b] Data were truncated for each species at different distances from the centerline: LCSP at 4m, SAVS at 6m, SEWR and SWSP at 5m.
[c] ESW was the perpendicular distance from the line for which the number of objects closer to the line that are missed equals the number of objects farther from the line within truncation distance.
[d] p-det was the probability of detecting all objects in the survey area.

A significant relationship was found between burn year and the presence of three of the four most common bird species (Figure 5a). LCSP were more common in 2- than 3-yr burn ($p = 0.0157$). SAVS were more common in 1- than 2-yr burn ($p = 0.0003$) and 3-yr burn ($p < 0.0001$) sites. SEWR were more common in 2-yr ($p = 0.0147$) and 3-yr ($p = 0.0001$) than 1-yr burn sites with no significant difference found between 2- and 3-yr burn. No significant relationships were found between burn year and SWSP.

Time since burn had no relationship with community type. *Schizachyrium* was the most common community type dominating 44% of all sites, *Spartina* was second dominating 29%, and 27% of the sites were dominated by a mixture of both species. Only one overall significant relationship was found between SAVS and plant community type ($p = 0.0026$). LCSP were more common in mixed vs. *Spartina* ($p = 0.0466$), SAVS were more common in mixed vs. *Schizachyrium* ($p = 0.0242$) and *Spartina* ($p = 0.0012$). SEWR were more common in *Schizachyrium* ($p = 0.0493$) or *Spartina* (0.0189) vs. mixed (Figure 5b). No significant relationship was found between abundance and the presence of water. Under Bonferoni rule, all pairwise comparisons regarding the above analyses are considered significant if $p < 0.016$.

LCSP were more common in areas of medium VEGDEN ($p = 0.0148$) and low VEGHT ($p = 0.0164$). GRNDEN was split into four categories, and LCSP were more common in medium-low density ($p = 0.0278$). LCSP were more common in areas of low ALLSHR ($p = 0.0184$) and low and medium LBACC ($p = 0.0427$). No significant relationship was found with height of shrubs. LCSP were less common where Macartney rose (*Rosa bracteata*) ($p = 0.0026$) were present, and more common where Wax myrtle (*Morella serifera*) ($p = 0.0048$) was present (Figure 6).

Table 4. List of raw number of transect links (n = 183) and proportion in each category of: total pole contacts (VEGDEN), contacts 0-20 cm from the ground (GRNDEN), vegetation height (VEGHT), shrub density (DENSHR), live saltbush density (LBACC), dead saltbush density (DBACC) and height for each shrub variable across burn treatments. All variables in this table significantly vary between burn years ($p < 0.05$).

		Burn 1			Burn 2			Burn 3		
		Low	Medium	High	Low	Medium	High	Low	Medium	High
VEGDEN	#[a]	46	10	4	13	27	23	3	18	39
	prop	0.766	0.167	0.067	0.206	0.429	0.365	0.050	0.300	0.650
GRNDEN	#	44	12	4	12	28	23	2	18	40
	prop	0.734	0.200	0.066	0.191	0.444	0.365	0.033	0.300	0.667
VEGHT	#	32	23	5	19	28	16	9	21	30
	prop	0.533	0.383	0.084	0.302	0.444	0.254	0.150	0.350	0.500
DENSHR	#	32	7	21	21	24	18	8	30	22
	prop	0.533	0.117	0.350	0.333	0.381	0.286	0.133	0.500	0.367
LBACC	#	42	7	11	14	30	19	5	23	32
	prop	0.700	0.117	0.183	0.222	0.476	0.302	0.084	0.383	0.533
DBACC	#	6	9	45	43	11	9	37	16	7
	prop	0.100	0.150	0.750	0.682	0.175	0.143	0.616	0.267	0.117
DENSHR HT	#	10	25	25	41	12	10	12	22	26
	prop	0.166	0.417	0.417	0.650	0.191	0.159	0.200	0.367	0.433
LBACC HT	#	12	9	14	23	28	12	1	25	34
	prop	0.343	0.257	0.400	0.365	0.444	0.191	0.017	0.417	0.566
DBACC HT	#	9	29	14	8	4	0	13	8	2
	prop	0.173	0.558	0.269	0.667	0.333	0	0.565	0.348	0.087

[a] # is the number of transect links in each category for each measurement.
prop = proportion of total links in each category for each measurement.

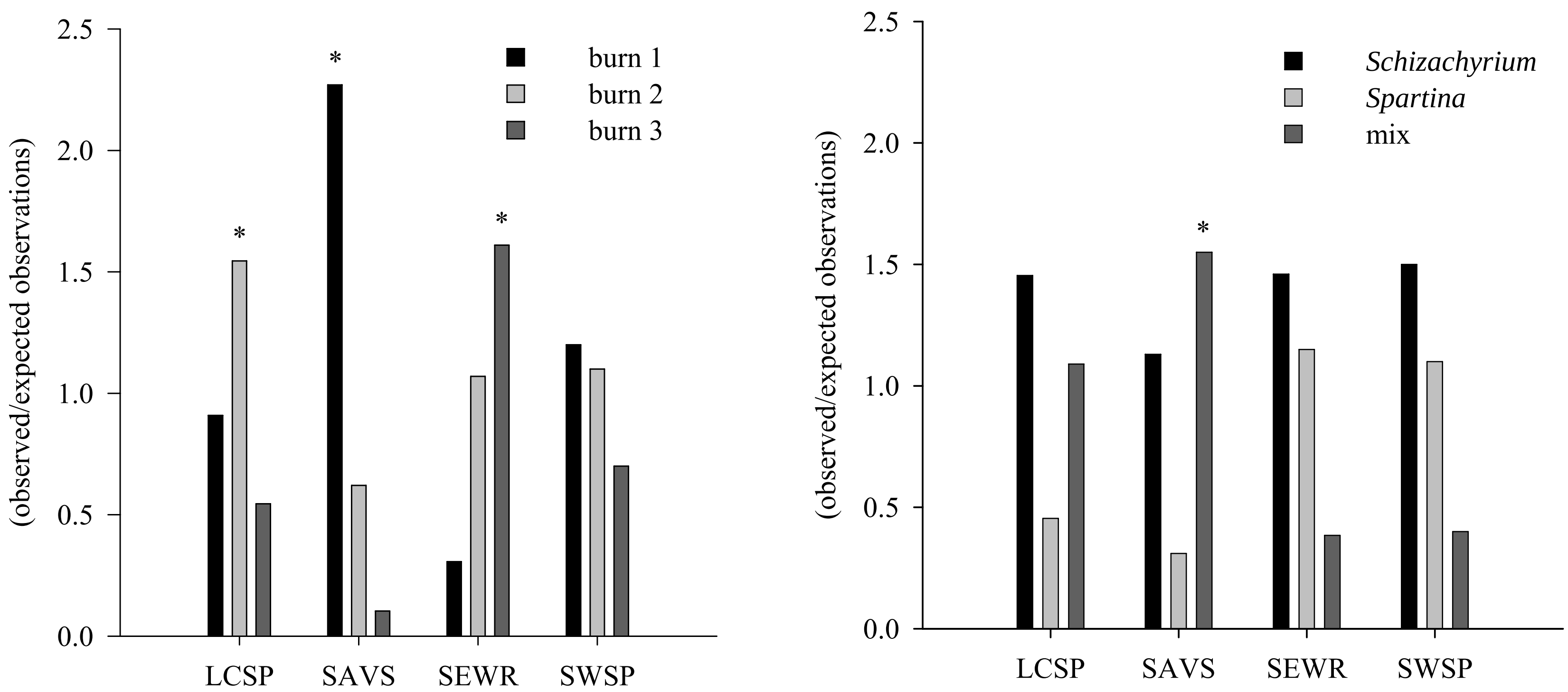

Figure 5. Ratio (observed/expected) of observations for each a) burn treatment, and b) community type. Asterisk (*) indicates significance between ratios for each species in each category ($p < 0.05$).

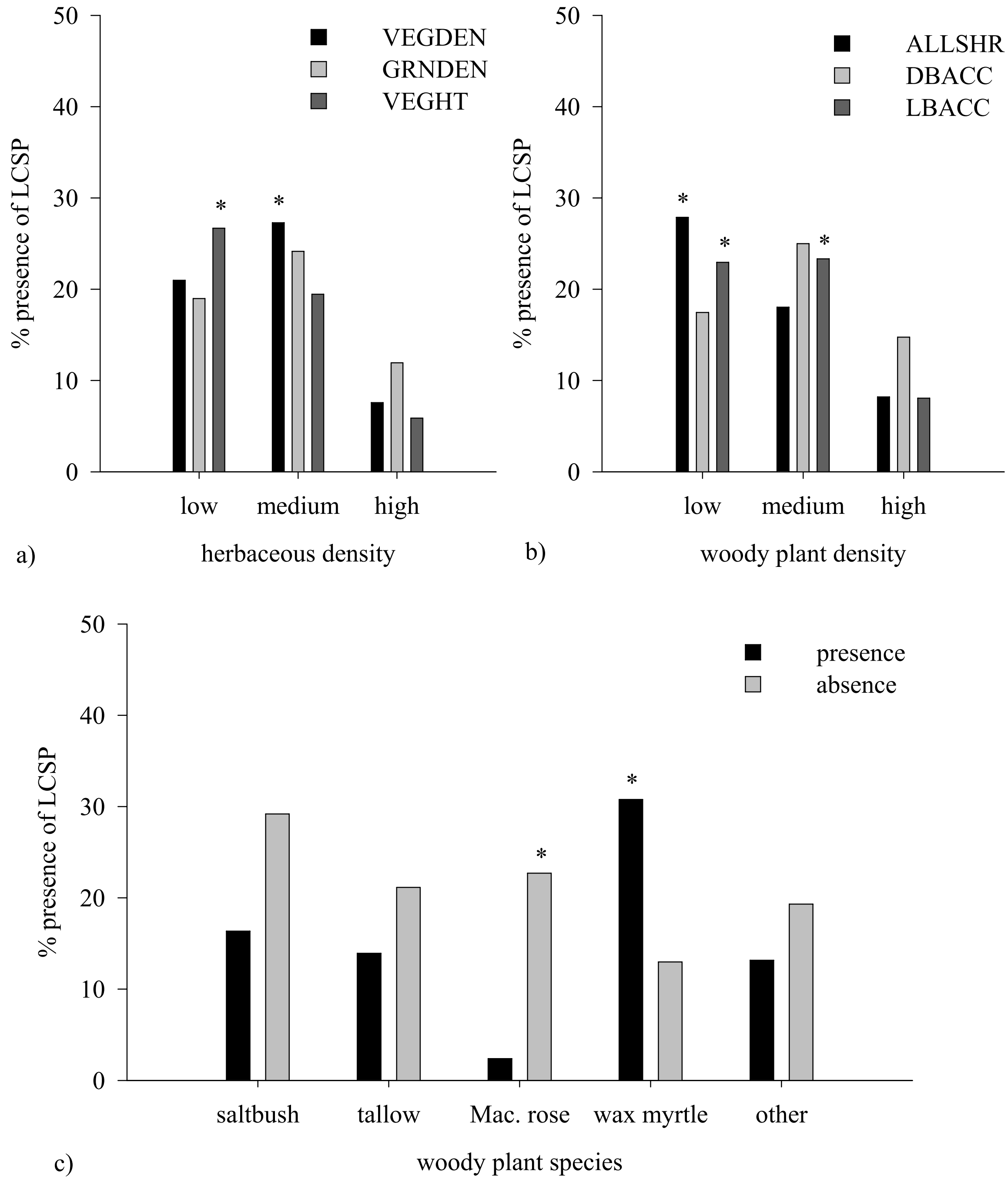

Figure 6. Percent of sites where LCSP were present in each category of a) herbaceous density, b) woody plant density, and c) woody plant species. Asterisk (*) indicates significance across categories for each variable (a and b) and for each shrub species individually (c).

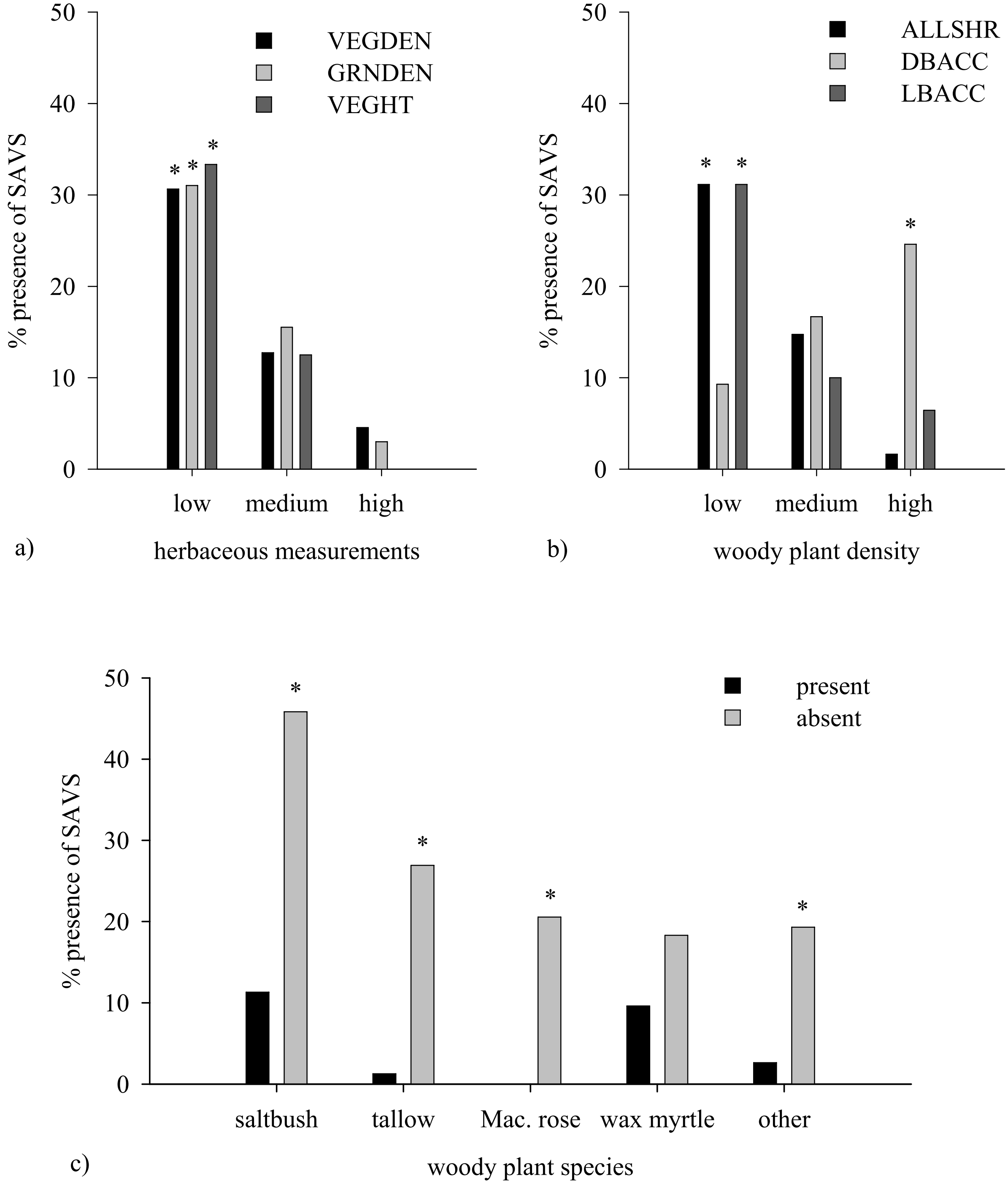

Figure 7. Percent of sites where SAVS were present in each category of a) herbaceous density, b) woody plant density, and c) woody plant species. Asterisk (*) indicates significance between density categories (a and b) for each variable, and for each woody plant species separately (c).

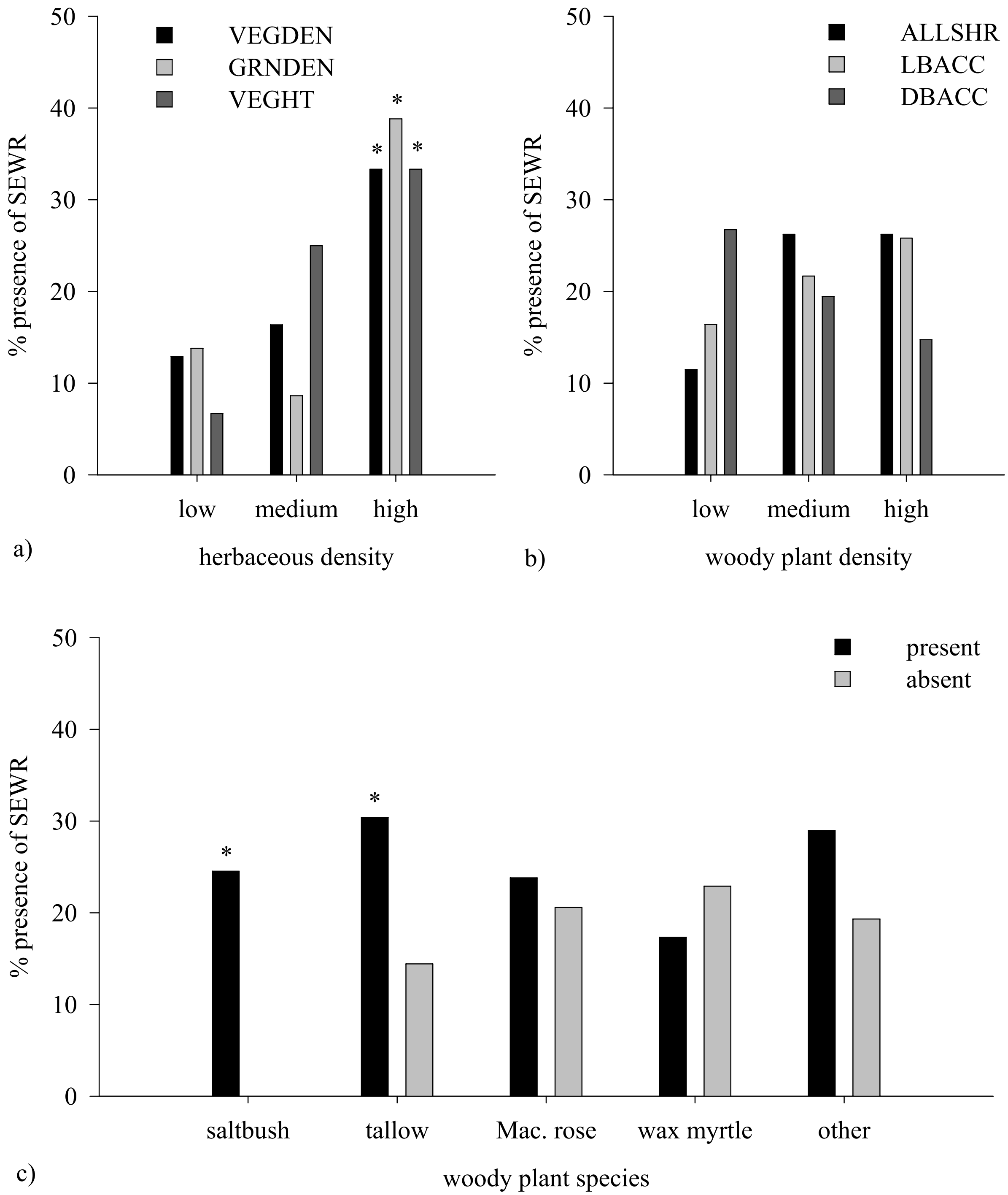

Figure 8. Percent of sites where SEWR were present in each category of a) herbaceous density, b) woody plant density, and c) woody plant species. Asterisk (*) indicates significance across categories for each variable (a and b) and for each shrub species individually (c).

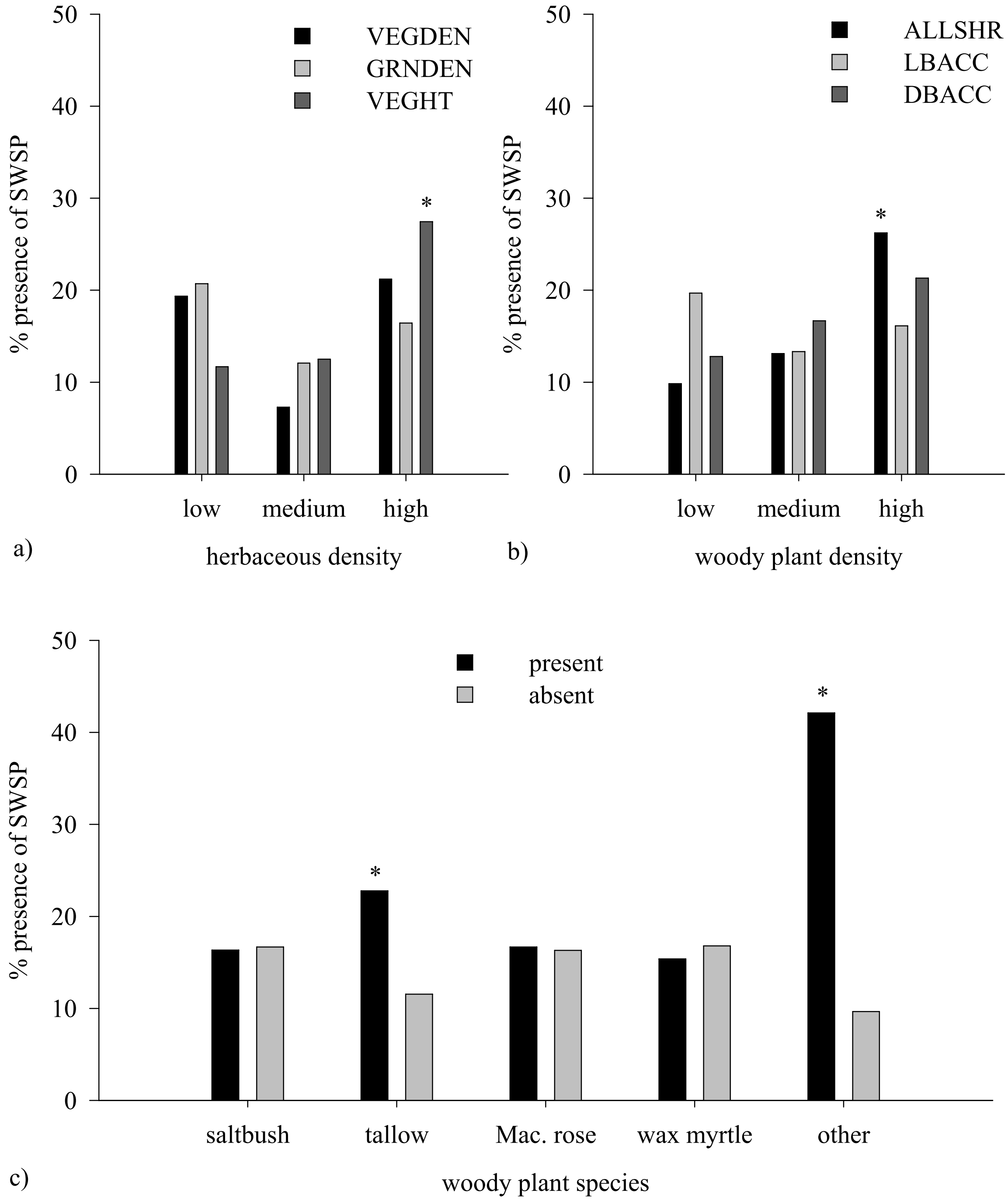

Figure 9. Percent of sites where SWSP were present in each category of a) herbaceous density, b) woody plant density, and c) woody plant species. Asterisk (*) indicates significance across categories for each variable (a and b) and for each shrub species individually (c).

SAVS were significantly more common in areas with low herbaceous density and low shrub density; VEGDEN ($p = 0.0002$), GRNDEN ($p = 0.0002$), VEGHT ($p < 0.0001$), ALLSHR ($p < 0.0001$), LBACC ($p = 0.0003$). SAVS were more common in areas of high DBACC ($p = 0.0433$) densities. No significant relationship to shrub height was found. Savannah Sparrows were more common where saltbush ($p < 0.0001$), tallow ($p < 0.0001$), Macartney rose ($p = 0.0014$) and other woody species ($p = 0.0122$), including *Ulmus* sp., *Ilex* sp. and other unidentifiable woody plants, were absent (Figure 7).

SEWR were more common in areas of high VEGDEN ($p = 0.0105$), GRNDEN ($p = 0.0021$), and VEGHT ($p = 0.0209$). No significant relationships to shrub densities or shrub heights were found. SEWR were more common in areas where saltbush ($p = 0.0062$) and tallow ($p = 0.0090$) were present (Figure 8).

SWSP were more common in high VEGHT ($p = 0.0423$), but no significant relationships were found for any other herbaceous measurements. They were more common in areas of high ALLSHR ($p = 0.0351$), but no significant relationships were found for any other shrub density or height. They were more common in areas where tallow ($p = 0.0418$) and other woody species ($p < 0.0001$) were present (Figure 9). Curvilinear regression was explored for all bird/vegetation relationships and revealed only one significant relationship between SWSP and GRNDEN (chi-square = 4.12, df = 1, $p = 0.0424$).

Structural Equation Modeling

Figures 10 thru 13 shows summaries of the SEM results for LCSP, SAVS, SEWR, and SWSP. Only variables that remained in the models are presented. The results for LCSP reveal that the probability of occurrence was positively and directly related to low shrub density and a medium density of herbaceous vegetation. LCSP were indirectly associated with recently burned

sites (burn years 1 and 2), though this can be explained by the presence of low levels of shrubs in such sites. They were more likely to be seen in areas dominated by bluestem or a mixture of Gulf cordgrass and bluestem than in areas that were strictly Gulf cordgrass. Because the shrub, herbaceous, and community type variables are largely uncorrelated, their influences can be directly compared based on the magnitudes of the standardized path coefficients. From this perspective, LCSP were most strongly associated with open areas low in shrub density (0.47), and somewhat less related to medium herbaceous densities and the two community types containing bluestem (both with coefficients of 0.27) (Figure 10).

SAVS were found in areas with low levels of herbaceous vegetation, regardless of shrub densities. Such areas were very highly associated with areas burned within one year, though they were sometimes also found in areas burned within two years. Thus, SAVS were indirectly related to recently burned sites. SAVS were modestly more common in mixed community type (Figure 11).

SEWR avoided areas having low and medium herbaceous density. This represents the only direct relationship to habitat found for this species. Low levels of herbaceous vegetation were, in turn, most strongly associated with areas burned within the previous year. Medium levels of herbaceous vegetation could be found in areas with any burn history (Figure 12).

SWSP were the only species unrelated to year since burn, either directly or indirectly. They were, however, associated with high shrub density and unrelated to herbaceous plant density. SWSP were uncommon in mixed prairie, but instead, positively associated with both bluestem and Gulf cordgrass communities. Of all species examined in this study, SWSP were most weakly associated with the habitat parameters measured (R-square = 0.18) (Figure 13).

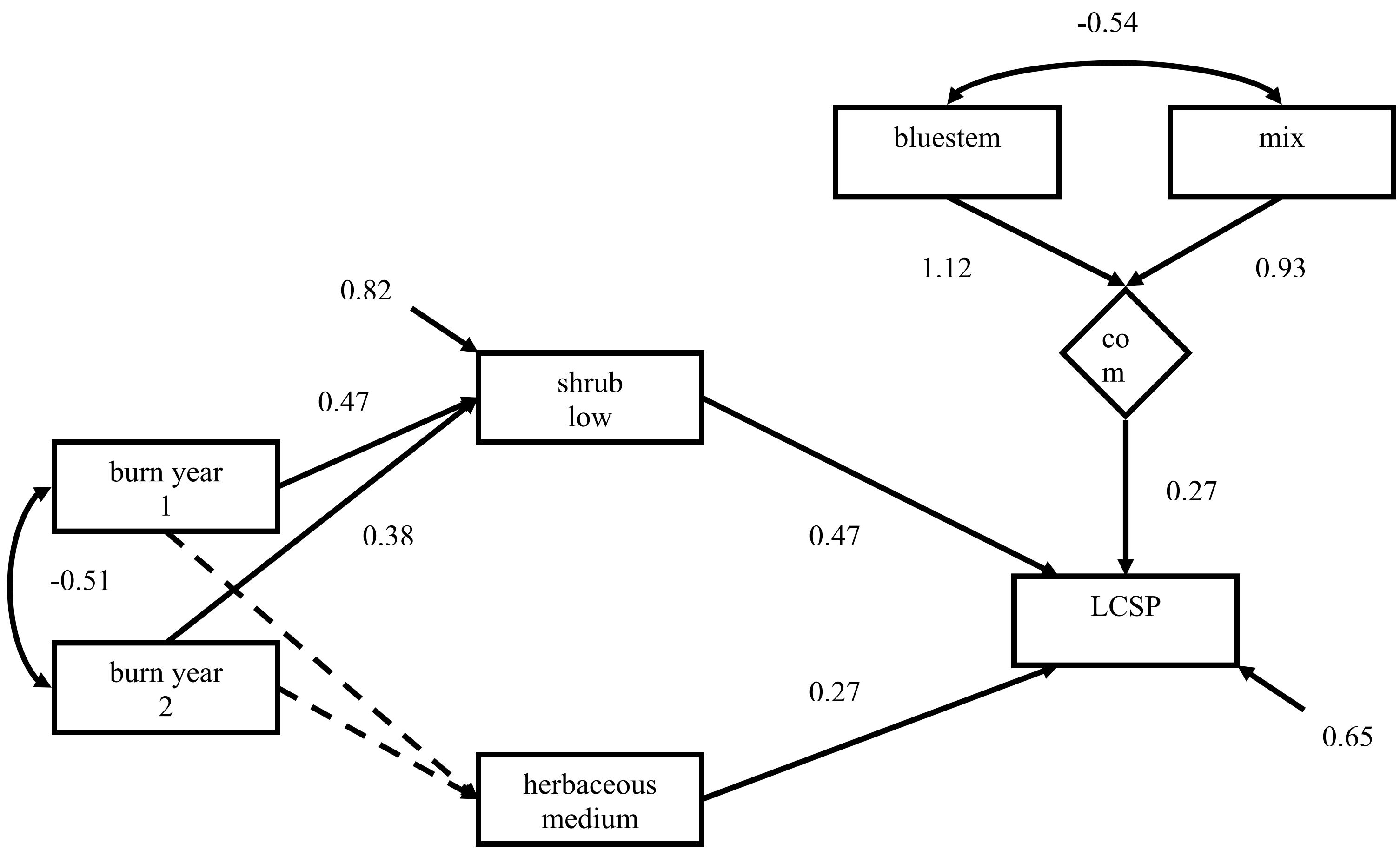

Figure 10. SEM results for LCSP. Values presented are standardized parameters. Dashed lines indicate paths not detectably different from zero. The diamond labeled "com" represents a composite giving the net influence of all vegetation types on the probability of bird presence.

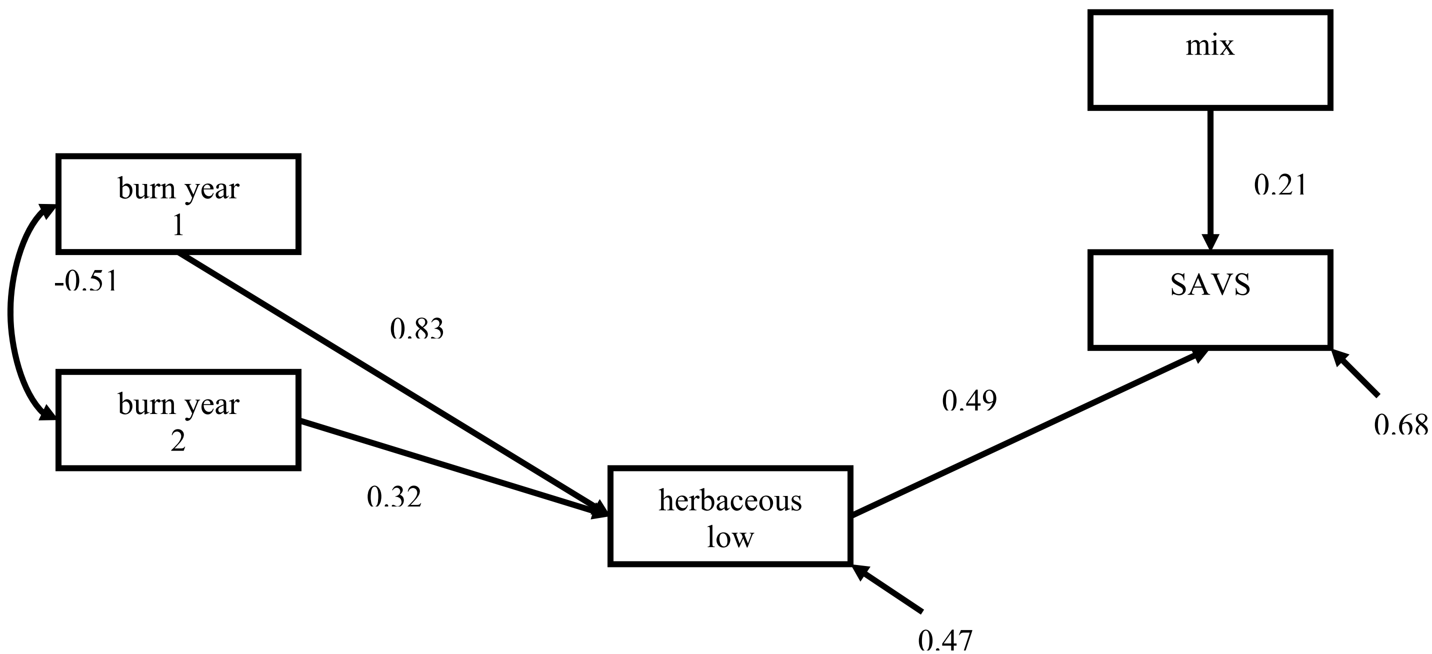

Figure 11. SEM results for SAVS. Values presented are standardized parameters.

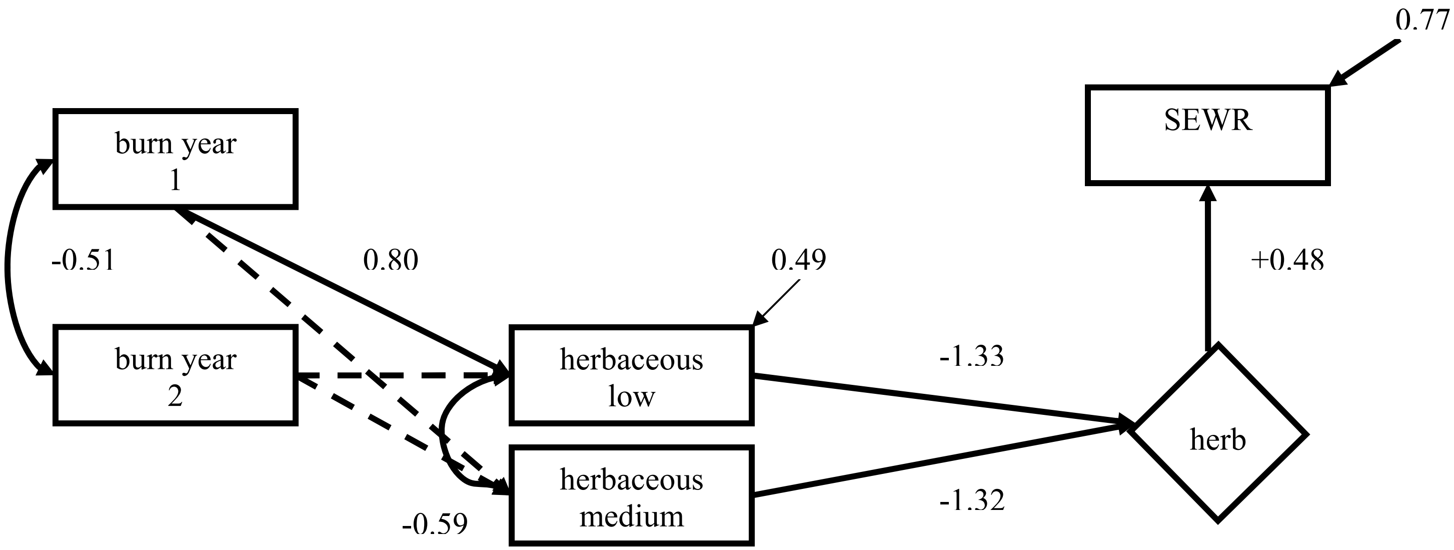

Figure 12. SEM results for SEWR. Values presented are standardized parameters. Dashed lines indicate paths not detectably different from zero. The diamond labeled “herb” represents a composite giving the net influence of herbaceous vegetation on the probability of bird presence.

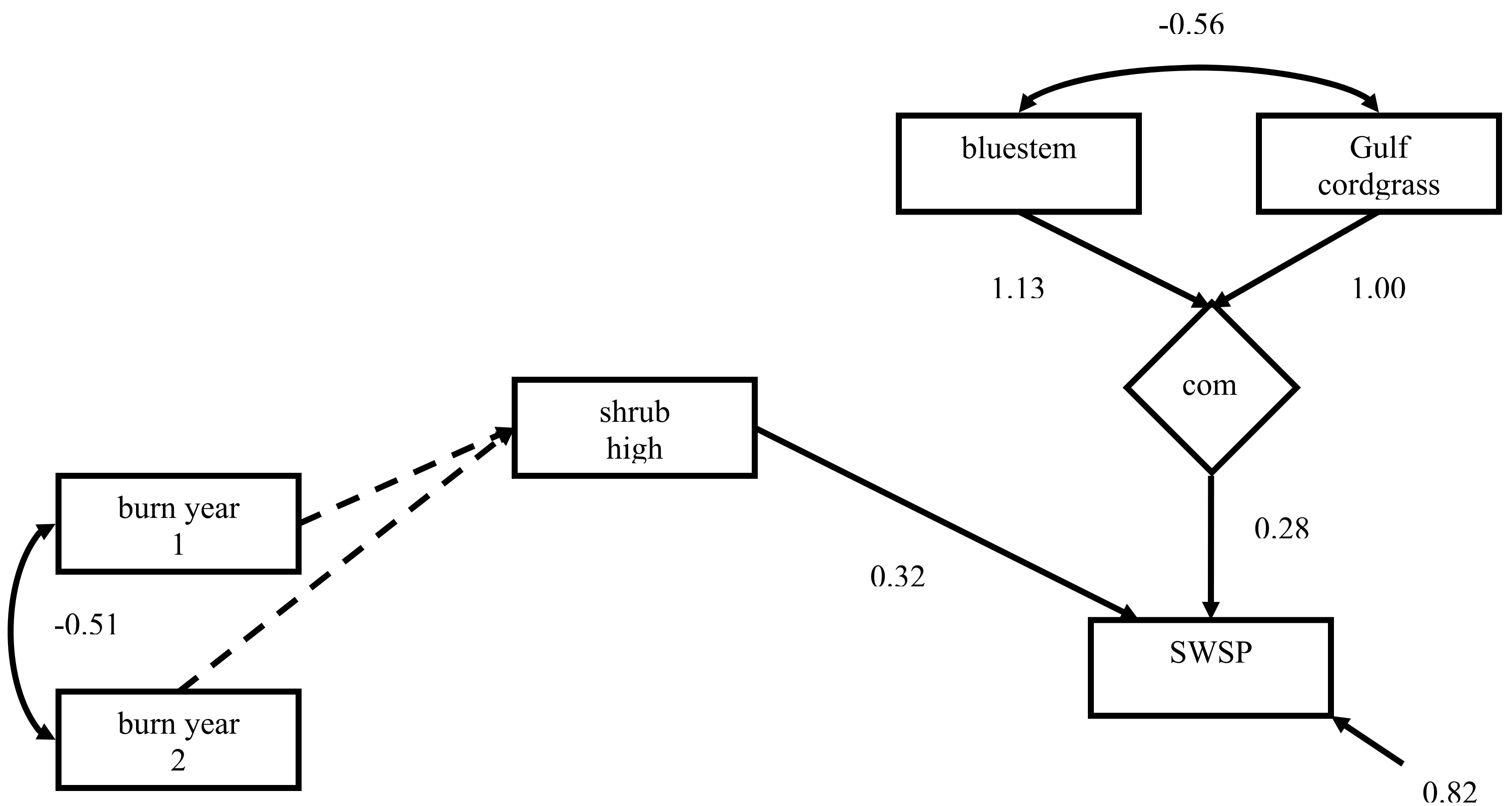

Figure 13. SEM results for SWSP. Values presented are standardized parameters. Dashed lines indicate paths not detectably different from zero. The diamond labeled “com” represents a composite giving the net influence of all vegetation types on the probability of bird presence.

DISCUSSION

LCSP, SAVS and SEWR are strongly associated with particular habitat conditions, thereby, influenced by time since burn. It also appears that each species has a different relationship to habitat conditions and fire management. SWSP demonstrated the weakest relationship to habitat variables measured in this study.

Species richness was not significantly different between burn treatments or herbaceous and woody plant density categories. The implications of these results are cautioned due to having only one year of data (Wiens 1981). Other studies have found that increased shrub density decreases grassland bird abundance but increases species richness (Wiens and Rotenberry 1981, Coppedge et al. 2001, Ribic and Sample 2001). Species richness is relatively low in grassland bird communities (Cody 1966, Johnsgard 2001). It is important to keep in mind that for conservation purposes, increased species richness is only a relevant measurement when all species are actually grassland dependent birds.

Time since burn was highly correlated with herbaceous vegetation and shrub density. Grasslands have a simple structure and the structure following fire is generally quite predictable. Bock and Bock (1990) found that vegetation structure will reassert itself quickly from surviving roots and will reach pre-burn structure within three years post-burn. Allain and Grace (2001) found that the susceptibility of woody plants to fire varies with fire intensity, age of plant, and season of burn, which reduces the efficiency of fire on woody plant control. Despite the dynamic characteristics of coastal prairie such as variable salinity, soil type, elevation variability and aggressive invasion of woody plants, which leads to heterogeneity in structure and fire intensity, the predictability of herbaceous and woody succession following fire is not greatly affected.

Patterns of bird/habitat relationships were found between three of the four species included in this study. It is an accepted finding that different species have specific requirements or more properly preferences or conditions that they are commonly associated (Pulliam and Mills 1977). As with many previous studies, these conditions generally are associated with vegetation measurements describing structure. Hypotheses attempting to explain these relationships primarily relate to food abundance (Tucker and Robinson 2003) and predator avoidance strategies (Pulliam and Mills 1977).

Seeds make up the primary diet of overwintering LCSP (Easterla 1962) and SAVS (Martin et al. 1951) and both spend much of their time on the ground. Therefore, a dense litter layer may affect foraging efficiency and mobility. LCSP were most often found in areas of medium vegetation density with low to medium litter densities, suggesting that they do not prefer areas with a dense litter layer. Gabrey et al. (1999) and Baker (1973) found that numerous species, particularly those associated with dense vegetation, temporarily avoided areas recently burned. On the wintering grounds, LCSP have been found to be less common following winter burns (Reynolds and Krausman 1998), possibly due to insufficient cover and low seed abundance. SAVS were most common in areas with low herbaceous vegetation density. These areas may have sufficient seed abundance yet less cover than areas with medium herbaceous density. SAVS may compensate for this by their capability of stronger, faster flight than LCSP. Studies of LCSP on the breeding grounds suggest they avoid high shrub densities (Dale et al. 1997, Madden et al. 1999, and Igl 1999) consistent with our results on the wintering grounds for both LCSP and SAVS. Low shrub density roughly correlates with low herbaceous vegetation. Additionally, high shrub density likely reduces grass seed production.

SEWR were most common in areas of dense herbaceous vegetation, but showed no relationship to shrub density or height. They were also associated with areas where saltbush and tallow were present. This is likely an indirect association with time since burn. Their association with dense herbaceous vegetation is likely related to their insectivorous winter diet (Howell 1932, Imhof 1976). Wiens (1973) found that carnivorous bird species were associated with more dense vegetation structure and omnivorous bird species associated with more sparse vegetation. Dense cover may serve as insulation and allow a sufficient abundance of insects to remain active enough to sustain overwintering SEWR populations.

SWSP were most common in areas of tall vegetation and high shrub densities, but demonstrated no relationship to herbaceous vegetation densities. SWSP reportedly use a variety of habitat types, which may explain the lack of significant habitat relationships (Mowbray 1997). Previous studies have found optimal habitat for SWSPs are marshes with open water and available perches (Mowbray 1997). The area with the highest concentration of SWSP was bordered on two sides by a river with small ponds located in the unit. This area also had the highest concentration of shrubs and small trees in the study.

LCSP and SEWR were almost always solitary when flushed in this study and most commonly found in areas with dense herbaceous vegetation. Grzybowski (1983) found that solitary passerines were not observed in sparsely vegetated areas. Solitary passerines are at greater risk of predation when foraging in sparse vegetation, versus foraging in groups, which would enhance predator detection. SAVS are more common in areas of sparse vegetation where they may be more vulnerable to predation, yet they usually feed in loose groups and are strong flyers. SEWR and LCSP are relatively weak flyers and may rely on their cryptic behavior and sufficient cover for predator defense.

My results indicate that different species are responsive to succession management using fire, and predictable associations with vegetation characteristics were found for most species. The abundance of grassland sparrows generally decreased in areas with high densities of woody plants. Therefore, maintaining a mosaic of prairie in different successional states, and controlling woody invasive such as tallow and saltbush, will help provide sufficient habitat for these species.

MANAGEMENT RECOMMENDATIONS

In the southern United States, grassland birds depend, in part, on a network of wildlife refuges along the gulf coast for winter habitat. I suggest maintaining a mosaic of areas with differing burn rotations of 2 and 3 years, with an emphasis on reducing woody vegetation.

Encouragement of tallgrass prairie restoration programs occurring in Louisiana and Texas are necessary to maintain grassland dependant bird populations, such as LCSP and SEWR, by increasing available habitat. These results may be used as a baseline for evaluation of prairie restoration efforts for overwintering grassland birds in coastal prairie.

HOME RANGE SIZE AND SITE FIDELITY OF OVERWINTERING LE CONTE'S SPARROWS

Within-season site fidelity is a common behavioral characteristic for many overwintering grassland birds, including: Henslow's Sparrow (*Ammodramus henslowii*) (Plentovich et al. 1998, Krementz and Thatcher 2001), Cassin's Sparrow (*Aimophila cassinii*), Grasshopper Sparrow (*Ammodramus savannarum*), Baird's Sparrow (*Ammodramus bairdii*), Vesper Sparrow (*Pooecetes gramineus*), Savannah Sparrow (*Passerculus sandwichensis)*, and Brewer's Sparrow (*Spizella breweri*) (Gordon 2000). Familiarity with an area may increase an individual's ability to acquire resources and avoid predators. Conservation of wintering grounds for species exhibiting high site fidelity may increase overwinter survival and positively influence breeding communities (Pulliam and Enders 1971, Fretwell 1972, Wiens 1974, Raitt and Pimm 1976, Grzybowski 1982).

Le Conte's Sparrows (*Ammodramus lecontii*) are short-distance migrants that commonly inhabit wet fields, tall grasslands, and marshes (Madden 1996). Their breeding range extends from central Canada to north central United States (Murray 1969). Their winter range extends from southern Texas to the Florida panhandle north to southern Illinois and central Missouri (Hubbard 1978, Kain 1987, Robinson 1990, Robertson and Woolfenden 1992, McNair and Post 1993). They are fairly uncommon over much of their range with the highest densities found in the western portions of their range (Lowther 1996). They arrive on wintering areas in November (Murray 1969) and are suspected to begin spring migration in early March (Cecilia Riley, Gulf Coast Bird Observatory, pers. comm.).

Little is known about the general ecology of Le Conte's Sparrows (LCSP), largely due to their secretive behavior (Igl and Johnson 1999). They reluctantly flush from observers and spend much of their time on the ground. Most literature describing their ecology is focused on

the breeding grounds and describes habitat relationships. LCSP prefer dense vegetation (Dale et al. 1997) and are more common in grasslands with a relatively high frequency of fire (Madden et al. 1999). Only two studies have examined LCSP winter ecology. Reynolds and Kraussman (1998) examined abundance and species richness following winter burns, and Grzybowski (1983) measured frequency of occurrence of unmarked individuals to describe space-use patterns of nine grassland bird species. LCSP are solitary and appear to inhabit small home ranges because they are only spaced 11 m to 42 m from other individuals (Grzybowski 1983). Although Grzybowski's findings were substantial, there is uncertainty that re-siting at a particular location were the same individual during the entire season. Additionally, no published information was found describing annual or intra-seasonal site fidelity.

Movement patterns of overwintering LCSP may influence restoration and maintenance strategies of prairie. Overwintering LCSP were found to be more abundant in areas two years post burn with medium vegetation density and a low to medium litter layer density (Baldwin et al. unpublished data). If LCSP tend to be nomadic, then maintaining unburned areas with similar vegetation and leaf litter densities adjacent to burned areas may be considered. If LCSP are relatively sedentary throughout the winter season, and managed areas do not have suitable adjacent habitat, then winter burning should be avoided. In this study, LCSP's were radio-marked to estimate home range size and monthly banding efforts were conducted to estimate within season site fidelity. High recapture rates, and home range sizes < 2 hectares were expected.

STUDY AREA AND METHODS

This study was conducted during the winter of 2002-03 at the Hoskins Mound Prairie, Brazoria National Wildlife Refuge, Texas. This refuge is part of the Texas Mid-Coast National

Wildlife Refuge Complex and is located along the upper Texas Gulf Coast. Prior to purchase in 1990, the land was used for rice farming and cattle ranching, which contributed to the dissection of the refuge into numerous well-defined units or areas surrounded by fire breaks such as levees, roads and ditches. Units included in this study were those that appeared to be well recovered from such disturbances (Grace and Allain, pers. comm.), probably due to adjacent seed banks. Dominant plant species in the units studied included little bluestem (*Schizachyrium scoparium*), broom sedge (*Schizachyrium virginicus*), cord grass (*Spartina patens*), switchgrass (*Panicum scoparium*), *Muhlenbergia expansa*, *Iva angustifolia*, *Tridens strictus*, *Dichanthelium* and sedges (*Cyperus* sp.). Saltbush (*Baccharis halemifolia*), a native and invasive shrub commonly found in coastal areas, occurred in scattered clumps throughout much of the refuge, and dominated portions of many units included in this study. Other woody trees/vines species found on study sites included *Rubus* spp., Macartney rose (*Rosa bracteata*), wax myrtle (*Morella cerifera*), and Chinese tallow tree (*Triadica sebifera*).

Approximately 3,200 hectares of Hoskins Mound is actively managed with prescribed burning. The burning program at Hoskins Mound was established in 1997, with an emphasis on growing season fires. In some areas, mowing and haying have also been employed for management. The management plan for Hoskins Mound seeks to achieve an average burn rotation of every 3 to 5 years, depending on site conditions and successional status. Typically, there is a substantial portion of the total refuge that is roughly in compliance with burn objectives as a result of their burn activities. However, weather conditions have significant influence on management's ability to implement annual burn plans completely and, as a result, there is a consistent shortfall in capacity to restore more badly degraded areas using frequent burning. The

overall result is a management environment directed by general objectives and guided by periodic monitoring of habitat conditions.

Management for Hoskins Mound was been designed to create a mosaic landscape of units 1-3 years since burn. Christmas Bird Counts conducted on Brazoria (Freeport) and/or San Bernard National Wildlife Refuge have been among the highest in the country (National Audubon Society 2002). Thus, the area provided an excellent opportunity to study LCSP winter ecology and to evaluate the effects of fire management on habitat use.

The overall study design called for the sampling of replicate burn units subjected to a discrete set of burn intervals. Sampled units were selected from those available using a completely randomized design. Each unit included in the study was required to have been burned within one, two or three years from the initiation of data collection, with the units included being selected from all possible prairie units on Hoskins Mound. Data were collected from 15 burn units, with five replicate units from each burn interval. Selected management units ranged in size from 40 ha to 520 ha. Banding sites were randomly selected for each unit in an area 50 to 500 m from the edge of the unit. Birds were radio-marked on only 1 and 2 year burn units. Searching for birds to radio-mark began from a random location at least 100 m from each unit boundary. Searchers moved away from the edge of the unit until a sparrow was located and captured. Later in the season, due to accessibility and time constraints, searching for birds to radio-mark began from a non-random location at least 100 m from the unit boundary. To reduce the chance of bird interaction and observer disturbance, searches for a second bird on a unit began at least 250 m from the first bird.

Telemetry

LCSP were captured and radio-marked on five 1-year and five 2-year burn units during January and February 2003. Each week, 4 birds were captured and radio-marked, 2 from a 1-year and a 2-year burn unit. A crew of 3-6 people located birds by walking in a line and flushing birds using poles and drag-lines. When a bird was located, a 12 m mist-net was set up downwind from the bird and people formed a semi-circle and rushed up to the net. This was repeated until a bird was netted. Standard measurements were recorded for each individual: wingchord, body mass and fat score.

Each sparrow was fitted with a 0.48 g radio transmitter (Holohil Systems, Ltd. Model LB-2; 10-day battery life) by placing it over the feathers of the synsacrum and attaching it with an elastic leg-loop harness (Rappole and Tipton 1991). Extra steps were taken to prepare the transmitters for application due to wet, salty conditions and dense herbaceous vegetation of coastal prairie. After the second application of transmitters, a rain event occurred and signals became weak, inconsistent to non-existent. After discovery of one of the censored radios, it was found that the antennae were rusting. Transmitters were coated with epoxy following this incident to resolve this problem. On one occasion, a bird was found entangled in the grass. The transmitter was immediately removed and the bird was released alive. All transmitters applied after these incidents were augmented by coating the antennae with epoxy and removing one inch of the antennae prior to each application. Change in reception was insignificant.

Each bird was located everyday or every other day, until a mortality event occurred, the signal disappeared, or the bird was recaptured. Locations were established from an estimated distance of 25-100 m from the bird. Azimuth directions were recorded from 2 GPS points, 20-40 m apart. At least one location was collected for radio-marked birds each day. Every other day a radioed bird was located every fifteen minutes for a one-hour period to obtain average daily

home range size. Recaptures of birds were attempted 6-11 days after capture to remove the transmitter.

Banding

Within-season site fidelity of wintering grassland sparrows was examined by monthly banding efforts. On each burn unit (n = 15), one hectare plot was netted once per month (December – February) with the assistance of ≥ 10 volunteers. Plots consist of a 100 m net lane with a 0.5 ha flushing zone on each side of net. Plots were selected by limited randomization to ensure accessibility of net lanes for logistical purposes, and a 50 m buffer zone from roads and fire breaks was maintained. Grass was cut (~ 1 m wide) to create a path for nets to stretch to the ground to reduce the chance of birds escaping under the net. Banding began at sunrise and continued into early afternoon. Plots were netted in a different order each month.

Each captured bird was banded with an individually numbered aluminum leg band (USGS), or their band number was recorded if recaptured. Wing chord (mm), fat score (scale 0-5), and mass (g) was recorded for each bird captured. To avoid observer bias, I measured fat score on all birds. Birds were released where they were captured. Wind speed (km/h), temperature (˚C), and time of day were recorded.

Statistical Analysis

Telemetry

The Home Range Extension (HRE) in ArcView 3.3 Geographic Information System (ESRI 2002) was used to estimate home range size and activity centers using the kernel method (Worton 1989). Movement patterns were analyzed with the Animal Tracking Extension in ArcView, and home range sizes were estimated at 50% and 95% probabilities. Results were compared using PROC MIXED (SAS Institute 1999).

Banding

Insufficient data were collected to explore the numerous modeling capabilities of program MARK (White and Burnham 1999). Therefore, only general information was derived and reported using model M_b in program CAPTURE (White et al. 1978, Rexstad and Burnham 1991). Model M_b was selected as the most appropriate model for this data. The three parameters produced under model M_b were: N, estimated population size; p, the probability of capture of an unmarked animal on any trapping occasion; and c, the probability that an animal is captured on any trapping occasion subsequent to the occasion on which it was first captured (Zippin 1956 and 1958, Otis et al. 1978). An index of body condition (IBC) was used to correct for variation associated with body mass. IBC are residuals from a regression line of wing chord (independent variable) and body mass (dependent variable). IBC, fat score and body mass were analyzed using repeated measures analysis of variance (PROC MIXED; SAS Institute 1999).

RESULTS

Telemetry

A total of 268 locations was obtained on birds monitored in 1-year burns and 236 locations in 2-year burns. Home range estimates were produced for 18 of the 26 birds radio-marked in this study. Of the 26 radios applied, 3 apparently fell off, 2 sparrows were killed by predators (1 suspected avian, 1 unknown), 1 died of unknown causes, and there were 9 censored events. It was concluded that a radio fell off if there was no evidence of predation (feathers, predator tracks or feces, etc.) and there was no damage to the transmitter or antenna. Recaptured birds were tracked for an average of 9.5 days and lost an average of 1.4 g (SE = 0.23) (Table 5). Transmitters were removed from 11 sparrows.

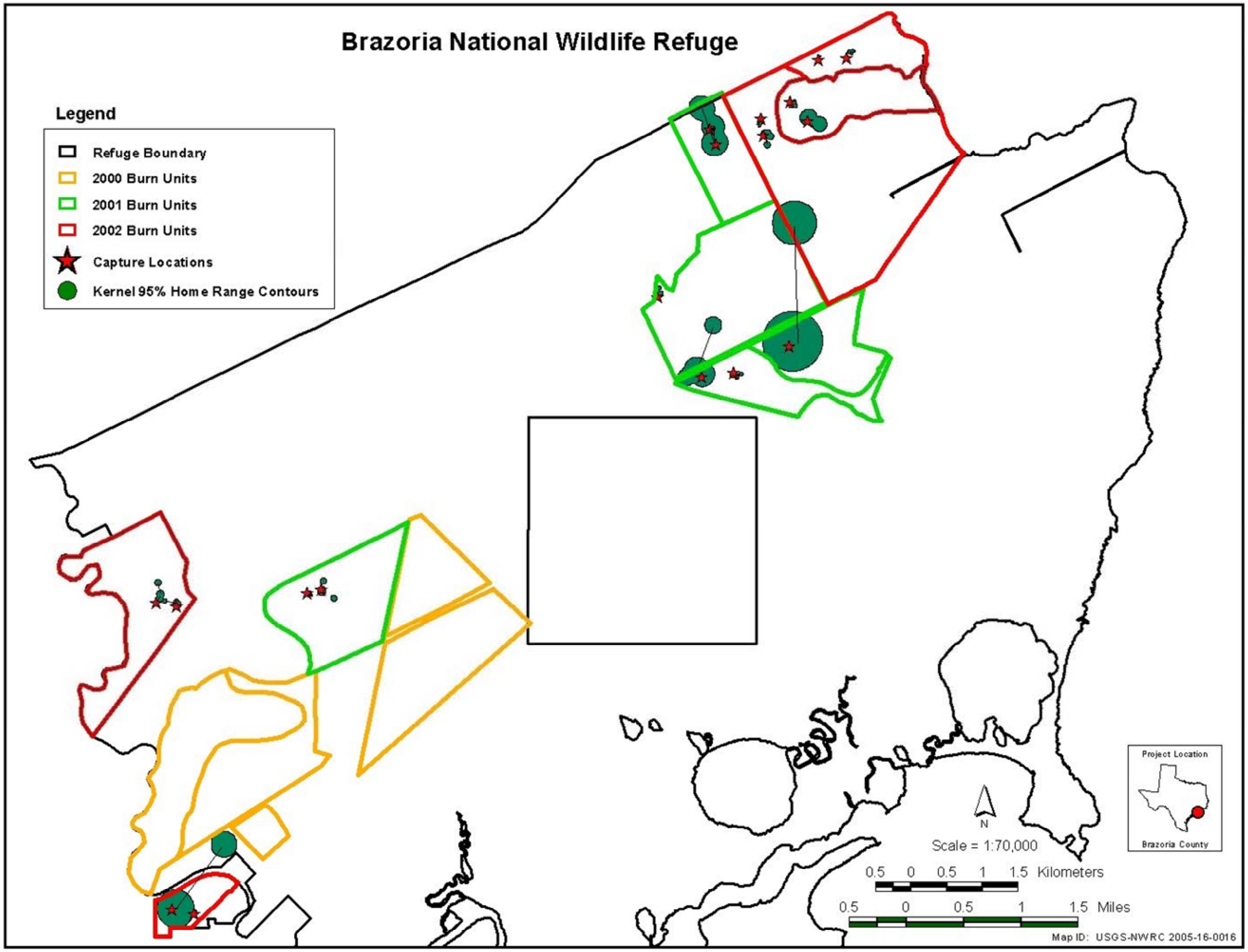

Figure 14. Map of Brazoria National Wildlife Refuge indicating 95% estimated home range size of each radio-marked Le Conte's Sparrow. Colored lines represent burn unit boundaries burned within 1 year (red), 2 years (green), and 3 years (yellow).

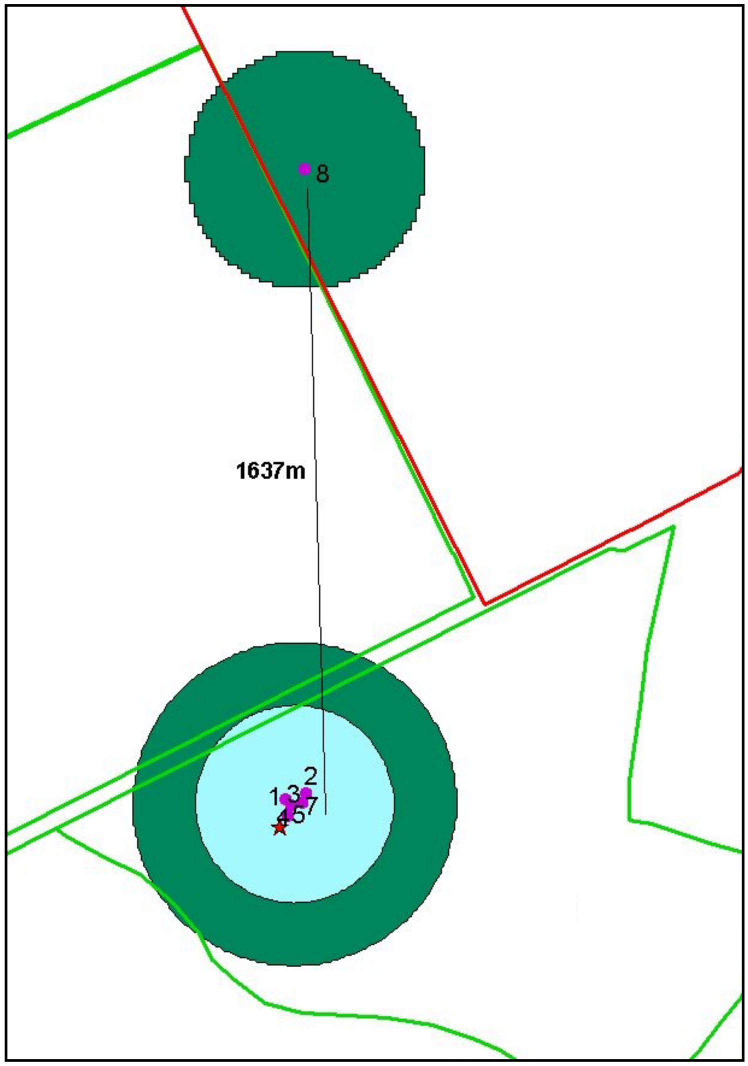

Figure 15. Map of estimated home range size of LCSP (#289); light green area = 50%, and dark green area = 95% probability of home range size. This bird traveled the largest distance of all tracked birds. Each dot represents the average daily location, and the number represents the number of days since the radio was applied. Dots indicate average daily locations and the number beside each dot represents the number of days since the radio was applied. The star represents the initial capture location. Lines represent burn unit boundaries burned within 2 years (green), and 3 years (yellow).

Mean home range estimates with a 50% (HRE50) and 95% (HRE95) probability of home range size were 2.41 ha (72% < 1 ha) and 10.31 ha (44% < 1 ha and 55% < 1.5 ha) (Table 5). Most birds limited movements to within ~ 200 m from initial capture location, which is more clearly shown at the scale of the refuge (Figure 14). Figure 16 is an example of a typical home range of LCSP. Four birds had inflated HRE because they moved 510 m to 1673 m from their initial capture areas. The bird that moved the largest distance did not return to the initial capture area and was located at this outlier distance for one day (Figure 15). Removal of day 8 location for bird # 289 reduced HRE50 from 20.91 ha to 0.08 ha, and HRE95 from 86.3 ha to 0.51 ha. Two of the birds that moved a large distance returned to their initial capture location the following day (Figure 18 and 19). Movement on day 3 inflated home range estimates for bird # 280 and # 203. Removal of the single outlier location reduced HRE50 from 4.50 ha to 1.54 ha and HRE95 from 20.39 ha to 4.50 ha for bird # 280. HRE50 for bird #203 was inflated from 0.06 ha to 7.94 ha and HRE95 from 0.45 ha to 32.01ha. The bird that moved ~ 510 m from initial location exhibited somewhat nomadic behavior by remaining at the initial area for at least 5 days, then moved ~ 250 m for one to two days and then an additional ~250 m from the initial location area for the final two days of monitoring (Figure 17).

Burn year had no significant effect on HRE50 ($p = 0.246$, $r^2 = 0.083$), HRE95 ($p = 0.227$, $r^2 = 0.090$) or weight loss of recaptured birds ($p = 0.460$, $r^2 = 0.080$). Month since burn had no significant effect on HRE50 ($p = 0.400$, $r^2 = 0.184$), HRE95 ($p = 0.378$, $r^2 = 0.192$) or weight loss of recaptured birds ($p = 0.860$, $r^2 = 0.129$). Initial weights of birds were not correlated with HRS50 ($p = 0.2812$) and HRS95 ($p = 0.3012$).

Table 5. Home range estimates of radio-marked birds and weight differences (wtdiff) of recaptured birds. HRS50 and HRS95 are the home range estimates at 50% and 95% probability. Fates are defined as: S = survived entire tracking period, C = censused, or loss of signal before end of tracking period, M = mortality.

id	burn treatment	# exposure days	# locations	HRS50	HRS95	wtdiff	fate
318	1-A	10	39	0.31	1.51	-0.6	S
319	1-A	11	33	0.43	2.19	-2.8	S
196	1-B	4	2	.	.	.	C
197	1-B	1	2	.	.	.	transmitter fell off
285	1-B	10	25	0.02	0.14	-1.3	S
287	1-B	13	26	0.05	0.53	.	C
291	1-C	10	20	0.21	0.93	.	C
292	1-C	6	9	1.53	7.21	.	C
281	1-D	6	27	0.11	0.51	-1.3	S
283	1-D	6	24	0.65	2.37	-2.2	S
202	1-E	7	27	0.03	0.14	.	C
203	1-E	9	34	7.94	32.01	-1.0	S
192	2-A	0	1	.	.	.	S
193	2-A	10	39	0.40	2.39	-0.8	S
194	2-A	1	2	.	.	.	transmitter fell off
195	2-A	6	29	0.08	0.34	.	M (unknown cause)
199	2-B	5	8	.	.	.	C
200	2-B	1	1	.	.	.	C
294	2-B	10	21	5.82	26.01	.	transmitter fell off
295	2-B	6	7	0.24	0.64	.	C
205	2-D	2	3	.	.	.	S (grass entanglement)
206	2-D	8	32	0.18	0.92	.	C
288	2-E	1	2	.	.	.	M (predation)
289	2-E	8	23	20.91	86.30	-1.6	S
279	2-F	8	32	0.16	1.04	-1.0	S
280	2-F	12	34	4.50	20.39	.	M (predation)

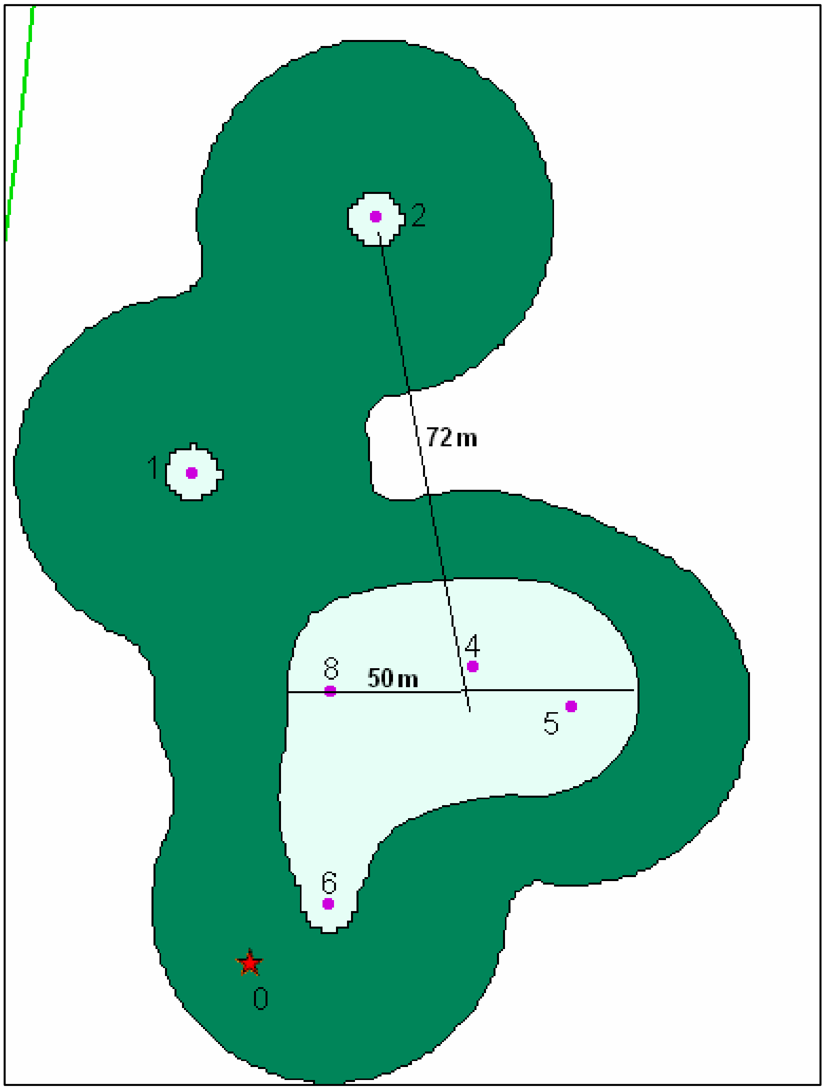

Figure 16. Estimated home range size of an individual LCSP (#206) representing a more typical distribution of locations. Estimated home range size of this individual is 50% probability of 0.18 ha, and 95% probability of 0.92 ha. Dots indicate average daily locations and the number beside each dot represents the number of days since the radio was applied. Each star represents the initial capture location. Lines represent burn unit boundaries burned within 2 years (green).

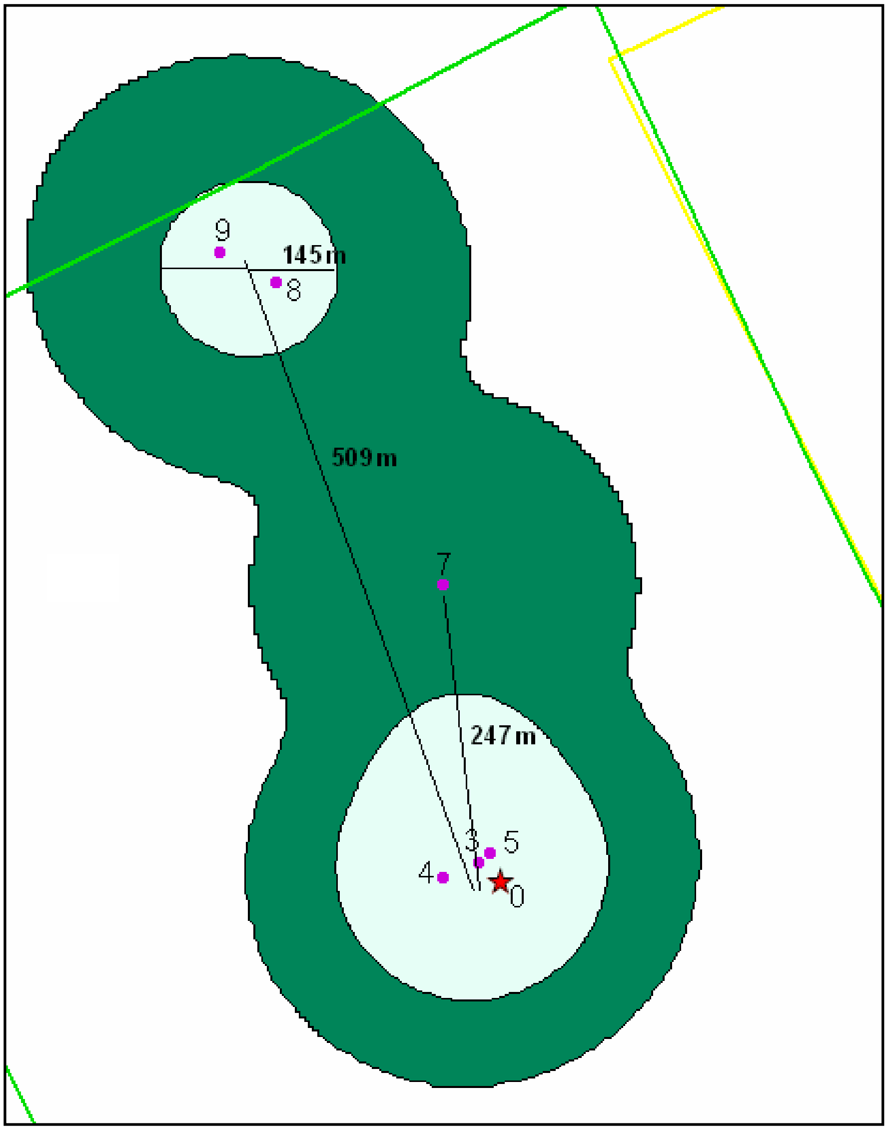

Figure 17. Map of estimated home range size of LCSP (#294); light green area = 50%, and dark green area = 95% probability of home range size. Each dot represents the average daily location, and the number represents the number of days since the radio was applied. Dots indicate average daily locations and the number beside each dot represents the number of days since the radio was applied. Each star represents the initial capture location. Lines represent burn unit boundaries burned within 2 years (green), and 3 years (yellow).

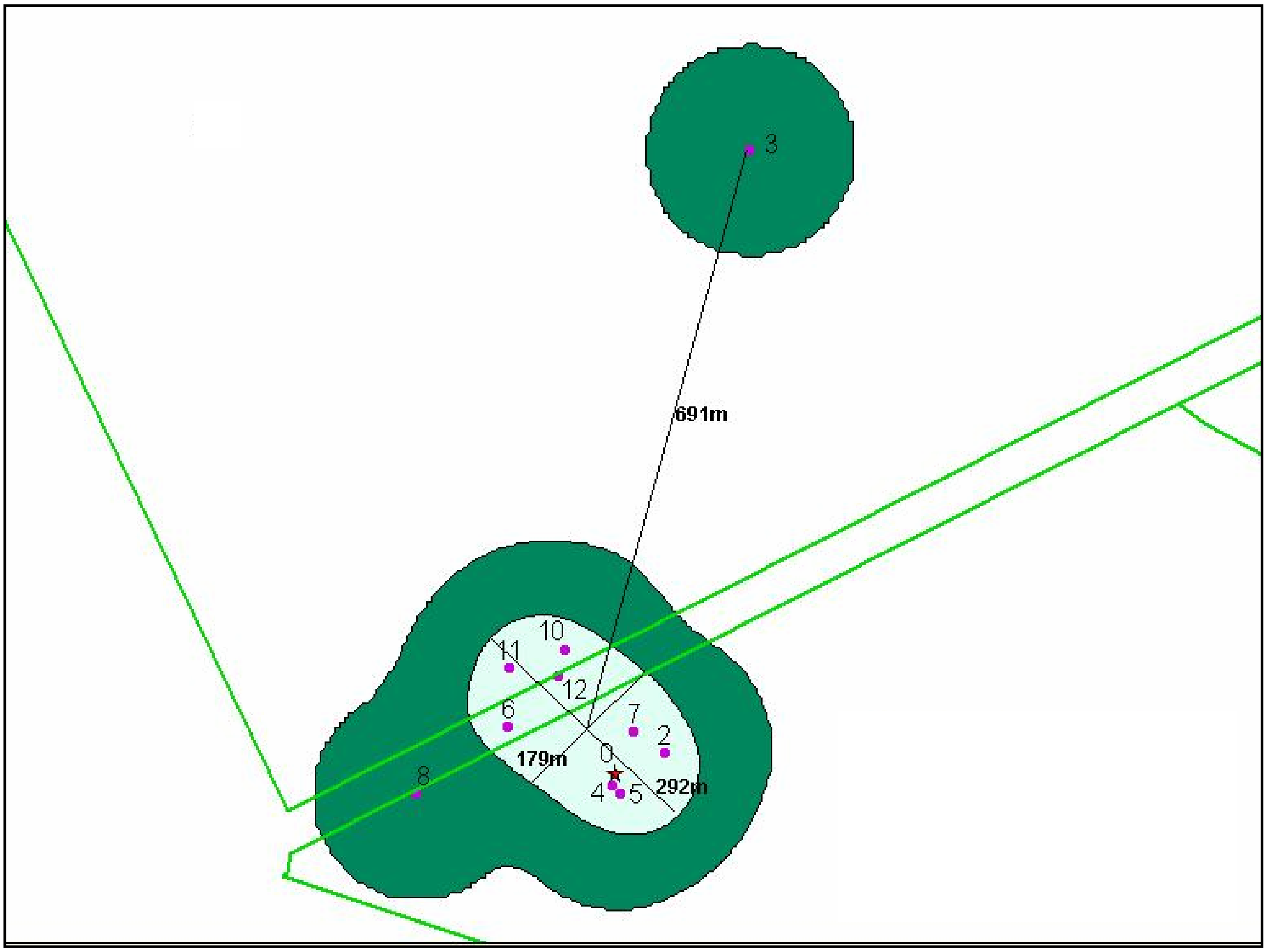

Figure 18. Home range size of bird #280, which was one of the four birds that exhibited large movement. Movement on the third day inflated home range estimates of HRE50 (50% probability) from 1.54 ha to 4.50 ha and HRE95 (95% probability) from 4.50 ha to 20.39 ha. This bird returned to initial capture area on the fourth day and remained until end of monitoring period. Dots indicate average daily locations and the number beside each dot represents the number of days since the radio was applied. Each star represents the initial capture location. Lines represent burn unit boundaries burned within 2 years (green).

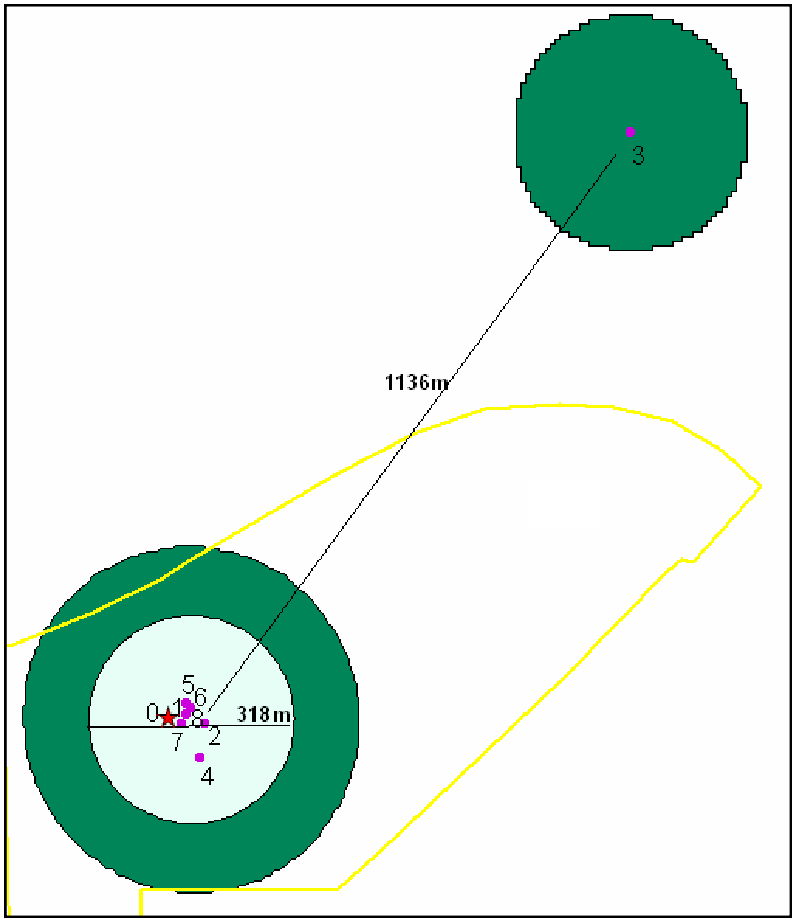

Figure 19. Home range size of bird #203, one of the four birds that exhibited large movement. HRE50 was fairly small, with a diameter of ~ 300m. Movement on the third day inflated home range estimates of HRE50 (50% probability) from 0.06 ha to 7.94 ha and HRE95 (95% probability) from 0.45 ha to 32.01ha. This bird returned to initial recapture area on the fourth day and remained until end of monitoring period. Dots indicate average daily locations and the number beside each dot represents the number of days since the radio was applied. Each star represents the initial capture location. Lines represent burn unit boundaries burned within 3 years (yellow).

Banding

A total of 103 LCSP was captured on three trapping occasions (December, n = 54; January, n = 34; February, n = 15), but only 8 individuals were recaptured. No bird was recaptured twice. In program CAPTURE, goodness of fit tests, revealed M_b as the best fit model ($\chi^2 = 1.554$, df = 2, p = 0.460). Model M_b tests for a behavioral response after initial capture. LCSP showed a significant behavioral response to capture ($p < 0.001$). Overall capture probability was estimated to be 0.462 and recapture probability of 0.056. Model M_b estimated that 122 (SE = 10.4) birds have home ranges that overlap into 15 separate 1 ha plots.

Burn treatment did not significantly influence overall body mass (p = 0.125), fat score (p = 0.850) or IBC (p = 0.313), and had no significant influence on monthly changes in body mass (p = 0.358), fat scores (p = 0.456) or IBC (p = 0.568). Mean body mass per unit significantly changed over time (p = 0.017). Body mass increased 0.3 g from December to January (p = 0.704) and significantly dropped 1.0 g from January to February (p = 0.011) and 0.7 g from December to February (p = 0.060). Significant monthly differences in fat score were found (p = 0.005), with the mean scores rising by 1.5 units between December and January ($p < 0.001$), 1.0 unit between December and February (p = 0.001), and dropped 0.5 units between January and February ($p > 0.178$). Mean IBC per unit significantly changed over time (p = 0.022). IBC increased 0.225 units from December to January (p = 0.756). IBC decreased 0.983 units from January to February (p = 0.012) and 0.631 units from December to February (p = 0.060) (Figure 20).

DISCUSSION

LCSP are primarily sedentary during winter inhabiting small home ranges, with most birds confining movements to an area < 2 ha. The degree to which within-season site-fidelity

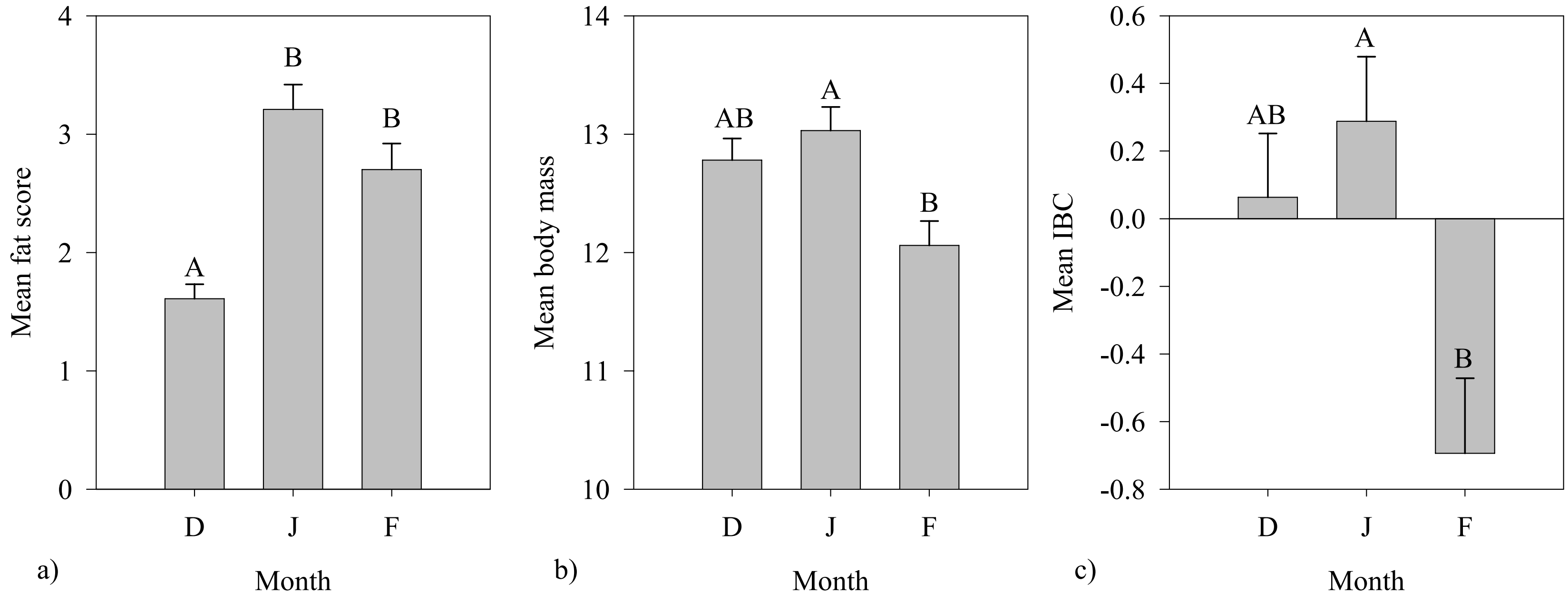

Figure 20. Mean monthly values per burn unit for a) fat score, b) body mass and c) IBC over time. Month D = December, J = January and F = February. IBC are the residuals from a regression of body mass and wing chord.

can be described is limited because of few recaptured birds. Banding results contrasted telemetry results, suggesting low recapture probability is likely due to avoidance of recapture, and not movement away from the area.

Previous findings (Baldwin et al. unpublished data) suggest that habitat selection of LCSP is related to vegetation structure. Habitat selection is likely based on cover (Pulliam and Mills 1977) and food abundance (Tucker and Robinson 2003). If they inhabit an area with sufficient cover and food supply, the tendency to exhibit nomadic movement is not necessary, and their survival is likely enhanced due to familiarity with the area (Sinclair 1984, Gordon 2000). Other studies have found similar movement patterns for grassland birds. Grzybowski (1983) found LCSP, Grasshopper Sparrows (*Ammodramus savannarum*) and Baird's Sparrows (*Ammodramus bairdii*) tended to be solitary and avoid other individuals when flushed from adjacent locations. LCSP were also suspected to inhabit restricted home ranges (Grzybowski 1983). Gordon (2000) found that Grasshopper Sparrows, Baird's Sparrows, Savannah Sparrows (*Passerculus sandwichensis*) and Vesper Sparrows (*Pooecetes gramineus*) remained within fixed home ranges in winter, and Grasshopper Sparrows were the most sedentary of those. LCSP were not included in Gordon's (2000) study.

Consistent weight loss of radio-marked LCSP may not have significantly impacted LCSP movement. Grzybowski (1983) examined winter frequency of occurrence of LCSP and estimated that they are spaced 11-45 m apart and speculated that they maintain small home ranges. Although Cooper's (1984) study was conducted during the breeding season, he found LCSP to maintain a territory size of roughly one hectare. Results from both studies were based on frequency of occurrence of individual, unmarked LCSPs. Therefore, I suspect the radios had

minimal influence on LCSP movement, and weight loss is likely attributed to the induced stress of carrying the radio.

I found no relationships between burn year or bird morphology that related to home range size. LCSP are more abundant in areas burned 1 and 2, than 3 years earlier (Baldwin et al., unpublished data); therefore, both 1- and 2-yr burn treatments likely provide suitable habitat for LCSP.

Although mark-recapture methods have advanced and are used in numerous studies, estimates of within-season site fidelity was limited due to few recaptures. Under closed population assumptions, I was able to perform a test among general models in program CAPTURE, and results suggest that LCSP may exhibit a significant behavioral response to capture (M_b). It is difficult to distinguish between capture avoidance, poor survival and/or emigration, therefore selection of model M_b may be confounded if emigration does occur (i.e., is an open population), but is not detected (Otis et al. 1978). Analysis of data using open population models was not successful due to lack of sufficient data. Small home range size (< 2 ha) and the selection of model M_b suggests that LCSP home ranges may overlap extensively, or they remain fairly sedentary for a period of time (> 10 days), and periodically move to another area with suitable habitat.

LCSP may exhibit annual site fidelity. In January 2002, preliminary banding of LCSP was conducted on one burn unit (3D) that was burned two years earlier. One of the net lanes in this study was located in the same unit, and one of the 84 LCSP banded the previous year was recaptured less than 90 m from the original capture site.

Anatomical measurements of LCSP suggest that body condition fluctuates with weather conditions. Fat scores were higher in January and February than December; however body mass

was significantly less in February than January. IBC was also significantly less in February than January. This decrease in body mass was not related to monthly mean temperatures for the month, or to weather events such as low temperatures and/or precipitation prior to or during banding efforts. January had the most frequent precipitation events (24 days) and highest number of days below freezing (7), and was the month with the highest fat scores, body mass and IBC. This suggests that the birds were carrying extra fat to buffer the effects of cold weather.

MANAGEMENT RECOMMENDATIONS

Behavior of LCSP after fire has not been examined. Their sedentary tendencies may repress significant movement from home ranges during, or following a fire event, hence jeopardizing survival (Plentovich et al. 1998). I suggest that winter burns should be avoided, in areas burned within 3 years, if sufficient habitat is not adjacent to burn area.

CONCLUSION

Herbaceous vegetation density and shrub density were found to be highly correlated with time since burn. Time since burn predicted herbaceous density and, to a lesser extent, woody plant density. LCSP, SAVS and SEWR exhibited strong habitat associations. LCSP were most often found in areas burned within 1- and 2- years, which had medium vegetation density, with low to medium litter densities, and areas with tall vegetation. They were also associated with low shrub densities, though abundance was significantly higher in areas where wax myrtle was present. SAVS were most often found in areas burned within the past year, which had low densities of herbaceous vegetation and shrubs. They tended to occur less often in areas with live saltbush, tallow and Macartnety rose. SEWR were most common in areas of dense herbaceous vegetation that had not been burned in the previous two years. However they showed no relationship to shrub density or height. They were also associated with areas where saltbush and tallow were present. SWSP did not exhibit such strong habitat associations. SWSP (*Melospiza georgiana*) were most common in areas of tall vegetation and high shrub densities, but demonstrated no relationship to herbaceous vegetation densities or year since burn. The results indicate that different species are quite responsive to succession management using fire. Overall, maintaining a mosaic of prairie in 2 and 3 year burn rotations, and controlling woody invasives such as tallow and saltbush, would appear to be an effective strategy for maintaining a diversity of grassland birds in coastal prairie.

Winter ranges of LCSP were small, with most having an estimated home range size < 2 ha, suggesting that they are fairly sedentary. Significant movement from home ranges during a fire event may be minimal, due to their sedentary tendencies, hence jeopardizing survival. Therefore, winter burns should be avoided, in areas burned within 3 years if sufficient habitat is

not adjacent to burn area. Examination of seasonal site fidelity was limited due to low recapture rate. LCSP were found to exhibit a significant behavioral response to capture (M_b). Model M_b estimated that 122 birds have home ranges that overlap into 15 separate 1 ha plots. Small home range size (< 2 ha) and the selection of model M_b suggests that LCSP home ranges may overlap extensively, or they remain fairly sedentary for a period of time (> 10 days), and may periodically move to another area with suitable habitat.

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