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Effects of Leafy Spurge (Euphorbia esula) Infestation on Breeding Birds of the Sheyenne National Grassland, ND

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Effects of Leafy Spurge (Euphorbia esula) Infestation on

Breeding Birds of the Sheyenne National Grassland, ND

(TITLE)

BY

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THESIS

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ABSTRACT

Leafy spurge (*Euphorbia esula*) is an exotic invasive weed in the northern Great Plains. We examined the effects of leafy spurge infestation on densities and nest success of breeding birds in grasslands on the Sheyenne National Grassland (SNG), ND. We categorized spurge-infested grasslands into three levels of infestation, based on the area covered by spurge patches: (a) low (0-20%), (b) medium (20-60%) and, (c) high (> 60%). We surveyed 60 100-m radius circular plots (20 in each category), and searched for nests in three 16-ha plots (one in each category). There were no statistically significant differences in mean species richness or mean species diversity among the three types of survey points. Of the eight most abundant grassland birds, only Upland Sandpiper (*Bartramia longicauda*) densities were significantly different among spurge categories, with highest mean density (13.5 ± 4.1 birds/100 ha) occurring on medium-spurge points. However, none of these species occurred in highest densities on high-spurge points. Le Conte's Sparrows (*Ammodramus leconteii*) and Savannah Sparrows (*Passerculus sandwichensis*) were significantly negatively correlated with spurge infestation (-0.23 and -0.24, respectively). Spurge infestation was not correlated with grazing intensity (number of stems/m^2: r_s = -0.01; % cover: r_s = -0.03). Le Conte's Sparrows were negatively correlated (-0.34) with grazing intensity; whereas Savannah Sparrows were positively correlated with this factor (0.28). The low-spurge plot contained the most nests (n = 24), but nests on the high-spurge plot (n = 11) experienced the highest nest success (0.745, χ^2 = 13.2, df = 2, P < 0.01). There were no significant differences between successful and unsuccessful nests or between nests and nearby paired sites with respect to number of spurge stems/m^2 or percent cover of spurge. However there were significant differences

for other measured vegetational features. Thus, based on these data, most birds appeared to show little response to leafy spurge per se. Birds may choose microhabitats based more on characteristics of vegetation structure (e.g. ground cover, vegetation height, vertical density, litter depth) than on particular plant species. Circumstantial evidence suggests that spurge may even provide benefits for certain species through foraging opportunities and nest protection. Assuming spurge can alter vegetation structure to the detriment of grassland birds, infestation may not be high enough over much of the SNG to show a strong negative effect on bird community parameters. Other factors may obscure relationships between bird densities and spurge infestation including strong avian preferences for other vegetation characteristics, cattle grazing intensity, and habitat productivity.

We surveyed the breeding bird communities of the five major habitat types (grassland, sedge meadow, wetland, savanna, and woodland) of the SNG. Grasslands contained the greatest number of total species (47), but species richness/point and species diversity/point were not significantly different among habitat types ($F = 1.33$, $P = 0.29$; $F = 0.65$, P 0.63, respectively). The most abundant species on grassland survey points was the Western Meadowlark (47.5 birds/100 ha). The Red-winged Blackbird was the most abundant species on sedge meadow and wetland survey points (88.5 and 382.2 birds/100 ha, respectively). Ground foragers were the most abundant guild on savanna and woodland points (236.6 and 229.3 birds/100 ha, respectively). The complex interspersion among habitat patches, combined with the relatively broad range of habitat preferences and flexibility displayed by many bird species probably lead to the observed patterns of species overlap among communities.

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CHAPTER I

INTRODUCTION

Grassland birds have shown more consistent population declines between 1966 and the 1990s than any other group of breeding birds in North America (Bollinger and Gavin 1992, Askins 1993, Herkert 1995, Igl and Johnson 1997, Sauer et al. 1999). Although the virtual elimination of prairie habitat in the Midwest had a major negative impact on grassland bird densities, this change occurred primarily before 1950 (Knopf 1994). Therefore, recent declines are likely due, at least in part, to factors reducing the **quality** of remaining grassland habitats. Introduced, or "exotic" species are one of the most important factors reducing habitat quality and negatively affecting biodiversity (Coblentz 1990, Parker et al. 1993).

Leafy spurge (*Euphorbia esula*) is a perennial Eurasian forb that has become an invasive weed in the northern Great Plains (Selleck et al. 1962, Dunn 1979, Messersmith and Lym 1983, Lym and Messersmith 1985, Lym and Kirby 1987, Belcher and Wilson 1989, Trammell and Butler 1995). Since its introduction in North America in 1827, it has spread to 26 states and six Canadian provinces (Dunn 1979). In North Dakota, the epicenter of leafy spurge distribution, over 485,600 ha, or 9.2% of the state's untilled land, were estimated to be infested in 1987, an area which more than doubled the infestation level of the previous decade (Leistritz et al. 1992).

Leafy spurge has the potential to alter plant community composition and structure by out-competing native vegetation for available resources, such as nutrients, light, and

space (Bedunah 1992, Parker et al. 1993, Trammell and Butler 1995, Svedarsky and Van Amburg 1996). Leafy spurge prefers disturbed areas (e.g., grazed land, burrow mounds, and trails) where it grows in dense patches (200-2,800 stems/m^2) in which native species are significantly reduced or absent (Selleck et al. 1962, Lym and Kirby 1987, Belcher and Wilson 1989, Wilson and Belcher 1989). In mixed-grass prairie in Manitoba, Belcher and Wilson (1989) found that native plant species richness declined from 11 species outside spurge patches to three at their center. Cattle grazing is an especially important disturbance that enables spurge to spread. Leafy spurge contains toxic secondary compounds (e.g. terpenoids and condensed tannins) in its milky latex that interfere with digestion and dissuade herbivory (Roberts and Olson 1999). As cattle forage around spurge patches and in non-infested sites, they may overgraze native vegetation, leaving bare areas suitable for leafy spurge seedling establishment (Selleck et al. 1962, Lym and Kirby 1987, Bedunah 1992). Degradation of native plant communities and local extinction of preferred plant species caused by spurge and other exotics may reduce the carrying capacity of the landscape for wildlife (Trammell and Butler 1995, Svedarsky and Van Amburg 1996). However, the effects of such changes on the abundance and productivity of wildlife, including grassland birds, are largely unknown (Bedunah 1992).

The Sheyenne National Grassland (SNG) consists of two units that encompass 28,400 ha of federally owned and managed habitats in southeastern North Dakota. These habitats include tallgrass prairie, mixed-grass prairie, woodland, cottonwood stands, oak savanna, lowland riparian forest, sedge meadow, and wetland (Seiler and Barker 1985, Svedarsky and Van Amburg 1996). It contains North Dakota's largest native tallgrass prairie and numerous sensitive plant and animal species (Svedarsky and Van Amburg

1996). Cattle grazing is a common management practice (Svedarsky and Van Amburg 1996). Currently, over 4,400 ha (16%) of the SNG are infested with leafy spurge (Bryan Stotts, U.S. Forest Service, Lisbon, ND, *pers. comm.*). Svedarsky and Van Amburg (1996:64) stated that this infestation "has greater potential than any other factor to significantly reduce the biodiversity of the SNG." With the serious decline of many grassland bird populations, coupled with the rapid spread of leafy spurge (Leistritz 1992), it is critically important to understand bird-spurge associations, especially in important grassland preserves such as the SNG.

The purpose of this study was to examine the effects of leafy spurge infestation on breeding densities of grassland birds on the SNG. The objectives were to (1) compare the densities of breeding birds on grasslands with various levels of spurge infestation, (2) determine the reproductive success of grassland birds on spurge-infested plots, and (3) what extent spurge was used for nest support or cover. We hypothesized that breeding bird densities and nest success would be negatively affected by spurge infestation given that spurge alters the taxonomic composition and habitat structure of grasslands that birds require for foraging and nesting cover (Wiens 1974).

METHODS

Study site.— The SNG is located in Ransom and Richland Counties in the Prairie Pothole Region of southeastern North Dakota. It is divided into two units. The northern unit is a matrix of federally owned and privately owned land with approximately 27,242 ha of federal land and 25,597 ha of private land (Svedarsky and Van Amburg 1996). The southern unit is approximately 1,157 ha of federal land. This study was conducted only on the northern unit. Although the dominant habitat type of the area is tallgrass prairie,

the SNG is a mosaic of habitat patches that grade from riverine to dry upland across a complex topography of river terrace, deltaic plain, hummock, and choppy sandhill (Seiler and Barker 1985, Hansen 1996, Svedarsky and Van Amburg 1996). Seasonal changes in temperature and precipitation, along with hilly topography, create potholes of various sizes and longevity, from wet-meadow swales to permanent ponds (Stewart 1975). This adds a temporal component to the complex spatial distribution of the plant and bird communities.

For the purposes of this study we defined grassland as habitats dominated by *Andropogon gerardii*, *Schizachyrium scoparium*, *Poa pratensis*, *Bouteloua gracilis*, or *Panicum virgatum*. Roughly 29,269.4 ha (55.4%) of the north unit (both federal and private land) is covered by grassland (Svedarsky and Van Amburg 1996). More detailed discussions of the climate, soils, topography, and plant communities of the SNG and its surroundings are provided by Stewart (1975), Seiler and Barker (1985, 1987), Hansen (1996), and Svedarsky and Van Amburg (1996).

Bird densities and point vegetation.—We established 60 100-m radius survey points in grasslands with the following levels of infestation, given as percent of the circular plot covered by spurge patches: (a) 0-20% ("low," 20 points); (b) 20-60% ("medium," 20 points); (c) 60-100% ("high," 20 points). Randomly generated Universal Transverse Mercator coordinates were placed on all U.S. Geological Survey 7½ minute topographic maps that cover the SNG. Then we located points in the field and categorized them by visual inspection. We accepted points if they encompassed only a single habitat type, and until each category was filled. Due to topography and the heterogeneous spatial distribution of vegetation communities, survey points did not

necessarily encompass similar levels of variability in possible confounding factors such as distance from habitat edge, habitat edge type, soil type, slope, aspect, and grazing intensity.

We surveyed birds using the fixed-radius point count technique (Ralph et al. 1995). For this technique we counted all birds (by species, and by sex for sexually-dimorphic species) seen or heard from a fixed point in the center of the circle. We estimated distances of birds within the circular plot in 20-m intervals. Only birds detected within the circular plot were used in data analyses, but birds beyond 100 m also were counted. We counted birds for three minutes per point and each point was surveyed twice. Surveys occurred from 31 May to 2 July 1999 between 0500 and 1000 CST. To minimize time-of-day bias we alternated visits to a particular point between earlier and later halves of the survey time period. Points were not surveyed during heavy rains or when wind speeds exceeded 16 km/hr (Martin and Conway 1994). To determine total species richness for the SNG, we also noted any additional species detected while walking to and from a point, as well as incidental observations made at other times.

For each of the eight most abundant grassland bird species (Bobolink [*Dolichonyx oryzivorus*], Brown-headed Cowbird [*Molothrus ater*], Clay-colored Sparrow [*Spizella pallida*], Grasshopper Sparrow [*Ammodramus savannarum*], Le Conte's Sparrow [*Ammodramus leconteii*], Savannah Sparrow [*Passerculus sandwichensis*], Upland Sandpiper [*Bartramia longicauda*], and Western Meadowlark [*Sturnella neglecta*]) we used a chi-squared goodness-of-fit test (Minitab 11.21 32 Bit; Minitab Inc. 1996) to determine if there were differences in detectability among spurge categories within a species. For each species we pooled sexes (see below) and compared the number of

individuals observed in each 20-m distance interval among the three spurge categories. Where expected counts were less than five we pooled adjacent 20-m distance intervals. We used $\alpha = 0.1$ for all statistical comparisons. No significant differences were detected, i.e. a species was not more or less likely to be detected at a particular distance for a particular level of spurge infestation. Therefore, we were able to use the raw counts for within-species analyses without first having to adjust for differences in detectability among spurge categories. However, there were differences in detectability between sexes of a species. Detectability will cause a bias in density estimates. For example, males tend to behave more conspicuously and so are more likely to be counted. Before summing counts for male and female of Bobolinks and Brown-headed Cowbirds, we used the program DISTANCE (Thomas et al. 1998) to obtain a correction factor, h(0), that adjusts the raw counts to account for detectability. DISTANCE (Thomas et al. 1998) input consisted of an entry for each individual of each species and the 20-m distance interval within which it was detected for each visit to each survey point. Detection function model selection was based on the minimum Akaike's Information Criterion (Thomas et al. 1998). Possible models consisted of uniform or half-normal key functions, with cosine or simple polynomial series expansions. For each of the eight species we averaged the two visits to each point to obtain a single estimate of abundance for each species at each point. We converted counts to a standardized birds per 100 ha, and then used Analysis of Variance (ANOVA; Minitab Inc. 1996) to determine if there were differences in densities among spurge categories. Because there were differences in detectability among species, we used DISTANCE (Thomas et al. 1998) to adjust counts

before calculating relative densities and species diversity (H'), and before making other interspecific comparisons.

We measured vegetation cover and structure at each grassland survey point between 29 June and 20 July 1999. We established four vegetation sampling points within each bird survey point by starting from the center and taking a random number of steps (within 100 m) in each of the four cardinal directions. At each vegetation sampling point we assessed visual obstruction (in dm), an index of the vertical density of the vegetation, using a Robel pole (Robel et al. 1970). We used a 0.5 X 0.5 m Daubenmire frame (Daubenmire 1959) to estimate the percentage of ground covered by leafy spurge, other forbs, grass (e.g. *Bouteloua gracilis*), bunchgrass (i.e. displays a clumped growth habitat, such as *Andropogon gerardii*), woody vegetation, bare ground, and litter. In addition, we counted the number of spurge stems, regardless of size, within the Daubenmire frame. Finally, we measured vegetation height (in cm) and litter depth (in mm) at each corner of the Daubenmire frame.

We used ANOVA (Minitab Inc. 1996) to detect potential differences in vegetation characteristics among survey points with low, medium, and high spurge cover. Then we used the Tukey-Kramer pairwise comparisons procedure with a family error rate of 0.10 (Minitab Inc. 1996, Devore and Peck 1997) to determine which pairs of spurge categories were significantly different. We used Spearman's rank correlation (Minitab Inc. 1996, Devore and Peck 1997) to examine relationships of bird species richness, diversity, and densities with vegetation characteristics. For those species that showed a significant correlation with at least one vegetation characteristic we used Best Subsets Regression to

find the best two-predictor regression equation (Minitab Inc. 1996, Devore and Peck 1997).

Grazing intensity may influence bird densities and vegetation characteristics. To develop an index of grazing intensity, we multiplied the number of cow/calf units (defined as a single female and her single offspring) in a given pasture (U.S. Forest Service grazing allotment schedule for the 1999 season, unpublished manuscript) by the number of days that the cattle grazed on that pasture until the latest date of grazing or until the latest date of bird surveying or vegetation sampling, whichever came first. For example, if 227 cattle/calf units grazed on a pasture from 30 May to 28 June, and the final bird survey at the circular plot on that pasture was conducted on 15 June, then the number of cattle grazing days is 16 (30 May to 15 June), and grazing intensity is 227 x 16 = 3,652. Similarly, if the vegetation was sampled on 12 July, then the number of cattle grazing days is 29 (30 May to 28 June) and grazing intensity is 227 x 29 = 6,583. This method assumes that each cattle/calf unit grazes at the same rate. We used Spearman's rank correlation to examine relationships of bird species richness, diversity, and densities, and vegetation variables with grazing intensity. Grazing intensity was incorporated into Best Subset Regression models for those species that were significantly correlated with it.

Nests and nest vegetation.—We established three 16-ha grassland plots, one plot for each level of spurge infestation ("Low Plot," "Medium Plot," and "High Plot"). We placed 25 markers in a 5 X 5 array with 100 m separating each marker in each plot. Medium Plot and High Plot were located in the same pasture and were separated by approximately 100 m. Low Plot was approximately 900 m from Medium Plot in a separate pasture, but was part of the same grazing allotment as the other two. All three

plots were chosen to encompass similar soil type, topography, vegetation type, grazing regime, and potential bird community (*pers. obs.*). We located grassland bird nests by observing adult behavior and by flushing birds with a stick while walking. When a nest was found we checked it every two to four days. We recorded of the number of eggs, young, and fledglings. If a nest failed, we determined the reasons for failure (e.g. predation or abandonment). Signs of predation included damage to the nest, disappearance of eggs, destruction of eggs before the projected hatching date, disappearance of nestlings before the projected fledging date, and dead and damaged nestlings. A nest was considered abandoned if the nest and eggs were intact but the eggs did not hatch by the projected hatching date and the adult was not detected for several consecutive visits, or if nestlings were dead but not damaged. In addition, we monitored Brown-headed Cowbird parasitism and the fate of the cowbird eggs. Once a nest was inactive, we gathered information about nest location features. We noted nest substrate and nest height. We sampled nest vegetation using procedures described above with one set of measurements centered on the nest cup and four more sets located 0.5 m from the nest in each of the cardinal directions. For nests that were still active by the end of the study, we counted the number of spurge stems and estimated percent cover of spurge within a single Daubenmire frame (Daubenmire 1959) centered on the nest. Red-winged Blackbird (*Agelaius phoeniceus*) nests (n = 2) were monitored but we did not measure vegetation around these nests because they nested off the ground and above standing water, and so were not likely to be influenced by spurge infestation. Between 28 June and 3 July we sampled plot vegetation. At each of the 25 markers we took a random number of steps in predetermined directions and conducted one set of vegetation

measurements as described above. We used predetermined directions to ensure that vegetation samples remained within plot boundaries, and to ensure that both sides of the three interior transects were sampled.

We calculated nest success using the Mayfield method (Mayfield 1961). Nests that were active at the end of the study were used as right-censored observations (Douglas H. Johnson, Northern Prairie Wildlife Research Center, Jamestown, ND, *pers. comm.*). For example, a nest located six days before the end of the study and still viable at the end contributed six exposure days and zero mortalities. The only nest not used in nest success calculations was one Greater-Prairie Chicken (*Tympanuchus cupido*) nest that was found on High Plot after fledging. We defined a successful nest as one having at least one young of the parental species fledged. The only species with a sufficient sample to meaningfully calculate nesting success for was the Grasshopper Sparrow. In addition, all species, including Grasshopper Sparrow, were pooled before calculating nest success. Because we averaged over all species, and there were both altricial and precocial species, we calculated exposure days using only the number of days for eggs to incubate and young to leave the nest, regardless of whether the young stayed with the parents after leaving the nest. We used a method formulated by Johnson (1990) to statistically compare nest success rates among spurge infestation levels for all species combined and for Grasshopper Sparrows. This method uses exposure days (e) and estimated daily mortality rate (r) for each of j groups of nests, and the estimated daily mortality rate for all nests combined (r_t) to compute a T-statistic: $T = \Sigma\, e_j\, (r_j - r_t)^2$. The T-statistic is then divided by $r_t (1 - r_t)$, and referred to a χ^2 distribution.

To compare vegetation characteristics among the three plots, we used ANOVA and Tukey-Kramer pairwise comparisons (Minitab Inc. 1996, Devore and Peck 1997). We performed a two-sample t-test assuming unequal variances (Minitab Inc. 1996) to compare vegetation characteristics between successful and unsuccessful nests. To determine whether birds were choosing nest sites that were different from what was available in the area surrounding the nests we used paired t-tests for sample means (Minitab Inc. 1996) to compare nest vegetation measurements to plot vegetation measurements from the nearest plot vegetation sampling point. We used only those species for which five or more nests were found: Grasshopper Sparrow (n = 24), Bobolink (n = 7), Mallard (*Anas platyrhynchos*; n = 5), and Savannah Sparrow (n = 5).

RESULTS

Bird densities and point vegetation.—Forty-seven species were detected within a circular plot during the 3-min surveys (Appendix 1). There were no significant differences in species richness among the three categories of spurge-infested grasslands (F = 0.34, P = 0.71; Table 1.1). The greatest number of species (31) was detected on all high-spurge survey points combined, whereas the fewest (27) were detected on all low-spurge points combined. Of the 48 species, 20 (42%) were detected on only one type of point (Appendix 1). However, some species (e.g. Gray Catbird [*Dumetella carolinensis*], Rose-breasted Grosbeak [*Pheucticus ludovicianus*], Scarlet Tanager [*Piranga olivacea*], and Warbling Vireo [*Vireo gilvus*]) are not generally associated with open grassland habitats (DeGraaf and Rappole 1995), and resulted from the presence of shrubby and woody thickets within the grassland complex (Stewart 1975). Some grassland species, such as Northern Harrier (*Circus cyaneus*), and Loggerhead Shrike (*Lanius ludovicianus*)

were found in such low densities that they were detected on only one or two points. The occurrence of these species on only one type of survey point is probably a result of the low chance of detection rather than a significant association with spurge. Fourteen species (29%) were detected on all three types of points, including all eight of the most abundant grassland birds (Appendix 1). Average species diversity was essentially equal across spurge levels ($F = 0.38$, $P = 0.69$; Table 1.1).

With the exception of Upland Sandpiper, there were no significant differences ($P > 0.10$) in breeding bird densities among low-, medium-, and high-spurge survey points (Table 1.1). Upland Sandpiper densities were significantly higher on medium-spurge points (14.3 birds/100 ha) than on low points (2.5 birds/100 ha; Table 1.1). However, this difference may not have practical significance; the upper limit of the Tukey-Kramer 90% Confidence Interval was close to zero (-0.7, -0.1). A pairwise comparison is considered insignificant when the confidence interval contains zero (Devore and Peck 1997). In addition, individual 95% confidence intervals for low and medium circular plots based on the pooled standard deviation (±0.21) nearly overlapped (upper limit for low-spurge points: 0.29; lower limit for medium-spurge points: 0.23). After correcting for detectability, Grasshopper Sparrow was consistently the most abundant species across spurge infestation levels, though this species' average density (32.6 birds/100 ha) was lowest on high-spurge points (Table 1.1). Furthermore, densities of four species (Clay-colored Sparrow, Grasshopper Sparrow, Le Conte's Sparrow, and Savannah Sparrow) were lowest on high-spurge points, whereas densities of the other four species were intermediate on high-spurge points (Table 1.1). None of these eight species occurred at higher densities on high-spurge plots.

Bird species richness, and species diversity were not significantly correlated (–0.21 < r_s < +0.21) with number or cover of spurge stems (Table 1.2). However, Le Conte's Sparrow and Savannah Sparrow densities were significantly ($P < 0.10$) negatively correlated with number and cover of spurge stems. In fact, Le Conte's Sparrow density was four times lower on high-spurge points than on low-spurge points (Table 1.1). Bobolinks, Clay-colored Sparrows, and Grasshopper Sparrows displayed negative trends with spurge stems and cover (Table 1.2). There were statistically significant trends among bird densities and other vegetation characteristics ($P < 0.10$; Table 1.2). For example, species diversity was negatively correlated with forb cover (-0.32). Bobolink density was positively correlated with grass cover (0.21), and negatively correlated with bare ground cover (-0.34). Brown-headed Cowbird density was positively correlated with woody vegetation cover (0.35), vegetation height (0.26), and vegetation density (0.25), but negatively correlated with litter cover (-0.25). Clay-colored Sparrow density was positively correlated with forb cover (0.26) and woody vegetation cover (0.22). Grasshopper Sparrow density was positively correlated with litter cover (0.43) but negatively correlated with vegetation height, litter depth, and vegetation density (-0.30, -0.29, and –0.35, respectively). Savannah Sparrow density was positively correlated with litter depth (0.28). Upland Sandpiper density was positively correlated with bare ground cover (0.21) and litter cover (0.40), and negatively correlated with vegetation density (-0.21).

Clay-colored Sparrow density was negatively correlated with grazing intensity (-0.34; Table 1.3). Savannah Sparrow density was positively correlated with grazing intensity (0.28). Number of spurge stems/m^2 and percent cover of spurge were not

correlated with grazing (-0.01, and –0.03, respectively; Table 1.3). As expected, vegetation height and density were significantly negatively correlated with grazing intensity (-0.42, and –0.40, respectively; Table 1.3). Forb and woody vegetation cover also were significantly negatively correlated with grazing intensity (-0.21, and -0.36, respectively; Table 1.3). Surprisingly, grass cover was positively correlated with grazing intensity (0.24; Table 1.3). Despite these significant correlations with structure and grazing, Best Subsets Regressions did not generate any powerful models ($R^2 \leq 18\%$ for best two-predictor models; Appendix 2).

On average, the number of spurge stems/m^2 was significantly higher on high-spurge points than on low or medium points ($F = 28.32$, $P < 0.001$; Table 1.4). The same was true for percent cover of spurge ($F = 34.50$, $P < 0.001$; Table 1.4). In contrast, average percent cover of other forbs was significantly higher on low-spurge points than on high-spurge points ($F = 6.06$, $P = 0.004$; Table 1.4).

Nests and nest vegetation.—We located a total of 57 nests of 13 species (Table 1.5). Low Plot contained the greatest number of nests (24) whereas High Plot held less than half as many nests (11) and half as many nesting species (4). However, Mayfield nest success of all species combined was almost twice as high on High Plot (0.753, SE = 0.013) as it was on Low Plot (0.403, SE = 0.011) and Medium Plot (0.328, SE = 0.014), and nest success rates differed significantly ($\chi^2 = 13.2$, df = 2, $P \approx 0.001$) among all three plots. The Grasshopper Sparrow was the most numerous nesting species on all plots (Table 1.5). Grasshopper Sparrow nest success was almost three times lower on Medium Plot (0.278, SE = 0.017) than on Low Plot (0.802, SE = 0.015) and High Plot (0.716, SE

= 0.014), and nest success differed significantly ($\chi^2 = 18.3$, df = 2, $P < 0.001$) among all three plots.

There were almost no differences among plots in mean number of Grasshopper Sparrow eggs per nest (Low Plot, 4.3; Medium Plot, 4.0; High Plot, 4.3). Brown-headed Cowbird parasitism was low across plots. One Savannah Sparrow nest on Medium Plot held two cowbird eggs, one Savannah Sparrow nest on Low Plot held 1 egg, and two Bobolink nests on Medium Plot each were parasitized with one egg. None of the nests successfully raised a cowbird chick; three were depredated and one Bobolink nest fledged its own young but the single cowbird egg did not hatch.

On average, the number of spurge stems/m^2, percent cover of spurge, percent cover of other forbs, percent cover of woody vegetation, vegetation height, and vegetation vertical density significantly differed among spurge categories (stems: F = 7.13, P = 0.001; spurge: F = 6.00, P = 0.004, other forbs: F = 6.21, P = 0.02; woody: F = 3.03, P = 0.055; height: F = 4.58, P = 0.01; density: F = 5.50, P = 0.006; Table 1.6). The number of spurge stems/m^2 and percent cover of spurge were higher on High Plot than on Low Plot (Tukey-Kramer 90% Confidence Interval—stems: 3.4, 11.8; spurge: 4.9, 19.7). In contrast, average percent cover of bunchgrass was significantly higher on Low Plot than on High Plot (Tukey-Kramer 90% Confidence Interval: -12.5, -1.5). On average, percent cover of other forbs, percent cover of woody vegetation, vegetation height, and vegetation vertical density were significantly greater on Medium Plot than on Low Plot (Tukey-Kramer 90% Confidence Interval—other forbs: 7.5, 30.6; woody: 0.1, 1.3; height: 2.5, 16.2; density: 0.3, 1.1).

We found no significant differences between number of spurge stems/m^2 or percent cover of spurge between successful and unsuccessful nests (stems: t = -0.12, df = 42, P = 0.91; % cover: t = -0.73, df = 47, P = 0.47; Table 1.7). However, successful nests were situated in significantly shallower litter layer (t = 2.42, df = 29, P = 0.02) and taller vegetation (t = -1.80, df = 47, P = 0.079) than unsuccessful nests (Table 1.7). When we performed the same analysis for only Grasshopper Sparrow nests we also found no significant differences for number of spurge stems/m^2 or percent cover of spurge (stems: t = -0.38, df = 16, P = 0.71; cover – t = -0.01, df = 12, P = 0.99), but successful nests had significantly more grass cover than unsuccessful nests (t = -2.09, df = 17, P = 0.05; Table 1.7).

There were no statistically significant differences between number of spurge stems/m^2 or percent cover of spurge around nests in comparison to the paired plot vegetation samples (P > 0.10 for all tests; Table 1.8). For nests of all species combined, there was significantly less forb cover (t = -3.95, df = 49, P < 0.001), more grass cover (t = 3.09, df = 49, P = 0.003), more bunchgrass cover (t = 2.10, df = 49, P = 0.048), and less bare ground (t = -2.44, df = 49, P = .018; Table 1.8) surrounding nests. Similarly, Grasshopper Sparrow nests had lower forb cover (t = -2.18, df = 19, P = 0.042; Table 1.8), Mallard nests had higher bunchgrass cover (t = 2.18, df = 4, P = 0.095), and Savannah Sparrow nests had higher grass cover (t = 5.09, df = 4, P = 0.007; Table 1.8) than the nearby plot vegetation.

DISCUSSION

Bird species richness, species diversity, and seven of eight breeding bird densities were not significantly different among survey points with different levels of spurge

infestation. However, none of the eight most abundant grassland birds occurred at highest densities on high-spurge points. Upland Sandpiper density was higher on medium-spurge survey points than on low-spurge survey points, but this difference was quantitatively small and may not be biologically meaningful. Furthermore, this species was not correlated with spurge stems or spurge cover. Densities of Le Conte's and Savannah Sparrows were negatively correlated with spurge infestation, and Le Conte's Sparrow densities were four times higher on low-spurge survey points. Le Conte's Sparrows favor dense stands of live and dead grass for foraging and nesting (Lowther 1996). Savannah Sparrow habitat preferences are relatively broad across their geographic range but they also typically prefer dense grass cover (Wheelwright and Rising 1993). Although not statistically significant, high-spurge points did have somewhat less grass cover, bunchgrass cover, and more bare ground cover than low- and medium-spurge points.

While some species could be affected by spurge infestation per se, other factors may play a stronger role in influencing breeding bird community parameters. Average species diversity, and densities of Brown-headed Cowbird, Clay-colored Sparrow, Grasshopper Sparrow, Savannah Sparrow, and Upland Sandpiper were significantly correlated with other vegetation characteristics. Some of these relationships are consistent with known habitat preferences. In the Midwest, Bobolinks prefer tall, dense vegetation (Rotenberry and Wiens 1980, Kantrud 1981, Delisle and Savidge 1997). In this study, Bobolink density was negatively correlated with bare ground cover and positively correlated with grass cover, vegetation height, and vertical density. Clay-colored Sparrow's correlation with forb and woody vegetation cover probably reflects

this species' preference for foraging and nesting in shrubby and weedy components of grasslands (Knapton 1994). Grasshopper Sparrows typically select sparser, patchier, moderately open grasslands (Vickery 1996, Delisle and Savidge 1997). Negative correlations between Grasshopper Sparrow densities and litter depth, vegetation height, and vertical density in this study may indicate this preference. The relatively strong positive correlation with litter cover could also reflect this species' preference for patchy vegetation assuming the presence of horizontal litter among grass clumps is a measure of patchiness for this species. Bare ground can also be used as an index of patchiness (Wiens 1974). Contrary to the reported positive association of this species with bare ground (Vickery et al. 1996), this species was negatively associated with percent bare ground on our survey points. Upland Sandpipers show a preference for the shorter, sparser cover of pastures (Kantrud and Higgins 1992, Bowen and Kruse 1993). This species was positively correlated with bare ground and litter cover, and negatively correlated with vegetation vertical density. Overall, survey points among the three levels of spurge infestation were similar to each other in all measured aspects except for spurge and percent cover of other forbs, and yet six of the eight bird species were correlated with vegetation features other than spurge. This could explain why there were few differences in breeding bird diversity, richness, and densities among spurge infestation categories. Despite these correlations, vegetation variables explained less than 19% of the variation in the bird community and population parameters. Therefore, other factors in addition to vegetation structure likely influenced the grassland bird community.

Cattle grazing intensity was another possible explanatory variable for patterns of breeding bird densities. Clay-colored Sparrow density was negatively correlated with

grazing whereas Savannah Sparrow density was positively correlated. Grazing may affect birds through alteration of vegetation structure, i.e. height and density (Kantrud 1981, Kantrud and Kologiski 1983, Lym and Kirby 1987, Gillen et al. 1991, Bowen and Kruse 1993, Hartnett et al. 1996). Vegetation height and vertical density were significantly negatively correlated with grazing. However, these two bird species were not correlated with vegetation height or density. Cattle may negatively affect grassland birds by trampling vegetation, trampling nests, attracting cowbirds, or interfering with bird behavior by their physical presence (Bowen and Kruse 1993). Though it is difficult to determine the magnitude of these disturbances on the SNG as a whole, nests on our plots were not trampled and cowbird parasitism was low. In any case, grazing intensity explained only a small percentage of the variation in bird community and population parameters.

Surprisingly, spurge stems and cover were not correlated with grazing intensity. We expected spurge infestation to be positively correlated with grazing given that cattle graze around spurge patches, creating disturbances which spurge finds favorable for seedling establishment and vegetative expansion (Selleck et al. 1962, Lym and Kirby 1987, Bedunah 1992). Intermediate levels of disturbance, such as rotational grazing, are theorized to contribute to increased levels of plant species diversity and invasibility by preventing domination by superior competitive species, and by shifting the availability of limiting resources (Collins 1987, Collins and Glen 1990, Damhoureyeh and Hartnett 1997, Smith and Knapp 1999, Stohlgren et al. 1999a and 1999b). Given that non-grazed forbs can undergo competitive release when the surrounding grass matrix is disturbed (Damhoureyeh and Hartnett 1997), and spurge is a superior competitor in disturbed

situations (Selleck et al. 1962, Lym and Kirby 1987) we predicted spurge infestation would increase with grazing. While grazing does occur every year on the SNG, pasture rotation schedules vary each year (Bryan Stotts, *pers. comm.*). The association between spurge infestation and grazing intensity may not be long enough in any given pasture to create a significant unidirectional relationship. Other factors such as plant species richness, composition, and abundance (Tilman 1997), soil characteristics (Stohlgren et al. 1999a and 1999b), distributions of limiting resources (Stohlgren et al. 1999a, Tilman 1999), plant species dispersal and recruitment (Tilman 1997, Lonsdale 1999), species-specific interactions (Tilman 1997, Lavorel et al. 1999, Lonsdale 1999, Stohlgren et al. 1999a), and trade-offs among these factors (Tilman 1999) likely affect spurge infestation levels.

The number of nests and nesting species were lowest on High Plot. However, nest success of all species combined was significantly higher on High Plot than on Low Plot or Medium Plot. We predicted fewer nests on High Plot assuming spurge negatively alters the habitat structure that birds prefer for nesting. However the higher nest success on High Plot suggests that spurge patches could provide nests with additional vertical cover from visual predators. Spurge germinates in April and can grow to heights of one meter (Selleck et al. 1962), so when birds arrive on the breeding grounds spurge is often the tallest plant on the grasslands. Furthermore, cattle grazing maintains lower heights of prairie grasses and other forbs relative to spurge. Predators may be discouraged from foraging in spurge patches because of the risk of skin irritation from the sap. Although we do not know of reports of this happening to wild animals, spurge sap has been known

to cause severe blistering and hair loss in horses and dermatitis in humans, and it is difficult to remove when it has coated the legs of livestock (Best et al. 1980).

Although not significant, on average, the number and cover of stems were greater around Grasshopper Sparrow, Mallard, and Savannah Sparrow nests. This supports the hypothesis that spurge could provide nest cover. However, successful nests did not have more or less spurge than unsuccessful nests for all species combined or Grasshopper Sparrow nests alone. Successful nests were situated in significantly shallower litter layer and taller vegetation than unsuccessful nests. This suggests that other structural features such as litter cover and vegetation height may have played more important roles in nest site selection and success.

Incidental observations of males and females perched atop leafy spurge stems suggest spurge could benefit birds by acting as a post for territory defense, mate attraction, mate guarding, predator vigilance, and surveillance for food. In addition, spurge could act as an indirect food source by hosting an insect community. Wilson and Belcher (1989) theorized that leafy spurge may support a relatively sparse insect fauna, especially grazers, due to the plant's toxic secondary compounds and milky sap. However, Roberts and Olson (1999) reported that captive-reared grasshopper nymphs (*Melanoplus sanguinipes*) fed spurge leaves experienced increased growth without increased mortality. In June and July spurge leaves contain more nutrients and less condensed tannin (Roberts and Olson 1999). The combination of higher nutritive value and lower toxin concentrations could allow grasshoppers and other insects to forage on spurge, thereby increasing insect biomass in spurge patches at a time when birds are foraging for their nestlings. Aside from insect herbivores, Selleck et al. (1962) reported

that pollination occurs almost entirely by insects. He observed bees, wasps, flies, mosquitoes, beetles, and ants visiting spurge flowers. Hymenoptera and Diptera dominated sweep net samples, with other insects and spiders collected as well (Selleck et al. 1962). All eight abundant grassland birds and all nesting species except Mourning Dove feed on terrestrial insects to some degree. However, the proportions of preferred insect taxa may differ from what is reportedly abundant in spurge. For example, Selleck et al. (1962) did not mention observing or capturing members of the orders Orthoptera or Lepidoptera. Grasshopper Sparrows (Vickery 1996) and Western Meadowlarks (Lanyon 1994) feed on orthopterans and lepidopterans in greater proportions than most other insect taxa. Kobal et al. (1998) reported that Henslow's Sparrows (*Ammodramus henslowii*), Dickcissels (*Spiza americana*), Bobolinks, Grasshopper Sparrows, Savannah Sparrows, Red-winged Blackbirds, and Eastern Meadowlarks (*Sturnella magna*) fed their nestlings adult orthopterans and larval lepidopterans in greater proportions than available in fields. Although their sweeps revealed insects to be concentrated around clumps of flowering forbs, they also lacked orthopterans and lepidopterans in their samples. They cautioned that it could be difficult to match field samples with diet. Thus, assuming birds forage in spurge patches, it is still possible that spurge patches host an insect community that birds find suitable.

Leafy spurge could also act as a direct food source by providing seeds. Seeds of the spurge family, Euphorbiaceae, are important food sources for Mourning Doves (Blockstein et al. 1987, Mirarchi and Baskett 1994). The majority of leafy spurge seeds fed to captive Mourning Doves did not germinate (Blockstein et al. 1987). This suggests that although Mourning Doves probably eat leafy spurge seeds in the wild, they rarely act

as dispersal agents (Blockstein et al. 1987). Grass and forb seeds constitute a large percentage of the diet of other grassland species such as the Bobolink (Martin and Gavin 1995), Brown-headed Cowbird (Lowther 1993) and Le Conte's Sparrow (Lowther 1996). If these species consume leafy spurge seeds then this could compensate for the reduction in seed availability of other plant species in spurge patches.

Studies have revealed that some birds can use invasive exotics extensively. Sutter et al. (1995) determined that Baird's Sparrow abundance in Manitoba was similar between mixed-grass prairies dominated by native species and prairies dominated by introduced crested wheatgrass (*Agropyron cristatum*). Analyses suggested that Baird's Sparrows were affected more by habitat structure than by plant species composition. Specifically, crested wheatgrass is structurally similar to native wheatgrasses (*A. dasystachyum* and *A. smithii*) and native June grass (*Koeleria gracilis*), so fields sown to crested wheatgrass might resemble native prairies. Working on the same prairie, Sutter and Brigham (1998) found little difference in grassland bird species richness, diversity, and abundance between native prairies and those converted to crested wheatgrass. They also believed birds cue in on vegetation structure (e.g. grass and sedge cover, bare ground, litter depth, and vegetation density) regardless of plant species composition. In contrast, Reynolds and Trost (1980) detected significantly lower bird species diversity and relative density in crested wheatgrass habitats. In addition they counted significantly fewer small and large mammals, and fewer reptiles in wheatgrass-planted areas as compared to native habitats. However, this study was conducted in a big sagebrush (*Artemisia tridentata*) community that is structurally more dissimilar to wheatgrass than mixed-grass prairie is to wheatgrass. This probably explains the difference in results and

emphasizes the point that vegetative physiognomy may be more important to birds, as well as other vertebrates, than floristic composition.

In New York, Rawinski and Malecki (1984) located more Red-winged Blackbird nests in purple loosestrife (*Lythrum salicaria*)-dominated wetlands than in cattail (*Typha* sp.) wetlands. They also made incidental observations of Black-crowned Night Heron (*Nycticorax nycticorax*) and Pied-billed Grebe (*Podilymbus podiceps*) nests in loosestrife stands. However, they found that Marsh Wrens (*Cistothorus palustris*) avoided nesting in loosestrife. Whitt et al. (1999) found that purple loosestrife-dominated wetlands in Michigan had higher avian densities in general, and higher densities of Swamp Sparrows (*Melospiza georgiana*) in particular, than other vegetation types. They found 12-27% of Swamp Sparrow nests in loosestrife-dominated wetlands, as well as ten other potential breeding species. They suggested that loosestrife may provide ample insects and nest-building material for some species. In a similar study, Hill (2000) did not find significant differences in bird species diversity or densities of the nine most abundant species. However, six of those species (Common Yellowthroat [*Geothlypis trichas*], Yellow Warbler [*Dendroica petechia*], American Goldfinch [*Carduelis tristis*], Red-winged Blackbird, Swamp Sparrow, and Song Sparrow [*Melospiza melodia*]) occurred at higher densities in loosestrife stands than in control sites. Furthermore, six species (Sora [*Porzana carolina*], American Coot [*Fulica americana*], Mourning Dove, Common Yellowthroat, Song Sparrow, and American Goldfinch) used loosestrife as nesting substrate. He concluded that purple loosestrife provides favorable habitat structure for certain species. However, he hypothesized that loosestrife is causing a shift in the avian

community by favoring birds that can tolerate the invasive plant, while excluding other species (e.g. Marsh Wren).

Shifts in native community composition have also been documented in grassland habitats. In these habitats, species-specific habitat preferences and flexibility determined avian responses to exotic plants. Wilson and Belcher (1989) found a shift in bird species composition between pure stands of native prairie and stands dominated by leafy spurge, Kentucky bluegrass (*Poa pratensis*), and smooth brome (*Bromus inermis*). They determined that Upland Sandpiper and Sprague's Pipit (*Anthus spragueii*) were significantly more abundant in areas dominated by native vegetation than in areas dominated by introduced plants. In addition Western Meadowlark, Baird's Sparrow (*Ammodramus bairdii*), and Savannah Sparrow were positively correlated with native prairie and negatively correlated with cover of introduced species. Meanwhile the opposite was true for Vesper Sparrow (*Poocetes gramineus*), Clay-colored Sparrow, and Grasshopper Sparrow, though none of these species were significantly correlated with leafy spurge alone. The average number of birds of all species per transect, and the number of species per transect also were lower in introduced vegetation. They attributed differences in bird species composition to differences in habitat structure and food supply between native and exotic vegetation. The three Eurasian plant species were relatively tall and homogenous in height and density compared to the native mixed-grass community (Belcher and Wilson 1989, Wilson and Belcher 1989). This may explain why species that prefer relatively short grass, such as Upland Sandpiper and Sprague's Pipit, were less abundant in introduced vegetation. Native plant species richness and cover values were significantly reduced in introduced vegetation. Wilson and Belcher

(1989) suggested that a reduction in plant diversity could lead to a relatively reduced structural diversity, sparse insect fauna, and reduced seed availability.

Bock et al. (1986) found that 26 plant, grasshopper, rodent, and bird species were significantly less common in Arizona semidesert grasslands planted with the African lovegrasses *Eragrostis lehmanniana* and *E. curvula*. Whereas, Botteri's Sparrow (*Aimophila botterii*), Hispid Cotton Rat (*Sigmodon hispidus*), and the grasshopper species *Phoetaliotes nebrascensis* were significantly more abundant in exotic patches. *P. nebrascensis* is a dietary generalist that prefers tall vegetation, such as that provided by African lovegrasses. Both Botteri's Sparrow and Hispid Cotton Rat are habitat specialists that were locally abundant in floodplains dominated by sacaton grass (*Sporobolus wrightii*). They may have preferred the exotic lovegrasses because these invasive species were structurally similar to sacaton grass insofar as they grew in relatively tall, nearly monotypic stands (Bock et al. 1986).

Bollinger (1995) determined that age, and hence structure, of New York hayfields influenced grassland breeding bird composition. Over time, hayfields changed from tall, dense, homogeneous stands of exotic legumes to short, sparse, patchy stands of mostly exotic grasses. Along this gradient of hayfield succession Red-winged Blackbird densities were highest on fields of intermediate age, Bobolink abundance increased with field age, and Upland Sandpipers, Eastern Meadowlarks (*Sturnella magna*), Grasshopper Sparrows, and Henslow's Sparrows were most abundant on the oldest hayfields. Field size also was a factor, but was usually of secondary importance to vegetation structure.

Schmidt and Whelan (1999) determined that American Robins (*Turdus migratorius*) and Wood Thrushes (*Hylocichla mustelina*) preferred nesting in introduced

honeysuckle (*Lonicera maackii* and *L. tatarica*) and buckthorn (*Rhamnus cathartica*) instead of native viburnums (*Viburnum* spp.) and hawthorns (*Crataegus* spp.) because these exotic shrubs produced leaves earlier in the season and provided favorable branching structure. Gray Catbirds, Northern Cardinals (*Cardinalis cardinalis*), Rose-breasted Grosbeaks, Blue Jays (*Cyanocitta cristata*), and Red-eyed Vireos (*Vireo olivacea*) also preferred exotic shrubs to natives (Whelan and Dilger 1992). However, nests in these shrubs experienced higher predation rates probably because of the open branching structure, absence of thorns, and higher nest densities. Thus, these exotic plants acted as ecological traps (Schmidt and Whelan 1999). Whelan and Dilger (1992) suggested that replacement of exotic shrubs with native species is necessary but it should be done gradually to prevent the complete removal of nesting habitat.

Cohan et al. (1979) also suggested that clearing and replanting in stands of the exotic, invasive saltcedar (*Tamarix chinensis*) would enhance the attractiveness of a given area to a wider range of bird guilds. Saltcedar is an aggressively spreading tree in the floodplains of the southwestern United States (Anderson et al. 1977, Cohan et al. 1979). Though there was seasonal variation in the saltcedar bird community, granivores tended to be the primary users. Insectivores occurred in lower numbers in connection with lower insect biomass associated with saltcedar (Cohan et al. 1979). Frugivores were absent because of a lack of mistletoe (*Phoradendron californicum*), their primary fruit source. Woodpeckers also occurred in reduced numbers in mature saltcedar stands because the relatively thin limbs and trunks did not provide suitable nest cavities (Anderson et al. 1977). Replacing portions of a pure stand of saltcedar with native trees

could provide more favorable forage and habitat structure for wildlife (Cohan et al. 1979).

Even in aquatic habitats invasive exotic plants have proven to be beneficial for some birds. When dense beds of Eurasian milfoil (*Myriophyllum spicatum*) spread into a national wildlife refuge in Virginia, overwintering waterfowl numbers increased significantly (Florschutz 1972). Analyses of waterfowl gastrointestinal tract contents revealed that, excluding grit, milfoil comprised approximately one-third of the total food volume of 170 birds of 12 species. Scaup (*Aythya* spp.) contained the largest amount (93.3%; Florschutz 1972). Similarly, hydrilla (*Hydrilla verticillata*) beds on Lake Okeechobee, Florida supported a greater density and diversity of waterfowl than native plant communities (Johnson 1987). The plant's floating growth form allowed surface-feeding ducks to use deeper water (Johnson 1987). In contrast, waterfowl do not consume water hyacinth (*Eichhornia crassipes*) (Lynch et al. 1947). In fact, its dense floating mats decrease the value of waterfowl habitat in the gulf coast states by blanketing open water and marshland which reduces native plant diversity by blocking sunlight, increasing turbidity, and uprooting other plants (Lynch et al. 1947). Water hyacinth also destroys Snail Kite (*Rostrhamus sociabilis*) nesting and feeding sites by coating cattails and bulrushes (*Scirpus* spp.), and covering submerged plants on which Apple Snails (*Pomacea paludosa*) feed (Griffen 1989).

Thus, the effects of invasive exotic plants on breeding bird communities vary from beneficial to neutral to detrimental, depending upon the plant and bird species involved. Clearly habitat structure and resource availability play major roles. Our results suggest that breeding bird responses to leafy spurge infestation on the SNG also ranged

from weakly negative to neutral to potentially beneficial. Species richness, species diversity, and seven of eight breeding bird densities were not significantly different among infestation levels. However, densities tended to be lower on high-spurge survey points, and Le Conte's Sparrows and Savannah Sparrows were negatively correlated with spurge. Although there were fewer nests and nesting species on High Plot, nest success for all species combined was highest on this plot. In addition, nest success and nest site selection appeared to be associated more with vegetation structural characteristics such as cover percentages, litter depth, height, and density than with spurge infestation per se.

It can be difficult to tease apart the effects of vegetation structure from the effects of the plant species themselves (Rotenberry 1985). Rotenberry (1985) argued that within a habitat type, bird distribution is determined by plant taxonomic composition. Specifically, he stated that birds are tied to specific plant species through food and foraging behavior. This may be especially evident for more specialized foragers such as nectivores and frugivores (e.g. Cohan et al. 1979). Cody (1981) also stated that, among other factors, foraging opportunities affect habitat choices. However, he believed that vegetation structure provided the link between birds and foraging sites, particularly for insectivores. We also believe that, at least for grassland birds, structure is probably more important than plant species composition. The importance of habitat physiognomy over floristics may be observed when native prairies are invaded by exotic plant species without a measurable change in the breeding bird community (e.g. Sutter et al. 1995, Sutter and Brigham 1998). Even among those studies that detected species-specific responses to invasive exotics, some (e.g. Cohan 1979, Bock et al. 1986, Bollinger 1995,

Schmidt and Whelan 1999, Whitt et al. 1999, Hill 2000) cited changes in vegetation structure as an underlying cause.

Given that vegetation structure can influence bird abundance, and that patches of relatively tall forbs such as leafy spurge intuitively should change vegetation structure, it is curious that we did not observe stronger responses from the grassland birds. Hull et al. (1995, 1996) hypothesized that forbs could increase bird use of CRP grasslands by adding structural complexity. However, Hull et al. (1995) observed no differences in winter bird abundances among fields with different levels of summer forb abundance because fields became structurally similar in winter. During the breeding season however, Delisle and Savidge (1997) found that forbs on brome-planted CRP fields in Nebraska created patches of tall vegetation that attracted Dickcissels. In contrast, Hull et al. (1996) did not find significant relationships between forb abundance and breeding bird abundances. Hull et al (1996) attributed this finding to low forb canopy coverages (≤ 24% per field) which might have been below the threshold preference levels of grassland birds. For survey points on the SNG, combined average cover values of leafy spurge and other forbs were approximately 24% (low), 28.5% (medium) and 57.7% (high). This suggests that at least low- and medium-spurge survey points had forb cover values below bird threshold preferences. Furthermore, the number of spurge stems/m^2 across survey points ranged from 0-304 (mean = 20, SD = 43). This agrees with Svedarsky and Van Amburg (1996) who reported patch densities of 200 stems/m^2 and higher on the SNG. In contrast, Selleck et al. (1962) stated that seedling densities of 2,800/m^2 were not uncommon, and after interspecific competition stem densities were 500/m^2 to 1000/m^2. Therefore, spurge infestation on much of the SNG is relatively low and almost certainly

has not reached its greatest possible coverage. Assuming that spurge has the potential to alter breeding bird composition, the current level of infestation may be below threshold levels for grassland birds. There may be enough non-spurge vegetation in and among spurge patches that vegetation structure is not altered enough to prevent birds from foraging and nesting. Furthermore, non-spurge forb cover significantly decreased at higher levels of spurge cover on the survey points. This suggests that leafy spurge may be replacing the forb component of the grasslands without significantly altering other vegetational features.

It is important to note that this study was conducted during one field season in one location. While our results suggest that differences in vegetation structure influence breeding bird community parameters, other factors such as interspecific interactions (Wiens 1974, Cody 1981), habitat productivity (Cody 1981, 1985, Rotenberry 1985), environmental and climatic variation (Rotenberry and Wiens 1980, Cody 1981, 1985), events during the non-breeding season (Willson 1974), species-specific responses (Wiens 1974, Cody 1981, Rotenberry 1985), and the spatial and temporal variability of these factors also play a role in population dynamics, and may obscure community-level patterns and generalizations. In any case, we believe the assumption that spurge has the potential to significantly affect the breeding bird community is valid. It is likely that as spurge spreads and alters both the plant community composition and structure, resource abundance and availability will be altered as well. We predict some bird species will be extirpated while others will show habitat flexibility (Sutter et al. 1995, Hill 2000) and use spurge patches for foraging and nesting. One possible shift in the grassland bird community is as follows. Le Conte's Sparrow, Savannah Sparrow, Grasshopper

Sparrow, and Brown-headed Cowbird abundances could decrease with increasing spurge levels. Le Conte's and Savannah Sparrows were negatively correlated with spurge. Grasshopper Sparrows (Vickery 1996) and Brown-headed Cowbirds (Lowther 1993) may not forage in tall, dense, homogenous stands of spurge. Upland Sandpipers may continue to show higher levels of abundance at intermediate spurge densities but it is likely that they too will not nest and forage in tall, dense fields (Bowen and Kruse 1993). Clay-colored Sparrow, Bobolink, and Western Meadowlark densities could increase with increasing infestation. These three are commonly found in weedy situations, may use forbs in nest construction, and consume weed seeds (Knapton 1994, Lanyon 1994, Bollinger 1995, Martin and Gavin 1995). We cannot predict, however, exactly what infestation level will be necessary to reach the tolerance thresholds of these species and hence ultimately lead to a decrease in the biodiversity of the SNG. Therefore, we recommend that current spurge control practices be continued with the added goal of preservation of bird species richness and diversity.

CHAPTER II

INTRODUCTION

The Sheyenne National Grassland (SNG) consists of two units that encompass 28,400 ha of federally owned and managed habitats in southeastern North Dakota. These habitats include tallgrass prairie, mixed-grass prairie, woodland, cottonwood stands, oak savanna, lowland riparian forest, sedge meadow, and wetland (Seiler and Barker 1985, Svedarsky and Van Amburg 1996). It contains North Dakota's largest native tallgrass prairie and numerous sensitive plant and animal species (Svedarsky and Van Amburg 1996). Despite its size and importance as a refuge for birds such as the Greater Prairie-Chicken (*Tympanuchus cupido*), the breeding bird community of the SNG has gone largely unstudied (Bryan Stotts, US Forest Service, Lisbon, ND, *pers. comm.*, but see Svedarsky and Van Amburg [1996] for a study of the Greater Prairie-Chicken). Thus, managers lack basic information on breeding bird habitat use. The purpose of this chapter is to describe the breeding bird communities of the major habitat types of the SNG with the intent that this information will aid habitat and wildlife management.

METHODS

Study site.—The SNG is located in Ransom and Richland Counties in the Prairie Pothole Region of southeastern North Dakota. It is divided into two units. The northern unit is a matrix of federally owned and privately owned land with approximately 27,242 ha of federal land and 25,597 ha of private land (Svedarsky and Van Amburg 1996). The southern unit is approximately 1,157 ha of federal land. This study was conducted on federally owned land of the northern unit, though incidental observations for purposes of compiling a species list were made throughout the matrix. Although the dominant habitat

type of the area is tallgrass prairie, the SNG is a mosaic of habitat patches that grade from riverine to dry upland across a complex topography of river terrace, deltaic plain, hummock, and choppy sandhill (Seiler and Barker 1985, Hansen 1996, Svedarsky and Van Amburg 1996). Seasonal changes in temperature and precipitation, along with hilly topography, create potholes of various sizes and longevity, from wet-meadow swales to permanent ponds (Stewart 1975). This adds a temporal component to the complex spatial distribution of the plant and bird communities.

For the purposes of this study we identified five broad habitat types: grassland, sedge meadow, wetland, savanna, and woodland. We defined grassland as habitats dominated by *Andropogon gerardii*, *Schizachyrium scoparium*, *Poa pratensis*, *Bouteloua gracilis*, or *Panicum virgatum*. Sedge meadows were areas dominated by *Carex lanuginosa*, *Calamagrostis inexpansa*, and *Juncus balticus*. Wetlands were those prairie potholes that held standing water throughout the summer season. Typha spp., and Salix exigua dominated these sites. Savannas were dominated by *Quercus macrocarpa* or *Populus tremuloides*, and had 10-80% canopy cover. Woodlands were habitat patches with greater than 80% canopy cover and dominated by *Fraxinus pennsylvanica*, *Populus deltoides*, *Ulmus americana*, or *Tilia americana*. Agricultural fields also are present within the SNG complex but primarily on private land and were not formally surveyed.

Roughly 29,269.4 ha (55.4%) of the north unit (both federal and private land) is covered by grassland, 7,334.8 ha (13.9%) by sedge meadow or wetland, 7,278.1 ha (13.8%) by savanna and woodland, and the remainder is by covered by cropland (Svedarsky and Van Amburg 1996). For more detailed discussions of the climate, soils,

topography, and plant communities of the SNG and its surroundings see Stewart (1975), Seiler and Barker (1985, 1987), Hansen (1996), and Svedarsky and Van Amburg (1996).

Bird surveys.— Randomly generated Universal Transverse Mercator coordinates were placed on all U.S. Geological Survey 7½ minute topographic maps that cover the SNG. Then we located these points in the field and categorized them into one of the five habitat types by visual inspection. We accepted points if they encompassed only a single habitat type. Due to topography and the heterogeneous spatial distribution of vegetation communities, survey points did not necessarily encompass similar levels of variability in possible confounding factors such as distance from habitat edge, habitat edge type, soil type, slope, aspect, and grazing intensity.

We established 60 100-m radius grassland circular plots and nine 100-m radius sedge meadow circular plots. We established seven 100-m radius half-circle plots, each with the base along the wetland edge and the half-circle extending into the wetland. Finally, seven savanna and five woodland survey points were established, each with a 50-m radius because of reduced visibility in these habitats. All points were at least 100 m from another point's perimeter.

We surveyed birds using the fixed-radius point count technique (Ralph et al. 1995). For this technique we counted all birds (by species, and by sex for sexually dimorphic species) seen or heard from a fixed point in the center of the circle, or the center of the base for half-circles. We estimated distances of birds within the point count circle in 20-m intervals for 100-m radius points, and in 10-m intervals for 50-m radius points. Only birds detected within the point count circle were used in data analyses, but birds beyond the circle's perimeter also were counted. We counted birds for three

minutes per point and each point was surveyed twice. Surveys occurred from 31 May to 2 July 1999 between 0500 and 1000 CST. To minimize time-of-day bias we alternated visits to a particular point between earlier and later halves of the survey time period. Points were not surveyed during heavy rains or when wind speeds exceeded 16 kilometers per hour (Martin and Conway 1994).

This survey method tends to underestimate those species repelled by observer presence such as waterfowl, gallinaceous birds, and cuckoos. It also overlooks secretive and nocturnal birds such as rails and owls. To determine total species richness for the SNG, we also noted any additional species detected while walking to and from a point, as well as incidental observations made at other times. However, we did not employ playbacks or nocturnal searches.

Data analysis.— For each species we combined sexes and then we averaged the two visits to each point to obtain a single estimate of abundance for each species at each point. We calculated densities as a standardized birds per 100 ha. Although there were differences in detectability among species, we did not adjust the raw counts. Sample sizes for most species were too small for DISTANCE calculations (Thomas et al. 1998). To be consistent we used raw counts for all species. The use of DISTANCE did change the exact order of numerical dominance for some species but the general dominance of common species did not differ. For convenience of analysis and interpretation, less abundant species were grouped (i.e. counts were summed) according to broad similarities in habitat (Stewart 1975, DeGraaf and Rappole 1995) or foraging preferences (Ehrlich et al. 1988; Table 2.1). We used a habitat-based classification for grassland, sedge meadow, and wetland habitats because most of the abundant species in these habitats could be

classified into one or two foraging guilds. Likewise, a foraging guild-based classification was more meaningful for savanna and woodland species because most of these species could be classified into one habitat group. We used Analysis of Variance (ANOVA, Minitab Inc. 1996) and Tukey-Kramer pairwise comparisons with a family error rate of 0.10 (Minitab Inc. 1996, Devore and Peck 1997) to test for differences in mean species richness and mean diversity among habitat types.

RESULTS

A total of 135 species of actually or potentially breeding birds were detected on the SNG and adjacent lands. Of these species, six (Eastern Screech-Owl [*Otus asio*], Short-eared Owl [*Asio flammeus*], Burrowing Owl [*Athene cunicularia*], Yellow Rail [*Coturnicops noveboracensis*], Purple Martin [*Progne subis*], and Chestnut-collared Longspur [*Calcarius ornatus*]) were not encountered during the study period but are likely to breed in the area (Stewart 1975). The list of bird species, habitat preferences, and densities (where estimated) are provided in Appendix 1.

Forty-seven species were detected within grassland point count circles during the 3-min surveys (Table 2.2). An average of 6.7 species per point was encountered. Western Meadowlarks (*Sturnella neglecta*) were the most numerous species detected (47.5 birds/100 ha), and Grasshopper Sparrows (*Ammodramus savannarum*) were the second most abundant species (41.9 birds/100 ha). Red-winged Blackbirds also were abundant (28.7 birds/100 ha), though this species was primarily associated with wetlands (Stewart 1975, DeGraaf and Rappole 1995, Yasukawa and Searcy 1995). Species more typical of sedge meadows and wetlands, or woodlands and savannas also were detected on the grasslands (16.2 and 12.2 birds/100 ha, respectively).

Twenty-two species were detected within point count circles in sedge meadows during the 3-min surveys (Table 2.3). An average of 8.1 species per point was detected. Red-winged Blackbirds were the most abundant species in this habitat type (88.5 birds/100 ha). Mallard was the second most numerous species (79.6 birds/100 ha). This number may be misleading, however, because a flock of approximately 44 individuals was counted on one circular plot whereas this species was not detected on seven other sedge meadow survey points. In either case, Mallards were a common species on the SNG. Not surprisingly, those species primarily associated with low-lying, wet habitats were, as a group, third in abundance (70.8 birds/100 ha). Six species primarily associated with upland grassland habitats also were detected; among these, Savannah Sparrow (*Passerculus sandwichensis*) and Western Meadowlark occurred at highest densities (26.5 and 24.8 birds/100 ha, respectively).

Twenty-three species were detected within wetland 100-m radius half-circles during survey periods (Table 2.4). On average, 8.6 species per point were detected. A variety of species typical of wetlands and the sedge meadows that border wetlands dominated the counts (232.0 birds/100 ha). However, Red-winged Blackbirds alone occurred in higher densities (382.2 birds/100 ha). Five grassland species (63.7 birds/100 ha combined) also were detected along the margins of the wetlands.

Twenty-seven species were detected during savanna point counts, with an average species richness of 6.6 species per point (Table 2.5). The ground foraging guild dominated savanna sites in terms of mean density (236.6 birds/100 ha) and number of species (12). Although the flycatcher guild contained only three members, this group was the second most abundant (127.4 birds/100 ha). This was due to the Eastern Wood-

Pewee (*Contopus virens*) that occurred at a higher average density (81.9 birds/100 ha) than any other species in this habitat.

Seventeen species were detected during 3-min survey periods on woodland point counts (Table 2.6). An average of 5.8 species per point were detected. Ground foraging birds occurred at the highest collective density (229.3 birds/100 ha). However, the Least Flycatcher (*Empidonax minimus*) occurred at much higher mean density (152.9 birds/100 ha) than any other individual species and accounted for 25% of the total density for all species combined in this habitat.

Discussion

Grasslands have been characterized as having low species diversity as well as domination by a few species (Wiens 1974, Cody 1985). However, there were no significant differences in species richness per point among the five habitat types ($F = 1.33$, $P = 0.29$) on the SNG. There also were no significant differences in species diversity per point among habitats ($F = 0.65$, $P = 0.63$).

The three open habitats (grassland, sedge meadow, and wetland) shared many bird species. This is not surprising given the complex interspersion and gradual gradation among the numerous, sometimes small patches of each habitat (Hansen 1996, Svedarsky and Van Amburg 1996), and the relatively broad range of habitat preferences and flexibility displayed by many bird species (Stewart 1975, Cody 1985, Renken and Dinsmore 1987, Ehrlich et al. 1988, DeGraaf and Rappole 1995). Ten species associated with woody habitats were detected on grassland points. This resulted from the presence of shrubby and woody thickets within the grassland complex (Stewart 1975). In addition, American Goldfinches (*Carduelis tristis*), Eastern Kingbirds (*Tyrannus tyrannus*),

Mourning Doves (*Zenaida macroura*), and Northern Flickers (*Colaptes auratus*) will feed in open habitats such as woodland-prairie edges and weedy fields (Ehrlich et al. 1988), and the Mourning Dove will nest in grasslands (Mirarchi and Baskett 1994). Bird community overlaps emphasize the difficulties inherent in generalized habitat classification schemes.

Interestingly, only three grassland species (Brown-headed Cowbirds, Clay-colored Sparrows [*Spizella pallida*], and Western Meadowlarks) occurred in savannas, and none were detected in woodlands. The occurrence of these three species in savannas is not surprising given their habitat preferences. Brown-headed Cowbirds prefer foraging in open habitats (Morris and Thompson 1998) and grasslands with scattered trees and shrubs, but primarily parasitize nests in wood-field ecotones where they can use trees as perch sites while locating nests (Lowther 1993). None of the woodland patches were extensive, so we also expected to find cowbirds in this habitat. The absence of this species on woodland points may be a result of female cowbirds' inconspicuous behavior while nest searching. The occurrence of Clay-colored Sparrows on savanna survey points was not surprising given that this species inhabits thickets, second-growth, and woodland edges, in addition to open shrubby habitats (Knapton 1994). While Western Meadowlarks are most commonly found on grasslands, they also occur in orchards (Lanyon 1994) and evidently other open areas with scattered trees and grassland-like ground cover such as our savanna sites.

Habitat spatial heterogeneity probably was responsible for the differences in bird community composition among grasslands, savannas, and woodlands. The addition of trees increases vertical heterogeneity with a corresponding alteration in horizontal

heterogeneity (Willson 1974, Roth 1976). This creates fine-grained habitat patches (Willson 1974). The addition or alteration of habitat patches leads to alterations in niche availability and hence changes in bird community composition (Roth 1976). Specifically, we predicted a change in dominance from ground foragers to foliage gleaners, and other species that use woody vegetation. Indeed, this is generally what we observed. Most of the grassland species are ground foragers and their numbers were greatly reduced with the progressive increase in vertical heterogeneity. Although the identity of the ground foragers changed, the dominance of this guild did not. The relatively open ground layer of savannas and woodlands (*pers. obs.*) on the SNG may explain why ground foragers continued to be abundant. A second prediction that stems from habitat heterogeneity-bird species diversity theory is that species richness will increase and then decrease along a gradient of increasing canopy closure (Willson 1974, Roth 1976). As new niches are created and segregated with the addition of trees and shrubs, more species will be able to colonize a given area. As canopy closure occurs subcanopy vegetation declines with a resultant loss of niches in the lower vegetational layers (Willson 1974, Roth 1976). Though differences were not significant, we did observe fewer species on woodland points as compared to savanna points. However, we also observed fewer species on savanna points as compared to grassland points. This may be a result of habitat patch area or isolation. The greater detectability and ease of flushing of grassland birds as compared to birds of wooded areas also may be a factor (Kantrud 1981).

The numerically dominant species on the SNG are abundant at the state and regional levels. Igl and Johnson (1997) reported that Red-winged Blackbirds, Western

Meadowlarks and Brown-headed Cowbirds were three of the five most abundant birds statewide through the period 1967-1993. Horned Larks (*Eremophila alpestris*), and Chestnut-collared Longspurs were the other two species. Horned Larks prefer short-grass prairie, mixed-grass prairie grazed short, and agricultural fields (Stewart 1975). The former two habitats are rare on the SNG and the latter was not surveyed. The SNG is on the edge of the Chestnut-collared Longspurs' range (Sauer et al. 1996), which may explain their absence in our surveys. Stewart (1975) divided North Dakota into four biotic regions. According to this scheme, the SNG is located on the Agassiz Lake Plain Region. Stewart (1975) listed Western Meadowlark and Brown-headed Cowbird as two of the six most abundant species in this region. Other grassland birds listed as fairly common were Bobolinks, Red-winged Blackbirds, Savannah Sparrows, and Clay-colored Sparrows. We encountered all 35 species he listed as characteristic of the region. Kantrud (1981) also recognized the Agassiz Lake Plain Region. Mean species richness for his grassland plots in this region was 6.9, which is similar to our mean of 6.7. The seven most abundant grassland birds on his plots were, in order of decreasing abundance: Savannah Sparrow, Western Meadowlark, Red-winged Blackbird, Bobolink, Clay-colored Sparrow, Brown-headed Cowbird, and Grasshopper Sparrow. Therefore we feel that the SNG does host a fairly representative sample of the breeding bird community of the area.

In addition to regionally abundant species, the SNG hosts regionally declining or rare species. According to the Breeding Bird Survey (Sauer et al. 1999) populations of Killdeer (*Charadrius vociferous*), Upland Sandpiper, Black-billed Cuckoo (*Coccyzus erythropthalmus*), Burrowing Owl, Short-eared Owl, Common Nighthawk (*Chordeiles*

minor), Red-headed Woodpecker (*Melanerpes erythrocephalus*), Eastern Wood-Pewee, Eastern Phoebe (*Sayornis phoebe*), Horned Lark, Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), Bank Swallow (*Riparia riparia*), Barn Swallow (*Hirundo rustica*), Veery (*Catharus fuscescens*), Brown Thrasher (*Toxostoma rufrum*), Black-and-white Warbler (*Mniotilta varia*), Ovenbird (*Seiurus aurocapillus*) Lark Bunting (*Calamospiza melanocorys*), Grasshopper Sparrow, Chestnut-collared Longspur, Dickcissel (*Spiza americana*), Red-winged Blackbird, Brown-headed Cowbird, and Baltimore Oriole (*Icterus galbula*) showed at least marginal declines in North Dakota during the period 1980-1999. All of these species can be found on the SNG. In addition, the SNG is inhabited by the Greater Prairie-Chicken. In fact, this population may act as a regional source. Hatch rate was estimated to be 85% and a spring count of 144 males is above the estimated critical threshold of 100 males (Svedarsky and Van Amburg 1996). Although 144 males may be below the number needed for long-term stability (Svedarsky and Van Amburg 1996), Prairie-Chickens and other grouse are typically underestimated by surveys (Sauer et al. 1999). Furthermore, the SNG contains the largest remaining native tallgrass prairie in the area, so its value as a Prairie-Chicken preserve should not be underestimated.

Although our surveys and incidental observations probably provide a fairly accurate index of the breeding bird communities of the SNG, our methods had inherent shortcomings. We were unable to determine densities for some widely dispersed species, and species that tended to be repelled by observers. The Greater Prairie-Chicken, a species of management concern on the SNG (Svedarsky and Van Amburg 1996), falls under both of these categories. Waterfowl, especially Blue-winged Teal (*Anas discors*),

were abundant but also tended to flush when approached, so their numbers probably were underestimated. Other species, such as Le Conte's Sparrow (Stewart 1975, Igl and Johnson 1995, Lowther 1996), can undergo dramatic population fluctuations from year-to-year due to climatic variation and the associated effects on habitat availability and productivity (Wiens 1974, Cody 1981, Cody 1985, Igl and Johnson 1997). Species such as Burrowing Owl and Chestnut-collared Longspur have occurred on the SNG (Bryan Stotts, *pers. comm.*) but were not encountered during the study period. It is obvious that a single year's survey cannot quantitatively describe the entire assemblage of breeding birds in an area the size of the SNG. However, a survey of this type is a first step towards a complete picture of the SNG avifauna. Although we cannot make specific management recommendations based upon these data, we do suggest that managers treat each habitat patch as part of a mosaic of habitats, and that a continuum of vegetation types be maintained to support the broad range of bird habitat preferences (Renken and Dinsmore 1987). Though some habitat patches will support fewer species than others will, each adds to the richness and diversity of this important preserve.

Literature Cited

American Ornithologists' Union. 1998. Check-list of North American birds, 7th ed. American Ornithologists' Union, Washington, D.C.

Anderson, B. W., A. Higgins, and R. D. Ohmart. 1977. Avian use of saltcedar communities in the lower Colorado River valley. Pages 128-136 *in* Importance, preservation, and management of riparian habitat: A symposium (R. R. Johnson, and D. A. Jones, Eds.). USDA Forest Service, Washington D.C., General Technical Report RM-43.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1-34.

Bedunah, D. J. 1992. The complex ecology of weeds, grazing and wildlife. Western Wildlands 18:6-11.

Belcher, J. W., and S. D. Wilson. 1989. Leafy spurge and the species composition of a mixed-grass prairie. Journal of Range Management 42:172-175.

Best, K. F., G. G. Bowes, A. G. Thomas, and M. G. Maw. 1980. The biology of Canadian weeds 39. *Euphorbia esula* L. Canadian Journal of Plant Science 60:651-663.

Blockstein, D. E., B. D. Maxwell, and P. K. Fay. 1987. Dispersal of leafy spurge seeds (*Euphorbia esula*) by Mourning Doves (*Zenaida macroura*). Weed Science 35:160-162.

Bock, C. E., J. H. Bock, K. L. Jepson, and J. C. Ortega. 1986. Ecological effects of planting African lovegrasses in Arizona. National Geographic Research 2:456-463.

BOLLINGER, E. K. 1995. Successional changes and habitat selection in hayfield bird communities. Auk 112:720-730.

BOLLINGER, E. K., AND T. A. GAVIN. 1992. Eastern Bobolink populations: Ecology and conservation in an agricultural landscape. Pages 497-506 *in* Ecology and conservation of neotropical migrant landbirds (J. M. Hagan, III, and D. W. Johnston, Eds.). Smithsonian Inst. Press, Washington, D.C.

BOWEN, B. S., AND A. D. KRUSE. 1993. Effects of grazing on nesting by Upland Sandpipers in southcentral North Dakota. Journal of Wildlife Management 57:291-301.

COBLENTZ, B. E. 1990. Exotic organisms: A dilemma for conservation biology. Conservation Biology 4:261-265.

CODY, M. L. 1981. Habitat selection in birds: The roles of vegetation structure, competitors, and productivity. BioScience 31:107-113.

CODY, M. L. (Ed.) 1985. Habitat selection in birds. Academic Press, Inc., Orlando.

COHAN, D. R., B. W. ANDERSON, AND R. D. OHMART. 1979. Avian population responses to salt cedar along the lower Colorado River. Pages 371-382 *in* Strategies for protection and management of floodplain wetlands and other riparian ecosystems: Proceedings of the symposium (R. R. Johnson, and J. F. McCormick, Eds.). USDA Forest Service, Washington D.C., General Technical Report Wo-12.

COLLINS, S. L. 1987. Interaction of disturbances in tallgrass prairie: A field experiment. Ecology 68:1243-1250.

COLLINS, S. L. AND S. M. GLENN. 1990. A hierarchical analysis of species' abundance patterns in grassland vegetation. The American Naturalist 135:633-648.

DAMHOUREYEH, S. A., AND D. C. HARTNETT. 1997. Effects of bison and cattle on growth, reproduction, and abundances of five tallgrass prairie forbs. American Journal of Botany 84:1719-1728.

DAUBENMIRE, R. F. 1959. A canopy coverage method of vegetational analysis. Northwest Science 33:43-64.

DEGRAAF, R. M. AND J. H. RAPPOLE (Eds.). 1995. Neotropical migratory birds: Natural history, distribution, and population changes. Comstock Publishing Associates, Ithaca.

DELISLE, J. M., AND J. A. SAVIDGE. 1997. Avian use and vegetation characteristics of conservation reserve program fields. Journal of Wildlife Management 61:318-325.

DEVORE, J., AND R. PECK. 1997. Statistics: The exploration and analysis of data. Brooks/Cole Pub., Pacific Grove.

DUNN, P. H. 1979. The distribution of leafy spurge (*Euphorbia esula*) and other weedy *Euphorbia* spp. in the United States. Weed Science 27:509-516.

EHRLICH, P. R., D. S. DOBKIN, AND D. WHEYE. 1988. The birder's handbook: A field guide to the natural history of North American birds. Simon & Schuster Inc., New York.

FAANES, C. A., AND R. E. STEWART. 1982. Revised checklist of North Dakota birds. The Prairie Naturalist 14:81-92.

FLORSCHUTZ, O., JR. 1972. The importance of Eurasian milfoil (*Myriophyllum spicatum*) as a waterfowl food. *in* Proceedings of the twenty-sixth annual conference (A. L. Mitchell, Ed.). Southeastern Association of Game and Fish Commissioners, Knoxville.

GILLEN, R. L., F. T. MCCOLLUM, M. E. HODGES, J. E. BRUMMER, AND K. W. TATE. 1991. Plant community responses to short duration grazing in tallgrass prairie. Journal of Range Management 44:124-128.

GRIFFEN, J. 1989. The Everglades Kite. Aquatics 11:17-19.

HANSEN, K. 1996. The vegetation of the Sheyenne National Grassland: An ecological classification, USDA Forest Service, Dakota Prairie Grasslands, Draft.

HARTNETT, D. C., K. R. HICKMAN, AND L. E. F. WALTER. 1996. Effects of bison grazing, fire and topography on floristic diversity in tallgrass prairie. Journal of Range Management 49:413-420.

HERKERT, J. R. 1995. An analysis of Midwestern breeding bird population trends: 1966-1993. American Midland Naturalist 134:41-50.

HILL, J. D. 2000. Avian use of purple loosestrife (*Lythrum salicaria*) in southern Michigan wetland complexes. M.S. Thesis, Michigan State University, East Lansing.

HULL, S. D., R. J. ROBEL, AND K. E. KEMP. 1995. Influence of forb abundance on winter bird use of conservation reserve program fields in Kansas. Prairie Naturalist 27:17-21.

HULL, S. D., R. J. ROBEL, AND K. E. KEMP. 1996. Summer avian abundance, invertebrate biomass, and forbs in Kansas CRP. Prairie Naturalist 28: 1-12.

IGL, L. D., AND D. H. JOHNSON. 1995. Dramatic increase of Le Conte's Sparrow in conservation reserve program fields in the northern Great Plains. Prairie Naturalist 27:89-94.

IGL, L. D., AND D. H. JOHNSON. 1997. Changes in breeding bird populations in North Dakota: 1967 to 1992-93. Auk 114:74-92.

JOHNSON, D. H. 1990. Statistical comparison of nest success rates. North Dakota Academy of Science Proceedings 44:67.

JOHNSON, F. A. 1987. Lake Okeechobee's waterfowl habitat: Problems and possibilities. Aquatics 9:20-21.

KANTRUD, H. A. 1981. Grazing intensity effects on the breeding avifauna of North Dakota native grasslands. Canadian Field-Naturalist 95:404-417.

KANTRUD, H. A., AND K. F. HIGGINS. 1992. Nest and nest site characteristics of some ground-nesting, non-passerine birds of northern grasslands. Prairie Naturalist 24:67-84.

KANTRUD, H. A., AND R. L. KOLOGISKI. 1983. Avian associations of the northern Great Plains grasslands. Journal of Biogeography 10:331-350.

KNAPTON, R. W. 1994. Clay-colored Sparrow (*Spizella pallida*). *in* The Birds of North America, no. 120 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

KNOPF, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15:247-257.

KOBAL S. N., N. F. PAYNE, AND D. R. LUDWIG. 1998. Nestling food habits of 7 grassland bird species and insect abundance in grassland habitats in northern Illinois. Transactions of the Illinois State Academy of Science 91:69-75.

LANYON, W. E. 1994. Western Meadowlark (*Sturnella neglecta*). *in* The Birds of North America, no. 104 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

LAVOREL, S., A. H. PRIEUR-RICHARD, AND K. GRIGULIS. 1999. Invasibility and diversity of plant communities: From patterns to processes. Diversity and Distributions 5:41-49.

LEISTRITZ, F. L., F. THOMPSON, AND J. A. LEITCH. 1992. Economic impact of leafy spurge (*Euphorbia esula*) in North Dakota. Weed Science 40:275-280.

LONSDALE, W. M. 1999. Global patterns of plant invasions and the concept of invasibility. Ecology 80:1522-1536.

LOWTHER, P. E. 1993. Brown-headed Cowbird (*Molothrus ater*). *in* The Birds of North America, no. 47 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

LOWTHER, P. E. 1996. Le Conte's Sparrow (*Ammodramus leconteii*). *in* The Birds of North America, no. 224 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

LYM, R. G., AND D. R. KIRBY. 1987. Cattle foraging behavior in leafy spurge (*Euphorbia esula*)-infested rangeland. Weed Technology 1:314-318.

LYM, R. G., AND C. G. MESSERSMITH. 1985. Leafy spurge control with herbicides in North Dakota: 20-year summary. Journal of Range Management 38:149-154.

LYNCH, J. J., J. E. KING, T. K. CHAMBERLAIN, AND A. L. SMITH, JR. 1947. Effects of aquatic weed infestations on the fish and wildlife of the gulf states. Special Scientific Report No. 39, U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

MARTIN, S. G., AND T. A. GAVIN. 1993. Bobolink (*Dolichonyx oryzivorous*). *in* The Birds of North America, no. 176 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

MARTIN, T. E., AND C. J. CONWAY. 1994. BBIRD field protocol. Breeding Biology Research & Monitoring Database, Montana Coop. Wildlife Research Unit, University of Montana, Missoula.

MAYFIELD, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

MESSERSMITH, C. G., AND R. G. LYM. 1983. Distribution and economic impacts of leafy spurge in North Dakota. North Dakota Farm Research 40:8-13.

MINITAB INC. 1996. Minitab for Windows, Release 11.21 32 Bit. State College, Pennsylvania.

MIRARCHI, R. E., AND T. S. BASKETT. 1994. Mourning Dove (*Zenaida macroura*). *in* The Birds of North America, no. 117 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

MORRIS, D. L. AND F. R. THOMPSON, III. 1998. Effects of habitat and invertebrate density on abundance and foraging behavior of Brown-headed Cowbirds. Auk:376-385.

PARKER, I. M., S. K. MERTENS, AND D. W. SCHEMSKE. 1993. Distribution of seven native and two exotic plants in a tallgrass prairie in southeastern Wisconsin: The importance of human disturbance. American Midland Naturalist 130:43-55.

RALPH, C. J., J. R. SAUER, AND S. DROEGE, eds. 1995. Monitoring bird population by point counts. USDA Forest Service, Washington, D.C. General Technical Report PSW-GTR-149.

RAWINSKI, T. J., AND R. A. MALECKI. 1984. Ecological relationships among purple loosestrife, cattail and wildlife at the Montezuma National Wildlife Refuge. New York Fish and Game Journal 31:81-87.

RENKEN, R. B., AND J. J. DINSMORE. 1987. Nongame bird communities on managed grasslands in North Dakota. Canadian Field-Naturalist 101:551-557.

REYNOLDS, T. D., AND C. H. TROST. 1980. The response of native vertebrate populations to crested wheatgrass planting and grazing by sheep. Journal of Range Management 33:122-125.

ROBEL, R. J., J. N. BRIGGS, A. D. DAYTON, AND L. C. HULBERT. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

ROBERTS, J. L., AND B. E. OLSON. 1999. Effect of *Euphorbia esula* on growth and mortality of migratory grasshopper nymphs. Journal of Agricultural and Urban Entomology 16:97-106.

ROTENBERRY, J. T. 1985. The role of habitat in avian community composition: Physiognomy or floristics? Oecologia 67:213-217.

ROTENBERRY, J. T., AND J. A. WIENS. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: A multivariate analysis. Ecology 61:1228-1250.

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

SAUER, J. R., J. E. HINES, I. THOMAS, J. FALLON, AND G. GOUGH. 1999. The North American Breeding Bird Survey, Results and Analysis 1966 - 1998. Version 98.1, USGS Patuxent Wildlife Research Center, Laurel, MD. [http://www.mbr.nbs.gov/bbs/bbs.html].

SCHMIDT, K. A., AND C. J. WHELAN. 1999. Effects of exotic *Lonicera* and *Rhamnus* on songbird nest predation. Conservation Biology 13:1502-1506.

SEILER, G. J., AND W. T. BARKER. 1985. Vascular flora of Ransom, Richland, and Sargent counties, North Dakota. Prairie Naturalist 17:193-240.

SEILER, G. J., AND W. T. BARKER. 1987. Life-forms and geographic affinities of the southeastern North Dakota flora. Prairie Naturalist 19:77-92.

SELLECK, G. W., R. T. COUPLAND, AND C. FRANKTON. 1962. Leafy spurge in Saskatchewan. Ecological Monographs 32:1-29.

SMITH, M. D., AND A. K. KNAPP. 1999. Exotic plant species in a C_4-dominated grassland: Invasibility, disturbance, and community structure. Oecologia 120:605-612.

STEWART, R. E. 1975. Breeding birds of North Dakota. Tri-College Center for Environmental Studies, Fargo.

STOHLGREN, T. J., D. BINKLEY, G. W. CHONG, M. A. KALKHAN, L. D. SCHNELL, K. A. BULL, Y. OTSUKI, G. NEWMAN, M. BASHKIN, AND Y. SON. 1999a. Exotic plant species invade hot spots of native plant diversity. Ecological Monographs 69:25-46.

STOHLGREN, T. J., L. D. SCHNELL, AND B. V. HEUVEL. 1999b. How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. Ecological Applications 9:45-64.

SUTTER, G. C., AND R. M. BRIGHAM. 1998. Avifaunal and habitat changes resulting from conversion of native prairie to crested wheat grass: Patterns at songbird community and species levels. Canadian Journal of Zoology 76:869-875.

SUTTER, G. C., T. TROUPE, AND M. FORBES. 1995. Abundance of Baird's Sparrows, *Ammodramus bairdii*, in native prairie and introduced vegetation. Ecoscience 2:344-348.

SVEDARSKY, D., AND G. VAN AMBURG. 1996. Integrated management of the Greater Prairie Chicken and livestock on the Sheyenne National Grassland. North Dakota Game and Fish Department, Bismarck.

THOMAS, L., J. L. LAAKE, J. F. DERRY, S. T. BUCKLAND, D. L. BORCHERS, D. R. ANDERSON, K. P. BURNHAM, S. STRINDBERG, S. L. HEDLEY, M. L. BURT, F. MARQUES, J. H. POLLARD, AND R. M. FEWSTER. 1998. Distance 3.5. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK.

TILMAN, D. 1997. Community invasibility, recruitment limitation, and grassland biodiversity. Ecology 78:81-92.

TILMAN, D. 1999. The ecological consequences of changes in biodiversity: A search for general principles. Ecology 80:1455-1474.

TRAMMELL, M. A., AND J. L. BUTLER. 1995. Effects of exotic plants on native ungulate use of habitat. Journal of Wildlife Management 59:808-816.

VICKERY, P. D. 1996. Grasshopper Sparrow (*Ammodramus savannarum*). *in* The Birds of North America, no. 239 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

WHEELWRIGHT, N. T., AND J. D. RISING. 1993. Savannah Sparrow (*Passerculus sandwichensis*). *in* The Birds of North America, no. 45 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

WHELAN, C. J., AND M. L. DILGER. 1992. Invasive, exotic shrubs: A paradox for natural area managers? Natural Areas Journal 12:109-110.

WHITT, M. B., H. H. PRINCE, AND R. R. COX, JR. 1999. Avian use of purple loosestrife dominated habitat relative to other vegetation types in a Lake Huron wetland complex. Wilson Bulletin 111:105-114.

WIENS, J. A. 1974. Habitat heterogeneity and avian community structure in North American grasslands. American Midland Naturalist 91:195-213.

WILLSON, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029.

WILSON, S. D., AND J. W. BELCHER. 1989. Plant and bird communities of native and introduced Eurasian vegetation in Manitoba, Canada. Conservation Biology 3:39-44.

YASUKAWA, K., AND W. A. SEARCY. 1995. Red-winged Blackbird (*Agelaius phoeniceus*). *in* The Birds of North America, no. 184 (A. Poole, and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

TABLE 1.1. Comparison of breeding bird species richness, species diversity, and densities for Grassland birds among 60 100-m radius point counts in three levels of spurge infestation on the Sheyenne National Grassland, ND (Summer 1999). Means (with standard error in parentheses) within rows followed by the same letter do not differ ($P > 0.10$) as determined by ANOVA and Tukey-Kramer pairwise comparisons. Values are adjusted for interspecific differences in detectability using DISTANCE (Thomas et al. 1998).

	Spurge infestation level		
Variable	Low	Medium	High
Bird community parameter			
Species richness/point	6.4 (0.4) A	6.8 (0.5) A	6.9 (0.5) A
Species diversity/point	0.7 (0.03) A	0.7 (0.03) A	0.7 (0.03) A
Density (birds/100 ha)			
Bobolink	18.6 (5.1) A	23.1 (7.6) A	20.9 (6.5) A
Brown-headed Cowbird	7.2 (3.0) A	8.8 (4.5) A	7.7 (2.5) A
Clay-colored Sparrow	33.0 (7.3) A	28.0 (7.7) A	28.0 (7.5) A
Grasshopper Sparrow	45.2 (8.1) A	54.4 (7.9) A	32.6 (7.1) A
Le Conte's Sparrow	10.4 (3.9) A	4.3 (2.1) A	2.6 (1.4) A
Savannah Sparrow	17.3 (3.8) A	13.0 (2.9) A	6.7 (3.0) A
Upland Sandpiper	2.5 (1.8) A	14.3 (4.3) B	6.7 (2.6) AB
Western Meadowlark	18 (2.1) A	11.6 (2.3) A	15.7 (3.1) A

TABLE 1.2. Spearman's rank correlation coefficients relating bird species richness, diversity, and densities to vegetation characteristics of spurge-infested grasslands on the Sheyenne National Grassland, ND (Summer 1999). Correlation coefficients in bold are ($P < 0.10$).

Vegetation Characteristic	Species richness	Species diversity	Bobolink	Brown-headed Cowbird	Clay-colored Sparrow	Grasshopper Sparrow
Number of spurge stems/m^2	-0.02	0.10	-0.13	0.06	-0.19	-0.19
Spurge cover (%)	-0.12	-0.04	-0.11	0.06	-0.17	-0.08
Other forb cover (%)	0.08	**-0.32**	0.06	0.15	**0.26**	0.01
Grass cover (%)	0.06	0.15	**0.21**	-0.02	-0.14	-0.10
Bunchgrass cover (%)	-0.16	-0.01	-0.04	-0.03	-0.17	0.02
Woody vegetation cover (%)	0.16	0.15	-0.07	**0.35**	**0.22**	-0.11
Bare ground cover (%)	0.14	0.15	**-0.34**	-0.01	0.09	-0.11
Litter cover (%)	-0.18	-0.09	-0.11	**-0.25**	0.09	**0.43**
Litter depth (mm)	-0.01	-0.01	0.20	0.12	-0.12	**-0.23**
Height (cm)	0.19	-0.10	0.20	**0.26**	0.03	**-0.30**
Vertical density (dm)	0.14	0.01	0.19	**0.25**	-0.04	**-0.35**

TABLE 1.2. (cont'd).

Vegetation Characteristic	Le Conte's Sparrow	Savannah Sparrow	Upland Sandpiper	Western Meadowlark
Number of spurge stems/m^2	**-0.23**	**-0.24**	0.06	-0.06
Spurge cover (%)	**-0.22**	-0.21	0.07	0.03
Other forb cover (%)	0.18	0.10	-0.04	0.03
Grass cover (%)	0.12	0.12	-0.14	0.01
Bunchgrass cover (%)	-0.07	0.09	-0.02	0.11
Woody vegetation cover (%)	0.01	0.00	-0.02	0.19
Bare ground cover (%)	-0.03	-0.16	**0.21**	0.05
Litter cover (%)	-0.19	0.01	**0.40**	-0.09
Litter depth (mm)	0.10	**0.28**	-0.03	0.00
Height (cm)	0.18	0.05	-0.03	-0.07
Vertical density (dm)	0.15	0.02	**-0.21**	0.02

TABLE 1.3. Spearman's rank correlation coefficients relating bird species richness, diversity, densities, and vegetation structure and cover to cattle grazing intensity on pastures containing 60 100-m radius survey points on the Sheyenne National Grassland, ND (Summer 1999). Grazing intensity is an index incorporating number of cattle/calf units and length of grazing period over the survey period. Correlation coefficients in bold are significant ($P < 0.10$).

Bird community parameter	Grazing Intensity	Vegetation Characteristic	Grazing Intensity
Species richness/point	-0.04	Number of spurge stems/m^2	-0.01
Species diversity/point	-0.07	Spurge cover (%)	-0.03
Density (birds/100 ha)		Other forb cover (%)	-0.20
Bobolink	0.08	Grass cover (%)	**0.24**
Brown-headed Cowbird	-0.06	Bunchgrass cover (%)	-0.15
Clay-colored Sparrow	**-0.34**	Woody vegetation cover (%)	**-0.31**
Grasshopper Sparrow	0.06	Bare ground cover (%)	**-0.31**
Le Conte's Sparrow	-0.04	Litter cover (%)	0.09
Savannah Sparrow	**0.28**	Litter depth (mm)	-0.19
Upland Sandpiper	0.13	Height (cm)	**-0.40**
Western Meadowlark	0.19	Vertical density (dm)	**-0.37**

TABLE 1.4. Comparison of vegetation cover and structure among 60 100-m radius circular plots in three levels of spurge infestation on the Sheyenne National Grassland, ND (Summer 1999). Means (with standard error in parentheses) within rows followed by the same letter do not differ ($P > 0.10$) as determined by ANOVA and Tukey-Kramer pairwise comparisons.

	Spurge infestation level		
Vegetation Characteristic	Low	Medium	High
Number of spurge stems/m^2	0.8 (0.6) A	12.8 (2.9) A	47.0 (6.9) B
Spurge cover (%)	0.7 (0.5) A	4.2 (0.9) A	16.1 (2.2) B
Other forb cover (%)	23.2 (3.0) A	15.7 (2.6) AB	10.7 (1.9) B
Grass cover (%)	48.8 (4.2) A	48.6 (3.7) A	41.5 (3.7) A
Bunchgrass cover (%)	1.5 (1.2) A	1.1 (1.0) A	0.3 (0.2) A
Woody vegetation cover (%)	2.2 (1.1) A	1.6 (0.9) A	4.2 (1.6) A
Bare ground cover (%)	2.2 (0.9) A	4.0 (1.7) A	5.3 (2.5) A
Litter cover (%)	19.0 (2.6) A	23.3 (2.3) A	20.3 (2.9) A
Litter depth (mm)	9.0 (21.9) A	8.4 (1.8) A	9.7 (1.6) A
Height (cm)	37.1 (2.9) A	32.8 (1.9) A	35.8 (2.1) A
Vertical density (dm)	2.2 (0.2) A	1.7 (0.1) A	2.3 (0.2) A

TABLE 1.5. Numbers of nests located by species on three 16-ha plots in spurge-infested grasslands on the Sheyenne National Grassland, ND (Summer 1999). Values are number of nests with number of nests inactive by 1 August, if different, in parentheses.

	Spurge infestation level			
Species	Low	Medium	High	Total
Blue-winged Teal	3	0	0	3
Bobolink	2	5	0	7
Gadwall	1	0	0	1
Grasshopper Sparrow	9 (7)	7 (6)	8 (7)	24 (20)
Greater Prairie-Chicken	0	0	1 [a]	1
Lark Sparrow	0	1	0	1
Mallard	3	2	0	5
Mourning Dove	2 (1)	0	0	2 (1)
Red-winged Blackbird	0	2	0	2
Savannah Sparrow	3	1	1	5
Sharp-tailed Grouse	0	1	0	1
Upland Sandpiper	0	1	0	1
Western Meadowlark	1	2	1	4
Total number of nests	24 (21)	22 (21)	11 (10)	57 (52)
Total number of species	8	9	4	13

[a] Nest located after fledging.

TABLE 1.6. Comparison of vegetation cover and structure among the three 16-ha plots used for nest searching in three levels of spurge infestation on the Sheyenne National Grassland, ND (1999). Means (with standard error in parentheses) within rows followed by the same letter do not differ ($P > 0.10$) as determined by ANOVA and Tukey-Kramer pairwise comparisons.

	Spurge infestation level		
Vegetation Characteristic	Low	Medium	High
Number of spurge stems/m^2	0.6 (0.6) A	18.2 (6.5) AB	30.9 (7.4) B
Spurge cover (%)	0.4 (0.4) A	6.6 (2.4) AB	12.7 (3.6) B
Other forb cover (%)	10.3 (2.6) A	29.4 (4.7) B	16.2 (4.2) AB
Grass cover (%)	35.6 (5.0) A	23.6 (4.1) A	32.1 (4.2) A
Bunchgrass cover (%)	8.0 (2.8) A	2.0 (1.4) AB	1.0 (1.0) B
Woody vegetation cover (%)	0.04 (0.04) A	0.7 (0.3) B	0.2 (0.1) AB
Bare ground cover (%)	6.4 (2.6) A	4.4 (2.5) A	2.4 (1.0) A
Litter cover (%)	39.0 (4.4) A	27.5 (4.9) A	34.8 (4.9) A
Litter depth (mm)	4.7 (1.3) A	29.3 (16.6) A	15.3 (2.9) A
Height (cm)	22.6 (2.1) A	32.0 (3.0) B	30.2 (1.8) AB
Vertical density (dm)	1.1 (0.1) A	1.8 (0.2) B	1.4 (0.1) AB

TABLE 1.7. Comparison of vegetation cover and structure between successful and unsuccessful nests of all species combined and only Grasshopper Sparrows in three 16-ha pots in spurge-infested grasslands on the Sheyenne National Grassland, ND (Summer 1999). A nest was considered successful if at least one young of the parental species fledged. Means (with standard error in parentheses) in bold are significant ($P < 0.10$).

TABLE 1.7.

	All species [a]			Grasshopper Sparrow		
Vegetation Characteristic	successful	unsuccessful	two-sample t	successful	unsuccessful	two-sample t
Number of spurge stems/m^2	23.1 (5.2)	22.0 (7.2)	-0.12	20.4 (6.9)	16.4 (8.2)	-0.38
Spurge cover (%)	9.0 (2.3	6.6 (2.4)	-0.73	5.8 (2.0)	5.8 (3.7)	-0.01
Other forb cover (%)	8.1 (1.7)	9.8 (1.8)	0.71	8.5 (3.0)	14.1 (3.2)	1.28
Grass cover (%)	40.4 (2.9)	39.9 (3.0)	-0.11	44.5 (5.0)	31.1 (4.1)	**-2.09**
Bunchgrass cover (%)	5.7 (2.3)	6.4 (1.8)	0.23	4.3 (1.9)	2.9 (1.0)	-0.65
Woody vegetation cover (%)	1.2 (0.6)	0.9 (0.4)	-0.40	0.7 (0.3)	1.6 (0.9)	0.92
Bare ground cover (%)	1.8 (0.5)	2.0 (0.6)	0.22	2.5 (0.9)	2.1 (0.8)	-0.35
Litter down cover (%)	30.7 (2.5)	30.6 (3.3)	-0.03	32.6 (3.5)	39.1 (4.2)	1.19
Litter depth (mm)	17.6 (2.1)	31.5 (5.3)	**2.42**	13.37 (2.9)	29.1 (8.0)	1.85
Height (cm)	27.6 (1.4)	24.1 (1.3)	**-1.80**	24.4 (1.4)	22.7 (2.1)	-0.65
Vertical density (dm)	1.4 (0.1)	1.5 (0.1)	0.84	1.2 (0.1)	1.3 (0.1)	1.31

[a] Includes: Blue-winged Teal, Bobolink, Gadwall, Greater Prairie-Chicken, Lark Sparrow, Mallard, Mourning Dove, Savannah Sparrow, Sharp-tailed Grouse, Upland Sandpiper and Western Meadowlark.

TABLE 1.8. Comparisons of nest vegetation cover and structure to the vegetation cover and structure of the nearest plot sampling point for each species for which five or more nests were located in 3 16-ha plots in spurge-infested grasslands on the Sheyenne National Grassland, ND (Summer 1999). Values are mean with standard error in parentheses. Paired t-values in bold are significant ($P < 0.10$).

TABLE 1.8.

	Bobolink (n = 7)			Grasshopper Sparrow (n = 20)		
Vegetation Characteristic	Nest	Plot	Paired t	Nest	Plot	Paired t
Number of spurge stems/m^2	32.1 (9.6)	42.9 (17.5)	-0.79	15.5 (4.5)[a]	7.2 (3.5)	1.37
Spurge cover (%)	13.7 (5.8)	15.7 (6.2)	-0.28	4.9 (1.7)[a]	2.7 (1.5)	0.88
Other forb cover (%)	7.5 (3.8)	17.4 (8.5)	-1.59	11.0 (2.2)	22.5 (4.4)	**-2.18**
Grass cover (%)	50.5 (5.4)	34.1 (7.7)	1.67	38.5 (3.6)	29.0 (4.8)	1.71
Bunchgrass cover (%)	0.9 (0.9)	2.9 (2.9)	-0.64	3.7 (1.1)	2.8 (1.5)	0.49
Woody vegetation cover (%)	2.3 (2.1)	1.6 (0.9)	0.47	1.1 (0.4)	0.7 (0.3)	0.68
Bare ground cover (%)	0.6 (0.4)	3.6 (2.8)	-1.14	2.3 (0.6)	4.3 (1.5)	-1.23
Litter cover (%)	22.6 (3.8)	24.7 (8.8)	-0.21	35.5 (2.7)	35.0 (5.3)	0.09
Litter depth (mm)	25.8 (4.0)	18.6 (5.5)	1.14	20.5 (4.2)	27.1 (20.8)	-0.34
Height (cm)	29.4 (3.6)	35.3 (7.3)	-0.62	23.6 (1.2)	25.4 (2.5)	-0.79
Vertical density (dm)	1.6 (0.2)	2.1 (0.5)	-0.95	1.2 (.05)	1.3 (0.2)	-0.56

[a] 24 nests.

TABLE 1.8. (cont'd).

	Mallard (n = 5)			Savannah Sparrow (n = 5)		
Vegetation Characteristic	Nest	Plot	Paired t	Nest	Plot	Paired t
Number of spurge stems/m^2	27.4 (20.4)	3.2 (3.2)	1.17	8.8 (5.4)	0.0 (0.0)	1.63
Spurge cover (%)	8.9 (6.8)	2.0 (2.0)	0.99	3.0 (1.8)	0.0 (0.0)	-2.09
Other forb cover (%)	8.0 (4.1)	25.8 (13.7)	-1.13	9.9 (4.8)	29.0 (12.8)	-1.38
Grass cover (%)	30.8 (3.0)	38.0 (7.8)	-0.96	44.6 (6.1)	17.0 (5.8)	**5.09**
Bunchgrass cover (%)	16.7 (7.7)	0.0 (0.0)	**2.18**	6.0 (4.1)	9.0 (4.0)	-0.99
Woody vegetation cover (%)	0.6 (0.4)	2.0 (1.2)	-1.61	1.2 (0.5)	1.2 (1.0)	0.00
Bare ground cover (%)	4.4 (2.6)	6.4 (4.7)	-0.43	0.2 (0.2)	5.8 (3.1)	-1.81
Litter cover (%)	18.6 (3.4)	25.8 (12.4)	-0.65	34.1 (6.8)	38.0 (12.7)	-0.45
Litter depth (mm)	35.1 (0.6)	1.0 (0.6)	1.99	24.3 (3.1)	25.8 (5.0)	-0.46
Height (cm)	28.2 (3.9)	30.3 (7.1)	-0.34	21.3 (7.2)	5.0 (3.8)	1.77
Vertical density (dm)	1.7 (0.3)	1.3 (0.3)	1.28	1.6 (0.4)	1.4 (0.3)	0.80

TABLE 2.1. Bird species composition of each of the habitat preference groups and foraging guilds for each of the five major habitat types found on the Sheyenne National Grassland, ND (Summer 1999). Birds are listed in order of decreasing abundance.

Grassland

Other grassland species: Vesper Sparrow, Brewer's Blackbird, Common Grackle, Field Sparrow, Horned Lark, Loggerhead Shrike, Lark Sparrow, Northern Harrier, and Song Sparrow.

Sedge meadow/wetland species: Sedge Wren, Common Yellowthroat, Blue-winged Teal, Killdeer, Marsh Wren, Marbled Godwit, Sora, Yellow-headed Blackbird, American Bittern, American Coot, Black Tern, Common Snipe, Gadwall, Mallard, Nelson's Sharp-tailed Sparrow.

Savanna/woodland: Eastern Kingbird, American Goldfinch, Gray Catbird, House Wren, Mourning Dove, Northern Flicker, Scarlet Tanager, Warbling Vireo, Rose-breasted Grosbeak, and Yellow Warbler.

Aerial foragers: Northern Rough-winged Swallow, and Barn Swallow.

TABLE 2.1. (cont'd).

Sedge Meadow

Other sedge meadow/wetland species: Wilson's Phalarope, Le Conte's Sparrow, Marbled Godwit, Marsh Wren, Black Tern, Common Snipe, Yellow-headed Blackbird, Nelson's Sharp-tailed Sparrow, Blue-winged Teal, Common Yellowthroat, Killdeer, and Sora.

Grassland species: Brown-headed Cowbird, Upland Sandpiper, Bobolink, Clay-colored Sparrow, and Grasshopper Sparrow.

Aerial foragers: Barn Swallow.

Wetland

Other sedge meadow/wetland species: Northern Shoveler, Killdeer, Common Yellowthroat, Marsh Wren, Wilson's Phalarope, Sedge Wren, Mallard, Sora, Common Snipe, American Bittern, Canvasback, and Ruddy Duck.

Grassland species: Bobolink, Upland Sandpiper, Common Grackle, Brown-headed Cowbird, Eastern Kingbird, and Western Meadowlark.

TABLE 2.1. (cont'd).

Savanna

Ground foragers: Blue Jay, Mourning Dove, Common Grackle, Field Sparrow, American Robin, Brown Thrasher, House Wren, Western Meadowlark, Brown-headed Cowbird, Clay-colored Sparrow, Chipping Sparrow, Vesper Sparrow.

Salliers: Eastern Wood-Pewee, Eastern Bluebird, and Eastern Kingbird.

Foliage gleaners: Red-eyed Vireo, Cedar Waxwing, Orchard Oriole, Baltimore Oriole, Common Yellowthroat, Scarlet Tanager, Warbling Vireo, and Yellow-throated Vireo.

Bark gleaners: Hairy Woodpecker, Yellow-bellied Sapsucker, White-breasted Nuthatch.

Aerial forager: Barn Swallow.

TABLE 2.1. (cont'd).

Woodland

Ground foragers: House Wren, Mourning Dove, Gray Catbird, Northern Flicker, Ovenbird, Brown Thrasher, Field Sparrow, and Song Sparrow.

Foliage gleaners: Baltimore Oriole, Common Yellowthroat, Rose-breasted Grosbeak, Red-eyed Vireo, Indigo Bunting, and Yellow-throated Vireo.

Salliers: Least Flycatcher, and Eastern Wood-Pewee.

Bark gleaners: Yellow-bellied Sapsucker.

TABLE 2.2. Breeding bird species richness, species diversity, and densities on 60 100-m radius grassland survey points on the Sheyenne National Grassland, ND during Summer 1999.

Variable	Mean	Standard Error	Range
Bird community parameter			
Species richness/point	6.7	0.3	3.0 - 10.0
Species diversity/point	0.7	0.02	0.4 - 1.0
Density (birds/100 ha)			
Western Meadowlark	47.5	4.7	0.0 - 207.0
Grasshopper Sparrow	41.9	4.3	0.0 - 127.4
Bobolink	29.7	5.2	0.0 – 222.9
Red-winged Blackbird	28.7	6.1	0.0 - 191.1
Clay-colored Sparrow	23.6	3.4	0.0 - 79.6
Savannah Sparrow	23.4	3.5	0.0 - 95.5
Brown-headed Cowbird	15.1	3.9	0.0 – 159.2
Upland Sandpiper	7.4	1.8	0.0 - 63.7
Le Conte's Sparrow	5.3	1.5	0.0 - 47.8
Other grassland spp.	6.6	1.7	0.0 - 63.7
Sedge Meadow/Wetland spp.	16.5	4.0	0.0 - 159.2
Savanna/Woodland spp.	12.2	3.0	0.0 - 111.5
Aerial Foragers	4.0	2.0	0.0 - 95.5

TABLE 2.3. Breeding bird species richness, species diversity, and densities on nine 100-m radius sedge meadow survey points on the Sheyenne National Grassland, ND during Summer 1999.

Variable	Mean	Standard Error	Range
Bird community parameter			
Species richness/point	8.1	1.2	5.0 - 16.0
Species diversity/point	0.7	0.04	0.5 - 0.9
Density (birds/100 ha)			
Red-winged Blackbird	88.5	30.4	0.0 – 207.0
Mallard	79.6	77.6	0.0 – 700.6
Sedge Wren	51.3	15.2	0.0 - 111.5
Savannah Sparrow	26.5	10.6	0.0 - 95.5
Western Meadowlark	24.8	4.7	15.9 - 47.8
Other sedge meadow/wetland spp.	70.8	13.6	31.8- 159.2
Grassland spp.	40.7	13.6	0.0 - 95.5
Aerial Foragers	1.8	1.8	0.0 - 15.9

TABLE 2.4. Breeding bird species richness, species diversity, and densities on seven 100-m radius half-circle wetland survey points on the Sheyenne National Grassland, ND during Summer 1999.

Variable	Mean	Standard Error	Range
Bird community parameter			
Species richness/point	8.6	1.0	5.0 - 12.0
Species diversity/point	0.8	0.1	0.5 - 0.7
Density (birds/100 ha)			
Red-winged Blackbird	382.2	72.9	127.4 – 636.9
Yellow-headed Blackbird	154.7	103.8	0.0 - 668.8
Black Tern	54.6	39.7	0.0 - 286.6
Blue-winged Teal	40.9	16.6	0.0 – 95.5
American Coot	36.4	12.9	0.0 – 63.7
Other sedge meadow/wetland spp.	232	44.3	0.0 – 382.2
Grassland spp.	81.9	26.8	0.0 - 159.2

TABLE 2.5. Breeding bird species richness, species diversity, and densities on seven 50-m radius savanna survey points on the Sheyenne National Grassland, ND during Summer 1999.

Variable	Mean	Standard Error	Range
Bird community parameter			
Species richness/point	6.6	0.9	4.0 - 11.0
Species diversity/point	0.8	0.1	0.6 - 1.0
Density (birds/100 ha)			
Ground Foragers	236.6	49.6	127.4 - 509.6
Salliers	127.4	39.3	0 - 254.8
Foliage Gleaners	109.2	71.8	0 - 509.6
Bark Gleaners	81.9	38.6	0 - 254.8
Aerial Foragers	9.1	9.1	0 - 63.7

TABLE 2.6. Breeding bird species richness, species diversity, and densities on five 50-m radius woodland survey points on the Sheyenne National Grassland, ND during Summer 1999.

Variable	Mean	Standard Error	Range
Bird community parameter			
Species richness/point	5.8	1.0	3.0 - 8.0
Species diversity/point	0.7	0.1	0.4 - 0.9
Density (birds/100 ha)			
Ground Foragers	229.3	74.3	0 - 445.9
Foliage Gleaners	178.3	54.8	63.7 - 382.2
Salliers	178.3	42.2	63.7 - 318.5
Bark Gleaners	25.5	25.5	0 - 127.4

APPENDIX 1. Habitat preferences of 135 actual or potential breeding birds of the Sheyenne National Grassland, ND. Habitat preferences include both breeding and foraging habitat. Grassland/Agriculture includes areas dominated by grasses and forbs such as tallgrass and mixed-grass prairie, prairie thicket, weedy fields, fencerows, and cropland. Sedge Meadow includes areas dominated by sedges and rushes such as drying seasonal ponds, fens, and wet-meadow swales. Wetland/Open Water includes seasonal, semipermanent, and permanent ponds, and rivers. Savanna includes wooded areas dominated by *Quercus macrocarpa* or *Populus tremuloides*, and with 10-80% canopy cover. Woodland includes areas with greater than 80% canopy cover such as upland and floodplain forest, and wooded borders around open water habitats. Residential/Farmstead includes towns, parks, lawns, gardens, and shelterbelts; some species of this habitat nest on man-made structures such as buildings, nest boxes, and bridges. Note that many habitats share a range of characteristics and that some birds occupy a range of habitat types. Densities (birds/100 ha) are provided where possible (i.e. the species was detected during a 3-min survey within the survey circle). Densities are averages of all survey points within a given habitat and are not corrected for differences in detectability. 'X' indicates a species' use of that habitat but it was not detected in that habitat during a 3-min survey within the circular plot. Residential/Farmstead habitats were not surveyed. Species list compiled from Stewart (1975), Faanes et al. (1982), Sauer et al. (1999), and observations by W. Cooper, C. Dahlin, J. Dechant, C. English, D. Scheiman, B. Stotts, M. Vial, and C. Wilkerson. Habitat preferences determined from Stewart (1975) and this study. Taxonomic classification follows the 7^{th} edition of the American Ornithologists' Union Check-list of North American Birds (American Ornithologists' Union 1998).

APPENDIX 1.

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Podicipedidae							
Pied-billed Grebe	*Podilymbus podiceps*			X			
Phalacrocoracidae							
Double-crested Cormorant	*Phalacrocorax auritus*			X			
Ardeidae							
American Bittern [L,M,H]	*Botarus lentiginosus*	0.53		9.10			
Great Blue Heron	*Ardea herodias*			X			
Great Egret	*Ardea alba*			X			
Cattle Egret	*Bubulcus ibis*			X			
Green Heron	*Butorides virescens*			X		X	
Cathartidae							
Turkey Vulture	*Cathartes aura*					X	

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Anatidae							
Canada Goose	*Branta canadensis*	X	X	X			
Tundra Swan	*Cygnus columbianus*			X			
Wood Duck	*Aix sponsa*			X	X	X	
American Wigeon	*Anas americana*	X	X	X			
Gadwall [H]	*Anas strepera*	0.27	X	X			
Mallard [L,M,H]	*Anas platyrynchos*	0.27	80.50	18.20			
Blue-winged Teal [L,M,H]	*Anas discors*	1.86	2.65	40.95			
Northern Shoveler	*Anas clypeata*	X	X	31.85			
Northern Pintail	*Anas actua*	X	X	X			
Green-winged Teal	*Anas crecca*	X	X	X			
Canvasback	*Aythya valisineria*			4.55			
Redhead	*Aythya americana*			X			

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Anatidae							
Lesser Scaup	*Aythya affinis*			X			
Hooded Merganser	*Lophodytes cucullatus*			X			
Ruddy Duck	*Oxyura jamaicensis*			4.55			
Accipitridae							
Osprey	*Pandion haliaetus*			X			
Northern Harrier [L]	*Circus cyaneus*	0.27	X	X			
Accipitridae							
Sharp-shinned Hawk	*Accipiter striatus*				X	X	
Cooper's Hawk	*Accipiter cooperii*				X	X	
Red-tailed Hawk	*Buteo lineatus*	X			X	X	
Swainson's Hawk	*Buteo swainsoni*	X					
Falconidae							
American Kestrel	*Falco sparverius*	X			X	X	

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Phasianidae							
Gray Partridge	*Perdix perdix*	X					
Ring-necked Pheasant	*Phasianus colchicus*	X					
Sharp-tailed Grouse	*Tympanuchus phasianellus*	X					
Greater Prairie-Chicken	*Tympanuchus cupido*	X					
Wild Turkey	*Meleagris gallopavo*					X	
Rallidae							
Yellow Rail	*Coturnicops noveboracensis*			X			
Virginia Rail	*Rallus limicola*			X			
Sora ^{M,H}	*Porzana carolina*	0.80	2.65	18.20			
American Coot ^{L,M,H}	*Fulica americana*	0.53		36.40			
Charadriidae							
Killdeer ^{L,M,H}	*Charadrius vociferus*	1.33	1.77	31.85			

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Recurvirostridae							
American Avocet	*Recurvirostra americana*		X	X			
Scolopacidae							
Spotted Sandpiper	*Actitis macularia*			X			
Upland Sandpiper [L,M,H]	*Bartramia longicauda*	7.43	7.08	18.20			
Marbled Godwit [L]	*Limosa fedoa*	0.80	7.08	X			
Common Snipe [L,M,H]	*Gallinago gallinago*	0.27	6.19	13.65			
American Woodcock	*Scolopax minor*					X	
Wilson's Phalarope	*Phalaropus tricolor*		22.12	22.75			
Laridae							
Black Tern [L,M]	*Childonias niger*	0.53	6.19	54.60			
Columbidae							
Rock Dove	*Columba livia*						X
Mourning Dove [L,M,H]	*Zenaida macroura*	1.06			36.40	38.22	X

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Cuculidae							
Black-billed Cuckoo	*Coccyzus erythropthalmus*	X			X	X	X
Yellow-billed Cuckoo	*Coccyzus americanus*					X	
Strigidae							
Eastern Screech-Owl	*Otus asio*				X	X	X
Great Horned Owl	*Bubo virginianus*	X				X	
Burrowing Owl	*Athene cunicularia*	X					
Short-eared Owl	*Asio flammeus*	X	X				
Caprimulgidae							
Common Nighthawk	*Chordeiles minor*	X	X	X	X	X	X
Apodidae							
Chimney Swift	*Chaetura pelagica*						X

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Trochilidae							
Ruby-throated Hummingbird	*Archilochus colubris*					X	X
Alcedinidae							
Belted Kingfisher	*Ceryle alcyon*			X		X	
Picidae							
Red-headed Woodpecker	*Melanerpes erythrocephalus*				X	X	X
Yellow-bellied Sapsucker	*Sphyrapicus varius*				27.30	25.48	
Downy Woodpecker	*Picoides pubescens*				X	X	X
Hairy Woodpecker	*Picoides villosus*				36.40	X	X
Northern Flicker [L,M,H]	*Colaptes auratus*	0.53			X	25.48	X
Pileated Woodpecker	*Dryocopus pileatus*					X	
Tyrannidae							
Eastern Wood-Pewee	*Contopus virens*				81.89	25.48	
Willow Flycatcher	*Empidonax trallii*				X	X	X

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Tyrannidae							
Least Flycatcher	*Empidonax minimus*					152.87	
Eastern Phoebe	*Sayornis phoebe*					X	X
Great Crested Flycatcher	*Myiarchus crinitus*					X	
Western Kingbird	*Tyrannus verticalis*	X			X	X	X
Eastern Kingbird [L,M,H]	*Tyrannus tyrannus*	3.72		9.10	18.20		
Laniidae							
Loggerhead Shrike [L]	*Lanius ludovicianus*	0.53			X		X
Vireonidae							
Blue-headed Vireo	*Vireo solitarius*				X	X	
Yellow-throated Vireo	*Vireo flavifrons*				9.10	12.74	X
Warbling Vireo [M,H]	*Vireo gilvus*	0.53			9.10	X	X
Red-eyed Vireo	*Vireo olivaceus*				27.30	38.22	

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Corvidae							
Blue Jay	*Cyanocitta cristata*				36.40	X	X
American Crow	*Corvus brachyrhynchos*	X			X	X	X
Alaudidae							
Horned Lark [M]	*Eremophila alpestris*	0.53					
Hirundinidae							
Purple Martin	*Progne subis*						X
Tree Swallow [M]	*Tachycineta bicolor*	0.27		X	X	X	
Northern Rough-winged Swallow [L,M]	*Stelgidopteryx serripennis*	2.39		X		X	
Bank Swallow	*Riparia riparia*	X		X	9.10		
Cliff Swallow [L]	*Petrochelidon pyrrhonota*	1.86		X		X	X
Barn Swallow [L,M]	*Hirundo rustica*	1.33	1.77				X
Paridae							
Black-capped Chickadee	*Poecile atricapillus*				X	X	X

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Sittidae							
White-breasted Nuthatch	*Sitta carolinensis*				18.20	X	X
Troglodytidae							
House Wren [L,M,H]	*Troglodytes aedon*	1.06			18.20	76.43	X
Sedge Wren [L,M,H]	*Cistothorus platensis*	7.17	51.31	22.75			
Marsh Wren [H]	*Cistothorus palustris*	1.06	13.27	27.30			
Turdidae							
Eastern Bluebird	*Sialia sialis*	X			27.30		X
Veery	*Catharus fuscescens*					X	
American Robin	*Turdus migratorius*	X			18.20	X	X
Mimidae							
Gray Catbird [M,H]	*Dumetella carolinensis*	1.06				25.48	
Northern Mockingbird	*Mimus polyglottos*				X		X
Brown Thrasher	*Toxostoma rufrum*				18.20	12.74	

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Sturnidae							
European Starling	*Sturnus vulgaris*						X
Bombycillidae							
Cedar Waxwing	*Bombycilla cedrorum*				18.20	X	X
Parulidae							
Yellow Warbler [L,M,H]	*Dendroica petechia*	0.27				X	X
Black-and-white Warbler	*Mniotilta varia*				X	X	
American Redstart	*Setophaga ruticilla*				X	X	
Ovenbird	*Seiurus aurocapillus*					25.48	
Common Yellowthroat [L,M,H]	*Geothlypis trichas*	5.04	1.77	27.30	9.10	38.22	
Thraupidae							
Scarlet Tanager [L,H]	*Piranga olivacea*	0.53			9.10	X	

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Emberizidae							
Chipping Sparrow	*Spizella passerina*				9.10	X	X
Clay-colored Sparrow [L,M,H]	*Spizella pallida*	23.62	1.77		9.10	X	
Field Sparrow [L,M,H]	*Spizella pusilla*	0.53			27.30	12.74	
Vesper Sparrow [L,M,H]	*Poocetes gramineus*	2.65					
Lark Sparrow [L,M]	*Chondestes grammacus*	0.27			9.10		
Lark Bunting	*Calamospiza melanocorys*	X					
Savannah Sparrow [L,M,H]	*Passerculus sandwichensis*	23.35	26.54				
Grasshopper Sparrow [L,M,H]	*Ammodramus savannarum*	41.93	1.77				
Le Conte's Sparrow [L,M,H]	*Ammodramus leconteii*	5.31	17.69				
Nelson's Sharp-tailed Sparrow [L]	*Ammodramus nelsoni*	0.27	3.54				
Song Sparrow [L,M,H]	*Melospiza melodia*	0.27				12.74	
Swamp Sparrow	*Melospiza georgiana*		X	X			
Chestnut-collared Longspur	*Calcarius ornatus*	X					

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Cardinalidae							
Rose-breasted Grosbeak ^{L,M}	*Pheucticus ludovicianus*	0.27				38.22	X
Indigo Bunting	*Passerina cyanea*					12.74	
Dickcissel	*Spiza americana*	X					
Icteridae							
Bobolink ^{L,M,H}	*Dolichonyx oryzivorus*	29.72	5.31	22.75			
Red-winged Blackbird ^{L,M,H}	*Agelaius phoeniceus*	28.66	108.81	382.17			
Western Meadowlark ^{L,M,H}	*Sturnella neglecta*	47.51	25.65	4.55	18.20		
Yellow-headed Blackbird ^{L,M,H}	*Xanthocephalus xanthocephalus*	0.80	17.69	154.69			
Brewer's Blackbird ^{M}	*Euphagus cyanocephalus*	1.06					X
Common Grackle ^{M,H}	*Quiscalus quiscula*	0.53		18.20	27.30	X	X
Brown-headed Cowbird ^{L,M,H}	*Molothrus ater*	15.13	23.00	9.10	9.10	X	X
Orchard Oriole	*Icterus spurius*				18.20		X
Baltimore Oriole	*Icterus galbula*				9.10	38.22	X

APPENDIX 1. (cont'd).

Species		Habitat Types					
Family Common Name	Scientific Name	Grassland / Agriculture	Sedge Meadow	Wetland / Open Water	Savanna	Woodland	Residential / Farmstead
Fringillidae							
House Finch	*Carpodacus mexicanus*						X
Pine Siskin	*Carduelis pinus*					X	X
American Goldfinch [L,M,H]	*Carduelis tristis*	3.18				X	X
Passeridae							
House Sparrow	*Passer domesticus*						X

[L] Detected on low-spurge points.

[M] Detected on medium-spurge points.

[H] Detected on high-spurge points.

APPENDIX 2. Regression equations of the best two-predictor models that relate bird species diversity and densities (birds/100 ha) to vegetation characteristics or grazing intensity. Litter, Bare Ground, and Forb are percent cover of litter, bare ground, and non-spurge forbs respectively. Density is vegetation vertical density (Robel et al. 1970). Grazing Intensity is an index incorporating number of cattle/calf units and length of grazing period over the survey period on the Sheyenne National Grassland, ND (Summer 1999).

Diversity = 0.734 - 0.003 Forb + 0.002 Bare Ground

Predictor	Coefficient	Standard Dev.	T	P
Constant	0.734	0.043	17.22	0.000
Forb	-0.003	0.001	-2.98	0.004
Bare Ground	0.002	0.001	1.95	0.057
S = 0.13	R^2= 15.6%	R^2 (adj.) = 12.6%		

Brown-headed Cowbird = 25.8 - 0.144 Litter + 0.298 Bare Ground

Predictor	Coefficient	Standard Dev.	T	P
Constant	25.815	5.824	4.43	0.000
Litter	-0.145	0.107	-1.35	0.183
Bare Ground	0.298	0.122	2.43	0.018
S = 13.94	R^2 = 14.8%	R^2(adj.) = 11.8%		

APPENDIX 2. (cont'd).

Clay-colored Sparrow = 29.2 + 0.244 Forb - 0.002 Grazing Intensity

Predictor	Coefficient	Standard Dev.	T	P
Constant	29.239	4.875	6.00	0.000
Forb	0.244	0.117	2.08	0.042
Grazing Intensity	-0.002	0.001	-2.41	0.019
S = 15.73	R^2= 15.3%	R^2 (adj.) = 12.3%		

Grasshopper Sparrow = 23.4 + 0.346 Litter - 0.114 Density

Predictor	Coefficient	Standard Dev.	T	P
Constant	23.439	8.987	2.61	0.012
Litter	0.346	0.157	2.20	0.032
Density	-0.114	0.157	-0.73	0.471
S = 15.81	R^2= 18.9%	R^2 (adj.) = 16.1%		

Savannah Sparrow = 15.5 + 0.297 Litter Depth + 0.002 Grazing Intensity

Predictor	Coefficient	Standard Dev.	T	P
Constant	15.529	5.059	3.07	0.003
Litter Depth	0.297	0.118	2.52	0.014
Grazing Intensity	0.002	0.001	2.31	0.025
S = 15.66	R^2= 15.6%	R^2 (adj.) = 12.6%		

APPENDIX 2. (cont'd).

Upland Sandpiper = 16.4 + 0.344 Litter + 0.117 Bare Ground

Predictor	Coefficient	Standard Dev.	T	P
Constant	16.430	5.449	3.02	0.004
Litter	0.344	0.100	3.43	0.001
Bare Ground	0.117	0.115	1.02	0.310
S = 13.05	R^2= 17.1%	R^2 (adj.) = 14.2%		