GRASSLAND BIRD CONSERVATION ON RECLAIMED SURFACE MINES: EVALUATING THE INFLUENCE OF VEGETATION STRUCTURE ON DISTRIBUTION, NEST PLACEMENT AND NESTING SUCCESS

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ABSTRACT

Reclaimed surface mines represent a conservation paradox in the Midwest in that they are occupied by grassland birds, yet they are highly disturbed areas and often dominated by introduced grasses. I examined 1) associations among woody vegetation and relative abundance of the grasshopper sparrow (*Ammodramus savannarum*), Henslow's sparrow (*Ammodramus henslowii*), eastern meadowlark (*Sturnella magna*), Savannah sparrow (*Passerculus sandwichensis*), bobolink *(Dolichonyx oryzivorus*) and dickcissel (*Spiza americana*) and 2) the influence of vegetation composition and structure on nest placement and nest survival of the grasshopper sparrow, Henslow's sparrow and eastern meadowlark . From May – August 2005 and 2006, I surveyed grassland birds, monitored nesting success, and quantified vegetation structure and composition within reclaimed surface mines in eastern Ohio. Abundance estimates were derived from 101 point-counts along randomly located transects, and nest monitoring focused on eight study plots. I applied a principle components analysis to 3 woody vegetation metrics (i.e., percent cover of woody vegetation and number of woody patches within 100-m, and distance to woodland edge) to create a single index of woody vegetation that was used in subsequent analyses. Relationships between woody vegetation and relative bird abundance were analyzed using generalized linear models, whereas differences in vegetation structure and composition between nest and random locations were examined using a discriminant function analysis for each species. I used an information-theoretic approach, incorporating a set of *a priori* models into a logistic-exposure method to model daily nest survival. Grasshopper sparrows and Henslow's sparrows were the most abundant grassland species recorded within both management areas. Although numbers of grasshopper sparrows, Henslow's sparrows, Savannah sparrows and bobolinks were negatively related to woody vegetation cover within 100-m of survey locations, only the grasshopper sparrow showed strong evidence of responding to woody vegetation within 100-m of nest locations. Grasshopper sparrow nests were located in areas with less visual obstruction of the surrounding vegetation and more bare ground, whereas Henslow's sparrow and eastern meadowlark nests were associated with deeper and greater coverage of litter within 100-m of the nest than randomly located plots. Daily nest survival was negatively related to the amount of woody vegetation in proximity to nests of grasshopper sparrow (n = 45) and Henslow's sparrow (n = 18) and marginally related to eastern meadowlark nests (n = 18). Although grassland birds seem to select nest sites based on a variety of habitat features surrounding nests, the amount of woody vegetation may be one of the factors that most strongly influences nest survival. Thus, managers should consider controlling woody encroachment on reclaimed surface mines if the goal is to provide quality habitat for a diverse community of grassland-breeding birds.

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CHAPTER 1

INTRODUCTION

Grassland birds have declined more rapidly than any other group of birds in the Midwest over the past 30 years, and continue to decline (Cully and Michaels 2000, Vickery and Herkert 2001). Among the most precipitously declining are area-sensitive species such as the grasshopper sparrow (*Ammodramus savannarum*), Henslow's sparrow (*Ammodramus henslowii*), bobolink (*Dolichonyx oryzivorus*), Savannah sparrow (*Passerculus sandwichensis*) and eastern meadowlark (*Magna sturnella)* (Herkert 1994a). These declines have been attributed to changes in agricultural practices (Johnson and Igl 2001), habitat loss (Askins 1993), and habitat degradation and fragmentation due to urbanization (Herkert 1994a, Vickery and Herkert 2001, Cully and Michaels 2002). Because large increases in the amount of native and managed grassland habitats in the Midwest are unlikely to materialize in many landscapes, successful conservation of grassland birds will require consideration of new and non-traditional opportunities to provide quality grassland habitat to area-sensitive species. Reclaimed surface mines represent one opportunity to manage for grassland bird species (Whitmore and Hall 1978; Whitmore1980, Wray et al. 1982).

Surface mining became a common practice in the Midwest in the 1920's, creating thousands of hectares of grasslands following reclamation efforts in the 1970's

(Whitmore 1980, Wray et al. 1982, Brothers 1990, Bajema et al. 2001). Because reclaimed surface mines were traditionally viewed as low quality grasslands, most ecologists failed to consider them as viable habitat for grassland birds (Wray et al. 1982, Bajema et al. 2001). Reclaimed surface mines have recently received attention for grassland-nesting birds. Although these grasslands are typically composed of introduced grasses and forbs (Brothers 1990), they are large enough to meet the area requirements for highly sensitive grassland bird species (Vickery et al. 1994, Walk and Warner 1999, Johnson and Igl 2001), such as the Henslow's sparrow (Bajema et al. 2001). Reclaimed surface mines represent some of the largest units of grasslands in Ohio, Illinois, Indiana, Pennsylvania and Kentucky (Bajema et al. 2001, Monroe and Ritchison 2005). Recent research has documented large populations of grassland birds nesting within reclaimed surface mines (DeVault 2002), particularly east of the Mississippi River (Bajema et al. 2001, Monroe and Ritchison 2005). Another advantage of reclaimed surface mines is that they are usually owned by a single entity, which facilitates management and long-term conservation planning (DeVault et al. 2002).

Despite apparent use of reclaimed surface mines by grassland-breeding birds, there are few data to evaluate their quality for reproduction (Wray et al. 1982). Nest predation is known to be a major cause of nest failure for grassland birds (Wray et al. 1982, Dion et al. 2000, Herkert et al. 2003) and may be influenced by nest concealment (Monroe and Ritchison 2005) and predator species richness and abundance (Renfrew and Ribic 2003). Two features of reclaimed surface mines suggest that they could promote high reproductive success: (1) reclaimed surface mines are subjected to mowing much less frequently than in agricultural grasslands (DeVault et al. 2002), which is an important cause of nest failure for grassland birds (Bollinger et al. 1990, Rodenhouse et al. 1995), and (2) reclaimed surface mines are generally very large in size (often > 1000 ha) (Bajema and Lima 2001) which may reduce the local abundance of woodland and edge-associated nest predators (Winter et al. 2000, Bajema et al. 2001, Bajema and Lima 2001, Renfrew and Ribic 2003). However, these assumptions have not been explicitly tested, and existing data are equivocal. For example, reproductive success of grasshopper sparrows on a reclaimed surface mine in West Virginia was found to be extremely low over a two-year period (Wray et al. 1982). In contrast, the nesting success of Henslow's sparrows (Monroe and Ritchison 2004) and grasshopper sparrows (Delisle and Savidge 1996) on reclaimed surface mines were comparable to success rates on unmined sites. Monroe and Ritchison (2004) concluded that reclaimed surface mines might play a vital role in stabilizing populations of grassland birds, including Henslow's sparrow, grasshopper sparrow (Delisle and Savidge 1996) and eastern meadowlark. Reclaimed surface mines also are extremely important for Hensow's sparrows, which is a species of high conservation concern with a breeding range contained entirely within the Midwest.

Nest predation is one of the most common causes of low reproductive success in birds (Martin 1995), especially ground-nesting birds in grassland systems (With 1994). For this reason, I expected grassland birds to select territories and nesting sites based on habitat features that reduce the possibility of predation. Thus, it is important to characterize habitat features that may affect distribution and nesting success (With 1994). Woodland and generalist predators such as the raccoon (*Procyon lotor),* striped skunk (*Mephitis mephitis*), fox (*Vulpes spp.*) white-tailed deer (*Odocoileus virginianus*) and an array of snake species (*Elaphe spp.*) are common grassland bird nest predators (Vickery et al. 1992, Davison and Bollinger 2000, Pietz and Granfors 2000a, Renfrew and Ribic 2003) that forage within grasslands and the surrounding landscape. Although reforestation of these grasslands is often not possible due to poor soil conditions post-reclamation, invasion by woody species such as autumn olive (*Elaeagnus umbellate*) and black locust (*Robinia pseudoacacia*) occurs rapidly if left unmanaged. Management of woody encroachment within reclaimed mines may decrease nest predation by reducing the number of and overall amount of woody vegetation patches that may harbor nest predators.

Additional research is needed to determine if reclaimed surface mines within the Ohio landscape act as surrogate grasslands, offering quality breeding habitat for nesting grassland birds. Such research requires effective monitoring of abundance, species composition, and reproductive success of grassland birds. Additionally, research linking reproductive success to microhabitat features would facilitate the generation of specific management strategies that could be used within reclaimed surface mines.

OBJECTIVES

This study seeks to evaluate the conservation value of reclaimed surface mines by answering two key questions: 1) how does woody vegetation affect abundance, nest placement and nest success of grassland birds and 2) how do nest-patch characteristics and habitat features of reclaimed surface mines influence the nest placement and reproductive success of the grasshopper sparrow, Henslow's sparrow and eastern meadowlark? To answer these questions, I will pursue the following specific objectives:

1) Determine the extent to which woody vegetation influences abundance of the grasshopper sparrow, Henslow's sparrow, Savannah sparrow, eastern meadowlark, bobolink and dickcissel.

2) Identify which elements of vegetation composition and structure may influence nest placement of the grasshopper sparrow, Henslow's sparrow and eastern meadowlark.

3) Examine how nest survival is influenced by woody vegetation, vegetative composition, structure and proximity to edge habitat.

THESIS FORMAT

In this first chapter, I review the effects of habitat fragmentation on grassland bird communities, the influence of vegetation structure and composition on grassland bird abundance and nest survival, and the importance of reclaimed surfaces mines for the conservation of grassland-breeding birds. Chapter 2 explicitly addresses the influence of woody vegetation on abundance, nest placement and nest success of grassland-breeding birds found on reclaimed surface mines and is formatted as a research article for *Journal of Wildlife Management*. Chapter 3 examines the influence of nest-patch habitat characteristics on nest placement and nest success of the grasshopper sparrow, Henslow's sparrow and eastern meadowlark and is formatted as a research article for *Wilson Journal of Ornithology*.

BACKGROUND

Landscape attributes and area sensitivity:

Landscape- and patch-level features are known to influence the density of grassland birds in different grassland habitats, although most species exhibit different levels of sensitivity to one or the other, or a combination of these features. Therefore, assessment of grassland habitat should be conducted at multiple spatial scales as some species may respond only to local conditions, while others might respond only to landscape-level attributes (Bakker et al. 2002). For example, although densities of several grassland birds were not strongly associated with field size, landscape- and field-level features of agricultural and non-agricultural grasslands in southern Wisconsin influenced densities of grasshopper sparrows and Savannah sparrows. Bobolinks and eastern meadowlarks were influenced solely by landscape-level attributes (Ribic and Sample 2001). Others have reported a lack of landscape-level influence on Henslow's sparrows (Bajema and Lima 2001) and bobolinks (Bakker et al. 2002), as bobolink density was related to patch-level variables only. Thus, landscape and area sensitivity appear to be regionally variable and the extent to which a species demonstrates sensitivity to them may depend strongly on context. Despite the possibility of regional variation in area and landscape requirements, there is general agreement that management of grassland birds is likely to be most effective in landscapes dominated by open lands that contain little non-linear woody habitat within 800 meters from the conservation site (With and King 2001). Because agricultural lands may promote use of certain landscapes, loss of secondary grassland areas, such as hayfields and pastures, is now directly contributing to the fragmented nature of midwestern grassland habitat and the continued decline in grassland bird species (Balent and Norman 2003). Grassland birds nesting in tallgrass prairies in Minnesota achieved the highest productivity rates in areas that were far from a forested edge. Occurrence of grasshopper sparrow nests was highest in plots located far from a wooded edge, although nest occurrence was also highest on plots that were subjected to four or more growing seasons, suggesting grasshopper sparrows fair better several years post-burning (Johnson and Temple 1990).

Grassland bird species are known to be area-sensitive (Vickery et al. 1994, Walk and Warner 1999, Johnson and Igl 2001) and tend to avoid small fragmented grasslands (Herkert 1994a). For example, grasshopper sparrows in a highly fragmented landscape in New York had return rates and productivity rates that were higher in larger than smaller patches, although larger habitat patches still seemed to function as population sinks (Balent and Norman 2003), suggesting grasshopper sparrow and other grassland bird populations are unlikely to persist in highly fragmented habitats without immigration. Herkert (1994b) reported that Henslow's sparrows in Illinois were almost exclusively found in grassland areas greater than 100 hectares. Grassland birds on restored grassland areas in the northern Great Plains exhibited greater area sensitivity spatially (north to south or east to west) and in patches where each species was more common (Johnson and Igl 2001). It has been suggested that this demonstrates the need for study replication because results from one area may not apply to other areas due to differences in study design, landscape matrices, range of the species and analytical methods used. Vickery et al (1994) also suggested incorporating area-dependency and minimum viable population requirements into management strategies in order to successfully protect threatened grassland birds. Therefore, conservation efforts should focus on protecting large patches of contiguous grasslands between 100 ha and 200 ha in size (Vickery et al. 1994), although 60 ha plots may be adequate to sustain viable populations of a diverse array of sensitive grassland bird species (Walk and Warner 1999).

Structure of breeding bird communities on fragmented grasslands within the midwestern landscape is known to be strongly influenced by area (Herkert 1994a) and habitat area may influence the perception of habitat suitability for grassland-breeding birds more than the size or configuration of management units (Walk and Warner 1999). Because large continuous grasslands most likely do not exist in eastern North America, alternative habitats should be considered for the conservation of grassland birds (Vickery et al. 1994). For this reason, reclaimed surface mines might be a more suitable habitat for grassland birds compared to other grassland patches, such as airports, that are surrounded by human disturbance regimes (noise pollution, mowing, chemical exposure).

Multiple edge effects within fragmented grasslands influenced the magnitude of observed edge effects (Fletcher 2005), suggesting that edge avoidance could also be contributing to the decline in densities of grassland birds in small habitat patches (Bollinger and Gavin 2004). For example, bobolink occurrence was much lower in double-edged plots compared to the interior (Fletcher 2005). In contrast, bobolink and eastern meadowlark nest densities did not show significant increase with an increase in distance to edge (Renfrew et al. 2005), and nesting success of bobolink was not consistently related to habitat edges in meadows and hayfields in New York; instead, nest success was dependent on the type of edge present (Bollinger and Gavin 2004). Renfrew et al. (2005) also found that birds did not locate nests near habitat edges, even if the adjacent land use was similar, including vegetative characteristics. Grassland units with close proximity to treelines (Walk and Warner 1999, O'Leary and Nyberg 2000) and large amounts of woody vegetation within tracts (Grant et al. 2004) have negative effects on the distribution of many grassland bird species (Walk and Warner 1999). Bobolinks especially avoided forest edges suggesting that small grasslands surrounded by forest are poor habitat for nesting bobolinks (Bollinger and Gavin 2004). Core areas >400 m from the edge were found to serve as source habitats for Florida grasshopper sparrows (Perkins et al. 2003), thus the only way for populations of grassland birds to persist is for recruitment to occur in large core areas (>4000 ha), compensating for sink habitats that might occur in nearby fragmented landscapes. Therefore, edge effects can be highly intensified when multiple edges intersect, which are a common occurrence in fragmented landscapes (Fletcher 2005). The diversity of land-cover types, density of edge habitat, and edge type and proportion of grassland within the landscape matrix may prove to be a significant consideration for future grassland bird conservation.

Nest-patch habitat characteristics:

Vegetation composition (Grant et al. 2004), structure (Whitmore and Hall 1978, DeVault et al. 2002, Scheiman et al. 2003, Chapman et al. 2004, Winter et al. 2005) and height (Madden et al. 2000) preferences among grassland birds imply that these are important characteristics when considering grassland management regimes for these declining species. Grasshopper sparrow abundance on Conservation Reserve Program (CRP) fields in Iowa was found to be negatively correlated with vertical vegetation cover, and grasshopper sparrows preferred short, clumped grasses such as orchard grass (*Dactylis glomerata*). Western meadowlark abundance was also negatively correlated with vertical cover, but positively correlated with vertical patchiness, preferring short vegetation (Patterson and Best 1996). Winter et al. (2005) found vegetation structure and grassland bird abundance varied the greatest among plots within regions, but woody coverage within study plots did not have a negative effect on Savannah sparrow and bobolink densities, which was possibly due to site selection. Furthermore, their findings suggest that there are many species-specific responses to vegetation characteristics. The only species for which nesting success was related to vegetation structure was the clay–colored sparrow, and success generally increased with nest cover. In addition, Winter et al. (2005) found nesting success to be positively related to grassland bird density, yet Vickery et al. (1992b) found a negative relationship between density and nesting success for Savannah sparrows. Grasshopper sparrow nests were found only in smooth brome and orchard grass litter on CRP fields in Iowa (Patterson and Best 1996). In addition, plots with tall, dense vegetation were found to contain more above-ground nesting birds compared to ground-nesting grassland birds such as the grasshopper sparrow (Patterson and Best 1996). Nest success rates of tallgrass prairie birds breeding in Minnesota were higher for nests located far from a wooded edge than near a wooded edge (Johnson and Temple 1990).

Chapman et al. (2004) found that grasshopper sparrow abundance increased with low levels of vertical vegetation structure and decreased with an increase in horizontal patchiness. In contrast, they found that eastern meadowlark abundance increased with high levels of vertical vegetation structure and high plant species diversity. Cully and Michaels (2000) found that Henslow's sparrow use patterns on a military reservation in Kansas were suggestive of the importance of vegetative characteristics when selecting their habitat. The primary preferred characteristics included high cover by litter and by dense, homogeneous vegetation. Monroe and Ritchison (2005) reported Henslow's sparrows nesting on reclaimed surface mines composed of large amounts of tall grass cover and high density of litter close to the ground. Zimmerman (1988) reported that

Henslow's sparrows in Kansas did not use forb coverage to select suitable territories; rather, they selected territories within habitat patches that contained large amounts of standing dead vegetation. Dickcissel abundance has been associated with landscape attributes, patch-level and edge characteristics, but nest survival rates were found to be associated only with patch-level vegetation characteristics such as percent canopy cover of both live and dead vegetation and percent litter cover. These three variables accounted for 59% of the variation in daily nest survival rates (Hughes et al. 1999). Vegetative structure (including density of live and residual, height and shrub density) was a vital predictor of grassland bird abundance in Saskatchewan (Walk and Warner 2000). Hull et al. (1996) found no significant relationship between an increase in floristic composition within CRP fields (mainly forb abundance) and grassland bird abundance. Henslow's sparrow abundance on tallgrass prairies in southwestern Missouri increased as litter cover increased and grasshopper sparrow abundance peaked in low to intermediate levels of litter cover (Swengel and Swengel 2001). Although the amount of litter cover seems to affect bird abundance, it is important to determine how litter was obtained (haying or burning) as Henslow's sparrows and grasshopper sparrows have been documented to fare poorly with the introduction of fire (Swengel and Swengel 2001).

Structure of vegetation within grasslands is an important indicator of habitat quality and resource availability for grassland birds (Scheiman et al. 2003), although few studies have looked at the effects of non-native plant species on grassland bird productivity and recruitment (Walk and Warner 2000). Introduced plant species can alter vegetation structure and resource availability, which can in turn negatively affect bird community composition. In addition, woody encroachment can alter grassland areas making them less attractive to grassland-breeding birds. Grassland bird species breeding in mixed-grass prairies in North Dakota were increasingly affected by nominal increases in the amount of woody vegetation and as height of woody plants increased (Grant et al. 2004). Occurrence of species such as the grasshopper sparrow, western meadowlark and bobolink declined as the extent of woody vegetation within a grassland area increased. In addition, when woodland cover exceeded about 25% on grassland sites, several species found these areas unsuitable. Nesting success of Henslow's sparrows and dickcissels nesting in tallgrass prairies in southwestern Missouri decreased with proximity to shrubby edges and possibly forested edges. This lowered nesting success may have been attributed to greater activity of mid-sized mammalian predators in close proximity to woody edges (Winter et al. 2000). Woody edges appear to be acting as travel corridors for mammalian nest predators (Winter et al. 2000) as has been documented in other studies on edge effects (Gates and Gysel 1978). Removing woody vegetation could potentially decrease the number of nest predators in an area by redistributing predator movement patterns, making these areas more attractive to species such as the Henslow's sparrow (Winter et al. 2000). Therefore, controlling invasive woody plant species within grasslands may be a critical management step to maintain preferred plant community composition and prevent further declines in grassland habitat quality and grassland bird populations (Scheiman et al. 2003).

Importance of reclaimed surface mines:

Grassland birds have been known to occupy reclaimed surface mines for many years (Whitmore 1978, 1980, Wray et al. 1982, Scott et al. 2002) and continue to occupy these grassland habitats throughout the Midwest (Bajema et al. 2001, DeVault et al. 2002, Ingold 2002, Rummel and Brenner 2003, Mattice et al. 2005, Galligan et al. 2006). Although reclaimed surface mines are typically low in plant diversity, contain infertile soil and very few native grasses and forbs, they seem to contain structural vegetative characteristics that are suitable for grassland-breeding birds (Wray et al. 1982, Herkert 1994a, Scott, et al 2002, DeVault et al. 2002). Herkert (1994a) reports that the structural characteristics of vegetation and patch size seem to be vitally important to the occurrence of grassland birds. The sheer size of mine grasslands makes them an important refuge for area-sensitive species (DeVault et al. 2002) such as the Henslow's sparrow, grasshopper sparrow and eastern meadowlark. Generally, grassland birds have been found to respond to vegetation characteristics on reclaimed surface mines similarly to the way these birds respond in natural grassland landscapes (Scott et al. 2002). Densities of grassland birds recorded on reclaimed surface mines did not vary much from those measured on grasslands in Illinois, which consisted of native prairie, restored prairie and cool season agriculture fields. Eastern meadowlarks were more common on reclaimed surface mines than on unmined grasslands. Grasshopper sparrows showed similar densities between mined sites and Illinois grasslands. Henslow's sparrows showed lower densities on mined grasslands compared to more prime sites (Scott et al. 2002) although Rummel and Brenner (2003) found Henslow's sparrows to be the most abundance species that occurred on reclaimed sites with densities of about 7 birds per hectare. The population size of several grassland birds occupying 35,000 ha of reclaimed surface mines in western Pennsylvania was recently estimated to be 9650 grasshopper sparrows, 1921 savannah sparrows and 4884 Henslow's sparrows (for singing males; Mattice et al. 2005). On reclaimed surface mines in southwestern Indiana, Henslow's sparrows were influenced by the composition and structure of local vegetation with little or no effect from the amount of grassland or landscape composition. The lack of landscape-level effects on Henslow's sparrows may be due to the large size of reclaimed surface mines rather than a lack of landscape-level sensitivity (Bajema and Lima 2001).

Predation:

Grassland bird populations are negatively affected by habitat fragmentation (Herkert 1994a), close proximity to wooded areas and woody encroachment within grassland units (With 1994, O'Leary and Nyberg 2000, Winter et al. 2000, Madden et al. 2004), which can all increase predation rates, contributing to the overall decline in bird populations (Renfrew and Ribic 2003). Typical predators of grassland areas include mice, snakes, squirrels, foxes, coyotes, skunks, raccoons, deer, crows, blue jays, hawks and cowbirds (Pietz and Granfors 2000b). Some of these predators are more common near edges (Winter et al. 2000) and others seem unaffected by habitat fragmentation (Herkert et al. 2003). Snakes are known to important nest predators in old-field areas (Zimmerman 1984), grassland pastures (Renfrew and Ribic 2003) and agricultural fields (Chalfoun, et al. 2002), in fact Thompson and Burhans (2003) found that snakes were the most common predator of ground-nesting birds nesting in old-fields in Missouri. Predation rates may drastically decrease as grassland area increases, especially areas in excess of 100 hectares. Although distance to several edge types was positively related to nest density in fragmented Wisconsin pastures, it was not the result of effects from wooded edges. There were no significant differences in nest density between nests located close to or far from wooded edges versus nonwooded edges (grassland or crop) (Renfrew et al. 2005). Grasshopper sparrows breeding in Nebraska were found to locate nests greater than 60-m from an edge habitat. Additionally, grasshopper sparrow nesting success was estimated at nearly 50%, which is much greater than what has been typically found for this species (Delisle and Savidge 1996). Possible reasons for a similar risk of predation in both interiors and edges in fragmented landscapes include small size, large number of resident grassland predators, and the ease of grassland predators accessing these areas. Grasshopper sparrow nest predation was found to be largely due to large mammals on CRP fields in Iowa, with a smaller percentage of predation by small mammals. Nest predation rates have been found to be higher in small grassland fragments due to the types of edges that occur on these areas (Herkert 1994a, Delisle and Savidge 1996). In fact, some proportion of nest predation in fragmented grasslands may be additive in nature in that a proportion of nests found by edge predators would not otherwise have been discovered by grassland predators (Renfrow et al. 2005). Wray et al. (1982) found predation rates on reclaimed surface mines to be in the range of 40-45% and reproductive success rates were typically low suggesting that these anthropogenic grasslands are acting as population sinks. In contrast, after examining reproductive success of grassland birds on a single reclaimed surface mine in eastern Ohio, Ingold (2002) suggested that reclaimed surface mine habitats may have the ability to support sustainable populations.

Abundance and productivity:

Knowledge of demographic responses to landscape context and grassland configuration is a key component of understanding potential source-sink dynamics and developing effective conservation strategies (With and King 2001). Much grassland bird research has focused on management areas consisting of burned, hayed, grazed and mowed units containing native cool and warm season grasses and native forbs (Walk and Warner 2000) and less attention has focused on more non-traditional habitats consisting of non-native plant species and less burning, haying, grazing and mowing practices. Haying practices are known to decrease grassland bird nesting success due to nest destruction (Dale et al. 1997); therefore, alternative grasslands, such as reclaimed surface mines might be very important surrogate grasslands to manage in order to increase grassland bird numbers.

As with many studies, an important unanswered question remains: do reclaimed surface mines represent quality nesting habitat for Henslow's sparrows and other declining grassland bird species (Perkins et al. 2003)? Density estimates for singing male Henslow's sparrows on reclaimed surface mines in northwestern Pennsylvania was recently estimated at 7.1 per hectare (Rummel and Brenner 2003), 0.14 per hectare in western Pennsylvania (Mattice et al. 2005), and in southwestern Indiana averaged 0.16 per hectare (Bajema et al. 2001), implying a male population of approximately 2000, making the overall adult population approaching 4000. Prairie fragments of southwestern Missouri have reported densities close to 0.70 per hectare over a three-year period (Winter and Fooborg 1999). Henslow's sparrow territories were found to be larger on unmined sites than on reclaimed sites, although both showed similar densities (Monroe and Ritchison 2005). This might suggest that reclaimed surface mines contain higher quality resources (food) and birds may not need as much space to meet their resource needs. Additionally, the nesting success of Henslow's sparrows on reclaimed surface mines in Kentucky was comparable to unmined areas, suggesting that reclaimed surface mines could play a large role in stabilizing Henslow's sparrow populations within the midwestern landscape (Monroe and Ritchison 2005). This is vitally important as a large proportion of the global population the Henslow's sparrow is contained within Ohio and surrounding states (Peterjohn and Sauer 1999).

Basic nesting information is of growing concern for managing grassland birds (Swanson 1996, Winter et al. 2004). Some of this much needed information includes suitability of habitat, determining the period when birds are susceptible to disturbance and how big of a priority grassland conservation is for certain regions. Until recently, research has exclusively focused on events on the breeding grounds (Vickery and Herkert 2001). Events on the wintering grounds may be partly responsible for grassland bird population declines. In addition, information on productivity is vital to determine if particular habitat types are serving as ecological traps or population sinks. In relationship to human disturbance, modification of habitats may alter food and predator abundance, directly affecting nest-site selection and nest success, creating possible ecological traps (Shochat, et al. 2005). Grasshopper sparrow nest success rates were found to be relatively high on CRP fields in Nebaska (Delisle and Savidge 1996) and relatively low on reclaimed surface mines in West Virginia (Wray et al. 1982). In addition, grasshopper sparrows nesting on reclaimed surface mines in West Virginia were the only species to produce a sufficient number of young to maintain a stable population without immigration, assuming a fledging survival rate of 12.5%. Henslow's sparrows and eastern meadowlarks did not produce sufficient young over a 3-year period to sustain viable populations (Wray et al. 1982).

Annual fecundity is another important element of population demography that is difficult to measure accurately. Using radio telemetry, researchers found that eastern meadowlarks nesting on grasslands in southeastern Illinois rarely attempted to raise two broods suggesting that double brooding for meadowlarks is very costly (Kershner et al. 2004). Due to the difficulty in following female birds through an entire breeding season, researchers estimating seasonal fecundity from productivity data should use a model that sets breeding-season length which will only indirectly constrain the possible number of nesting attempts and successful broods (Grzybowski and Pease 2005). In contrast, Jones et al. (2005) found that season-fecundity predictions that were based on nest survival values underestimated the observed fecundity by over 30% and therefore population growth was underestimated by 20%.

SIGNIFICANCE

Despite recent widespread concern for conservation of grassland birds and their use of reclaimed surface mines, there are few studies that have examined the effect of woody vegetation, vegetation composition and structure, and edge habitat on the distribution, nest-site selection and nest success of grassland-breeding birds. Additional research is needed in order to determine what influence microhabitat features (amount of woody encroachment, grassland structure, floristic composition and edge habitat) within reclaimed surface mines may have on the abundance, nest-site selection and reproductive success of grassland birds. Thus, it is vitally necessary to identify how woody encroachment, floristic composition and structure, edge habitat and habitat management practices within reclaimed surface mines affects the distribution and nest success of grassland birds. Gaining insight into the role habitat features of reclaimed surface mines and current management practices can play in grassland conservation may help mitigate declines in grassland bird populations.

LITERATURE CITED

Ammann, R.L. and D.W. Nyberg. 2005. Vegetation height and quality of original and reconstructed tallgrass prairies. The American Midland Naturalist 154:55-66.

Applegate, R.D., B.E. Flock and G.J. Horak. 2002. Spring burning and grassland area: Effects on Henslow's sparrow and dickcissel in Eastern Kansas, USA. Natural Areas Journal 22(2):160-162.

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

Bajema, R.A., T.V. DeVault, P.E. Scott and S.L. Lima. 2001. Reclaimed coal mine grasslands and their significance for Henslow's sparrows in the American midwest. The Auk 118(2):422-431.

------- and S.L. Lima. 2001. Landscape-level analyses of Henslow's sparrow (*Ammodramus henslowii*) abundance in reclaimed coal mine grasslands. The American Midland Naturalist 145:288-298.

Bakker, K.K., D.E. Naugle and K.F. Higgins. 2002. Incorporating landscape attributes into models for migratory grassland bird conservation. Conservation Biology 16(6):1638-1646.

Balent, K.L. and C.J. Norment. 2003. Demographic characteristics of a grasshopper sparrow population in a highly fragmented landscape of western New York state. Journal of Field Ornithology 74(4):341-348.

Barg, J.J., J.Jones and R.J. Robertson. 2005. Describing breeding territories of migratory passerines: suggestions for sampling, choice of estimator, and delineation of core areas.

Bibby, C.J., N.D. Burgess, D.A. Hill and S.H. Mustoe. 2000. Bird census techniques. Academic Press, San Diego, California, USA.

Bollinger, E.K., P.B. Bollinger and T.A. Gavin. 1990. Effects of hay-cropping on eastern populations of the bobolink. Wildlife Society Bulletin 2:142-150.

------- and T.A. Gavin. 2004. Responses of nesting bobolinks (Dolichonyx oryzivorus) to habitat edges. The Auk 121(3):767-776.

Brennan, L.A. and W.P. Kuvlesky, Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69(1):1-13.

Brothers, T. S. 1990. Surface-mine grasslands. The Geographical Review 80(3): 209-225.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L, Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press.

Chalfoun, A.D., M.J.Ratnaswamy and F.R. Thomspson III. 2002. Songbird nest predators in forest-pasture edge and forest interior in a fragmented landscape. Ecological Applications 12(3):858-867.

Chapman, R.N., D.M. Engle, R.W. Masters and D.M. Leslie. 2004. Grassland vegetation and bird communities in the southern Great Plains of North America. Agriculture, Ecosystems and Environment 104:577-585.

Cully, J.F., and H.L. Michaels. 2000. Henslow's sparrow habitat associations on Kansas tallgrass prairie. Wilson Bulletin 112(1):115-123.

Cunningham, M.A. and D.H. Johnson. 2006. Proximate and landscape factors influence grassland bird distributions. Ecological Applications 16(3):1062-1075.

Dale, B.C., P.A. Martin and P.S. Taylor. 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin 25(3): 616-626.

Daubenmire, R.F. 1959. Canopy coverage method of vegetation analysis. Northwest Scientist 33:43-64.

Davis, S.K. 2004. Area sensitivity in grassland passerines: Effects of patch size, patch shape and vegetation structure on bird abundance and occurrence in southern Saskatchewan. The Auk 121(4):1130-1145.

Davis, S.K., R.M. Brigham, T.L. Shaffer and P.C. James. 2006. Mixed-grass prairie passerines exhibit weak and variable response to patch size. The Auk 123(3):807-821.

Davison, W.B. and E. Bollinger. 2000. Predation rates on real and artificial nests of grassland birds. The Auk 117(1):147-153.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, M. P. Nenneman, and B. R. Euliss. 2003. Effects of management practices on grassland birds: Grasshopper Sparrow. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/grasbird/grsp/grsp.htm (Version 12AUG2004).

Delisle, J.M. and J.A. Savidge. 1996. Reproductive success of grasshopper sparrows in relation to edge. The Prairie Naturalist 28(3):107-113.

DeVault, T.L., P.E. Scott, R.A. Bajema and S.L. Lima. 2002. Breeding bird communities of reclaimed coal-mine grasslands in the American midwest. The Journal of Field Ornithology 73(3):228-275.

Diefenbach, D.R., D.W. Brauning and J.A. Mattice. 2003. Variability in grassland bird counts related to observer differences and species detection rates. The Auk 20(4):1168-1179

Dieni, J.S. and S.L. Jones. 2002. A field test of the area search method for measuring bird populations. Journal of Field ornithology 73(3):253-257.

-------, and -------. 2003. Grassland songbird nest site selection patterns in Northcentral Montana. Wilson Bulletin 115(4):388-396.

------- and P. Scherr. 2004. Roadside bias in point count surveys at Arrowwood National Wildlife Refuge, North Dakota. The Prairie Naturalist 36(4):203-211.

Dinsmore, S.J., G.C. White and F.L. Knopp. 2002. Advanced techniques for modeling avian nest survival. Ecology 83(12):3476-3488.

Dion, N., K.A. Hobson and S. Lariviere. 2000. Interactive effects of vegetation and predators on the success of natural and simulated nests of grassland songbirds. The Condor 102:629-634.

Farnsworth, G.L., K.H. Pollock, J.D. Nichols, T.R. Simons, J.E. Hines and J.R. Sauer. 2002. A removal method for estimating detection probabilities from point-count surveys. The Auk 119(2):414-425.

Fletcher, R.J. 2005. Multiple edge effects and their implications in fragmented landscapes. Journal of Animal Ecology 74:342-352.

Galligan, E.W., T.L. DeVault and S.L. Lima. 2006. Nesting success of grassland and savanna birds on reclaimed coal mines of the Midwestern United States. The Wilson Journal of Ornithology 118(4):537-546.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59(5):871-883.

Grant, T.A., E. Madden and G.B. Berkey. 2004. Tree and shrub invasion in Northern mixed-grass prairie: Implications for breeding grassland birds. Wildlife Society Bulletin 32(3):807-818.

Grzybowski, J.A. and C.M. Pease. 2005. Renesting determines seasonal fecundity in songbirds: What do we know? What should we assume? The Auk 122(1):280-291.

Hazler, K.R. 2004. Mayfield logistic regression: a practical approach for analysis of nest survival. The Auk 121(3):707-716.

Hensler, G.L. and J.D. Nichols. 1981. The Mayfield method of estimating nesting success: a model, estimators and simulation results. Wilson Bulletin 93(1):42-53.

Herkert, J.R. 1994a. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4(3):461-471.

-------. 1994b. Status and habitat selection of the Henslow's sparrow in Illinois. Wilson Bulletin 106(1):35-45.

-------. 1994c. Breeding bird communities of midwestern prairie fragments: The effects of prescribed burning and habitat-area. Natural areas journal 14:128-135.

-------, D. L. Reinking, D.A. Wiedenfeld, M. Winter, J.L. Zimmerman, W.E. Jensen, E.J. Finck, R. R. Koford, D.H, Wolfe, S.K. Sherrod, M.A. Jenkins, J. Faaborg and S.K. Robinson. 2003. Effects of prairie fragmentation on the nest success of breeding birds in the midcontinental United States. Conservation Biology 17(2):587-594.

-------. 2003. Effects of management practices on grassland birds: Henslow's Sparrow. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/grasbird/hesp/hesp.htm (Version 12DEC2003).

Hughes, J.P., R.J. Robel, K.E. Kemp,and J.L. Zimmerman. 1999. Effects of habitat on dickcissel abundance and nest success in conservation reserve program fields in Kansas. Journal of Wildlife Management 63(2):523-529.

Hull, S.D., R. J. Robel and K.E. Kemp. 1996. Summer avian abundance, invertebrate biomass, and forbs in Kansas CRP. The Prairie Naturalist 28(1):1-12.

-------. 2003. Effects of management practices on grassland birds: Eastern Meadowlark. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Ingold, D.J. 2002. Use of reclaimed stripmine by grassland nesting birds in East-central Ohio. Ohio Journal of Science 102(3):56-62.

James, F.C., C.E. McCulloch, and D.A. Wiedenfeld. 1996. New approaches to the analysis of population trends in land birds. Ecology 77:13-27.

Johnson, D.H. and L.D. Igl. 2001. Area requirements of grassland birds: A regional perspective. The Auk 118(1):24-34.

Johnson, R.G. and S.A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. Journal of Wildlife Management 54(1):106-111.

Jones, J., P.J. Doran, L.R. Nagy and R.T. Holmes. 2005. Relationship between Mayfield nest-survival and seasonal fecundity: a cautionary note. The Auk 122(1):306-312.

Kershner, E.L., J.W. Walk and R.E. Warner. 2004. Breeding-season decisions, renesting, and annual recundity of female Eastern meadowlarks (Sturnella magna) in Southeastern Illinois. The Auk 121(3):796-805.

Lawler, J.J. and R.J. O'Connor. 2004. How well do consistently monitored breeding bird survey routes represent the environments of the conterminous United States? The Condor 1006:801-814.

MacKenzie, D.I. 2005. What are the issues with presence-absence data for wildlife managers? Journal of Wildlife Management 69(3):849-860.

Madden, E.M., R.K. Murphy, A.J. Hansen and L. Murray. 2000. Models for guiding management of prairie bird habitat in northwestern North Dakota. American Midland Naturalist 144:377-392.

Manley, P.N., M.D. Schlesinger, J.K. Roth and B. Van Horne. 2005. A field-based evaluation of presence-absence protocol for monitoring ecoregional-scale biodiversity. Journal of Wildlife Management 69(3):960-966.

Martin, T.E. 1995. Avian life history evolution in relation to nest sites, nest predation, and food. Ecol. Monogr. 65:101-127.

Mattice, J.A., D.W. Brauning and D.R. Diefenbach. 2005. Abundance of grassland sparrows on reclaimed surface mines in western Pennsylvania. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.

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

-------. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Monroe, M.S. and G. Ritchison. 2005. Breeding biology of Henslow's sparrow on reclaimed coal mine grasslands in Kentucky. Journal of Field Ornithology 76(2):143-149.

O'Leary C.H. and D.W. Nyberg. 2000. Treelines between fields reduce the density of grassland birds. Natural Areas Journal 20:243-249.

Patterson, M.P. and L.B. Best. 1996. Bird abundance and nesting in Iowa CRP fields: the importance of vegetation structure and composition. American Midland Naturalist 135:153-167.

Peak, R.G., F.R. Thompson III, and T.L. Shaffer. 2004. Factors affecting songbird nest survival in riparian forests in a midwestern agricultural landscape. The Auk 121(3):726-737.

Perkins, D.W., P.D. Vickery and W.G. Shriver. 2003. Spatial dynamics of source-sink habitats: Effects on rare grassland birds. Journal of Wildlife Management 67(3):588-599.

Peterjohn, B.G. and J.R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-96. Studies in Avian Biology 19:27-44.

Pietz, P.J. and D.A. Granfors. 2000a. White-tailed deer (*Odocoileus virginianus*) predation on grassland songbird nestlings. American Midland Naturalist 144:419-422.

------- and -------. 2000b. Identifying predators and fates of grassland passerine nests using miniature video cameras. Journal of Wildlife Management 64(1):71-87.

Ransom, D. and W.E. Pinchak. 2003. Assessing accuracy of a laser rangefinder in estimating grassland bird density. Wildlife Society Bulletin 31(2):460-463.

Renfrew, R.B. and C.A. Ribic. 2002. Influence of topography on density of grassland passerines in pastures. American Midland Naturalist 147:315-325.

------- and -------. 2003. Grassland passerine nest predators near pasture edges identified on videotape. The Auk 120(2):371-383.

-------, ------- and J.L. Nack. 2005. Edge avoidance by nesting grassland birds: A futile strategy in a fragmented landscape. The Auk 122(3):618-636.

Ribic, C.A. and D.W. Sample. 2001. Associations of grassland birds with landscape factors in southern Wisconsin. The American Midland Naturalist 146:105-121.

Robel, R.J., J.N. Briggs, A.D. Dayton and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Rodenhouse, N. L., L. B. Best, R. J. O'Connor, and E. K. Bollinger. 1995. Effects of agricultural practices and farmland structures on Neotropical migratory birds. Pages 269-293 *in* T. E. Martin, and D. M. Finch, editors. Ecology and management of Neotropical migratory birds: a synthesis and review of critical issues. Oxford University Press, New York, New York.

Rosenstock, S.S., D.R. Anderson, K.M. Giesen, T. Leukering and M.F. Carter. 2002. Landbird counting techniques: current practices and an alternative. The Auk 119(1):6-53.

Rotella, J.J., M.L. Taper and A.J. Hansen. 2000. Correcting nesting-success estimates for observer effects: Maximum-likelihood estimates of daily survival rates with reduced bias. The Auk 117(1):92-109.

Rummel S.M. and F.J. Brenner. 2003. Relationships between vegetation and bird populations in reclaimed mine grasslands and native grasslands. Journal of Pennsylvania Academy of Science 76(2/3):56-61.

Scheiman, D.M., E.K. Bollinger and D.H. Johnson. 2003. Effects of leafy spurge infestation on grassland birds. Journal of Wildlife Management 67(1):115-121.

Scott, P.E., T.L. DeVault, R.A. Bajema and S.L. Lima. 2002. Grassland vegetation and bird abundances on reclaimed midwestern coal mines. Wildlife Society Bulletin 30(4):1006-1014.

Shaffer, T.L 2004. A unified approach to analyzing nest success. The Auk 121(2): 526-540.

Shochat, E., M.A. Patten, D.W. Morris, D.L. Reinking, D.H. Wolfe and S.K. Sherrod. 2005. Ecological traps in isodars: Effects of tallgrass prairie management on bird nest success. Oikos 111:159-169.

Skagen, S.K., A.A. Yackel Adams and R. D. Adams. 2005. Nest survival relative to patch size in a highly fragmented shortgrass prairie landscape. Wilson Bulletin 117(1):23-34.

Stanley, T.R. 2004. When should Mayfield model data be discarded? Wilson Bulletin 116(3):267-269.

------- and J.A. Royle. 2005. Estimating site occupancy and abundance using indirect detection indices. Journal of Wildlife Management 69(3):874-883.

Swanson, D. A. 1996. Nesting ecology and nesting habitat requirements of Ohio's grassland-nesting birds: A literature review. Ohio Department of Natural Resources, Division of Wildlife, Ohio Fish and Wildlife Report 13. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/birds/ohionest/ohionest.htm (Version 16JUL97).

Swengel, S.R. and A.B. Swengel. 2001. Relative effects of litter and management on grassland bird abundance in Missouri, USA. Bird Conservation International 11:113-128.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H., Bishop, J.R.B. and Marques, T.A. 2005. Distance 5.0. Release "x"[1]. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Thompson, F.R. and D.E. Burhans. 2003. Predation of songbird nests differs by predator and between field and forest habitats. Journal of Wildlife Management 67(2):408-416.

Vickery, P.D., M.L. Hunter and J.V. Wells. 1992. Use of new reproductive index to evaluate relationship between habitat quality and breeding success. The Auk 109(4):697-705.

-------, ------- and -------. 1992a. Evidence of incidental nest predation and its effects on nests of grassland birds. Oikos 63:281-288.

-------, ------- and -------. 1992b. Is density an indicator of breeding success? Auk 109:706-710.

-------, ------- and S.M. Melvin. 1994. Effects of habitat area on the distribution of grassland birds in Maine. Conservation Biology 8(4):1087-1097.

------- and J.R. Herkert. 2001. Recent advances in grassland bird research: Where do we go from here? The Auk 118(1):11-15.

Walk, J.W. and R.E. Warner. 1999. Effects of habitat are on the occurrence of grassland birds in Illinois. The American Midland Naturalist 141:339-344.

------- and -------. 2000. Grassland management for the conservation of songbirds in the Midwestern USA. Biological Conservation 94(2000):165-172.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120-138.

Whitmore, R.C. and G.A. Hall. 1978. The response of passerine species to a new resource: reclaimed surface mines in West Virginia. American Birds 32(1):6-9.

-------. 1980. Reclaimed surface mines as avian habitat islands in the eastern forest. American Birds 34(1):13-14.

Winter, M. 1999. Nesting biology of dickcissels and Henslow's sparrows in southwestern Missouri prairie fragments. Wilson Bulletin 111(4):515-527.

------- and J. Faaborg, 1999. Patterns of area sensitivity in grassland-nesting birds. Conservation Biology 13(6):1424-1436.

-------, D.H. Johnson and J. Faaborg. 2000. Evidence for edge effects on multiple levels in tallgrass prairie. The Condor 102:256-266.

-------, ------, J.A. Shaffer and W.D. Svedarsky. 2004. Nesting biology of three grassland passerines in the Northern tallgrass prairie. Wilson Bulletin 116(3):211-223.

-------, D.H. Johnson and J.A.Shaffer. 2005. Variability in vegetation effects on density and nesting success of grassland birds. Journal of Wildlife Management 69(1):185-197.

With, K.A. 1994. The hazards of nesting near shrubs for a grassland bird, the McCowans longspur. The Condor 96:1009-1019.

------- and A.W. King. 2001. Analysis of landscape sources and sinks: The effect of spatial pattern on avian demography. Biological Conservation 100(2001):75-88.

Wray, T., K.A. Strait and R.C. Whitmore. 1982. Reproductive success of grassland sparrows on a reclaimed surface mine in West Virginia. Auk 99:157-164.

Zimmerling, J.R., G.E. Craigie and A.E. Robinson. 2004. A comparison of techniques for marking passerine nestlings. Wilson Bulletin 116(3):240-245.

Zimmerman, J.L. 1984. Nest predation and its relationship to habitat and nest density in dickcissels. Condor 86:68-72.

-------. 1988. Breeding season habitat selection by the Henslow's sparrow (*Ammodramus henslowii)* in Kansas. Wilson Bulletin 100(1):17-24.

CHAPTER 2

INFLUENCE OF WOODY VEGETATION ON GRASSLAND BIRD ABUNDANCE, NEST PLACEMENT AND NESTING SUCCESS ON RECLAIMED SURFACE MINES IN OHIO

Abstract. Reclaimed surface mines are a conservation paradox in many parts of the eastern U.S. in that grassland birds occupy them yet they are highly disturbed areas, often dominated by exotic vegetation. I examined the influence of woody vegetation on 1) relative abundance of the grasshopper sparrow (*Ammodramus savannarum*), Henslow's spaorrow (*Ammodramus henslowii*), eastern meadowlark (*Sturnella magna*), Savannah sparrow (*Passerculus sandwichensis*), bobolink *(Dolichonyx oryzivorus*) and dickcissel (*Spiza americana*), and 2) nest-site selection and nesting success of the grasshopper sparrow, Henslow's sparrow and eastern meadowlark. From May – August 2005 and 2006, I surveyed grassland birds, monitored nesting success, and quantified the amount of woody vegetation on reclaimed surface mines in eastern Ohio. Abundance estimates were derived from 101 point-counts along randomly located transects, and nest monitoring focused on eight study sites. I applied a principle components analysis to the 3 woody vegetation metrics (i.e., percent cover of woody vegetation and number of woody patches within 100-m, and distance to woody edge) to create a single index of woody vegetation, which was used in subsequent analyses. Relationships between woody vegetation and relative abundance were analyzed using generalized linear models,

whereas differences between nest and random locations were examined using discriminant function analysis for each species. I used an information-theoretic approach, incorporating a set of *a priori* models into a logistic-exposure method to model daily nest survival. Grasshopper sparrows and Henslow's sparrows were the most abundant grassland species recorded in both management areas. Although numbers of grasshopper sparrows, Henslow's sparrows, Savannah sparrows and bobolinks were negatively related to percent cover of woody vegetation within 100-m of survey locations, only the grasshopper sparrow showed strong evidence of responding to woody vegetation at nest-patch scales, as nest locations had over 2.5 times less woody cover than random locations. Daily nest survival was negatively related to the amount of woody vegetation in proximity to nests of grasshopper sparrow (n = 45) and Henslow's sparrow (n = 18) and marginally negatively related to eastern meadowlark nests (n = 18). Given the apparent avoidance of woody vegetation by grassland-breeding birds and the comparatively lower daily nest survival of grasshopper sparrow and Henslow's sparrow nests near woody vegetation in this study, these results suggest that managers of reclaimed surface mines who aim to conserve grassland birds should direct efforts towards reducing woody encroachment.

INTRODUCTION

Grassland birds have declined more rapidly than any other group of birds in the Midwest over the past 30 years (Peterjohn and Sauer 1999, Cully and Michaels 2000, Vickery and Herkert 2001). Among the most precipitously declining are area-sensitive species such as the grasshopper sparrow (*Ammodramus savannarum*), Henslow's sparrow (*Ammodramus henslowii*) and eastern meadowlark (*Magna sturnella)* (Herkert 1994a). These declines have been largely attributed to changes in agricultural practices (Johnson and Igl 2001), habitat loss (Askins 1993), and habitat degradation and fragmentation due to urbanization (Herkert 1994a, Vickery and Herkert 2001, Cully and Michaels 2002). Because large gains in native and managed grassland habitats in the Midwest are unlikely to materialize in many landscapes, successful conservation of grassland birds will require consideration of new and non-traditional opportunities to provide quality grassland habitat for area-sensitive grassland-breeding species. Reclaimed surface mines represent one opportunity to manage for grassland bird species (Whitmore and Hall 1978; Whitmore1980, Wray et al. 1982).

Reclaimed surface mines are a conservation paradox in that grassland birds occupy them yet they are highly disturbed areas dominated by exotic grasses and are vulnerable to invasion by woody vegetation such as autumn olive (*Elaeagnus umbellate*). In particular, woody encroachment is regarded as one of the key management issues with the potential to impact the conservation value of reclaimed surface mines for grassland-breeding birds. Even so, few studies have explicitly examined the extent to which woody vegetation affects distribution, abundance and reproduction of grassland birds within reclaimed surface mines.

One management dilemma associated with reclaimed surface mines is the decision to actively keep lands open or alternatively to allow woody encroachment. This decision is critical because woody vegetation has been shown to be one of the most important habitat characteristics negatively affecting grassland birds. For example, grassland bird occurrence in North Dakota was best predicted by percent woodland within 500-m (Grant et al. 2004), the amount of tall shrub cover and the extent of woody vegetation surrounding grassland patches in eastern South Dakota (Bakker et al. 2002) and the amount of woodland edge habitat within the surrounding landscape matrix in north-central Iowa (Fletcher and Koford 2002). Although reforestation of mined grasslands is often not possible due to poor soil conditions (Wray et al. 1982, Brothers 1990, DeVault et al. 2002, Scott et al. 2002), invasion by woody species such as autumn olive and black locust (*Robinia pseudoacacia)* can occur if left unmanaged (Rummel and Brenner 2003). Removal of woody vegetation within reclaimed surface mines may help alleviate nest predation by redistributing movement patterns of some common mammalian nest predators (Winter et al. 2000). In contrast, others have found that some grassland species may be tolerant of woodland encroachment at the landscape scale (Grant et al. 2004).

Effective bird conservation on reclaimed surface mines ultimately requires an understanding of the consequences that unmanaged woody patches and woodland edge habitat can have on the distribution, nest-site selection and nesting success of grassland birds. In this study I examined (1) how woody vegetation features were related to habitat use and distribution of grassland birds breeding within reclaimed surface mines, (2) to what extent these woody habitat features were related to nest-site selection and (3) if these woody habitat features affected daily nest survival of the grasshopper sparrow, Henslow's sparrow and eastern meadowlark.

METHODS

Study Area

This study was conducted on reclaimed surface mines within wildlife management areas in eastern Ohio managed by the Ohio Department of Natural Resources (ODNR), Division of Wildlife (DOW). Collectively, these wildlife management areas represented the range of reclaimed surface mine habitats available to grassland birds in eastern Ohio. Tri-Valley Wildlife Management Area, located in northern Muskingum County, Ohio is a 6,100-ha wildlife area comprised of approximately 50% openland (grasslands, wetlands, and food plots), 40% woodland and 10% brushland. Reclamation efforts began in 1985 and continue today as mining still occurs within Tri-Valley. Approximately 2,600 hectares of reclaimed grasslands are located within Tri-Valley (ODNR, DOW 2007). Woodbury Wildlife Management Area is located in southern Coshocton County, Ohio and is a 7,600-ha wildlife area that consists of roughly 35% openland (grasslands, wetlands, and food plots), 8% brushland and 57% woodland. Woodbury's reclamation efforts began in the early 1970's and were completed in 1987. These areas are comprised of approximately 1,200 hectares of reclaimed surface mine grasslands (ODNR 2007).

Research focused on six grassland species that are receiving national and regional conservation attention (Walk and Warner 2000, Bajema et al. 2001, Vickery and Herkert 2001, DeVault et al. 2002): the Henslow's sparrow (*Ammodramus henslowii),* grasshopper sparrow (*Ammodramus savannarum)*, eastern meadowlark (*Sturnella* *magna*), Savannah sparrow (*Passerculus sandwichensis)*, bobolink (*Dolichonx oryzivorus)*, and dickcissel (*Spiza americana)*. Other passerines found on these grassland sites included field sparrow (*Spizella arborea)*, song sparrow (*Melospiza melodia)*, red-winged blackbird (*Agelaius phoeniceus)*, indigo bunting (*Passerina cyanea)*, common yellowthroat (*Geothlypis trichas),* sedge wren (*Cistothorus platensis)*, northern harrier (*Circus cyaneus)* and short-eared owl (*Asio flammeus).* The dominant vegetation represented on these two sites included non-native cool season grasses such as fescue (*Festuca spp.)*, redtop (*Agrostis gigantea*), timothy (*Phleum pratense)* and orchard grass (*Dactylis glomerata*) as well as native warm season grasses, such as switchgrass (*Panicum virgatum*), indian grass (*Sorghastrum nutans*)*,* big bluestem (*Andropogon gerardii*)*,* and little bluestem (*Schizachyrium scoparium*)*.* Native and non-native forbs (M*elilotus spp., Trifolium spp., Solidago spp., Lotus corniculatus*), and woody vegetation such as autumn olive (*Elaeagnus umbellata*)*,* black locust (*Robinia pseudoacacia*), blackberry (*Rubus allegheniensis*), multiflora rose (*Rosa multiflora*), lespedeza (*Lespedeza spp.*) flowering dogwood (*Cornus florida*) and pines (*Pinus spp.*) were also well represented.

Bird Surveys:

Over two years, birds were surveyed at 101 point-count locations. Point-counts were randomly distributed relatively evenly between Tri-Valley (24 in 2005 and 29 in 2006) and Woodbury (24 in 2005 and 24 in 2006). I used a systematic random sampling design for point-count location. Starting locations of point-count survey transects were randomly selected using GIS and a random number generator was then used to determine the distance (m) to walk from the initial starting location to the first point-count location. The subsequent point-count locations were systematically placed, separated by a 250-m distance until it was not possible to place the next point 250-m from the previous location (i.e. barrier such as a road, woodland, wetland). All point-count locations (*n*=101) were recorded with a handheld GPS unit. Grassland bird surveys were performed at each point location three times each from 15 May to 15 July, 2005 and 2006 between the hours of 0630 and 1100 on days without fog, precipitation or winds >24 kph. At each point-count location, trained observers first allowed a 2-minute period for birds to adjust to surveyor presence followed by a 6-minute survey period wherein all singing male grasshopper sparrows, Henslow's sparrows, Savannah sparrows, bobolinks, eastern meadowlarks and dickcissels were recorded within a 100-m radius. During each point-count survey, the time of detection of each bird was recorded along with the species code and the straight-line distance (m) to each bird observation with the use of a laser rangefinder (Ransom and Pinchak 2003).

Nest monitoring:

I established 8, 5-ha study plots for nest searching. In order to facilitate locating nests, field teams used a spot-mapping protocol (Bibby et al. 2000) to identify breeding territories. As part of the spot-mapping efforts, grids were visited 8 times during morning hours from 15 May – 16 June 2006 and an observer walked the entire 5-hectare plot on parallel transects (separated by 75-m). These spot-maps helped field teams to extensively search plots for nests of grasshopper sparrows, Henslow's sparrows and eastern meadowlarks from 1 May – 1 August 2005 and 2006. Nest searching was conducted by rope-dragging techniques. A 30-meter rope was dragged behind two individuals while a third walked several meters behind the rope looking for birds that flushed from the ground. Nest searching while rope dragging was conducted for 5-8 minutes for each bird flushed. In addition to rope dragging, we relied on behavioral cues to find nests and carefully followed adults that were carrying food and nesting material until a nest was located. Systematically searching known breeding territories obtained from spot maps also proved to be a useful method for locating nests. Nests were also located by chance while performing bird surveys and vegetation measurements. Nest locations were marked with a handheld GPS unit as well as with orange flagging placed 2-5 m from the nest. Nests were checked every 4-5 days during the incubation period and every 3-4 days when nests neared the fledging stage. The number of eggs and/or nestlings, the date the nest was checked and the species name was recorded. A nest was considered active if at least one egg was present. A typical nest period for the three focal species was 26 days with only 8-10 days post-hatching to fledge young. Nests were considered successful if they were active for $\geq$ 8 days post-hatching (Vickery 1996) and there were no obvious signs of predation. A nest was considered lost to predation if the eggs were removed or broken or if the nest was disturbed and the nestlings were no longer in the nest during the first week post hatching (Ingold 2002).

Vegetation measurements:

Amount of woody vegetation was estimated by using National Agricultural Imagery Program (NAIP) aerial photographs from 2005 and 2006 (resolution of 2 meters) of Coshocton and Muskingum counties, which were projected using ArcGIS 9.1 (ERSI, 2005). Percentage of woody vegetation and number of woody patches were estimated for 100-m radius plots centered on each nest (n=81) and survey locations (n=101). In order to verify the size of woody plants detectable in aerial photographs, I visited plots and directly compared vegetation shown in images to actual vegetation on plots seen during field visits. This ground-truthing revealed that woody vegetation patches < $4m^2$ in area were not reliably detectable from aerial photographs; consequently patches of woody vegetation ≥ 4 m^2 in size were defined as woody vegetation patches for this study. Each woody patch of vegetation ≥ 4 m^2 located within 100-m of each nest and survey point was digitized and the area of each of these digitized polygons was calculated in order to determine the total area of woody vegetation within a 100-m radius surrounding each nest and survey location. Total percentage of woody vegetation was calculated by dividing the total area (m^2) of woody vegetation by the total area of the circle (31,415 m^2) multiplied by 100. Aerial photographs, projected in ArcGIS 9.1, were used to measure the distance in meters from each nest and each survey location to the nearest woodland edge.

Data analysis:

To determine which woody vegetation features were used as cues by grassland birds in selecting suitable habitat, I compared an *a priori* set of woody vegetation variables (percent cover of woody vegetation, number of woody patches and distance to woodland edge) on bird survey locations. I used 101 survey locations as replicates for this analysis to identify woody habitat features used by grasshopper sparrows, Henslow's sparrows, eastern meadowlarks, Savannah sparrows, bobolinks and dickcissels as cues in selecting suitable habitat for breeding locations. I transformed bird counts where appropriate to minimize non-normality and variance heterogeneity. A log transformation was applied to counts of grasshopper sparrow, Henslow's sparrow and eastern meadowlark. A Poisson distribution was designated for counts of Savannah sparrow, bobolink and dickcissel.

Percent woody vegetation, number of woody vegetation patches ≥ 4 m^2 and the distance from plot center to the nearest woodland edge were only mildly correlated ($r < |0.5|$) and, as such, they were incorporated into a principal components analysis (PROC FACTOR in SAS Version 9.1, SAS Institute) to characterize the woody vegetation surrounding survey locations using a single parameter. Of the 3 principle components derived from the analysis, the first factor explained >56% of the variation in woody vegetation among survey points (Eigenvalue = 1.69). This first factor loaded positively for percent woody cover (0.88) and number of woody patches (0.70), and loaded negatively for distance to woodland edge (-0.65).

I compared an *a priori* set of woody vegetation variables on individual nests and random locations to determine which woody vegetation variables were used by grassland birds in nest-site selection. I used 81 nests as replicates for this analysis to identify woody habitat features used by individual birds to select nest-site locations during individual nest attempts. I transformed the variables where appropriate to minimize non-normality and variance heterogeneity. Percent woody vegetation, number of woody vegetation patches and the distance from plot center to the nearest woodland edge were used in a discriminant function analysis (Quinn and Keough 2002) (DFA; PROC CANDISC in SAS Version 9.1, SAS Institute) in order to determine which variables best discriminated between nest and random plots (Table 2.1). Variables that best discriminated between nest and random plots were interpreted as potential habitat cues used by grassland birds in selecting locations for nest placement (Quinn and Keough 2002).

I determined how woody habitat features and nest placement influenced nest success by incorporating the first principal component describing woody vegetation (PCwood) into the logistic-exposure method (Shaffer 2004) to model daily nest survival rates of the Henslow's sparrow, grasshopper sparrow and eastern meadowlark. This approach models the success or failure of nests during each interval between nest checks and the probability of nest success can be evaluated over a range of values for influential categorical and continuous explanatory variables. Nest losses to all sources were classified as failures. Nests that were abandoned prior to laying or found after depredation had already occurred were excluded. I fit the model (PCwood interacting with species) with PROC GENMOD (SAS Version 9.1, SAS Institute) by using a binomial response distribution (interval nest fate = 1 if success, and 0 if fail) and provided the user-defined logit link function ($g(\theta)=\log_e(\theta 1/t/[1-\theta 1/t])$) where t = the length of the interval (Shaffer 2004).

RESULTS

Grasshopper sparrows and Henslow's sparrows were the most abundant species on Tri-Valley and Woodbury Wildlife Management Areas during 2005 - 2006. A total of 1491 birds were detected during surveys of Henslow's sparrow (732 detections), grasshopper sparrow (465 detections), eastern meadowlark (209 detections), bobolink (39 detections), dickcissel (31 detections) and Savannah sparrow (15 detections). Mean relative abundance ranged from 2.33 birds per survey point for Henslow's sparrow at Tri-Valley to 0 for Savannah sparrow and bobolinks at Woodbury (Table 2.1). Amount of woody vegetation was associated with abundances of grasshopper sparrow (Beta estimate = -0.14 ± 0.041 SE; X^2 = 11.34, P < 0.001, Figure 2.1), Henslow's sparrow (Beta estimate = -0.15 ± 0.051 SE; X^2 = 7.73, P = 0.005, Figure 2.2), Savannah sparrow (Beta estimate = -2.47 ± 0.975 SE; X^2 = 7.38, P = 0.007, Figure 2.5) and bobolink (Beta estimate = -2.35 ± 0.745 SE; X^2 = 11.48, P < 0.001, Figure 2.4), but not for eastern meadowlark (Beta estimate = -0.11 ± 0.241 SE; X^2 = 0.21, P = 0.648, Figure 2.3) or dickcissel (Beta estimate = -0.57 ± 0.704 SE; X^2 = 0.84, P = 0.360, Figure 2.6).

Eighty-one active nests of 3 species were monitored for the eastern meadowlark (*n*=18), grasshopper sparrow (*n*=45) and Henslow's sparrow (*n*=18). Habitat variables discriminated between random locations and nest sites of grasshopper sparrows (Canonical correlation = 0.25, Likelihood ratio = 0.936; Wilks' Lambda $F_{3,\ 142}$ = 3.24, P = 0.024). In particular, nest locations of grasshopper sparrows had over 2.5 times less woody vegetation within 100-m than randomly located points ($F_{1,144}$ = 5.41, P = 0.021; Table 2.1). Nest placement of grasshopper sparrow was not associated with the number of woody patches ($F_{1,144}$ = 1.75, P = 0.188) or distance to woodland edge ($F_{1,44}$ = 0.96, P = 0.330) . Habitat variables did not discriminate between nests of Henslow's sparrow (Wilks' Lambda $F_{3,\ 114}$ = 1.12, P = 0.345) and eastern meadowlark (Wilks' Lambda $F_{3,\ 114}$ = 1.35, P = 0.263) from random plot locations.

Overall, 20 of 45 (44%) grasshopper sparrow nests, 16 of 18 (89%) Henslow's sparrow nests and 9 of 18 (50%) eastern meadowlark nests were successful (i.e. fledged at least one young). Amount of woody vegetation surrounding nest locations was related to daily nest survival of grasshopper sparrow, Henslow's sparrow and eastern meadowlark (Beta estimate = -1.19 ± 0.457 SE; X^2 = 6.57, P = 0.010), despite the fact that all three species differed in their daily nest survival rates (Beta estimates: eastern meadowlark = -1.55 ± 1.17 SE, grasshopper sparrow = -2.39 ± 1.13 SE, Henslow's sparrow = 0.00; X^2 = 11.71, P = 0.003). There was no evidence of significant interaction and all three species responded similarly to woody vegetation surrounding their nests (X^2 = 4.32, P = 0.115). Mean daily nest survival rate was 0.76 ± 0.001 SE for grasshopper sparrows, 0.94 ± 0.020 SE for Henslow's sparrows, and 0.87 ± 0.006 SE for eastern meadowlarks. Specifically, grasshopper sparrow and Henslow's sparrow daily nest survival was negatively associated with the amount of woody vegetation surrounding nest locations. Eastern meadowlark daily nest survival was marginally associated with the amount of woody vegetation in proximity to nest locations (Figure 2.7).

DISCUSSION

My findings suggest that the amount and distribution of woody vegetation influenced abundance of grassland species on reclaimed surface mines as well as nest placement and nesting success of certain grassland species. Four of the 6 focal species in this study responded negatively to the amount of woody vegetation. Interestingly, although numbers of grasshopper sparrows, Henslow's sparrows, Savannah sparrows and bobolinks were negatively related to percent cover of woody vegetation within 100-m of survey locations, only the grasshopper sparrow showed evidence of selecting nest-patches with lower amounts of woody vegetation than random locations. Despite small sample sizes of nests, my study also provides evidence that the amount of woody vegetation surrounding the nest can negatively affect daily nest survival of common grassland species. These findings are unique in that they address the influence of woody vegetation on abundance, nest-site selection and nest success specifically within reclaimed surface mines, which have not been the focus of other published studies, although Galligan et al. (2006) examined nest success within open grassland, shrub/savanna and a mixture of the two habitat types on reclaimed surface mines in southwestern Indiana.

Results from this study are consistent with previous studies on the effects of woody vegetation on grassland bird occurrence in the midwestern U.S. Densities of singing male Savannah sparrows and bobolinks on tall and mixed-grass prairies in Minnesota and North Dakota were negatively associated with percent shrub and tree cover within a 200-m radius (Winter et al. 2006) and occurrence of 12 grassland species declined with an increase in shrub cover within 100-m (Grant et al. 2004). Woody vegetation was also negatively related to grassland bird abundance, especially for Henslow's sparrow and grasshopper sparrow in southwestern Missouri (Winter and Faaborg 1999), Illinois (O'Leary and Nyberg 2000), eastern South Dakota (Bakker et al. 2002), and West Virginia (Wray et al. 1982). My failure to detect an association between woody vegetation and abundance of the eastern meadowlark and dickcissel was possibly an artifact of the relatively large territory sizes of these species and the use of a fixed radius sampling method (hence, detections outside of 100-m were not recorded). However, Winter and Faaborg (1999) also found no significant association between woody vegetation and density of these two species. In other cases where I did not detect significant associations (e.g., Savannah sparrow and dicksissel), the small number of detections on surveys (Table 2.1) may have limited my ability to detect patterns.

Despite apparent sensitivity to woody encroachment at macrohabitat scales, only the grasshopper sparrow showed strong evidence of responding to woody vegetation at nest-patch scales wherein nest locations had over 2.5 times less woody cover than random locations. Although not statistically significant, nest locations of eastern meadowlarks also had > 2 times less woody cover and fewer woody patches within 100-m than random locations. The failure to discriminate between nest and random locations for eastern meadowlarks may be reflected by the small sample size (*n*=18) of nests. Another possibility is my comparison of used to random plots (i.e. comparing a part to the whole) represents a much more conservative test than comparing used to unused plots (Aldredge and Griswold 2006, Burkirk and Milspaugh 2006, Johnson et al. 2006, Thomas and Taylor 2006).

The literature on the effects of woody vegetation on nest-site selection of grassland birds has yet to show consistent relationships. For example, Sutter and Ritchison (2005) reported grasshopper sparrow nest sites had fewer shrubs and more trees than randomly selected territory sites (Sutter and Ritchison 2005), although Hubbard et al. (2006) reported that grasshopper nests were located further from woody vegetation (shrubs/trees/perches) than random locations. Henslow's sparrow nests were located more frequently >100-m from both forest edge and shrubland edge than <100-m (Winter et al. 2000). Eastern meadowlark nest sites were not associated with the percent of woody vegetation surrounding nest locations (Warren and Anderson 2005), although Hubbard et al. (2006) found that eastern meadowlark nests were further from a woody edge than random locations. Hull (2000) also noted that eastern meadowlarks tended to avoid nesting in areas that contained large amounts of woody vegetation. Because birds select nesting locations based on the ability to produce and fledge viable offspring, grassland birds may have evolved and adapted to nest in disturbed habitats such as reclaimed surface mines. Thus, they may be selecting nest-site locations lacking woody vegetation because predators (i.e. mice) and brood parasites (i.e. brown-headed cowbird) are known to use woody vegetation as cover from aerial and mammalian predators as well as visual perches, making it more efficient to locate nests (With 1994).

Consistent with other studies examining the influence of woody habitat features on grassland bird nesting success, I found that daily nest survival was related to the amount of woody vegetation surrounding nests of grasshopper sparrow and Henslow's sparrow and marginally related to eastern meadowlark nests. Nest success of the grasshopper sparrow decreased as shrub density increased on tallgrass prairies in North Dakota (Scheiman et al. 2003). Winter et al. (2000) found that predation rates were higher for Henslow's sparrow and dickcissel nests near shrubby edges. Bollinger and Gavin (2004) reported that nesting success of bobolinks was lower near forest and wooded hedgerow edges than far from these edges. In contrast, Grant et al. (2006) found that daily nest survival of clay-colored sparrows and vesper sparrows were highest near woodland edges compared to those at greater distances.

Woody vegetation and woodland edges may support a diverse predator community not otherwise present in grassland systems (Renfrew and Ribic 2003). Woody elements are generally thought to attract predators because they are better able to conceal themselves from both their prey and larger predators and thus may be adding to the overall nest predation of grassland-nesting birds (Thompson and Burhans 2003, Renfrew et al. 2005). In addition, woody vegetation provides elevated perches for avian nest predators. Because nest predation is the leading cause of nest failure for grassland birds on reclaimed surface mines, it is important to reduce woody elements in an attempt to lower nest predation events caused by woodland associated predators (i.e. small and mid-sized mammals) (Galligan et al. 2006).

Estimates of daily nest survival from this study may not match those reported in studies elsewhere in the Midwest due to differences in the abundance and composition of woodland, generalist, and grassland specialists. Although the wildlife management areas that were the focus of this study are very large in size (> 3000 ha), they contain many grassland patches that are isolated from other grassland patches by mining roads, wetlands, narrow treelines and hedgerows, and intact woodland patches which may differentiate these areas from other reclaimed surface mines and more natural grassland areas in terms of habitat characteristics (i.e. amount of contiguous grassland areas). This fragmentation may be responsible for the frequent occurrence of nest predation events; for example, all but one nest failure was attributed to predation. In addition, grassland-nesting birds may not be able to find suitable nest-site habitat characteristics, such as adequate litter depth and density, far enough from woody vegetation to alleviate predation pressures from woodland predator species. Thus, birds may be placing nests in the only habitat perceived to fit their needs, which may be in close proximity to woody vegetation. Birds may also have been forced to place nests in close proximity to woody vegetation due to interspecific competition with other species that already occupied the highest quality habitat (Davis 2005).

The overall large size of these reclaimed surface mine grasslands may explain why birds are not responding strongly to woody vegetation at the nest-patch level and instead are selecting habitat based on landscape context or other habitat features and characteristics of reclaimed surface mines that have not been considered in this study, such as patch shape and size. Lastly, the relatively short duration of this study (2-year) and the small sample size of nests found for Henslow's sparrows (*n*=18) and eastern meadowlarks (*n*=18) are possible reasons for the apparent negative relationship between woody vegetation and daily nest survival for these two species.

MANAGEMENT IMPLICATIONS

Given the apparent avoidance of woody vegetation and the overall low daily nest survival of the grasshopper sparrow and Henslow's sparrow, coupled with results from other studies relating low nesting success to the presence of woody vegetation, this study suggests that efforts to remove woody vegetation will enhance the value of reclaimed surface mines to grassland birds. In addition, removal of encroaching woody plants will increase grassland area, provide less edge habitat and decrease fragmentation from other grassland areas, and decrease numbers of woodland predators by creating fewer movement corridors, making the grasslands units more productive and attractive to a diverse community of grassland-nesting birds. Although this study emphasizes the role of woody vegetation in grassland bird management on reclaimed surface mines, managers should also remain attentive to landscape and patch-scale issues given their known influence on grassland birds (Bakker et al. 2002, Winter et al. 2005). My results coupled with others (Bajema, et al. 2001) suggest that reclaimed surface mines may act as surrogate grasslands and may play a vital role in conserving populations of grassland birds, especially the Henslow's sparrow (Monroe and Richison 2005). Long-term studies of survival and reproductive success of grassland birds on reclaimed surface mines are needed in order to determine if reclaimed surface mines are quality nesting habitats.

LITERATURE CITED

Aldredge, J.R. and J. Griswold. 2006. Design and analysis of resource selection studies for categorical resource variables. Journal of Wildlife Management 70:337-346.

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

Bajema, R.A., T.V. DeVault, P.E. Scott and S.L. Lima. 2001. Reclaimed coal mine grasslands and their significance for Henslow's sparrows in the American midwest. The Auk 118(2):422-431.

Bakker, K.K., D.E. Naugle and K.F. Higgins. 2002. Incorporating landscape attributes into models for migratory grassland bird conservation. Conservation Biology 16(6):1638-1646.

Bibby, C.J., N.D. Burgess, D.A. Hill and S.H. Mustoe. 2000. Bird census techniques. Academic Press, San Diego, California, USA.

Bollinger, E.K. and T.A. Gavin. 2004. Responses of nesting bobolinks (*Dolichonyx oryzivorus*) to habitat edges. Auk 121:767-776.

Brothers, T. S. 1990. Surface-mine grasslands. The Geographical Review 80(3): 209-225.

Buskirk, S.W. and J. J. Millspaugh. 2006. Metrics for studies of resource selection. Journal of Wildlife Management 70:358-366.

Cully, J.F. and H.L. Michaels. 2000. Henslow's sparrow habitat associations on Kansas tallgrass prairie. Wilson Bulletin 112(1):115-123.

Davis, S.K. 2005. Nest-site selection patterns and the influence of vegetation on nest survival of mixed-grass prairie passerines. The Condor 107:605-616.

DeVault, T.L., P.E. Scott, R.A. Bajema and S.L. Lima. 2002. Breeding bird communities of reclaimed coal-mine grasslands in the American midwest. The Journal of Field Ornithology 73(3):228-275.

ESRI. 2005. ArcGIS version 9.1, Earth Systems Research Institute, Redlands, California, USA.

Fletcher, R.J. and R.R. Koford. 2002. Habitat and landscape associations of breeding birds in native and restored grasslands.

Galligan, E.W., T.L. DeVault and S.L. Lima. 2006. Nesting success of grassland and savanna birds on reclaimed coal mines of the Midwestern United States. The Wilson Journal of Ornithology. 118(4):537-546.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59(5):871-883.

Grant, T.A., E. Madden and G.B. Berkey. 2004. Tree and shrub invasion in Northern mixed-grass prairie: Implications for breeding grassland birds. Wildlife Society Bulletin 32(3):807-818.

-------, -------, T.L. Shaffer, P.J. Pietz, G.B. Berkey and N.J. Kadrmas. 2006. Nest survival of clay-colored and vesper sparrows in relation to woodland edge in mixed-grass prairies. Journal of Wildlife Management 70(3):691-701.

Herkert, J.R. 1994a. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4(3):461-471.

-------. 1994b. Status and habitat selection of the Henslow's sparrow in Illinois. Wilson Bulletin 106(1):35-45.

Hubbard, R.D., D.P. Althoff, K.A. Blecha, B.A. Bruvold and R.D. Japuntich. 2006. Nest site characteristics of eastern meadowlarks and grasshopper sparrows in tallgrass prairie at the Fort Riley military installation, Kansas. Transactions of the Kansas Academy of Science 109(3/4):168-174.

Hull, S.D. 2000. Effects of management practices on grassland birds: eastern meadowlark. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Ingold, D.J. 2002. Use of reclaimed stripmine by grassland nesting birds in East-central Ohio. Ohio Journal of Science 102(3):56-62.

Johnson, C.J., S.E. Nielsen, E.H. Merrill, T.L. McDonald and M.S. Boyce. 2006. Resource selection functions based on use-availability data: theoretical motivation and evaluation methods. Journal of Wildlife Management 70:347-357.

Johnson, D.H. and L.D. Igl. 2001. Area requirements of grassland birds: A regional perspective. The Auk 118(1):24-34.

Monroe, M.S. and Gary Ritchison. 2005. Breeding biology of Henslow's sparrow on reclaimed coal mine grasslands in Kentucky. Journal of Field Ornithology 76(2):143-149.

Ohio Department of Natural Resources, Division of Wildlife. 2007. ODNR, Columbus, Ohio, USA.

O'Leary C.H. and D.W. Nyberg. 2000. Treelines between fields reduce the density of grassland birds. Natural Areas Journal 20:243-249.

Peterjohn, B.G. and J.R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-96. Studies in Avian Biology 19:27-44.

Quinn, G.P., and M.J. Keough. 2002. Chapter 16. Multivariate analysis of variance and discriminant analysis. pp. 425-442 in Gerry P. Quinn and Michael J. Keough, editors. Experimental Designs and Data Analysis for Biologists. University Press, Cambridge, United Kingdom.

Ransom, D. and W.E. Pinchak. 2003. Assessing accuracy of a laser rangefinder in estimating grassland bird density. Wildlife Society Bulletin 31(2):460-463.

Renfrew, R.B. and C.A. Ribic. 2003. Grassland passerine nest predators near pasture edges identified on videotape. The Auk 120(2):371-383.

-------, ------- and J.L. Nack. 2005. Edge avoidance by nesting grassland birds: A futile strategy in a fragmented landscape.

Ribic, C.A. and D.W. Sample. 2001. Associations of grassland birds with landscape factors in southern Wisconsin. The American Midland Naturalist 146:105-121.

Rummel S.M. and F.J. Brenner. 2003. Relationships between vegetation and bird populations in reclaimed mine grasslands and native grasslands. Journal of Pennsylvania Academy of Science 76(2/3):56-61.

SAS Institute. 2002. SAS/STAT software, release 9.1. SAS Institute, Cary, North Carolina, USA.

Scheiman, D.M., E.K. Bollinger and D.H. Johnson. 2003. Effects of leafy spurge infestation on grassland birds. Journal of Wildlife Management 67:115-121.

Scott, P.E., T.L. DeVault, R.A. Bajema and S.L. Lima. 2002. Grassland vegetation and bird abundances on reclaimed midwestern coal mines. Wildlife Society Bulletin 30(4):1006-1014.

Shaffer, T.L 2004. A unified approach to analyzing nest success. The Auk 121(2): 526-540.

Sutter, B. and G. Ritchison. 2005. Effects of grazing on vegetation structure, prey availability, and reproductive success of grasshopper sparrows. Journal of Field Ornithology 76(4):345-351.

Thomas, D.L. and E.J. Taylor. 2006. Study designs and tests for comparing resource use and availability II. Journal of Wildlife Management 70:324-336.

Thompson, F.R. and D.E. Burhans. 2003. Predation of songbird nests differs by predator and between field and forest habitats. Journal of Wildlife Management 67(2):408-416.

Vickery, P.D. 1996. Grasshopper sparrow (*Ammodramus savannarum*). In: Poole A, Gill F, editors. The Birds of North America. No 239. Philadelphia (PA): Acadamy of Natural Science; Washington (DC): American Ornithologits' Union. P 1-5.

------- and J.R. Herkert. 2001. Recent advances in grassland bird research: Where do we go from here? The Auk 118(1):11-15.

Walk, J.W. and R.E. Warner. 1999. Effects of habitat are on the occurrence of grassland birds in Illinois. The American Midland Naturalist 141:339-344.

------- and -------. 2000. Grassland management for the conservation of songbirds in the Midwestern USA. Biological Conservation 94(2000):165-172.

Warren, K.A. and J.T. Anderson. 2005. Grassland songbird nest-site selection and response to mowing in West Virginia. Wildlife Society Bulletin 33(1):285-292.

Whitmore, R.C. and G.A. Hall. 1978. The response of passerine species to a new resource: reclaimed surface mines in West Virginia. American Birds 32(1):6-9.

-------. 1980. Reclaimed surface mines as avian habitat islands in the eastern forest. American Birds 34(1):13-14.

Winter, M. and J. Faaborg, 1999. Patterns of area sensitivity in grassland-nesting birds. Conservation Biology 13(6):1424-1436.

-------, D.H. Johnson and J. Faaborg. 2000. Evidence for edge effects on multiple levels in tallgrass prairie. The Condor 102:256-266.

-------, ------- and J.A.Shaffer. 2005. Variability in vegetation effects on density and nesting success of grassland birds. Journal of Wildlife Management 69(1):185-197.

Winter, M., D.H. Johnson, J.A. Shaffer, T.M. Donovan and W.D. Svedarsky. 2006. Patch size and landscape effects on density and nesting success of grassland birds. Journal of Wildlife Management 70(1):158-172.

With, K.A. 1994. The hazards of nesting near shrubs for a grassland bird, the McCowans longspur. The Condor 96:1009-1019.

Wray, T., K.A. Strait and R.C. Whitmore. 1982. Reproductive success of grassland sparrows on a reclaimed surface mine in West Virginia. Auk 99:157-164.

TABLES AND FIGURES

	Tri-Valley			Woodbury		
Species	**$\bar{X}$ (SE)**	**% Points**	**DSR**	**$\bar{X}$ (SE)**	**% Points**	**DSR**
Grasshopper Sparrow	1.62 (0.13)	92	0.77	0.95 (0.13)	82	0.71
Henslow's Sparrow	2.33 (0.22)	98	0.96	2.02 (0.24)	90	0.91
Eastern Meadowlark	0.20 (0.04)	43	0.87	0.19 (0.04)	35	0.87
Savannah Sparrow	0.12 (0.07)	14	-	0	0	-
Bobolink	0.07 (0.04)	8	-	0	0	-
Dickcissel	0.06 (0.03)	11	-	0.02 (0.01)	6	-

Table 2.1. Mean number of singing male birds (+/- SE) recorded within 100-m radius of point-count locations, percentage of points with birds and mean daily survival rates for grasshopper sparrow, Henslow's sparrow and eastern meadowlark at Tri-Valley and Woodbury Wildlife Management Areas in 2005 and 2006.

	Grasshopper Sparrow			Henslow's Sparrow			Eastern Meadwolark			Random
Variable	$\bar{X}$ (SE)	F	P	$\bar{X}$ (SE)	F	P	$\bar{X}$ (SE)	F	P	$\bar{X}$ (SE)
% Woody Vegetation	1.5 (0.29)	5.4	0.021	2.3 (1.38)	1.0	0.325	1.5 (0.64)	2.2	0.137	4.0 (0.70)
No. Woody Patches	3.1(0.49)	1.8	0.188	2.7 (1.04)	1.4	0.233	1.9 (0.42)	3.6	0.061	4.2 (0.51)
Distance to Woodland	165.27 (11.70)	1.0	0.331	161.1 (16.09)	0.7	0.396	201.8 (19.39)	0.7	0.391	181.1 (9.49)

Table 2.2 . Mean percent woody vegetation, number of woody patches and distance to woodland edge (+/- SE) for nest-site locations of grasshopper sparrows, Henslow's sparrows, eastern meadowlarks and random vegetation plots and the associated F- and P-values from discriminant function analyses.

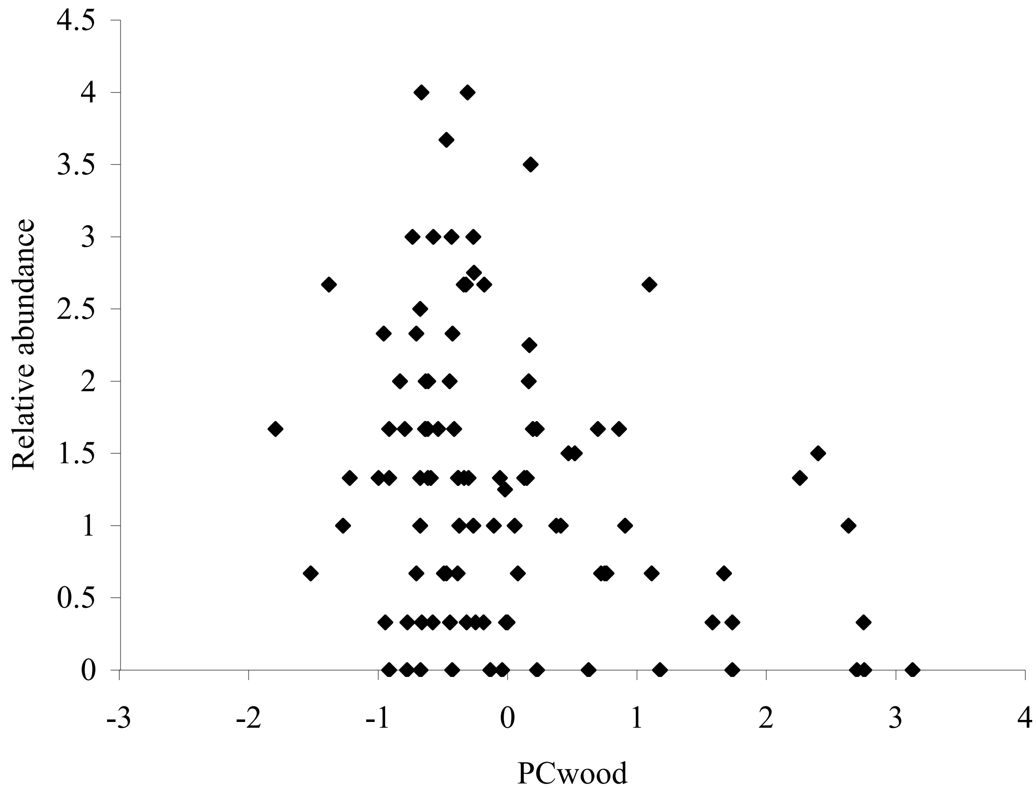


Figure 2.1. Relative abundance of grasshopper sparrows within 100-m radius of point count locations on reclaimed surface mines in relation to amount of woody vegetation (PCwood) in eastern Ohio, 2005-2006.

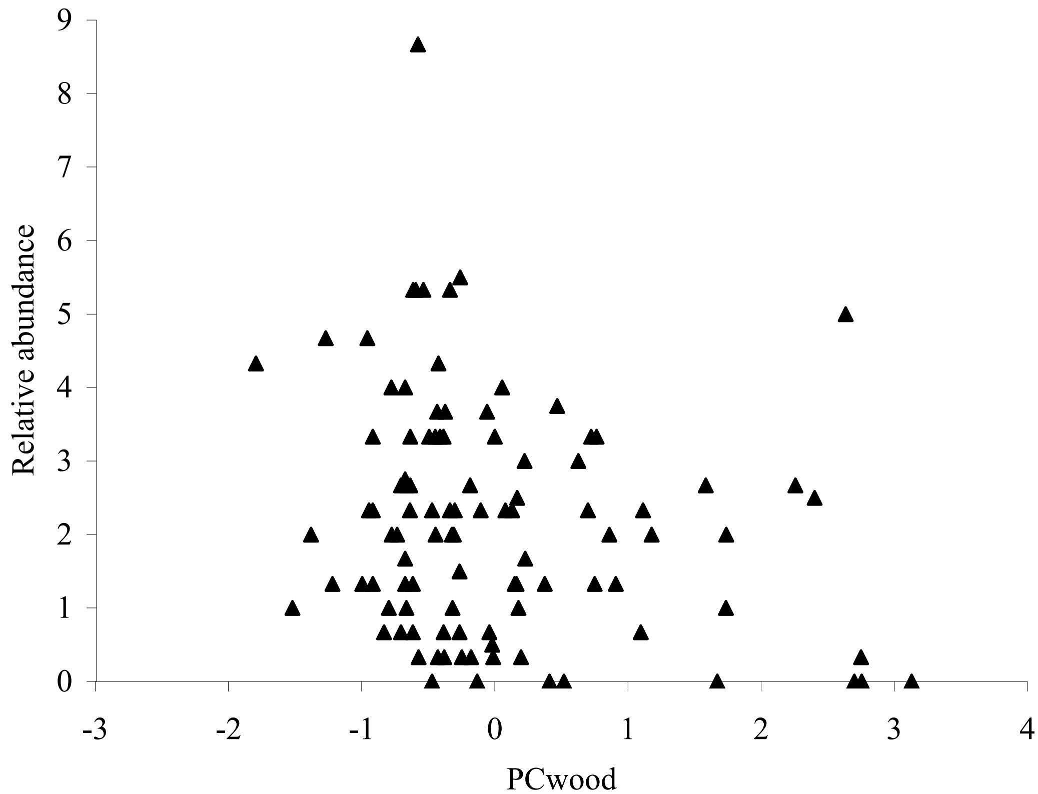


Figure 2.2. Relative abundance of Henslow's sparrows within 100-m radius of point count locations on reclaimed surface mines in relation to amount of woody vegetation (PCwood) in eastern Ohio, 2005-2006.

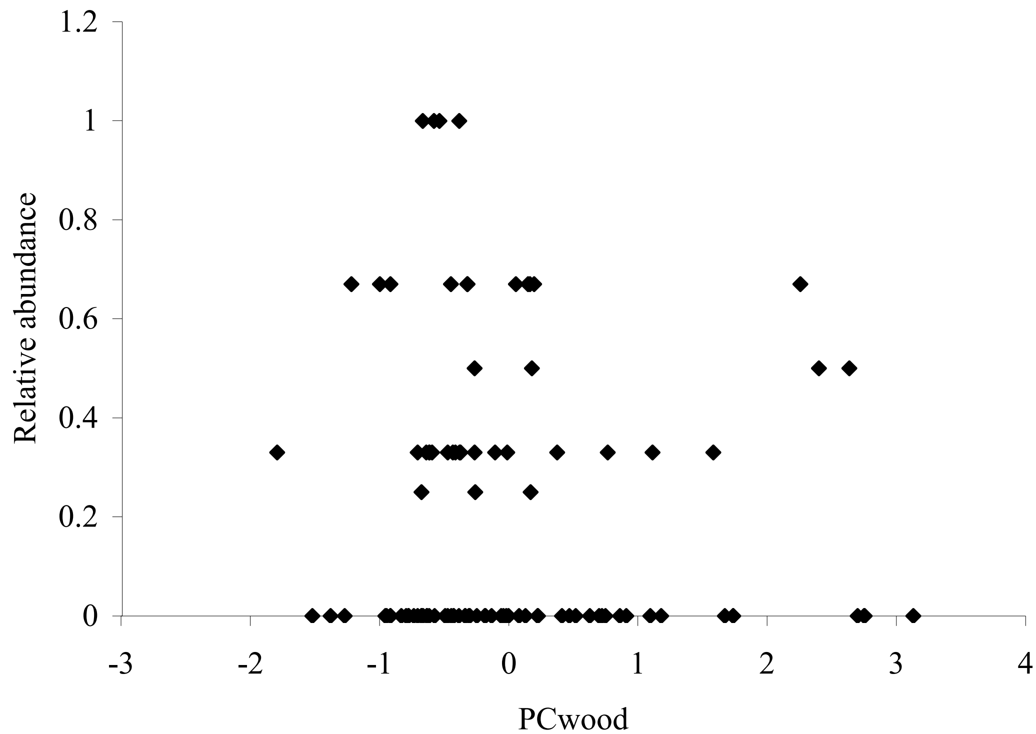


Figure 2.3. Relative abundance of eastern meadowlarks within 100-m radius of point count locations on reclaimed surface mines in relation to amount of woody vegetation (PCwood) in eastern Ohio, 2005-2006.

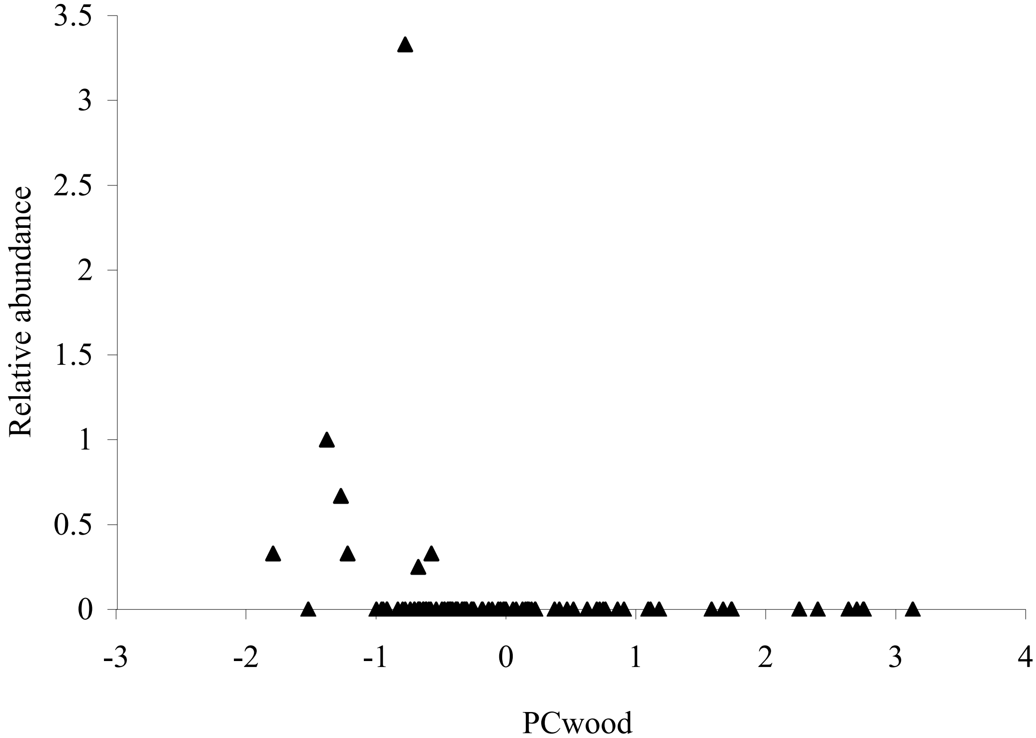


Figure 2.4. Relative abundance of bobolinks within 100-m radius of point count locations on reclaimed surface mines in relation to amount of woody vegetation (PCwood) in eastern Ohio, 2005-2006.

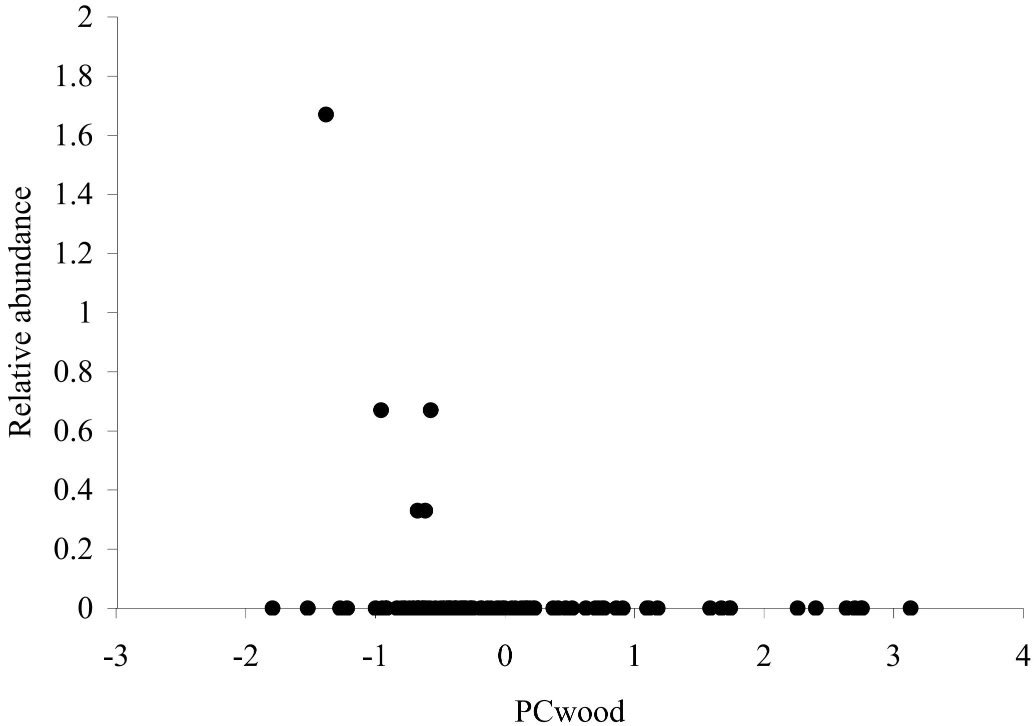


Figure 2.5. Relative abundance of Savannah sparrows within 100-m radius of point count locations on reclaimed surface mines in relation to amount of woody vegetation (PCwood) in eastern Ohio, 2005-2006.

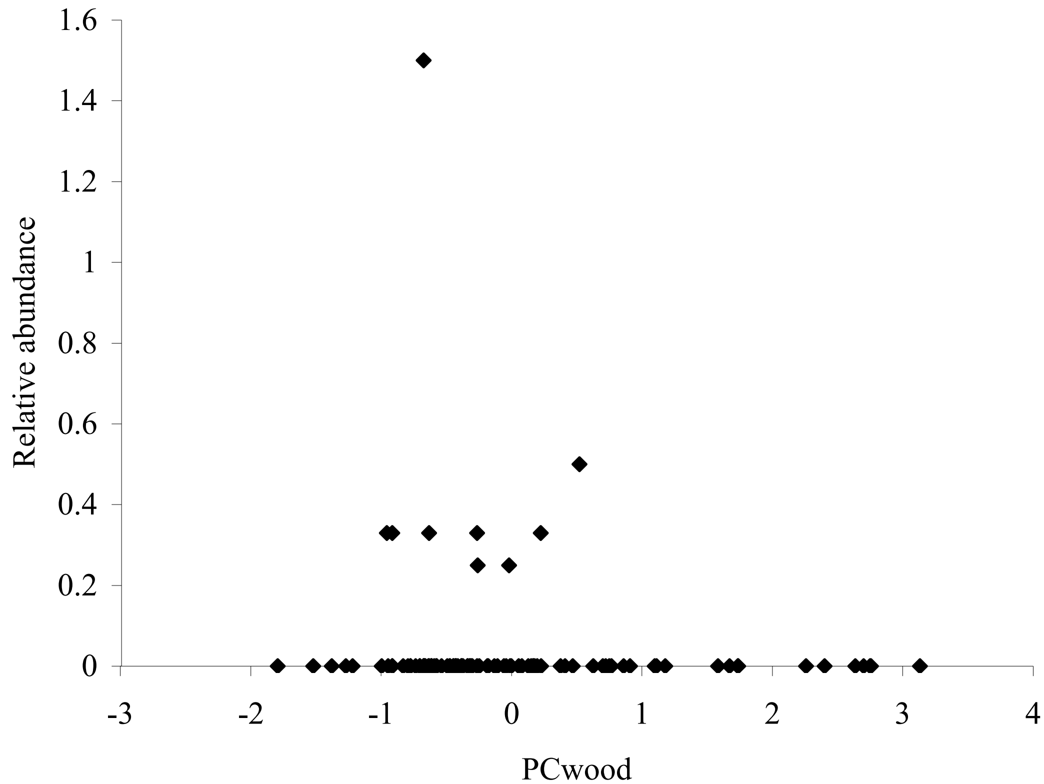


Figure 2.6. Relative abundance of dickcissels within 100-m radius of point count locations on reclaimed surface mines in relation to amount of woody vegetation (PCwood) in eastern Ohio, 2005-2006.

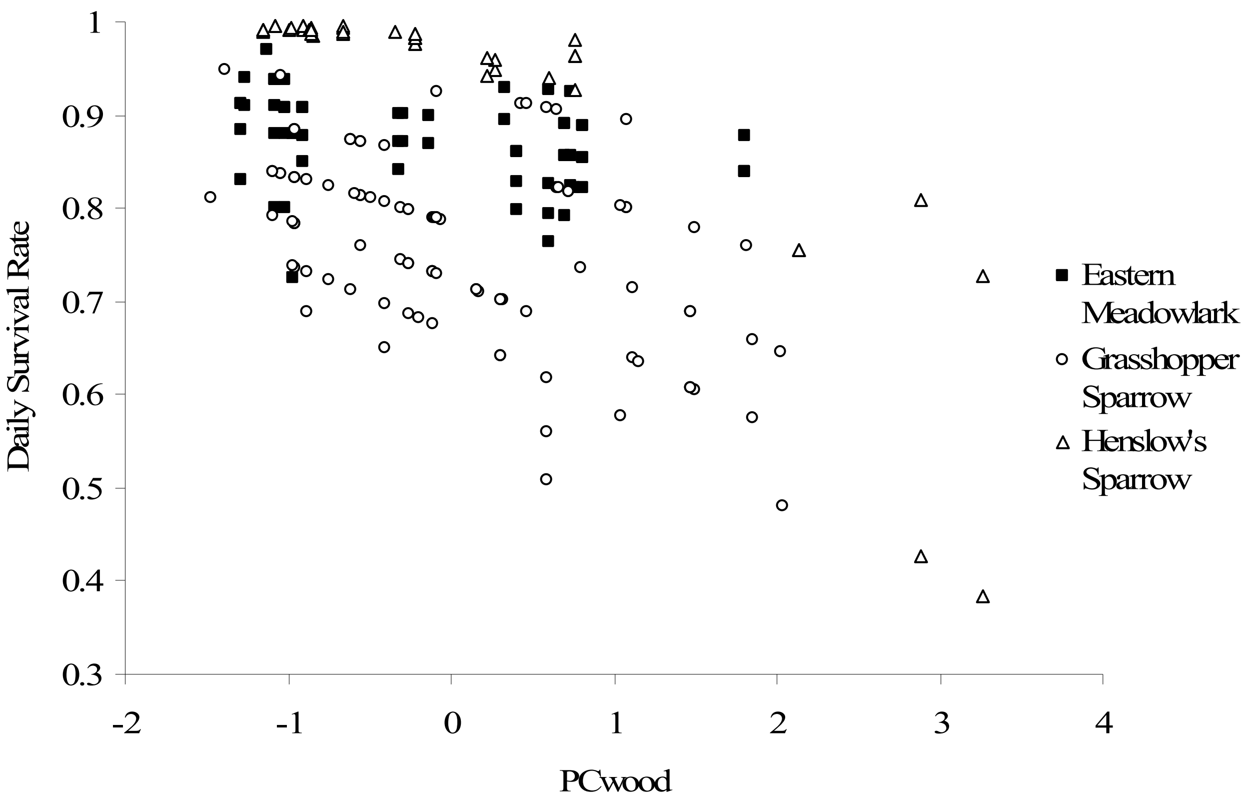


Figure 2.7. Daily survival rates of grasshopper sparrow, Henslow's sparrow and eastern meadowlark nests in relation to amount of woody vegetation (PCwood) in proximity to nest-site locations at Tri-Valley and Woodbury Wildlife Management Areas in eastern Ohio, 2005-2006.

CHAPTER 3

NEST-PATCH HABITAT CHARACTERISTICS AND NEST SUCCESS OF THE GRASSHOPPER SPARROW, HENSLOW'S SPARROW AND EASTERN MEADOWLARK ON RECLAIMED SURFACE MINES

Abstract. Reclaimed surface mines in eastern Ohio support many grassland-nesting birds of conservation concern. I examined the influence of vegetation structure and composition on nest-site selection and nesting success of the grasshopper sparrow, Henslow's sparrow and eastern meadowlark. I established eight study sites for nest searching and vegetation measurements within two reclaimed surface-mined wildlife management areas in eastern Ohio. During the 2006 breeding season, 64 active nests of 3 species were monitored for eastern meadowlark (*n*=13), grasshopper sparrow (*n*=34) and Henslow's sparrow (*n*=17). Detailed measurements describing vertical structure of the vegetation, distance from each nest to the nearest woodland edge, road and disturbed area were recorded for each nest as well as random-located plots. To determine which vegetation habitat cues were used in nest-site selection, I compared the vegetation variables on individual nests and random locations in a discriminate function analysis. I used an information-theoretic approach incorporating a set of *a priori* models into a logistic-exposure method to model daily nest survival and models were ranked using Akaike's Information Criterion (AIC).

Grasshopper sparrow nests were located in areas with less visual obstruction and greater amounts of bare ground, whereas Henslow's sparrow and eastern meadowlark nest placement was associated with deeper and greater amounts of litter within 100-m than randomly located plots. Results suggest that microhabitat features influence the nest-site selection for grassland birds breeding within reclaimed surface mines. Variation in daily survival rates of grasshopper sparrow nests was best explained by a model containing distance to woodland edge interacting with distance to a disturbed area. Nests of grasshopper sparrows that were located close to disturbed areas had relatively high nest survival irrespective of distance to woodland edge, whereas nests farther from disturbed areas were more likely to survive as distance to woodland edge increased. Two models were equally ranked in their ability to explain variation in daily nest survival of eastern meadowlark nests. Surprisingly, eastern meadowlark nests located in areas with relatively low vertical structure had overall higher daily survival rates than nest locations with relatively high vertical structure, regardless of distance to woodland edge. Although grassland birds seem to be selecting nest sites based on a variety of habitat features surrounding nests, the amount of woody vegetation may be one of the factors that most strongly influences nest survival. Thus, managers should consider ways to reduce woody encroachment on reclaimed surface mines if their goal is to provide habitat to grassland birds.

INTRODUCTION

Populations of grassland birds have declined more rapidly than any other group of birds in the Midwest over the past 30 years (Peterjohn and Sauer 1999, Cully and Michaels 2000, Vickery and Herkert 2001). Among the most precipitously declining are area-sensitive species such as the grasshopper sparrow (*Ammodramus savannarum*), Henslow's sparrow (*Ammodramus henslowii*) and eastern meadowlark (*Magna sturnella)* (Herkert 1994a). These declines have been largely attributed to changes in agricultural practices (Johnson and Igl 2001), habitat loss (Askins 1993), and habitat degradation and fragmentation due to urbanization (Herkert 1994a, Vickery and Herkert 2001, Cully and Michaels 2002). Reclaimed surface mines represent one unique opportunity to manage for grassland bird species (Whitmore and Hall 1978; Whitmore 1980, Wray et al. 1982) as they are an important habitat for grassland bird communities in the Midwest (Rummel and Brenner 2003)? Reclaimed surface mines represent a conservation paradox in that grassland birds nest within them but they are highly disturbed areas usually dominated by introduced grasses and forbs. Vegetation species composition is known to be dramatically different within reclaimed surface mines compared to more natural breeding areas, such as tallgrass prairies. Thus, additional research is needed in order to determine how microhabitat features (grassland structure and floristic composition) and edge habitat within reclaimed surface mines influence reproductive success of grassland-breeding birds. In this study, I examined the extent to which nest-patch habitat features were related to nest-site selection and daily nest survival of grasshopper sparrow, eastern meadowlark and Henslow's sparrow.

STUDY AREA AND METHODS

Study Area

This study was conducted on reclaimed surface-mined wildlife management areas in eastern Ohio managed by the Ohio Department of Natural Resources (ODNR), Division of Wildlife (DOW). These areas collectively represent the full range of reclaimed surface mine habitats available to grassland-nesting birds in eastern Ohio. Tri-Valley Wildlife Management Area is a 6100-ha wildlife area and Woodbury Wildlife Management Area is a 7600-ha wildlife area. Both Wildlife Management Areas are comprised mainly of a mixture of planted reclaimed surface-mined grasslands, wetlands, food plots, and hardwood forests (ODNR 2007). Research focused on three grassland species that are receiving national and regional conservation attention: the Henslow's sparrow (*Ammodramus henslowii*), grasshopper sparrow (*Ammodramus savannarum*) and eastern meadowlark (*Sturnella magna*). Other passerines occupying these grassland sites included Savannah sparrow (*Passerculus sandwichensis*), bobolink (*Dolichonx oryzivorus*), dickcissel (*Spiza americana*), field sparrow (*Spizella arborea*), song sparrow (*Melospiza melodia*), red-winged blackbird (*Agelaius phoeniceus*), indigo bunting (*Passerina cyanea*), common yellowthroat (*Geothlypis trichas*), sedge wren (*Cistothorus platensis*), northern harrier (*Circus cyaneus*) and short-eared owl (*Asio flammeus*). As with many reclaimed surface mines, the dominant flora represented on these areas included non-native cool season grasses such as fescue (*Festuca spp*.), redtop (*Agrostis alba*), timothy (*Phleum pratense*) and orchard grass (*Dactylis glomerata*) as well as native warm season grasses, such as switchgrass (*Panicum virgatum*), indian grass

(*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium*). Native and non-native forbs (M*elilotis spp.*, *Trifolium pratense, Rosa multiflora, Lespedeza spp.*), and woody vegetation such as autumn olive (*Elaeagnus umbellata*), black locust (*Robinia pseudoacacia*) and flowering dogwood (*Cornus florida*) were also well represented.

Nest monitoring:

Four 5-ha study plots were randomly chosen within grassland units at both Tri-Valley and Woodbury Wildlife Management Areas (*n*=8). The 8, 5-ha study plots were extensively searched for nests of grasshopper sparrows, Henslow's sparrows and eastern meadowlarks from 1 May – 1 August 2006. As part of the spot-mapping efforts, plots were visited 8 times during morning hours from 15 May – 16 June 2006 and an observer walked the entire 5-hectare plot on parallel transects (separated by 75-m). These spot-maps helped field teams to extensively search plots for nests of grasshopper sparrows, Henslow's sparrows and eastern meadowlarks from 1 May – 1 August 2006. Nest searching was conducted by rope-dragging techniques. A 30-m rope was dragged behind two individuals while a third walked several meters behind the rope looking for birds to flush from the ground. Nest searches while rope dragging was conducted for 5-8 minutes for each bird flushed. In addition to rope dragging, we relied on behavioral cues to find nests and carefully followed adults that were carrying food and nesting material until a nest was located. Systematically searching known breeding territories obtained from spot maps proved to be a useful method for locating nests. Nests were also located by chance while performing vegetation measurements. Nest locations were marked with a handheld GPS unit as well as with orange flagging placed at a distance of 2-5 m from the nest.

Nests were checked every 4-5 days during the incubation period and every 3-4 days once nests were closer to the fledging stage. The number of eggs and/or nestlings and the date the nest was checked, and the species name was recorded. A nest was considered active if at least one egg was present. A typical nest period for the three focal species was 26 days with only 8-10 days post-hatching to fledge young. Nests were considered successful if they were active for ≥ 8 days post-hatching (Vickery 1996) and there were no obvious signs of predation. A nest was considered lost to predation if the eggs were removed or broken or if the nest was disturbed and the nestlings were no longer in the nest during the first week post hatching (Ingold 2002).

Vegetation measurements:

Vegetation sampling was conducted between 15 May – 15 July 15, 2006 (Chapman et al. 2004). Within each study plot (*n*=8), 20 random vegetation plots separated by 30-m, were established along the parallel spot-mapping transects. The vertical structure of the vegetation at each sampling point was indexed by estimating the visual obstruction of a Robel pole (Robel et al. 1970). Readings were taken north, east, south, and west of the pole positioned at a distance of 4-m from the observer and at a height of 1-m. Vegetation structure and composition was estimated using a 20 cm x 50 cm Daubenmire frame (Daubenmire 1959) that was randomly placed at each sampling point. The percent grass and herbaceous forb canopy cover as well as litter (both standing and lying dead plants) and percent bare ground coverage was measured. Litter depth was measured in centimeters with the use of a standard metric ruler. In addition, visual obstruction measurements were taken with a Robel pole at each nest location and in four cardinal directions: 1-m, 3-m and 5-m away from the nest location. A

Daubenmire frame was placed over the nest location, 1-m, 3-m and 5-m away from the nest, and vegetation cover measurements, as outlined above, were recorded. Litter depth was also measured using a standard metric ruler. In addition, distance from the nest to the nearest woodland edge, road and disturbed area was recorded using either a 100-m tape measure or if the distance was greater than 100-m, a laser rangefinder was used to estimate distances. Disturbed areas included grassland units that were burned, herbicide sprayed or mowed, and firebreaks. Prescribed burning is a management tool used within these management areas to control woody invasion and the density of grasses and forbs; thus firebreaks are created around burn units to control fire dispersion. In addition, herbicide application is used within some grassland units to kill all herbaceous vegetation in order to plant food plots for other wildlife species (i.e. northern bobwhite quail) (DOW 2007). Lastly, some areas are mowed in order to create vehicle pathways for assessing habitat use and wildlife populations and to allow access of management equipment (i.e. spray and burn equipment).

Data Analysis:

I used an information-theoretic approach (Burnham and Anderson 2002) to evaluate support for a set of *a priori* models representing hypotheses concerning factors expected to influence nest success of grasshopper sparrows, Henslow's sparrows and eastern meadowlarks. I used the logistic-exposure method (Shaffer 2004) to model factors hypothesized to affect nest success and to estimate daily nest survival rates. This approach models the success or failure of nests during each interval between nest checks and the probability of nest success can be evaluated over a range of values for influential categorical and continuous explanatory variables.

Nest losses to all sources were classified as failures. Nests that were abandoned prior to laying or initially found depredated were excluded. I fit models with PROC GENMOD (SAS Version 9.1, SAS Institute) by using a binomial response distribution (interval nest fate = 1 if success, and 0 if fail) and provided the user-defined logit link function ($g(\theta)=\log_e(\theta 1/t/[1-\theta 1/t])$) where t = the length of the interval (Shaffer 2004). I evaluated support for 19 *a priori* models using Akaike's Information Criteria for small sample sizes (AIC_c) to rank the competing models from most supported to least (Burnham and Anderson 2002). The best approximating model was the model with the lowest AIC_c value and $\Delta AIC_c = 0$ (Burnham and Anderson 2002). The models were ranked by the Akaike weights (w_i), which reflect the relative weight of evidence in support of each model hypothesized for the data (Burnham and Anderson 2002). I reported log-likelihood, K, AICc, ΔAICc, and w_i for the models representing a cumulative $w_i \geq .90$ (Burnham and Anderson 2002). Model ranking and model averaging procedures were also performed in SAS, using macros developed by Terry Shaffer (Shaffer 2004).

To determine which nest-patch habitat cues were used by grassland birds in nest-site selection, I compared an *a priori* set of vegetation variables on individual nests and random locations. I used 64 nests and 101 random plots as replicates for this analysis to identify nest-patch habitat features used by individual birds to select nest site locations during individual nest attempts. The visual obstruction, percent litter, grass and forb canopy coverage, litter depth and amount of bare ground measurements were incorporated into a discriminant function analysis (Quinn and Keough 2002) (DFA; PROC CANDISC in SAS 9.1, SAS Institute) in order to determine which variables best discriminated between nest and random plots. The variables that best discriminated between nest and random plots were interpreted as potential habitat cues used by grassland birds in selecting locations for nest placement (Quinn and Keough 2002).

RESULTS

Habitat variables discriminated nest sites from random plot locations for grasshopper sparrows (Wilks' Lambda $F_{6, 176} = 4.55$, $P < 0.001$), Henslow's sparrows (Wilks' Lambda $F_{6, 159} = 23.86$, $P < 0.001$) and eastern meadowlarks (Wilks' Lambda $F_{6, 155} = 6.78$, $P < 0.001$). Grasshopper sparrow nests were located in areas with less visual obstruction ($F_{1,181} = 21.14$, $P < 0.001$) and 2 times greater amounts of bare ground ($F_{1,181} = 4.32$, $P = 0.039$) within 100-m than randomly located plots (Table 3.1). Henslow's sparrow nest placement was associated with 3.5 times deeper litter ($F_{1,164} = 129.46$, $P <0.001$), 17% greater litter density ($F_{1,164} = 4.18$, $P = 0.042$) and 65% greater percent canopy coverage of grasses ($F_{1,164} = 13.26$, $P = 0.001$) within 100-m than randomly located plots (Table 3.1). Eastern meadowlark nests were located in areas with less visual obstruction ($F_{1,160} = 6.66$, $P = 0.011$) and nest placement was associated with 25% greater litter density ($F_{1,160} = 7.35$, $P = 0.007$) and 2 times deeper litter ($F_{1,160} = 27.65$, $P < 0.001$) within 100-m than randomly located plots (Table 3.1).

Variation in daily nest survival rates for grasshopper sparrows were best explained by a model containing distance to woodland edge interacting with distance to disturbed area (burned or sprayed plot, firebreak or mowed grass lane) ($\Delta AIC_c = 0.00$, $w_i = 0.455$; Beta estimates: distance to woodland edge = 0.01 ± 0.005 SE, distance to disturbed areas = 0.03 ± 0.012 SE, interaction term = 0.003 ± 0.0001 SE) (Table 3.2). Grasshopper sparrow nests that were located close to disturbed areas had relatively high nest survival regardless of distance to woodland edge. Nests farther from disturbed areas, in contrast, were more likely to survive as distance to woodland edge increased (Figure 3.1). No single model best explained daily nest survival for eastern meadowlark (Table 3.3); rather daily nest survival was explained by distance to edge, vertical structure (visual obstruction and amount of bare ground) and an interaction between the two (Beta estimates: distance to woodland edge = -0.21 $\pm$ 0.102 SE, visual obstruction = -5.31 $\pm$ 4.088, bare ground = -364.77 $\pm$ 145.980, interaction terms = 0.03 $\pm$ 0.187, 2.29 $\pm$ 0.865). Surprisingly, eastern meadowlark nest locations with relatively low vertical structure had overall higher daily survival rates than nest locations with relatively high vertical structure, regardless of distance to woodland edge. For nest locations with high vertical structure, daily survival rate decreases with an increase in distance to woodland edge (Figure 3.2). In addition, other nest-site characteristics, including percent grass and forb cover, litter depth and density and visual obstruction, explained some variation in daily nest survival rates among eastern meadowlark nests (ΔAIC_c = 1.61, w_i = 0.1243) (Table 3.3). Because Henslow's sparrows had nest success nearing 100% in this study, I was unable to identify potentially important factors explaining daily nest survival.

DISCUSSION

Results suggest that microhabitat features (i.e. litter depth and density) influence the nest-site selection and nest success for grassland birds breeding within reclaimed surface mines. Particularly interesting were the interactions that were detected between distance to woodland edge and visual obstruction, and amount of bare ground surrounding nests of grasshopper sparrows and visual obstruction, and amount and depth of litter surrounding nests of eastern meadowlarks. These findings suggest that edge-related nest predation in grassland systems is complex and may be dependent upon other structural characteristics of the grassland habitat, such as perimeter to area ratio.

As a whole, findings are consistent with other studies of the nesting requirements of grassland birds. For example, regarding nest-site selection, grasshopper sparrows are known to prefer short vegetation with low vertical structure and a relatively sparse litter layer interspersed with bare ground (Whitmore 1981, Swanson 1996), whereas Henslow's sparrows prefer taller vegetation with a deep litter layer (Swanson 1996, Herkert 1998) and eastern meadowlarks prefer moderate vegetation height with a moderate to heavy litter layer (Swanson 1996, Hull 2000). Hubbard et al. (2006) found that eastern meadowlark nest locations had less litter and bare ground than random plots, whereas eastern meadowlark nests in West Virginia were associated with more standing dead vegetation, deeper litter and taller live vegetation than random plots (Warren and Anderson 2005). Grasshopper sparrow nests were located in areas with less litter and greater amounts of bare ground than random plots in northeast Kansas (Hubbard et al 2006), although Dieni and Jones (2003) reported that grasshopper sparrow nest locations contained little if any bare ground and appeared to be selecting for vertical vegetation structure, as visual obstruction and vertical density surrounding nest locations were greater than random locations. The variation in nest-site requirements underscores the need to use a variety of management approaches in grassland habitats. Although implementing several management practices (i.e. prescribed burning, herbicide application, etc.) may initially decrease the amount of quality habitat for some species, over the long-term utilization of these different management practices can provide a mosaic of grassland habitats to support the greatest diversity of grassland-nesting species.

Despite apparent sensitivity to local habitat features at the nest-patch level, I found no evidence that suggests daily nest survival of grasshopper sparrows, Henslow's sparrows and eastern meadowlarks was related to nest-patch habitat features of reclaimed surface mines. Instead, daily nest survival decreased near woodland edge and disturbed areas used for habitat management practices (i.e. prescribed burns, herbicide application, firebreaks, mowed areas). Consistency among other studies of the effects of vegetation structure and composition on nesting success of grassland species has yet to emerge (Galligan et al. 2006). For example, many studies have reported that vegetation features had little influence on nesting success of grassland-breeding birds (Vickery et al. 1992, Koford 1999, Howard et al. 2001, Burhans et al. 2002), while others have found that nest survival is influenced by local vegetation (Winter et al. 2000, Winter et al. 2005)

Nest predation is the leading cause of nest failure within grassland systems (Vickery et al. 1992, Wray and Whitmore 1979), and these pressures presumably should lead grassland-nesting birds to match the cues they use to select nests with those features most related to predation risk. In my study area, nest locations of grasshopper sparrows, eastern meadowlarks and Henslow's sparrows were highly variable and were partitioned along a vegetation gradient from relatively short, sparse vegetation with relatively large amounts of bare ground to tall, dense vegetation with no bare ground. Grasshopper sparrows may have occupied areas with shorter, sparser vegetation due to being excluded from areas with more cover. In addition, birds may be avoiding the tallest, densest vegetation as a result of a trade-off between nest concealment and the need to quickly escape due to the risk of predation (Davis 2005). Partitioning of nest sites may also be the result of birds selecting areas that differ from other species in order to reduce the probability of predation (Martin 1995). Tri-Valley and Woodbury Wildlife Management Areas are structurally heterogeneous and if birds were to locate nests only in areas containing the tallest and densest vegetation, predators may develop better search strategies (Davis 2005). My failure to find a strong relationship between nest-site selection cues and daily survival rate may stem from the fact that grassland birds nesting within reclaimed surface mines are exposed to a wide array of predators (Vickery et al. 1992, Galligan et al. 2006), which precludes any single nest site from being predictably safe (Davis 2005). Another possibility is that due to fluctuations in predator pressure in grassland systems, nest-site selection of grassland birds may still reflect optimal conditions over the long-term, yet appear to be maladaptive over a relatively short period of time (Wray and Whitmore 1979). In my study, the single year of data (small sample size) may not reflect typical nest survival rates and how nest-patch features generally relate to nest survival.

One of the most interesting findings of this study was that nest survival for grasshopper sparrows was affected by an interaction between distances from the nest to woodland edge and disturbed areas, such that nests close to disturbed areas had relatively high nest survival irrespective of distance to woodland edge. Nests farther from disturbed areas, in contrast, were more likely to survive as distance to woodland edge increased. Although woodland and generalist predators are known to be more abundant near forest edges (Gates and Gysel 1978, Chalfoun et al. 2002) my results suggest that predators may use disturbed areas (burned or sprayed plot, firebreak or mowed grass lane) as movement corridors when searching for prey. It may be more effective for predators to move from woodlands through these disturbed areas that consist of very little, if any live vegetation rather than directly through grassland patches consisting of tall, dense vegetation; thus nests that are located in close proximity to a disturbed area are more likely to encounter a predator (Dion et al. 2000, Johnson and Temple 1990). For example, nesting success in ungrazed areas was higher for grasshopper sparrows (Sutter and Ritchison) and Savannah sparrows (Fondell and Ball 2003) than grazed areas, which consisted of shorter, less dense vegetation. Taller, denser vegetation within grassland patches might restrict predator movement (Johnson and Temple 1990), whereas shorter vegetation may facilitate predator movement and make adult birds more visible, resulting in predators being more likely to locate nests by observing parental activity (Sutter and Ritchison 2005).

Although nest survival was better predicted by vegetation characteristics than distance to habitat edge, Henslow's sparrow nests within 50-m of an edge were less successful than those placed further (Winter et al. 2000) and overall nest predation for several bird species increased as distance to woodland edge decreased (Johnson and Temple 1990). Grasshopper sparrows within reclaimed surface mines in Indiana that nested in shrub/savanna habitats had substantially lower daily nest survival rates than those that nested within open grasslands, yet eastern meadowlarks revealed greater nesting success in shrub/savanna habitat compared with open grassland areas (Galligan et al. 2006).

This study provides evidence that although grassland birds select nest sites based on a variety of structural habitat features surrounding nests, woody vegetation may be one of the factors that most strongly influences nest survival. At the same time however, my results suggest that the influence of woody vegetation is complex and may be affected by other management activities, such as burning. Thus, managers should consider ways to control woody encroachment on reclaimed surface mines if they aim to provide habitat to grassland birds.

LITERATURE CITED

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

Bakker, K.K., D.E. Naugle and K.F. Higgins. 2002. Incorporating landscape attributes into models for migratory grassland bird conservation. Conservation Biology 16(6):1638-1646.

Bibby, C.J., N.D. Burgess, D.A. Hill and S.H. Mustoe. 2000. Bird census techniques. Academic Press, San Diego, California, USA.

Bollinger, E.K., P.B. Bollinger and T.G. Gavin. 1990. Effects of hay-cropping on eastern populations of the bobolink. Wildlife Society Bulletin 18:142-150.

Burhans, D.E., D. Dearborn, F.R. Thompson, III and J. Faaborg. 2002. Factors affecting predation at songbird nests in old fields. Journal of Wildlife Management 66(1):240-249.

Burnham, K.P. and D.R. Anderson. 2002. Model selection and inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

Chalfoun, A.D., M.J.Ratnaswamy and F.R. Thomspson III. 2002. Songbird nest predators in forest-pasture edge and forest interior in a fragmented landscape. Ecological Applications 12(3):858-867.

Cully, J.F. and H.L. Michaels. 2000. Henslow's sparrow habitat associations on Kansas tallgrass prairie. Wilson Bulletin 112(1):115-123.

Daubenmire, R.F. 1959. Canopy coverage method of vegetation analysis. Northwest Scientist 33:43-64.

Davis, S.K. 2005. Nest-site selection patterns and the influence of vegetation on nest survival of mixed-grass prairie passerines. The Condor 107:605-616.

Dion, N., K.A. Hobson and S. Lariviere. 2000. Interactive effects of vegetation and predators on the success of natural and simulated nests of grassland songbirds. The Condor 102:629-634.

ESRI. 2005. ArcGIS version 9.1, Earth Systems Research Institute, Redlands, California, USA.

Fletcher, R.J. and R.R. Koford. 2002. Habitat and landscape associations of breeding birds in native and restored grasslands.

Fondell, T.F. and I.J. Ball. 2004. Density and success of bird nests relative to grazing on western Montana grasslands. Biological Conservation 117:203-213.

Galligan, E.W., T.L. DeVault and S.L. Lima. 2006. Nesting success of grassland and savanna birds on reclaimed coal mines of the Midwestern United States. The Wilson Journal of Ornithology. 118(4):537-546.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59(5):871-883.

Grant, T.A., E. Madden and G.B. Berkey. 2004. Tree and shrub invasion in Northern mixed-grass prairie: Implications for breeding grassland birds. Wildlife Society Bulletin 32(3):807-818.

Herkert, J.R. 1994a. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4(3):461-471.

-------. 1998. Effects of prairie management on grassland birds: Henslow's sparrow. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Horn, D.J. and R.R. Koford. 2000. Relation of grassland bird abundance to mowing of Conservation Reserve Program fields in North Dakota. Wildlife Society Bulletin 28(3):653-659.

Howard, M.N., S.K. Skagen and P.L. Kennedy. 2001. Does habitat fragmentation influence nest predation in the shortgrass prairie? Condor 103:530-536.

Hubbard, R.D., D.P. Althoff, K.A. Blecha, B.A. Bruvold and R.D. Japuntich. 2006. Nest site characteristics of eastern meadowlarks and grasshopper sparrows in tallgrass prairie at the Fort Riley military installation, Kansas. Transactions of the Kansas Academy of Science 109(3/4):168-174.

Hull, S.D., R. J. Robel and K.E. Kemp. 1996. Summer avian abundance, invertebrate biomass, and forbs in Kansas CRP. The Prairie Naturalist 28(1):1-12.

Ingold, D.J. 2002. Use of reclaimed stripmine by grassland nesting birds in East-central Ohio. Ohio Journal of Science 102(3):56-62.

Johnson, D.H. and L.D. Igl. 2001. Area requirements of grassland birds: A regional perspective. The Auk 118(1):24-34.

Johnson, R.G. and S.A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. Journal of Wildlife Management 54:106-111.

Koford, R.R. 1999. Density and fledging success of grassland birds in Conservation Reserve Program fields in North Dakota and west-central Minnesota. Pages 187-195 in P.D. Vickery and J.R. Herkert, editors. Ecology and conservation of grassland birds of the western hemisphere. Studies in Avian Biology 19.

Martin, T.E. 1995. Avian life history evolution in relation to nest sites, nest predation, and food. Ecological Monographs 65(1):101-127.

Ohio Department of Natural Resources, Division of Wildlife. 2007. ODNR, Columbus, Ohio, USA.

Peterjohn, B.G. and J.R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-96. Studies in Avian Biology 19:27-44.

Quinn, G.P., and M.J. Keough. 2002. Chapter 16. Multivariate analysis of variance and discriminant analysis. pp. 425-442 in Gerry P. Quinn and Michael J. Keough, editors. Experimental Designs and Data Analysis for Biologists. University Press, Cambridge, United Kingdom.

Ransom, D. and W.E. Pinchak. 2003. Assessing accuracy of a laser rangefinder in estimating grassland bird density. Wildlife Society Bulletin 31(2):460-463.

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.

Rummel S.M. and F.J. Brenner. 2003. Relationships between vegetation and bird populations in reclaimed mine grasslands and native grasslands. Journal of Pennsylvania Academy of Science 76(2/3):56-61.

SAS Institute. 2002. SAS/STAT software, release 9.1. SAS Institute, Cary, North Carolina, USA.

Schmidt, K.A. and C.J. Whelan. 1999. Nest placement and mortality: is nest predation a random event in time and space? Condor 101:916-920.

Shaffer, T.L 2004. A unified approach to analyzing nest success. The Auk 121(2): 526-540.

------- and J.R. Herkert. 2001. Recent advances in grassland bird research: Where do we go from here? The Auk 118(1):11-15.

Sutter, B. and G. Ritchison. 2005. Effects of grazing on vegetation structure, prey availability, and reproductive success of grasshopper sparrows. Journal of Field Ornithology 76(4):345-351.

Swanson, D.A. 1996. Nesting ecology and nesting habitat requirements of Ohio's grassland-nesting birds: A literature review. Ohio Department of Natural Resources, Division of Wildlife, Ohio Fish and Wildlife Report 13. Jamestown, North Dakota, USA.

Vickery, P.D., M.L. Hunter, Jr. and J.V. Wells. 1992. Evidence of incidental nest predation and its effects on nests of threatened grassland birds. Oikos 63:281-288.

-------. 1996. Grasshopper sparrow (*Ammodramus savannarum*). In: Poole A, Gill F, editors. The Birds of North America. No 239. Philadelphia (PA): Acadamy of Natural Science; Washington (DC): American Ornithologits' Union. P 1-5.

------- and J.R. Herkert. 2001. Recent advances in grassland bird research: Where do we go from here? The Auk 118(1):11-15.

Whitmore, R.C. and G.A. Hall. 1978. The response of passerine species to a new resource: reclaimed surface mines in West Virginia. American Birds 32(1):6-9.

-------1980. Reclaimed surface mines as avian habitat islands in the eastern forest. American Birds 34(1):13-14.

------- 1981. Structural characteristics of grasshopper sparrow habitat. Journal of Wildlife Management 45(3):811-814.

Wiens, J.A. 1985. Habitat selection in variable environments: Shrub-steppe birds. Pages 227-251 in Habitat selection in birds (M.L. Cody, Ed.). Academic Press, New York.

Winter, M., D.H. Johnson and J. Faaborg. 2000. Evidence for edge effects on multiple levels in tallgrass prairie. The Condor 102:256-266.

-------, D.H. Johnson and J.A.Shaffer. 2005. Variability in vegetation effects on density and nesting success of grassland birds. Journal of Wildlife Management 69(1):185-197.

Wray, T. II, and R.C. Whitmore. 1979. Effects of vegetation on nesting success of vesper sparrows. Auk 96:802-805.

-------, K.A. Strait and R.C. Whitmore. 1982. Reproductive success of grassland sparrows on a reclaimed surface mine in West Virginia. Auk 99:157-164.

Zuckerberg, B. and P.D. Vickery. 2006. Effects of mowing and burning on shrubland and grassland birds on Nantucket Island, Massachusetts. The Wilson Journal of Ornithology 118(3):353-363.

TABLES AND FIGURES

	Grasshopper Sparrow			Henslow's Sparrow			Eastern Meadwolark			Random
Variable	**$\bar{X}$ (SE)**	**F**	**P**	**$\bar{X}$ (SE)**	**F**	**P**	**$\bar{X}$ (SE)**	**F**	**P**	**$\bar{X}$ (SE)**
Visual Obstruction	2.76 (0.21)	21.1	<0.001	4.91 (0.34)	2.6	0.111	2.94 (0.25)	6.7	0.011	4.20 (0.14)
% Litter Density	69.85 (4.24)	0.1	0.756	80.29 (6.48)	4.2	0.042	85.23 (2.76)	7.4	0.007	68.52 (1.80)
Litter Depth	4.15 (0.35)	0.0	0.997	14.42 (1.83)	129.5	<0.001	8.40 (0.89)	27.7	<0.001	4.14 (0.23)
% Forb Cover	23.12 (3.68)	0.0	0.956	22.65 (7.01)	0.0	0.968	17.31 (5.07)	0.8	0.383	22.89 (1.83)
% Grass Cover	19.41 (2.94)	0.9	0.342	36.18 (7.24)	13.3	<0.001	26.15 (3.59)	1.3	0.252	21.89 (1.05)
% Bare Ground	6.41 (1.54)	4.3	0.039	2.06 (1.20)	0.3	0.565	0.92 (0.52)	1.1	0.306	3.19 (0.65)

Table 3.1. Mean values of habitat variables (+/- SE) at nest locations of grasshopper sparrows, Henslow's sparrows, eastern meadowlarks and random locations and associated F- and P-values from discriminant function analyses.

Model	Log-likelihood	K[a]	AIC_c[b]	ΔAIC_c[c]	w_i[d]
	Grasshopper Sparrow				
Distance to woodland | distance to disturbed	-35.9895	4	80.1791	0.0000	0.4549
Floristics:nest	-38.5186	3	83.1565	2.9775	0.1027
Visual obstruction:nest	-39.9028	2	83.8649	3.6859	0.0720
Null model	-41.5861	1	85.1918	5.0127	0.0371
Vertical structure + floristics:nest	-37.5556	5	85.4126	5.2335	0.0332
Visual obstruction:nest-patch	-40.7170	2	85.4934	5.3143	0.0319
Vertical structure:nest	-39.6886	3	85.4965	5.3174	0.0319
Floristics:nest-patch	-39.8066	3	85.7327	5.5536	0.0283
Vertical structure:nest-patch	-39.8423	3	85.8040	5.6249	0.0273
Distance to woodland edge + vertical	-38.9669	4	86.1337	5.9546	0.0232
Distance to roadway	-41.2460	2	86.5514	6.3723	0.0188
Distance to disturbed	-41.2970	2	86.6533	6.4742	0.0179
Vertical structure + floristics:nest-patch	-38.3684	5	87.0384	6.8593	0.0147
Distance to woodland	-41.5482	2	87.1558	6.9767	0.0139

a Number of parameters in model. In addition to the explanatory variables, models also include intercept term.

b Akaike's information criterion. A lower AICc score indicates better explanatory power.

c Difference in AIC_c score between given model and the best-ranked model. Models with ΔAICc <2 are considered to be equally plausible given the data.

d Akaike's weight on a 0-1 scale. Indicates the weight of evidence for a particular model.

Table 3.2. Model selection results from the top logistic-exposure models of daily survival rate for grasshopper sparrow nests in 2006.

Model	Log-likelihood	K[a]	AIC_c[b]	Δ AIC_c[c]	w_i[d]
Eastern Meadowlark					
Distance to woodland | vertical	-14.4743	6	41.5123	0	0.2781
Full habitat model:nest	-14.1830	7	43.1228	1.6105	0.1243
Litter structure:nest-patch	-18.7377	3	43.6332	2.1209	0.0963
Null model	-21.2421	1	44.5101	2.9979	0.0621
Floristics:nest	-19.4266	3	45.0112	3.4989	0.0484
Floristics:nest-patch	-19.4653	3	45.0885	3.5762	0.0465
Visual obstruction:nest	-20.5532	2	45.1848	3.6725	0.0443
Vertical structure + floristics:nest	-17.3992	5	45.1985	3.6862	0.0440
Visual obstruction:nest-patch	-20.7067	2	45.4918	3.9795	0.0380
Vertical structure:nest	-19.8294	3	45.8166	4.3044	0.0323
Distance to disturbed	-21.0490	2	46.1765	4.6642	0.0270
Distance to roadway	-21.2245	2	46.5274	5.0151	0.0227
Distance to woodland	-21.2416	2	46.5617	5.0495	0.0223
Vertical structure:nest-patch	-20.6456	3	47.4490	5.9368	0.0143

a Number of parameters in model. In addition to the explanatory variables, models also include intercept term.
b Akaike's information criterion. A lower AICc score indicates better explanatory power.
c Difference in AIC_c score between given model and the best-ranked model. Models with ΔAICc <2 are considered to be equally plausible given the data.
d Akaike's weight on a 0-1 scale. Indicates the weight of evidence for a particular model.

Table 3.3. Model selection results from the top logistic-exposure models of daily survival rate for eastern meadowlark nests in 2006.

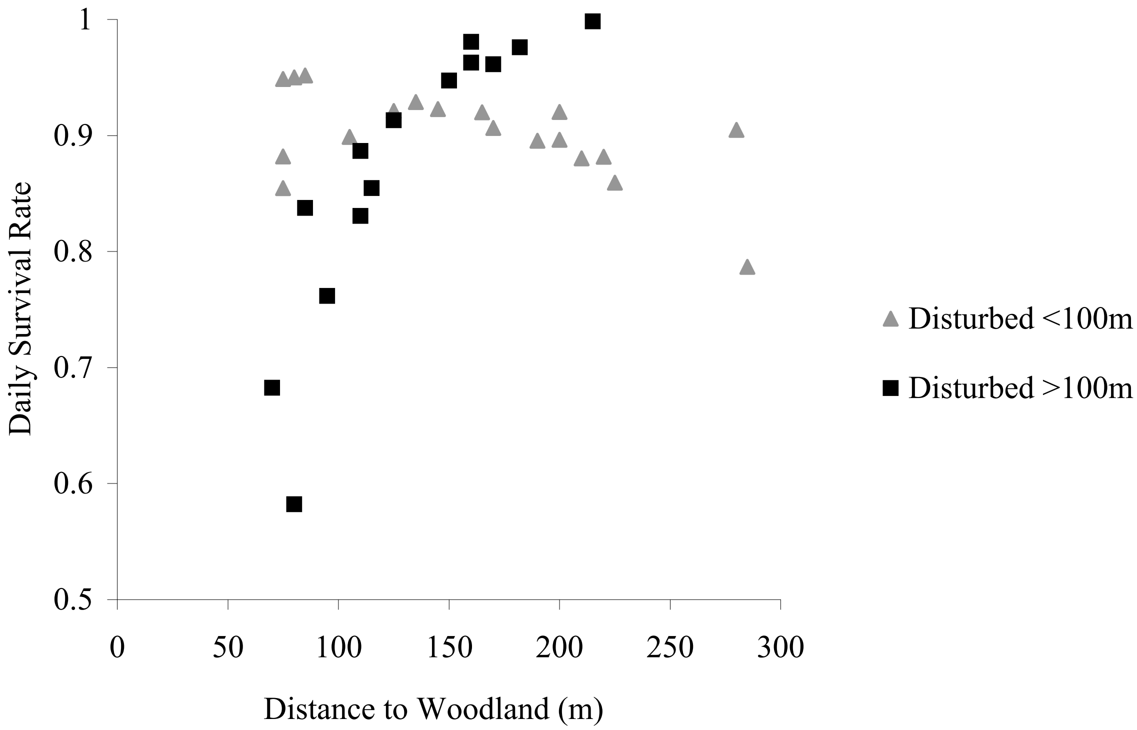


Figure 3.1. Relationship between distance to woodland (m) interacting with distance to a disturbed area (<100-m or >100-m) and daily survival rate for grasshopper sparrow nests in 2006 from top logistic-exposure model. The model used distance to disturbed as a continuous variable, thus the category shown here was only used to ease visual interpretation.

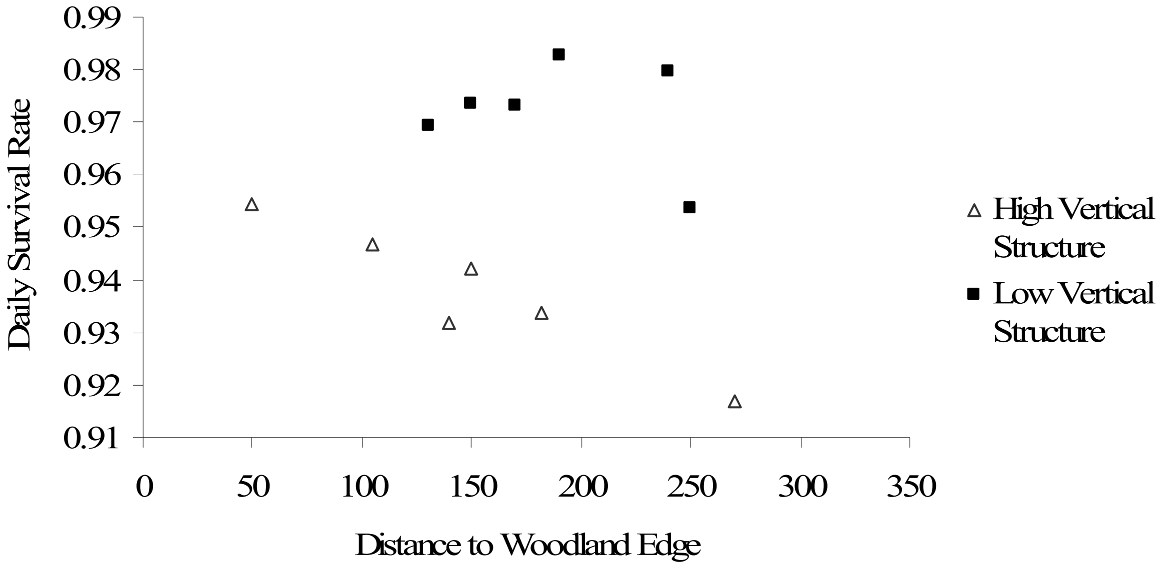


Figure 3.2. Relationship between distance to woodland edge and high or low vertical structure (visual obstruction and amount of bare ground) and daily survival rate for eastern meadowlark nests in 2006 from top logistic-exposure model. The model used vertical structure as a continuous variable, thus the category shown here was only used to ease visual interpretation.

APPENDIX A

Mean number of singing male grassland bird species (+/- SE) recorded within 100-m radius of point-count locations at Woodbury Wildlife Management Area in 2005

Point	GRSP $\bar{X}$ (SE)	HESP $\bar{X}$ (SE)	EAME $\bar{X}$ (SE)	BOBO $\bar{X}$ (SE)	SAVS $\bar{X}$ (SE)	DICK $\bar{X}$ (SE)	UTM
WA1	1.0 (0.00)	1.3 (0.88)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416283 4455802
WA2	0.7 (0.33)	2.3 (0.88)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416262 4455561
WA3	1.3 (0.33)	2.3 (1.20)	0.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416240 4455355
WA4	0.3 (0.33)	2.7 (1.20)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416195 4455106
WB1	0.0 (0.00)	1.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416455 4455050
WB2	0.3 (0.33)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416541 4455282
WB3	0.3 (0.33)	1.0 (0.58)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416639 4455512
WB4	0.0 (0.00)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416877 4455454
WD1	0.3 (0.33)	2.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 414999 4456582
WD2	2.0 (0.58)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 414815 4456758
WD3	0.3 (0.33)	3.3 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 414644 4456960
WD4	0.7 (0.67)	2.3 (0.67)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 414516 4457171
WF1	0.0 (0.00)	3.0 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416626 4456071
WF2	1.3 (0.33)	2.7 (1.67)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416872 4456112
WF3	1.3 (0.33)	3.7 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417075 4455962
WF4	0.3 (0.33)	2.0 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417239 4455786
WG1	0.0 (0.00)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 415414 4455341
WG2	0.7 (0.67)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 415396 4455591
WG3	0.67 (0.33)	0.3 (0.33)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 415374 4455864
WG4	0.0 (0.00)	1.3 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 415339 4456136
WH1	0.0 (0.00)	2.0 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 413064 4457398
WH2	0.7 (0.33)	1.3 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 413311 4457486
WH3	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 413512 4457657
WH4	0.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 412986 4457124

APPENDIX B

Mean number of singing male grassland bird species recorded (+/- SE) within 100-m radius of point-count locations at Tri-Valley Wildlife Management Area in 2005.

	GRSP	HESP	EAME	BOBO	SAVS	DICK	
Point	**$\bar{X}$ (SE)**	**$\bar{X}$ (SE)**	**$\bar{X}$ (SE)**	**$\bar{X}$ (SE)**	**$\bar{X}$ (SE)**	**$\bar{X}$ (SE)**	**UTM**
TA1	1.7 (0.33)	2.0 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419172 4441400
TA2	1.3 (0.33)	0.7 (0.33)	0.3 (0.33)	0.3 (0.33)	0.3 (0.33)	0.0 (0.00)	17T 419289 4441179
TA3	2.7 (0.67)	2.0 (0.00)	0.0 (0.00)	1.0 (0.58)	1.7 (0.33)	0.0 (0.00)	17T 419541 4441134
TA4	3.3 (0.33)	0.3 (0.33)	0.0 (0.00)	0.7 (0.67)	0.7 (0.67)	0.0 (0.00)	17T 419701 4440949
TA5	4.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419564 4440738
TB1	2.3 (0.88)	4.3 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 420245 4441594
TB2	1.3 (0.88)	5.3 (0.33)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 420492 4441530
TB3	1.0 (0.58)	4.3 (0.67)	0.7 (0.33)	1.7 (0.67)	0.0 (0.00)	0.0 (0.00)	17T 420620 4441315
TB4	2.0 (0.00)	4.7(0.88)	0.7 (0.33)	0.7 (0.67)	0.0 (0.00)	0.0 (0.00)	17T 420593 4441067
TB5	0.0 (0.00)	4.0 (0.50)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 420769 4440888
TC1	2.7 (0.33)	2.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 418400 4441117
TC2	1.7 (0.33)	2.7 (0.88)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 418164 4441032
TC3	1.3 (0.33)	0.3 (0.33)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 418015 4440829
TC4	2.0 (0.58)	4.0 (0.33)	0.7(0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417801 4440701
TC5	3.0 (1.00)	2.0 (2.00)	1.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417617 4440868
TD1	1.3 (0.33)	2.3 (1.33)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419974 4437202
TD2	1.7 (0.33)	1.3 (1.33)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419808 4437388
TD3	1.7 (0.33)	1.3 (1.33)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419588 4437240
TD4	0.7 (0.33)	3.3 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419339 4437244
TD5	1.3 (1.33)	0.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419546 4437387
TE1	1.5 (0.29)	3.7 (0.48)	0.3 (0.25)	0.0 (0.00)	0.0 (0.00)	0.2 (0.25)	17T 419125 4436158
TE2	2.5 (0.29)	5.5 (0.50)	0.5 (0.29)	0.5 (0.29)	0.0 (0.00)	0.3 (0.25)	17T 419346 4436037
TE3	2.3 (0.48)	2.5 (0.65)	0.5 (0.50)	0.5 (0.50)	0.0 (0.00)	0.0 (0.00)	17T 419491 4435856
TE4	2.5 (0.29)	2.8 (0.48)	0.3 (0.25)	0.3 (0.25)	0.0 (0.00)	1.0 (0.41)	17T 419683 4435696
TE5	2.3 (0.33)	4.7 (0.88)	0.0 (0.00)	0.0 (0.00)	0.7 (0.33)	1.0 (0.00)	17T 419861 4435518
TF1	1.0 (0.00)	3.7 (0.33)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419668 4438944
TF2	3.0 (1.00)	3.7 (0.88)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419435 4438954
TF3	2.0 (0.00)	5.7 (0.67)	0.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419198 4438886
TF4	1.3 (0.33)	5.3 (1.86)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419183 4438650

APPENDIX C

Mean number of singing male grassland bird species (+/- SE) recorded within 100-m radius of point-count locations at Woodbury Wildlife Management Area in 2006.

Point	GRSP $\bar{X}$ (SE)	HESP $\bar{X}$ (SE)	EAME $\bar{X}$ (SE)	BOBO $\bar{X}$ (SE)	SAVS $\bar{X}$ (SE)	DICK $\bar{X}$ (SE)	UTM
WA1	0.7 (0.33)	3.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416283 4455802
WA2	1.0 (0.00)	4.0 (0.58)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416262 4455561
WA3	0.3 (0.33)	8.7 (0.33)	1.0 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416240 4455355
WA4	1.7 (0.67)	5.3 (1.33)	1.0 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416195 4455106
WB1	1.3 (0.33)	2.7 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416455 4455050
WB2	0.7 (0.33)	2.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416541 4455282
WB3	1.0 (0.58)	3.7 (1.20)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416639 4455512
WB4	1.7 (0.67)	2.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416877 4455454
WC1	1.0 (1.00)	5.0 (2.00)	0.5 (0.50)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 415293 4455083
WC2	0.0 (0.00)	1.0 (1.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 415274 4454839
WC3	0.0 (0.00)	1.0 (1.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 415513 4454702
WC4	1.5 (0.50)	3.0 (1.00)	0.5 (0.50)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 415496 4454952
WF1	0.3 (0.33)	2.7 (0.88)	1.0 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416626 4456071
WF2	0.3 (0.33)	3.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 416872 4456112
WF3	1.7 (0.33)	3.3 (1.20)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417075 4455962
WF4	1.7 (0.67)	3.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417239 4455786
WI1	1.8 (0.48)	0.5 (0.50)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.3 (0.25)	17T 417099 4456852
WI2	1.5 (0.50)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.5 (0.29)	17T 417181 4457090
WI3	2.7 (0.67)	0.7 (0.33)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417340 4457284
WI4	2.7 (0.33)	2.0 (0.58)	1.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417464 4457503
WI5	1.0 (0.00)	1.3 (0.88)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417560 4457731
WI6	2.7 (0.88)	2.3 (1.20)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417313 4457763
WI7	3.5 (0.5)	1.0 (1.00)	0.5 (0.50)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417114 4457613
WI8	4.0 (0.00)	1.5 (0.50)	1.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417198 4457378

APPENDIX D

Mean number of singing male grassland bird species recorded (+/- SE) within 100-m radius of point-count locations at Tri-

Valley Wildlife Management Area in 2006.

Point	GRSP $\bar{X}$ (SE)	HESP $\bar{X}$ (SE)	EAME $\bar{X}$ (SE)	BOBO $\bar{X}$ (SE)	SAVS $\bar{X}$ (SE)	DICK $\bar{X}$ (SE)	UTM
TA1	1.7 (0.33)	2.0 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419172 4441400
TA2	1.3 (0.33)	0.7 (0.33)	0.3 (0.33)	0.3 (0.33)	0.3 (0.33)	0.0 (0.00)	17T 419289 4441179
TA3	2.7 (0.67)	2.0 (0.00)	0.0 (0.00)	1.0 (0.58)	1.7 (0.33)	0.0 (0.00)	17T 419541 4441134
TA4	3.3 (0.33)	0.3 (0.33)	0.0 (0.00)	0.7 (0.67)	0.7 (0.67)	0.0 (0.00)	17T 419701 4440949
TA5	4.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419564 4440738
TB1	2.3 (0.88)	4.3 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 420245 4441594
TB2	1.3 (0.88)	5.3 (0.33)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 420492 4441530
TB3	1.0 (0.58)	4.3 (0.67)	0.7 (0.33)	1.7 (0.67)	0.0 (0.00)	0.0 (0.00)	17T 420620 4441315
TB4	2.0 (0.00)	4.7(0.88)	0.7 (0.33)	0.7 (0.67)	0.0 (0.00)	0.0 (0.00)	17T 420593 4441067
TB5	0.0 (0.00)	4.0 (0.50)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 420769 4440888
TC1	2.7 (0.33)	2.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 418400 4441117
TC2	1.7 (0.33)	2.7 (0.88)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 418164 4441032
TC3	1.3 (0.33)	0.3 (0.33)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 418015 4440829
TC4	2.0 (0.58)	4.0 (0.33)	0.7(0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417801 4440701
TC5	3.0 (1.00)	2.0 (2.00)	1.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 417617 4440868
TD1	1.3 (0.33)	2.3 (1.33)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419974 4437202
TD2	1.7 (0.33)	1.3 (1.33)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419808 4437388
TD3	1.7 (0.33)	1.3 (1.33)	0.7 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419588 4437240
TD4	0.7 (0.33)	3.3 (0.88)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419339 4437244
TD5	1.3 (1.33)	0.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419546 4437387
TE1	1.5 (0.29)	3.7 (0.48)	0.3 (0.25)	0.0 (0.00)	0.0 (0.00)	0.2 (0.25)	17T 419125 4436158
TE2	2.5 (0.29)	5.5 (0.50)	0.5 (0.29)	0.5 (0.29)	0.0 (0.00)	0.3 (0.25)	17T 419346 4436037
TE3	2.3 (0.48)	2.5 (0.65)	0.5 (0.50)	0.5 (0.50)	0.0 (0.00)	0.0 (0.00)	17T 419491 4435856
TE4	2.5 (0.29)	2.8 (0.48)	0.3 (0.25)	0.3 (0.25)	0.0 (0.00)	1.0 (0.41)	17T 419683 4435696
TE5	2.3 (0.33)	4.7 (0.88)	0.0 (0.00)	0.0 (0.00)	0.7 (0.33)	1.0 (0.00)	17T 419861 4435518
TF1	1.0 (0.00)	3.7 (0.33)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419668 4438944
TF2	3.0 (1.00)	3.7 (0.88)	0.3 (0.33)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419435 4438954
TF3	2.0 (0.00)	5.7 (0.67)	0.7 (0.67)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419198 4438886
TF4	1.3 (0.33)	5.3 (1.86)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	17T 419183 4438650

APPENDIX E

Percent of woody vegetation, number of woody patches and distance to woodland edge within 100-m radius of point count locations at Tri-Valley Wildlife Management Area in 2005.

Point	% Woody	No. Patches	Distance to Edge (m)
TVA1	0.70	7	135
TVA2	1.88	2	250
TVA3	1.78	5	200
TVA4	1.76	4	300
TVB1	31.04	6	30
TVB2	0.00	0	220
TVB3	0.00	0	400
TVB4	0.00	0	325
TVC1	10.88	6	50
TVC2	0.67	7	250
TVC3	0.13	2	240
TVC4	0.14	2	300
TVD1	5.40	7	160
TVD2	0.23	3	120
TVD3	1.95	7	150
TVD4	0.00	0	190
TVE1	2.64	7	155
TVE2	0.10	1	110
TVE3	0.00	0	215
TVE4	3.97	2	80
TVF1	0.00	0	190
TVF2	0.00	0	125
TVF3	0.00	0	180
TVF4	2.56	3	225

APPENDIX F

Percent of woody vegetation, number of woody patches and distance to woodland edge within 100-m radius of point count locations at Woodbury Wildlife Management Area in 2005.

Point	% Woody	No. Patches	Distance to Edge (m)
WA1	3.28	5	90
WA2	0.00	0	140
WA3	0.00	0	250
WA4	0.71	1	220
WB1	0.00	0	250
WB2	0.86	4	180
WB3	9.18	4	350
WB4	3.32	3	250
WD1	1.69	18	460
WD2	0.86	4	325
WD3	0.92	8	200
WD4	1.52	20	175
WF1	13.22	6	230
WF2	27.92	10	175
WF3	8.31	8	350
WF4	0.90	3	210
WG1	0.37	4	120
WG2	0.08	1	140
WG3	0.77	6	160
WG4	1.37	11	435
WH1	18.98	5	40
WH2	9.98	4	100
WH3	36.19	5	10
WH4	14.27	9	50

APPENDIX G

Percent of woody vegetation, number of woody patches and distance to woodland edge within 100-m radius of point count locations at Woodbury Wildlife Management Area in 2006.

Point	% Woody	No. Patches	Distance to Edge (m)
WA1	4.43	8	85
WA2	1.13	4	110
WA3	0.21	2	210
WA4	0.77	2	210
WB1	0.49	7	140
WB2	1.46	8	190
WB3	6.10	10	145
WB4	2.75	10	100
WC1	19.12	20	120
WC2	19.11	20	90
WC3	20.81	17	75
WC4	9.39	28	160
WF1	10.62	12	65
WF2	17.33	9	90
WF3	0	0	250
WF4	0	0	180
WI1	0.67	3	100
WI2	7.42	2	70
WI3	11.95	5	70
WI4	0.41	1	130
WI5	10.78	3	55
WI6	0.46	1	135
WI7	4.44	1	80
WI8	0.08	1	110

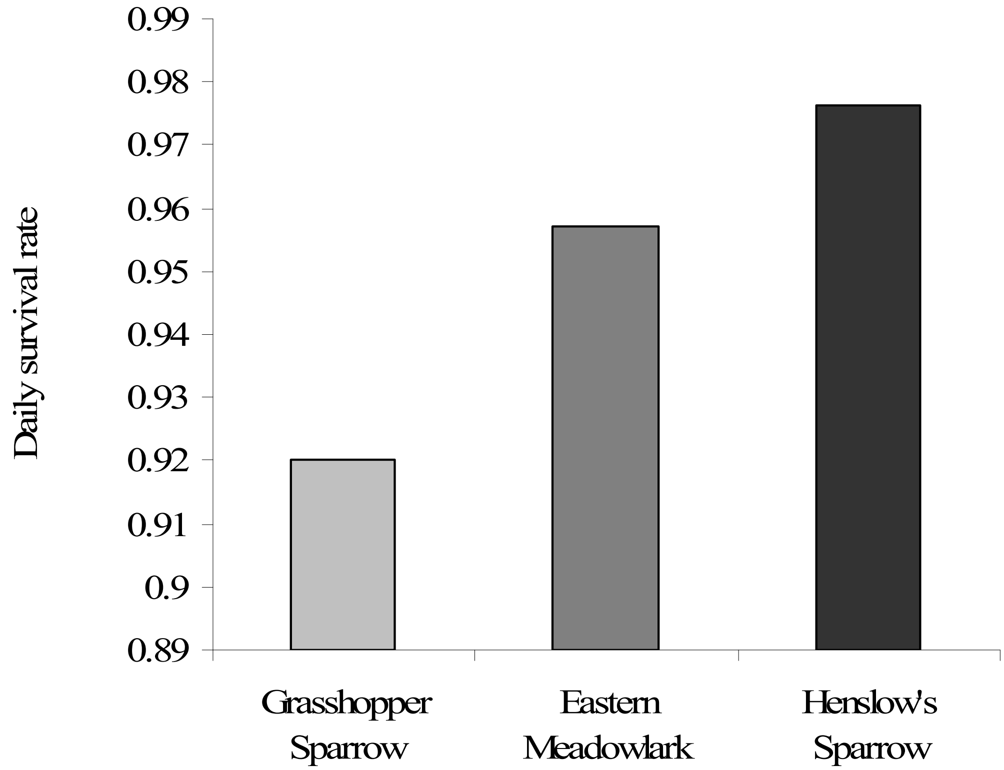
APPENDIX H

Percent of woody vegetation, number of woody patches and distance to woodland edge within 100-m radius of point count locations at Tri-Valley Wildlife Management Area in 2006.

Point	% Woody	No. Patches	Distance to Edge (m)
TA1	13.11	4	130
TA2	0.25	1	200
TA3	0	0	365
TA4	0	0	165
TA5	0	0	140
TB1	0.65	4	220
TB2	0	0	170
TB3	0.11	1	360
TB4	0.13	1	490
TB5	0.26	2	260
TC1	0.67	3	270
TC2	0.22	2	225
TC3	0.16	2	160
TC4	0.89	3	210
TC5	0.54	3	275
TD1	1.13	2	110
TD2	2.96	3	100
TD3	0	0	270
TD4	0	0	145
TD5	0.04	1	120
TE1	6.47	2	65
TE2	0.98	1	125
TE3	4.03	1	75
TE4	0	0	190
TE5	0	0	260
TF1	0.26	3	180
TF2	0	0	130
TF3	0	0	175
TF4	3.47	3	230

APPENDIX I

Daily survival rate estimates for nests of three grassland bird species at Woodbury and Tri-Valley Wildlife Management Areas in 2006 generated from null model of logistic-exposure analyses. Because illustrated daily survival rates were generated using the null model for each species, there is only a single estimate produced (i.e. no standard error).



APPENDIX J

Map of Ohio counties with approximate location of Woodbury Wildlife Management Area in southern Coshocton County, Ohio and Tri-Valley Wildlife Management Area in northern Muskingum County, Ohio.

APPENDIX K

Tri-Valley Wildlife Management Area and associated 5-ha nest searching plots (1:24,000).

APPENDIX L

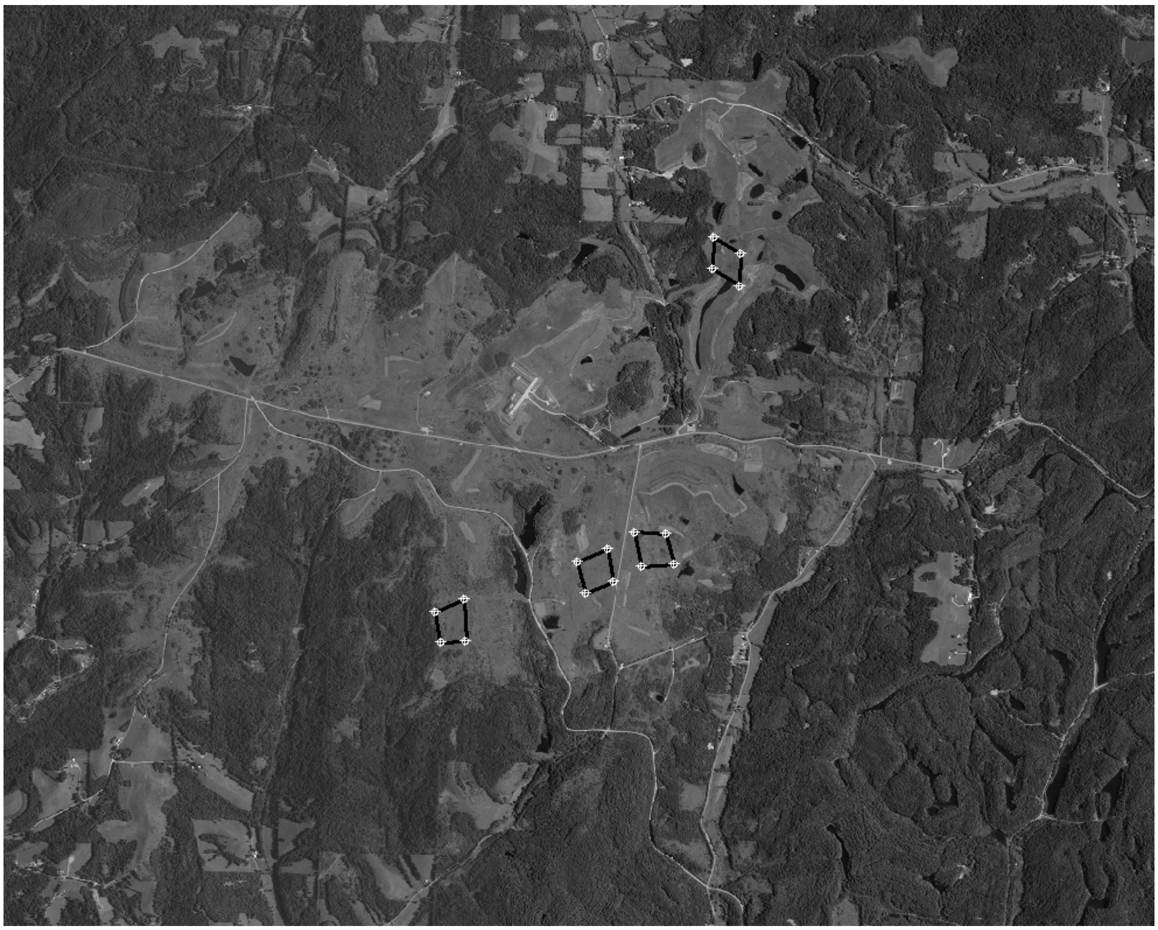
Woodbury Wildlife Management Area and associated 5-ha nest searching plots (1:23,000).

APPENDIX M

Tri-Valley Wildlife Management Area and associated 5-ha nest searching plots (1:44,000).

APPENDIX N

Woodbury Wildlife Management Area and associated 5-ha nest searching plots (1:40,000).



BIBLIOGRAPHY

Aldredge, J.R. and J. Griswold. 2006. Design and analysis of resource selection studies for categorical resource variables. Journal of Wildlife Management 70:337-346.

Ammann, R.L. and D.W. Nyberg. 2005. Vegetation height and quality of original and reconstructed tallgrass prairies. The American Midland Naturalist 154:55-66.

Applegate, R.D., B.E. Flock and G.J. Horak. 2002. Spring burning and grassland area: Effects on Henslow's sparrow and dickcissel in Eastern Kansas, USA. Natural Areas Journal 22(2):160-162.

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

Bajema, R.A., T.V. DeVault, P.E. Scott and S.L. Lima. 2001. Reclaimed coal mine grasslands and their significance for Henslow's sparrows in the American midwest. The Auk 118(2):422-431.

------- and S.L. Lima. 2001. Landscape-level analyses of Henslow's sparrow (Ammodramus henslowii) abundance in reclaimed coal mine grasslands. The American Midland Naturalist 145:288-298.

Bakker, K.K., D.E. Naugle and K.F. Higgins. 2002. Incorporating landscape attributes into models for migratory grassland bird conservation. Conservation Biology 16(6):1638-1646.

Balent, K.L. and C.J. Norment. 2003. Demographic characteristics of a grasshopper sparrow population in a highly fragmented landscape of western New York state. Journal of Field Ornithology 74(4):341-348.

Barg, J.J., J.Jones and R.J. Robertson. 2005. Describing breeding territories of migratory passerines: suggestions for sampling, choice of estimator, and delineation of core areas.

Bibby, C.J., N.D. Burgess, D.A. Hill and S.H. Mustoe. 2000. Bird census techniques. Academic Press, San Diego, California, USA.

Bollinger, E.K., PB. Bollinger and T.A. Gavin. 1990. Effects of hay-cropping on eastern populations of the bobolink. Wildlife Society Bulletin 2:142-150.

------- and T.A. Gavin. 2004. Responses of nesting bobolinks (Dolichonyx oryzivorus) to habitat edges. The Auk 121(3):767-776.

Brennan, L.A. and W.P. Kuvlesky, Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69(1):1-13.

Brothers, T. S. 1990. Surface-mine grasslands. The Geographical Review 80(3): 209-225.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L, Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press.

Burhans, D.E., D. Dearborn, F.R. Thompson, III and J. Faaborg. 2002. Factors affecting predation at songbird nests in old fields. Journal of Wildlife Management 66(1):240-249.

Burnham, K.P. and D.R. Anderson. 2002. Model selection and inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

Buskirk, S.W. and J. J. Millspaugh. 2006. Metrics for studies of resource selection. Journal of Wildlife Management 70:358-366.

Chapman, R.N., D.M. Engle, R.W. Masters and D.M. Leslie. 2004. Grassland vegetation and bird communities in the southern Great Plains of North America. Agriculture, Ecosystems and Environment 104:577-585.

Chalfoun, A.D., M.J.Ratnaswamy and F.R. Thomspson III. 2002. Songbird nest predators in forest-pasture edge and forest interior in a fragmented landscape. Ecological Applications 12(3):858-867.

Cully, J.F., and H.L. Michaels. 2000. Henslow's sparrow habitat associations on Kansas tallgrass prairie. Wilson Bulletin 112(1):115-123.

Cunningham, M.A. and D.H. Johnson. 2006. Proximate and landscape factors influence grassland bird distributions. Ecological Applications 16(3):1062-1075.

Dale, B.C., P.A. Martin and P.S. Taylor. 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin 25(3): 616-626.

Daubenmire, R.F. 1959. Canopy coverage method of vegetation analysis. Northwest Scientist 33:43-64.

Davis, S.K. 2004. Area sensitivity in grassland passerines: Effects of patch size, patch shape and vegetation structure on bird abundance and occurrence in southern Saskatchewan. The Auk 121(4):1130-1145.

-------. 2005. Nest-site selection patterns and the influence of vegetation on nest survival of mixed-grass prairie passerines. The Condor 107:605-616.

-------, R.M. Brigham, T.L. Shaffer and P.C. James. 2006. Mixed-grass prairie passerines exhibit weak and variable response to patch size. The Auk 123(3):807-821.

Davison, W.B. and E. Bollinger. 2000. Predation rates on real and artificial nests of grassland birds. The Auk 117(1):147-153.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, M. P. Nenneman, and B. R. Euliss. 2003. Effects of management practices on grassland birds: Grasshopper Sparrow. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/grasbird/grsp/grsp.htm (Version 12AUG2004).

Delisle, J.M. and J.A. Savidge. 1996. Reproductive success of grasshopper sparrows in relation to edge. The Prairie Naturalist 28(3):107-113.

DeVault, T.L., P.E. Scott, R.A. Bajema and S.L. Lima. 2002. Breeding bird communities of reclaimed coal-mine grasslands in the American midwest. The Journal of Field Ornithology 73(3):228-275.

Diefenbach, D.R., D.W. Brauning and J.A. Mattice. 2003. Variability in grassland bird counts related to observer differences and species detection rates. The Auk 20(4):1168-1179.

Dieni, J.S. and S.L. Jones. 2002. A field test of the area search method for measuring bird populations. Journal of Field ornithology 73(3):253-257.

-------, and -------. 2003. Grassland songbird nest site selection patterns in Northcentral Montana. Wilson Bulletin 115(4):388-396.

------- and P. Scherr. 2004. Roadside bias in point count surveys at Arrowwood National Wildlife Refuge, North Dakota. The Prairie Naturalist 36(4):203-211.

Dinsmore, S.J., G.C. White and F.L. Knopp. 2002. Advanced techniques for modeling avian nest survival. Ecology 83(12):3476-3488.

Dion, N., K.A. Hobson and S. Lariviere. 2000. Interactive effects of vegetation and predators on the success of natural and simulated nests of grassland songbirds. The Condor 102:629-634.

ESRI. 2005. ArcGIS version 9.1, Earth Systems Research Institute, Redlands, California, USA.

Farnsworth, G.L., K.H. Pollock, J.D. Nichols, T.R. Simons, J.E. Hines and J.R. Sauer. 2002. A removal method for estimating detection probabilities from point-count surveys. The Auk 119(2):414-425.

Fletcher, R.J. and R.R. Koford. 2002. Habitat and landscape associations of breeding birds in native and restored grasslands.

-------. 2005. Multiple edge effects and their implications in fragmented landscapes. Journal of Animal Ecology 74:342-352.

Fondell, T.F. and I.J. Ball. 2004. Density and success of bird nests relative to grazing on western Montana grasslands. Biological Conservation 117:203-213.

Galligan, E.W., T.L. DeVault and S.L. Lima. 2006. Nesting success of grassland and savanna birds on reclaimed coal mines of the Midwestern United States. The Wilson Journal of Ornithology. 118(4):537-546.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59(5):871-883.

Grant, T.A., E. M. Madden and G.B. Berkey. 2004. Tree and shrub invasion in Northern mixed-grass prairie: Implications for breeding grassland birds. Wildlife Society Bulletin 32(3):807-818.

-------, -------, T.L. Shaffer, P.J. Pietz, G.B. Berkey and N.J. Kadrmas. 2006. Nest survival of clay-colored and vesper sparrows in relation to woodland edge in mixed-grass prairies. Journal of Wildlife Management 70(3):691-701.

Grzybowski, J.A. and C.M. Pease. 2005. Renesting determines seasonal fecundity in songbirds: What do we know? What should we assume? The Auk 122(1):280-291.

Hazler, K.R. 2004. Mayfield logistic regression: a practical approach for analysis of nest survival. The Auk 121(3):707-716.

Hensler, G.L. and J.D. Nichols. 1981. The Mayfield method of estimating nesting success: a model, estimators and simulation results. Wilson Bulletin 93(1):42-53.

Herkert, J.R. 1994a. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4(3):461-471.

-------. 1994b. Status and habitat selection of the Henslow's sparrow in Illinois. Wilson Bulletin 106(1):35-45.

-------. 1994c. Breeding bird communities of midwestern prairie fragments: The effects of prescribed burning and habitat-area. Natural areas journal 14:128-135.

-------. 1998. Effects of prairie management on grassland birds: Henslow's sparrow. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

-------, D. L. Reinking, D.A. Wiedenfeld, M. Winter, J.L. Zimmerman, W.E. Jensen, E.J. Finck, R. R. Koford, D.H, Wolfe, S.K. Sherrod, M.A. Jenkins, J. Faaborg and S.K. Robinson. 2003. Effects of prairie fragmentation on the nest success of breeding birds in the midcontinental United States. Conservation Biology 17(2):587-594.

-------. 2003. Effects of management practices on grassland birds: Henslow's Sparrow. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/grasbird/hesp/hesp.htm (Version 12DEC2003).

Horn, D.J. and R.R. Koford. 2000. Relation of grassland bird abundance to mowing of Conservation Reserve Program fields in North Dakota. Wildlife Society Bulletin 28(3):653-659.

Howard, M.N., S.K. Skagen and P.L. Kennedy. 2001. Does habitat fragmentation influence nest predation in the shortgrass prairie? Condor 103:530-536.

Hubbard, R.D., D.P. Althoff, K.A. Blecha, B.A. Bruvold and R.D. Japuntich. 2006. Nest site characteristics of eastern meadowlarks and grasshopper sparrows in tallgrass prairie at the Fort Riley military installation, Kansas. Transactions of the Kansas Academy of Science 109(3/4):168-174.

Hughes, J.P., R.J. Robel, K.E. Kemp,and J.L. Zimmerman. 1999. Effects of habitat on dickcissel abundance and nest success in conservation reserve program fields in Kansas. Journal of Wildlife Management 63(2):523-529.

Hull, S.D., R. J. Robel and K.E. Kemp. 1996. Summer avian abundance, invertebrate biomass, and forbs in Kansas CRP. The Prairie Naturalist 28(1):1-12.

-------. 2003. Effects of management practices on grassland birds: Eastern Meadowlark. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Ingold, D.J. 2002. Use of reclaimed stripmine by grassland nesting birds in East-central Ohio. Ohio Journal of Science 102(3):56-62.

James, F.C., C.E. McCulloch, and D.A. Wiedenfeld. 1996. New approaches to the analysis of population trends in land birds. Ecology 77:13-27.

Johnson, C.J., S.E. Nielsen, E.H. Merrill, T.L. McDonald and M.S. Boyce. 2006. Resource selection functions based on use-availability data: theoretical motivation and evaluation methods. Journal of Wildlife Management 70:347-357.

Johnson, D.H. and L.D. Igl. 2001. Area requirements of grassland birds: A regional perspective. The Auk 118(1):24-34.

Johnson, R.G. and S.A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. Journal of Wildlife Management 54:106-111.

Jones, J., P.J. Doran, L.R. Nagy and R.T. Holmes. 2005. Relationship between Mayfield nest-survival and seasonal fecundity: a cautionary note. The Auk 122(1):306-312.

Kershner, E.L., J.W. Walk and R.E. Warner. 2004. Breeding-season decisions, renesting, and annual recundity of female Eastern meadowlarks (Sturnella magna) in Southeastern Illinois. The Auk 121(3):796-805.

Koford, R.R. 1999. Density and fledging success of grassland birds in Conservation Reserve Program fields in North Dakota and west-central Minnesota. Pages 187-195 in P.D. Vickery and J.R. Herkert, editors. Ecology and conservation of grassland birds of the western hemisphere. Studies in Avian Biology 19.

Lawler, J.J. and R.J. O'Connor. 2004. How well do consistently monitored breeding bird survey routes represent the environments of the conterminous United States? The Condor 1006:801-814.

MacKenzie, D.I. 2005. What are the issues with presence-absence data for wildlife managers? Journal of Wildlife Management 69(3):849-860.

Madden, E.M., R.K. Murphy, A.J. Hansen and L. Murray. 2000. Models for guiding management of prairie bird habitat in northwestern North Dakota. American Midland Naturalist 144:377-392.

Manley, P.N., M.D. Schlesinger, J.K. Roth and B. Van Horne. 2005. A field-based evaluation of presence-absence protocol for monitoring ecoregional-scale biodiversity. Journal of Wildlife Management 69(3):960-966.

Martin, T.E. 1995. Avian life history evolution in relation to nest sites, nest predation, and food. Ecological Monographs 65(1):101-127.

Mattice, J.A., D.W. Brauning and D.R. Diefenbach. 2005. Abundance of grassland sparrows on reclaimed surface mines in western Pennsylvania. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.

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

-------. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Monroe, M.S. and Gary Ritchison. 2005. Breeding biology of Henslow's sparrow on reclaimed coal mine grasslands in Kentucky. Journal of Field Ornithology 76(2):143-149.

Ohio Department of Natural Resources, Division of Wildlife. 2007. ODNR, Columbus, Ohio, USA.

O'Leary C.H. and D.W. Nyberg. 2000. Treelines between fields reduce the density of grassland birds. Natural Areas Journal 20:243-249.

Patterson, M.P. and L.B. Best. 1996. Bird abundance and nesting in Iowa CRP fields: the importance of vegetation structure and composition. American Midland Naturalist 135:153-167.

Peak, R.G., F.R. Thompson III, and T.L. Shaffer. 2004. Factors affecting songbird nest survival in riparian forests in a midwestern agricultural landscape. The Auk 121(3):726-737.

Perkins, D.W., P.D. Vickery and W.G. Shriver. 2003. Spatial dynamics of source-sink habitats: Effects on rare grassland birds. Journal of Wildlife Management 67(3):588-599.

Peterjohn, B.G. and J.R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-96. Studies in Avian Biology 19:27-44.

Pietz, P.J. and D.A. Granfors. 2000a. White-tailed deer (*Odocoileus virginianus*) predation on grassland songbird nestlings. American Midland Naturalist 144:419-422.

------- and -------. 2000b. Identifying predators and fates of grassland passerine nests using miniature video cameras. Journal of Wildlife Management 64(1):71-87.

Quinn, G.P., and M.J. Keough. 2002. Chapter 16. Multivariate analysis of variance and discriminant analysis. pp. 425-442 in Gerry P. Quinn and Michael J. Keough, editors. Experimental Designs and Data Analysis for Biologists. University Press, Cambridge, United Kingdom.

Ransom, D. and W.E. Pinchak. 2003. Assessing accuracy of a laser rangefinder in estimating grassland bird density. Wildlife Society Bulletin 31(2):460-463.

Renfrew, R.B. and C.A. Ribic. 2002. Influence of topography on density of grassland passerines in pastures. American Midland Naturalist 147:315-325.

------- and -------. 2003. Grassland passerine nest predators near pasture edges identified on videotape. The Auk 120(2):371-383.

-------, ------- and J.L. Nack. 2005. Edge avoidance by nesting grassland birds: A futile strategy in a fragmented landscape. The Auk 122(3):618-636.

Ribic, C.A. and D.W. Sample. 2001. Associations of grassland birds with landscape factors in southern Wisconsin. The American Midland Naturalist 146:105-121.

Robel, R.J., J.N. Briggs, A.D. Dayton and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Rodenhouse, N. L., L. B. Best, R. J. O'Connor, and E. K. Bollinger. 1995. Effects of agricultural practices and farmland structures on Neotropical migratory birds. Pages 269-293 *in* T. E. Martin, and D. M. Finch, editors. Ecology and management of Neotropical migratory birds: a synthesis and review of critical issues. Oxford University Press, New York, New York.

Rosenstock, S.S., D.R. Anderson, K.M. Giesen, T. Leukering and M.F. Carter. 2002. Landbird counting techniques: current practices and an alternative. The Auk 119(1):6-53.

Rotella, J.J., M.L. Taper and A.J. Hansen. 2000. Correcting nesting-success estimates for observer effects: Maximum-likelihood estimates of daily survival rates with reduced bias. The Auk 117(1):92-109.

Rummel S.M. and F.J. Brenner. 2003. Relationships between vegetation and bird populations in reclaimed mine grasslands and native grasslands. Journal of Pennsylvania Academy of Science 76(2/3):56-61.

SAS Institute. 2002. SAS/STAT software, release 9.1. SAS Institute, Cary, North Carolina, USA.

Scheiman, D.M., E.K. Bollinger and D.H. Johnson. 2003. Effects of leafy spurge infestation on grassland birds. Journal of Wildlife Management 67(1):115-121.

Schmidt, K.A. and C.J. Whelan. 1999. Nest placement and mortality: is nest predation a random event in time and space? Condor 101:916-920.

Scott, P.E., T.L. DeVault, R.A. Bajema and S.L. Lima. 2002. Grassland vegetation and bird abundances on reclaimed midwestern coal mines. Wildlife Society Bulletin 30(4):1006-1014.

Shaffer, T.L 2004. A unified approach to analyzing nest success. The Auk 121(2): 526-540.

Shochat, E., M.A. Patten, D.W. Morris, D.L. Reinking, D.H. Wolfe and S.K. Sherrod. 2005. Ecological traps in isodars: Effects of tallgrass prairie management on bird nest success. Oikos 111:159-169.

Skagen, S.K., A.A. Yackel Adams and R. D. Adams. 2005. Nest survival relative to patch size in a highly fragmented shortgrass prairie landscape. Wilson Bulletin 117(1):23-34.

Stanley, T.R. 2004. When should Mayfield model data be discarded? Wilson Bulletin 116(3):267-269.

------- and J.A. Royle. 2005. Estimating site occupancy and abundance using indirect detection indices. Journal of Wildlife Management 69(3):874-883.

Sutter, B. and G. Ritchison. 2005. Effects of grazing on vegetation structure, prey availability, and reproductive success of grasshopper sparrows. Journal of Field Ornithology 76(4):345-351.

Swanson, D.A. 1996. Nesting ecology and nesting habitat requirements of Ohio's grassland-nesting birds: A literature review. Ohio Department of Natural Resources, Division of Wildlife, Ohio Fish and Wildlife Report 13. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/birds/ohionest/ohionest.htm (Version 16JUL97).

Swengel, S.R. and A.B. Swengel. 2001. Relative effects of litter and management on grassland bird abundance in Missouri, USA. Bird Conservation International 11:113-128.

Thomas, D.L. and E.J. Taylor. 2006. Study designs and tests for comparing resource use and availability II. Journal of Wildlife Management 70:324-336.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H., Bishop, J.R.B. and Marques, T.A. 2005. Distance 5.0. Release "x"[1]. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/.

Thompson, F.R. and D.E. Burhans. 2003. Predation of songbird nests differs by predator and between field and forest habitats. Journal of Wildlife Management 67(2):408-416.

Vickery, P.D., M.L. Hunter and J.V. Wells. 1992. Use of new reproductive index to evaluate relationship between habitat quality and breeding success. The Auk 109(4):697-705.

-------, ------- and -------. 1992a. Evidence of incidental nest predation and its effects on nests of grassland birds. Oikos 63:281-288.

-------, ------- and -------. 1992b. Is density an indicator of breeding success? Auk 109:706-710.

-------, ------- and S.M. Melvin. 1994. Effects of habitat area on the distribution of grassland birds in Maine. Conservation Biology 8(4):1087-1097.

-------. 1996. Grasshopper sparrow (*Ammodramus savannarum*). In: Poole A, Gill F, editors. The Birds of North America. No 239. Philadelphia (PA): Acadamy of Natural Science; Washington (DC): American Ornithologits' Union. P 1-5.

------- and J.R. Herkert. 2001. Recent advances in grassland bird research: Where do we go from here? The Auk 118(1):11-15.

Walk, J.W. and R.E. Warner. 1999. Effects of habitat are on the occurrence of grassland birds in Illinois. The American Midland Naturalist 141:339-344.

------- and -------. 2000. Grassland management for the conservation of songbirds in the Midwestern USA. Biological Conservation 94(2000):165-172.

Warren, K.A. and J.T. Anderson. 2005. Grassland songbird nest-site selection and response to mowing in West Virginia. Wildlife Society Bulletin 33(1):285-292.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120-138.

Whitmore, R.C. and G.A. Hall. 1978. The response of passerine species to a new resource: reclaimed surface mines in West Virginia. American Birds 32(1):6-9.

-------. 1980. Reclaimed surface mines as avian habitat islands in the eastern forest. American Birds 34(1):13-14.

------- 1981. Structural characteristics of grasshopper sparrow habitat. Journal of Wildlife Management 45(3):811-814.

Wiens, J.A. 1985. Habitat selection in variable environments: Shrub-steppe birds. Pages 227-251 in Habitat selection in birds (M.L. Cody, Ed.). Academic Press, New York.

Winter, M. 1999. Nesting biology of dickcissels and Henslow's sparrows in southwestern Missouri prairie fragments. Wilson Bulletin 111(4):515-527.

------- and J. Faaborg, 1999. Patterns of area sensitivity in grassland-nesting birds. Conservation Biology 13(6):1424-1436.

-------, D.H. Johnson and J. Faaborg. 2000. Evidence for edge effects on multiple levels in tallgrass prairie. The Condor 102:256-266.

-------, ------, J.A. Shaffer and W.D. Svedarsky. 2004. Nesting biology of three grassland passerines in the Northern tallgrass prairie. Wilson Bulletin 116(3):211-223.

-------, D.H. Johnson and J.A.Shaffer. 2005. Variability in vegetation effects on density and nesting success of grassland birds. Journal of Wildlife Management 69(1):185-197.

-------, -------, -------, T.M. Donovan and W.D. Svedarsky. 2006. Patch size and landscape effects on density and nesting success of grassland birds. Journal of Wildlife Management 70(1):158-172.

With, K.A. 1994. The hazards of nesting near shrubs for a grassland bird, the McCowans longspur. The Condor 96:1009-1019.

------- and A.W. King. 2001. Analysis of landscape sources and sinks: The effect of spatial pattern on avian demography. Biological Conservation 100(2001):75-88.

Wray, T. II, and R.C. Whitmore. 1979. Effects of vegetation on nesting success of vesper sparrows. Auk 96:802-805.

-------, K.A. Strait and R.C. Whitmore. 1982. Reproductive success of grassland sparrows on a reclaimed surface mine in West Virginia. Auk 99:157-164.

Zimmerling, J.R., G.E. Craigie and A.E. Robinson. 2004. A comparison of techniques for marking passerine nestlings. Wilson Bulletin 116(3):240-245.

Zimmerman, J.L. 1984. Nest predation and its relationship to habitat and nest density in dickcissels. Condor 86:68-72.

-------. 1988. Breeding season habitat selection by the Henslow's sparrow (*Ammodramus henslowii)* in Kansas. Wilson Bulletin 100(1):17-24.

Zuckerberg, B. and P.D. Vickery. 2006. Effects of mowing and burning on shrubland and grassland birds on Nantucket Island, Massachusetts. The Wilson Journal of Ornithology 118(3):353-363.