To the Graduate Council:

I am submitting herewith a dissertation written by James J. Giocomo entitled "Conservation of Grassland Bird Populations on Military Installations in the Eastern United States with Special Emphasis on Fort Campbell Army Base, Kentucky." I have examined the final paper copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Natural Resources.

David Buehler, Major Professor

We have read this dissertation and recommend its acceptance:

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Vice Chancellor and Dean of Graduate Studies

CONSERVATION OF GRASSLAND BIRD POPULATIONS ON MILITARY INSTALLATIONS IN THE EASTERN UNITED STATES WITH SPECIAL EMPHASIS ON FORT CAMPBELL ARMY BASE, KENTUCKY

A Dissertation

Presented for the

Doctor of Philosophy degree

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James J. Giocomo

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ABSTRACT

Grassland bird populations have decline significantly over the past 30 years because of the dramatic decrease of native grasslands through clearing of non-forested land for agriculture, and discontinued use of fire. It is imperative to understand the distribution and productivity of these birds and the potential for grassland management to enhance these declining populations, especially in land areas where the landuses may be compatible with grassland bird conservation.

This study was conducted to provide needed basic life history and nest site habitat use information as well as information about populations and potential region-wide habitat availability to enhance current and future land management planning. This study focused on Grasshopper Sparrows (*Ammodramus savannarum*), Henslow's Sparrows (*Ammodramus henslowii*), Field Sparrows (*Spizella pusillia*), Dickcissels (*Spiza Americana*), and Eastern Meadowlarks (*Sturnella magna*)The specific objectives of this project were: 1) to provide basic life history parameters for five species of conservation concern at Fort Campbell Army Base, Kentucky, over a five-year period (1999-2003; Chapter 2); 2) to use the basic life history parameters to examine population viability grassland bird populations at Fort Campbell, and examine the implications of management activities within the breeding season on these population viabilities (Chapter 3); 3) to examine nest site habitat selection of the five focal species (Chapter 4); and 4) to examine the potential for US Department of Defense installations in the eastern US to provide grassland habitat for breeding and wintering grassland bird populations (Chapter 5). Finally, in Chapter 6, I discuss the management implications developed from the results of this project.

A total of 811 nests of target species were monitored between 1999-2003, and nest success ranged between 14.7% and 33.8% for each species. Most nest failures were attributed to predation. Brown-Headed Cowbird (*Molothrus ater*) nest parasitism rates were very low for all species. Clutch size decreased during the nesting season for Dickcissels, Grasshopper Sparrows, and Field Sparrows. Nesting phenology suggests the possibility of at least double-brooding for all five species in this study. Eastern Meadowlarks initiated nests earliest, mid-April. Field Sparrow nest initiation started the next week, followed by Henslow's Sparrows the next week, and then Grasshopper Sparrows. Dickcissels were consistently the last species to arrive and began nesting during the second week of May. For all species, nest initiation continued through mid-July, and nesting activity continued through August. This study provided the biological parameters necessary to create population models to evaluate population trajectories and alternative management plans.

I constructed a simple population model incorporating typical demographic parameters collected in the field supplemented by values found in the literature for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Eastern Meadowlarks and Field Sparrows. Species-specific parameters collected in the field included clutch size, nesting phenology, Mayfield (1975) nesting success, and number of fledglings per successful nest. This analysis produced population viability plots with curves representing the threshold between source and sink populations. I also modeled the effects of breeding season length and hay management within the nesting season on the number of possible nesting attempts to examine the population trajectories of Grasshopper Sparrows and Henslow's Sparrows.

For Henslow's Sparrows (triple-brooded, 4 attempts), the basic model using the mean estimates of nest success and young per successful nest for all years combined indicated the population could not sustain itself without immigration. The estimates of nesting success and young produced per successful nest for 2 of the 5 years (2001 and 2003) indicated source populations with 4 nesting attempts (A) and 3 years (1999, 2000 and 2002) indicated sink populations. For Grasshopper Sparrows (triple-brooded) population viability for 3 of the 5 years (2000, 2002 and 2003) indicated source populations with 4 nesting attempts (A) and 2 years (1999 and 2001) indicated sink populations.

For Dickcissels (single-brooded), Field Sparrows (double-brooded), and Eastern Meadowlarks (double-brooded), the mean estimates of nest success and young per successful nest for all years combined were too low to indicate any source populations under the conditions of this model. For Dickcissels, the estimates of nest success and young per successful nest for any single year were also too low to indicate any source populations under the conditions of this model.

For Grasshopper Sparrows, the mowing model indicated "No mowing" and mowing after 1 August allowed for the possibility of a source population with the overall estimates of nest success and young produced per successful nest. Point-estimates for 1999, 2001, and 2002 indicated source populations only with no mowing. Mowing on 15 June or after 15 July allowed the Grasshopper Sparrow population in 2000 to be a source, whereas mowing 15 May, 1 June, and 1 July caused sink populations under the model assumptions. In 2003, the nesting success rate and the number of young produced per successful nest were great enough to compensate for mowing after 15 Jul with maximum breeding effort. For Henslow's Sparrows, mowing before 15 July indicated sink populations in all years (Figure 3-15). The "no mowing" threshold did not allow a possible source population for the nesting success and young per successful nest estimates for all years combined with maximum breeding effort, but the variation indicated "no mowing" may allow for a source population. In 1999, 2000, and 2002, under conditions for maximum breeding output the estimates indicated a sink population even with no mowing. Year 2003 was a source population only with "no mowing." Mowing after 1 August allowed the 2001 population to be a source.

I examined habitat differences between selected nest sites and available habitats (univariate analysis), and examined microhabitat selection (niche) relationships among the five target species (multivariate analysis). Based on the univariate analysis, litter depth was significantly greater at the nest sites for all species than at the random sites. The random sites also had greater bare ground cover and lower grass height than all species except Grasshopper Sparrows. Henslow's Sparrow nest sites had the greatest warm-season grass cover and Eastern Meadowlark nest sites had the greatest cool-season grass cover. Field Sparrow nest sites had the greatest cover in woody vegetation. Based on the multivariate analysis, Field Sparrows and Dickcissels were using similar habitats; the discriminant function analysis had difficulty separating the nest sites of these species. The random vegetation plots, representing available microhabitat at Fort Campbell, were centrally located when plotted using the discriminant function coefficients calculated with the vegetation measurements at the nest sites of the five grassland species. Thus available habitat, on average, had intermediate litter depth and vertical cover, and relatively high forb cover and low warm-season grass cover. The random locations also occupied a relatively large area in the multivariate space, and extended well beyond the area of overlap of the five species along the second discriminant function axis. This result demonstrated that available habitat included unsuitable areas of grassland habitat for these five species. In a large portion of the random areas, burning occurred annually, which was too frequent to create suitable habitat for these grassland species of high conservation concern.

Finally, I used a course-filter analysis to determine which military installations in the eastern United States have the potential to provide significant grassland habitat by identifying military installations that contain large (>40 ha) grassland patches in the eastern US, identifying areas where open habitats (e.g., grassland, hayfields, agriculture) occupy a significant portion of the landscape, and overlaying the areas of high diversity for obligate grassland birds during the breeding and wintering seasons in the eastern US. I also conducted a buffer analysis to determine if the extent of grassland within the military installation was representative of grassland habitat within the surrounding landscape, and determine how much potential the surrounding landscape (within 30 km) had for grassland restoration.

Of the 186 land areas in the eastern US managed by the DOD, 45 contained at least one large (>40 ha) patch of grassland, including 1 port managed by the Army Corps of Engineers, 23 Army, 3 Air Force, 3 Marine, 11 Navy, and 4 National Guard installations. Military installations with significant grassland habitat were found throughout the eastern US providing at least 65,000 ha of grassland in patches greater than 40 ha. Most of the selected military installations were located in the southern US within 300 km of the coast, and could be especially important for wintering habitat.

Military installations could have major positive impacts on the declining populations of bird and other wildlife species, which depend on frequent habitat disturbance to maintain early-successional habitats like grasslands. Because many military activities require or cause the maintenance of large areas of open, grassy or shrubby habitats, tailoring habitat management to enhance grassland populations would not require major changes in existing management plans. The location of some of the larger eastern US military installations in landscapes with relatively large amounts of open habitats may also serve as a refuge for many grassland species displaced by modern, "clean" farming practices. With a few considerations to the type and timing of disturbances, military installations could serve as a model for other federal and private land management for the conservation of grassland habitats, and may even serve as a control sites for comparison with grassland restoration efforts.

Military lands comprise over 10-million ha of land in the US and could provide unique management opportunities to provide breeding and wintering habitat for birds. Conservation strategies for grassland species could be developed to take advantage of the unique need for open habitats for military training, especially in the eastern US. Land managers need to understand although grassland habitat used by different species superficially may seem very similar, different management actions will benefit different sets of species and may negatively impact others. Local habitat conditions can influence not only the presence of grassland birds but also other life history parameters like the number of successful broods and the number of nesting attempts. Planning across a temporal gradient is needed to provide suitable habitat for all species of concern.

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CHAPTER 1

INTRODUCTION

Birds that use early-successional, ephemeral habitats, such as grasslands, for breeding areas have experienced greater population declines than any other group of birds monitored by the Breeding Bird Survey (BBS; Askins 1993, Peterjohn and Sauer 1999). According to the BBS results of North America, 10 species of open grassland and savanna birds decreased in abundance whereas only 4 species increased between 1966 and 2001 in the eastern United States (US; Sauer et al. 2004). Reported population declines have been attributed to the dramatic decrease of native grasslands during the 20th century because of conversion of land for agriculture or development and discontinued use of prescribed fire (Herkert et al. 1996).

It remains largely unknown what habitat conditions are needed to sustain viable populations of these declining species. Fort Campbell Army Base on the state border between Kentucky and Tennessee has extensive grasslands and is an excellent place to study early-successional birds because it has sustained an almost complete suite of grassland species (Moss 2001). Many bird species of management concern occur at the installation, including Henslow's Sparrows, Grasshopper Sparrows, Upland Sandpipers, Dickcissels, Bachman's Sparrows, Horned Larks, Bobolinks, Sedge Wrens, Eastern Meadowlarks, Vesper Sparrows, Lark Sparrows, Savannah Sparrows and Northern Harriers (see Table 5-1 for scientific names; all Table and Figures are found in the Appendix). I focused most of my work on Henslow's

Sparrow, Grasshopper Sparrow, Field Sparrow, Eastern Meadowlark and Dickcissel populations at Fort Campbell because a sufficient number of nests could be found and monitored each year in the grassland and shrub-scrub habitats on the base.

All 5 focal species have breeding ranges that extend from the east coast of the United States (US) to the Great Plains in the west with the core of their breeding ranges south of the US-Canada border. These species share similar habitats during the breeding season, but have different strategies for surviving winter months. All 5 species are migratory in some portion of their range. Eastern Meadowlarks are partial migrants; the extreme northern populations move south during the winter months. Henslow's Sparrow, Grasshopper Sparrow and Field Sparrow are short-distance migrants, spending their winters in the southeastern US and northern Mexico. The Dickcissel is one of the few Neotropical migrant grassland songbirds that spend the winter months concentrated in the llanos region of central Venezuela (Temple 2002).

A habitat use gradient exists from the short grass conditions used by the Grasshopper Sparrow (Vickery 1996) and Eastern Meadowlark (Lanyon 1995), to the grass-dominated habitat with relatively tall, dense residual vegetation and a thick litter layer used by the Henslow's Sparrows (Herkert et al. 2002), to the old-field and shrub habitat used by the Dickcissels (Temple 2002) and Field Sparrows (Carey et al. 1994). Grasshopper Sparrows and Henslow's Sparrows tend to avoid fields with many saplings, but Field Sparrows and Dickcissels use saplings for nesting substrate and singing perches. Grasshopper Sparrows can be found breeding in recently burned or mowed fields, but Henslow's Sparrows tend to prefer older (2-3 years post-burn) burned fields (Moss 2001).

Henslow's Sparrow populations have declined about 91% over the last 30 years, based on BBS data (Peterjohn et al. 1994). Henslow's Sparrow has been listed as a species of concern on many federal and state lists. In 1991, Henslow's Sparrow was listed by the US Fish and Wildlife Service (USFWS) as a candidate species (C-2) for possible Endangered Species Act protection (US Fish and Wildlife Service 1996). In 1997, the candidate list was removed from use, and the Henslow's Sparrow was listed as a species of management concern by the USFWS. Currently, Henslow's Sparrow is listed on the Partners in Flight Watch List as a species of high management concern (Pashley et al. 2000). Until a relatively large breeding population was found on Fort Campbell Army Base, no confirmed Henslow's Sparrow breeding record existed for Tennessee (Nicholson 1997).

Grasshopper Sparrow populations also have declined substantially, with a 71% decline reported from 1966-1996, based on BBS data (Vickery 1996). Annual population declines vary regionally from 5.9%/year decline in abundance in the eastern US to 2.9%/year decline in central US (Vickery 1996). In Tennessee, Grasshopper Sparrows showed a 10.9%/year decline from 1966 to 1979, but they have increased (4.3%/year) since 1979 (Sauer et al. 2004). Nicholson (1997) suggested this reported recent increase may be attributed to increased sampling of rural areas during the BBS in the past 15 years or the conversion of cropland to grassland through the US Department of Agriculture Conservation Reserve Program.

Dickcissels also have undergone substantial population in population abundance since 1966. According to BBS data, Dickcissels have declined >30% between 1966 and 1978, but since 1979, populations have leveled off at approximately two-thirds the 1966 level (Temple 2002). In Tennessee, Dickcissels concentrate in the western part of the state in areas of extensive agriculture (Nicholson 1997), and their populations have shown a similar pattern to Grasshopper Sparrows. Dickcissels increased in abundance 2.5%/year throughout the state, with a decrease of 7.3%/year between 1966 and 1979, and then an increase since 1979 of 3.7%/year (Sauer et al. 2004).

Field Sparrows and Eastern Meadowlarks have shown similar population declines over the past 3 decades. Field Sparrow populations have decreased nationally 3.4% per year between 1966-1993 (Peterjohn et al. 1994). In Tennessee, Field Sparrows are found throughout the state but have been declining by 2.1%/year since 1966 (Nicholson 1997, Sauer et al. 2004). Eastern Meadowlarks have shown similar population declines (-2.9%/year) throughout their range and within Tennessee (Sauer et al. 2004).

Breeding Grasshopper Sparrows, Eastern Meadowlarks, and Dickcissels are usually found in large (>40 ha) fields. Breeding Henslow's Sparrows are usually found in large fields or in small fields near large fields of suitable habitat (Zimmerman 1988, Herkert et al. 2002). Field Sparrows are found in most open habitats and do not seem to be affected by size of the field although they avoid human habitation (Carey et al. 1994).

All 5 species have been affected by the changes in land use and land management that has reduced the amount and quality of available habitat. Since the early 1900's, farmers converted native grasslands to row crops and cool season forages for livestock, which reduced the quality of nesting habitat. Successional transformation from fire suppression is another threat to the maintenance of grassland habitats. In eastern grasslands, succession from grassland habitats to shrub and forest habitats can occur relatively fast, within 1 or 2 decades (DeSelm and Murdock 1993). If regular disturbance is not introduced to open habitats at least every few years through burning, mowing, grazing, or use of herbicides, trees will quickly overtake an area and make it unsuitable for use by grassland birds.

Military lands in the eastern US are an exception to the trend in loss of native grasslands. Some of these installations have maintained considerable acreage in native grasses to facilitate military training through the use of prescribed burning and mowing. Fort Campbell (a 41,842-ha U.S. Army Base), for example, has maintained approximately 10,000 ha of grasslands, representing 1 of the largest remnant grasslands east of the Mississippi River (Moss 2001). Other military installations with land areas currently providing early-successional habitats include Fort Knox in Kentucky, Fort Bragg in North Carolina, and Fort Drum in New York (Eberly 2002). Each of these installations could increase native grassland area through restoration if suitable management strategies are developed and employed.

There is an opportunity to provide training needs for the military and habitat needs for grassland birds simultaneously on Department of Defense (DOD) managed lands. Military lands comprise over 10-million ha in the US, providing unique management opportunities for breeding and wintering habitat for birds (Eberly 2000). For example, military exercises at Fort Campbell (including airborne training into open "drop zones," ground-based infantry and light-mechanized training, and various artillery ranges) require large areas of open lands. Native grasslands provide ideal conditions for such training exercises because the grasslands are durable, provide great visibility, and can be managed cheaply and effectively using fire. Thus, conditions suitable for military training activities could also provide suitable habitat for breeding and wintering grassland birds. Natural resource management may be integrated with the military mission to provide open habitats for military training and contribute to grassland conservation goals.

In the face of population declines and loss of habitat, it is imperative to understand not only the distribution of early-successional bird species across the eastern US, but the productivity of early-successional habitats. Many bird studies report densities and diversity of bird species, but density may not indicate habitat quality or breeding success (Van Horne 1983, Vickery et al. 1992*a*). Few studies collect the demographic information needed to understand the productivity of declining populations of grassland birds (i.e., nesting success, clutch size, return rates).

Most studies of nesting birds focus on 1 or 2 species. During this study, I had the opportunity to look at nesting habitat and nesting success of 5 species within the same community (grassland), in the same landscape (Fort Campbell), over the same time period (2001-2003). I was also able to examine the vegetation structure around nests to study microhabitat use of these 5 species.

Because of the great cost and difficulty of finding bird nests, basic demographic information for most bird species is difficult to obtain and usually provides information over a relatively short period (2-3 years). There is a need for demographic information over longer periods to estimate parameters needed to create reliable population models useful to decision makers. Using the natural history information collected over a 5-year period, I investigated the influences of nesting phenology and the timing of land management practices on the potential breeding success of 2 high conservation priority grassland species, Henslow's Sparrow and Grasshopper Sparrow. This analysis allowed me to examine the possible implications of activities such as early-summer mowing dates, which can cut nesting seasons short.

Finally, the DOD manages over 10-million ha in the US, and there is a need to understand how DOD installations can contribute to the region-wide conservation of these vulnerable bird populations. Many DOD installations "...exist as oases of habitat in the midst of [habitat] fragmentation and developed landscapes (Eberly 2002)." Security concerns and safety buffers around military installations allow for the maintenance of large areas of uninhabited land adjacent to active training areas. Basic landscape-scale information about potential breeding and wintering habitat use of military bases by grassland birds is needed to provide a starting point to begin managing these bird populations. Therefore, I examined the potential for DOD lands in the eastern US to provide breeding and wintering habitat for early-successional species.

This study was conducted to provide basic information on life history, nest site habitat selection, population viability, and region-wide habitat availability to enhance current and future land management planning. The specific objectives of my study were to:

1) Estimate basic life history parameters for 5 grassland species of conservation concern (Henslow's Sparrow, Grasshopper Sparrow, Field Sparrow, Dickcissel and Eastern Meadowlark) at Fort Campbell over a 5-year period (1999-2003) (Chapter 2);
2) Use life history parameters to examine population viability of the focal grassland populations at Fort Campbell, and examine the effects of grassland management scenarios during the breeding season on the population viabilities (Chapter 3);
3) Examine nest site selection of the 5 focal species (Chapter 4); and
4) Examine the potential for DOD installations in the eastern US to provide grassland habitat for breeding and wintering grassland bird populations (Chapter 5).

Finally, in Chapter 6, I discuss the management implications developed from the results of this project.

CHAPTER 2

NESTING BIOLOGY OF HENSLOW'S SPARROWS, GRASSHOPPER SPARROWS, FIELD SPARROWS, DICKCISSELS, AND EASTERN MEADOWLARKS AT FORT CAMPBELL ARMY BASE, KENTUCKY

Introduction

Grassland bird species have experienced greater population declines than any other group of birds monitored by the Breeding Bird Survey (BBS) of North America (Askins 1993, Peterjohn and Sauer 1999). Between 1966 and 2001, 10 species of open grassland and savanna birds decreased in abundance while only 4 species increased in the eastern US (Sauer et al. 2004). Population declines have been attributed to the dramatic decrease of native grasslands during the 20th century because of clearing of non-forested land for agriculture or development, and discontinued use of prescribed fire (Herkert et al. 1996). Military lands in the eastern US are one exception to the trend in loss of native grasslands. Some of these installations have maintained large areas of native grasses or other grasslands to facilitate military training through the use of prescribed burning and mowing. Fort Campbell, for example is a 42,000-ha US Army Base that includes 10,000 ha of native grasses (Moss 2001). Other military installations have large land areas currently providing early-successional habitats including Fort Knox in Kentucky, Fort Bragg in North Carolina and Fort Drum in New York (Eberly 2002). Each installation could have potential for even more native grassland restoration if suitable management strategies are developed.

In the face of grassland bird population declines and loss of grassland habitats, it is imperative to understand not only the distribution of these early-successional species in the eastern US, but the productivity of different early-successional habitats. Many bird studies report densities and diversity of bird species, but these measures may be a misleading indicator of habitat quality or breeding success (Van Horne 1983, Vickery et al. 1992*a*). Few studies have collected the detailed demographic information needed to understand productivity within populations of these declining species (i.e. nesting success, clutch size, return rates). Many grassland bird nests are notoriously difficult to find and monitor, and relatively few studies have attempted to monitor more than 1 or 2 species for more than more than just a few years (see Winter 1998). To understand how different management strategies impact bird populations on military installations, managers need baseline demographic information. To provide this demographic information, I monitored Henslow's Sparrow, Grasshopper Sparrow, Field Sparrow, Eastern Meadowlark and Dickcissel nests at Fort Campbell from 1999 through 2003. The objectives of this study were to provide basic annual, species-specific demographic information including, nest success, clutch size, young produced per successful nest, causes for nest failure, nest parasitism rates, timing of nest initiation, and seasonal clutch size variation, and to compare these basic demographic rates among years within species and among species.

Methods

Study Area- The study was conducted on Fort Campbell Army Base, Kentucky, located on the Kentucky-Tennessee state border. Fort Campbell contains some of the largest remaining blocks of native prairie "barrens" east of the Mississippi River. Barrens were grass-dominated, treeless areas occurring on the hilly, karst topography of west-central Kentucky and northwestern Tennessee (Chester et al. 1997). Historically, these grasslands were maintained primarily through regular burning by native Americans (Delcourt et al. 1993). Grasslands on Fort Campbell contain native-warm season grasses including little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), indiangrass (*Sorghastrum nutans*), and broomsedge (*Andropogon virginicus*). Approximately 70% of the base is covered in oak (*Quercus sp.*)-hickory (*Carya sp.*) forests, and there are several leased agricultural fields (cool-season grass, millet, and soybeans) interspersed among the grasslands (D. Moss, Fort Campbell contract biologist, personal communication).

Nest Searching- Nest searching was concentrated primarily on Henslow's Sparrow, Grasshopper Sparrow, Dickcissel, Eastern Meadowlark, and Field Sparrow nests. Nests of all species found incidentally while searching for target species were also monitored. Fields with appropriate grassland habitat were systematically searched for males of target species defending territories or exhibiting nesting behavior between 1 May and 30 July. Behavioral cues, such as birds flushing close to an observer, chipping, carrying nesting material, or carrying food or fecal sacs, were used to locate nest sites.

Once nests were located, a flag was placed at least 5 m from the nest, and detailed maps of the nest locations were drawn. Nests were monitored every 2-4 days to determine nest fate. I calculated apparent yearly nest success (# successful nests/total nests) and Mayfield (1961, 1975) nest success and standard error (Johnson 1979) for individual species where sample sizes were sufficient (n > 9, Johnson 1979). Mayfield (1961, 1975) nest success was calculated to account for the different nest exposure times, because many nests were not found at the beginning of the incubation stage.

Nest success estimates- Successful nests were defined as any nest fledging at least 1 host young. Nests with no exposure time (e.g., induced fledging when the nest was found) and unknown nest fates were not included in the nest success calculations. Several nests were found presumably after young successfully fledged and were not included in the analysis or the total number of nests found. I calculated the probability of nesting success for 5 nesting periods, including egg laying, incubation, nestling, incubation and nestling combined, and all periods. The combined probability of nesting success during the incubation and nestling stages was calculated to facilitate comparison with studies that did not explicitly include the egg laying stage.

For the 5 target species, 1 egg is laid per day until the clutch is completed and incubation starts with the laying of the last egg (Bent 1968). I rounded the mean clutch size to the nearest half-egg for the mean number of days during the laying stage for each species, and I used values from the literature for mean number of days in the period for the incubation and nestling stage (Ehrlich et al. 1988). The number of days in the incubation and nestling stages combined and all stages combined were the sum of the appropriate number of days in the respective component stages. I used these mean period lengths as exponents to calculate the probability of nest success from the daily survival probabilities for each species. To allow for comparisons, nest success probabilities among years, nesting periods, and species was calculated using means plus or minus 2 standard errors (~95% confidence interval), as suggested by Johnson (1979).

Seasonal analysis- Nest incubation initiation dates were estimated to the week incubation started (forward dating for nests that failed during egg laying, back dating for nests found during incubation or brooding). The mean (and standard error) number of nests initiated per week was calculated by averaging the number of nests initiated during each week per year. Mean clutch size per week was calculated similarly. I used linear regression to examine the relationship between clutch size and nest initiation dates. The level of significance was set at $\alpha = 0.05$.

Results

Basic demographic information- A total of 811 nests of target species were monitored between 1999-2003, and apparent nest success ranged between 42% and 64% for each species (Table 2-1). Most nest failures were attributed to predation. Based on the numerous observations of snakes in the nests and the lack of disturbance of the nest material at empty nests, the primary predators of nests appeared to be snakes. Other causes of nest failures included abandoned nests, hay mowing and harvesting, military training activities, and abandonment because of Brown-Headed Cowbird (*Molothrus ater*) parasitism. Brown-headed Cowbird nest parasitism was observed in 4 nests (1 Henslow's Sparrow and 3 Field Sparrows; Table 2-1). Average clutch size ranged from 3.6 eggs per nest for Field Sparrows to 4.6 eggs per nest for Eastern Meadowlarks, and hatching success ranged from 90.3% for Dickcissels to 95.9% for Field Sparrows (Table 2-1). Average young fledged per nest ranged from 1.6-2.6, and the average number of young per successful nest ranged from 3.6 for Field Sparrows to 4.1 for Grasshopper Sparrows (Table 2-1).

Nesting Phenology- Eastern Meadowlarks initiated nests earliest with nest incubation starting during the week of 10-16 April (Figure 2-1d). Field Sparrow nest initiation started next (17-23 April, Figure 2-1e), and was followed by Henslow's Sparrows (24-30 April, Figure 2-1a), and then Grasshopper Sparrows (1-7 May, Figure 2-1b). Dickcissels consistently were the last species to arrive and began nesting during the second week of May (Figure 2-1c). For all species, nest initiation continued through mid-July, and nesting activity continued through August. Based on visual inspection, Henslow's Sparrows, Grasshopper Sparrows, and Dickcissels exhibited a distribution indicating these species could be at least double brooded at Fort Campbell (Figure 2-1a, b, c; Winter 1998). For Field Sparrows and Eastern Meadowlarks, the length of the nesting season was long enough to allow for the possibility of double-brooding, but they did not show similar patterns (Figure 2-1d,e). In the case of Field Sparrows, low nesting success (see below) may mask a pattern (Winter 1998).

Clutch size- Clutch size did not vary during the nesting season for Henslow's Sparrows ($F = 0.13$, $df = 1$, $P = 0.71$) and Eastern Meadowlark ($F = 0.88$, $df = 1$, $P = 0.35$) (Figure 2-2a, d). Clutch size decreased during the nesting season for Dickcissels ($F = 38.33$, $df = 1$, $P < 0.001$), Grasshopper Sparrows ($F = 4.97$, $df = 1$, $P = 0.03$), and Field Sparrows ($F = 30.50$, $df = 1$, $P < 0.001$) (Figure 2-2b, c, e). On average, Dickcissel clutch size reduced by 1 egg every 50 days, and Grasshopper Sparrow and Field Sparrow clutch sizes reduced by 1 egg every 123 and 102 days, respectively.

Nesting success- In most cases, Mayfield nesting success did not differ between laying, incubation, or nestling stages within or between years (Table 2-2, 2-3, 2-4, 2-5, and 2-6). In 2001, Dickcissel nesting success during the incubation stage was lower than nesting success during the nestling stage (Table 2-4). The same was true for Field Sparrow nesting success in 2002 (Table 2-6). Generally, nesting success was greatest during the laying stage and least during the incubation stage. Nesting success among years did not differ for any species. Combining nests found in all years, nesting success for Field Sparrows was lower than Grasshopper Sparrows, probably because of the difference in nest success during the incubation stage (Table 2-7).

Discussion

Overall nesting success rates were in the middle of the range of values previously reported for Henslow's Sparrows (27% Mayfield; reported range 7%-46%), Dickcissels (26% Mayfield; reported range 12-50%), and Eastern Meadowlark (22% Mayfield; reported range 10-25%) (Table 2-8). Grasshopper Sparrow nesting success rate was near the high end of previously reported values (41% Mayfield; reported range 7-52%). Most of the nests for these 4 species were found in the largest fields (> 400 ha) on the base, which may indicate these larger fields provide quality habitat for these grassland species. Field Sparrow nesting success (20 % Mayfield; reported range 21-47%) was lower at Fort Campbell than most previously reported values. Low nesting success may be related to the ubiquitous distribution of monitored nests in grassland fields, including some fields as small as 2 ha. Smaller fields had more habitat features that might attract potential predators (e.g., small trees for perch sites), and possibly accounting for reduced nesting success rates (Herkert 1994).

Nesting success rates in the literature do not include the egg laying stage. This study is one of only a few studies that report a daily survival rate of nests during the laying stage explicitly. Because incubation usually starts sometime between laying the penultimate egg and up to a few days after the last egg is laid, the egg laying stage should be treated separately from the incubation stage. Eggs usually are less conspicuous when the female is on the nest during incubation, reducing the probability predators will find the nest through visual cues. Thus, exposed eggs during the laying stage may be more vulnerable to predators such as raccoons (*Pycron lotor*) or Blue Jays (*Cyanocitta cristata*). Conversely, not incubating eggs during the laying stage may reduce the chances of loss because of predators that use heat to detect nests, like some snakes, because the temperature of the eggs would be closer to the temperature of the surrounding habitat. In either case, considering the laying stage separately would lower nesting success rates unless the success during the laying stage was 100%.

Henslow's Sparrow, Grasshopper Sparrow, Dickcissel, and Eastern Meadowlark clutch sizes were near the high end of the range of previously reported clutch sizes (Lanyon 1995, Vickery 1996, Herkert et al. 2002, Temple 2002), whereas Field Sparrow average clutch size was lower than some of the previously reported values (Carey et al. 1994; Table 2-8). At least 90% of all eggs hatched if they were not depredated during incubation. It was common to find ≤ 2 eggs left in the nest after the nestlings fledged. On several occasions, nests were found with an egg in the nest, presumably after the nest successfully fledged young; many of these nests were of Henslow's Sparrows not included in this analysis.

Brown-headed Cowbird parasitism rates were very low at Fort Campbell for these grassland species, but they were within the range of reported parasitism rates for each species. The lack of Dickcissel nest parasitism was particularly noteworthy when compared with other areas, but was consistent with records from Tennessee (Nicholson 1997). My parasitism rates probably were low because most of the nests were found in large grassland fields (>100 ha and up to 600 ha) far from forest edges or other tall woody perch sites, except Field Sparrow nests, which were found in a large range of field sizes. It has also been suggested that nest parasitism rates are related to the proximity of the songbird population to the highest density areas of the Brown-headed Cowbird (Basili et al. 1997, Winter et al. 2004). Fort Campbell is well outside of the highest density areas for Brown-headed Cowbird populations (Sauer et al. 2004). Finally, Morris and Thompson (1998) found Brown-headed Cowbirds were most associated with grazed pastures, regardless of grass height. At Fort Campbell, there is no grazing and cowbird densities would be expected to be low.

Nesting phenology suggests the possibility of multiple-brooding for all 5 species in this study. Compared with forest birds, grassland birds have relatively low nesting success, which is compensated for by several nesting attempts within a single season (Wiens 1969, Martin 1995, Winter 1999). Henslow's Sparrows, Grasshopper Sparrows, and Dickcissels exhibited one sharp peak in nest initiation the second week after nesting began, and a second, less-apparent peak in nest initiation about 40-45 days later, consistent with the expected time between first and second successful nest initiations. Henslow's Sparrows and Grasshopper Sparrows generally are considered at least double brooded, although 3 pairs from a color-banded population in Kentucky had 3 successful broods in 1 season (Monroe 2001). Some of the nests initiated in July could represent the third successful brood for some of the nesting pairs. The amount of time from the start of the nesting season (early May) and the last nests (early August) allows for the possibility of 3 broods given that the amount of time to finish a complete nest cycle is less than 30 days including nest building (Ehrlich 1988).

Dickcissels, on the other hand, are considered single brooded, or may move to a different location to re-nest (Winter 1998), which could explain why Dickcissels at Fort Campbell exhibited a weak second peak of nest initiation. Field Sparrows and

Eastern Meadowlarks did not show a clear pattern, but the recorded nesting season was longer than the other species in this study. Nest success of Field Sparrow was very low (14.7%), which could mask any patterns in subsequent nest initiation (Winter 1999). Eastern Meadowlarks may wait for a longer time period between successive nests than expected. Kershner et al. (2004) radio-tracked female Eastern Meadowlarks in Illinois and found that although they had time in the season to nest more than once, many birds chose not to re-nest in the same territory. This behavior would spread the distribution of nesting attempts across the season, and could account for the distribution of Eastern Meadowlark nest initiation in this study.

Clutch size was not related to time during the nesting season for Henslow's Sparrows and Eastern Meadowlark. Winter (1998) was the first to report this lack of relationship between clutch size and time in nesting season for Henslow's Sparrow. Clutch size decreased during the nesting season for Dickcissels, Grasshopper Sparrows, and Field Sparrows. On average, if these species were double brooded, the second brood would be expected to be reduced by about 1 egg for Dickcissels, and about 0.5 eggs for Grasshopper Sparrows and Field Sparrows.

Although open fields at Fort Campbell are used extensively for large army training exercises throughout the breeding season of grassland birds, most (88%) recorded nest losses were attributed to predation and very few (<1%) nests were affected directly by military activities. In fact, land management practices during the nesting season, including mowing for hay, and weather accounted for more recorded nest losses (3% and 1.7%, respectively) than military activities. Because nest searching activities were concentrated in areas not managed specifically for hay production, the land management effects I observed are not representative of all grasslands on the base. Undoubtedly, a much larger proportion of nests failed because of land management activities than reported in fields mowed for hay. However, nest searching was concentrated in areas used extensively for military training, so nest failure rates may be considered representative of military training impacts at Fort Campbell.

This study provided estimates of key biological parameters needed to develop reliable population models. Understanding how various life history parameters vary annually and among species will help managers understand how their decisions may affect grassland bird species.

CHAPTER 3

MODELING GRASSLAND SONGBIRD POPULATION VIABILITY: IMPLICATIONS OF LIFE HISTORY PARAMETERS AND THE TIMING OF LAND MANAGEMENT

Introduction

Nest success is just one of several demographic factors that can affect population viability. For birds, other basic demographic components include the number of young produced per nest, number of nest attempts (including re-nesting after an unsuccessful nesting attempt and multiple-broods after successful nesting attempts), survival of young birds in their first year of life (juvenile survival), and the annual survival of adult birds (Ricklefs 1973). Each of these parameters impact the growth potential of the population. Most field studies do not measure all demographic parameters simultaneously, and usually only nest success and a measure of the number of young produced are reported. Few studies incorporate adult and juvenile survival in songbird population models (Donovan et al. 1995, Powell et al. 2001), but even less have incorporated the other life history parameters, particularly for grassland bird populations.

Recently, method for calculating nest success received considerable attention (Hazler 2004, Jehle et al. 2004, Michaud et al. 2004, Nur et al. 2004, Shaffer 2004), but emphasis on nesting success can be misleading when considering avian populations (DeCecco et al. 2000, Murray 2000, Thompson et al. 2001). Under certain circumstances, nest success can be correlated with the overall health of the population. However, for birds that produce more than 1 nest in a single breeding season (e.g., many grassland songbirds), annual productivity is a better measure of population viability (Murray 2000). In many species, females can make up for low nesting success by producing more nests in a season (Murray 2000). Martin (1995) suggested re-nesting frequency and number of broods have a greater influence on annual productivity than nest success.

Because of the large and consistent declines in grassland bird populations (Askins 1993, Peterjohn et al. 1994, Peterjohn and Sauer 1999, Sauer et al. 2004), more attention is being focused on restoration and management of grassland habitats. To manage for stable populations (population growth rate [λ] = 1), there is a need to identify habitat characteristics associated with populations that can sustain themselves without immigration (Martin 1992). However, areas containing potential population sources ($\lambda > 1$) and sinks ($\lambda < 1$; Pulliam 1988) need to be identified first to target management strategies that enhance bird populations. Using nest success as the sole indicator of productivity among grassland songbird species that attempt multiple re-nests or multiple broods will not allow researchers or managers to differentiate population sources from population sinks (Herkert and Knopf 1998).

Reported grassland bird population declines have been attributed to the dramatic decrease of native grasslands during the 20th century through clearing of non-forested land for agriculture and discontinued use of fire (Herkert et al. 1996). Over 50% of the land area in the 48 contiguous states in the United States is in farms

(Rodenhouse et al. 1995). Some agricultural practices (e.g., hay production) produce the habitat structure suitable for nesting grassland birds, but field operations during the breeding season destroy many active nests in the field (Bollinger et al. 1990, Bollinger and Gavin 1992, Rodenhouse et al. 1995). Although nests destroyed early in the breeding season may be replaced, the timing of agricultural land management (e.g., mowing for hay) during the nesting season may restrict the total number of nests birds may attempt in a season. The effects of the timing of mowing during the nesting season on populations of grassland bird populations are largely unknown.

Because nest searching is both costly and labor intensive, studies reporting basic demographic parameters are rare and usually restricted to <3 years of data collection (Heske et al. 2001). Long-term demographic information is needed to create accurate and dynamic population models required by resource managers. Using demographic parameters (i.e., phenology, clutch size, nesting success, abandonment rate, hatching rate) collected over a 5-year period (1999-2003) at Fort Campbell, I investigated the effects of the number of nesting attempts (as related to the length of the nesting cycle) on population viability of 5 grassland species. These species included Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks. I also examined the demographic implications of mowing regimes on 2 of these grassland species: Grasshopper Sparrows and Henslow's Sparrows.

My objectives were to (1) construct simple population models for all 5 species to examine the effects of re-nesting and multiple brooding on avian productivity, (2) conduct sensitivity analysis to examine the effects of variation of adult survival, juvenile survival, number of nesting attempts, number of successful broods possible, and re-nesting rate on measures of population viability, and (3) relate population models to the timing of land management practices within Fort Campbell for Grasshopper Sparrows and Henslow's Sparrows.

Methods

Population viability assessment- I constructed a population model incorporating typical demographic parameters collected in the field supplemented by values found in the literature for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Eastern Meadowlarks and Field Sparrows. Species-specific parameters collected in the field included clutch size, nesting phenology, Mayfield (1975) nesting success, and number of young per successful nest.

First, I plotted the average nest success against the average number of young produced per successful nest for each species for all years individually and all years combined. I then created a threshold line between potential source and sink populations by rearranging a 2-stage population model. I solved for young produced per successful nest in terms of nest success using the following formula:

$$\lambda = S_a + (f) * (S_j)$$

(Ricklefs 1973). In this formula, Lambda (λ) is the population growth rate, S_a is annual adult survival, S_j is annual juvenile survival (assumed to be one-half adult survival), and f is the annual fecundity given the number of young produced per successful nest (b), and the mean number of successful broods (R). R is related to the number of nesting attempts (A), maximum number of successful broods possible in 1 season (C), and nesting success (p). When $\lambda = 1$, the population is considered stable.

I set $\lambda = 1$, $S_j = 0.5 * S_a$, and $f = b * R$. Then $1 = S_a + (b * R) * (0.5 * S_a)$, and I solved for b:

$$b = \frac{2 * (1 - S_a)}{(0.5 * S_a) * R}$$

I then plotted all possible combinations of young per successful nest (b) and nesting success (p) by varying nesting success from 0.0 – 1.0.

To calculate R, I needed to know the maximum number of successful broods possible in 1 season (C) for multiple-brooded species and the maximum number of nesting attempts (A). A branching process was used to calculate the mean number of broods given p (probability of a successful nest) and 1-p (probability of an unsuccessful nest) (Figure 3-1). Nest success was multiplied across each possible combination of nest histories (successful and unsuccessful attempts) and then multiplied by the number of successful nests in each combination. These combinations were then summed to get mean number of broods (R) (Table 3-1).

I calculated productivity as female young produced per breeding female with the following assumptions; (1) 100% pairing success and re-nesting rate, (2) immigration and emigration rates were equal, and therefore, offsetting, (3) juvenile survival was one half adult survival rates, (4) constant average annual rates of Mayfield (1975) nesting success, number of young per successful brood, and annual adult survival, (5) all individuals breed in their first breeding season after hatch year, and (6) no age-related differences in parameters (Donovan et al. 1995, Michaud et al. 2004).

This analysis produced plots with curves representing the threshold between source (increasing) and sink (decreasing) populations. On these plots, point estimates of nesting success and young produced per successful nest were plotted with their associated standard errors. Points to the left of the threshold curves were considered to represent decreasing or sink populations and points to the right of the curve represented increasing or source populations.

Species analysis- I used demographic parameters collected at Fort Campbell during 1999-2003 to analyze the yearly and overall average population trajectories under species-specific assumptions (Table 3-2). For all species, I used an adult survival of 0.5 and juvenile survival of 0.25. Reported survival rates for the 5 species range from 0.46 – 0.6 (Carey et al. 1994, Donovan et al. 1995, Lanyon 1995, Martin 1995, Vickery 1996, Herkert et al. 2002, Temple 2002). Henslow's Sparrows and Grasshopper Sparrows were modeled as triple-brooded species (C = 3) (Ehrlich et al. 1988, Monroe 2001, see Chapter 2). Eastern Meadowlarks and Field Sparrows were modeled as double-brooded species (C = 2) (Ehrlich et al. 1988). Dickcissels were modeled as single brooded species (C = 1) (Ehrlich et al. 1988). I limited the number of nesting attempts (A) based on species-specific nest season observations at Fort Campbell (see Chapter 2).

Sensitivity analysis- A sensitivity analysis of estimated parameters was conducted. It was designed to evaluate the overall effect of a range of values of the parameter in question (holding all other parameters constant, see Table 3-1) on the source-sink assessment relative to average values of nest success and number of young produced per successful nest. I evaluated maximum number of successful broods (C = 1, 2, 3), adult survival (S_a = 0.1 - 0.8), juvenile survival (S_j = 0.1 – 0.8), and re-nesting rate (0.2 – 1.0) to determine how the threshold between source and sink would change relative to measured values for nesting success and number of young produced per successful nest. I also evaluated the maximum number of nesting attempts (A = 1, 2, 3, 4) for single- (C = 1), double- (C = 2) and triple-brooded (C = 3) species. For all calculations, I assumed double-brooded nesting (C = A = 2), adult survival = 0.5, juvenile survival = 0.25, and 100% re-nesting rate unless otherwise specified.

Population analysis application- To simulate the effects of breeding season length and hay management within the nesting season on the number of possible nesting attempts for Grasshopper Sparrows and Henslow's Sparrows, I calculated the number of days (T) a successful nest would require by adding the number of days in the egg laying, incubation and brooding stages (Ehrlich et al. 1988). I assumed females laid 1 egg per day, rendering the egg laying stage equal to the average clutch size rounded to the nearest half day.

To calculate the average time to failure, I used the following equations:

$$T_f = \frac{(1-p) - mpT}{m(1-p)}$$

where T_f = average time to nest failure, p = nest success, and m = the daily mortality rate of the nest calculated by:

$$m = \frac{-\log_e(p)}{T}$$

following Ricklefs (1973). I assumed the time between fledging a successful nest and the next nest attempt (laying of first egg) was 10 days, and the time between a failure of a nest and next nest attempt was 4 days (Perkins et al. 2003). Little is known about the actual time between nesting attempts for these species, but banded Henslow's Sparrows and Grasshopper Sparrows at Fort Campbell were observed building a new nest while feeding young in their current nests.

The nest initiation window (the number of days over which nest initiation can occur within 1 season) was determined by backdating early nests (late April through early May) and late nests (mid-July through early-August) to the date of incubation initiation (see Chapter 2). The possibility of re-nesting was then determined by the amount of time left in the nest initiation window after a nest failed or was completed and a sufficient time for nest building has passed.

To simulate hay management, I considered all nests active during the mowing date as failed nests. I then allowed nesting to start 15 days after the mowing date to allow time for haying activities (cutting, drying, and bailing) and nest building activities after mowing. Mowing dates were chosen to represent the range of typically observed mowing dates in the agricultural lease areas at Fort Campbell. Mowing started as early as 15 May and continued until the end of the major portion of the breeding season to early August. I chose mowing dates approximately every 15 days, from 15 May to 1 August to examine the effects of mowing date choices throughout the nesting season.

Assuming the maximum breeding effort within the nesting season window observed at Fort Campbell, up to 6 nest attempts (A = 6) were allowed with at least 1 successful nest for Grasshopper Sparrows and Henslow's Sparrows and a maximum of 3 broods (C = 3). Grasshopper Sparrows were assumed to resume nesting after the mowing event, but the nesting success was reduce by 25% to simulate the effects of reduced cover for the nest. Henslow's Sparrows were assumed to abandon the nesting area after mowing, and therefore would not breed within the modeled population after mowing. In actuality, Henslow's Sparrows could move to other areas to nest, and they have been found in fields at Fort Campbell in July that were not occupied by Henslow's Sparrows in May and early June. Therefore, Henslow's Sparrow analysis could be considered conservative because other fields in the area could provide nesting habitat later in the nesting season, even in areas that were unsuitable in the beginning of the season. This would tend to increase the probability of Henslow's Sparrows producing young that are not included in this analysis.

Results

Species analysis- For Henslow's Sparrows, the mean estimates of nest success and young per successful nest for all years combined indicated the population could not sustain itself without immigration (sink; Figure 3-2). The estimates of nesting success and young produced per successful nest for 2 of the 5 years (2001 and 2003) indicated source populations with 4 nesting attempts (A) and 3 years (1999, 2000 and 2002) indicated sink populations. The mean nest success in 2001 was great enough for estimates of nest success and young per successful nest to be in the source side of the plot with 3 nesting attempts (A).

The mean estimates of nest success and young per successful nest for all years combined for Grasshopper Sparrows indicated potential source populations with 3 or 4 nesting attempts (Figure 3-3). However, the variation in the estimates nest success and young per successful nest include some area in the sink portion of the life-history plot. The estimates of nesting success and young produced per successful nest for 3 of the 5 years (2000, 2002 and 2003) indicated source populations with 4 nesting attempts (A) and 2 years (1999 and 2001) indicated sink populations. The mean nest success estimates in 2000 and 2003 were great enough for estimates of nest success and young per successful nest to be in the source side of the plot with 3 nesting attempts.

For Dickcissels, Field Sparrows, and Eastern Meadowlarks, the mean estimates of nest success and young per successful nest for all years combined were too low to indicate any source populations under the conditions of this model (Figure 3-4, 3-5, and 3-6). For Dickcissels, the estimates of nest success and young per successful nest for any single year were also too low to indicate any source populations under the conditions of this model (Figure 3-4).

The estimates of nest success and young per successful nest for Field Sparrows indicated the population was within the source area of the plot for 1 year (2003) with 4 nesting attempts (A = 4), but very near the threshold between source and sink populations (Figure 3-5). Four of the 5 years (1999-2002) had estimates in the sink area of the plot for Field Sparrows, even with 4 nesting attempts. Field Sparrow estimates for both nesting success and young produced per successful nests in 2003 were much greater than any other year monitored.

For Eastern Meadowlarks, yearly estimates of nest success and young per successful nest indicate a probable source population with 4 nesting attempts in 2002, although there was some overlap in the variation into the 3 nesting attempts area and the sink area of the plot (Figure 3-6). Four years (1999, 2000, 2001, and 2003) indicated sink populations even with 4 nesting attempts (A = 4). There was some overlap in the variation of the estimates for 2001 and 2003 into the source area with 4 nesting attempts.

Sensitivity analysis- As the threshold shifted to the left, there was an increase in the amount of area of the graph representing the potential to be a source population in the life-history plot (source area) and a corresponding decrease in the amount of sink area on the graph. An increase in the amount of source area on the graph indicated a relatively lower nesting success or fewer of young per successful nest was needed to sustain the population thus indicating positive effect on population viability.

Increasing from single- to double-brooded had a greater positive effect (increasing the source area) on the threshold between source and sink than increasing from double- to triple-brooded (Figure 3-7). Looking at mean estimates for nesting success and young per successful nest for all years combined, Grasshopper Sparrow populations would be a source as triple-brooded species with 3 attempts (Figure 3-7). Henslow's Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks estimates of nest success or young produced per nest were too low to sustain the populations (sink) even with 3 nesting attempts (Figure 3-7).

Incremental increases in adult survival (S_a) caused fairly uniform increases in the source area of the plot (Figure 3-8). Incremental increases in juvenile survival (S_j) showed a similar increase as adult survival, but increased less as the juvenile survival rate increased (Figure 3-9). Adjusting the re-nesting rate (from 100%) had the greatest relative effect on the source/sink threshold; each incremental decrease in re-nesting shifted decreased the amount of source area on the plot (Figure 3-10).

Adjusting the number of nesting attempts for single-, double-, and triple-brooded species generally had a positive effect on the source/sink threshold (increasing source area) as the number of attempts increased (Figures 3-11, 3-12, and 3-13). The magnitude of the increase in source area decreased as the number of attempts increased. There was very little difference between double- and triple-brooded species with equal number of attempts (Figures 3-12 and 3-13).

Mowing and grassland bird population analysis- For Grasshopper Sparrows, the source area increased on the life-history plot in a non-consecutive order of mowing dates from 1 June, 1 July, 15 May, 15 June, 15 July, 1 August, and "no mowing" (Figure 3-14). As the source area on the plot increased, lower nesting success or young per successful nests were needed for the population to sustain itself under maximum breeding effort. "No mowing" and mowing after 1 August allowed for the possibility of a source population with the overall estimates of nest success and young produced per successful nest, although the variation overlapped into the sink area of the plot for the 15 July mowing date. Point-estimates for 1999, 2001, and 2002 indicated source populations only with no mowing. Mowing on 15 June or after 15 July allowed the Grasshopper Sparrow population in 2000 to be a source, whereas mowing 15 May, 1 June, and 1 July caused sink populations under the model assumptions. In 2003, the nesting success rate and the number of young produced per successful nest were great enough to compensate for mowing after 15 Jul with maximum breeding effort.

For Henslow's Sparrows, mowing before 15 July indicated sink populations in all years (Figure 3-15). The "no mowing" threshold did not allow a possible source population for the nesting success and young per successful nest estimates for all years combined with maximum breeding effort, but the variation indicated "no mowing" may allow for a source population. In 1999, 2000, and 2002, under conditions for maximum breeding output the estimates indicated a sink population even with no mowing. Year 2003 was a source population only with "no mowing." Mowing after 1 August allowed the 2001 population to be a source.

Discussion

Nest success is a fundamental component of annual productivity in birds and has received tremendous attention (Hazler 2004, Jehle et al. 2004, Michaud et al. 2004, Nur et al. 2004, Schaffer 2004). However, nesting success is just one component affecting avian demographics. All 6 parameters in this study (nesting success, adult survival, juvenile survival, number of successful broods, number of nesting attempts, and fecundity) affected the population viability to varying degrees (Ricklefs 1973). Re-nesting rate also may be very important to songbird populations (Martin 1995).

Many long-distance or Neotropical migrants generally are considered to have a lower number of successful breeding attempts per season than short-distance migrant or resident birds especially in the northern extent of their ranges (Whitcomb et al. 1981). Neotropical migrants are thought to have just enough time or energy to successfully produce 1 brood, but they may have time to replace nests if their first attempts were unsuccessful. Monitoring radio-tagged and color-marked Dickcissels, Walk et al. (2004) found 36% of Dickcissel females initiated second nests after their first nest failed, thus increasing the overall productivity of the population. They found 95% of the females monitored ceased breeding after fledging at least 1 young and only 1 female initiated a second nest after the first nest successfully fledged (Walk et al. 2004).

In contrast, resident and short-distance migrant birds are thought to produce >1 successful brood in a season because their nesting seasons tend to be longer than nesting seasons of Neotropical migrant. Kershner et al. (2004) however, reported that Eastern Meadowlarks in Illinois, which have enough time to double or triple brood, did not re-nest as frequently as expected. Only 44% of females re-nested and 53% emigrated from the local population after successfully fledging their first nest. This tendency results in a lower productivity than generally expected for this species. Their observation also suggests there may be a substantial cost associated with re-nesting, even if there is enough time in the breeding season (Kershner et al. 2004).

In general, my models represent a conservative scenario. I also assumed constant clutch sizes and nesting success rates. I would expect clutch sizes and nest success to vary throughout the season, thus possibly affecting the number of young produced. The implications of variable clutch size and nesting success within season could impact the importance of nests at the end of the season relative to nests at the beginning of the season. For example, nesting success could increase during the season because of increasing grass cover. On the other hand, nesting success could decrease with time in the breeding season because the temperature increases may make potential predators, such as snakes, more active later in the breeding season. Clutch size could decrease with time in the breeding season possibly because of energetic costs to produce eggs (see Chapter 2).

Variation among estimates of the parameters could provide important information for bird conservation. For example, variation of Mayfield (1975) nesting success rates generally were large, even with relatively large sample sizes over 5 years combined (n = 86-276 per species, see Chapter 2). Yearly variation in demographic parameters may not be statistically significant, however small changes in demographic parameters have potentially large biologically significant consequences. Similarly, confidence limits around estimated survival rates are usually very large, if they can be estimated at all. In most cases, very little is known about annual survival of many grassland species and even less is known about juvenile survival. Both parameters are difficult to estimate because it is difficult to separate mortality from dispersal by yearly observations of banded birds. Between-year dispersal rates for grassland birds generally are greater than for forest species, and juvenile dispersal rates generally are greater than adults (Martin 1995). Despite this variation, demographic models can help elucidate general population trends for management purposes, even if model assumptions are based on limited data.

My models indicated different patterns of source and sink populations for each species. The Grasshopper Sparrow population at Fort Campbell generally exhibited the greatest productivity, and may be producing surplus individuals in most years. Henslow's Sparrows were sink populations 3 out of the 5 years monitored. Field Sparrows and Eastern Meadowlarks were sink populations 4 out of the five years. The other years these species could be source populations depending upon how many nest attempts each species could try within a season. Field Sparrow populations generally were sink populations even under the most generous assumptions (4 nesting attempts). In 2003, Field Sparrow population indicated very high nest success and young produced per successful nest, thus indicating greater productivity in 1 out of the 5 years monitored. For Field Sparrows, however, the one good year was not enough to sustain the populations given the generally low nesting success during the other years.

Dickcissels were sink populations in all years. The adult survival rate used in this model may have been too conservative. A previously reported adult survival rate was similar to the 0.5 survival rate used in this model (0.49; Temple 2002), but the adult survival rate was calculated from the return rate of banded males to their territories from the previous year, and represents a minimum survival rate. There are undoubtedly individuals that did not return to the same area to nest the next year, but survived to breed the next year. Not accounting for individuals that disperse between years biases estimated survival rates low.

One of the advantages of this graphical approach to modeling is a range of parameter estimates can be evaluated simultaneously. For example, there are very few estimates of adult survival for many bird species. A range of reasonable values can be evaluated on the same graph. Other advantages include these models can be created in a simple spreadsheet program, and the models can easily incorporate new information as it becomes available.

The mowing model with Grasshopper Sparrows indicated that mowing at the end of the season was better than mowing in the beginning or the middle of the breeding season. This model assumed all females stayed and re-nested after the disturbance, which may not be realistic. Also, this model does not consider the young outside the nest that may be killed during mowing activities. Bollinger et al. (1990) found at least 50% of recently fledged Bobolinks in New York were killed by hay-cropping activities. Fledged young are vulnerable (unable to fly well) 1 to 2 weeks after leaving the nest, and the lack of cover could leave the adults and juvenile birds more exposed to predators (Bollinger et al. 1990).

My study indicated mowing at any time in the nesting season of Henslow's Sparrows does not allow for the possibility of stable or increasing (source) populations under reasonable model conditions (adult survival = 0.5, juvenile survival 0.25, maximum number of successful nests = 3). Although Henslow's Sparrow populations have evolved to survive in ephemeral habitats, they may not have developed strategies to deal with regular disturbances during the breeding season (e.g., mowing). Thus, the timing of the disturbance is an important factor in determining population persistence.

Sound management decisions require more detailed information on annual reproductive success than is generally available (Murray 2000). Although there is a trade-off between time investment and the amount and types of data collected, more intensive studies over longer time periods (≥5 years) would provide better information. The models presented here represent a starting point for incorporating important life-history parameters into a relatively simple model. Understanding the yearly variation patterns of parameters, other than nesting success and number of young produced, would provide a more realistic view of the viability of these populations. More monitoring of color-banded populations would be required to understand how population growth may be affect by other life-history parameters not normally considered (Murray 2000).

CHAPTER 4

GRASSLAND BIRD NEST SITE SELECTION AT FORT CAMPBELL ARMY BASE, KENTUCKY

Introduction

According to the Breeding Bird Survey results of North America, 10 species of open grassland and savanna birds decreased in abundance whereas only 4 species increased between 1966 and 2001 in the eastern US (Sauer et al. 2004). Changes in land use and land management have reduced the amount and quality of habitat available to these bird species. The dramatic decrease of native grasslands during the 20th Century can mainly be attributed to habitat loss through clearing non-forested land for agriculture and less frequent use of prescribed fire (Herkert et al. 1996). More recently, increasing urbanization and a shift from pastures and small grains to row crops of corn and soybeans may have continued the decline in some grass-dominated habitats (Rodenhouse et al. 1995). It remains largely unknown what habitat conditions are capable of sustaining populations of these declining species.

Grassland habitats are dynamic and ephemeral, relying on frequent disturbances, like fire and other forms of management, to maintain grass cover. There are many studies documenting the general habitat used by breeding grassland species (see Carey et al. 1994, Lanyon 1995, Vickery 1996, Herkert et al. 2002), but differences in nest-site microhabitat among groups of coexisting species has not been studied extensively (Winter 1998, Dieni and Jones 2003). To maintain a community of grassland bird species, there is need to understand the extent of different grassland habitats used during the breeding season compared to what is locally available, and how habitat preferences vary among species.

For this study, I focused my work on nesting habitats used by 5 coexisting grassland-breeding birds at Fort Campbell between 2001 and 2003; Henslow's Sparrows, Grasshopper Sparrows, Field Sparrows, Eastern Meadowlarks, and Dickcissels. The objectives of this study were to (1) examine habitat differences between selected nest sites and available habitats, and (2) examine microhabitat selection relationships among the 5 target species.

Methods

Study area- The study was conducted on Fort Campbell Army Base, Kentucky, a 42,000-ha base located on the Kentucky-Tennessee state border. Fort Campbell contains one of the largest remaining blocks of native prairie "barrens" east of the Mississippi. Barrens are grass-dominated, treeless areas occurring on the hilly, karst topography in west central Kentucky and northwestern Tennessee (Chester et al. 1997). These grasslands historically were maintained through regular burning by native Americans (Delcourt et al. 1993). Fort Campbell grasslands contain native warm-season grasses, including little bluestem, big bluestem, switchgrass, indiangrass, and broomsedge. Oak-hickory forests and a limited number of leased agricultural fields (hay, millet, and soybeans) are interspersed among the grasslands. Portions of most of the larger fields used by Grasshopper Sparrows and Henslow's Sparrows are leased to local farmers for haying. Many of these leased areas were seeded with non-native cool-season grasses such as tall fescue (*Festuca arundinacea*), although programs are now in place to eliminate the cool-season grasses in some areas and planting of new areas with tall fescue is prohibited.

Nest searching- Nest searches were concentrated in about a dozen different fields each year that contained Henslow's Sparrow and Grasshopper Sparrow territories, because these species were the most difficult to locate at Fort Campbell. I systematically searched all fields by looking for males on territory or exhibiting nesting behavior. Behavioral cues, such as birds flushing close to an observer, birds chipping close to observer, birds carrying nesting material, or birds carrying food or fecal sacs were used to locate nest sites. I monitored nests of all species found. Once nests were located, a flag was placed at least 5 m from the nest, and detailed maps of the nest locations were drawn. Nests were monitored every 3-4 days to determine nest fate. I monitored 522 nests of the focal species between 2001-2003 (see Chapter 2).

Vegetation sampling- Vegetation was sampled at all Grasshopper Sparrow (n = 70), Henslow's Sparrow (n = 56), and Eastern Meadowlark (n = 45) nests. Vegetation measurements for ≥20 randomly selected nests were recorded for each year for Dickcissels (n = 71) and Field Sparrows (n = 72). A total of 314 nest vegetation plots were sampled. Some nests were destroyed by field management activities before measurements could be made. Vegetation was measured within 2 weeks of the completion of nesting activities. Samples among all years were pooled to ensure adequate sample sizes for analysis of all species, and to provide a sample of the nest conditions present across multiple years.

I also collected vegetation measurements in up to 30 fields per year to represent habitat availability. I took vegetation measurements at 379 random locations in the selected fields in 2001 (n = 181), 2002 (n = 107) and 2003 (n = 91). Some fields were converted to row crop agriculture during the study and sampling was discontinued. Within each field, up to 10 vegetation plots were randomly located at least 50 m apart, depending on field size. Field sizes ranged from 3 to 600 ha. Fields were selected to be representative of field size and burn regimes at Fort-Campbell (Moss 2001).

Grass height, litter depth, percent cover, and vertical cover were measured centered on the nest site or random point. Percent cover was visually estimated within a 1-m^2 frame and divided into litter, bare ground, woody, dead woody, cool-season grass, native warm-season grass, and forb cover (Moss 2001). Litter included all dead vegetative matter on the ground. "Forb" cover was defined as all herbaceous vegetation (e.g., forbs, rushes, sedges), excluding grasses, but very few sedges and rushes were detected near the nest sites. I assessed vertical cover by placing a density board (15 X 15 cm squares; 2 squares wide and 10 high) 15 m from the center of the vegetation point (or nest) and counting the squares obstructed by vegetation from the center point (Nudds 1977). Nest heights were measured from the ground to the rim of the nest cup.

Statistical analysis- All statistical analysis was conducted using NCSS (2001). Nest heights were examined using a 1-way ANOVA and a Tukey-Kramer test for multiple comparisons. Individual nest sites and random vegetation plots were treated as independent samples. Random vegetation plots were included as a separate group to represent the habitat generally available at Fort Campbell. Habitat variables were first examined at the univariate level to examine individual differences (Dieni and Jones 2003). First, a correlation matrix was calculated to evaluate the relationship for all combinations of variables. Second, an ANOVA was conducted to examine differences among nest sites and random points. Finally, a *post hoc* comparison using Dunnett's pairwise multiple comparison *t*-test was calculated to allow comparison between each of the species nest sites to the random vegetation plots. All percentages were transformed using an ARCSIN transformation. The significance level was set at $\alpha = 0.05$ for all tests.

I also examined multivariate relationships among habitat variables using discriminant function (DF) analysis. I tested the ability of the DF to classify nesting habitat among the 5 species by generating a classification table using a jackknife procedure. Using the coefficients generated from the DF of the grassland bird nest sites, discriminant function scores were generated for each random point and plotted to examine the implications of niche breadth and available habitat at Fort Campbell. I then graphed the centroids of the discriminant function scores for each species and the associated random locations. I plotted 50% confidence ellipses for each species and the random points to show the general distribution of the points around the means. I also plotted 95% confidence ellipse for the random locations to encompass all possible habitat conditions.

Results

Nest height- Average nest height ranged from 0 cm for Grasshopper Sparrows to 32.1 cm for Dickcissels (Table 4-1). Grasshopper Sparrow and Eastern Meadowlarks were similar with the lowest average nest heights. Henslow's Sparrows built nests in the middle range of the nest heights, and Field Sparrows and Dickcissels had the greatest average nest heights. All species had at least a few nests located on the ground.

Univariate analysis- Each habitat variable differed between nest site and random locations for at least 1 variable (Table 4-2). Henslow's Sparrows and Grasshopper Sparrows had the greatest number of differences with the random plots (8 out of 12 variables), and Dickcissels, Field Sparrows and Eastern Meadowlarks showed the fewest differences (6 out of 12 variables). Considering all habitat measurements, each species varied from the random location measurements independently. Litter depth was greater at nest sites for all species. Nest sites also had less bare ground cover and greater grass height for all species except Grasshopper Sparrows. Henslow's Sparrow nest sites had the greatest warm-season grass cover and Eastern Meadowlark nest sites had the greatest cover of cool-season grass. Field Sparrow nest sites had the greatest cover of woody vegetation.

Multivariate analysis- A correlation matrix showed only 1 pair of variables highly correlated ($r > 0.70$). Percent woody vegetation cover was highly correlated with woody vegetation height ($r = 0.92$), and woody vegetation height was removed from further analysis. Four discriminant functions were derived (Wilk's Lambda, $p < 0.05$). The first 2 functions accounted for 91% of the total discriminating power of the DFA (Table 4-3). The first discriminant function (DF1) was most correlated with mean litter depth ($r = 0.590$) and vertical cover ($r = 0.631$). The second discriminant function (DF2) was most correlated with percent cover in forb cover ($r = 0.550$) and percent cover in warm-season grasses ($r = -0.507$). The relative ability of the discriminating functions to separate groups, indexed by the correlation coefficients, was greater for DF1 ($R = 0.734$) than the DF2 ($R = 0.535$).

Overall, 52.2% of the individual nest sites were correctly classified, which is greater than expected by random chance (20%; Table 4-4). Dickcissel and Field Sparrow nest sites were the least likely to be classified correctly (40.8% and 48.6%, respectively) with the greatest misclassification occurring between the 2 species. This result indicated the discriminant function had some difficulty discriminating between Field Sparrow and Dickcissel nesting habitat. Most of the Grasshopper Sparrow and Henslow's Sparrow nest sites were correctly classified (62.9% and 58.9%, respectively).

Dickcissel and Field Sparrow centroids were located very close to each other indicating some overlap (Figure 4-1). The centroid for the random locations was almost centrally located to all 5 species. There were areas of overlap for all species among each other and into the area occupied by the random locations (Figure 4-2). The ellipses for Dickcissel and Field Sparrows overlapped almost completely. The 95% confidence ellipse for random locations included all areas occupied by the 50% confidence ellipses for each of the 5 species.

Discussion

The structure of the vegetation within grassland habitats has long been recognized as one of the important determinants of habitat selection for grassland birds (e.g., Weins 1969, Roseberry and Kilmstra 1970, Cody 1985, Bollinger 1995). Most of these studies were based on vegetation measurements that were related to bird distributions within fields, but not necessarily related to a specific area selected by the individual birds. Recently, studies examining the patterns of nesting habitat selection among several species within a single community have become more common as the number of studies monitoring large numbers of nests increases (Winter 1998, Dieni and Jones 2004, Winter et al. 2004). Understanding how nesting site selection differs among species is helping managers to understand how the management of the vegetation structure for one grassland bird species may impact the presence of other grassland birds. The differences among species that I detected suggest there is not just one management practice to provide habitat for all grassland species (Winter et al. 2004).

My univariate analysis revealed differences between the habitats selected for nesting by each species and available habitat at Fort Campbell, as represented by random vegetation plots (Table 4-2). In most cases, habitat measurements for at least 2 species differed from random vegetation plots except percent litter cover, which was greater for Grasshopper Sparrows than random sites. For all species, litter depth at the nest site was greater than in the random locations. All other habitat variables showed species-specific patterns when compared to the random plots.

Multivariate analysis generally matched the nest-site selection patterns found in the univariate analysis (Figures 4-1 and 4-2). The DF1 was positively associated with litter depth and vertical vegetation density, and the DF2 was positively associated with forb cover and negatively associated with native warm-season grass cover. The DF1 can be thought of as a measure of disturbance (i.e., fire or mowing) history in the fields. At Fort Campbell, Moss (2001) found litter depth increased as the duration between disturbances (years since prescribed burning) increased. The DF2 represents the ratio of grasses to forbs, increasing as the relative amount of forb cover increases.

Nesting habitat use was generally consistent with previously reported general habitat use for all species. Grasshopper Sparrow selected areas with extensive cool-season grass and forb cover, relatively low vertical vegetation height, and sparse woody vegetation (Dechant et al. 2001*a*). Eastern Meadowlarks used areas with extensive cool-season grass cover and relatively deep litter layer for nesting habitat. They also preferred areas with relatively little woody vegetation and forb cover, which is consistent with other studies (see Hull 2000). Henslow's Sparrow nest sites had well-developed litter layers, and were characterized by relatively extensive grass cover (cool- and warm-season grasses), low forb cover, and little woody vegetation; these findings were consistent with Herkert (2003). Dickcissels and Field Sparrows selected areas with a deep litter layer and relatively tall herbaceous vegetation (Dechant et al. 2001*b*, 2001*c*). Field Sparrows selected relatively more woody cover whereas Dickcissel preferred greater forb cover.

Using the 50% ellipses to represent the relative multivariate niche space of nesting habitat for each species, habitat use by Grasshopper Sparrow overlapped the multivariate niche space of other species the least, indicating Grasshopper Sparrow niche space was most distinct (Figure 4-2). Eastern Meadowlarks used habitat intermediate between Grasshopper Sparrow and Henslow's Sparrow habitat. The niche spaces occupied by Grasshopper Sparrows and Eastern Meadowlarks were almost completely separated from those of Dickcissel and Field Sparrow space with Henslow's Sparrows occupying a niche space intermediate to all 4 species. Niche space of Dickcissel and Field Sparrow almost completely overlapped, thus explaining the low success rate of the jack-knife validation procedure (Table 4-4). The 50% ellipse of Henslow's Sparrows encircled the least area of multivariate space indicating they have the most specialized requirements for nesting habitat.

The centroid and 50% ellipse of the random vegetation plots, representing available nesting habitat indicated that available habitat had intermediate litter depth and vertical cover (DF 1), and a relatively large proportion in cover of forbs and low proportion in cover of warm-season grasses (DF 2). The random locations occupied a relatively large area in multivariate space, extending well beyond the area of overlap of the 5 species along the second discriminant function axis (95% ellipse; Figure 4-2). Thus available habitat included areas of grassland habitat that were unsuitable for these 5 species. However, the 50% ellipse for the random points encircled the middle of the plot overlapping the 50% ellipses for each of the 5 species nesting areas, indicating at least some habitat suitable for each of these species is provided across the installation (Figure 4-2). There appeared to be many areas with relatively large proportion in cover of forbs. Many fields may not establish grass cover because of too frequent disturbance. Moss (2001) found that cover of native warm-season grass at Fort Campbell tended to increase as the number of years since burn increased. In a large portion of the random areas, burning occurred annually, which was too frequent to create suitable habitat for the 5 grassland species. This frequent burning was intended to keep the fields clear of woody vegetation for military training purposes.

Although the niche space occupied by the random vegetation plots overlaps major portions of each of the species niche space, microhabitat features may not be the only factors influencing nest-site selection. The occupancy of habitats may be influenced by other local factors such as food availability, competition, predation levels, climate, and landscape factors (e.g., patch size and landscape composition). For example, Grasshopper Sparrows and Eastern Meadowlarks, which are generally considered area sensitive (Herkert 1994, Vickery et al. 1999), were only found in the largest fields (>100 ha). So even if the microhabitat was suitable, the smaller fields were unoccupied by these species. Henslow's Sparrows and Dickcissels, on the other hand, were found in all fields where microhabitat was suitable. Winter (1998) found that Dickcissel and Henslow's Sparrow populations reacted more to close proximity of grassland patches than the size of the individual patches. Because of the high percentage of grassland cover at the landscape scale (~30%, D. Moss, unpublished data), Fort Campbell has potential to provide habitat for these 2 declining grassland species. However, the microhabitat would need to be managed for deeper litter depth and more grass cover by burning less frequently (every 2-4 year).

Although niche space of Field Sparrows almost completely overlapped Dickcissels, my sample of Field Sparrow nest sites may be somewhat biased. Most nest searching activity was concentrated in open fields where Grasshopper Sparrows and Henslow's Sparrows were present. Field Sparrows will use areas near woody edges (Carey 1994), whereas both Henslow's Sparrows and Grasshopper Sparrows tend to choose areas with sparse woody vegetation (Dechant et. al 2001*c*, Herkert 2003). My sample of Field Sparrow nests was biased toward open field nests and away from nests near woody edges, where some Field Sparrows undoubtedly nested.

CHAPTER 5

CONSERVATION POTENTIAL FOR GRASSLAND BIRDS ON EASTERN UNITED STATES DEPARTMENT OF DEFENSE INSTALLATIONS

Introduction

Grassland birds have experienced greater population declines than any other group of birds monitored by the Breeding Bird Survey (BBS; Askins 1993, Peterjohn and Sauer 1999). Reported population declines have been attributed to the dramatic decrease of native grasslands during the 20th Century through clearing of non-forested land for agriculture or development, discontinued use of fire and fragmentation of large grasslands (Herkert et al. 2003).

Land areas managed by the US Department of Defense (military lands) in the eastern US are one exception to the trend in loss of native grasslands. Some installations have maintained areas in native grasses to facilitate military training through the use of prescribed burning and mowing. There is an opportunity to provide training needs for the military and habitat needs for grassland birds simultaneously on Department of Defense (DOD) managed lands. Military lands comprise over 10 million ha of land in the US, and offer unique management opportunities to provide breeding and wintering habitat for birds (Cohen 1996, Eberly 2002). For example, military exercises that occur on Fort Campbell Army Base on the state border of Kentucky and Tennessee include airborne training into open "drop zones," ground-based infantry, light-mechanized training, and various artillery ranges. These exercises require large areas of open lands to facilitate related training activities. Native grasslands provide ideal conditions for such training exercises because the grasslands are durable, provide great visibility, and can be managed cheaply and effectively using fire. Thus, the habitat conditions that provide suitable conditions for training activities also could provide breeding and wintering grassland bird habitat (Figure 5-1). Natural resource management can be integrated with the military mission to provide open habitats for military training and contribute to grassland conservation goals. Understanding how DOD lands can contribute to the conservation of vulnerable grassland species is vital because of the extent and intensity of current management practices on these lands.

Management recommendations for grassland bird habitat include grassland patches of 40 ha or greater in a landscape matrix of at least 40% open (non-forested) habitat, preferably grassland (Sample and Mossman 1997, Fitzgerald et al. 2000, Ford et al. 2000, Knutson et al. 2001, Burhans 2002). The 40-ha patches allow for the management (e.g., prescribed burning, mowing) of between a third (~13 ha) and half (20 ha) of the field in any 1 year while providing habitat for species needing conditions created 1 or 2 years after disturbance.

Because of security concerns and safety buffers maintained adjacent to active training areas, many DOD lands "exist as oases habitat in the midst of [habitat] fragmentation and developed landscapes (Eberly 2002)." This creates 2 challenges for the DOD when land managers try to maintain habitats needed for military training. First, as urban development around military installations pushes closer to the boundaries of the installation, the effective area that can be used for training is reduced to maintain safety buffers. Second, as grassland habitats outside the installations are converted because of urbanization and agriculture, grasslands within the installations become more important for species of concern. There is a need to understand how the landscape composition within military installations compares with lands near military installations. This understanding should help to prioritize areas for targeted grassland management outside the installation to reduce the military's perceived "management burden" inside the installation.

My first objective was to use a coarse-filter approach to determine (1) which military installations have the potential to provide grassland habitat by identifying military installations that contain large grassland patches ($\geq$40 ha) in the eastern US, (2) identify areas where open habitats (e.g., grassland, hayfields, agriculture) occupy a substantial portion of the landscape military installations occur in, and (3) overlay the areas of high diversity for obligate grassland birds during the breeding and wintering seasons in the eastern US. This coarse-filter approach helped identify which DOD installations in the eastern US could provide important wintering or breeding habitat for grassland bird conservation by examining landscape context and species diversity in installations containing at least 1 large grassland patch.

The second objective was to (1) conduct a buffer analysis to determine if the extent of grassland within the military installation was representative of grassland habitat within the surrounding landscape, and (2) determine how much potential the surrounding landscape (within 30 km) had for grassland restoration. This analysis helped to identify areas where military installations already contain more grassland than the surrounding landscape and areas where partnerships with surrounding landowners would be most effective for the DOD and for grassland bird populations.

Methods

Characterizing grassland habitat- This study includes all DOD managed lands and military bases located in 26 states in the eastern US (east of the Mississippi River) with contiguous grassland patches greater than 40 ha within their boundaries. Using a GIS coverage of US federal lands, all military installations were mapped (US Geological Survey 2002). Using US Geological Survey (1992) National Land-use/Land-cover data (NLCD; 30 by 30-m pixels), I examined the presence and distribution of grassland habitats within generally open habitats (i.e., grasslands, barrens, scrub-shrub) in the eastern US.

I reclassified the NLCD values to reflect the potential value as grassland bird habitat of the land-cover type (Table 5-1). Land-cover types that provided some value as grassland habitat were assigned values greater than zero depending upon how much potential early-successional habitat occurred in each pixel. For example, areas classified as grasslands were assigned a value of 100 and areas classified as hay or pasture were assigned a value of 50. Areas that were generally treeless but provide no habitat value, like urban grasslands and agricultural lands, were assigned a value of 0. Finally, areas that did not provide any potential habitat value for grassland birds (e.g., forests, high-density urban, and commercial areas) were assigned a value of negative 100.

For each group of 9 pixels, I calculated a regional sum for a 3-pixel by 3-pixel square (9 pixels, 0.81 ha) by adding the reclassified values of each of the 9 pixels and assigning the total to the group of pixels. This was done to reduce the amount of data to be processed across the eastern US by reducing the overall grain size of the analysis. Areas with values greater than zero were considered potential grassland habitat; areas with a value of 900 were considered optimal grassland habitat.

I then selected all open areas (0.81 ha) with values greater than 300 to ensure that selected areas had at least some existing grassland habitat. Adjacent grid-cells with open areas were aggregated into patches, and patches ≥40 ha were selected as potential grassland bird habitats. These patches represented grassland habitat availability. To obtain a measure of potential habitat (areas that could be restored to grasslands), all open, early-successional habitats were combined with all agricultural habitats (e.g., row crops and small grains; Table 5-1).

I examined grassland habitat availability and potential within military bases and in 3 concentric 10-km buffers around each of the DOD installations with at least 1 grassland patch ≥40 ha. I also calculated the proportion of open habitats within 30 km of the boundary of each selected installation including the interior of the installation to represent a measure of landscape context for each installation. The 30-km distance was assumed to be a maximum distance a bird would disperse within a breeding season from an initial nesting attempt. Finally, I calculated the proportion of each county in the eastern US providing grassland habitat or potential grassland habitat.

Characterizing grassland bird distributions- I mapped the ranges of selected obligate grassland birds (Table 5-2) that have a major portion of their wintering and breeding range in the eastern US. I defined obligate grassland birds as any upland birds that use grasslands as their primary habitat for the breeding and wintering seasons, and place their nests within ~0.5 m of the ground in grasses (Vickery et al. 1999).

Breeding range maps were produced for each species by compiling state breeding bird atlases where available to map counties where the birds were documented to exist (Laughlin and Kibbe 1985, Illinois Department of Natural Resources 1986-1991, Adamus 1987, Andrle and Carroll 1988, Carolina Bird Club 1988-1995, Virginia Society of Ornithology 1989, Brewer et al. 1991, Peterjohn and Rice 1991, Brauning 1992, Enser 1992, Veit and Petersen 1993, Bevier 1994, Buckelew 1994, Foss 1994, Palmer-Ball 1996, Robbins 1996, Nicholson 1997, Castrale et al. 1998, Hess et al. 2000, Wiedenfeld and Swan 2000, Peterjohn 2001, Wisconsin Society for Ornithology 2002, Florida Fish and Wildlife Conservation Commission 2003). Some states did not have breeding bird atlases (Alabama, Georgia, and Mississippi), so data from the Breeding Bird Survey and other state map summaries were used (Turcotte and Watts 1999, Sauer et al. 2004). For wintering bird ranges, Christmas Bird Count summary range maps were used to make county level maps of each of the grassland species (Audubon Society 1959 – 1988, Root 1988). From these range maps, I calculated the number of species potentially found in each county of the 26 states in the eastern US to determine areas of high grassland bird richness in the breeding and wintering seasons.

Priority DOD installations- To create a list of priority DOD installations for grassland conservation, each installation was classified by the amount of area in patches ≥40 ha (AREA), proportion of open habitats within 30 km of the installation (LANDSCAPE), number of potential wintering bird species (WINTERING), number of potential breeding bird species (BREEDING), number of high-priority breeding (HIGH PRIORITY BREEDING) and wintering (HIGH PRIORITY WINTERING) grassland bird species. Installations were categorized as having high, medium, or low values for AREA, LANDSCAPE, WINTERING, and BREEDING and were assigned values of 1 (high), 0.5 (medium) and 0 (low) (Table 5-3). HIGH PRIORITY BREEDING was calculated by summing the number of species on the Partner's in Flight Watch List (Pashley et al. 2000) divided by the maximum number at any 1 installation (3 species) to obtain values between 0 and 1. Watch list species included Henslow's Sparrow, Bachman's Sparrow, Dickcissel, Short-eared Owl, and Bobolink. HIGH PRIORITY WINTERING was calculated in a similar manner, but the maximum number of species at any 1 installation was 4.

Final priority scores were calculated on a scale from 0 to 10 using the following formulas:

Overall Score = (3 * AREA) + (3 * LANDSCAPE) + BREEDING + WINTERING + HIGH PRIORITY BREEDING + HIGH PRIORITY WINTERING;

Breeding Score = (3 * AREA) + (3 * LANDSCAPE) + (2 * BREEDING) + (2 * HIGH PRIORITY BREEDING);

Wintering Score = (3 * AREA) + (3 * LANDSCAPE) + (2 * WINTERING) + (2 * HIGH PRIORITY WINTERING);

The overall score represents the capacity of the installation to support breeding and wintering grassland birds, whereas the breeding score and the wintering score represent the capacity of the installation to support grassland birds during the respective seasons. The scores weight the potential of the base to provide habitat (60%) greater than the richness of grassland species potentially present (40%). These scores reflect the assumption that the existence of the ideal land configuration (area and landscape) is generally more important than the species presence for the potential management of grassland species.

Results

Of the 186 land areas in the eastern US managed by the DOD, 45 contained at least 1 large patch of grassland, including 1 port managed by the Army Corps of

Engineers, 23 Army, 3 Air Force, 3 Marine Corps, 11 Navy, and 4 National Guard installations (Table 5-4). Military installations with significant grassland habitat were found throughout the eastern US providing at least 65,000 ha of grassland in patches greater than 40 ha (Figure 5-2). Selected installations were found in most states in the eastern US, except West Virginia, Illinois, Delaware, and all New England states. Most of the selected installations were concentrated in the Southeast, although there were a few installations clustered in Indiana, Kentucky, and Tennessee. Single installations were selected in Wisconsin, Michigan, New York, Ohio and Pennsylvania.

The selected DOD installations were grouped into 4 regions including northern, inland central, northern-coastal, and southern-coastal (Figure 5-2). The northern region included installations from Wisconsin, Michigan, Ohio, and New York including 1 National Guard and 3 Army installations. The inland central region included 8 installations concentrated in Kentucky, Tennessee, southern Indiana, and northern Alabama in areas with relatively high proportions of existing grassland habitats including 1 National Guard, 1 Navy, and 6 Army installations (Figure 5-2).

The last 2 regions included 33 installations within 300 km of either the Atlantic Ocean or the Gulf of Mexico. The northern-coastal region included 16 installations in Virginia, Maryland, New Jersey, and southern Pennsylvania: 1 Marine Corps, 1 Air Force, 6 Army, and 8 Navy installations. Thirteen out of the 16 installations were relatively small (<15,000 ha). The southern-coastal region included 17 installations within 300 km of the coast in North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana: 1 port managed by the Army Corp of Engineers, 2 Air Force, 2 National Guard, 2 Navy, 2 Marine Corps, and 8 Army installations. Eleven of the 17 selected installations were greater than 20,000 ha in total area, including the 5 largest selected installations.

Overall, the installations ranged in size from 583 to 184,00 ha (Table 5-4). The proportion of large grassland patch habitats ranged from 0.6 to 51.2% of the installation with the proportion of potential grassland ranging from 4.8 to 71.2% of the installation (Table 5-4). The difference between the proportion of grassland patches and proportion of potential grassland habitats represents the amount of habitat available for grassland restoration. This difference ranged from 2.8% to 46.6% (Table 5-4).

Existing grassland patches were concentrated in 5 different areas including southern Wisconsin, southern Florida, southern Louisiana, central Pennsylvania to northern Virginia, and a line from southern Illinois and Kentucky extending northeast to northwest New York (Figure 5-3). Areas considered potential grassland habitat were concentrated in the prairie peninsula extending from central Illinois to central Ohio and the Atlantic coastal plain including Florida (Figure 5-4).

Species richness for obligate grassland birds during the breeding season was concentrated in the northern states from Wisconsin south to Illinois and east to New York (Figure 5-5). Species richness ranged from 2 to 11 (mean = 5.4) breeding obligate grassland species in the counties containing the selected military installations (Table 5-4). Species richness for obligate grassland birds during the wintering season was concentrated in the southern states along the Gulf of Mexico (Louisiana, Alabama, Mississippi, and northern Florida) and along the coast of the Atlantic Ocean (South Carolina, through North Carolina to Virginia; Figure 5-6). Species richness in the wintering season ranged from 5 to 14 (average 10.4) in the counties containing each of the selected military installations (Table 5-4). Most installations contained ≥9 wintering grassland species (out of 14 total). Individual potential breeding and wintering species for each base are included in Tables 5-5 and 5-6.

Prioritization of the 45 selected military installations resulted in 24 installations with relatively high (>5) scores for the overall capacity to provide habitat for grassland birds during the breeding and wintering seasons (Table 5-7). Scores for breeding habitat were relatively high for 20 installations, and scores for wintering habitat were relatively high for 30 installations. The top 20 installations included 16 Army, 1 Marine Corps, 1 Air Force, and 2 Navy installations.

Overall, the average proportion of large grassland patches was generally similar within the installations to the proportion outside the military installation (up to 30 km), but the proportion of potential habitat was generally greater outside the military installations (Table 5-8). For installations >7,500 ha, the proportion of large grassland patches within the military installations was generally similar (plus or minus 5%) to the proportion of grassland patches in each of the 3 concentric 10-km buffer areas around the bases. For these larger installations, the proportion of potential habitats was generally greater outside the installation than inside the boundaries.

Installations <7,500 ha showed a different pattern; smaller installations had a greater proportion of potential habitat inside the boundaries (Table 5-8).

Discussion

Installations in each region in the US shared basic characteristics related to the proportion of existing large grassland patches and potential grassland (generally open, early-successional and agricultural habitats) in the landscape, and species richness during the wintering and breeding seasons. Very few selected military installations were located in the northern region, and all selected installations were relatively large (>8000 ha). The low number may reflect that the northern states are dominated by forested habitats, and there are generally few installations in the northern states. Installations in this region generally had low species richness for wintering birds, but some of the greatest breeding species richness values recorded for any of the installations in this analysis. Fort Drum in New York and Fort McCoy in Wisconsin were among the top 12 installations in the prioritization list (Table 5-7). Both Army installations were located in landscapes with relatively large proportions of existing grasslands (see Figure 5-3), relatively great breeding grassland bird richness (see Figure 5-5), and potentially contain 3 out of the 5 high-priority grassland species during the breeding season (including Henslow's Sparrows, Dickcissels [Ft. McCoy only], Short-eared Owls [Ft. Drum only], and Bobolinks). The buffer analysis indicated the proportion of grassland habitats within Fort Drum was similar to the proportion of grasslands within 30 km of the base (Table 5-8). On the other hand, Fort

McCoy was surrounded by an agricultural landscape (potential habitat > 40%), but the installation contained less grassland (existing and potential) habitat than the 3 surrounding 10-km buffers (Table 5-8). This suggests that past management at Fort McCoy allowed some of the grassland habitats to succeed to forests, and forest clearing for grassland restoration may be warranted.

The inland central region included 8 installations concentrated in Kentucky, Tennessee, southern Indiana, and northern Alabama in areas with relatively great proportions of existing grassland habitats, including 1 National Guard, 1 Navy, and 6 Army installations (Figure 5-2). These installations were located in an area with a relatively great proportion of existing grassland patches and relatively medium to high species richness for wintering and breeding grassland species. On average, installations in this region had the smallest proportion of existing grassland patches, but the greatest proportion of potential grassland habitat (Table 5-4). These installations are at the southern extent of many of the breeding ranges and at the northern extent of many of the wintering ranges, which contributes to their disproportionate importance. The installations in this central region also may serve as important stopover sites for migrating birds during the fall and spring (Figure 5-2).

In the inland central region, Fort Campbell on the border of Kentucky and Tennessee, Redstone Arsenal in northern Alabama, and the Naval Weapons Support Center, Crane, Indiana were among the top 12 installations. These 3 installations had some of the greatest scores for breeding species because of the great overall grassland bird species richness. Also, at least 2 out of the 5 breeding species of high concern have been found in the county the installations occupy: Henslow's Sparrows (Fort Campbell and Crane only), Bachman's Sparrow (Fort Campbell and Redstone only), and Dickcissels (all 3). Fort Campbell is also at the northern extent of the southern-breeding Bachman's Sparrow and near the southern extent of the northern-breeding Henslow's Sparrow.

The buffer analysis indicated Fort Campbell and Crane had relatively low proportions of grassland habitat within the installation compared with the proportion of grassland habitat in the three 10-km buffers. This result implies these installations could manage for a greater proportion of grassland habitats. In contrast, Redstone in Alabama had relatively more grassland within the installation than in the surrounding landscape although the proportion was low (>5% of the total area). All 3 of these installations were located in landscapes with relatively high potential for grassland management; 36-64% potential grassland habitat in the surrounding buffers.

Fort Knox in Kentucky also deserves mention because it had the lowest proportion of existing grassland habitats of any of the 45 installations considered. This was true despite the relatively great proportion of potential grassland habitats within the inland central region; 20-68% potential grassland habitat in the surrounding buffers of all 8 installations. Even with the relatively low proportion of grassland habitat within Fort Knox, small populations of Henslow's Sparrows, Eastern Meadowlarks, and Grasshopper Sparrows persist in the small patches of available habitat (personal observation). Local habitat conditions may be more important for habitat selection for these species, when the landscape has a relatively great proportion of potential grassland habitats (see Chapter 4).

The last 2 regions included 33 installations within 300 km of either the Atlantic Ocean or the Gulf of Mexico. The northern coastal region included 16 installations in Virginia, Maryland, New Jersey, and southern Pennsylvania: 1 Marine, 1 Air Force, 6 Army, and 8 Navy installations. Thirteen of the 16 installations were relatively small (<15,000 ha). These installations were located in an area with relatively great proportion of existing grassland habitats, relatively low breeding species richness, and great wintering species richness.

Letterkenny Army Depot in Pennsylvania, Marine Corps Combat Development Command, Quantico in Virginia, and Fort Detrick in Maryland were among the top 12 installations on the priority list. Both Letterkenny and Fort Detrick potentially contain Bobolinks and Dickcissels, and Letterkenny and Quantico may also provide breeding habitat for Henslow's Sparrows. Letterkenny and Quantico were relatively large (>7,500 ha) installations within a relatively open landscape (high potential grassland). Fort Detrick on the other hand was the smallest (852 ha) installation in the top 12, located in a landscape with the highest proportion of existing (≈50%) and potential (>60%) grassland habitat. The inclusion of Fort Detrick in the top 12 demonstrates even a small military installation could be important for the conservation of grassland birds in the appropriate landscapes.

The southern coastal region included 17 installations within 300 km of the coast in North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and

Louisiana: 1 port managed by the Army Corp of Engineers, 2 Air Force, 2 National Guard, 2 Navy, 2 Marine Corps, and 8 Army installations. Eleven of the 17 selected installations were greater than 20,000 ha in total area, including the 5 largest selected installations. Most of these installations were located in areas with very little existing grassland, but great potential for grassland restoration because of the extensive agricultural development in the region. These installations also had relatively low richness of breeding species, but the wintering species richness was among the greatest possible for the grassland obligate species considered in this analysis. Therefore, installations in this region may be especially important for wintering grassland species.

Avon Park in Florida, Fort Jackson in South Carolina, Fort Bragg in North Carolina, and Fort Rucker in Alabama were among the top 12 installations. All 4 installations had medium to large proportion of grassland habitats, low breeding species richness, and very high wintering species richness. Also, these installations potentially provide breeding and wintering habitat for Bachman's Sparrows.

Avon Park and Fort Rucker were located in landscapes with relatively great proportion of grassland and potential grassland habitats, but they both contained relatively less grassland habitat than the surrounding landscape (Table 5-8). Fort Jackson and Fort Bragg were on the other end of the landscape cover spectrum. Each contained relatively greater proportion of grassland habitat than the surrounding landscape (Table 5-8), thus providing an island of grassland habitat within a generally inhospitable landscape for grassland obligate birds.

Army installations made up the bulk of the land areas with significant grassland areas, because they tend to be large bases with open habitats for training. Several relatively small Navy and Marine installations were also selected, but this may be a product of including herbaceous wetlands in the landcover classification of grasslands. Installations in coastal areas contain large areas of herbaceous wetlands, as classified by the NLCD. These wetland areas were included as grassland because this habitat could not be differentiated from inland herbaceous wetland used by some of the obligate grassland birds considered in this analysis (e.g., Henslow's Sparrows), and because herbaceous wetlands may provide wintering habitat in the southeastern US.

The priority scoring did have some inherent limitations, which should be considered before using this kind of a scheme to rank priority areas for conservation investment. By grouping species richness and percent cover of large grassland into counties, I may be under-estimating or over-estimating the importance of certain areas within the county. For example, certain parts of the county may have greater importance than others, and averaging within counties may obscure the importance. Averaging within counties was necessary because of the different mapping scales used by the various state breeding bird atlases. The county level was the most fine-grained resolution at which I could reliably map all of the atlas records. Mapping species richness and available habitat on a landscape scale was appropriate for the kind of coarse filter analysis conducted in this study to indicate areas that would require further consideration.

Savanna habitats, which are particularly prevalent in the Southeast, are difficult to detect in this analysis, but are important habitats for several grassland birds in the winter (Plentovich et al. 1999). This analysis may be underestimating the amount of potential wintering habitat by classifying these savannas as forested habitats. This underestimation may be most important when trying to predict Bachman's Sparrow breeding habitat from NLCD, because Bachman's Sparrows use these habitats extensively for nesting (Tucker et al. 1998).

Finally, very little is known about wintering ranges and wintering habitat use (Herkert and Knopf 1998). Christmas Bird Count sampling for grassland birds is difficult at best, inaccurate at worst. The nomadic habits of some of these species and temperature-induced movements are problematic for mapping distribution and habitat use. Species, such as Dickcissels, are known to migrate to the Neotropics but are sometimes found within the US during the winter months. These individuals may not ultimately survive, thus at the population level their presence in the US may be insignificant.

Many breeding species specializing in grassland habitats are considered area sensitive, and tend to be found only in large habitat patches. For example, breeding Henslow's Sparrows, Grasshopper Sparrows, Eastern Meadowlarks and Dickcissels usually are found in larger (>40 ha) field habitats (Zimmerman 1988, Herkert 1994, Herkert et al. 2002). All 4 species have been affected by the changes in land use and land management that has reduced the amount and quality of habitat available to these bird species (Lanyon 1995, Vickery 1996, Temple 2002, Burhans 2002, Herkert et al.

2002). Farmers converted native grasslands to cool-season forages for livestock and to small grains, which reduced nesting habitat quality. More recently, increasing urbanization and a shift from pastures and small grains to row crops of corn and soybeans have continued the decline in grass-dominated habitats (Rodenhouse et al. 1995). Military lands can be important for wildlife conservation because of the lack of urbanization or intensive agriculture (Quist et al. 2003). Another advantage of military installations is the relatively large areas with limited public access (Cohen 1996).

Military training can have negative impacts on the grassland bird populations and grassland habitats. Military training activities can cause direct mortality either by destroying nests or adult mortality (e.g., bird strikes with aircraft). Direct nest mortality can be minimized by avoiding important breeding areas during the breeding season, although in this study I found very few nests were lost specifically because of military training activities (see Chapter 2). Additionally, heavy track vehicles can cause soil compaction. This compaction can, in turn, change the plant communities and indirectly affect the grassland bird populations (Quist et al. 2003).

Military installations on lands managed by the DOD could have major positive impacts on the declining populations of bird and other wildlife species, which depend on frequent habitat disturbance to maintain early-successional habitats. Because many military activities require or cause the maintenance of large areas of open, grassy or shrubby habitats, tailoring habitat management to enhance grassland populations would not require major changes in existing management plans. The location of some of the larger eastern US military installations in landscapes with relatively large amounts of open habitats may also serve as a refuge for many grassland species displaced by modern, "clean" farming practices (Peterjohn 2003, Murphy 2003). With a few considerations to the type and timing of disturbances, military installations could serve as a model for other federal and private land management for the conservation of grassland habitats, and may even serve as control sites for comparison with grassland restoration efforts (Cohen 1996, Dykes 2005).

Successional transformation because of the suppression of fire is also a serious threat to the maintenance of grassland habitats. In eastern grasslands, succession from grassland habitats to forest habitats can occur relatively fast, within 1 or 2 decades (DeSelm and Murdock 1993). If regular disturbance is not introduced to open habitats at least every few years through burning, mowing, grazing, or use of herbicides, forest will quickly overtake an area to make it unsuitable for use by grassland birds. On the other hand, increasing the amount of grassland habitat could ultimately reduce the amount of forest habitat provided by the military installations. There is a need to recognize the balance between forested habitats and grassland habitat on each base. There may be a unique mix of forest and grassland based on military training needs and needs of various species.

With the dramatic decrease of native grasslands during the 20th century, regional planning is becoming more important to restore populations of declining grassland bird populations (Pashley et al. 2000). Large-scale management recommendations call for a "core area" of native grassland surrounded by management zones measured in the thousands of hectares (Burhans 2002). In the eastern US, there are very few land areas containing grassland habitats that are not actively managed for agricultural production. There is not enough land area under public ownership to provide habitat for all grassland birds, but federally managed lands, especially DOD lands, could provide large enough core areas to build grassland conservation efforts around. Cooperation with private landowners will be important for the development of any successful plans.

This analysis will help to target areas where private lands could be managed for the benefit of grassland bird populations and the military. Targeting management and conservation efforts for grassland habitats in these installations could help to maximize limited funding for wildlife management while providing open areas needed for military activities.

CHAPTER 6

FORT CAMPBELL MANAGEMENT RECOMMENDATIONS

Fort Campbell Army Base provides suitable habitat for many grassland species of management concern. Results from this study indicate there are several management recommendations that could be incorporated into the base management plans to enhance not only habitat for grassland birds, but also training opportunities for the Army.

First, the timing of management activities could be altered to allow nesting birds to produce sustainable populations. Because the primary mission of Fort Campbell is military training, harvesting of hay may be conducted after the breeding season in August, as long as troop training and safety are not impacted. Habitat management (haying and prescribed burning) during the breeding season (15 April – 15 August) should be restricted to after August 1 to avoid the bulk of the nesting season. If mowing is necessary, mowing before the nesting season begins (early April) and continuously mowing every two to three weeks would help to prevent individual birds from attempting to nest in a population sink area. The timing of management could be stipulated in the agricultural lease between the farmers and Fort Campbell. If hay production is still desirable, converting fields from non-native, cool-season grasses back to native, warm-season grasses would allow haying in August while avoiding the main portion of the nesting season.

Second, many of the fields at Fort Campbell are relatively small and could be combined to create several larger fields, as suggested by Moss (2001). Larger fields would not only provide greater habitat for grassland birds, but also provide more useful training area for airborne military activities. Combining small fields would increase the relative amount of open area within the installation, which would be consistent with the configuration of the surrounding landscape. Within the installation boundaries, my analysis indicated there was only 6% cover in large patches and 20% cover in open habitat; whereas the surrounding 3-10 km concentric buffers contained 10-12% cover in large grassland patches and 40-50% cover in open habitats.

My habitat analysis of nest sites of the 5 grassland birds indicated deeper litter depths, less bare ground cover, and taller grass height than random points, representing available habitat within fields at Fort Campbell. These results indicate prescribed burning within the fields may be too frequent (almost every year) to allow grasses to establish a litter layer, which is used by many of these grassland bird species. For Henslow's Sparrows, Grasshopper Sparrows, and Eastern Meadowlarks, woody cover at the nest sites was very sparse, indicating woody encroachment needs to be controlled to provide suitable nesting habitat for these 3 species. Creating larger fields and burning under suitable conditions every 2 to 3 years would help keep woody vegetation from overtaking fields while reducing the amount of management needed and increasing the area for grassland bird habitat.

Finally, management at Fort Campbell could benefit from an adaptive management framework, where monitoring efforts feed directly into a hypothesis testing and modeling process that would generate options to direct future management decisions. Further population monitoring would then evaluate the various management actions most effectively enhance grassland bird populations while providing areas for military training (Zabel et al. 2000). Adaptive management would be an iterative process that integrates monitoring, modeling, and management components. Adaptive management efforts would benefit from collaboration between the land managers at Fort Campbell, private landowners around the installation, and other interested stakeholders, such as resource specialists at The Nature Conservancy and scientists at The University of Tennessee. The benefits to the Army would include more training areas and less reliance on Fort Campbell to provide habitat for grassland birds. The adaptive management process would facilitate integration of new information into existing management plans, and the relatively quick turnover in grassland ecosystems (every 3-5 years) would generate new information about optimal management strategies quickly. This study provides a solid foundation for an adaptive management process to build new management strategies that enhance military training opportunities and grassland bird conservation.

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APPENDIX

TABLES

CHAPTER 2

Table 2-1. Nest fates, clutch size, hatching success, young produced per successful nest, and nests parasitized for Henslow's Sparrow, Grasshopper Sparrow, Dickcissel, Eastern Meadowlark, and Field Sparrow at Fort Campbell Army Base, Kentucky, 1999-2003.

	Henslow's Sparrow (n = 113)	Grasshopper Sparrow (n = 131)	Dickcissel (n = 204)	Eastern Meadowlark (n = 87)	Field Sparrow (n = 276)
Nesting data					
Successful nests	65	85	87	36	126
Depredated nests	44	38	97	45	139
Unknown fate	1	0	0	1	0
Abandoned nests	3	3	9	2	7
Abandoned due to parasitism	0	0	0	0	1
Mowing for hay	0	4	4	1	2
Military activity	0	1	3	0	0
Weather	0	0	4	2	1
Nest success (%)	57.5	64.9	42.6	41.4	45.7
Nesting biology					
Clutch size average	4.1	4.4	4.3	4.6	3.6
Clutch size range	(2-6)	(2-5)	(3-9)	(1-10)	(3-5)
(n)	(108)	(131)	(191)	(87)	(264)
Hatching success (%)	90.4	93.2	90.3	94.1	95.9
(n)	(80)	(104)	(116)	(53)	(171)
Young fledged/nest	2.2	2.6	1.7	1.7	1.6
Young fledged/successful nest	3.9	4.1	3.9	4.0	3.6
Nest parasitism					
Parasitized nests	1	0	0	0	3

Table 2-2. Nesting success of Henslow's Sparrows at Fort Campbell Army Base, Kentucky,1999-2003.

Year	Nest cycle interval[a]	Mean days in period[b]	n[c]	Failures (n)[d]	Exposure days[e]	Daily survival[f]	SE	Success (%)[g]
1999	Laying	4.0	0	0	0.0	1.00	0.00	100.0
	Incubating	11.0	2	1	11.5	0.91	0.08	4.0 < 36.8 < 100.0
	Nestling	9.5	5	2	14.0	0.86	0.09	2.2 < 23.1 < 100.0
	Inc. + nest.	20.5	6	3	25.5	0.88	0.06	0.3 < 7.7 < 100.0
	All stages	24.5	6	3	25.5	0.88	0.06	0.1 < 4.7 < 100.0
2000	Laying	4.0	3	0	5.0	1.00	0.00	100.0
	Incubating	11.0	22	8	122.5	0.93	0.02	27.8 < 47.6 < 79.5
	Nestling	9.5	33	14	149.0	0.91	0.02	23.4 < 39.2 < 63.8
	Inc. + nest.	20.5	40	22	271.5	0.92	0.02	8.3 < 17.7 < 36.6
	All stages	24.5	40	22	276.5	0.92	0.02	5.4 < 13.1 < 30.7
2001	Laying	4.0	3	1	9.5	0.89	0.10	23.4 < 64.1 < 100.0
	Incubating	11.0	19	7	101.5	0.93	0.03	24.7 < 45.6 < 81.3
	Nestling	9.5	17	2	124.5	0.98	0.01	68.8 < 85.7 < 100.0
	Inc. + nest.	20.5	25	9	226.0	0.96	0.01	24.8 < 43.5 < 75.2
	All stages	24.5	26	10	235.5	0.96	0.01	17.5 < 34.5 < 67.0
2002	Laying	4.0	1	0	3.0	1.00	0.00	100.0
	Incubating	11.0	8	4	44.0	0.91	0.04	11.6 < 35.0 < 95.4
	Nestling	9.5	17	3	69.0	0.96	0.02	39.7 < 65.6 < 100.0
	Inc. + nest.	20.5	20	7	113.0	0.94	0.02	9.8 < 27.0 < 71.0
	All stages	24.5	20	7	116.0	0.94	0.02	6.7 < 21.8 < 67.1
2003	Laying	4.0	1	1	2.0	0.50	0.35	0.2 < 6.3 < 100.0
	Incubating	11.0	3	1	18.0	0.94	0.05	14.0 < 53.3 < 100.0
	Nestling	9.5	18	2	57.5	0.97	0.02	43.9 < 71.4 < 100.0
	Inc. + nest.	20.5	19	3	75.5	0.96	0.02	16.3 < 43.6 < 100.0
	All stages	24.5	20	4	77.5	0.95	0.03	7.2 < 27.3 < 96.7

[a] Nesting cycle intervals include laying stage, incubating, nestling, incubation & nestling combined, and all stages combined.

[b] Expected length of each stage in days from Ehrlich et al. (1988).

[c] Number of nests monitored in each nest cycle interval.

[d] Total number of failed nests.

[e] Total number of exposure days (Mayfield 1975).

[f] Probability of daily nest success (Mayfield 1975).

[g] Probability of nest success through the nesting cyle interval including mean and 95% confidence intervals (Johnson 1979).

Table 2-3. Nesting success of Grasshopper Sparrows at Fort Campbell Army Base, Kentucky,1999-2003.

Year	Nest cycle interval[a]	Mean days in period[b]	n[c]	Failures (n)[d]	Exposure days[e]	Daily survival[f]	SE		Success (%)[g]	
1999	Laying	4.5	1	0	4.0	1.000	0.000		100.0	
	Incubating	11.5	7	2	29.5	0.932	0.046	13.4 <	44.6 <	100.0
	Nestling	9.0	17	3	62.5	0.952	0.027	37.9 <	64.2 <	100.0
	Inc. + nest.	20.5	19	5	92.0	0.946	0.024	11.1 <	31.8 <	86.5
	All stages	25.0	19	5	96.0	0.948	0.023	7.7 <	26.3 <	84.5
2000	Laying	4.5	0	0	0.0	1.000	0.000		100.0	
	Incubating	11.5	18	6	94.5	0.937	0.025	25.0 <	47.0 <	85.7
	Nestling	9.0	26	1	163.0	0.994	0.006	84.6 <	94.6 <	100.0
	Inc. + nest.	20.5	30	7	257.5	0.973	0.010	36.9 <	56.8 <	86.7
	All stages	25.0	30	7	257.5	0.973	0.010	29.7 <	50.2 <	84.1
2001	Laying	4.5	1	0	2.0	1.000	0.000		100.0	
	Incubating	11.5	13	6	81.0	0.926	0.029	19.6 <	41.3 <	83.2
	Nestling	9.0	20	6	132.0	0.955	0.018	46.4 <	65.8 <	92.0
	Inc. + nest.	20.5	26	12	213.0	0.944	0.016	15.2 <	30.5 <	59.8
	All stages	25.0	26	12	215.0	0.944	0.016	10.2 <	23.8 <	53.8
2002	Laying	4.5	3	0	4.0	1.000	0.000		100.0	
	Incubating	11.5	19	6	116.5	0.948	0.020	32.8 <	54.4 <	88.5
	Nestling	9.0	18	5	110.5	0.955	0.020	45.0 <	65.9 <	95.0
	Inc. + nest.	20.5	24	11	227.0	0.952	0.014	19.4 <	36.1 <	66.2
	All stages	25.0	24	11	231.0	0.952	0.014	14.0 <	29.5 <	61.0
2003	Laying	4.5	3	0	7.0	1.000	0.000		100.0	
	Incubating	11.5	16	3	123.5	0.976	0.014	54.1 <	75.4 <	100.0
	Nestling	9.0	27	8	153.0	0.948	0.018	43.5 <	61.7 <	86.3
	Inc. + nest.	20.5	30	11	276.5	0.960	0.012	26.2 <	43.5 <	71.4
	All stages	25.0	30	11	283.5	0.961	0.011	20.3 <	37.2 <	67.1

[a] Nesting cycle intervals include laying stage, incubating, nestling, incubation & nestling combined, and all stages combined.

[b] Expected length of each stage in days from Ehrlich et al. (1988).

[c] Number of nests monitored in each nest cycle interval.

[d] Total number of failed nests.

[e] Total number of exposure days (Mayfield 1975).

[f] Probability of daily nest success (Mayfield 1975).

[g] Probability of nest success through the nesting cyle interval including mean and 95% confidence intervals (Johnson 1979).

Table 2-4. Nesting success of Dickcissels at Fort Campbell Army Base, Kentucky, 1999-2003.

Year	Nest cycle interval[a]	Mean days in period[b]	n[c]	Failures (n)[d]	Exposure days[e]	Daily survival[f]	SE	Success (%)[g]
1999	Laying	4.0	5	1	11.0	0.909	0.087	29.3 < 68.3 < 100.0
	Incubating	12.5	10	6	67.5	0.911	0.035	11.6 < 31.2 < 78.1
	Nestling	9.0	7	3	32.5	0.908	0.051	14.4 < 41.8 < 100.0
	Inc. + nest.	21.5	13	9	100.0	0.910	0.029	3.3 < 13.2 < 48.9
	All stages	25.5	14	10	111.0	0.910	0.027	1.9 < 9.0 < 39.5
2000	Laying	4.0	16	3	48.0	0.938	0.035	56.7 < 77.2 < 100.0
	Incubating	12.5	24	14	168.0	0.917	0.021	18.6 < 33.7 < 59.5
	Nestling	9.0	23	4	108.0	0.963	0.018	50.4 < 71.2 < 99.4
	Inc. + nest.	21.5	37	18	276.0	0.935	0.015	11.7 < 23.5 < 46.0
	All stages	25.5	40	21	324.0	0.935	0.014	8.5 < 18.1 < 37.8
2001	Laying	4.0	32	3	101.0	0.970	0.017	76.9 < 88.6 < 100.0
	Incubating	12.5	61	29	383.5	0.924	0.014	25.8 < 37.4 < 53.6 *
	Nestling	9.0	42	11	271.0	0.959	0.012	54.8 < 68.9 < 86.0 *
	Inc. + nest.	21.5	71	40	654.5	0.939	0.009	16.7 < 25.8 < 39.4
	All stages	25.5	74	43	755.5	0.943	0.008	14.2 < 22.4 < 35.3
2002	Laying	4.0	8	2	23.0	0.913	0.059	40.1 < 69.5 < 100.0
	Incubating	12.5	21	4	150.0	0.973	0.013	50.6 < 71.3 < 99.6
	Nestling	9.0	24	10	138.0	0.928	0.022	32.8 < 50.8 < 77.2
	Inc. + nest.	21.5	28	14	288.0	0.951	0.013	19.2 < 34.3 < 60.3
	All stages	25.5	30	16	311.0	0.949	0.013	13.1 < 26.0 < 50.6
2003	Laying	4.0	14	4	46.0	0.913	0.042	47.4 < 69.5 < 98.5
	Incubating	12.5	29	14	228.0	0.939	0.016	29.4 < 45.3 < 68.7
	Nestling	9.0	28	9	145.0	0.938	0.020	37.9 < 56.2 < 81.9
	Inc. + nest.	21.5	42	23	373.0	0.938	0.012	14.3 < 25.5 < 44.7
	All stages	25.5	46	27	419.0	0.936	0.012	9.4 < 18.3 < 34.9

[a] Nesting cycle intervals include laying stage, incubating, nestling, incubation & nestling combined, and all stages combined.

[b] Expected length of each stage in days from Ehrlich et al. (1988).

[c] Number of nests monitored in each nest cycle interval.

[d] Total number of failed nests.

[e] Total number of exposure days (Mayfield 1975).

[f] Probability of daily nest success (Mayfield 1975).

[g] Probability of nest success through the nesting cyle interval including mean and 95% confidence intervals (Johnson 1979).

* Intervals do not overlap

Table 2-5. Nesting success of Eastern Meadowlarks at Fort Campbell Army Base, Kentucky, 1999-2003.

Year	Nest cycle interval[a]	Mean days in period[b]	n[c]	Failures (n)[d]	Exposure days[e]	Daily survival[f]	SE	Success (%)[g]
1999	Laying	4.0	1	0	2.0	1.000	0.000	100.0
	Incubating	12.5	11	5	80.5	0.938	0.027	21.4 < 44.9 < 90.1
	Nestling	9.0	7	5	43.0	0.884	0.049	11.4 < 32.9 < 84.5
	Inc. + nest.	21.5	12	10	123.5	0.919	0.025	5.0 < 16.3 < 49.8
	All stages	25.5	12	10	125.5	0.920	0.024	3.0 < 12.0 < 44.4
2000	Laying	4.0	3	0	3.0	1.000	0.000	100.0
	Incubating	12.5	11	7	76.0	0.908	0.033	11.6 < 29.9 < 72.2
	Nestling	9.0	10	6	70.0	0.914	0.033	22.5 < 44.6 < 84.3
	Inc. + nest.	21.5	17	13	146.0	0.911	0.024	4.3 < 13.5 < 39.8
	All stages	25.5	17	13	149.0	0.913	0.023	2.6 < 9.7 < 34.4
2001	Laying	4.0	4	0	7.0	1.000	0.000	100.0
	Incubating	12.5	13	6	85.5	0.930	0.028	18.7 < 40.3 < 82.9
	Nestling	9.0	17	5	109.0	0.954	0.020	44.5 < 65.5 < 94.9
	Inc. + nest.	21.5	23	11	194.5	0.943	0.017	13.3 < 28.6 < 60.1
	All stages	25.5	23	11	201.5	0.945	0.016	9.9 < 23.9 < 55.9
2002	Laying	4.0	2	0	6.0	1.000	0.000	100.0
	Incubating	12.5	10	3	65.5	0.954	0.026	27.8 < 55.7 < 100.0
	Nestling	9.0	12	4	71.0	0.944	0.027	34.7 < 59.3 < 98.6
	Inc. + nest.	21.5	15	7	136.5	0.949	0.019	13.5 < 32.2 < 74.6
	All stages	25.5	15	7	142.5	0.951	0.018	10.3 < 27.7 < 71.8
2003	Laying	4.0	3	0	8.0	1.000	0.000	100.0
	Incubating	12.5	9	4	47.0	0.915	0.041	10.3 < 32.9 < 95.5
	Nestling	9.0	15	5	94.0	0.947	0.023	38.9 < 61.1 < 94.0
	Inc. + nest.	21.5	19	9	141.0	0.936	0.021	9.2 < 24.2 < 61.1
	All stages	25.5	19	9	149.0	0.940	0.020	6.9 < 20.4 < 57.6

[a] Nesting cycle intervals include laying stage, incubating, nestling, incubation & nestling combined, and all stages combined.

[b] Expected length of each stage in days from Ehrlich et al. (1988).

[c] Number of nests monitored in each nest cycle interval.

[d] Total number of failed nests.

[e] Total number of exposure days (Mayfield 1975).

[f] Probability of daily nest success (Mayfield 1975).

[g] Probability of nest success through the nesting cyle interval including mean and 95% confidence intervals (Johnson 1979).

* Intervals do not overlap

Table 2-6. Nesting success of Field Sparrows at Fort Campbell Army Base, Kentucky, 1999-2003.

Year	Nest cycle interval[a]	Mean days in period[b]	n[c]	Failures (n)[d]	Exposure days[e]	Daily survival[f]	SE	Success (%)[g]
1999	Laying	3.5	0	0	0.0	1.000	0.000	100.0
	Incubating	12.0	16	8	73.5	0.891	0.036	9.0 < 25.1 < 64.3
	Nestling	7.5	15	6	77.0	0.922	0.031	32.5 < 54.4 < 88.0
	Inc. + nest.	19.5	23	14	150.5	0.907	0.024	5.2 < 14.9 < 40.2
	All stages	23.1	23	14	150.5	0.907	0.024	3.0 < 10.5 < 34.0
2000	Laying	3.5	17	4	55.0	0.927	0.035	58.3 < 76.8 < 99.1
	Incubating	12.0	50	23	233.5	0.901	0.020	16.9 < 28.8 < 47.9
	Nestling	7.5	57	19	234.0	0.919	0.018	39.4 < 53.0 < 70.5
	Inc. + nest.	19.5	80	42	467.5	0.910	0.013	9.0 < 16.0 < 27.9
	All stages	23.1	84	46	522.5	0.912	0.012	6.3 < 11.9 < 22.1
2001	Laying	3.5	20	6	43.0	0.860	0.053	37.4 < 59.1 < 88.6
	Incubating	12.0	49	21	278.0	0.924	0.016	25.6 < 39.0 < 58.4
	Nestling	7.5	44	16	215.0	0.926	0.018	41.7 < 56.0 < 74.4
	Inc. + nest.	19.5	65	37	493.0	0.925	0.012	13.2 < 21.8 < 35.8
	All stages	23.1	71	43	536.0	0.920	0.012	8.0 < 14.5 < 25.9
2002	Laying	3.5	5	1	12.0	0.917	0.080	37.8 < 73.7 < 100.0
	Incubating	12.0	32	20	162.5	0.877	0.026	10.0 < 20.7 < 41.0 *
	Nestling	7.5	27	7	123.5	0.943	0.021	46.0 < 64.6 < 89.2 *
	Inc. + nest.	19.5	47	27	286.0	0.906	0.017	6.8 < 14.5 < 30.0
	All stages	23.1	47	28	298.0	0.906	0.017	4.3 < 10.2 < 23.9
2003	Laying	3.5	5	0	14.0	1.000	0.000	100.0
	Incubating	12.0	29	11	165.0	0.933	0.019	26.2 < 43.7 < 71.3
	Nestling	7.5	40	8	200.0	0.960	0.014	59.1 < 73.6 < 91.1
	Inc. + nest.	19.5	51	19	365.0	0.948	0.012	21.7 < 35.3 < 56.6
	All stages	23.1	51	19	379.0	0.950	0.011	17.6 < 30.5 < 52.2

[a] Nesting cycle intervals include laying stage, incubating, nestling, incubation & nestling combined, and all stages combined.

[b] Expected length of each stage in days from Ehrlich et al. (1988).

[c] Number of nests monitored in each nest cycle interval.

[d] Total number of failed nests.

[e] Total number of exposure days (Mayfield 1975).

[f] Probability of daily nest success (Mayfield 1975).

[g] Probability of nest success through the nesting cyle interval including mean and 95% confidence intervals (Johnson 1979).

* Intervals do not overlap

Table 2-7. Nesting success of grassland birds at Fort Campbell Army Base, Kentucky, 1999-2003.

Species	Nest cycle interval[a]	Mean days in period[b]	n[c]	Failures (n)[d]	Exposure days[e]	Daily survival[f]	SE	Success (%)[g]			
HESP[h]	Laying	4.0	8	2	19.5	0.897	0.069	33.4 <	64.9 <	100.0	
GRSP	Laying	4.5	8	0	17.0	1.000	0.000		100.0		
DICK	Laying	4.0	75	13	229.0	0.943	0.015	69.4 <	79.2 <	89.9	
EAME	Laying	4.0	13	0	26.0	1.000	0.000		100.0		
FISP	Laying	3.5	47	11	124.0	0.911	0.026	58.2 <	71.6 <	87.1	
HESP	Incubating	11.0	54	21	297.5	0.929	0.015	31.3 <	44.7 <	63.2	
GRSP	Incubating	11.5	73	23	445.0	0.948	0.010	42.0 <	54.3 <	69.9	*
DICK	Incubating	12.5	145	67	997.0	0.933	0.008	33.8 <	41.9 <	51.7	
EAME	Incubating	12.5	54	25	354.5	0.929	0.014	27.7 <	40.1 <	57.5	
FISP	Incubating	12.0	176	83	912.5	0.909	0.010	24.7 <	31.8 <	40.8	*
HESP	Nestling	9.5	88	23	412.5	0.944	0.011	46.1 <	58.0 <	72.6	
GRSP	Nestling	9.0	108	23	621.0	0.963	0.008	61.7 <	71.2 <	81.9	
DICK	Nestling	9.0	124	37	694.5	0.947	0.009	51.9 <	61.1 <	71.7	
EAME	Nestling	9.0	61	25	387.0	0.935	0.012	43.0 <	54.8 <	69.5	
FISP	Nestling	7.5	183	56	849.5	0.934	0.009	52.2 <	60.0 <	68.7	
HESP	Inc. + nest.	20.5	111	44	710.0	0.938	0.009	18.1 <	26.9 <	39.9	
GRSP	Inc. + nest.	20.5	129	46	1066.0	0.957	0.006	31.0 <	40.5 <	52.8	*
DICK	Inc. + nest.	21.5	191	104	1691.5	0.939	0.006	19.5 <	25.6 <	33.3	
EAME	Inc. + nest.	21.5	86	50	741.5	0.933	0.009	14.5 <	22.3 <	33.9	
FISP	Inc. + nest.	19.5	266	139	1762.0	0.921	0.006	15.3 <	20.1 <	26.4	*
HESP	All stages	24.5	113	46	729.5	0.937	0.009	12.6 <	20.3 <	32.3	
GRSP	All stages	25.0	129	46	1083.0	0.958	0.006	24.5 <	33.8 <	46.4	*
DICK	All stages	25.5	204	117	1920.5	0.939	0.005	14.9 <	20.1 <	27.0	
EAME	All stages	25.5	86	50	767.5	0.935	0.009	11.0 <	17.9 <	29.0	
FISP	All stages	23.1	276	150	1886.0	0.920	0.006	10.8 <	14.7 <	20.1	*

[a] Nesting cycle intervals include laying stage, incubating, nestling, incubation & nestling combined, and all stages combined.

[b] Expected length of each stage in days from Ehrlich et al. (1988).

[c] Number of nests monitored in each nest cycle interval.

[d] Total number of failed nests.

[e] Total number of exposure days (Mayfield 1975).

[f] Probability of daily nest success (Mayfield 1975).

[g] Probability of nest success through the nesting cyle interval including mean and 95% confidence intervals (Johnson 1979).

[h] HESP = Henslow's Sparrow, GRSP = Grasshopper Sparrow, DICK = Dickcissel, EAME = Eastern Meadolark, FISP = Field Sparrow.

* - Intervals do not overlap

Table 2-8. Reported demographic rates for Henslow's Sparrow, Grasshopper Sparrow, Field Sparrow, Eastern Meadowlark, and Dickcissel.

Species	Sample Size	Clutch Size	Hatching Success	Parasitism	Mayfield Success	Apparent Success	Location	Citation
Henslow's Sparrow	11	4.40				0.55	Michigan	Robins 1971
	12	3.90		0.08			Ontario	Peck and James 1987
	59	3.80	0.93	0.05	0.40	0.58	Missouri	Winter 1998
	24	3.30		0.08	0.46	0.29	Oklahoma	Reinking et al. 2000
	21	4.20		0.00	0.33	0.43	Indiana	Galligan and Lima unpublished
	31	3.50				0.74	Kentucky	Monroe 2001
	136			0.01	0.23		Indiana	Robb unpublished data
	16				0.07	0.19	Missouri	McCoy unpublished data
	113	**4.10**	**0.90**	**0.01**	**0.27**	**0.58**	**Tennessee**	***This Study***

Table 2-8. Continued.

Species	Sample Size	Clutch Size	Hatching Success	Parasitism	Mayfield Success	Apparent Success	Location	Citation
Grasshopper Sparrow	14			0.02			Ohio	Price 1934
	14			0.50			Kansas	Elliot 1978
	18			0.50			Kansas	Elliot 1978
	16	4.50		0.00	0.47	0.70	West Virginia	Wray et al. 1982
	15	4.50		0.00	0.08	0.22	West Virginia	Wray et al. 1982
	13	4.10		0.00	0.07	0.15	West Virginia	Wray et al. 1982
	438	4.30					US-Rangewide	McNair 1987
	51	3.71					Florida	McNair 1987
	60			0.00		0.42	Maine	Vickery et al. 1992
	121			0.07			Oklahoma	Reinking cited in Vickery 1996
	23	3.72	0.98	0.00	0.22	0.65	Missouri	Winter 1998
	42				0.52	0.24	New York	Balent and Norment 2003
	85				0.31	0.47	Wisconsin	Vos 2003

Table 2-8. Continued.

Species	Sample Size	Clutch Size	Hatching Success	Parasitism	Mayfield Success	Apparent Success	Location	Citation
Grasshopper Sparrow	5	4.60				0.80	Tennessee	Giocomo *in review*
	131	**4.40**	**0.93**	**0.00**	**0.41**	**0.65**	**Tennessee**	***This Study***
Field Sparrow	159			0.32			Ohio	Hicks 1934
	97					0.51	Michigan	Walkinshaw 1939
	20			0.80			Iowa	Crooks 1948
	5	3.40		0.00		0.40	West Virginia	Wray et al. 1982
	18	3.80		0.00	0.47	0.72	West Virginia	Wray et al. 1982
	147			0.11		0.10	Illinios	Best 1978
	47	3.96					Missouri	Carey et al. 1994
	148			0.14			Missouri	Carey et al. 1994
	371			0.00			Pennsylvania	Carey et al. 1994
	158	3.69					Pennsylvania	Carey et al. 1994
	369					0.39	Pennsylvania	Carey et al. 1994

Table 2-8. Continued.

Species	Sample Size	Clutch Size	Hatching Success	Parasitism	Mayfield Success	Apparent Success	Location	Citation
Field Sparrow	40				0.23	0.53	Arkansas	Barber et al. 2001
	23				0.21	0.39	Arkansas	Barber et al. 2001
	21				0.25		Wisconsin	Vos 2003
	276	**3.60**	**0.96**	**0.01**	**0.20**	**0.46**	**Tennessee**	***This Study***
Eastern Meadowlark	23	4.57					New York	Saunders 1932
	26	5.20					Kansas	Johnston 1964
	262	4.16	0.98			0.31	Illinois	Roseburry and Kilmestra 1970
	40			0.70			Kansas	Elliot 1978
	370			0.02			Ontario	Peck and James 1987
	37	4.70				0.30	Ontario	Knapton 1988
	66	4.51				0.52	Ontario	Knapton 1988
	38	4.80		0.16			Wisconsin	Lanyon 1995
	10				0.17		Kansas	Granfors et al. 1996

Table 2-8. Continued.

Species	Sample Size	Clutch Size	Hatching Success	Parasitism	Mayfield Success	Apparent Success	Location	Citation
Eastern Meadowlark	11				0.25		Kansas	Granfors et al. 1996
	44				0.10		Kansas	Granfors et al. 1996
	30				0.20		Kansas	Granfors et al. 1996
	47	4.10	1.00	0.10	0.20	0.70	Missouri	Winter 1998
	87	**4.60**	**0.94**	**0.00**	**0.22**	**0.41**	**Tennessee**	***This Study***
Dickcissel	5		0.74				Kansas	Long 1963
	29	4.03					Illinois	Gross 1968
	19			0.95			Kansas	Elliot 1978
	149	4.00					Kansas	Zimmerman 1982
	385			0.60			Kansas	Zimmerman 1983
	235			0.84			Kansas	Zimmerman 1983
	24				0.23		Texas	Basili et al. 1997
	111				0.21		Oklahoma	Basili et al. 1997

Table 2-8. Continued.

Species	Sample Size	Clutch Size	Hatching Success	Parasitism	Mayfield Success	Apparent Success	Location	Citation
Dickcissel	395			0.18			Oklahoma	Basili et al. 1997
	28			0.50			Kansas	Basili et al. 1997
	33			0.48			Kansas	Basili et al. 1997
	143			0.79			Kansas	Basili et al. 1997
	161			0.57			Kansas	Basili et al. 1997
	10			0.90			Nebraska	Basili et al. 1997
	17			0.53			Nebraska	Basili et al. 1997
	34			0.56			Nebraska	Basili et al. 1997
	61			0.48			Iowa	Basili et al. 1997
	10			0.10			Louisiana	Basili et al. 1997
	150			0.14			Wisconsin	Basili et al. 1997
	134	4.67					Texas	Basili et al. 1997
	281	3.89					Oklahoma	Basili et al. 1997

Table 2-8. Continued.

Species	Sample Size	Clutch Size	Hatching Success	Parasitism	Mayfield Success	Apparent Success	Location	Citation
Dickcissel	124				0.14		Oklahoma	Basili et al. 1997
	160				0.15		Oklahoma	Basili et al. 1997
	56				0.20		Kansas	Basili et al. 1997
	92				0.21		Kansas	Basili et al. 1997
	74				0.50		Kansas	Basili et al. 1997
	69				0.50		Kansas	Basili et al. 1997
	78				0.32		Wisconsin	Basili et al. 1997
	33				0.12		Wisconsin	Basili et al. 1997
	39				0.26		Wisconsin	Basili et al. 1997
	22			0.05			Texas	Basili et al. 1997
	143			0.03			Texas	Basili et al. 1997
	29			0.21			Oklahoma	Basili et al. 1997
	75			0.21			Oklahoma	Basili et al. 1997

Table 2-8. Continued.

Species	Sample Size	Clutch Size	Hatching Success	Parasitism	Mayfield Success	Apparent Success	Location	Citation
Dickcissel	30	3.73					Kansas	Basili et al. 1997
	149	4.00					Kansas	Basili et al. 1997
	81	3.77					Kansas	Basili et al. 1997
	9	4.22					Kansas	Basili et al. 1997
	13	4.15					Arkansas	Basili et al. 1997
	29	4.03					Illinois	Basili et al. 1997
	96	3.81					Wisconsin	Basili et al. 1997
	242	3.90	0.93	0.09	0.30	0.46	Missouri	Winter 1998
	21				0.50	0.67	Wisconsin	Vos 2003
	127			0.56			Kansas	Jensen and Finck 2004
	204	**4.30**	**0.90**	**0.00**	**0.26**	**0.43**	**Tennessee**	***This Study***

CHAPTER 3

Table 3-1. Formulas to calculate productivity (R) given the number of attempts (A), the maximum number of broods (C), and nest success (p).

	Maximum Number of Broods (C)		
Number of Attempts (A)	**1**	**2**	**3**
1	p	-	-
2	$2p-p^2$	2p	-
3	$3p-3p^2+p^3$	$3p-p^3$	3p
4	$4p-6p^2+4p^3-p^4$	$4p-4p^3+2p^4$	$4p-p^4$

Table 3-2. Basline conditions for model populations of Dickcissels, Eastern Meadowlarks, Field Sparrows, Grasshopper Sparrows, and Henslow's Sparrows at Fort Campbell, Kentucky.

Species	Adult Survival (S_a)	Juvenile Survival (S_j)	Maximum Number of Successful Nests (C)	Number of Nest Attempts (A)
Dickcissel	0.5	0.25	1	2-4
Eastern Meadowlark	0.5	0.25	2	2-4
Field Sparrow	0.5	0.25	2	2-4
Grasshopper Sparrow	0.5	0.25	3	3-4
Henslow's Sparrow	0.5	0.25	3	3-4

CHAPTER 4

TABLE 4-1: Mean nest height (cm) for five grassland songbirds at Fort Campbell Army Base, Kentucky, 2001-2003 (ANOVA; $F = 40.74$, df = 4, $P < 0.01$).

Nest Type	*n*	mean	SE	Similarity*	Minimum	Maximum
Grasshopper Sparrow	70	0.19	1.55	a	0	13
Eastern Meadowlark	45	0.00	0.00	a	0	0
Henslow's Sparrow	56	15.10	10.54	b	0	36
Dickcissel	71	26.14	20.05	c	0	86
Field Sparrow	72	32.09	31.48	c	0	170

*- Similar letters indicate nest heights did not differ among species ($p > 0.05$).

TABLE 4-2: Vegetation measurements for nest sites of five songbird species and randomly selected plots at Fort Campbell Army Base, Kentucky, 2001-2003. For each habitat variable, the values for each bird species are compared to those of random plots (Dunnett's t-test: * = $P < 0.05$).

		% Litter		% Bare ground		% Woody		% Dead woody		% Cool-season grass		% Warm-season grass	
Nest/Site Type	n	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Dickcissel	71	3.7	5.0	4.6	6.9 *	9.4	19.0	0.9	2.7 *	12.9	16.9	16.7	25.2
Eastern Meadowlark	45	8.4	10.6	4.2	6.4 *	1.4	7.5	0.0	0.1	46.5	34.0 *	16.5	27.5
Field Sparrow	72	6.7	8.3	3.3	4.9 *	14.8	19.4 *	1.2	3.4 *	9.9	14.2	24.8	27.7
Grasshopper Sparrow	70	10.0	15.6 *	11.4	12.3	0.8	3.7 *	0.0	0.0	26.5	27.5 *	13.1	18.7 *
Henslow's Sparrow	56	7.6	9.8	3.2	4.5 *	1.0	4.1 *	0.4	1.6	21.7	29.9 *	43.5	30.1 *
Random	379	6.5	9.8	11.4	16.9	6.7	13.6	0.3	0.9	12.5	18.0	22.0	22.1

TABLE 4-2. Continued.

		% Forbs		Herbaceous height (cm)		Grass height (cm)		Woody height (cm)		Litter depth (mm)		Vertical cover	
Nest/Site Type	*n*	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Dickcissel	71	51.6	29.7	58.2	30.9 *	39.1	25.3 *	32.5	50.3 *	6.6	2.9 *	22.0	16.7
Eastern Meadowlark	45	23.0	23.7 *	38.5	19.1	39.4	28.4 *	2.9	9.9	9.1	3.1 *	13.8	7.6 *
Field Sparrow	72	38.9	29.5	49.7	21.1	40.5	21.7 *	46.5	51.8 *	5.9	3.0 *	26.1	16.3 *
Grasshopper Sparrow	70	38.2	28.2	30.6	18.3 *	26.5	14.6	2.1	7.1	11.1	3.2 *	9.5	4.1 *
Henslow's Sparrow	56	22.0	20.4 *	56.1	44.7 *	48.8	26.3 *	7.3	20.0	6.8	2.4 *	18.3	9.0
Random	379	40.0	23.7	41.3	23.2	18.7	26.0	12.3	29.3	3.9	4.9	20.2	12.1

TABLE 4-3: Discriminant function analysis of nest site habitat characteristics of five grassland bird species, Fort Campbell Army Base, Kentucky, 2001-2003. The first two discriminant functions (DF1 and DF2) accounted for over 91% of the total discriminating power.

Variable	**DF1**	**DF2**	R^2
Constant	-1.112	2.146	
Forb cover	-1.129	0.273	0.930
Warm-season grass cover	-0.944	-2.711	0.920
Cool-season grass cover	-2.638	-2.125	0.917
Woody cover	-1.561	0.978	0.804
Litter cover	-2.965	-2.441	0.688
Bare ground cover	-5.193	3.866	0.616
Litter depth (mm)	0.121	0.055	0.438
Vertical density	0.187	-0.074	0.406
Grass height (cm)	-0.001	-0.012	0.290
Herbaceous height (cm)	0.004	-0.003	0.283
Dead woody cover	6.517	-1.311	0.192
% of variance	67.9	23.2	
Canonical correlation	0.734	0.535	
P	<0.01	<0.01	

TABLE 4-4: Re-classification table from the discriminanat function analysis for five grassland songbirds at Fort Campbell Army Base, Kentucky, 2001-2003.

	Predicted						
Actual	Dickcissel	Eastern Meadowlark	Field Sparrow	Grasshopper Sparrow	Henslow's Sparrow	Total	Correct classification
Dickcissel	29	3	20	5	14	71	40.8%
Eastern Meadowlark	3	23	1	9	9	45	51.1%
Field Sparrow	22	1	35	0	14	72	48.6%
Grasshopper Sparrow	9	15	0	44	2	70	62.9%
Henslow's Sparrow	6	9	6	2	33	56	58.9%
Total						314	52.2%

CHAPTER 5

Table 5-1. National Land-use/Land-cover Data (NLCD) codes and habitat types used for analysis. The re-classification values indicate how relatively useful each habitat is as grassland bird habitat. Values greater than zero indicate grassland habitats. Values less than zero indicate hostile habitats. Habitat values equal to zero indicate neutral open habitats that do not provide habitat, but contribute to the "openness" of the landscape. Potential grassland habitats include all habitats that could be converted to native grasslands through various government programs or current grassland habitats.

NLCD code	Habitat type	Re-classification value	Potential grassland habitats
11	Water	0	
21	Low intensity residential	0	*
22	High intensity residential	-100	
23	Comercial/industrial/transportation	-100	
31	Bare rock/sand/ clay	0	
32	Quarries/strip mines/gravel pits	0	
33	Transitional	50	*
41	Deciduous forest	-100	
42	Evergreen forest	-100	
43	Mixed forest	-100	
51	Shrubland	50	*
61	Orchards/vineyards/other non-natural woody	0	
71	Grassland/herbaceous	100	*
81	Pasture/hay	50	*
82	Row crops	0	*
83	Small grains	0	*
84	Fallow	0	*
85	Urban/recreational grasslands (air strips)	0	*
91	Woody wetlands	-100	
92	Emergent herbaceous wetlands	100	*

Table 5-2: Obligate grassland bird species found in the eastern US during the breeding and wintering seasons (Vickery et al. 1999).

Common name	**Scientific name**	**Breeding**	**Wintering**
Upland Sandpiper	*Bartrama longicauda*	*	
Northern Harrier	*Circus cyaneus*	*	*
Short-eared Owl	*Asio flammeus*	*	*
Horned Lark	*Eremophila alpestris*	*	*
Sedge Wren	*Cistothorus platensis*	*	*
Bachman's Sparrow	*Aimophila aestivalis*	*	*
Vesper Sparrow	*Pooecetes gramineus*	*	*
Savannah Sparrow	*Passerculus sanwichensis*	*	*
Grasshopper Sparrow	*Ammodramus savannarum*	*	*
Henslow's Sparrow	*Ammodramus henslowii*	*	*
Le Conte's Sparrow	*Ammodramus leconteii*	*	*
Lapland Longspur	*Calcarius lapponicus*		*
Snow Bunting	*Plectrophenax nivalis*		*
Dickcissel	*Spiza americana*	*	*
Bobolink	*Dolichonyx oryzivorus*	*	
Eastern Meadowlark	*Sturnella magna*	*	*

Table 5-3. Definitions for priority scores used to calculate overall scores for conservation potential. Area is the number of hectares of large (> 40 Ha) grassland patches within the installation boundaries. Landscape represents the proportion of open habitat within 30 km of the outside border of the installation. Species diversity represents the number of species of grassland birds within the county occupied by the installation as indicated by State Breeding Bird Atlases, Breeding Bird Surveys, Christmas Bird Counts, and other range maps as needed. Installations assigned to the high category are assigned a value of 1, medium are assigned a value of 0.5 and low are assigned a value of 0.

	High	**Medium**	**Low**
Area (Ha)	>500 ha	300-500 ha	<300 ha
Landscape (%)	>40%	20 to 40%	<20%
Species richness, breeding (# species)	>4	4	<4
Species richness, winter (# species)	>10	9 to10	<9

Table 5-4. Selected military installations in the eastern US with the potential to provide significant grassland habitat for bird conservation.

Installation	Identification number	Type	State	Region	Total area (Ha)	% 40-ha patches	% Open habitat	Species richness* Wintering	Breeding
Fort McCoy	1	Army	Wisconsin	Northern	25558	7.4	23.3	5	[redacted]
Camp Grayling	2	National Guard	Michigan	Northern	16100	2.9	12.1	7	[redacted]
Ravenna Training and Logistics Site	3	Army	Ohio	Northern	8295	1.0	17.9	[redacted]	[redacted]
Fort Drum	4	Army	New York	Northern	44009	17.7	32.0	8	[redacted]
Camp Atterbury	5	National Guard	Indiana	Inland central	16191	1.6	29.6	[redacted]	[redacted]
Naval Weapons Support Center, Crane	6	Navy	Indiana	Inland central	25165	3.3	14.0	[redacted]	[redacted]
Fort Knox	7	Army	Kentucky	Inland central	44389	0.6	6.2	[redacted]	[redacted]
Blue Grass Army Depot	8	Army	Kentucky	Inland central	6014	17.3	54.6	[redacted]	[redacted]
Fort Campbell	9	Army	Kentucky	Inland central	42772	6.3	20.5	[redacted]	[redacted]
Milan Army Ammunition Plant	10	Army	Tennessee	Inland central	10092	1.8	48.4	[redacted]	[redacted]
Redstone Arsenal	11	Army	Alabama	South-coastal	15740	4.8	25.2	[redacted]	[redacted]
Volunteer Army Ammunition Plant	12	Army	Tennessee	Inland central	2859	4.5	11.0	[redacted]	3
Letterkenny Army Depot	13	Army	Pennsylvania	North-coastal	7823	14.7	36.0	[redacted]	[redacted]
Naval Air Development Center, Warminster	14	Navy	Pennsylvania	North-coastal	1363	11.8	58.1	[redacted]	[redacted]
Earle Naval Complex	15	Navy	New Jersey	North-coastal	4065	2.0	4.8	[redacted]	3
Fort Detrick	16	Army	Maryland	North-coastal	852	51.2	71.2	[redacted]	[redacted]
Marine Corps Combat Development Command, Quantico	17	Marines	Virginia	North-coastal	25070	3.5	11.1	8	[redacted]
Naval Surface Warfare Center, Dahlgren	18	Navy	Virginia	North-coastal	1159	5.6	25.3	8	[redacted]
Fort A. P. Hill	19	Army	Virginia	North-coastal	30304	2.3	9.3	[redacted]	[redacted]
Camp Peary	20	Navy	Virginia	North-coastal	3838	3.7	17.7	[redacted]	[redacted]
Naval Weapons Station, Yorktown	21	Navy	Virginia	North-coastal	4237	4.6	15.7	[redacted]	[redacted]
Fort Eustis	22	Army	Virginia	North-coastal	3262	6.7	35.2	[redacted]	3
Langley Air Force Base	23	Air Force	Virginia	North-coastal	1185	10.5	45.9	[redacted]	3
Craney Island US Naval Res	24	Navy	Virginia	North-coastal	1286	9.3	19.5	[redacted]	[redacted]

Table 5-4: (Continued).

Installation	Identification number	Type	State	Region	Total area (Ha)	% 40-ha patches	% Open habitat	Species richness* Winter	Breeding
Naval Air Station, Oceana	25	Navy	Virginia	North-coastal	2136	5.7	38.3		3
Fort Pickett	26	Army	Virginia	North-coastal	15374	1.1	9.9		
Fort Bragg	27	Army	North Carolina	South-coastal	53365	10.9	18.9		
Marine Corps Base, Camp Lejune	28	Marines	North Carolina	North-coastal	41329	1.1	7.2		
Fort Jackson	29	Army	South Carolina	South-coastal	21331	6.4	18.1		
Polaris Missile Facility	30	Navy	South Carolina	South-coastal	7308	8.8	26.2		2
Fort Gordon	31	Army	Georgia	South-coastal	22384	7.0	21.8		
Port of Savannah	32	Port	Georgia	South-coastal	583	10.4	21.0		3
Hunter Army Airfield	33	Army	Georgia	South-coastal	2064	9.4	36.3		3
Fort Stewart	34	Army	Georgia	South-coastal	113135	2.8	9.8		3
Naval Submarine Base, Kings Bay	35	Navy	Georgia	South-coastal	5614	12.7	31.6		2
Camp Blanding	36	National Guard	Florida	South-coastal	29932	23.0	33.1		2
Avon Park Bombing and Gunnery Range	37	Air Force	Florida	South-coastal	34084	29.3	51.4		
Marine Corps Logistics Base, Albany	38	Marines	Georgia	South-coastal	1438	8.6	33.8		
Fort Benning	39	Army	Georgia	South-coastal	74199	1.1	6.8		
Fort Rucker	40	Army	Alabama	South-coastal	23920	1.7	11.3		3
Eglin Air Force Base	41	Air Force	Florida	South-coastal	184793	7.6	14.0		3
Camp Shelby	42	National Guard	Mississippi	South-coastal	3203	3.0	18.7		3
Fort Polk	43	Army	Louisiana	South-coastal	46036	3.0	8.2		3
Fort Story	44	Army	Virginia	North-coastal	599	13.0	21.5		3
Little Creek Naval Amphibious Base	45	Navy	Virginia	North-coastal	660	9.6	24.6		3
AVERAGE					**22780**	**8.3**	**24.6**	**10.4**	**4.7**

* Species richness is the maximum number of species possible in the county or counties occupied by the installation. Darker shading indicates high species richness, light gray shading indicates medium species richness and white indicates low species richness.

Table 5-5. Potential breeding grassland bird species in selected military installations in the eastern U.S.

Installation	State	Upland Sandpiper	Northern Harrier	Short-eared Owl	Horned Lark	Sedge Wren	Bachman's Sparrow	Vesper Sparrow	Savannah Sparrow	Henslow's Sparrow	Grasshopper Sparrow	Leconte's Sparrow	Dickcissel	Bobolink	Eastern Meadowlark	Total
Avon Park Bombing and Gunnery Range	Florida	0	1	0	0	0	1	0	0	0	1	0	0	0	1	**4**
Blue Grass Army Depot	Kentucky	0	0	0	0	0	0	0	0	1	1	0	1	0	1	**4**
Camp Atterbury	Indiana	0	1	0	1	1	0	1	1	1	1	0	1	1	1	**10**
Camp Blanding	Florida	0	0	0	0	0	1	0	0	0	0	0	0	0	1	**2**
Camp Grayling	Michigan	1	1	0	1	1	0	1	1	0	1	0	1	1	1	**10**
Camp Peary	Virginia	0	1	0	1	0	0	0	0	0	1	0	0	0	1	**4**
Camp Shelby	Mississippi	0	0	0	0	0	1	0	0	0	0	0	1	0	1	**3**
Craney Island US Naval Res	Virginia	0	1	0	1	0	0	1	0	0	0	0	0	0	1	**4**
Earle Naval Complex	New Jersey	0	0	0	0	0	0	0	0	0	1	0	0	1	1	**3**
Eglin Air Force Base	Florida	0	1	0	0	0	1	0	0	0	0	0	0	0	1	**3**
Fort A. P. Hill	Virginia	0	0	0	1	0	0	1	0	0	1	0	0	0	1	**4**
Fort Benning	Alabama	0	1	0	0	0	1	0	0	0	1	0	0	0	1	**4**
Fort Bragg	North Carolina	0	0	0	1	0	1	0	0	0	1	0	0	0	1	**4**
Fort Campbell	Kentucky	0	1	0	1	0	1	0	0	1	1	0	1	0	1	**7**
Fort Detrick	Maryland	0	1	0	1	0	0	1	1	0	1	0	1	1	1	**8**
Fort Drum	New York	1	1	1	1	1	0	1	1	1	1	0	0	1	1	**11**
Fort Eustis	Virginia	0	1	0	1	0	0	0	0	0	0	0	0	0	1	**3**
Fort Gordon	Georgia	0	0	0	1	0	1	0	0	0	1	0	0	0	1	**4**
Fort Jackson	South Carolina	0	0	0	1	0	1	0	0	0	1	0	1	0	1	**5**
Fort Knox	Kentucky	0	0	0	1	0	0	0	0	1	1	0	1	0	1	**5**
Fort McCoy	Wisconsin	1	1	0	1	1	0	1	1	1	1	1	1	1	1	**12**
Fort Pickett	Virginia	0	1	0	1	0	0	0	0	0	1	0	0	0	1	**4**
Fort Polk	Louisiana	0	0	0	0	0	1	0	0	0	0	0	1	0	1	**3**

Table 5-5.Continued.

Installation	State	Upland Sanpiper	Northern Harrier	Short-eared Owl	Horned Lark	Sedge Wren	Bachman's Sparrow	Vesper Sparrow	Savannah Sparrow	Henslow's Sparrow	Grasshopper Sparrow	Leconte's Sparrow	Dickcissel	Bobolink	Eastern Meadowlark	Total
Fort Rucker	Alabama	0	0	0	0	0	1	0	0	0	1	0	0	0	1	**3**
Fort Stewart	Georgia	0	0	0	0	0	1	0	0	0	1	0	0	0	1	**3**
Fort Story	Virginia	0	1	0	1	0	0	0	0	0	0	0	0	0	1	**3**
Hunter Army Airfield	Georgia	0	0	0	0	0	1	0	0	0	1	0	0	0	1	**3**
Langley Air Force Base	Virginia	0	1	0	1	0	0	0	0	0	0	0	0	0	1	**3**
Letterkenny Army Depot	Pennsylvania	1	1	0	1	0	0	1	1	1	1	0	1	1	1	**10**
Little Creek Naval Amphibious Base	Virginia	0	1	0	1	0	0	0	0	0	0	0	0	0	1	**3**
Marine Corps Base, Camp Lejune	North Carolina	0	1	0	1	0	1	0	0	0	0	0	0	0	1	**4**
Marine Corps Combat Development Command, Quantico	Virginia	0	0	0	1	0	0	1	1	1	1	0	0	0	1	**6**
Marine Corps Logistics Base, Albany	Georgia	0	0	0	1	0	1	0	0	0	1	0	0	0	1	**4**
Milan Army Ammunition Plant	Tennessee	0	0	0	1	0	1	0	0	0	1	0	1	0	1	**5**
Naval Air Development Center, Warminster	Pennsylvania	0	1	0	0	0	0	0	1	0	1	0	0	1	1	**5**
Naval Air Station, Oceana	Virginia	0	1	0	1	0	0	0	0	0	0	0	0	0	1	**3**
Naval Submarine Base, Kings Bay	Georgia	0	0	0	0	0	1	0	0	0	0	0	0	0	1	**2**
Naval Surface Warfare Center, Dahlgren	Virginia	0	0	0	1	0	0	1	0	0	1	0	0	0	1	**4**
Naval Weapons Station Yorktown	Virginia	0	1	0	1	0	0	0	0	0	1	0	0	0	1	**4**
Naval Weapons Support Center, Crane	Indiana	0	1	0	1	1	0	1	1	1	1	0	1	0	1	**9**
Polaris Missile Facility	South Carolina	0	0	0	0	0	1	0	0	0	0	0	0	0	1	**2**
Port of Savannah	Georgia	0	0	0	0	0	1	0	0	0	1	0	0	0	1	**3**
Ravenna Training and Logistics Site	Ohio	1	1	0	1	1	0	1	1	0	1	0	0	1	1	**9**
Redstone Arsenal	Alabama	0	0	0	1	0	1	0	0	0	1	0	1	0	1	**5**
Volunteer Army Ammunition Plant	Tennessee	0	0	0	0	0	0	0	0	0	1	0	1	0	1	**3**

Table 5-6. Potential wintering grassland bird species in selected military installations in the eastern U.S.

Installation	State	Northern Harrier	Short-eared Owl	Horned Lark	Sedge Wren	Bachman's Sparrow	Vesper Sparrow	Savannah Sparrow	Henslow's Sparrow	Grasshopper Sparrow	Leconte's Sparrow	Lapland Longspur	Snow Bunting	Dickcissel	Eastern Meadowlark	Total
Avon Park Bombing and Gunnery Range	Florida	1	1	0	1	1	1	1	1	1	1	0	0	1	1	**11**
Blue Grass Army Depot	Kentucky	1	1	1	0	0	1	1	0	0	0	1	1	1	1	**9**
Camp Atterbury	Indiana	1	1	1	0	0	1	1	1	0	0	1	1	0	1	**9**
Camp Blanding	Florida	1	1	1	1	1	1	1	1	1	1	0	1	0	1	**12**
Camp Grayling	Michigan	1	1	1	0	0	1	0	0	0	0	1	1	0	1	**7**
Camp Peary	Virginia	1	1	1	1	0	1	1	0	0	0	1	1	1	1	**10**
Camp Shelby	Mississippi	1	1	0	1	1	1	1	1	1	1	1	0	1	1	**12**
Craney Island US Naval Res	Virginia	1	1	1	1	0	1	1	0	0	1	1	1	1	1	**11**
Earle Naval Complex	New Jersey	1	1	1	0	0	1	1	0	1	0	1	1	1	1	**10**
Eglin Air Force Base	Florida	1	1	0	1	1	1	1	1	1	1	1	0	1	1	**12**
Fort A. P. Hill	Virginia	1	1	1	1	0	1	1	0	1	0	1	1	1	1	**11**
Fort Benning	Alabama	1	1	1	1	1	1	1	1	1	1	0	0	1	1	**12**
Fort Bragg	North Carolina	1	1	1	1	1	1	1	1	0	0	1	0	1	1	**11**
Fort Campbell	Kentucky	1	1	1	1	0	1	1	0	0	1	1	1	1	1	**11**
Fort Detrick	Maryland	1	1	1	0	0	1	1	0	1	0	1	1	0	1	**9**
Fort Drum	New York	1	1	1	0	0	1	1	0	0	0	1	1	0	1	**8**
Fort Eustis	Virginia	1	1	1	1	0	1	1	0	0	0	1	1	1	1	**10**
Fort Gordon	Georgia	1	0	1	1	1	1	1	1	1	0	1	0	0	1	**10**
Fort Jackson	South Carolina	1	0	1	1	1	1	1	1	1	0	0	0	1	1	**10**
Fort Knox	Kentucky	1	1	1	1	0	1	1	0	1	1	1	1	0	1	**11**
Fort McCoy	Wisconsin	1	1	1	0	0	0	0	0	0	0	1	1	0	0	**5**
Fort Pickett	Virginia	1	1	1	1	0	1	1	0	1	0	1	1	1	1	**11**
Fort Polk	Louisiana	1	1	1	1	1	1	1	1	1	1	1	0	1	1	**13**

Table 5-6.Continued.

Installation	State	Northern Harrier	Short-eared Owl	Horned Lark	Sedge Wren	Bachman's Sparrow	Vesper Sparrow	Savannah Sparrow	Henslow's Sparrow	Grasshopper Sparrow	Leconte's Sparrow	Lapland Longspur	Snow Bunting	Dickcissel	Eastern Meadowlark	Total
Fort Rucker	Alabama	1	1	0	1	1	1	1	1	1	1	1	0	1	1	12
Fort Stewart	Georgia	1	0	1	1	1	1	1	1	1	1	0	0	1	1	11
Fort Story	Virginia	1	1	1	1	0	1	1	0	1	1	1	1	1	1	12
Hunter Army Airfield	Georgia	1	0	1	1	1	1	1	1	1	1	0	0	1	1	11
Langley Air Force Base	Virginia	1	1	1	1	0	1	1	0	0	0	1	1	1	1	10
Letterkenny Army Depot	Pennsylvania	1	1	1	0	0	1	1	0	1	0	1	1	0	1	9
Little Creek Naval Amphibious Base	Virginia	1	1	1	1	0	1	1	0	1	1	1	1	1	1	12
Marine Corps Base, Camp Lejune	North Carolina	1	1	1	1	1	1	1	1	1	0	0	1	1	1	12
Marine Corps Combat Development Command, Quantico	Virginia	1	1	1	0	0	1	1	0	0	0	1	1	0	1	8
Marine Corps Logistics Base, Albany	Georgia	1	0	1	1	1	1	1	1	1	0	0	0	1	1	10
Milan Army Ammunition Plant	Tennessee	1	1	1	1	0	1	1	0	0	1	1	1	1	1	11
Naval Air Development Center, Warminster	Pennsylvania	1	1	1	0	0	1	1	1	1	0	1	1	1	1	11
Naval Air Station, Oceana	Virginia	1	1	1	1	0	1	1	0	1	1	1	1	1	1	12
Naval Submarine Base, Kings Bay	Georgia	1	1	0	1	1	1	1	1	1	1	0	1	1	1	12
Naval Surface Warfare Center, Dahlgren	Virginia	1	1	1	0	0	1	1	0	0	0	1	1	0	1	8
Naval Weapons Station Yorktown	Virginia	1	1	1	1	0	1	1	0	0	0	1	1	1	1	10
Naval Weapons Support Center, Crane	Indiana	1	1	1	0	0	1	1	0	0	0	1	1	1	1	9
Polaris Missile Facility	South Carolina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Port of Savannah	Georgia	1	0	1	1	1	1	1	1	1	1	0	0	1	1	11
Ravenna Training and Logistics Site	Ohio	1	1	1	0	0	1	1	0	1	0	1	1	0	1	9
Redstone Arsenal	Alabama	1	1	1	1	0	1	1	0	0	1	1	0	0	1	9
Volunteer Army Ammunition Plant	Tennessee	1	1	1	1	0	1	1	1	1	1	0	0	0	1	10

Table 5-7. Grassland bird conservation priority scores for selected military installations in the eastern US. Included are scores for the area of grassland large (>40 ha) patches, landscape composition, grassland bird species richness in the breeding and wintering seasons and a score for the presence of species of high conservation concern (Partners in Flight watch list). The overall (O), breeding (B) and winter (W) season scores represent the conservation potential for grassland birds with a score of 10 representing higest potential.

			Species richness		High concern		Scores[1]		
Installation	**Area**	**Landscape**	**Breeding**	**Wintering**	**Breeding**	**Wintering**	**O**	**B**	**W**
Fort Campbell	1.0	1.0	1.0	1.0	1.0	0.5	[redacted]	[redacted]	[redacted]
Avon Park Bombing and Gunnery Range	1.0	1.0	0.5	1.0	0.3	1.0	[redacted]	[redacted]	[redacted]
Letterkenny Army Depot	1.0	1.0	1.0	0.5	1.0	0.3	[redacted]	[redacted]	[redacted]
Naval Weapons Support Center, Crane	1.0	1.0	1.0	0.5	0.7	0.5	[redacted]	[redacted]	[redacted]
Redstone Arsenal	1.0	1.0	1.0	0.5	0.7	0.3	[redacted]	[redacted]	[redacted]
Fort McCoy	1.0	1.0	1.0	0.0	1.0	0.3	[redacted]	[redacted]	[redacted]
Fort Jackson	1.0	0.5	1.0	0.5	0.7	0.8	[redacted]	[redacted]	[redacted]
Fort Bragg	1.0	0.5	0.5	1.0	0.3	1.0	[redacted]	[redacted]	[redacted]
Fort Detrick	0.5	1.0	1.0	0.5	0.7	0.5	[redacted]	[redacted]	[redacted]
Fort Rucker	0.5	1.0	0.0	1.0	0.3	1.0	[redacted]	[redacted]	[redacted]
Marine Corps Combat Development Command, Quantico	1.0	0.5	1.0	0.0	0.3	1.0	[redacted]	[redacted]	[redacted]
Fort Drum	1.0	0.5	1.0	0.0	1.0	0.3	[redacted]	[redacted]	[redacted]
Naval Submarine Base, Kings Bay	1.0	0.5	0.0	1.0	0.3	0.8	[redacted]	[redacted]	[redacted]
Fort Gordon	1.0	0.5	0.5	0.5	0.3	0.8	[redacted]	[redacted]	[redacted]
Fort A. P. Hill	1.0	0.5	0.5	1.0	0.0	0.5	[redacted]	[redacted]	[redacted]
Blue Grass Army Depot	1.0	0.5	0.5	0.5	0.7	0.3	[redacted]	[redacted]	[redacted]
Fort Stewart	1.0	0.5	0.0	1.0	0.3	0.5	[redacted]	[redacted]	[redacted]
Camp Blanding	1.0	0.5	0.0	1.0	0.3	0.3	[redacted]	[redacted]	[redacted]

Table 5-7. Continued.

Installation	Area	Landscape	Species richness: Breeding	Species richness: Wintering	High concern: Breeding	High concern: Wintering	Scores[1]: O	Scores[1]: B	Scores[1]: W
Camp Atterbury	0.0	1.0	1.0	0.5	1.0	0.5	[illegible]	[illegible]	[illegible]
Fort Benning	1.0	0.0	0.5	1.0	0.3	1.0	[illegible]	4.7	[illegible]
Fort Polk	1.0	0.0	0.0	1.0	0.7	1.0	[illegible]	4.3	[illegible]
Eglin Air Force Base	1.0	0.0	0.0	1.0	0.3	1.0	[illegible]	3.7	[illegible]
Polaris Missile Facility	1.0	0.0	0.0	1.0	0.3	1.0	[illegible]	3.7	[illegible]
Fort Pickett	0.0	1.0	0.5	1.0	0.0	0.5	[illegible]	4.0	[illegible]
Naval Air Development Center, Warminster	0.0	0.5	1.0	1.0	0.3	1.0	4.8	4.2	[illegible]
Milan Army Ammunition Plant	0.0	0.5	1.0	1.0	0.7	0.5	4.7	4.8	4.5
Naval Air Station, Oceana	0.0	1.0	0.0	1.0	0.0	0.5	4.5	3.0	[illegible]
Fort Knox	0.0	0.5	1.0	1.0	0.7	0.3	4.4	4.8	4.0
Marine Corps Base, Camp Lejune	0.5	0.0	0.5	1.0	0.3	0.8	4.1	3.2	[illegible]
Fort Eustis	0.0	1.0	0.0	0.5	0.0	0.5	4.0	3.0	[illegible]
Port of Savannah	0.0	0.5	0.0	1.0	0.3	0.8	3.6	2.2	[illegible]
Hunter Army Airfield	0.0	0.5	0.0	1.0	0.3	0.8	3.6	2.2	[illegible]
Marine Corps Logistics Base, Albany	0.0	0.5	0.5	0.5	0.3	0.8	3.6	3.2	4.0
Ravenna Training and Logistics Site	0.0	0.5	1.0	0.5	0.3	0.3	3.6	4.2	3.0
Camp Grayling	0.5	0.0	1.0	0.0	0.7	0.3	3.4	4.8	2.0
Camp Peary	0.0	0.5	0.5	0.5	0.0	0.5	3.0	2.5	3.5
Naval Weapons Station, Yorktown	0.0	0.5	0.5	0.5	0.0	0.5	3.0	2.5	3.5
Earle Naval Complex	0.0	0.5	0.0	0.5	0.3	0.5	2.8	2.2	3.5
Camp Shelby	0.0	0.0	0.0	1.0	0.7	1.0	2.7	1.3	4.0
Langley Air Force Base	0.0	0.5	0.0	0.5	0.0	0.5	2.5	1.5	3.5
Craney Island US Naval Reservation	0.0	0.0	0.5	1.0	0.0	0.5	2.0	1.0	3.0
Little Creek Naval Amphibious Base	0.0	0.0	0.0	1.0	0.0	0.5	1.5	0.0	3.0
Fort Story	0.0	0.0	0.0	1.0	0.0	0.5	1.5	0.0	3.0
Volunteer Army Ammunition Plant	0.0	0.0	0.0	0.5	0.3	0.5	1.3	0.7	2.0
Naval Surface Warfare Center, Dahlgren	0.0	0.0	0.5	0.0	0.0	0.3	0.8	1.0	0.5

1 O = Overall score, B = Breeding Score, W = Wintering Score; Shading indicates high (dark shading) and medium (gray shading) scores.

Table 5-8. Buffer analysis for selected military installations in the eastern US. Percent patches (Patches) represents the proportion of large (>40 ha) existing grassland patches within the installation and in each of the three 10-km buffers around the installation. Percent potential (Potential) includes all agricultural lands as well as existing grasslands indicating the potential for grassland restoration. The difference indicates how different the proportion oflandcover within the installation is from the average proportion of landcover in the three buffers. Negative numbers indicate the installtion has less grassland (Patches) or open habitat (Potential) than the surrounding landscape, while positive numbers indicate the installation has more grassland or open habitat than in the surrounding landscape.

		Installation		10-Km buffer		20-Km buffer		30-Km buffer		Difference*	
Name	Total area (Ha)	Patches	Potential	Patches	Potential	Patches	Potential	Patches	Potential	Patches	Potential
Eglin Air Force Base	184793	7.6	14.0	3.7	18.9	2.7	17.6	4.0	20.9	[redacted]	[redacted]
Fort Stewart	113135	2.8	9.8	2.0	25.6	3.9	26.7	4.8	30.9	[redacted]	[redacted]
Fort Benning	74199	1.1	6.8	2.5	14.0	2.2	16.8	2.4	18.1	[redacted]	[redacted]
Fort Bragg	53365	10.9	18.9	0.3	23.2	0.3	31.1	0.6	33.6	10.5	[redacted]
Fort Polk	46036	3.0	8.2	3.4	12.3	8.6	18.2	5.5	14.7	[redacted]	[redacted]
Fort Knox	44389	0.6	6.2	7.9	39.0	7.8	44.0	8.8	43.7	[redacted]	[redacted]
Fort Drum	44009	17.7	32.0	15.0	29.5	14.2	29.6	14.4	30.5	[redacted]	[redacted]
Fort Campbell	42772	6.3	20.5	11.1	50.3	11.8	44.0	10.0	40.6	[redacted]	[redacted]
Marine Corps Base, Camp Lejune	41329	1.1	7.2	0.8	11.0	1.6	13.8	1.4	13.6	[redacted]	[redacted]
Avon Park Bombing and Gunnery Range	34084	29.3	51.4	35.0	53.9	36.7	53.0	43.4	59.2	[redacted]	[redacted]
Fort A. P. Hill	30304	2.3	9.3	5.0	30.3	3.0	24.4	3.0	21.6	[redacted]	[redacted]
Camp Blanding	29932	23.0	33.1	10.7	25.6	8.6	24.1	4.5	19.6	15.1	10.0
Fort McCoy	25558	7.4	23.3	12.8	45.5	10.5	42.5	10.2	41.3	[redacted]	[redacted]
Naval Weapons Support Center, Crane	25165	3.3	14.0	11.9	56.1	9.3	61.8	8.2	63.9	[redacted]	[redacted]
Marine Corps Combat Development Command, Quantico	25070	3.5	11.1	7.0	22.4	6.7	23.8	9.2	28.5	[redacted]	[redacted]

Table 5-8. Continued.

Name	Total area (Ha)	Installation Patches	Installation Potential	10-Km buffer Patches	10-Km buffer Potential	20-Km buffer Patches	20-Km buffer Potential	30-Km buffer Patches	30-Km buffer Potential	Difference* Patches	Difference* Potential
Fort Rucker	23920	1.7	11.3	2.3	32.6	4.0	38.3	4.0	43.1		
Fort Gordon	22384	7.0	21.8	2.4	32.1	2.1	31.5	1.3	30.6		
Fort Jackson	21331	6.4	18.1	0.5	17.1	0.7	22.0	0.3	21.1	5.9	
Camp Atterbury	16191	1.6	29.6	4.1	60.4	4.4	67.0	4.9	63.1		
Camp Grayling	16100	2.9	12.1	2.4	10.0	1.9	15.3	1.8	15.1		
Redstone Arsenal	15740	4.8	25.2	0.8	36.2	1.9	47.1	3.8	44.3		
Fort Pickett	15374	1.1	9.9	6.0	27.1	5.8	24.9	5.7	23.8		
Milan Army Ammunition Plant	10092	1.8	48.4	4.6	59.6	5.7	53.5	13.0	62.4		
Ravenna Training and Logistics Site	8295	1.0	17.9	5.0	43.6	5.3	41.8	6.1	37.6		
Letterkenny Army Depot	7823	14.7	36.0	36.6	58.6	26.4	45.5	23.4	41.9		
Polaris Missile Facility	7308	8.8	26.2	5.0	18.9	3.5	16.4	0.7	12.3	5.8	10.3
Blue Grass Army Depot	6014	17.3	54.6	15.0	50.3	5.5	27.8	9.7	30.6	7.2	18.4
Naval Submarine Base, Kings Bay	5614	12.7	31.6	18.3	28.0	13.0	20.9	14.8	22.9		7.7
Naval Weapons Station, Yorktown	4237	4.6	15.7	0.5	15.6	2.7	17.5	3.4	19.6		
Earle Naval Complex	4065	2.0	4.8	4.0	23.1	1.1	11.6	2.7	16.3		
Camp Peary	3838	3.7	17.7	2.0	18.5	2.9	19.1	3.9	19.8		
Fort Eustis	3262	6.7	35.2	1.4	14.1	2.2	22.5	3.1	21.1		15.9
Camp Shelby	3203	3.0	18.7	3.4	24.1	2.7	18.6	2.6	20.4		
Volunteer Army Ammunition Plan	2859	4.5	11.0	1.7	19.1	4.5	20.7	3.8	20.1		
Naval Air Station, Oceana	2136	5.7	38.3	1.7	20.0	2.0	21.1	3.0	21.2		17.6
Hunter Army Airfield	2064	9.4	36.3	14.1	29.2	12.1	25.1	3.9	13.9		13.6
Marine Corps Logistics Base, Albany	1438	8.6	33.8	7.7	55.9	5.8	58.2	6.1	54.3		
Naval Air Development Center, Warminster	1363	11.8	58.1	0.4	30.3	1.3	26.8	4.6	30.2	9.7	29.0
Craney Island US Naval Res	1286	9.3	19.5	1.5	11.5	2.1	19.3	2.5	23.0	7.3	
Langley Air Force Base	1185	10.5	45.9	4.3	13.3	1.5	7.3	1.3	15.3	8.1	34.0
Naval Surface Warfare Center, Dahlgren	1159	5.6	25.3	1.7	18.5	1.4	21.7	2.8	23.0		
Fort Detrick	852	51.2	71.2	39.3	61.1	37.7	60.7	34.2	61.5	14.1	10.1
Little Creek Naval Amphibious Base	660	9.6	24.6	0.5	8.2	0.8	9.0	3.0	21.6	8.2	11.7
Fort Story	599	13.0	21.5	0.6	5.2	1.1	10.8	2.9	16.1	11.4	10.8
Port of Savannah	583	10.4	21.0	10.6	24.4	6.5	21.5	6.5	20.5		
AVERAGE		**8.3**	**24.6**	**7.3**	**29.4**	**6.6**	**29.2**	**6.9**	**29.9**	**1.3**	**-4.9**

*- Dark shading indicates differences less than -5%, gray shading indicates differences between -5% and 5%, no shading indicates differences greater than 5%.

FIGURES

CHAPTER 1

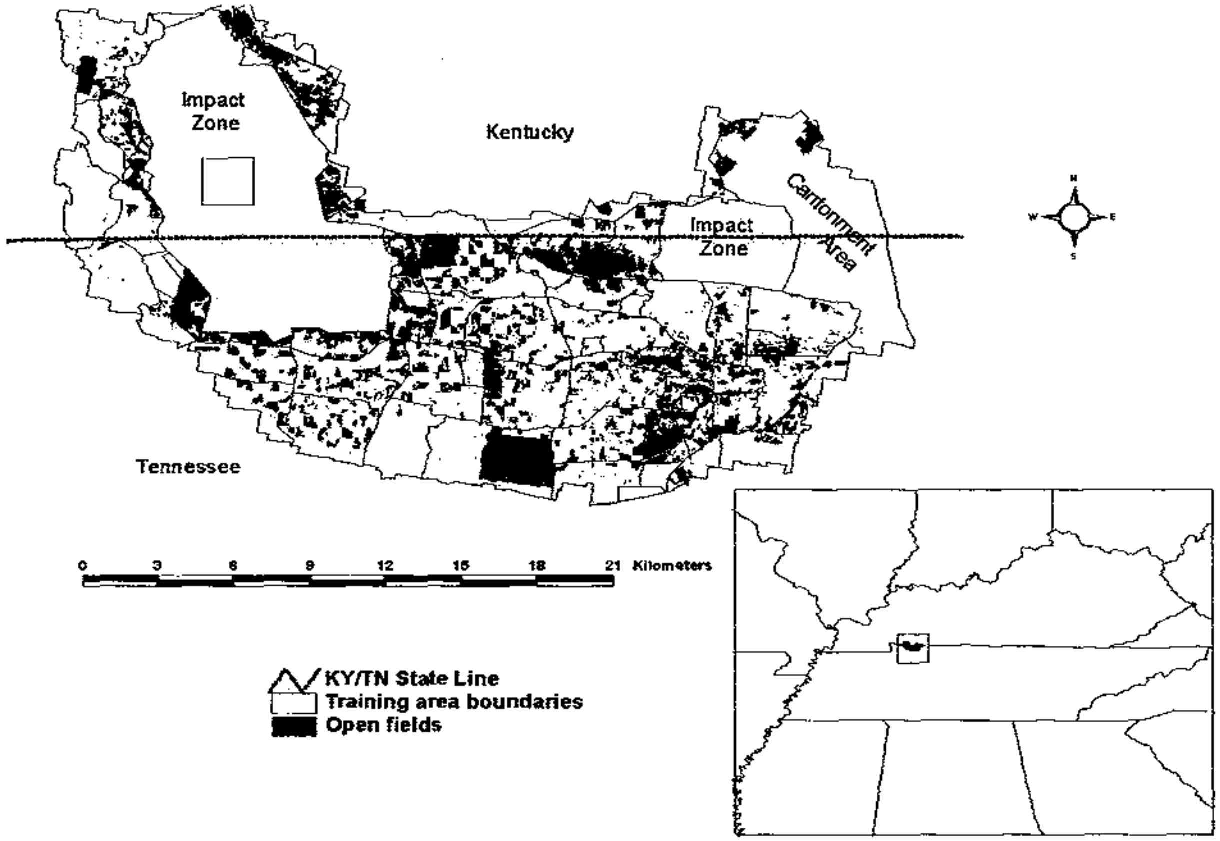
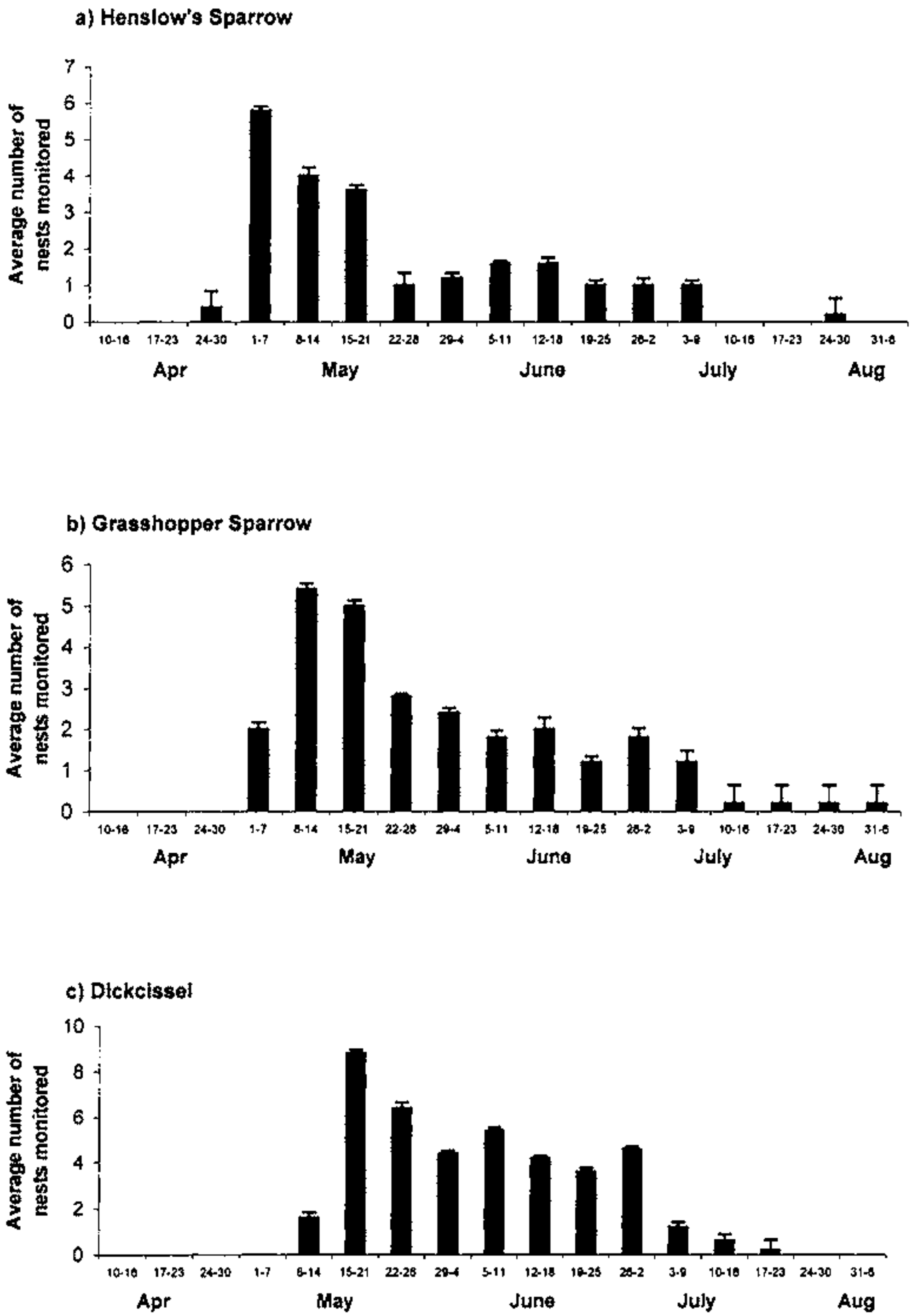
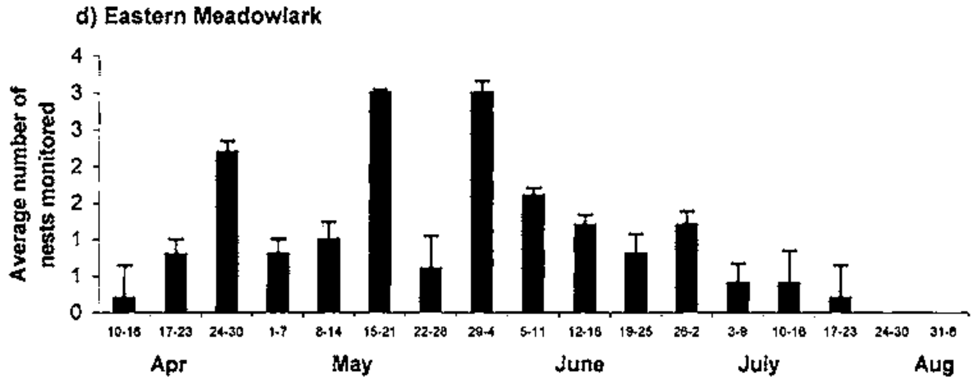


Figure 1-1. Open lands (non-forest) on Fort Campbell Military Base, Kentucky, including native grass fields, hay fields, and row crop areas.

CHAPTER 2

Figure 2-1. Average number of nests monitored each week for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Eastern Meadowlarks, and Field Sparrows at Fort Campbell Army Base, Kentucky, 1999-2003.


a) Henslow's Sparrow
Average number of nests monitored
10-16 17-23 24-30 1-7 8-14 15-21 22-28 29-4 5-11 12-18 19-25 26-2 3-9 10-16 17-23 24-30 31-6
Apr May June July Aug
b) Grasshopper Sparrow
Average number of nests monitored
10-16 17-23 24-30 1-7 8-14 15-21 22-28 29-4 5-11 12-18 19-25 26-2 3-9 10-16 17-23 24-30 31-6
Apr May June July Aug
c) Dickcissel
Average number of nests monitored
10-16 17-23 24-30 1-7 8-14 15-21 22-28 29-4 5-11 12-18 19-25 26-2 3-9 10-16 17-23 24-30 31-6
Apr May June July Aug



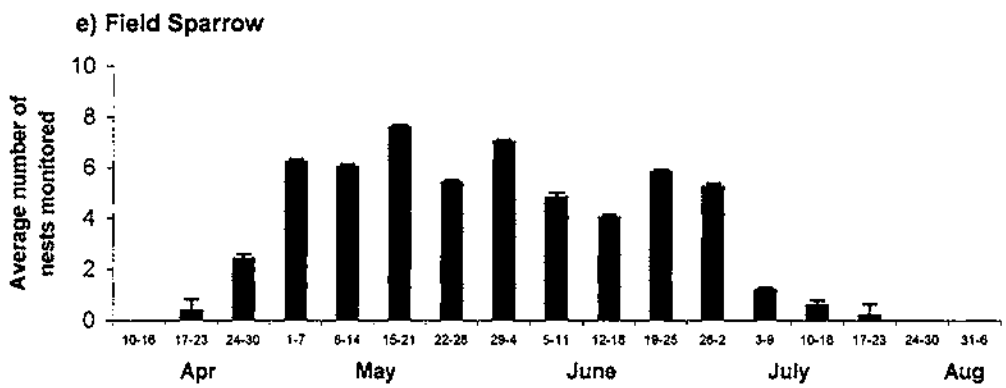
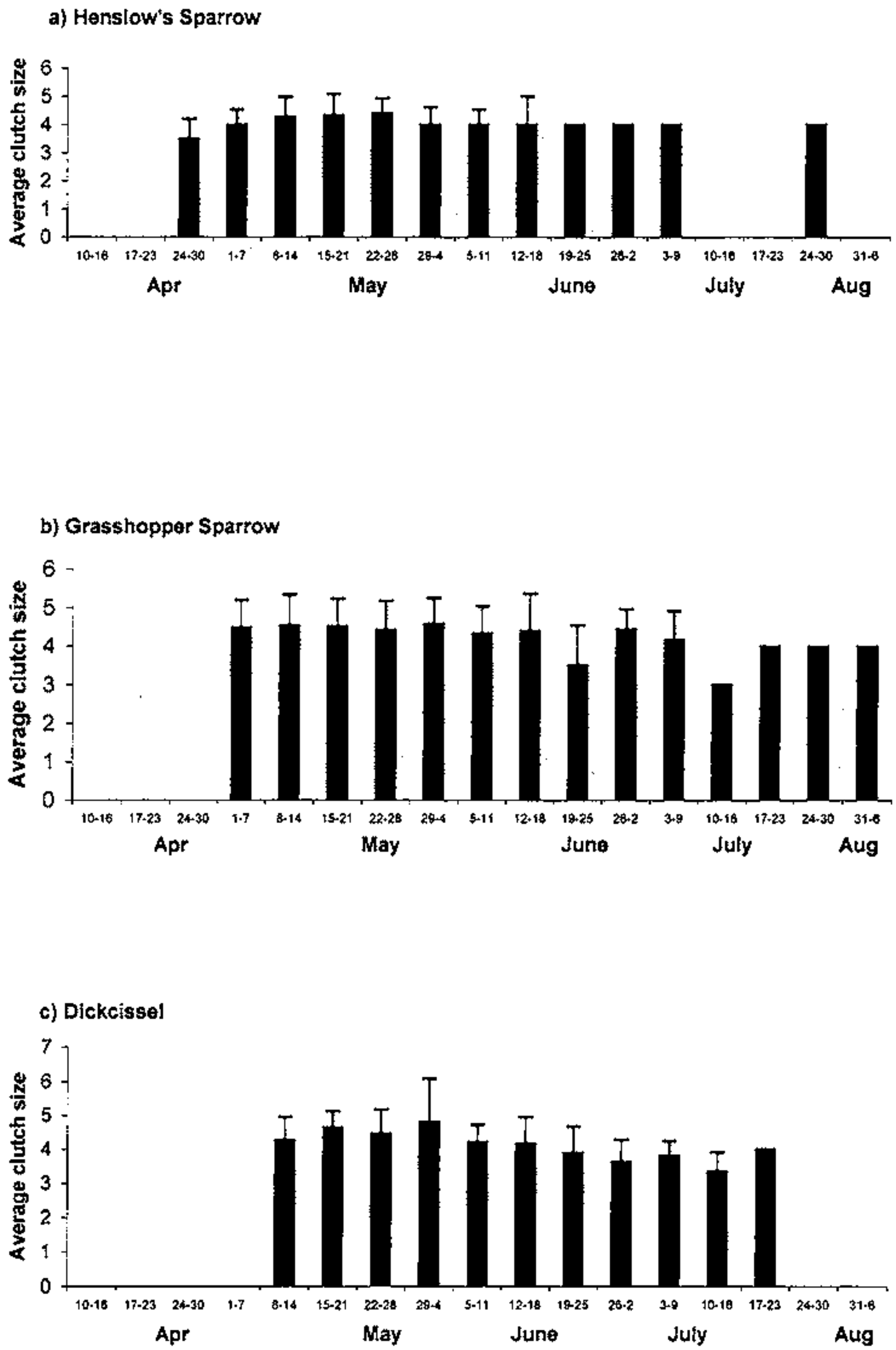
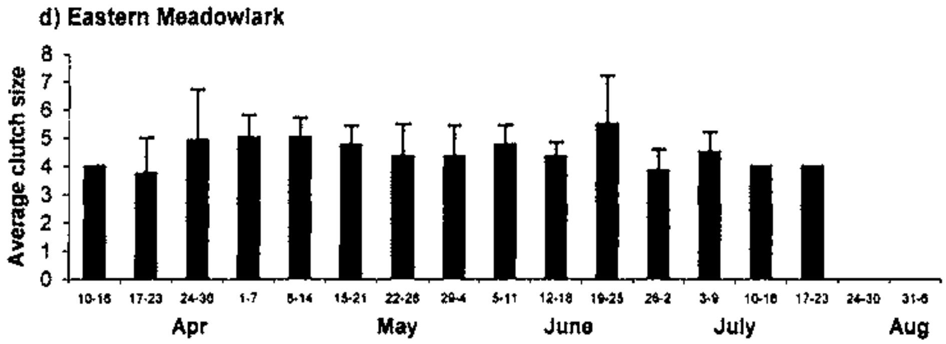


Figure 2-1. Continued.

Figure 2-2. Average weekly clutch size of nests monitored for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Eastern Meadowlarks, and Field Sparrows at Fort Campbell Army Base, Kentucky, 1999-2003.


a) Henslow's Sparrow
Average clutch size
0
1
2
3
4
5
6
10-16
17-23
24-30
1-7
8-14
15-21
22-28
29-4
5-11
12-18
19-25
26-2
3-9
10-16
17-23
24-30
31-6
Apr
May
June
July
Aug
b) Grasshopper Sparrow
Average clutch size
0
1
2
3
4
5
6
10-16
17-23
24-30
1-7
8-14
15-21
22-28
29-4
5-11
12-18
19-25
26-2
3-9
10-16
17-23
24-30
31-6
Apr
May
June
July
Aug
c) Dickcissel
Average clutch size
0
1
2
3
4
5
6
7
10-16
17-23
24-30
1-7
8-14
15-21
22-28
29-4
5-11
12-18
19-25
26-2
3-9
10-16
17-23
24-30
31-6
Apr
May
June
July
Aug



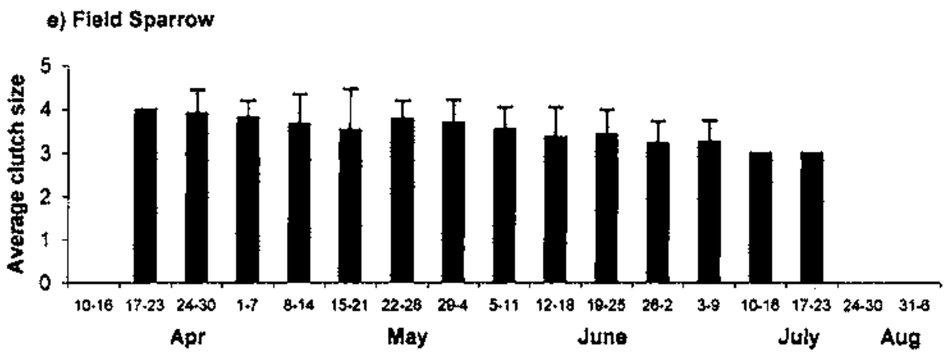
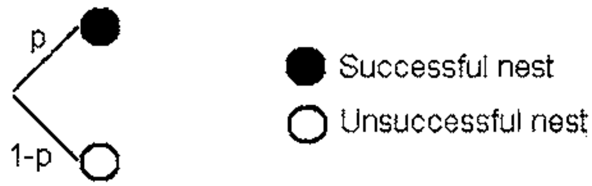


Figure 2-2. Continued.

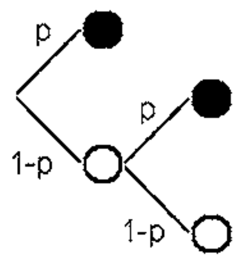
CHAPTER 3

Figure 3-1. Example branching process diagrams used to calculate the productivity of nests given p (probability of a successful nest) and 1-p (probability of an unsuccessful nest). The number of branches is based on the maximum number of successful broods possible in one season (C) for multiple brooded species and the maximum number of nesting attempts (A). Nest success is multiplied across each possible combination of nest histories (successful and unsuccessful attempts) and then multiplied by the number of successful nests in each combination (Black dots). These combinations are then summed to get an overall productivity (R) (see Table 3-1).

a) Single brood with one attempt (C = 1, A = 1)



b) Single brood with two attempts (C = 1, A = 2)



c) Double brood with three attempts (C = 2, A = 3)

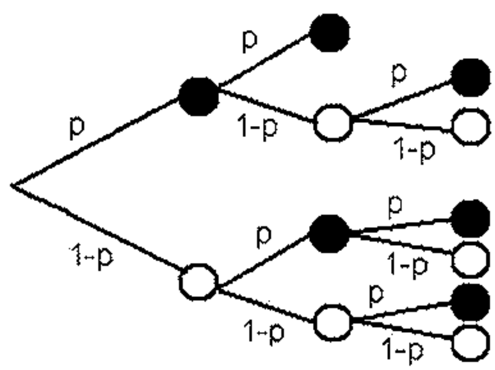


Figure 3-2. Average nest success (±SE) and young produced per successful nest (±SE) for triple-brooded (C = 3) Henslow's Sparrows at Fort Campbell Army Base, Kentucky, 1999-2003. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line) for three and four nest attempts.

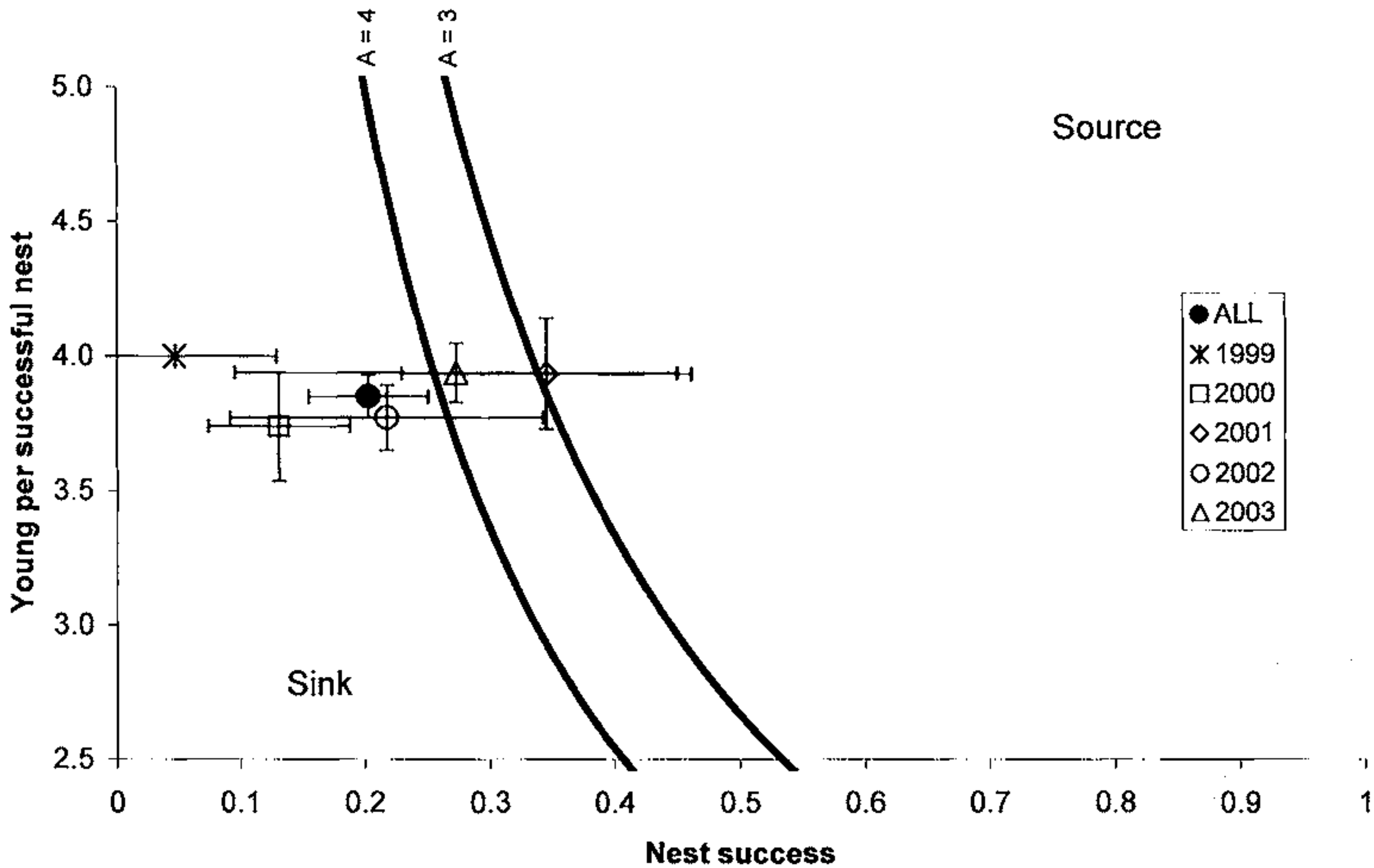

A = 4
A = 3
Source
Sink
Young per successful nest
5.0
4.5
4.0
3.5
3.0
2.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Nest success
ALL
1999
2000
2001
2002
2003

Figure 3-3. Average nest success (±SE) and young produced per successful nest (±SE) for triple-brooded (C = 3) Grasshopper Sparrows at Fort Campbell Army Base, Kentucky, 1999-2003. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line) for three and four nest attempts.

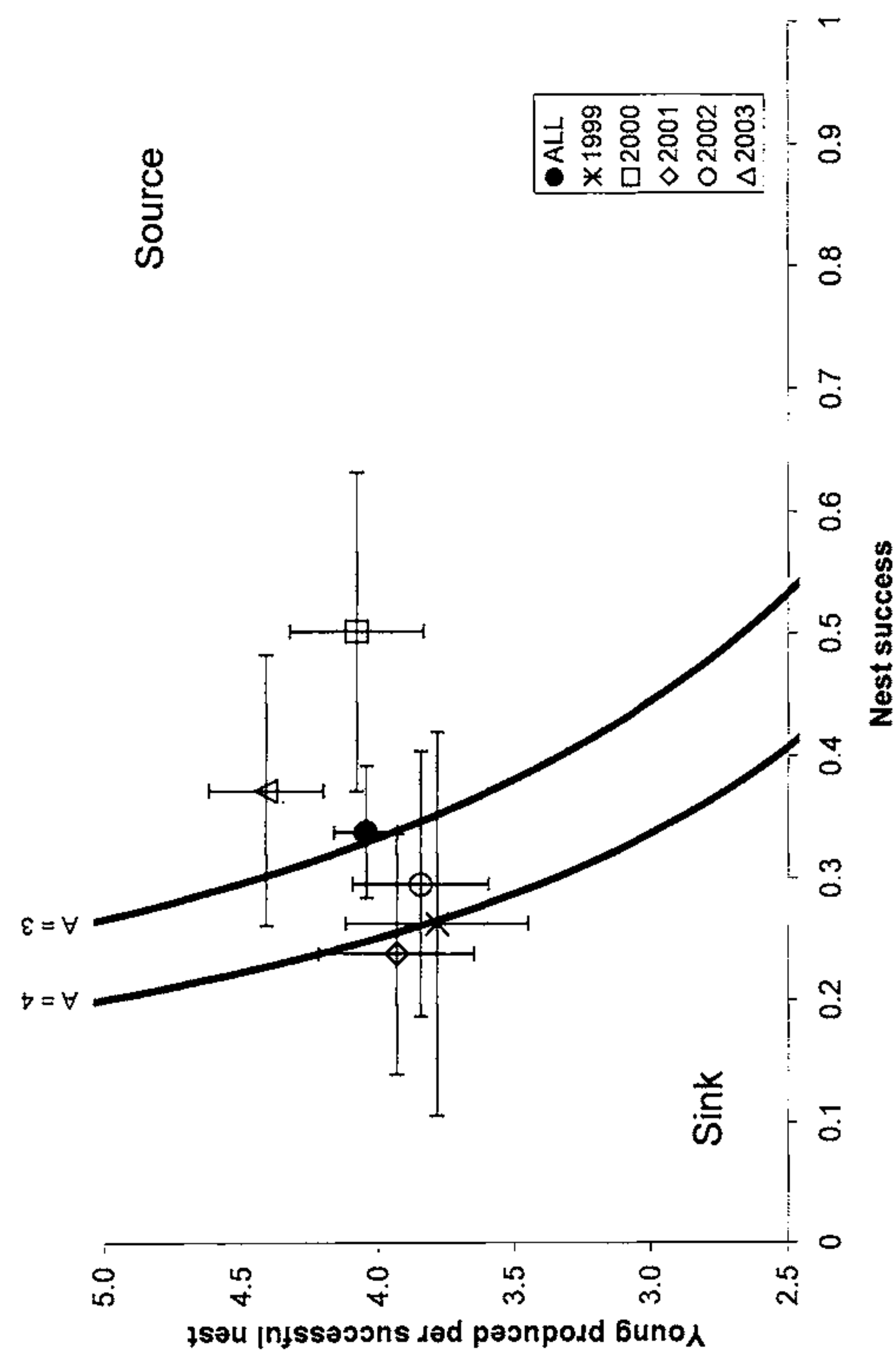

Young produced per successful nest
Nest success
Source
Sink
A = 3
A = 4
ALL
1999
2000
2001
2002
2003
5.0
4.5
4.0
3.5
3.0
2.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 3-4. Average nest success (±SE) and young produced per successful nest (±SE) for single-brooded (C = 1) Dickcissels at Fort Campbell Army Base, Kentucky, 1999-2003. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line) for two, three, and four nest attempts.

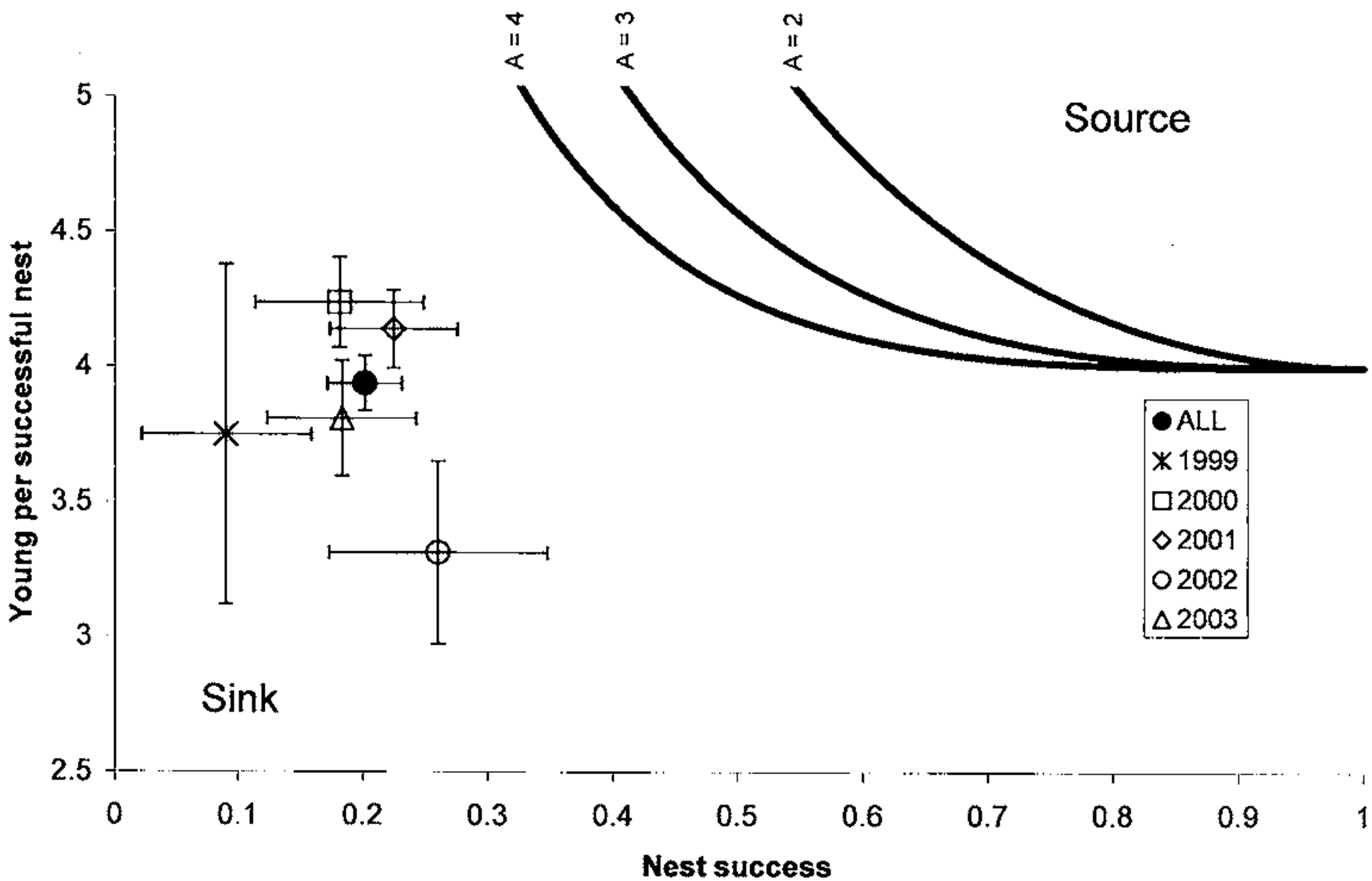

A = 4
A = 3
A = 2
Source
Sink
Young per successful nest
Nest success
5
4.5
4
3.5
3
2.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
ALL
1999
2000
2001
2002
2003

Figure 3-5. Average nest success (±SE) and young produced per successful nest (±SE) for double-brooded (C = 2) Field Sparrows at Fort Campbell Army Base, Kentucky, 1999-2003. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line) for two, three, and four nest attempts.

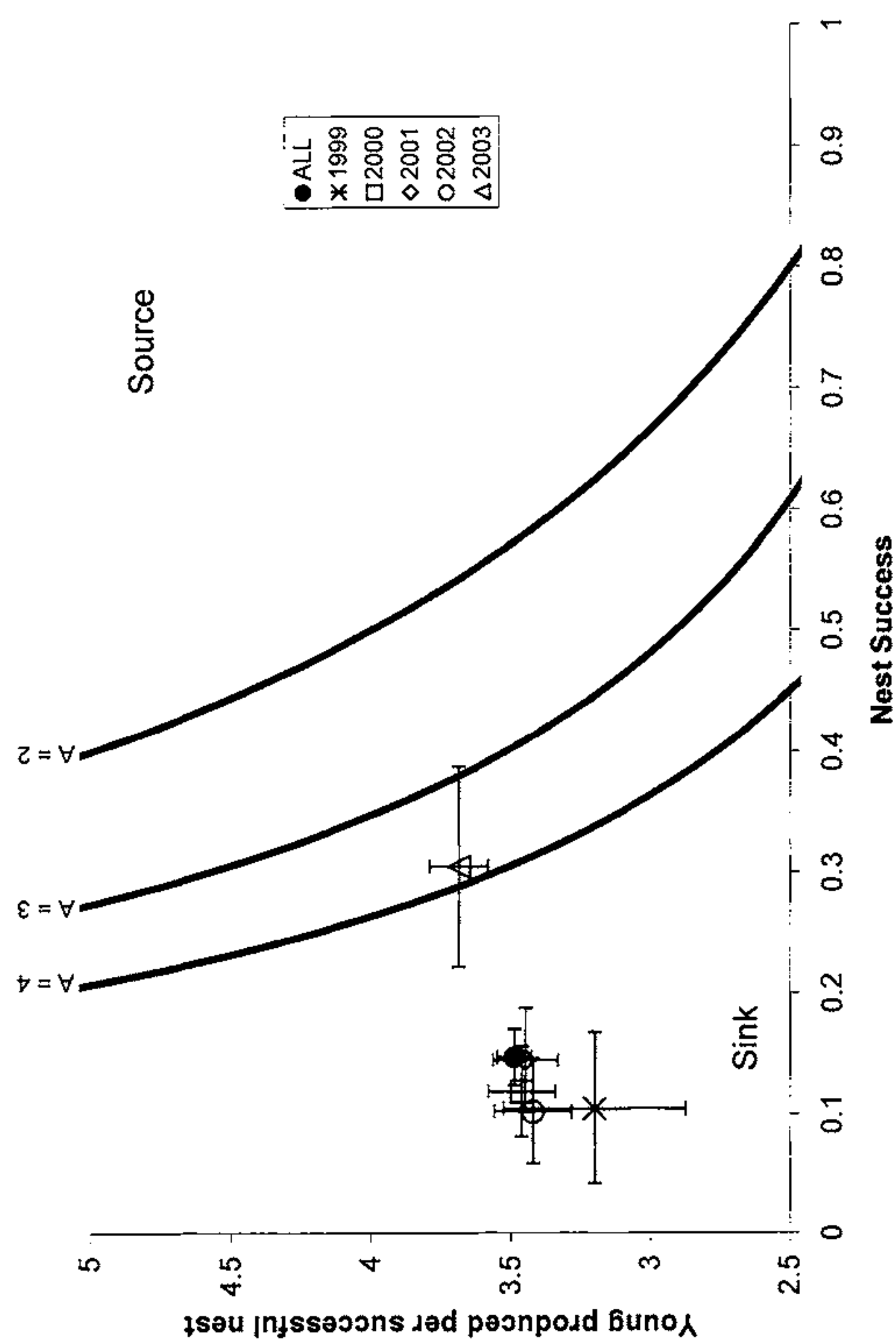

Young produced per successful nest
Nest Success
Source
Sink
A = 2
A = 3
A = 4
ALL
1999
2000
2001
2002
2003
5
4.5
4
3.5
3
2.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 3-6. Average nest success (±SE) and young produced per successful nest (±SE) for double-brooded (C = 2) Eastern Meadowlarks at Fort Campbell Army Base, Kentucky, 1999-2003. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line) for two, three, and four nest attempts.

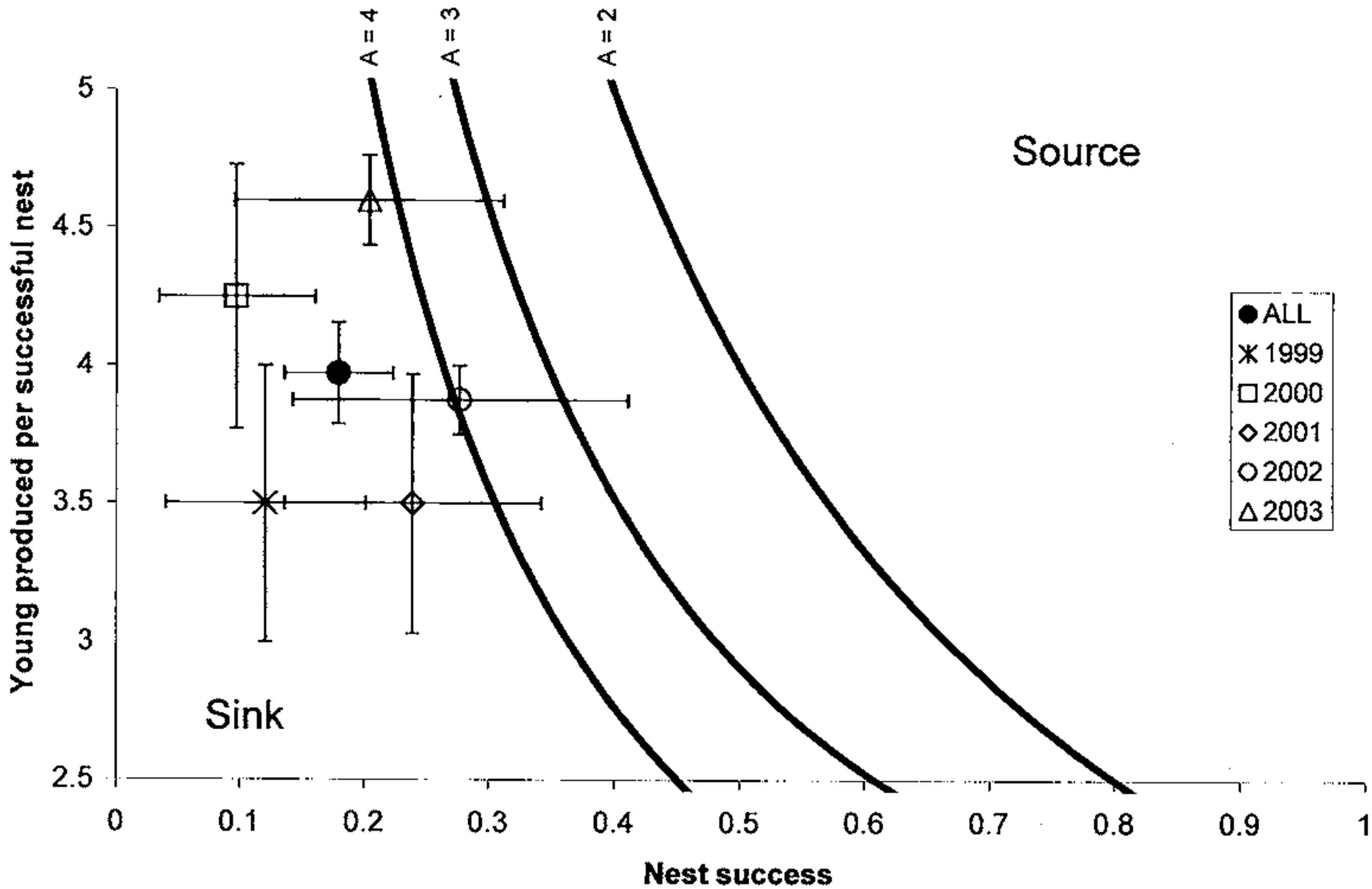

A = 4
A = 3
A = 2
Source
Sink
ALL
1999
2000
2001
2002
2003
Young produced per successful nest
Nest success
5
4.5
4
3.5
3
2.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 3-7. Overall average nest success (±SE) and young produced per successful nest (±SE) for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks monitored at Fort Campbell Army Base, Kentucky, 1999-2003. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line) for single-, double-, and triple brooding.

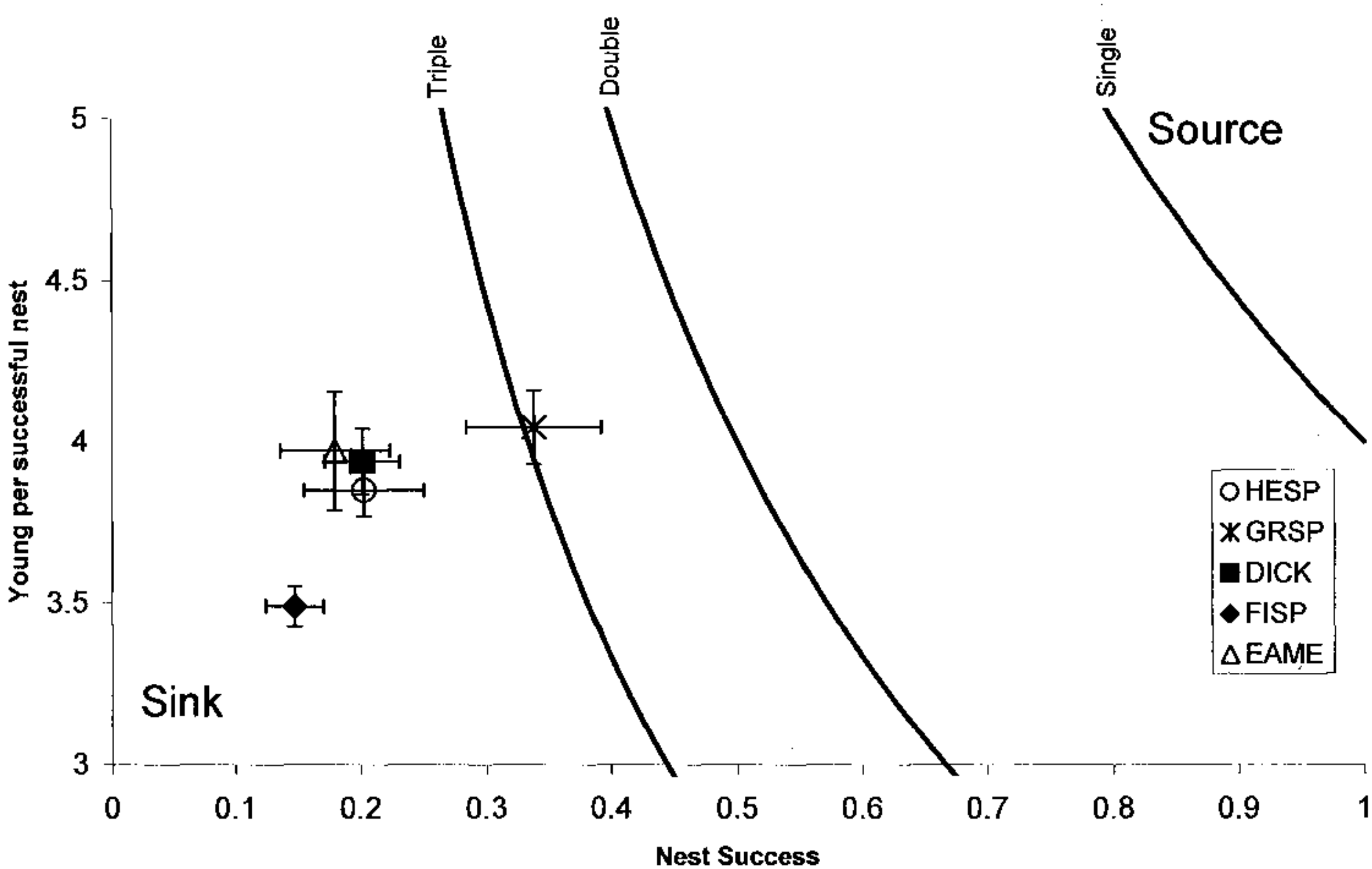
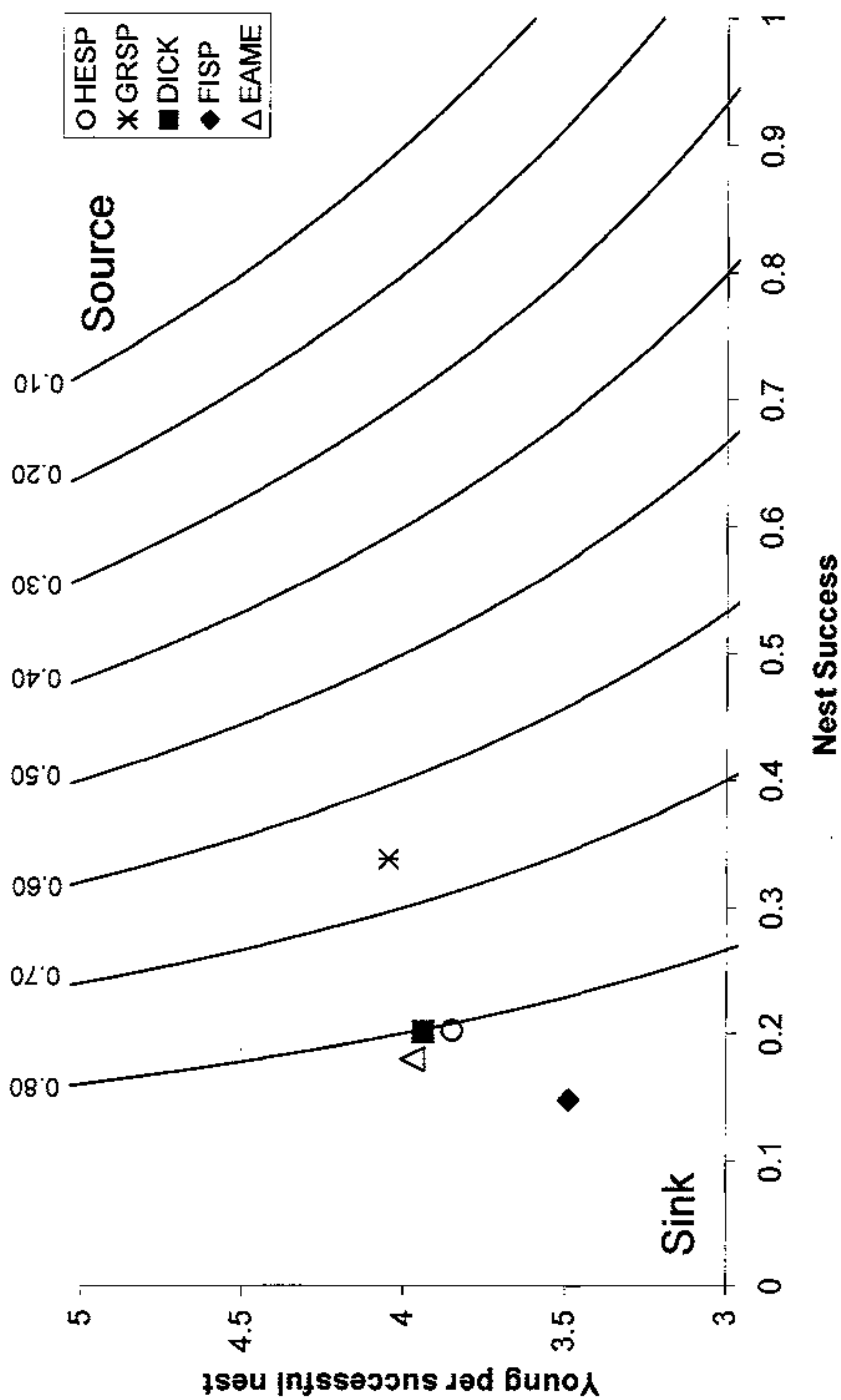

Triple
Double
Single
Source
Sink
Young per successful nest
Nest Success
5
4.5
4
3.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
HESP
GRSP
DICK
FISP
EAME

Figure 3-8. Effects of varying the adult survival (S_a) rate, assuming all species were double-brooded (C = 2, A = 2), on the population viability of grassland birds at Fort Campbell Army Base, Kentucky, 1999-2003. The points represent average nest success and young produced per successful nest for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks monitored. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line).



Source
Sink
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
HESP
GRSP
DICK
FISP
EAME
Young per successful nest
5
4.5
4
3.5
3
Nest Success
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 3-9. Effects of varying the juvenile survival (S_j) rate, assuming all species were double-brooded (C = 2, A = 2), on the population viability of grassland birds at Fort Campbell Army Base, Kentucky, 1999-2003. The points represent average nest success and young produced per successful nest for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks monitored. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line).

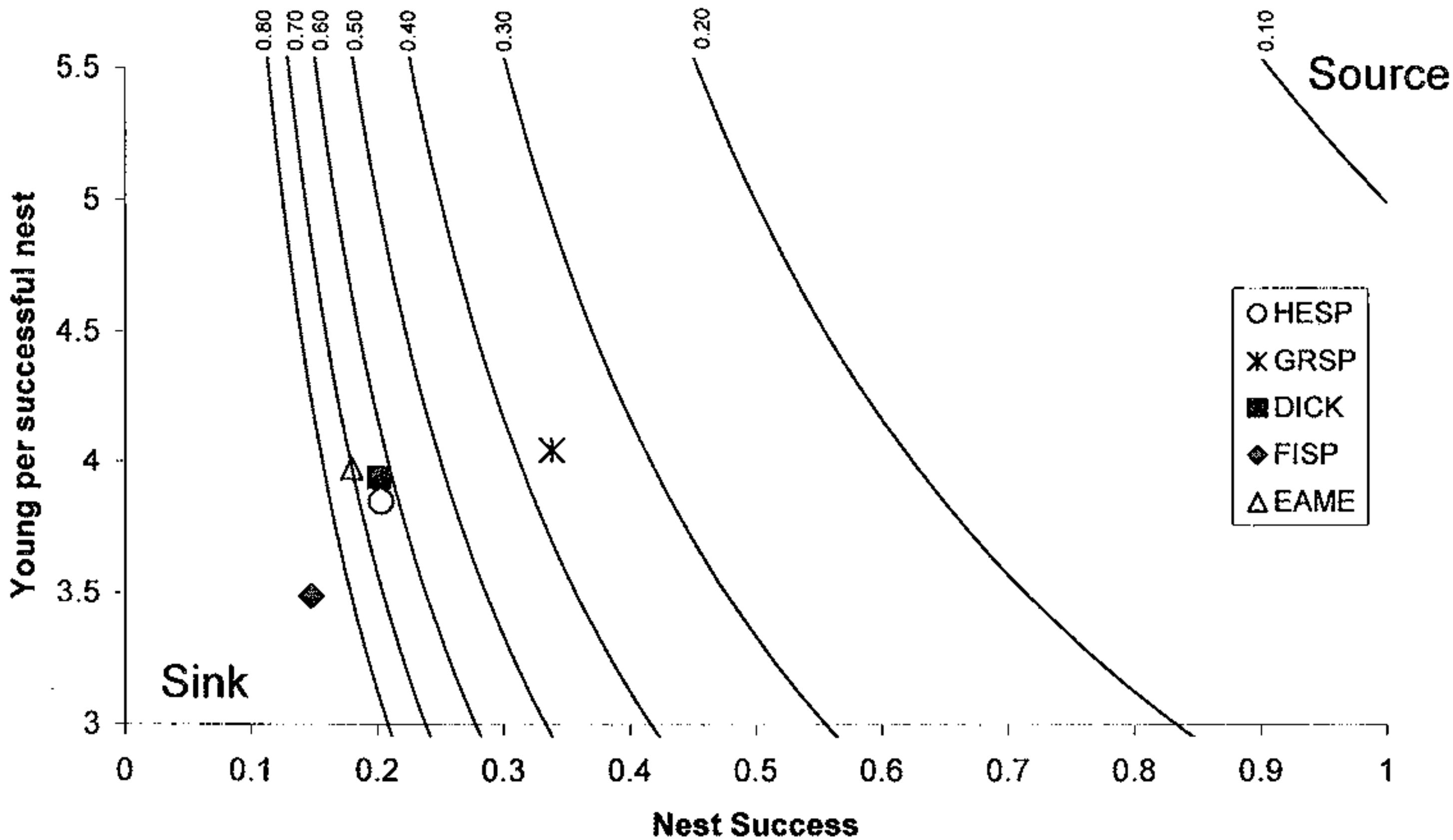
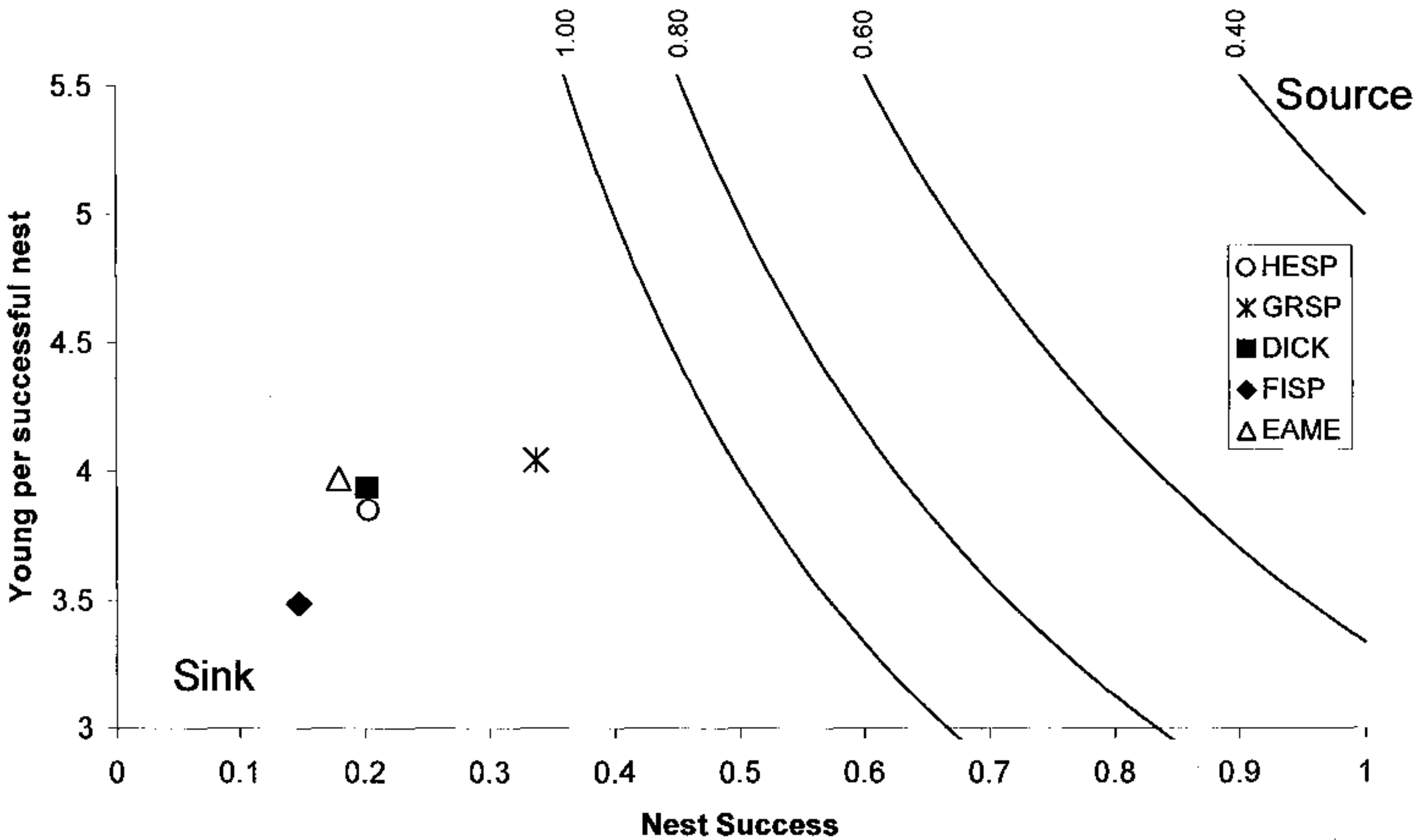

0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Source
Sink
HESP
GRSP
DICK
FISP
EAME
Young per successful nest
5.5
5
4.5
4
3.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Nest Success

Figure 3-10. Effects of varying the re-nesting rate, assuming all species were double-brooded (C = 2, A = 2), on the population viability of grassland birds at Fort Campbell Army Base, Kentucky, 1999-2003. The points represent average nest success and young produced per successful nest for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks monitored. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line).



1.00
0.80
0.60
0.40
Source
Sink
HESP
GRSP
DICK
FISP
EAME
Young per successful nest
Nest Success
5.5
5
4.5
4
3.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 3-11. Effects of varying the number of nesting attempts (A), assuming all species were single-brooded (C = 1), on the population viability of grassland birds at Fort Campbell Army Base, Kentucky, 1999-2003. The points represent average nest success and young produced per successful nest for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks monitored. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line).

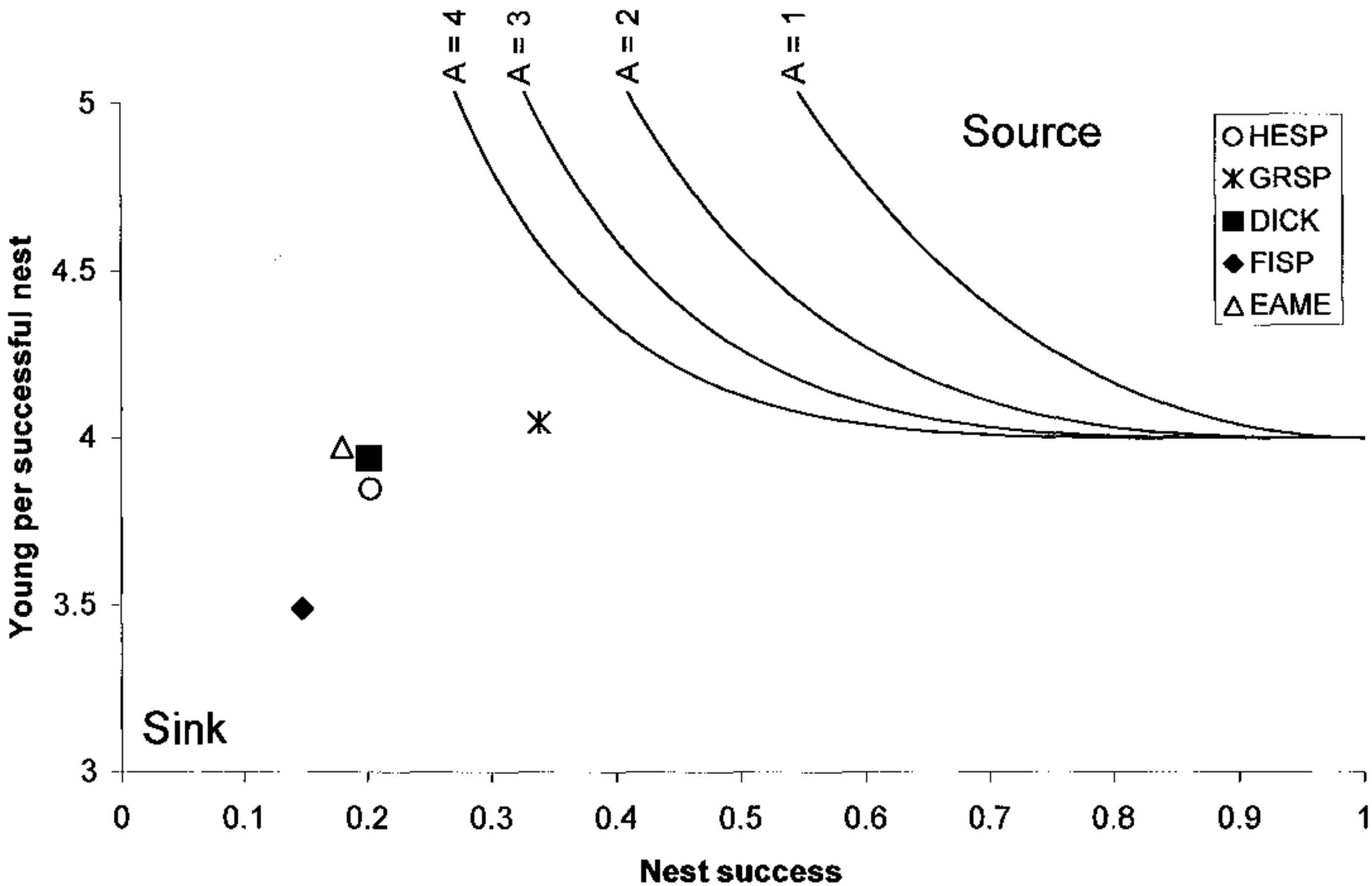
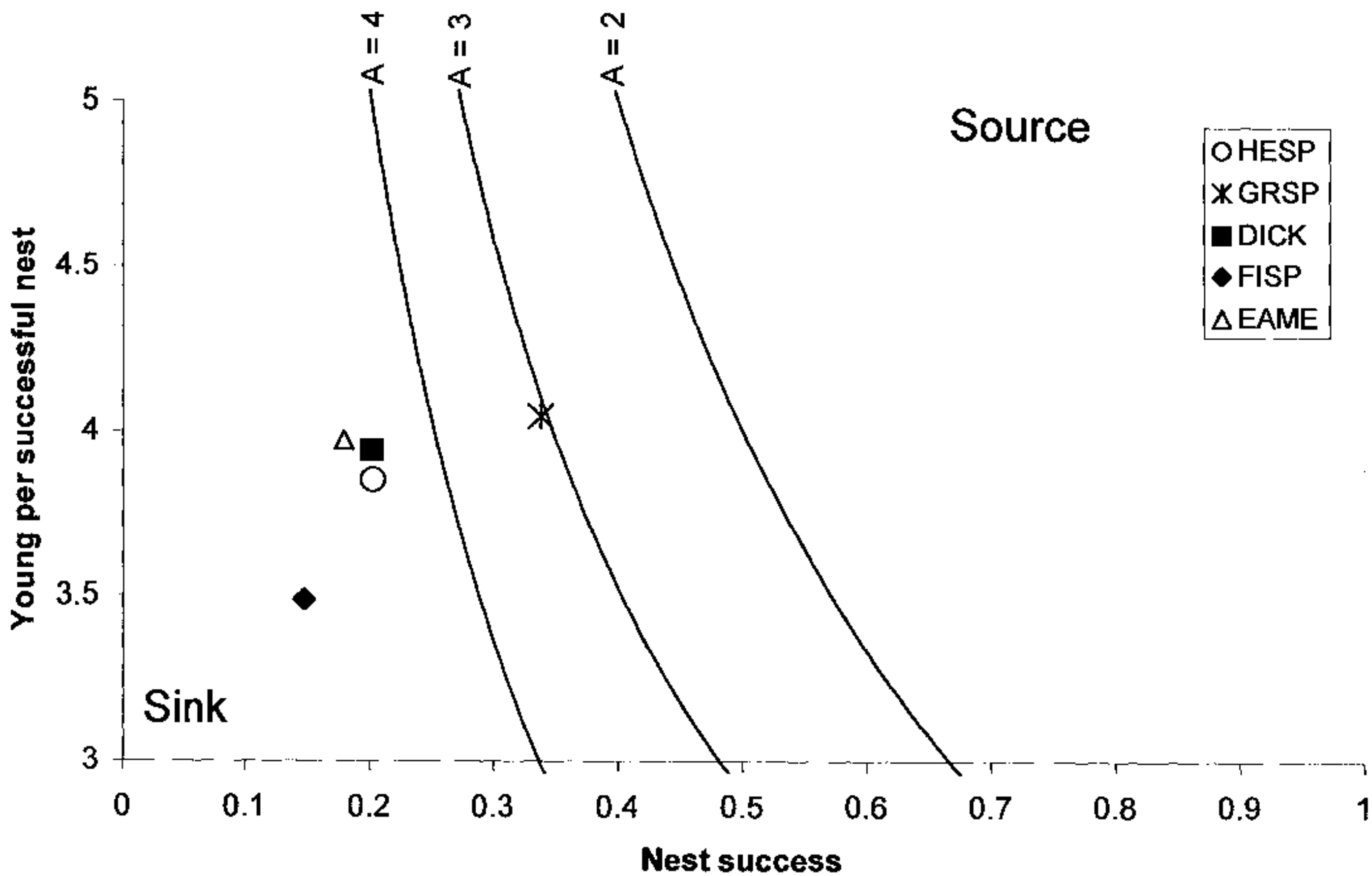

A = 4
A = 3
A = 2
A = 1
Source
Sink
HESP
GRSP
DICK
FISP
EAME
Young per successful nest
Nest success
5
4.5
4
3.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 3-12. Effects of varying the number of nesting attempts (A), assuming all species were double-brooded (C = 2), on the population viability of grassland birds at Fort Campbell Army Base, Kentucky, 1999-2003. The points represent average nest success and young produced per successful nest for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks monitored. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line).



A = 4
A = 3
A = 2
Source
Sink
HESP
GRSP
DICK
FISP
EAME
Young per successful nest
Nest success
5
4.5
4
3.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 3-13. Effects of varying the number of nesting attempts (A), assuming all species were triple-brooded (C = 3), on the population viability of grassland birds at Fort Campbell Army Base, Kentucky, 1999-2003. The points represent average nest success and young produced per successful nest for Henslow's Sparrows, Grasshopper Sparrows, Dickcissels, Field Sparrows, and Eastern Meadowlarks monitored. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line).

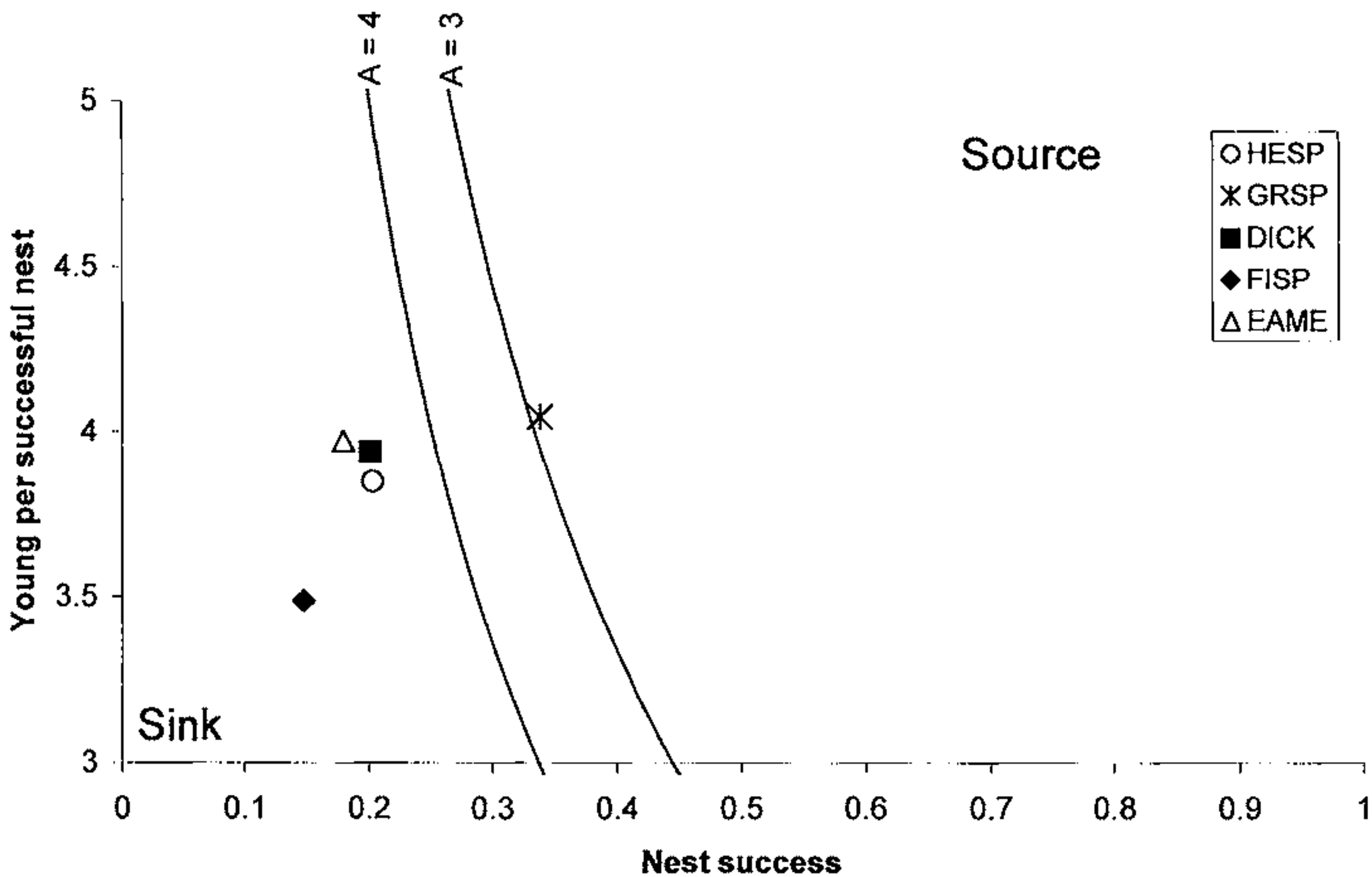

A = 4
A = 3
Source
Sink
HESP
GRSP
DICK
FISP
EAME
Young per successful nest
Nest success
5
4.5
4
3.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 3-14. Effects of hay mowing dates on the population viability of Grasshopper Sparrows at Fort Campbell Army Base, Kentucky, 1999-2003. The points represent average nest success and young produced per successful nest for Grasshopper Sparrows. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line).

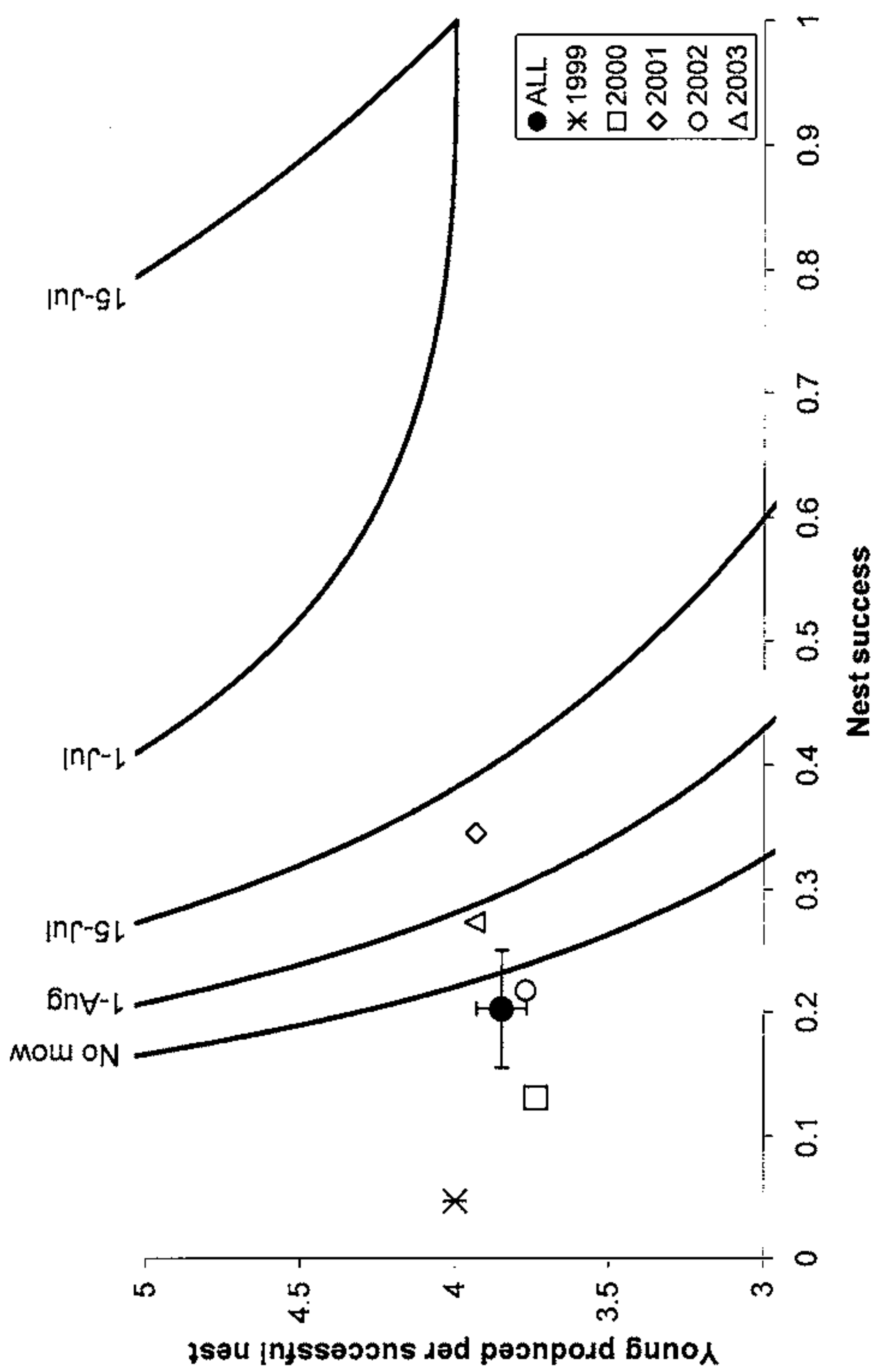
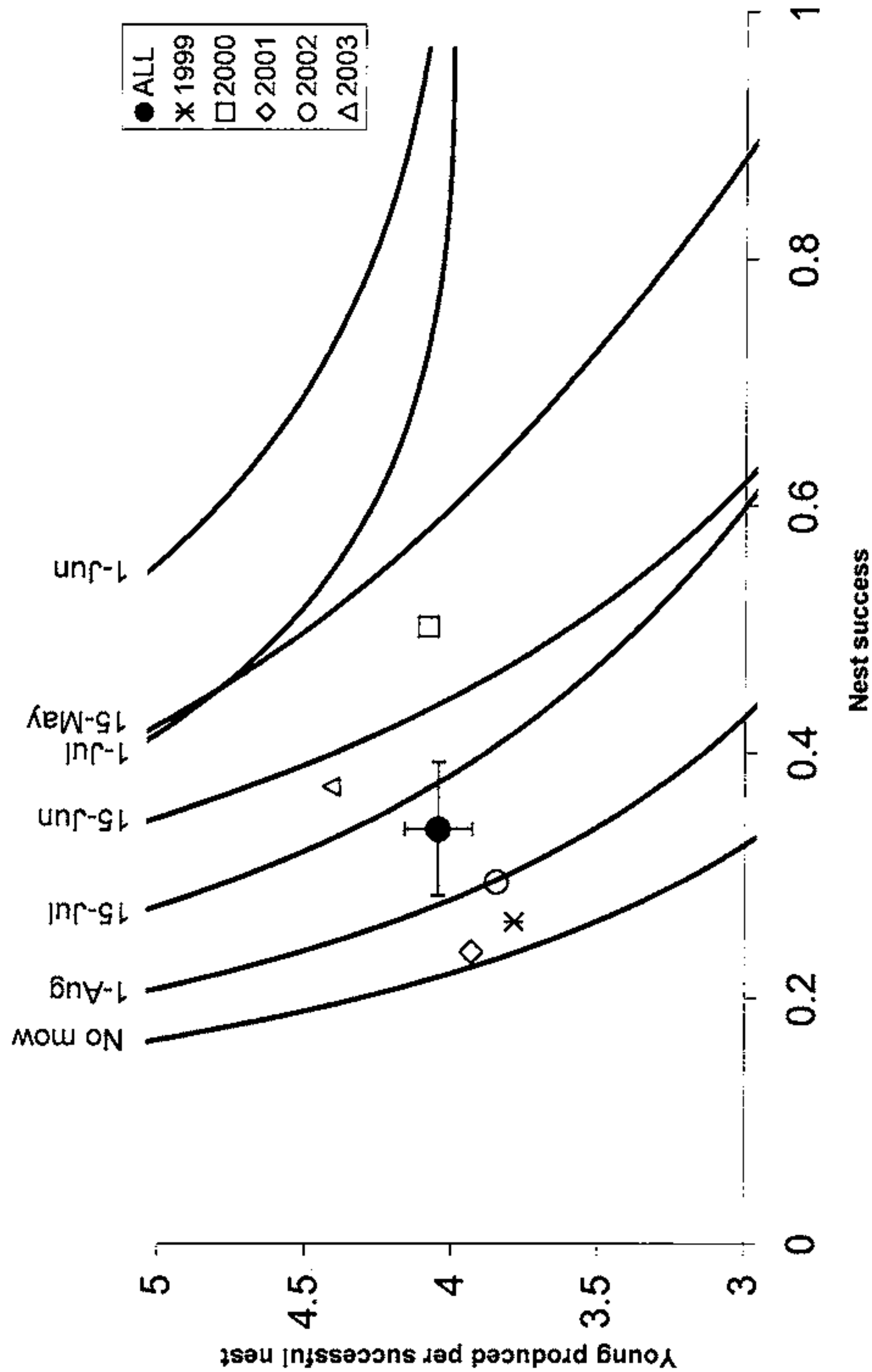

Young produced per successful nest
5
4.5
4
3.5
3
Nest success
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
No mow
1-Aug
15-Jul
1-Jul
15-Jul
ALL
1999
2000
2001
2002
2003

Figure 3-15. Effects of hay mowing dates on the population viability of Henslow's Sparrows at Fort Campbell Army Base, Kentucky, 1999-2003. The points represent average nest success and young produced per successful nest for Henslow's Sparrows. Lines indicate the threshold between increasing populations (points to the right of a line) and decreasing populations (points to the left of a line).



Young produced per successful nest
Nest success
No mow
1-Aug
15-Jul
15-Jun
1-Jul
15-May
1-Jun
ALL
1999
2000
2001
2002
2003
0
0.2
0.4
0.6
0.8
1
3
3.5
4
4.5
5

CHAPTER 4

Figure 4-1. Group centroids (±2 SE) from the discriminant function analysis of the nest site vegetation measurements for grassland birds at Fort Campbell Army Base, Kentucky, 2001-2003. Average scores were plotted for Dickcissels (DICK), Field Sparrows (FISP), Grasshopper Sparrows (GRSP), Henslow's Sparrows (HESP), Eastern Meadowlarks (EAME) and random locations (RANDOM).

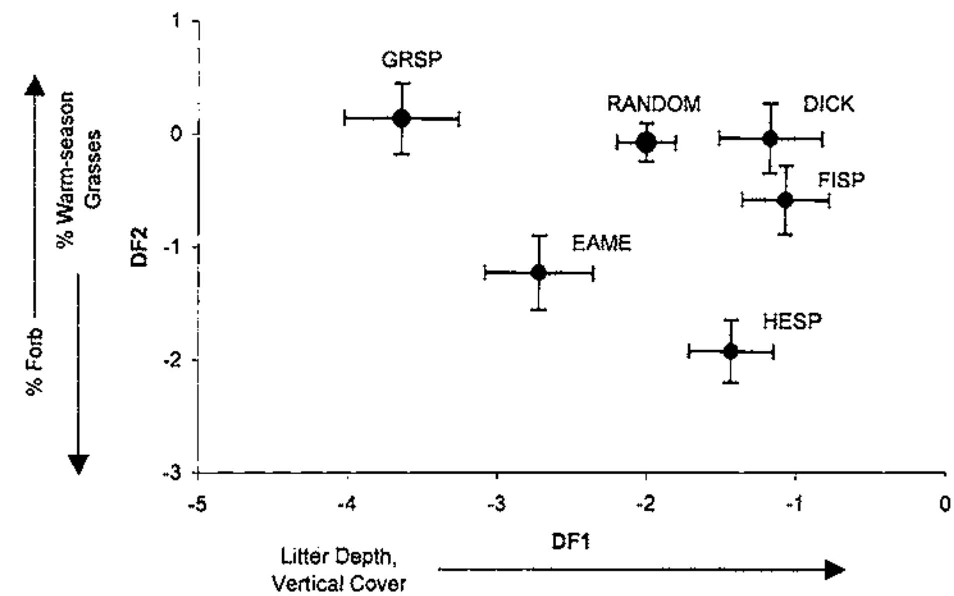
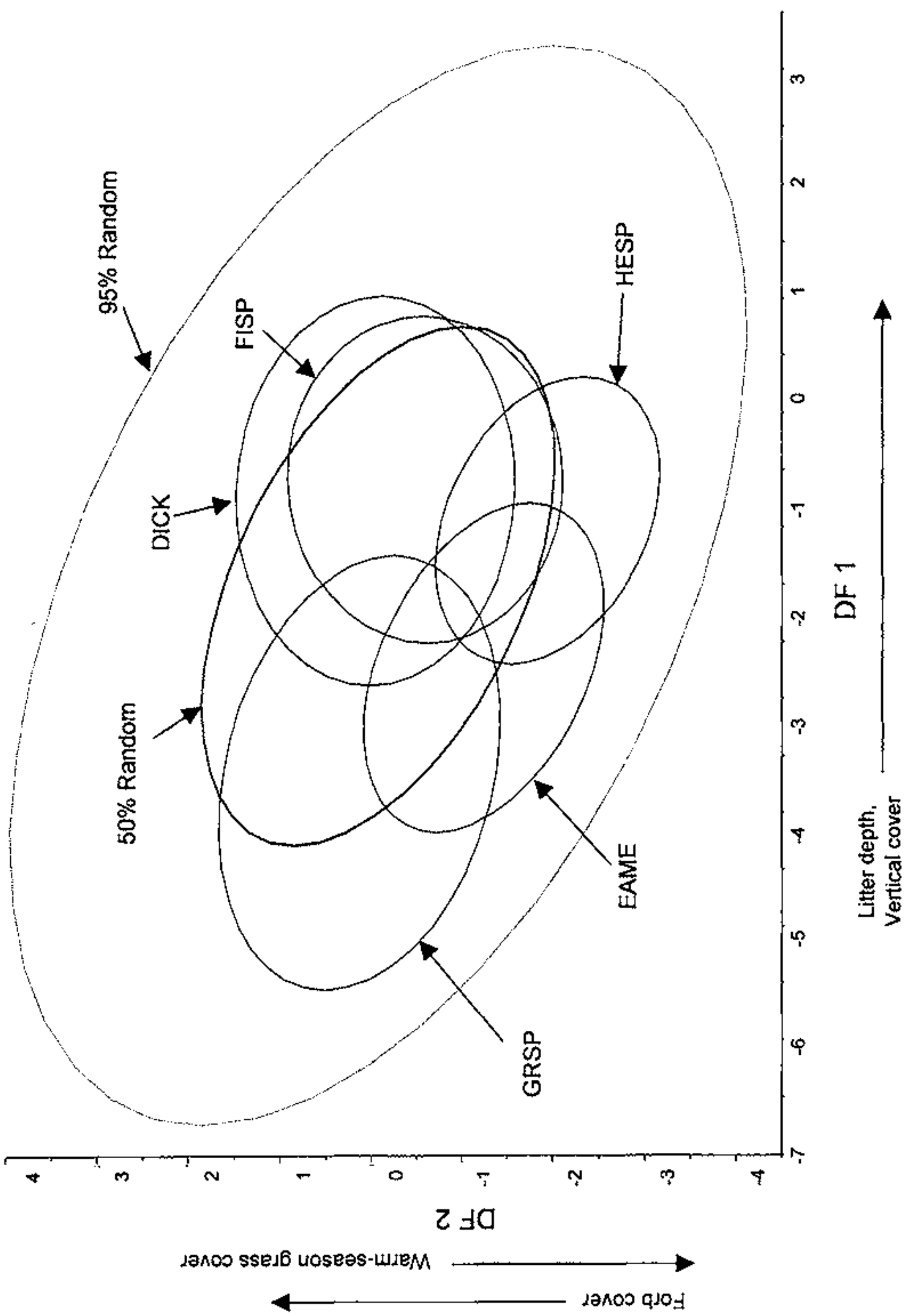


Figure 4-2. Fifty percent confidence ellipses for grassland bird nest site vegetation analysis at Fort Campbell Army Base, Kentucky, 2001-2003. Also presented are the 50% confidence ellipse for random vegetation analysis scores, and the 95% confidence ellipse (dotted line). Scores were generated using a discriminant function analysis of the nest site vegetation measurements for Dickcissels (DICK), Field Sparrows (FISP), Grasshopper Sparrows (GRSP), Henslow's Sparrows (HESP), and Eastern Meadowlarks (EAME).


95% Random
FISP
HESP
DICK
50% Random
EAME
GRSP
DF 1
Litter depth,
Vertical cover
DF 2
Warm-season grass cover
Forb cover
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4

CHAPTER 5

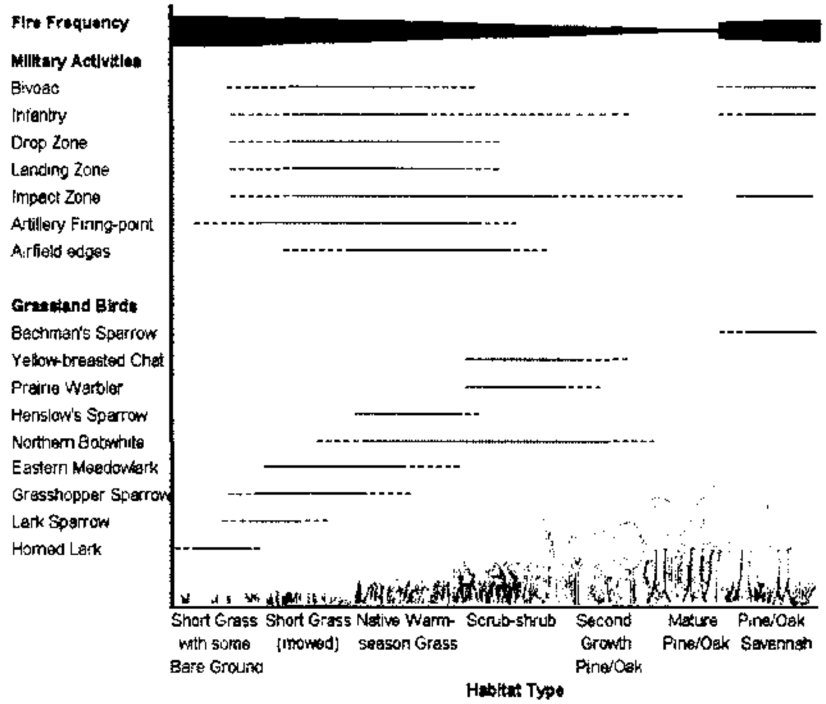


Figure 5-1. Ideal habitats for military training and grassland birds.

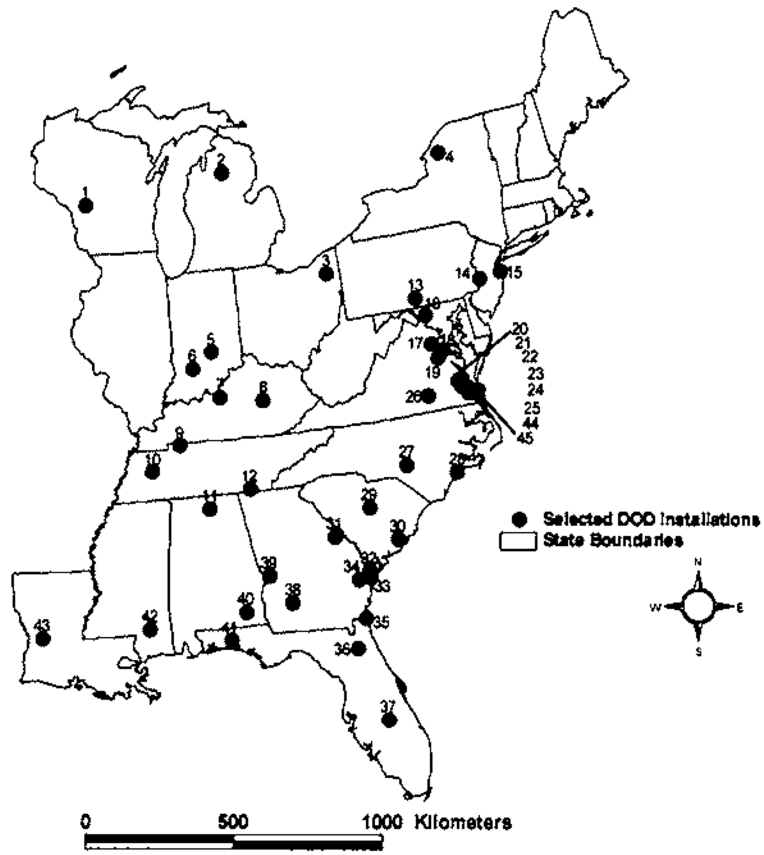


Figure 5-2: Department of Defense (DOD) installations in the eastern US with at least one large (>40 ha) patch of grassland habitats (see Table 5-4 for installation names and identification numbers).

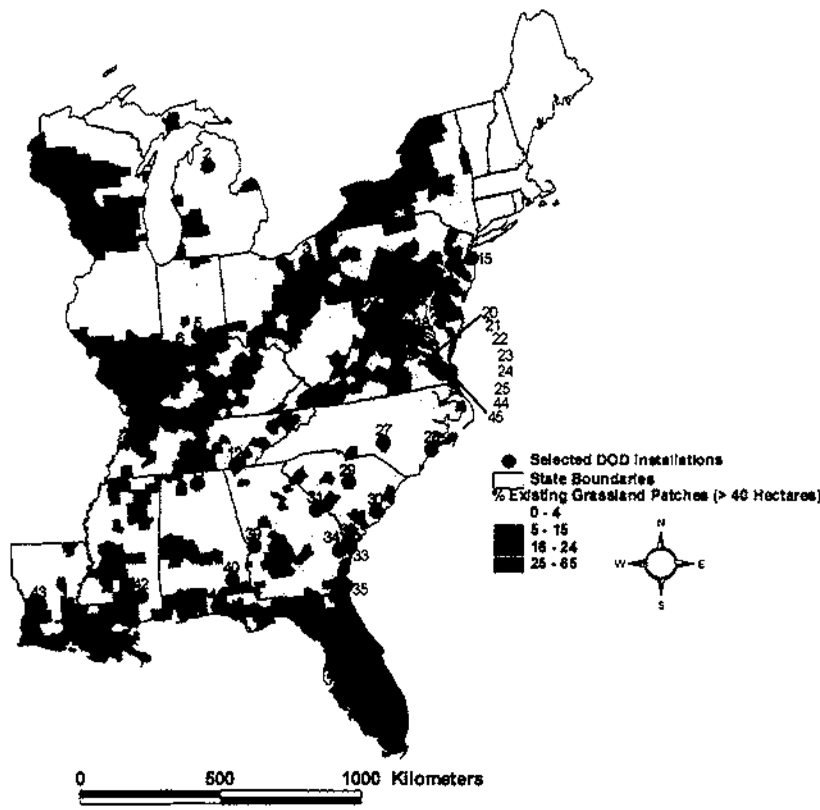


Figure 5-3. Proportion of existing large (>40 ha) grassland patches in the eastern US by county. Darker areas represent higher proportions. The red dots represent selected Department of Defense (DOD) installations (see Table 5-4 for installation names).

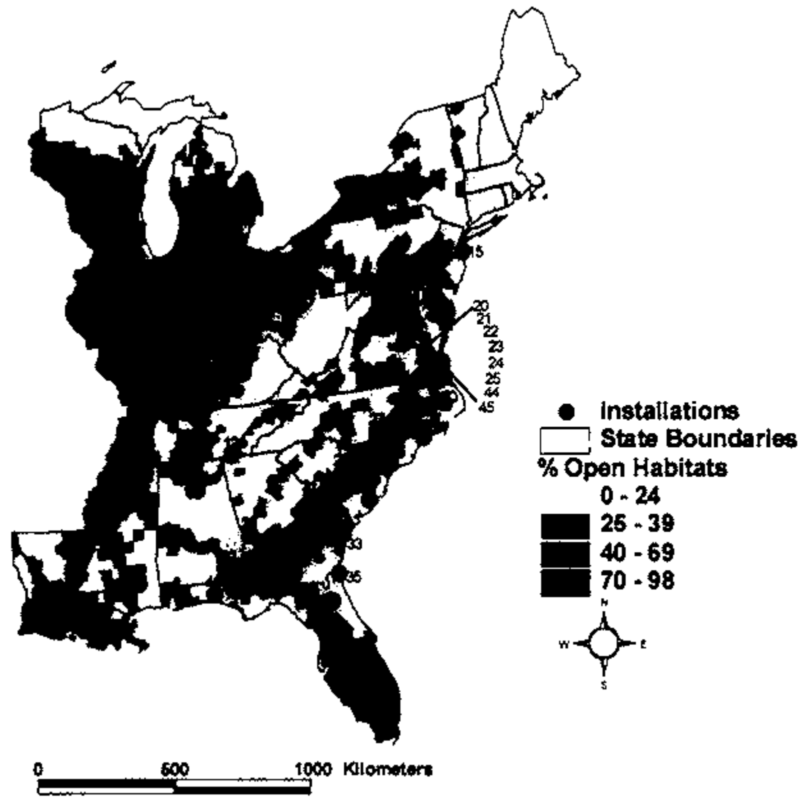


Figure 5-4. Proportion of open habitats (e.g., native grasslands, hay-fields, and other agricultural lands) in the eastern US by county. The open habitats represent potential areas for grassland restoration. Darker areas represent higher proportions. The red dots represent selected Department of Defense (DOD) installations (see Table 5-4 for installation names).

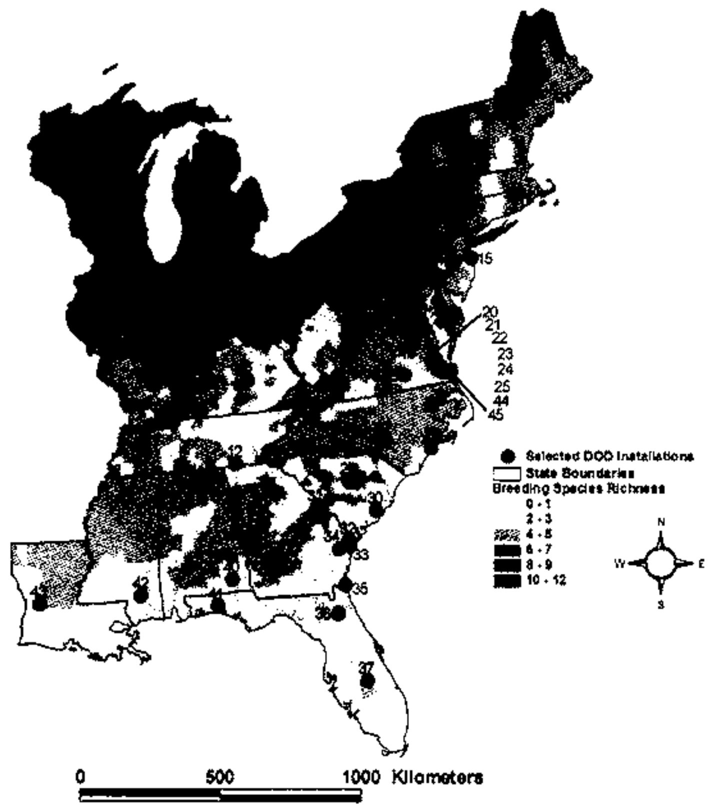


Figure 5-5. Breeding obligate grassland bird richness in the eastern US by county. Species range maps were compiled from Laughlin and Kibbe 1985, Illinois Department of Natural Resources 1986-1991, Adamus 1987, Andrle and Carroll 1988, Carolina Bird Club 1988-1995, Virginia Society of Ornithology 1989, Brewer et al. 1991, Peterjohn and Rice 1991, Brauning 1992, Enser 1992, Veit and Petersen 1993, Bevier 1994, Buckelew 1994, Foss 1994, Palmer-Ball 1996, Robbins 1996, Nicholson 1997, Castrale et al. 1998, Hess et al. 2000, Wiedenfeld and Swan 2000, Peterjohn 2001, Wisconsin Society for Ornithology 2002, Florida Fish and Wildlife Conservation Commission 2003, and Sauer et al. 2004. The red dots represent selected Department of Defense (DOD) installations (see Table 5-4 for installation names).

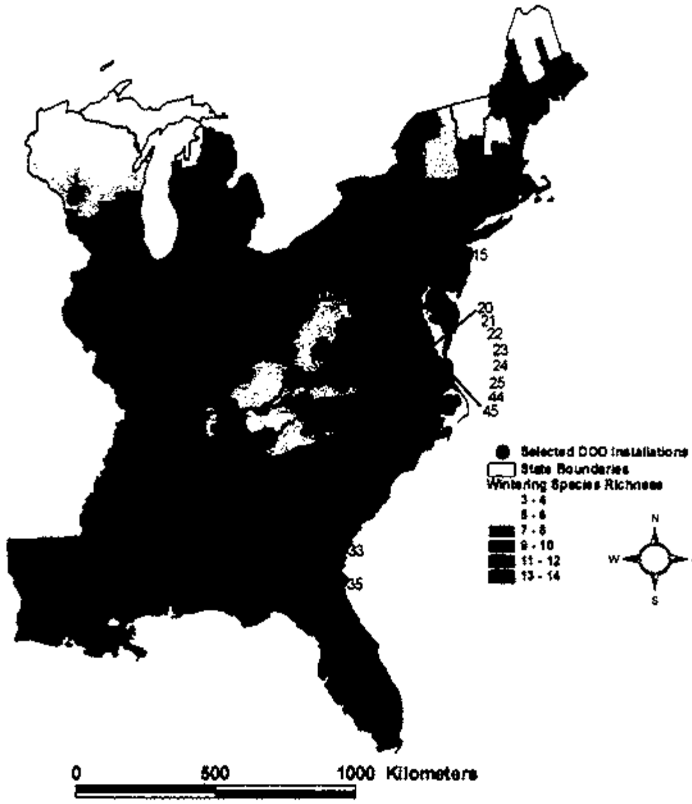


Figure 5-6. Wintering grassland bird species richness in the eastern US by county. Species wintering ranges were compiled from Audubon Society (1959 – 1988) and Root (1988). The red dots represent selected Department of Defense (DOD) installations (see Table 5-4 for installation names).

VITA

James Giocomo was born in Schamburg, Illinois and moved to Camp Hill, Pennsylvania in 1987. He attended Millersville University in Pennsylvania and graduated with a Bachelor of Science in Biology in December 1993. His interest in birds developed in the last few years of his undergraduate education. He then spent portions the next 2 years working as a field technician and intern at Hawk Mountain Sanctuary in Kempton, Pennsylvania. He began a Master of Science degree in Ecology at the Pennsylvania State University in 1996 and graduated in 1998. Another 2 years were spent working on various research projects involving bird populations or working part-time for the Pennsylvania Audubon Society designing bird monitoring protocols for the state Important Bird Areas program. James would like to continue his work on the conservation of bird populations as a means to help conserve the environment in general for future generations.