CLEARANCE REQUEST FOR PUBLIC RELEASE OF DEPARTMENT OF DEFENSE INFORMATION

(See Instructions on back.)

(This form is to be used in requesting review and clearance of DoD information proposed for public release in accordance with DoDD 5230.9.)

TO: *(See Note)* **Chief, Office of Security Review, 1155 Defense Pentagon, Washington, DC 20301-1155**

Note: Regular mail address shown above. For drop-off/next day delivery, use:
Room 12047, 1777 North Kent Street, Rosslyn, VA 22209-2133

1. DOCUMENT DESCRIPTION

a. TYPE Report	b. TITLE Building partnerships for regional grassland bird conservation in the southeastern US
c. PAGE COUNT 86	d. SUBJECT AREA Conservation

2. AUTHOR/SPEAKER

a. NAME *(Last, First, Middle Initial)* Boice, L. Peter	b. RANK NH IV	c. TITLE Conservation Team Leader
d. OFFICE ODUSD(IE)-CO		e. AGENCY OSD

3. PRESENTATION/PUBLICATION DATA *(Date, Place, Event)*

To be posted on the public side of DENIX www.denix.osd.mil. Please fax copy of cleared form to 703-607-3124 or email to Pedro.Morales.ctr@osd.mil

4. POINT OF CONTACT

a. NAME *(Last, First, Middle Initial)* Morales-Muniz, Pedro J	b. TELEPHONE NO. *(Include Area Code)* OSD

5. PRIOR COORDINATION

a. NAME *(Last, First, Middle Initial)*	b. OFFICE/AGENCY	c. TELEPHONE NO. *(Include Area Code)*
Morales-Muniz, Pedro J.	ODUSD(IE)-CO	(703) 604-1933

6. REMARKS

(Legacy 06-105) Grassland birds have been declining at greater rates over the past 35 years than any other avian group across North America. Several of the key priority species are declining to the point that listing for protection under the Endangered Species Act is a possibility if significant conservation efforts are not focused on this critical problem. This project demonstrates the value of military bases for supporting sustainable breeding populations of key high priority species (e.g., Henslow's Sparrow) demonstrates how the needs of grassland birds are compatible with troop training needs at Fort Campbell, and includes a grassland bird conservation strategy for eastern military bases in general.

7. RECOMMENDATION OF SUBMITTING OFFICE/AGENCY

a. THE ATTACHED MATERIAL HAS DEPARTMENT/OFFICE/AGENCY APPROVAL FOR PUBLIC RELEASE *(qualifications, if any, are indicated in Remarks section)* AND CLEARANCE FOR OPEN PUBLICATION IS RECOMMENDED UNDER PROVISIONS OF DODD 5320.9. I AM AUTHORIZED TO MAKE THIS RECOMMENDATION FOR RELEASE ON BEHALF OF:

____

b. CLEARANCE IS REQUESTED BY 20090105 *(YYYYMMDD)*.

c. NAME *(Last, First, Middle Initial)* Boice, L. Peter	d. TITLE Conservation Team Leader
e. OFFICE ODUSD(IE)-CO	f. AGENCY OSD
g. SIGNATURE L Peter Boice	h. DATE SIGNED *(YYYYMMDD)* 20090123

Department of Defense
Legacy Resource Management Program

PROJECT NUMBER 06-105

Building partnerships for regional grassland bird conservation in the southeastern US

Dr. David A. Buehler
Dr. James J. Giocomo
Mr. Daniel Hinnebusch
February 2007

Title:
Building partnerships for regional grassland bird conservation in the southeastern US

Principal Investigators:
David Buehler, University of Tennessee
James Giocomo, University of Tennessee
Daniel Hinnebusch, University of Tennessee

Abstract:
Grassland birds have been declining at greater rates over the past 35 years than any other avian group across North America (BBS data, 1966-2003). Several of the key priority species are declining to the point that listing for protection under the Endangered Species Act is a possibility if significant conservation efforts are not focused on this critical problem. Eastern military bases are in a unique situation because these bases support many of the priority species that are at risk and military bases also are vulnerable to major disruption if listing were to occur. Proactive management by the military may very well help solve this problem, thereby minimizing impacts on the primary military mission. Our research, supported in part by funding from the DoD Legacy Resources Management Program, has been focused on helping the military develop conservation strategies for grassland birds to mitigate potential impacts in the future. We have demonstrated the value of military bases for supporting sustainable breeding populations of key high priority species (e.g., Henslow's Sparrow). Furthermore, we have demonstrated how the needs of grassland birds are compatible with troop training needs at Fort Campbell. Finally, we have developed a grassland bird conservation strategy for eastern military bases in general based on our Fort Campbell experience.

In this project, we are taking a significant step by extending our research beyond the breeding season to winter and beyond the boundaries of Fort Campbell to address encroachment and conservation issues and opportunities on public and private lands in the surrounding landscape.

Military installations are being threatened by encroachment. Bases become islands of wildlife habitat, attractive to an inordinate share of threatened wildlife species because of human development pressures in the surrounding communities. To solve this problem, we need to promote significant conservation in the surrounding community to relieve the burden that has been placed on the military. This project will use Fort Campbell to demonstrate how it is possible to promote regional conservation by developing a partnership between the Army, The Nature Conservancy, The University of Tennessee, state wildlife agencies, and USDA NRCS. Through this partnership, we propose to determine what opportunities there are in the surrounding community to promote grassland bird conservation and bring state and federal assistance to targeted landowners to achieve that conservation. A Memorandum of Agreement between Fort Campbell, The Nature Conservancy and The University of Tennessee has already been drafted but has stalled because of military budget limitations. This project would serve as the catalyst to get this effort started again, as well as bring in other partners. We envision this

partnership as the foundation for planning growth and development and managing encroachment issues around Fort Campbell in the future.

The southeastern U.S. is the winter home for many high priority grassland species. Some of the most significant patches of grassland bird wintering habitat occur on military bases. Information on winter health and survival of grassland birds is the missing link in population assessments to allow for accurate identification of the key bottlenecks in grassland bird populations. As part of this project, we propose to fill some of those wintering grassland bird information gaps.

In addition, we propose to take our existing data from previous work and extend it to all eastern military bases via an interactive website to provide land managers on every installation in the East access to information about grassland birds that are likely to occur on their base. Significant Legacy resources have already been spent to develop this GIS database of documented and potential grassland habitat for birds breeding and wintering on eastern U.S. military lands. This information can serve as a starting point for developing a management strategy for military grasslands.

To achieve the goals of this project, we have the following specific objectives:

1) Develop a partnership among Fort Campbell, The Nature Conservancy, the University of Tennessee, state agencies, USDA NRCS, and others and use that partnership as the vehicle to promote grassland bird conservation on public and private lands surrounding Fort Campbell;

2) Inventory breeding and wintering grassland bird populations and habitat within and adjacent to Fort Campbell as a means of identifying potential cooperating landowners;

3) Use Fort Campbell as a case study to identify specific management recommendations to meet military training needs and winter habitat requirements for declining grassland bird species;

4) Based on our previous work and with the assistance of the DOD Partner's In Flight coordinator, construct an interactive website of potential high priority breeding and wintering grassland birds at bases in the eastern U.S.

PROGRESS TO DATE:

1) OBJECTIVE 1---In May 2006 grassland bird conservation in the Fort Campbell/Big Barrens region was discussed with the Partners in Flight (PIF) Central Hardwoods Region Joint Venture Steering Committee. Another meeting is planned for the Southeastern PIF conference in February 2007.

2) OBJECTIVES 2 & 3---One winter (2005-06) and one breeding (2006) field season have been completed (summary of results below). We intend on collecting data for two more winters (2006-07 and 2007-08) and one more breeding season (2007).

3) OBJECTIVE 4---Management recommendations and other information important for military land managers (e.g., air strike records for each species) have been compiled for each of the fifteen obligate grassland bird species. Composite range maps for breeding and wintering ranges were created. Land cover maps and spatial statistics for 45 DOD installations have been compiled and organized for website presentation. The completed website should be fully tested and online by May 2007.

Expected Products:

1) TECHNICAL ANALYSIS- Conduct an analysis of breeding and wintering grassland bird populations and habitats within and adjacent to Fort Campbell

2) TECHNICAL REPORT- Use Fort Campbell as a case study to identify specific management recommendations to meet military training needs and winter habitat requirements for declining grassland bird species

3) WEBSITE- Based on our previous work and with the assistance of the DOD Partner's In Flight coordinator, construct an interactive website of potential high priority breeding and wintering grassland birds at bases in the eastern U.S.

4) TECHNICAL REPORT- Progress report 2006 (this report).

5) TECHNICAL REPORT- Final report (MS thesis) 2008.

6) PEER-REVIEWED PUBLICATIONS- At least three peer-reviewed publications are expected to be generated by this work as a means to get the results of this effort out to the scientific community.

   Giocomo, J. J., E. D. Moss, D. A. Buehler and W. G. Minser. *Accepted with revisions*. Nesting ecology of grassland birds at Fort Campbell, Kentucky and Tennessee. Wilson Bulletin.

   Giocomo, J. J. and D. A. Buehler. *In Review*. A graphical tool for assessing songbird population status with an application for three grassland songbirds. The Auk.

   Giocomo, J. J., E. D. Moss, D. A. Buehler, W. G. Minser and C. H. Harper. *In prep*. Grassland bird nesting habitat selection at Fort Campbell Army Base, Kentucky and Tennessee.

APPROACH

Study Site Selection

The field study is being conducted in grassland habitats on Fort Campbell Military Reservation, a 42,000-ha base located on the Tennessee-Kentucky state line, and eight surrounding counties in Tennessee (Stewart, Montgomery and Robertson) and Kentucky (Trigg, Christian, Todd, Logan, and Simpson; Figure 1). This area composes much of the original Kentucky Barrens (Chester 1988), grasslands historically maintained through regular burning by Native Americans (Baskin et al. 1994). Today grasslands on the base are maintained by burning on a 2-3 year rotation. Prescribed fire is largely absent from the landscape surrounding the base. A series of individual grassland sites inside and outside the base will be selected for evaluation based on size of the patch, years since burn, presence of target species, and access restrictions.

Methods

We collected data on breeding grassland birds in the Fort Campbell, KY and TN, and the surrounding region from May 3 to July 31, 2006. Half of our time was spent working on several fields in Fort Campbell and the other half split between private fields in KY and two Tennessee Wildlife Resources Agency Wildlife Management Areas, Cedar Hill Swamp and Haynes Bottom.

Our primary focus was nest searching because many grassland bird species have well hidden nests and secretive behavior. We specifically searched for Henslow's Sparrow nest because it was our primary target species. All other nests that were found while searching for Henslow's Sparrow nests were marked and monitored as well. Nests were visited every 3-5 days to determine the outcome while minimizing disturbance to the birds. Nest success was estimated using the Mayfield method (Mayfield 1975).

We also surveyed birds at each field site to estimate the density of each species using the site. All birds were counted within a 300x300m grid (9 Ha.). If the standard plot did not fit in the fit on a field, the entire field was surveyed. All surveys were conducted by one observer (DH) to eliminate observer bias. Each survey was run twice and the higher of the two counts for each species was used.

Vegetation was sampled at each nest site after the nest was completed and at several locations within each survey plot.

Breeding Season 2006 Nest Searching Results

We found a total of 155 nests of 13 species including 20 Henslow's Sparrow nests, our primary species of interest (Table 1). We also found nests of three other target species: Prairie Warbler, Field Sparrow, and Dickcissel.

Table 1. Number of nests monitored per species by ownership class.

Species	Military	Private	TWRA	Total
Field Sparrow	23	15	25	**63**
Prairie Warbler	20	1	1	**22**
Henslow's Sparrow	18	2	0	**20**
Dickcissel	14	2	0	**16**
Indigo Bunting	7	6	2	**15**
Northern Cardinal	0	0	4	**4**
Yellow-breasted Chat	1	0	3	**4**
Blue Grosbeak	3	0	0	**3**
Common Yellowthroat	2	0	0	**2**
Eastern Meadowlark	2	0	0	**2**
Wild Turkey	1	0	1	**2**
Eastern Towhee	0	0	1	**1**
Red-winged Blackbird	0	1	0	**1**
Total	**91**	**27**	**37**	**155**

We calculated Mayfield nest success estimates for the five species of which the most nests were found (Table 2). Greatest success was observed for Dickcissel and lowest for Indigo Bunting, but there were no significant differences between any of the species analyzed. We had a sufficiently large sample of Field Sparrow nests to calculate nest success on each of the three land types for that species. There were no significant differences between nest success estimates for each field type for Field Sparrow. The ability to detect differences in nest success by ownership class or between species is limited at this point by sample sizes. Additional data from 2007 will increase the power of the analysis.

Table 2. Mayfield nest success estimates and 95% confidence intervals for five focal species. Nest exposure days are the effective sampling unit for this analysis.

Species	Mayfield Estimate	Nest Days
Prairie Warbler	21.0±17.8%	186.5
Field Sparrow	13.8±10.2%	357.0
Military	14.8±19.6%	122.5
Private	26.8±31.9%	87.5
TWRA	8.7±10.4%	147.0
Henslow's Sparrow	24.8±19.6%	104.5
Indigo Bunting	8.9±13.1%	181.5
Dickcissel	30.0±28.5%	110.5

Breeding Season 2006 Bird Survey Results

We surveyed eight plots on Fort Campbell with a total area of 54.9 ha and nine plots off Fort Campbell (private and TWRA fields pooled) with a total of 37.5 ha. We calculated the densities of birds in each of three habitat classifications: grassland obligate, grassland facultative, and shrub/scrub species. Figure 1 shows the mean density of each species on and off Fort Campbell. The four-letter bird codes used in Figure 1 are translated Table 6 in the Appendix.

The bird communities showed some clear differences between field types (Table 3). Private and military fields both had two Partners in Flight Regional Concern species (Central Hardwoods BCR, Field Sparrow and Henslow's Sparrow) among the five most common species while TWRA had none.

Table 3. Observed density (birds / 100 ha) for top five species observed by ownership class.

n	Private	n	Military	n	TWRA
69	Henslow's Sparrow	95	Dickcissel	180	Field Sparrow
68	Field Sparrow	91	Indigo Bunting	101	Indigo Bunting
68	Red-winged Blackbird	87	Field Sparrow	99	Common Yellowthroat
66	Indigo Bunting	87	Henslow's Sparrow	72	Common Grackle
47	Dickcissel	75	Common Yellowthroat	58	Cliff Swallow

n = Birds / 100 Ha.

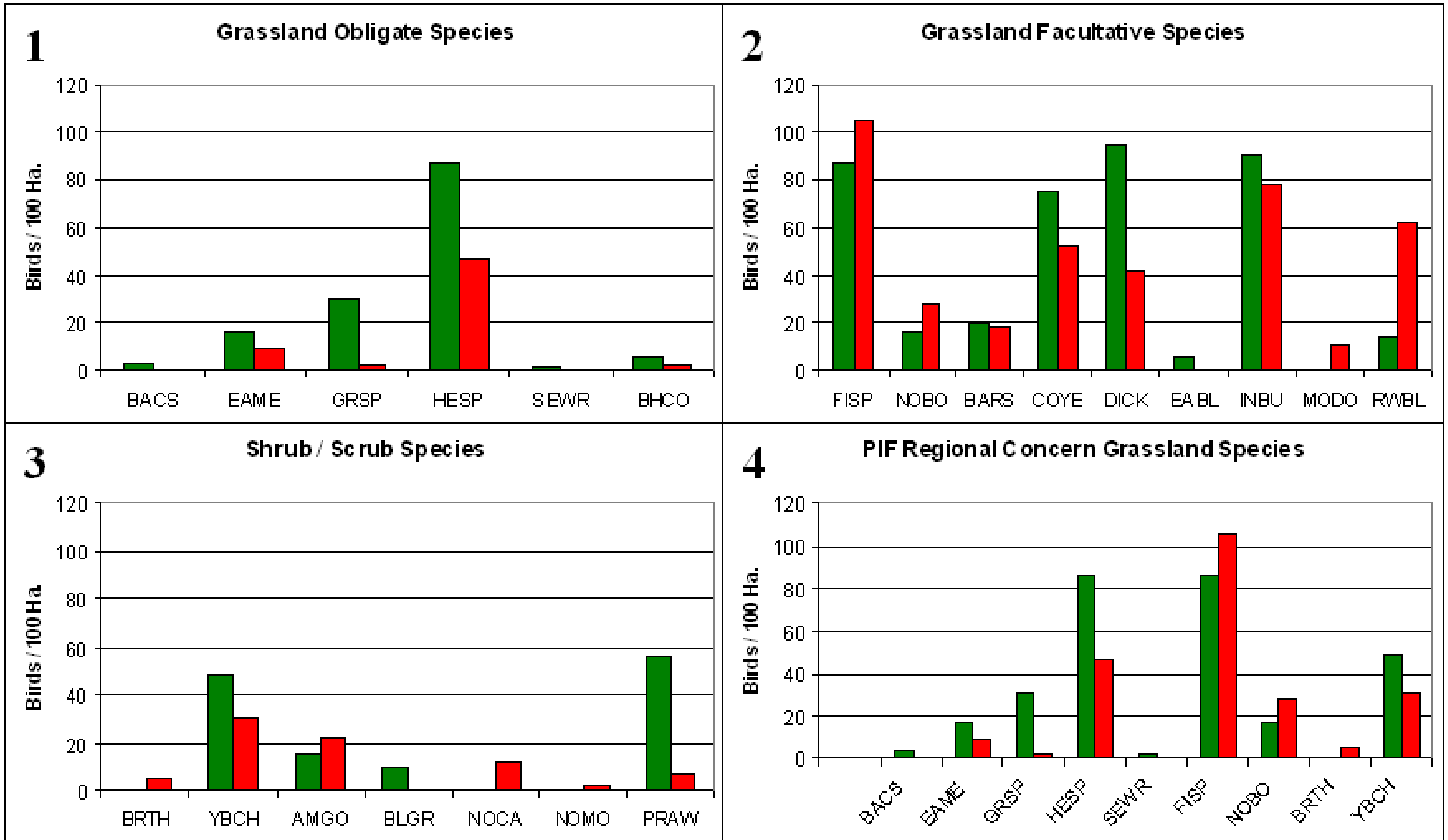

Figure 1. Density of Bird Populations On and Off Ft. Campbell. Graphs 1 and 2 show the densities of two groups of birds that require grasslands to different degrees. Graph 3 shows density of shrub/scrub species, which use similar habitat. Graph 4 shows all the species in the first three graphs that are listed as species of regional concern by Partners in Flight (Central Hardwoods Region).

Winter 2005-06 Results

Our main goal in Winter 2005-06 was to collect preliminary data to identify which species were using different grassland habitats in the study area. Our observations from that first field season will be used in planning of our next two winter field seasons.

We sampled bird communities by dragging a 50-m rope across the field between two or more observers on four field types, AG (harvested soy, bean, corn, and winter wheat fields), managed fescue fields (Ag-lease), Mowed, and Native. The greatest species richness for sparrows was found in native grasslands (7 species, Table 4) and the greatest richness for all bird species was on AG fields (10 species). Population densities differed by field type ($F = 4.97$, $df = 3$, $P = 0.01$).

We observed a total of nine sparrow species and 20 species overall (Table 5). Of those birds, three species; Northern Bobwhite, Field Sparrow, and Eastern Meadowlark; were listed by Partners in Flight as regional conservation concern species for the Central Hardwoods region.

Table 4. Results of rope dragging at Fort Campbell (Dec 2005-Feb 2006).

				Species		Count		Density (Birds/Ha)	
	Fields	Area (m2)	Area (ha)	Sparrows	All	Sparrows	All	Sparrows*	All
AG	7	212421	21.2	3	10	12	492	0.6	23.2
Ag-lease	4	65237	6.5	2	2	79	109	12.1	16.7
Mowed	6	126387	12.6	1	5	40	64	3.2	5.1
Native	6	91872	9.2	7	8	313	320	34.1	34.8
TOTAL	**23**	**474132**	**47.4**	**8**	**20**	**444**	**985**	**9.4**	**20.8**

*(ANOVA: F=4.97, df=3, p=0.01)

Table 5. Bird species observed using the rope dragging method for winter 2005-06.

Sparrows	Others	Flyovers
Dark-eyed Junco	American Crow	American Crow
Field Sparrow	American Goldfinch	American Goldfinch
Lincoln's Sparrow	American Pipit	blackbirds
Savannah Sparrow	American Robin	Northern Harrier
Song Sparrow	Cedar Waxwing	Sandhill Crane
Swamp Sparrow	Eastern Meadowlark	
Vesper Sparrow	Horned Lark	
White-crowned Sparrow	Mourning Dove	
White-throated Sparrow	Northern Bobwhite	
	Northern Harrier	
	Short-eared Owl	

FUTURE PLANS

Our second breeding field season will be conducted from May-July 2007 and will differ little methodologically from the first breeding field season. One small change will be a heavier focus on nest searching on private fields in the study area to obtain sample sizes large enough to compare nesting success between fields on and off Fort Campbell.

LITERATURE CITED

Baskin, J. M., C. C. Baskin, and E. W. Chester. 1994. The big barrens region of Kentucky and Tennessee: further observations and considerations. Castanea 59:226-254.

Chester, E. W. 1988. The Kentucky prairie barrens of northwest middle Tennessee: an historical and floristic perspective. Pp. 145-163. In: Proceedings of the first annual symposium on the natural history of lower Tennessee and Cumberland River Valleys (D. H. Snyder, ed.) The center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Herkert, J. R. 1994. Status and habitat selection of the Henslow's sparrow in Illinois. Wilson Bulletin 106:35-45.

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

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Monroe, B. L., Jr., A. L. Stamm, and B. L. Palmer-Ball Jr. 1988. Annotated checklist of the birds of Kentucky. Commonwealth Printing Co., Louisville, Kentucky.

Nicholson, C. P. 1997. Atlas of the breeding birds of Tennessee. The University of Tennessee Press, Knoxville. 426 pp.

Peterjohn, B. G., and J. R. Sauer, and W. A. Link. 1994. The 1992 & 1993 summary of the North

American Breeding Bird Survey. Bird Populations 2:46-61.

Robinson, S. K. 1998. Conservation issues for migrant neotropical birds. Paper presented at Annual Conference of The Wildlife Society. Buffalo, N.Y.

U.S. Fish and Wildlife Service. 1996. Endangered and threatened wildlife species; Review of plant and animal taxa that are candidates for listing as endangered or threatened species. Federal Register 61:7596-7613.

APPENDIX

Species Codes

Code	Common Name	Latin Name
AMCR	American Crow	*Corvus brachyrhynchos*
AMGO	American Goldfinch	*Carduelis tristis*
AMPI	American Pipit	*Anthus rufescens*
AMRO	American Robin	*Turdus migratorius*
BACS	Bachman's Sparrow	*Aimophila aestivalis*
BARS	Barn Swallow	*Hirundo rustica*
BHCO	Brown-headed Cowbird	*Molothrus ater*
BLGR	Blue Grosbeak	*Guiraca caerulea*
BRTH	Brown Thrasher	*Toxostoma rufum*
CEDW	Cedar Waxwing	*Bombycilla cedrorum*
COYE	Common Yellowthroat	*Geothlypis trichas*
DEJU	Dark-eyed Junco	*Junco hyemalis*
DICK	Dickcissel	*Spiza americana*
EABL	Eastern Bluebird	*Sialia sialis*
EAME	Eastern Meadowlark	*Sturnella magna*
FISP	Field Sparrow	*Spizella pusilla*
GRSP	Grasshopper Sparrow	*Ammodramus savannarum*
HESP	Henslow's Sparrow	*Ammodramus henslowii*
HOLA	Horned Lark	*Eremophila alpestris*
INBU	Indigo Bunting	*Passerina cyanea*
LISP	Lincoln's Sparrow	*Melospiza lincolnii*
MODO	Mourning Dove	*Zenaida macroura*
NOBO	Northern Bobwhite	*Colinus virginianus*
NOCA	Northern Cardinal	*Cardinalis cardinalis*
NOHA	Northern Harrier	*Circus cyaneus*
NOMO	Northern Mockingbird	*Mimus polyglottos*
PRAW	Prairie Warbler	*Dendroica discolor*
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*
SACR	Sandhill Crane	*Grus canadensis*
SAVS	Savannah Sparrow	*Passerculus sandwichensis*
SEOW	Short-eared Owl	*Asio flammeus*
SEWR	Sedge Wren	*Cistothorus platensis*
SOSP	Song Sparrow	*Melospiza melodia*
SWSP	Swamp Sparrow	*Melospiza georgiana*
VESP	Vesper Sparrow	*Pooectes gramineus*
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*
WTSP	White-throated Sparrow	*Zonotrichia albicollis*
YBCH	Yellow-breasted Chat	*Icteria virens*

NESTING BIOLOGY OF GRASSLAND BIRDS AT FORT CAMPBELL, KENTUCKY AND TENNESSEE

JAMES J. GIOCOMO[1, 3], E. DANIEL MOSS[2], DAVID A. BUEHLER[1], AND WILLIAM G. MINSER[1]

[1] Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington PSB, Knoxville, TN 37996, USA.
[2] Directorate of Public Works, IMSE-CAM-PWE, 865 16th Street, Fort Campbell, KY 42223,

USA.

[3] James Giocomo; e-mail: jgiocomo@utk.edu

ABSTRACT.--- Among the groups of birds monitored by the North American Breeding Bird Survey, grassland birds have experienced greater population declines than any other. Our objectives were to provide 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 demographic rates among years within species and among species. Eight-hundred and eleven nests of Henslow's Sparrows (*Ammodramus henslowii*), Grasshopper Sparrows (*Ammodramus savannarum*), Field Sparrows (*Spizella pusilia*), Dickcissels (*Spiza americana*), and Eastern Meadowlarks (*Sturnella magna*) were monitored between 1999 and 2003. Mayfield nest success including the egg-laying stage as well as the incubation and nestling periods was 20, 33, 15, 20, and 18% respectively. Most nest failures were attributed to predation. Nest parasitism by Brown-Headed Cowbirds (*Molothrus ater*) was infrequent (<2% of all nests parasitized). Clutch size decreased during the nesting season for Dickcissels, Grasshopper Sparrows, and Field

Sparrows. Nesting phenology suggests the possibility of multiple-brooding for all five species in this study.

Grassland bird 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, but military lands in the eastern U.S. are an exception to the trend in loss of native grasslands (Askins 1993, Herkert et al. 1996, Peterjohn and Sauer 1999). Some installations have maintained large areas of grasslands to facilitate military training through use of prescribed burning and mowing. Fort Campbell Military Reservation in Kentucky and Tennessee, is a 42,000-ha U.S. Army Base with approximately 10,000 ha of grassland habitat including remnant patches of native grassland (Moss 2001). Several other military installations provide large areas of early-successional habitats including Fort Knox, Kentucky, Fort Bragg, North Carolina, and Fort Drum, New York (Eberly 2002). Each installation could have potential for even more grassland restoration if suitable management strategies are developed.

It is imperative to understand not only the distribution of grassland bird species in the eastern U.S., but also their productivity. Many bird studies report densities and diversity of bird species, but these measures may be misleading indicators of habitat quality or breeding success (Van Horne 1983, Vickery et al. 1992). Few studies have collected the detailed demographic information needed to understand productivity (i.e., nesting success, clutch size) (Marzluff and Sallabanks 1998). Many grassland bird nests are difficult to find and monitor, and relatively few studies have attempted to monitor more than one or two species for more than a few years (Winter 1998). Managers on military installations need demographic information to understand if and how their management actions and military training may impact bird populations on military installations.

We monitored Henslow's Sparrow (*Ammodramus henslowii*), Grasshopper Sparrow (*A. savannarum*), Field Sparrow (*Spizella pusilla*), Dickcissel (*Spiza americana*) and Eastern Meadowlark (*Sturnella magna*) nests at Fort Campbell from 1999 through 2003. Our objectives were to provide 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 demographic rates among years within species and among species.

METHODS

Study Area.--- The study was conducted on Fort Campbell on the Kentucky-Tennessee border. Fort Campbell contains some of the largest remaining blocks of native prairie "barrens" east of the Mississippi River. Barrens are 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 burning by native Americans (Delcourt et al. 1993). Many grasslands on Fort Campbell contain at least some native warm-season grasses including little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), indiangrass (*Sorghastrum nutans*), and broomsedge (*Andropogon virginicus*). Approximately 60% of the base is in oak (*Quercus sp.*)-hickory (*Carya sp.*) forests, and there are many leased agricultural fields (cool-season grass, corn, millet, and soybeans) interspersed among the grasslands. Most of the grassland areas monitored in this study were managed mainly for military training and not specifically for hay production.

Nest Searching.--- Nest searching concentrated primarily on finding an adequate sample (~20) of nests each year for our five target species including Henslow's Sparrow, Grasshopper Sparrow, Dickcissel, Eastern Meadowlark, and Field Sparrow. Fields with appropriate grassland habitat, such as dead standing clumps of grass, were systematically searched by one crew leader and four field assistants for males of target species defending territories or exhibiting nesting behavior between 1 May and 31 July, 1999-2003. Fields were chosen to provide the maximum opportunity to find a representative sample of nests for the more difficult species to monitor, especially Henslow's Sparrows. Most fields on Fort Campbell are burned every 1 to 3 years, so a different set of fields was searched each year allowing us to search in areas with dead standing vegetation that is not present the first year after a field is burned. Up to 20 fields were searched each year, but most nest searching was concentrated in a few larger fields (> 150 ha) that provided habitat for all five species all years. Field sizes ranged from 4-600 ha. 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 ascertain nest fate. We calculated apparent yearly nest success (# successful nests/total nests), Mayfield (1961, 1975) nest success, and standard error (Johnson 1979) for individual species where sample sizes were sufficient (approximately 9 nests, Johnson 1979).

Demographic Rate Estimates.--- Average clutch size were calculated by using the highest number of eggs or young for nests with a stable clutch size for two consecutive visits. Successful nests were defined as any nest fledging at least one host young. Nests with no exposure time (e.g., induced fledging when the nest was found) were not included in the nest success calculations. We calculated daily survival rates and the probability of nesting success for five 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.

We used these mean period lengths as exponents to calculate the probability of nest success from daily survival probabilities for each species. We rounded the mean clutch size to the nearest half-egg for the mean number of days during the egg laying stage for each species, because generally one egg is laid per day for the five target species until the clutch is completed and incubation starts with the laying of the last egg (Bent 1968). We used published values 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. Mean and standard errors for daily survival probabilities and mean nest success were calculated by nesting period and year for each species (Johnson 1979).

Statistical Analysis.--- Yearly means of young per successful nest were compared within species using one-way ANOVA. Nest initiation dates were estimated to the day laying started by back dating for nests from the day the nest was found. Average start and end dates of nest initiation were calculated by averaging the first and last 10% of all nests combined for each species. We used the difference between start and end dates as a measure of the minimum window of time available for each species to initiate nesting (nest initiation window). We used linear regression to examine the relationship between clutch size and nest initiation dates. We used the program CONTRAST to test for differences among daily survival rates within species, by comparing different nesting intervals, and among species. The level of significance was set at $\alpha = 0.05$, and we used a Bonferoni correction to adjust our level of significance for multiple tests.

RESULTS

Eight-hundred and eleven nests were monitored between 1999-2003; apparent nest success ranged between 41% and 65% for each species (Table 1). Most nest failures were attributed to predation. The primary predators of nests appeared to be snakes based on the numerous observations of snakes in the nests. Other causes of nest failures included abandonment, hay mowing and harvesting, military training activities, and Brown-headed Cowbird (*Molothrus ater*) parasitism. Brown-headed Cowbird nest parasitism was observed in four nests (1 Henslow's Sparrow, and 3 Field Sparrows; Table 1). Average clutch size ranged from 3.6 for Field Sparrows to 4.6 eggs for Eastern Meadowlarks. Hatching success ranged from 90% for Dickcissels to 96% for Field Sparrows (Table 1). Average young fledged per nest ranged from 1.6 to 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 1).

Eastern Meadowlarks initiated nests earliest with average nest incubation starting 16 April. Field Sparrow nest initiation started 25 April, followed by Henslow's Sparrows (27 April), and Grasshopper Sparrows (1 May). Dickcissels consistently were the last species to arrive and began incubation 10 May. The average end of the nest initiation window was between 28 June and 4 July for all five species, but active nests were found through August for all species. The length of the nest initiation window was longest for Eastern Meadowlarks (75 days), intermediate for Henslow's Sparrows (63 days), Grasshopper Sparrows (64 days), and Field Sparrows (64 days), and shortest for Dickcissels (51 days).

Clutch size decreased during the nesting season for Dickcissels (t = -6.19, df = 190, P < 0.001), Grasshopper Sparrows (t = -2.23, df = 130, P = 0.03), and Field Sparrows (t = -5.52, df = 259, P < 0.001). On average, Dickcissel clutch size reduced by one egg every 50 days, and Grasshopper Sparrow and Field Sparrow clutch sizes reduced by 0.5 eggs every 62 and 52 days, respectively. We did not detect a linear decrease in clutch size during the nesting season for Henslow's Sparrows (t = -0.37, df = 104, P = 0.71) and Eastern Meadowlark (t = -0.94, df = 85, P = 0.35). Instead, the clutch size for both Henslow's Sparrows and Eastern Meadowlarks initially increased, peaked in the middle of the season, and then gradually decreased.

Generally, nesting success was greatest during the laying stage and least during the incubation stage. Combining nests found in all years, nesting success for Field Sparrows was lower than Grasshopper Sparrows, because of the difference in nest success during the incubation stage (Table 2). Nesting success varied among years, but we were unable to detect differences after Bonferoni correction (Table 3).

DISCUSSION

Overall mean nesting success rates were within the range of values previously reported for Henslow's Sparrows (27% Mayfield [incubation and nestling stages only]; Table 4), and Dickcissels (26%). Eastern Meadowlark (22%) and Grasshopper Sparrow (41%) nesting success was near the high end of previously reported values (Table 4). Almost all nests for these four species were found in the largest fields (> 150 ha). A few Henslow's Sparrow nests were found in fields as small as 4 ha, but the small fields were within 10 km of larger fields. Henslow's Sparrow densities were too low in the small fields to allow for an adequate sample size of nests each year. Field Sparrow nesting success was lower at Fort Campbell (20%) than previously reported values (Table 4). Low nesting success may be related to the ubiquitous distribution of Field Sparrow 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), possibly accounting for reduced nesting success rates (Herkert 1994). Henslow's Sparrow, Grasshopper Sparrow, Dickcissel, and Eastern Meadowlark clutch sizes were near the high end of the range of those previously reported, whereas Field Sparrow average clutch size was lower (Table 4).

Published nesting success rates usually do not include the egg laying stage. Between 6 and 36% of our nests were found during the egg laying stage. This study is one of only a few that explicitly reports a daily survival rate of nests during the laying stage. For three out of the five species we monitored we detected nest failures during this short but critical part of the nesting cycle, resulting in estimates of nest success during the egg-laying stage of 65-79%. The egg laying stage should be treated separately from the incubation stage because incubation usually starts sometime between laying the penultimate egg and up to a few days after the last egg is laid. 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. Exposed eggs during the laying stage may be more vulnerable to predators such as raccoons (*Procyon lotor*) or Blue Jays (*Cyanocitta cristata*). The laying stage tended to have the greatest nest success rates followed by the nestling stage and the incubation stage (Table 2).

Brown-headed Cowbird parasitism rates were low at Fort Campbell for these grassland species, but were within the range of reported parasitism rates for each species (Table 4). The lack of Dickcissel nest parasitism was particularly noteworthy when compared with other areas, but was consistent with records from Tennessee (Nicholson 1997). Our nest parasitism rates probably were low because most nests were in large grassland fields (>100 ha) far from forest edges or other tall woody perch sites (Hauber and Russo 2000, Jensen and Cully 2005), except those of Field Sparrows, which were found in the full range of field sizes (4-600 ha). Nest parasitism rates may be related to the proximity of songbird populations to the greatest densities of Brown-headed Cowbirds (Basili et al. 1997, Winter et al. 2004). Fort Campbell is outside the greatest density areas for Brown-headed Cowbird populations (Sauer et al. 2004). Morris and Thompson (1998) found Brown-headed Cowbirds were most associated with grazed pastures, regardless of grass height. There is no grazing activity at Fort Campbell.

The clutch size of Henslow's Sparrows, Grasshopper Sparrows, Dickcissels and Eastern Meadowlarks were slightly greater at Fort Campbell than average and within the range published rates (Table 4). Field Sparrow clutch size was less than average, but within the range of published rates. The average clutch sizes included two nests with more than twice the average number of eggs, one Dickcissel with nine eggs and one Eastern Meadowlark with ten eggs. These individual nests may represent the egg laying efforts of more than one female each. Both nests were lost to predation before the eggs hatched, and we did not have time to confirm the number of parents visiting the nest.

Grassland birds have relatively low nesting success, compensated by several nesting attempts within a single season (Wiens 1969, Martin 1995, Winter 1999). The length of the nest initiation window (51-75 days) suggests the possibility of multiple breeding attempts or multiple successful broods within a single breeding season for all five species. Henslow's Sparrows and Grasshopper Sparrows are generally considered at least double brooded, although two pairs from a color-banded Henslow's Sparrow population in Kentucky had three successful broods in one season (Monroe 2001). Some of our nests initiated in July could represent third successful broods for some nesting pairs. The amount of time from the start of the nesting season (late April) and the last nests (early August) allows for the possibility of three broods if the time to finish a complete nesting cycle is less than 32 days including nest building (Ehrlich et al. 1988). Dickcissels are considered single brooded, or may move to a different location to re-nest (Winter 1998), but the nest initiation window for Dickcissels at Fort Campbell seemed long enough to allow for the possibility of double brooding (51 days). Field Sparrow are considered double brooded, but their nesting success was so low at Fort Campbell that very few pairs could produce two successful nests within the nesting season without many unsuccessful nesting attempts. They had more than enough time to complete at least two successful nests with several unsuccessful attempts (64 days).

The length of the nest initiation window for Eastern Meadowlarks at Fort Campbell was almost long enough for 3 successful nesting attempts, but Eastern Meadowlarks may delay for a longer period between successive nests than expected. Kershner et al. (2004) radio-tracked female Eastern Meadowlarks in Illinois and reported although they had time in the season to nest more than once, many birds did not re-nest in the same territory. This behavior would spread the distribution of nesting attempts across the season, and could account for the long nesting season for Eastern Meadowlark (75 days) in this study.

Clutch size decreased during the nesting season for Dickcissels, Grasshopper Sparrows, and Field Sparrows. The second brood would be reduced by about 1 egg for Dickcissels, and about 0.5 eggs for Grasshopper Sparrows, and Field Sparrows if these species were double brooded. Clutch size did not show a linear relationship with time of egg laying during the nesting season for Henslow's Sparrows and Eastern Meadowlarks. Winter (1998) reported this lack of relationship between clutch size and time in nesting season for Henslow's Sparrow. Eastern Meadowlarks and Henslow's Sparrows tended to have smaller clutch sizes at the beginning and end of the nesting season.

Monitored fields at Fort Campbell were used extensively for army training exercises, such as airborne-troop parachute drops and associated vehicle activity, throughout the breeding season of grassland birds. However, most (88%) recorded nest losses were attributed to predation and very few (<1%) nests were affected directly by military activities. Vehicle or troop movements in the fields crushed a few nests. Mowing for hay and weather accounted for more recorded nest losses (3 and 1.7%, respectively) than military activities. Nest searching activities were concentrated in grasslands not managed specifically for hay production, and land management effects observed were not representative of all grasslands on the base. Undoubtedly, a much larger proportion of nests failed because of mowing in grassland fields managed for hay production. However, nest searching was concentrated in areas used extensively for military training, and nest failure rates may be considered representative of direct military training impacts at Fort Campbell.

ACKNOWLEGEMENTS

The Department of Defense Legacy Resource Management Program, Fort Campbell, and the University of Tennessee Agricultural Experiment Station sponsored this project. We thank the staff in the Conservation Branch at Fort Campbell for assistance with project logistics, and the many field assistants who helped search for nests.

LITERATURE CITED

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

Balent, K. L. and C. J. Norment. 2003. Demographic characteristics of a Grasshopper Sparrow population in a highly fragmented landscape of western New York State. Journal of Field Ornithology 74:341-348.

Barber, D. R., T. E. Martin, M. A. Melchiors, R. E. Thill, and T. B. Wigley. 2001. Nesting success of birds in different silvicultural treatments in southeastern U.S. pine forests. Conservation Biology 15:196-207.

Basili, G. D. 1997. Continental scale ecology and conservation of the Dickcissel. Dissertation. University of Wisconsin, Madison, USA.

Bent, A.C. 1968. Life histories of North-American cardinals, grosbeaks, buntings, towhees, finches, sparrows and allies. Part I and III. Smithsonian Institution Press, Washington D.C., USA.

Best, L. B. 1978. Field Sparrow reproductive success and nesting ecology. Auk 95:9-22.

Burhans, D. E. 2002. Conservation assessment for Henslow's Sparrow *Ammodramus henslowii*.

General Technical Report NC-226. USDA, Forest Service, North Central Research Station, St. Paul, Minnesota, USA.

Carey, M., D. E. Burhans, and D. A. Nelson. 1994. Field Sparrow (*Spizella pusilla*). The birds of North America, Number 103.

Chester, E. W., B. E. Wofford, J. M. Baskin, and C. C. Baskin. 1997. A floristic study of barrens on the southwestern Pennyroyal Plain, Kentucky and Tennessee. Castanea 62:161-172.

Crooks, M. P. 1948. Field sparrow life history in central Iowa. Iowa Bird Life 23:10-13.

Delcourt, P.A., H.R. Delcourt, D.F. Morse, and P.A. Morse. 1993. History, evolution, and organization of vegetation and human culture. Pages 47-80 *in* Biodiversity of the southeastern United States. (W.H. Martin, S.G. Boyce, and A.C. Echternacht, Editors). John Wiley & Sons, Inc. New York, USA.

Eberly, C. 2002. Defending the stepping stones of migration. Birding 34:450-458.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. The birder's handbook. Simon and Schuster Inc., New York, USA.

Elliot, P. F. 1978. Cowbird parasitism in the Kansas tallgrass prairie. Auk 95:161-167.

Fletcher, R. J., Jr., R. R. Koford, and D. A. Seaman. 2006. Critical demographic parameters for declining songbirds breeding in restored grasslands. The Journal of Wildlife Management 70:145-157.

Giocomo, J. 2005. Grasshopper Sparrows nesting in eastern Tennessee. The Migrant 75:48-49.

Granfors, D. A., K. E. Church, and L. M. Smith. 1996. Eastern Meadowlarks nesting in rangelands and conservation reserve program fields in Kansas. Journal of Field Ornithology 67:222-235.

Gross, A. O. 1968. Dickcissel. Pp. 158-191. *in* Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows and their allies (O. L. Austin. ed.). U. S. National Museum Bulletin. no. 237, Pt. 1.

Hauber, M. E. and S. A. Russo. 2000. Perch proximity correlates with higher rates of cowbird

Parasitism of ground nesting song sparrows. Wilson Bulletin 112:150-153.

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

Herkert, J. R., D. W. Sample, and R. E. Warner. 1996. Management of Midwestern grassland landscapes for the conservation of migratory grassland birds. Pages 89-116 *in* Management of Midwestern landscapes for the conservation of Neotropical migratory birds. (F. R. Thompson, III, Editor). General Technical Report NC-187. USDA, Forest Service, North Central Research Station, St. Paul, Minnesota, USA.

Herkert, J. R., P. D. Vickery, and D. E. Kroodsman. 2002. Henslow's Sparrow (*Ammodramus henslowii*). The birds of North America, Number 672.

Hicks, L. E. 1934. A summary of cowbird host species in Ohio. Auk 51:385-386.

Jensen, W. E. and E. J. Finch. 2004. Edge effects on nesting dickcissels (*Spiza americana*) in relation to edge type of remnant tallgrass prairie in Kansas. American Midland Naturalist 151:192–199.

Jensen, W. E. and J. F. Cully, Jr. 2005. Density-dependent habitat selection by brown-headed cowbirds (*Molothrus ater*) in tallgrass prairie. Oecologia 142:136-149.

Johnson, R.G. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Kershner, E. L., J. W. Walk, and R. E. Warner. 2004. Breeding-season decisions, renesting, and annual fecundity of female Eastern Meadowlarks (*Sturnella magna*) in southeastern Illinois. Auk 121:796-805.

Knapton, R. W. 1988. Nesting success is higher for polygynously mated females than for monogamously mated females in the Eastern Meadowlark. Auk 104: 325-338.

Lanyon, W. E. 1995. Eastern Meadowlark (*Sturnella magna*). The birds of North America,
Number 160.

Long, C. A. 1963. Production of sterile eggs in the Dickcissel. Wilson Bulletin 75:456.

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

Marzluff, J. M. and R. Sallabanks. 1998. Past approaches and future directions for avian conservation biology. Pages 5-14 *in* Avian Conservation: Research and Management (J. M. Marzluff and R. Salabanks, Edsitors) Island press, Washington, D.C. USA.

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

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

McNair, D. B. 1987. Egg data slips-are they useful for information on egg-laying dates and clutch size? Condor 89:369-376.

Monroe, M. S. 2001. Reproductive success of Henslow's Sparrows in Kentucky: Effects of season, nest characteristics, and vegetation structure. Master's thesis, Eastern Kentucky State University, Richmond, Kentucky. 46 p.

Morris, D. L. and F. R. Thompson, III. 2004. Effects of habitat and invertebrate density on abundance and foraging behavior of the Brown-headed Cowbird. Auk 115:376-385.

Moss, E. D. 2001. Distribution and reproductive success of native grassland birds in response to burning and field size at Fort Campbell Military Reservation: special focus on Henslow's and Grasshopper Sparrows. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Nicholson, C. P. 1997. Atlas of the breeding birds of Tennessee. University of Tennessee Press,

Knoxville, Tennessee, USA.

Peck, G. and R. James. 1987. Breeding birds of Ontario: nidiology and distribution. Vol. 2: passerines. Royal Ontario Museum Life Sciences Miscellaneous Publications, Toronto, Canada. 387 p.

Peterjohn, B. G. and J. R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey 1966-1996. Studies in Avian Biology 19:27-44.

Price, H. F. 1934. A few cowbird notes. Oologist 51: 107-108.

Reinking, D. A., D. A. Wiedenfeld, D. H. Wolfe, and R. Rohrbaugh. 2000. Distribution, habitat use, and nesting success of Henslow's Sparrows in Oklahoma. Prairie Naturalist 32:219-232.

Robins, J. D. 1971. A study of Henslow's Sparrow in Michigan. Wilson Bulletin 83:39-48.

Roseberry, J. L. and W. D. Kilmestra. 1970. The nesting ecology and reproductive performance of the Eastern Meadowlark. Wilson Bulletin 82:243-267.

Sauer, J. R., J. E. Hines, and J. Fallon. 2004. The North American Breeding Bird Survey, results

and analysis 1966 - 2003. Version 2004.1. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA. Online at <http://www.mbr-pwrc.usgs.gov/bbs/bbs.html> (Accessed 1 February 2005).

Saunders, G. B. 1932. A taxonomic revision of the meadowlarks of the genus

Sturnella (Vieillot) and natural history of the Eastern Meadowlark, *Sturnella magna magna* (Linnaeus). PhD Thesis, Cornell University, Ithica, New York.

Sutter, B. and G Ritchison. 2005. Effects of grazing on vegetation structure, prey availability,
and reproductive success of Grasshopper Sparrows. Journal of Field Ornithology 76:345-351.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife
Management 47:893-901.

Vickery, P. D. 1996. Grasshopper Sparrow (*Ammodramus savannarum*). The birds of North
America, Number 239.

Vickery, P. D., M. L. Hunter, and J. V. Wells. 1992. Is density an indicator of breeding success?
Auk 109:706-710.

Vos, S. M. 2003. Distribution, abundance, and productivity of grassland birds on Fort McCoy
military base. Thesis. University of Wisconsin, Madison, USA.

Walkinshaw, L.H. 1939. Nesting of Field Sparrow and survival of young.
Bird-banding 10:107-114, 149-157.

Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds.
Ornithological Monographs 8.

Winter, M. 1998. Effect of habitat fragmentation on grassland-nesting birds in southwestern

Missouri. Dissertation. University of Missouri, Columbia, USA.

Winter, M. 1999. Nesting biology of Dickcissels and Henslow's Sparrows in southwestern Missouri prairie fragments. Wilson Bulletin 111:515-527.

Winter, M, J. A. Shaffer, D. H. Johnson, T. M. Donovan, W. D. Svedarsky, P. W. Jones, and B. R. Euliss. 2004. Habitat and nesting of Le Conte's Sparrows in the northern tallgrass prairie. Journal of Field Ornithology 76:61-71.

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

Zimmerman, J. L. 1982. Nesting success of Dickcissels in preferred and less preferred habitats. Auk 99:292-298.

Zimmerman, J. L. 1983. Cowbird parasitism of Dickcissels in different habitats at different nest densities. Wilson Bulletin 95:7-25.

Table 1. Demographic information for Henslow's Sparrow, Grasshopper Sparrow, Dickcissel, Eastern Meadowlark, and Field Sparrow at Fort Campbell, Kentucky, 1999-2003.

	Henslow's Sparrow (n = 113)[a]	Grasshopper Sparrow (n = 131)	Dickcissel (n = 204)	Eastern Meadowlark (n = 87)	Field Sparrow (n = 276)
Successful nests	65	85	87	36	126
Unknown fate	1	0	0	1	0
Failed nests	47	46	117	50	150
Depredated	44	38	97	45	139
Abandoned	3	3	9	2	7
Abandoned-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
Apparent nest success (%)	58	65	43	41	46
Clutch size average (*n*)	4.1(108)	4.4(131)	4.3(191)	4.6(87)	3.6(264)
Hatching success (*n*)	90.4(80)	93.2(104)	90.3(116)	94.1(53)	95.9(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

Parasitized nests	1	0	0	0	3

[a] *n* refers to the number of nests.

TABLE 2. Mayfield nesting success of grassland birds at Fort Campbell, Kentucky, 1999-2003, by nest cycle interval.

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	64.9
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	79.2
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	71.6
HESP	Incubating	11.0	54	21	297.5	0.929	0.015	44.7
GRSP	Incubating	11.5	73	23	445.0	0.948	0.010	54.3
DICK	Incubating	12.5	145	67	997.0	0.933	0.008	41.9
EAME	Incubating	12.5	54	25	354.5	0.929	0.014	40.1
FISP	Incubating	12.0	176	83	912.5	0.909	0.010	31.8
HESP	Nestling	9.5	88	23	412.5	0.944	0.011	58.0
GRSP	Nestling	9.0	108	23	621.0	0.963	0.008	71.2
DICK	Nestling	9.0	124	37	694.5	0.947	0.009	61.1
EAME	Nestling	9.0	61	25	387.0	0.935	0.012	54.8
FISP	Nestling	7.5	183	56	849.5	0.934	0.009	60.0

HESP	Inc. and nestling	20.5	111	44	710.0	0.938	0.009	26.9
GRSP	Inc. and nestling	20.5	129	46	1066.0	0.957	0.006	40.5
DICK	Inc. and nestling	21.5	191	104	1691.5	0.939	0.006	25.6
EAME	Inc. and nestling	21.5	86	50	741.5	0.933	0.009	22.3
FISP	Inc. and nestling	19.5	266	139	1762.0	0.921	0.006	20.1
HESP	All stages	24.5	113	46	729.5	0.937	0.009	20.3
GRSP	All stages	25.0	129	46	1083.0	0.958	0.006	33.8
DICK	All stages	25.5	204	117	1920.5	0.939	0.005	20.1
EAME	All stages	25.5	86	50	767.5	0.935	0.009	17.9
FISP	All stages	23.0	276	150	1886.0	0.920	0.006	14.7

[a] Nesting cycle intervals include laying stage, incubating, nestling, incubation and 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 (Mayfield) through the nesting cycle interval.

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

Table 3. Annual daily survival and nest success rates for grassland birds at Fort Campbell, Kentucky, 1999-2001.

Year	Rate	Henslow's Sparrow	Grasshopper Sparrow	Dickcissel	Eastern Meadowlark	Field Sparrow
1999	Days(*n*)[a]	25.5(6)	96.0(19)	111.0(14)	125.5(12)	150.5(23)
	DSR(SE)[b]	-	0.948(0.023)	0.910(0.027)	0.920(0.024)	0.907(0.024)
	Success	-	26.3	9.0	12.0	10.5
2000	Days(*n*)	276.5(40)	257.5(30)	324.0(40)	149.0(17)	522.5(84)
	DSR(SE)	0.920(0.016)	0.973(0.010)	0.935(0.014)	0.913(0.023)	0.912(0.012)
	Success	13.1	50.2	18.1	9.7	11.9
2001	Days(*n*)	235.5(26)	215.0(26)	755.5(74)	201.5(23)	536.0(71)
	DSR(SE)	0.958(0.013)	0.944(0.016)	0.943(0.008)	0.945(0.016)	0.920(0.012)
	Success	34.5	23.8	22.4	23.9	14.5
2002	Days(*n*)	116.0(20)	231.0(24)	311.0(30)	142.5(15)	298.0(47)
	DSR(SE)	0.940(0.022)	0.952(0.014)	0.949(0.013)	0.951(0.018)	0.906(0.017)
	Success	21.8	29.5	26.0	27.7	10.2
2003	Days(*n*)	77.5(20)	283.5(30)	419.0(46)	149.0(19)	379.0(51)
	DSR(SE)	0.948(0.025)	0.961(0.011)	0.936(0.012)	0.940(0.020)	0.950(0.011)
	Success	27.3	37.2	18.3	20.4	30.5

[a] Days = total exposure days, n = number of nests. Nest exposure includes laying, incubation and nestling stages.

[b] DSR = Daily survival rate (Mayfield 1975).

TABLE 4. Weighted average and range of published demographic rates for Henslow's Sparrow, Grasshopper Sparrow, Field Sparrow, Eastern Meadowlark, and Dickcissel.

Species		Clutch Size	Parasitism	Apparent Success	Mayfield Success[a]
Henslow's Sparrow[b]	Average[c]	3.8	0.03	0.51	0.29
	Range[d]	3.3-4.4	0.00-0.08	0.19-0.74	0.07-0.46
Grasshopper Sparrow[e]	Average	4.2	0.09	0.44	0.32
	Range	3.7-4.6	0.00-0.50	0.15-0.80	0.07-0.52
Dickcissel[f]	Average	4.0	0.40	0.48	0.26
	Range	3.7-4.7	0.03-0.95	0.46-0.67	0.12-0.50
Eastern Meadowlark[g]	Average	4.4	0.08	0.32	0.10
	Range	4.1-5.2	0.00-0.70	0.30-0.70	0.10-0.25
Field Sparrow[h]	Average	3.7	0.12	0.36	0.27
	Range	3.4-4.0	0.00-0.80	0.10-0.72	0.21-0.47

[a] Probability of nest success corrected for exposure time (Mayfield 1975).

[b] Robins 1971, Peck and James 1987, Winter 1998, Reinking et al. 2000, Monroe 2001, Burhans 2002.

[c] Average for published values weighted by sample size.

[d] Range of published average values.

[e] Price 1934, Elliot 1978, Wray et al. 1982, McNair 1987, Vickery et al. 1992, Reinking cited in Vickery 1996, Winter 1998, Balent and Norment 2003, Vos 2003, Dutter and Ritchison 2005, Giocomo 2005.

[f] Long 1963, Gross 1968, Elliot 1978, Zimmerman 1982, Zimmerman 1983, Basili et al. 1997, Winter 1998, Vos 2003, Jensen and Finck 2004, Fletcher et al. 2006.

[g] Saunders 1932, Johnston 1964, Roseburry and Kilmestra 1970, Elliot 1978, Peck and James 1987, Knapton 1988, Lanyon 1995, Granfors et al. 1996, Winter 1998.

[h] Hicks 1934, Walkinshaw 1939, Crooks 1948, Wray et al. 1982, Best 1978, Carey et al. 1994, Barber et al. 2001, Vos 2003.

A GRAPHICAL TOOL FOR ASSESSING SONGBIRD POPULATION STATUS WITH AN APPLICATION FOR THREE GRASSLAND SONGBIRDS

James J. Giocomo[1, 2] and David A. Buehler[1]

1 Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington PSB, Knoxville, TN 37996
2 Corresponding Author: James J. Giocomo, Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington PSB, Knoxville, TN 37996, jgiocomo@utk.edu

ABSTRACT.--We constructed a simple graphical population model for three grassland birds, Dickcissels (*Spiza Americana*), Eastern Meadowlarks (*Sturnella magna*), and Grasshopper Sparrows (*Ammodramus savanarum*), incorporating variability in commonly measured life history parameters, nest success and young produced per nest, and a range of plausible values for parameters that are more difficult to obtain including adult survival, juvenile survival, re-nesting rate and the number of nest attempts. We created population replacement threshold plots by rearranging a two-stage population model, and conducted sensitivity analyses to examine the effects of the model inputs on measures of population growth rates. With optimistic species-specific assumptions our analysis shows it is very unlikely that our Dickcissel population was stable or increasing, whereas Grasshopper Sparrows and Eastern Meadowlarks seemed to be producing surplus individuals in at least 2 out of the five years we examined. Our sensitivity analysis indicated the population models were impacted by all population parameters considered, but the re-nesting rate showed the most dramatic effects. Our modeling approach extended existing methods by allowing us to evaluate the effects of three demographic variables simultaneously, and providing a quick, easy way to evaluate populations of species "in need of management." Our approach demonstrated the limitations of the field data collected for making meaningful determinations on population status for grassland birds, and represents a starting point for incorporating all the important life-history parameters that impact species at the population level into a relatively simple model.

Key Words. Population modeling, demography, grassland birds, management

Nest success is just one of several demographic factors affecting population growth. Other basic demographic components include the number of young produced per nest, number of nesting attempts including re-nesting and multiple-broods, survival of young birds in their first year of life (juvenile survival), and the annual survival of adult birds (Ricklefs 1973). Recently, arguments focusing upon methods for calculating nest success received tremendous attention (Hazler 2004, Jehle et al. 2004, Michaud et al. 2004, Nur et al. 2004, Shaffer 2004), but emphasis on nest success can be misleading when evaluating avian population growth (DeCecco et al. 2000, Murray 2000, Thompson et al. 2001, Underwood and Roth 2002).

Nest success needs to be supplemented with other factors to truly understand population trends. Some researchers have incorporated adult and juvenile survival in songbird population models (Donovan et al. 1995), but few researchers have incorporated the other life history parameters, especially for grassland bird populations (Perkins et al. 2003).

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. In some limited circumstances, nest success can be correlated with the overall health of the population, but for birds that produce more than one nest in a single breeding season, like many grassland songbirds, annual productivity is a better measure of population viability (Herkert and Knopf 1998, Murray 2000, Jones et al. 2005). In many species, females can make up for poor nest success by producing multiple nests in a season (Murray 2000). Re-nesting frequency and number of broods may have a greater influence on annual productivity than nest success (Martin 1995).

Restoration and management of grassland habitats has become a conservation priority because of the large and consistent declines in grassland bird populations (Askins 1993, Sauer et al. 2005). Conservation efforts require identification of areas where populations are increasing or decreasing (e.g., potential population sources [$\lambda > 1$] and sinks [$\lambda < 1$]; Pulliam 1988), and the demographic factors that contribute to these population trends. Several studies estimated annual productivity, but the models tended to be complex or required large amounts of species data (Pease and Grzybowski 1995, Powell et al. 1999, Woodworth 1999, Powell and Knutson 2006). There are simple population models, but they do not incorporate variability in measured and estimated parameters (Donovan et al. 1995). Finally, some applications of the simple models result in tables of population trajectories (Perkins et al. 2003, Michaud et al. 2004). There is a need to have a simple graphical population model for grassland birds incorporating variability in commonly measured life history parameters (e.g., nest success and young produced per nest) and a range of plausible values for parameters that are more difficult to obtain (e.g., adult survival, juvenile survival, re-nesting rate).

Using demographic parameters collected over a five-year period (1999-2003) at Fort Campbell Military Reservation, Kentucky/Tennessee (Fort Campbell), we modeled population growth rates for three grassland songbird species (Dickcissels [*Spiza Americana*], Eastern Meadowlarks [*Sturnella magna*], and Grasshopper Sparrows [*Ammodramus savanarum*]). Our objective was to construct dynamic, deterministic population models for single-, double- and triple-brooded species, incorporating variation in nest success and young per successful nests. We conducted sensitivity analyses to examine the effects of uncertainty in several of the model inputs including adult survival, juvenile survival, number of nesting attempts, number of successful broods possible, and re-nesting rate on measures of population growth rates. We then discuss how the model extends existing methods, and how it could be used to assist in species management.

METHODS

Basic increasing-decreasing (source-sink) population assessment.-- We constructed the model in a Microsoft Excel spreadsheet incorporating data from Fort Campbell including nest success and young produced per successful nest, supplemented by values found in the literature for Dickcissels, Eastern Meadowlarks, and Grasshopper Sparrows (Giocomo 2005). We created a population replacement threshold plot by rearranging a two-stage population model. We solved for brood size per successful nest in terms of nest success using the following formula:

$$\lambda = S_a + (\beta) * (S_j) \qquad (1)$$

(Ricklefs 1973). In this formula, λ = finite population growth rate, S_a = annual adult survival, S_j= annual juvenile survival, and β = annual fecundity given the number of young produced per successful nest (b), and the relationship ($R_{C,A}$) between maximum number of successful broods possible in one season (C), the number of nesting attempts (A), and nest success (p). When $\lambda = 1$, the population is considered stable.

We 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 were offsetting, (3) juvenile survival rate was correlated with the adult survival rate, and was one half adult survival rates, (4) constant average annual rates of Mayfield (1975) nest success, number of young per successful brood, and annual adult survival, (5) all individuals bred in their first breeding season after hatch year, and (6) no age-related differences in parameters (Donovan et al. 1995, Michaud et al. 2004). Many of these assumptions are optimistic, and over-estimate the value of λ.

We set $\lambda = 1$, $S_j = 0.5 * S_a$, and $\beta = 0.5 * b * R_{C,A}$. Then $1 = S_a + (0.5 * S_a) * (0.5 * b * R)$, and we solved for b.

$$b = \frac{4 * (1 - S_a)}{S_a * R_{C,A}} \qquad (2)$$

We then plotted all possible combinations of young per successful nest (b) and nest success (p) by varying nest success from 0.0 – 1.0 to create the replacement threshold.

To calculate $R_{C,A}$, we determined the maximum number of successful broods possible in one season (*C*) for multiple-brooded species and the maximum number of nesting attempts (*A*) for each species. A branching process was used to calculate the productivity of nests given p = probability of a successful nest and 1-p = probability of an unsuccessful nest (Fig. 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 overall annual productivity for the population (Table 1).

This analysis produced plots with curves representing the threshold between source (increasing; $\lambda > 1$) and sink (decreasing; $\lambda < 1$) populations (hereafter replacement threshold). On these plots, point estimates of nest success and young produced per successful nest were plotted with their associated variability (1*SE). Points to the left of the replacement threshold curve were considered to represent sink populations and points to the right of the curve represented source populations.

Species analysis.-- We used collected demographic information to analyze the yearly and overall average population trajectories under species-specific assumptions. Dickcissels were modeled as single brooded species (*C* = 1), Eastern Meadowlarks were double-brooded (*C* = 2), and Grasshopper Sparrows were triple-brooded species (*C* = 3) (Ehrlich et al. 1988). We used an annual adult survival rate of 0.5 (±0.1) and juvenile survival rate of 0.25 for Dickcissels. For Eastern Meadowlarks, we used an annual adult survival rate of 0.6 (±0.1) and juvenile survival rate of 0.3, and for Grasshopper Sparrows, we used an annual adult survival rate of 0.4 (±0.1) and juvenile survival rate of 0.2. Reported male return rates for these three species range from 0.33 – 0.6 (Lanyon 1995, Martin 1995, Vickery 1996, Temple 2002, Michel et al. 2005). We limited the number of nesting attempts (*A*) to 5 based on species-specific nest season observations at Fort Campbell (Giocomo 2005) using calculations suggested by Ricklefs (1973).

Sensitivity analysis.-- We conducted a sensitivity analysis to evaluate the overall effect of each parameter in question (holding all other parameters constant, see Table 1) on the replacement threshold relative to average values of nest success and number of young produced per successful nest at Fort Campbell. We evaluated the maximum number of successful broods (C = 1, 2, 3), adult survival (S_a = 0.3 - 0.9), juvenile survival (S_j = 0.15 – 0.75), and re-nesting rate (0.6 – 1.0) to determine how the threshold would change relative to measured values for nest success and number of young produced per successful nest. We also evaluated the number of nesting attempts (A = 1-5) for single (C = 1), double (C = 2) and triple (C = 3) brooded species. For all sensitivity analysis calculations, we assumed double-brooded nesting (C = 2), number of nest attempts = 5, adult survival = 0.5, juvenile survival = 0.25, and 100% re-nesting rate unless otherwise specified.

RESULTS

Adjusting the assumptions in the model tended to shift the replacement threshold lines to the lower-left or the upper-right to varying degrees (e.g., see Fig. 2). As the threshold shifted to the lower-left, there was an increase in the amount of area of the graph representing the potential to be a source population in the plot and a corresponding decrease in the amount of sink area. An increase in the amount of source area on the graph indicated a relatively lower nest success and lower number of young per successful nest was needed to sustain the population at current levels.

Species Analysis.-- For Dickcissels, adult survival rates below 0.6 held population growth below replacement levels for all years except 2001, resulting in sinks (Fig. 2A). The point-estimate for 2001 indicated source populations when adult survival rate was 0.6. The variation around the point-estimates indicated there was some overlap into the source area of the plot during most years (2000-2003) with the most optimistic survival rate.

For Eastern Meadowlarks, the overall point-estimate indicated a probable source population with an adult survival rate near 0.5, although there was some overlap into the sink area of the plot (Fig. 2B). Two years (1999 and 2000) indicated stable populations only with the optimistic survival rate (0.7). Point estimates for three years (2001-2003) indicated source populations with adult survival rates 0.5, although the variation around those estimates overlapped the sink area unless the adult survival rate was near 0.7.

The point-estimate of the overall average for Grasshopper Sparrows indicated source populations with an adult survival rate between 0.3 and 0.4 (Fig. 2C). The variation around the overall point-estimate was well within the source area of the plot and did not include any sink area of the plot with an adult survival of 0.5. In 1999 and 2001, an adult survival greater than 0.5 was needed to produce an increasing population.

Sensitivity Analysis.-- Increasing from single- to double-brooded had a greater positive effect (shifting the replacement threshold to the lower-left) on the replacement threshold than increasing from double- to triple-brooded (Fig. 3A). Looking at average values for nest success and young produced per successful nest, Grasshopper Sparrow populations could sustain themselves (source) in most years as a double-brooded species (Fig. 3A). Dickcissels and Eastern Meadowlarks failed to replace themselves even when triple-brooded and other demographic parameters meet the general assumptions ($A = 5$, $S_a = 0.5$, $S_j = 0.25$) (Fig. 3A).

Varying the re-nesting rate (from 100%) had the greatest relative effect on the replacement threshold; each incremental decrease in re-nesting shifted the threshold to the right (Fig. 3B). Incremental increases in adult survival caused uniform shifts to the left in the replacement threshold (Fig. 3C). Incremental increases in juvenile survival showed a similar effect as adult survival did on replacement thresholds, but had greater effects on the threshold with smaller values of S_j than with larger values (Fig. 3D).

Adjusting the number of nesting attempts for single-, double-, and triple-brooded species had a positive effect on the source/sink threshold (shifting to the left) as the number of attempts increased (Figs. 4A, B, and C). The magnitude of the shift to the left decreased as the number of attempts increased. There was very little difference between double- and triple-brooded species with equal number of attempts (Figs. 4B and C).

DISCUSSION

Our models and sensitivity analysis showed annual productivity was very sensitive to all seven of the demographic parameters we used and tested (nest success, young per successful nest, number of broods, number of nesting attempts, adult survival rate, juvenile survival rate, and re-nesting rate). For example, the number of nesting attempts and the associated re-nesting rate appeared to be very important to songbird populations. Our model indicated that increasing nesting attempts had a decreasing, but positive impact on population growth rates.

Many long-distance or Neotropical migrants are generally considered to have less successful breeding attempts per season than resident or short-distance migrant birds especially in the northern extent of their ranges (Whitcomb et al. 1981). Nearctic-Neotropical migrants may have just enough time or energy to successfully produce one brood, but they may replace nests if their first attempts are unsuccessful. Monitoring radio-tagged and color-marked individual Dickcissels (a Nearctic-Neotropical migrant), Walk et al. (2004) found on average 36% of Dickcissel females initiated second nests after their first nest failed, thus increasing the overall productivity of the population. They found 95% of females monitored ceased breeding after fledging at least one young and only one female initiated a second nest after the first nest successfully fledged. Even when we used the maximum number of nesting attempts (5) possible from the nesting season length as suggested by Grzybowski and Pease (2005), our analysis shows it is very unlikely that the Fort Campbell Dickcissel population can be a source given this level of fecundity. This conclusion is supported by Breeding Bird Survey data (-0.9%/yr., P = 0.05, 1966-2004, Sauer et al. 2005).

In contrast, resident and short-distance migrant birds may or may not be limited to a single successful brood in a season because their nesting seasons tend to be longer than the nesting seasons of Nearctic-Neotropical migrants. Kershner et al. (2004) found Eastern Meadowlarks in Illinois, which have more than 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 (Kershner et al. 2004). These behavioral patterns resulted in lower productivity than generally expected for these birds. Apparently there may be a substantial cost associated with re-nesting even if there is enough time in the breeding season (Kershner et al. 2004).

Our results suggested that grassland songbird populations vary annually in terms of their source/sink status. Grasshopper Sparrows and Eastern Meadowlarks at Fort Campbell exhibited the greatest productivity, possibly producing surplus individuals in two or three of the five years. Those years when surplus individuals are produced may serve to "rescue" the local population from an overall decline. Instead of labeling a given population as a source or a sink, it becomes a question of balance over years of ups and downs. Emigration and immigration further confound the situation by offsetting or exacerbating the short-comings of annual productivity at the local scale. Dickcissel populations were well below the replacement threshold most years even with the most optimistic assumption for adult survival.

Our models generally represented conservative or "best-case" scenarios. We optimistically assumed pairing success and the re-nesting rate to be 100%. We also assumed constant annual clutch sizes and nest success rates, although these parameters often vary throughout the season. Variable clutch size and nest success within season places differential importance on nest attempts at the beginning of the season versus attempts at the end of the season. For example, nest success could increase during the season because of increasing cover and concealment. On the other hand, nest success could decrease with time in the breeding season because the temperature increases may make potential predators, like 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. In fact, clutch size tended to decrease during the season for Dickcissels and Grasshopper Sparrows at Fort Campbell, but we did not detect a decreasing trend for Eastern Meadowlarks (Giocomo 2005).

The variation around Mayfield (1975) nest success rates was generally large, even with relatively large sample sizes over five years combined (n = 87-204 nests monitored per species). Annual variation in demographic parameters may not be statistically significant, but small changes in demographic parameters have potentially large biological consequences. Similarly, confidence limits around estimated survival rates are usually very large. In most cases, very little is known about annual survival rates for many grassland species and even less is known about juvenile survival rates. 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 are generally greater than dispersal rates forest species, and juvenile dispersal rates are generally greater than adult dispersal rates (Martin 1995). Despite this variation, demographic models can help elucidate general population trends for management purposes, even if model assumptions are based on best guesses or values from the literature.

Our modeling approach extended existing methods in several ways. First, our approach allowed us to evaluate the effects of three demographic variables simultaneously. The plots can also be set up to show a range of values within the natural range of variability for each of the key population parameters. Second, our approach provided a quick, easy way to evaluate populations of species “in need of management,” and to identify locations where most of the population parameters were below what would be needed for a stable population under reasonable assumptions. Third, our approach allows comparison of previous studies in other locations because most nest monitoring studies provide a measure of nest success and young produced per nest (e.g., young per successful nest or clutch size). This approach may provide a means for standardizing methods to assess population health (Pease and Grzybowski 1995).

Although the replacement threshold plots were easy to develop, much of the data needed to parameterize these models do not exist for most species. Reasonable ranges of values can be estimated and used, but with many unknown parameters in the model, it becomes difficult to determine the model outcome with certainty (i.e., source or sink; Pease and Grzybowski 1995). The modeling exercise demonstrated the limitations of the field data collected for making meaningful determinations on population status for grassland birds, and represents a starting point for incorporating all the important life-history parameters that impact species at the population level into a relatively simple model. Understanding the annual variation in parameters other than nest success and number of young produced would provide a more realistic view of the health of these populations. Because population models are very sensitive to estimates of adult survival, additional survival estimates from color-marked populations are critically needed across each bird’s range of to allow for reliable population growth modeling. Additional information on how juvenile survival and adult female survival rates differ from adult males is needed. Finally, we hope this modeling effort will focus more attention on the population parameters needed, in addition to nest success and young per nesting attempt, to model population growth rates. We need more data on reproductive behavior, including pairing success, renesting rates, number of nesting attempts and broods, age-specific reproductive success, and within-season variability in reproductive rates.

ACKNOWLEDGEMENTS

This project was sponsored by the Department of Defense Legacy Resource Management Program, Fort Campbell Army Base, and The University of Tennessee Agricultural Experiment Station. We thank E. D. Moss, J. G. Jones, A. G. Leonard, and G. A. Zirkle at Fort Campbell for assistance with project logistics.

LITERATURE CITED

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

Dececco J. A., M. R. Marshall, A. B. Williams, G. A. Gale, and R. J. Cooper. 2000. Comparative seasonal fecundity for four neotropical migrants in middle Appalachia. Condor 102:653-663.

Donovan T. M., F. R. Thompson, J. Faaborg, and J. R. Probst. 1995. Reproductive Success of migratory birds in habitat sources and sinks. Conservation Biology 9:1380-1395.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. The birder’s handbook. Simon and Schuster Inc., New York. 785 p.

Giocomo, J. J. 2005. Conservation of grassland bird populations on military installatios in the Eastern United States with special emphasis on Fort Campbell Army Base, Kentucky. Ph.D. dissertation, University of Tennessee, Knoxville.

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

Hazler, K. R. 2004. Mayfield logistic regression: A practical approach for analysis of nest survival. Auk 121:707-716.

Herkert, J. R. and F. L. Knopf. 1998. Research needs for grassland bird conservation. Pp. 273-282 *in* J. M. Marzluff and R. Sallabanks (eds.). Avian Conservation: Research and management. Island Press, Washington, D.C.

Jehle, G., A. A. Y. Adams, J. A. Savidge, and S. K. Skagen. 2004. Nest survival estimation: A review of alternatives to the Mayfield estimator. Condor 106:472-484.

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

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

Lanyon, W. E. 1995. Eastern Meadowlark (*Sturnella magna*). *In* A. Poole and F. Gill, (eds.). The Birds of North America, No. 160. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

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

Michaud, J. C., T. Gardali, N. Nur, and D. J. Girman. 2004. Effects of nest predation and brood parasitism on population viability of Wilson's Warbler in coastal California. Wilson Bulletin 116:41-47.

Michel, N., D. F. DeSante, D. R. Kaschube, and M. P. Nott. 2005. The Monitoring Avian Productivity and Survivorship (MAPS) Program Annual Reports, 1989-2001. NBII/MAPS Avian Demographics Query Interface. http://www.birdpop.org/nbii/NBIIHome.asp (February 2005).

Murray, B. G., Jr. 2000. Measuring annual reproductive success in birds. Condor 102:470-473.

Nur N., A. L. Holmes, and G. R. Geupel. 2004. Use of survival time analysis to analyze nesting success in birds: An example using Loggerhead Shrikes. Condor 106:457-471.

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

Pease, C. M. and J. A. Grzybowski. 1995. Assesing the consequences of brood parasitism and nest predation on seasonal fecundity in passerine birds. Auk 112:343-363.

Powell, L. A., M. J. Conroy, D. G. Krementz, and J. D. Lang. 1999. A model to predict breeding-season productivity for multibrooded songbirds. Auk 116:1001-1008.

Powell, L.A. and M. G. Knutson. 2006. A productivity model for parasitized multibrooded songbirds. Condor 108:292-300.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. American Naturalist 132:652-661.

Ricklefs, R. E. 1973. Fecundity, mortality and avian demography. Pp. 366-435 *In* Breeding biology of Birds (D. S. Farner, ed.). National Academy of Sciences, Washington D.C.

Sauer, J. R., J. E. Hines, and J. Fallon. 2005. The North American Breeding Bird Survey, Results and Analysis 1966 - 2003. Version 2004.1. USGS Patuxent Wildlife Research Center, Laurel, MD. http://www.mbr-pwrc.usgs.gov/bbs/bbs.html (February 2005).

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

Temple, S. A. 2002. Dickcissel (*Spiza Americana*). *In* A. Poole and F. Gill, (eds.). The Birds of North America, No. 703. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Thompson, B. C, G. E. Knadle, D. L. Brubaker, and K. S. Brubaker. 2001. Nest success is not an adequate comparative estimate of avian reproduction. Journal of Field Ornithology 72:527-536.

Underwood, T. J. and R. R. Roth. 2002. Demographic variables are poor indicators of Wood Thrush productivity. Condor 104:92-102.

Vickery, P. D. 1996. Grasshopper Sparrow (*Ammodramus savannarum*). *In* A. Poole and F. Gill, (eds.). The Birds of North America, No. 239. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Walk, J. W., K.Wentworth, E. L. Kershner, E. K. Bollinger, and R. E. Warner. 2004. Renesting decisions and annual fecundity of female Dickcissels (Spiza americana) in Illinois. Auk 121:1250-1261.

Whitcomb, R. F., C. S. Robbins, J. F. Lynch, B. L. Whitcomb, M. K. Klimkiewicz, and D. Baystrak. 1981. Effects of fortes fragmentation in the avifauna of the wastern deciduous forest. Pp. 125-205. *In* Forest Island Dynamics in man-dominated landscapes. R. L. Burgess and D. M. Sharpe (eds.). Springer-Verlag, New York, New York.

Woodworth, B. L. 1999. Modeling population dynamics of a songbird exposed to parasitism and predation and evaluating management options. Conservation Biology 13:67-76.

Table 1. Formulas to calculate productivity ($R_{C,A}$) given the number of attempts (A), maximum number of successful 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 2. Baseline conditions for model populations of Dickcissels, Eastern Meadowlark, and Grasshopper 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	0.6	0.30	1	2-4
Eastern Meadowlark	0.6	0.30	2	2-4
Grasshopper Sparrow	0.5	0.25	3	3-4

Fig. 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 and multiplied by the estimate of young per successful nest to calculate overall annual productivity ($R_{A,C}$). Included are (A) single brooded with one nesting attempt, (B) single brooded with two nesting attempts, (C) single brooded with four nesting attempts, (D) and double brooded with four nesting attempts.

Fig. 2**.** Average nest success (±SE) and young produced per successful nest (±SE) for (A) single brooded Dickcissels, (B) double-brooded Eastern Meadowlarks, (C) triple-brooded Grasshopper Sparrows at Fort Campbell, KY/TN, 1999-2003. Lines indicate the threshold between increasing populations ($\lambda > 1$, points to the right of a line) and decreasing populations ($\lambda < 1$, points to the left of a line) assuming species specific ranges of annual adult survival.

Fig. 3. Sensitivity analysis of model parameters including (A) number of successful broods per season, (B) re-nesting rate, (C) annual adult survival rate, and (D) juvenile survival rate when all other rates are held constant. Plotted points indicate the average nest success and young produced per successful nest for Grasshopper Sparrow, Dickcissel, and Eastern Meadowlark populations at Fort Campbell, KY from 1999-2003. Lines indicate the threshold between increasing populations ($\lambda > 1$, points to the right of a line) and decreasing populations ($\lambda < 1$, points to the left of a line).

Fig. 4. Sensitivity analysis of number of nesting attempts for a (A) single-, (B) double- and (C) triple-brooded species when all other demograpηιχ ρατεσ αρε ηελδ χονσταντ. Πλοττεδ ποιντσ ινδιχατε τηε αϖεραγε νε στ συχχεσσ ανδ ψουνγ προδυχεδ περ συχχεσσφυλ νεστ φορ Γρασσηοππερ Σπαρρ οω, Διχκχισσελ, ανδ Εαστερν Μεαδοωλαρκ ποπυλατιονσ ατ Φορτ Χαμπβελλ, Κ Ψ φρομ 1999–2003. Λινεσ ινδιχατε τηε τηρεσηολδ βετωεεν ινχρεασινγ ποπυλατι ονσ ($\lambda > 1$, points to the right of a line) and decreasing populations ($\lambda < 1$, points to the left of a line).

James J. Giocomo
Department of Forestry, Wildlife and Fisheries
University of Tennessee
274 Ellington Plant Sciences Building
Knoxville, TN 37996-4563, USA
865-974-6351; Fax: 865-974-4714; jgiocomo@utk.edu

RH: Grassland Bird Nest Habitat Selection • *Giocomo* et al.

Grassland Bird Nesting Habitat Selection at Fort Campbell Army Base, Kentucky and Tennessee

James J. Giocomo[1], Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington, Knoxville, TN 37996, USA
E. Daniel Moss, Directorate of Public Works, IMSE-CAM-PWE, 865 16th Street, Fort Campbell, KY 42223, USA
David A. Buehler, Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington, Knoxville, TN 37996, USA
Craig A. Harper, Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington, Knoxville, TN 37996, USA
William G. Minser, III., Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington, Knoxville, TN 37996, USA

ABSTRACT We examined the nesting habitats used by five co-existing grassland-breeding birds: Henslow's sparrows (*Ammodramus henslowii*), grasshopper sparrows (*Ammodramus savanarum*), field sparrows (*Spizella pusillia*), dickcissels (*Spiza Americana*) and eastern meadowlarks (*Sturnella magna*), at Fort Campbell Army Base, on the border of Kentucky and Tennessee between 2001 and 2003. Our objectives were to (1) examine habitat differences in nest placement between selected nest sites and available sites for each species, and (2) examine microhabitat differences among the five target species. Litter depth was greater at nest sites for all species than the random plots. Nest sites also had less bare ground cover and greater grass height than the random plots for all species except grasshopper sparrows. Henslow's sparrow nest sites had the greatest warm-season grass cover, eastern meadowlark nest sites had the greatest cover of cool-season grass, and field sparrow nest sites had the greatest cover of woody

vegetation. Management for these grassland species requires a mosaic of grassland habitats of different structure and composition to meet the needs of all species simultaneously.

KEY WORDS: dickcissel, eastern meadowlark, field sparrow, grasshopper sparrow, grasslands, habitat selection, Henslow's sparrow.

[1]Corresponding author e-mail: jgiocomo@utk.edu

Based on North American Breeding Bird Survey results, 9 native species of open grassland and savanna habitats decreased in abundance, whereas only 3 species increased between 1966 and 2006 in the eastern US (Sauer et al. 2006). Changes in land use and land management have reduced the amount and quality of breeding 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 1994, Askins 1999). 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 (Herkert and Knopf 1998).

The structure of the vegetation within grassland habitats has long been recognized as one of the important determinants of habitat selection for grassland birds (Weins 1969, Roseberry and Klimstra 1970, Cody 1985, Bollinger 1995). Grassland habitats are dynamic and ephemeral, relying on frequent disturbance, such as fire, grazing or mowing, to maintain grass cover. Many studies have documented the general habitat used by breeding grassland species (see Carey et al. 1994, Lanyon 1995, Vickery 1996, Herkert et al. 2002). Most studies were based on vegetation measurements related to bird distributions within fields, but not necessarily related to a specific area selected by individual birds. Recently, studies examining patterns of nesting habitat selection among several species within a single community have become more common (Winter 1998, Dieni and Jones 2003, Winter et al. 2004).

To maintain a community of grassland birds, it is important to understand the extent of grassland habitats used during the breeding season compared to what is available locally, and how habitat preference varies among species. Understanding how nesting site selection differs among species will help managers understand how managing vegetation structure for one grassland bird species may impact the presence of other grassland birds.

We focused our work on nesting habitats used by five coexisting grassland-breeding birds at Fort Campbell Army Base, Kentucky and Tennessee between 2001 and 2003; Henslow's sparrows (*Ammodramus henslowii*), grasshopper sparrows (*Ammodramus savanarum*), field sparrows (*Spizella pusillia*), dickcissels (*Spiza americana*) and eastern meadowlarks (*Sturnella magna*). Our objectives were (1) to examine habitat differences between selected nest sites and available habitats, and (2) to examine microhabitat selection and niche space occupancy differences among the five target species.

STUDY AREA

The study was conducted on Fort Campbell Army Base, a 42,000-ha base located on the Kentucky-Tennessee border (Giocomo et al. 2008). Fort Campbell contains large blocks of grasslands on hilly, karst topography in west-central Kentucky and northwestern Tennessee (Chester et al. 1997). Fort Campbell grasslands contain native warm-season grasses including little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), indiangrass (*Sorghastrum nutans*), and broomsedge (*Andropogon virginicus*). Oak-hickory (*Quercus-Carya*) forests and a limited number of leased agricultural fields (millet and soybeans) are interspersed among the grasslands. Portions of most larger fields are leased for haying. In addition to native grasses, these fields contain non-native cool-season grasses such as tall fescue (*Lolium arundinaceum*), orchardgrass (*Dactylis glomerata*), timothy (*Phleum pretense*), and smooth brome (*Bromus inermis*).

METHODS

Nest searching.— Nest searches were concentrated in fields that contained Henslow's sparrow and grasshopper sparrow territories because these species were the most difficult to locate at Fort Campbell. We systematically searched fields between 1 May – 30 July by looking for males on territory or exhibiting nesting behavior. We used behavioral cues, such as birds flushing or chipping close to observer and birds carrying nesting material, food or fecal sacs, to locate nests. We monitored nests of all species found. Once nests were located, we placed a flag at least 5 m from the nest, and detailed maps of nest locations were drawn. Nests were monitored every 3-4 d to determine nest fate.

Vegetation sampling.—We sampled vegetation at all grasshopper sparrow, Henslow's sparrow, and eastern meadowlark nests and at least 20 randomly-selected dickcissel and field sparrow nests each year. We measured nest site vegetation within 2 weeks of completion of nesting activities. We pooled measurements among all years to ensure adequate sample sizes for analysis of all species, and to provide a sample of nest conditions present across multiple years.

We collected vegetation measurements in up to 30 selected fields per year to represent habitat availability. Some fields were converted to row crop agriculture during the study and sampling was discontinued. Within each field, up to 10 vegetation plots, depending on field size, were randomly located at least 50 m apart. Field sizes ranged from 3 to 600 ha. We measured grass height, litter depth, percent cover, and vertical cover centered on the nest site or random plot. 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. Litter included all dead vegetative matter on the ground. To assess vertical cover, we placed a density board (15 X 15 cm squares; 2 squares wide and 10 squares high) 15 m from the center of the vegetation point (or nest) and counted the squares obstructed by vegetation from the center point (Nudds 1977).

Statisitcal analysis.— We treated all individual nest sites and random vegetation plots as independent samples. Random vegetation plots were included as a separate group to represent habitat available at Fort Campbell. We first examined habitat variables at the univariate level to examine individual differences (Dieni and Jones 2003). We calculated a correlation matrix estimate the relationship for all combinations of variables, and an ANOVA to examine differences among nest sites of all the species and random plots. Additionally, we used a *post hoc* comparison using Dunnett's pairwise multiple comparison *t*-test to allow comparison between each 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.

We examined multivariate relationships among the nest habitat variables of the five bird species (without the random vegetation plots) using discriminant function (DF) analysis. We then tested the ability of the DF to classify nesting habitat among the 5 species by generating a classification table using a jackknife procedure. We used the coefficients generated by the DF to calculate average (±2 * SE) group centroids for each species and for the random vegetation plots. We further grouped each of the random vegetation plots by number of years since prescribed burn (0 to 3 years post burn) to plot average centroids for each group of random vegetation points.

RESULTS

We monitored 522 nests of the focal species between 2001-2003. A total of 314 nest vegetation plots were measured. Vegetation measurements were collected at 379 random plots in the selected fields in 2001 (n = 181), 2002 (n = 107) and 2003 (n = 91).

Univariate analysis.— Each habitat variable differed between nest site and random plots for at least 1 species (Table 1). Eight of 12 habitat variables measured at Henslow's sparrow and grasshopper sparrow nest sites differed from random plots, whereas 6 of 12 variables differed between random sites and dickcissel, field sparrow, and eastern meadowlark nest sites. Considering all habitat measurements, each species varied from the random plot measurements independently. Litter depth was greater at nest sites than random plots for all species. Nest sites also had less bare ground cover and greater grass height than random plots for all species except grasshopper sparrows. Henslow's sparrow nest sites had the greatest warm-season grass cover, eastern meadowlark nest sites had the greatest cover of cool-season grass, and field sparrow nest sites had the greatest cover of woody vegetation.

Multivariate analysis.— A correlation matrix showed only one pair of habitat 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 2). The first discriminant function (DF1) was most correlated with mean litter depth (*r* = 0.59) and vertical cover (*r* = 0.63). The second discriminant function (DF2) was most correlated with percent forb cover (*r* = 0.55) and percent warm-season grass cover (*r* = -0.50). The relative ability of the discriminating functions to separate groups, indexed by the correlation coefficients, was somewhat greater for DF1 (*r* = 0.73) than for DF2 (*r* = 0.54).

Overall, 52% of the individual nest sites were correctly classified, which is greater than expected by random chance (20%; Table 3). Dickcissel and field sparrow nest sites were least likely to be classified correctly (41% and 49%, respectively) with the greatest misclassification occurring between the two species. Most grasshopper sparrow and Henslow's sparrow nest sites were correctly classified (63% and 59%, respectively).

The group centroid for the random locations was located near the middle of group centroids for all five grassland bird species (Fig. 1). The group centroids for dickcissel and field sparrows showed overlapping standard errors. The group centroid for the 3 years post-burn was separated from the other year since burn groups and the overall random plot centroid, but overlapped the group centroids for dickcissel and field sparrows.

DISCUSSION

Our univariate analysis revealed distinct differences between the habitats selected for nesting by each species and available habitat at Fort Campbell, as represented by random vegetation plots (Table 1). Litter depth in the random plots was close to half the litter depth at the nest sites of all five species. Random plot averaged more than twice the forb cover as nest sites for eastern meadowlarks and Henslow's Sparrows. Also random plots averaged half the grass height and twice the bare ground cover for all species nest sites except grasshopper sparrows. All of these differences indicate the frequency (1-3 years) of habitat management is too short to maintain the maximum area of diverse habitat for all five species. At Fort Campbell, Moss (2001) found litter depth increased as the duration between disturbances (years since prescribed burning) increased from 0 to 3 years post-disturbance.

Multivariate analysis generally matched the nest-site selection patterns found in the univariate analysis (Fig. 1). The DF1 was positively associated with litter depth and vertical vegetation density, and can be thought of as an index of time since disturbance (fire or mowing) in the fields. The DF2 was positively associated with forb cover and negatively associated with native warm-season grass cover and cool-season grass cover, and represents the ratio of forb cover to grass cover, increasing as the relative amount of forb cover increases.

Using the group centroids to represent the relative multivariate niche space of sampled nesting habitat for each species, the grasshopper sparrow centroid appeared to be the most distinct compared to the niche space of the other species (Fig. 1). Eastern meadowlarks used habitat intermediate between grasshopper sparrow and Henslow's sparrow habitat. Niche space of dickcissels and field sparrows overlapped considerably, thus explaining the low success rate of the jack-knife validation procedure (Table 3).

Although niche space of field sparrows almost completely overlapped with dickcissels, our 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 (Herkert 2003). Our sample of field sparrow nests was most likely biased toward open field nests and away from nests near woody edges, where some field sparrows undoubtedly nested.

The centroid for the random vegetation plots indicated available habitat had intermediate litter depth and vertical cover (DF 1), and a relatively large proportion in forb cover and low proportion in grass cover (DF 2, Fig. 1). When we grouped the random vegetation points by year since burn (Fig. 1), we found only the 3 years after burn group separated from the average of all the random points and had overlapping standard errors with the field sparrow and dickcissel nest site vegetation plots. In a large portion random plots, burning occurred annually (Moss 2001). Annual burning was intended to keep the fields clear of woody vegetation for military training purposes, and tended to favor forbs.

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 at Fort Campbell (>100 ha). Even when the microhabitat seemed suitable, the smaller fields were unoccupied by these species. Conversely, Henslow's sparrows and dickcissels were found in all fields where microhabitat was suitable. Winter (1998) found dickcissel and Henslow's sparrow populations reacted more to close proximity of grassland patches than size individual patches. Because of the high percentage of grassland cover at the landscape scale (>30%, D. Moss, Fort Campbell, unpublished data), Fort Campbell has potential to provide more habitat for these two species. However, the microhabitat would need to be managed for deeper litter depth and more grass cover by burning less frequently (every 3-4 years) to increase the quantity of suitable habitat.

MANAGEMENT IMPLICATIONS

The diversity of conditions selected for by these 5 grassland species highlight the need to manage for a diversity of conditions in grasslands if overall grassland bird conservation is the goal. Our understanding of how to manage grassland habitats to create these conditions is increasing. For example, if more dickcissel or field sparrow habitat is desired, then burning less frequently (e.g., 3-year rotation rather than 1-2 year rotation) will allow for taller vegetation with a greater warm-season grass component to develop in Kentucky and Tennessee (Moss 2001). In contrast, grasshopper sparrow habitat can be maintained by more frequent disturbance, in the form of burning which will reduce litter depth (Gruchy 2007). Season of burn also becomes critical for control of woody vegetation in these fields. Gruchy (2007) found that late growing season burns were far more effective at controlling woody vegetation that dormant season burns on various grassland in Tennessee.

It is important to recognize, however, that when fields are small (e.g., <10 ha), which is often the case at Fort Campbell, it is difficult to create the entire range of conditions required by all grassland bird species in any one field at any one time. Therefore, under these circumstances, it is necessary to manage a suite of fields with different types and timing of disturbance to provide for all the habitat conditions required to sustain a grassland bird community.

ACKNOWLEDGMENTS

This project was sponsored by the Department of Defense Legacy Resource Management Program, Fort Campbell Army Base, and The University of Tennessee. We especially thank the Conservation Branch at Fort Campbell for assistance with project logistics. We are grateful for the hard work many field assistants and colleagues provided to collect these data.

LITERATURE CITED

Askins, R. A. 1999. History of grassland birds in eastern North America. *In* Vickery, P. and J. Herkert (editors). Studies in Avian Biology 19: 60-71.

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

Carey, M., D. E. Burhans, and D. A. Nelson. 1994. Field sparrow (Spizella pusilla). Account 103 *in* A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C., USA.

Chester, E. W., B. E. Wofford, J. M. Baskin, and C. C. Baskin. 1997. A floristic study of barrens on the southwestern Pennyroyal Plain, Kentucky and Tennessee. Castanea 62:161-172.

Cody, M. L. 1985. Habitat selection in grassland and open-country birds. Pages 191-226 *in* M. L. Cody, editor. Habitat selection in birds. Academic Press, New York, USA.

Dieni, S. J., and S. L. Jones. 2003. Grassland songbird nest site selection patterns in northcentral Montana. Wilson Bulletin 115:388-396.

Giocomo, J. J., E. D. Moss, D. A. Buehler and W. G. Minser. 2008. Nesting ecology of grassland birds at Fort Campbell, Kentucky and Tennessee. Wilson Bulletin 119 in press.

Gruchy, J.P. 2007. An evaluation of field management practices for improving bobwhite habitat. Thesis. University of Tennessee. Knoxville, USA.

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

Herkert, J. R. 2003. Effects of management practices on grassland birds: Henslow's Sparrow. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource /literatr/grasbird/hesp/hesp.htm>. Accessed 2007 Oct 5.

Herkert, J. R. and F. L. Knopf. 1998. Research needs for grassland bird conservation. Pages 273-282 *in* J. M. Marzluff and R. Sallabanks, editors. Avian conservation: research and management. Island Press, Washington, D.C., USA.

Herkert, J. R., P. D. Vickery, and D. E. Kroodsman. 2002. Henslow's sparrow (*Ammodramus henslowii*) . Account 672 *in* A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C., USA.

Lanyon, W. E. 1995. Eastern meadowlark (*Sturnella magna*). Account 160 *in* A. Poole And F. Gill, editors. The birds of North America, No. 160. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C., USA.

Moss, E. D. 2001. Distribution and reproductive success of native grassland birds in response to burning and field size at Fort Campbell Military Reservation: Special focus on Henslow's and grasshopper Sparrows. Thesis, University of Tennessee, Knoxville, USA.

Nudds,T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife

Society Bulletin 5:113-117.

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

Roseberry, J. L. and W. D. Kilmestra. 1970. The nesting ecology and reproductive performance of the eastern meadowlark. Wilson Bulletin 82:243-267.

Sauer, J. R., J. E. Hines, and J. Fallon. 2006. The North American Breeding Bird Survey, Draft results and analysis 1966 - 2006. Version 6.2.2006. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Vickery, P. D. 1996. Grasshopper sparrow (*Ammodramus savannarum*). *in* A. Poole and F. Gill, editors. The birds of North America, No. 239. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C., USA.

Vickery, P. D., P. L. Tubaro, J. M. Cardosa da Silva, B. G. Peterjohn, J. R. Herkert, and R. B. Cavacanti. 1999. Conservation of grassland birds in the Western Hemisphere. Studies in Avian Biology 19:2-26.

Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. Ornithological Monographs 8:1-93.

Winter, M. 1998. Effect of habitat fragmentation on grassland-nesting birds in southwestern Missouri. Dissertation, University of Missouri, Columbia, USA.

Winter, M, J.A. Shaffer, D.H. Johnson, T.M. Donovan, W.D. Svedarsky, P.W. Jones, and B.R. Euliss. 2004. Habitat and nesting of Le Conte's Sparrows in the northern tallgrass prairie. Journal of Field Ornithology 76:61-71.

Associate Editor:

Figure 1. Group centroids (± 2*SE) of the nest site vegetation measurements for dickcissels (DICK), field sparrows (FISP), grasshopper sparrows (GRSP), Henslow's sparrows (HESP), eastern meadowlarks (EAME) and random locations (RANDOM) at Fort Campbell Army Base, Kentucky, 2001-2003. The group centroids were generated using the coefficients from the discriminant function analysis for the nest sites of the five grassland birds. The random vegetation sites were then grouped by years-since-burn (Burn0-Burn 3).

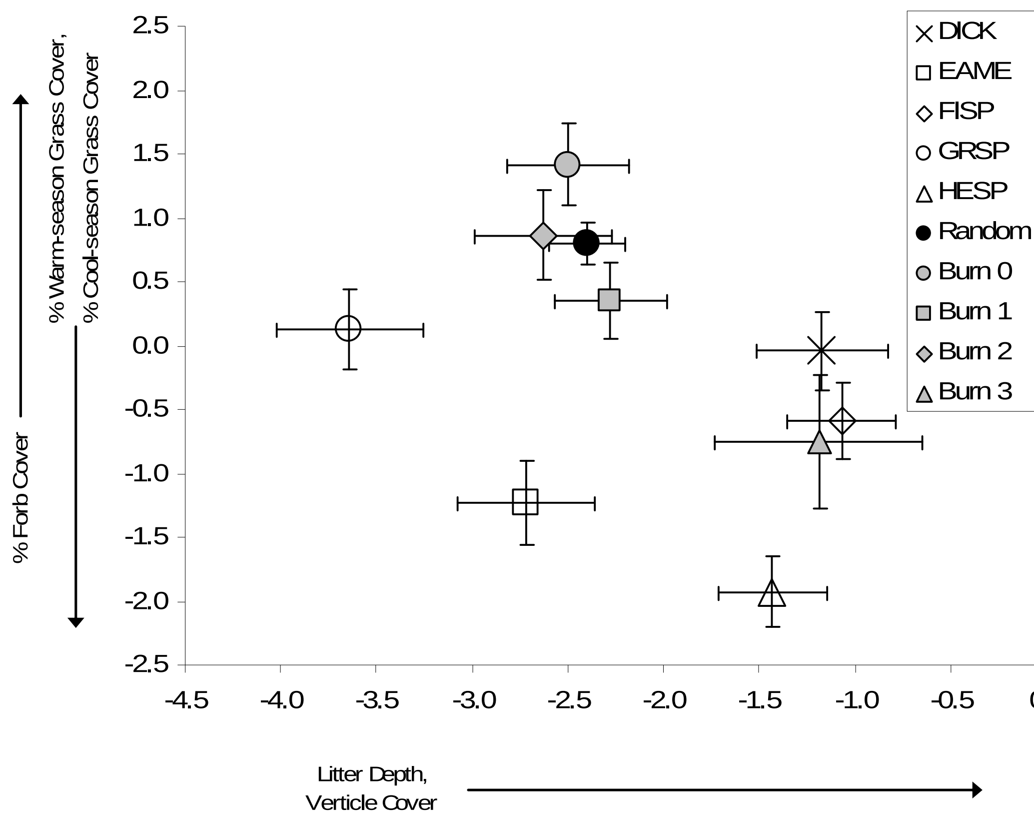

TABLE 1: Vegetation measurements for nest sites of five songbird species and randomly selected plots at Fort Campbell Army Base, Kentucky, 2001-2003. For each habitat variable, the values for each bird species are compared to those of random plots (Dunnett's *t*-test: * = $P < 0.05$).

		% Litter			% Bare ground			% Woody			% Dead woody			% Cool-season grass			% Warm-season grass		
Nest/Site Type	*n*	mean	SE		mean	SE		mean	SE		mean	SE		mean	SE		mean	SE	
Dickcissel	71	3.7	0.6		4.6	0.8	*	9.4	2.3		0.9	0.3	*	12.9	2.0		16.7	3.0	
Eastern Meadowlark	45	8.4	1.6		4.2	0.8	*	1.4	0.9		0.0	0.0		46.5	4.0	*	16.5	3.3	
Field Sparrow	72	6.7	1.0		3.3	0.6	*	14.8	2.3	*	1.2	0.4	*	9.9	1.7		24.8	3.3	
Grasshopper Sparrow	70	10.0	1.9	*	11.4	1.5		0.8	0.4	*	0.0	0.0		26.5	3.3	*	13.1	2.2	*
Henslow's Sparrow	56	7.6	1.3		3.2	0.5	*	1.0	0.5	*	0.4	0.2		21.7	3.5	*	43.5	3.6	*
Random	379	6.5	0.5		11.4	2.0		6.7	1.6		0.3	0.1		12.5	2.1		22.0	2.6	

TABLE 1. Continued.

		% Forbs			Herbaceous height (cm)			Grass height (cm)			Woody height (cm)			Litter depth (mm)			Vertical cover		
Nest/Site Type	*n*	mean	SE		mean	SE		mean	SE		mean	SE		mean	SE		mean	SE	
Dickcissel	71	51.6	3.5		58.2	3.7	*	39.1	3.0	*	32.5	6.0	*	6.6	0.3	*	22.0	16.7	
Eastern Meadowlark	45	23.0	2.8	*	38.5	2.3		39.4	3.4	*	2.9	1.2		9.1	0.4	*	13.8	7.6	*
Field Sparrow	72	38.9	3.5		49.7	2.5		40.5	2.6	*	46.5	6.1	*	5.9	0.4	*	26.1	16.3	*
Grasshopper Sparrow	70	38.2	3.3	*	30.6	2.2	*	26.5	1.7		2.1	0.8		11.1	0.4	*	9.5	4.1	*
Henslow's Sparrow	56	22.0	2.4	*	56.1	5.3	*	48.8	3.1	*	7.3	2.4		6.8	0.3	*	18.3	9.0	
Random	379	40.0	2.8		41.3	2.8		18.7	3.1		12.3	3.5		3.9	0.6		20.2	12.1	

TABLE 2. Discriminant function coefficients and summary for nest-site habitat characteristics of five grassland bird species, Fort Campbell Army Base, Kentucky and Tennessee, 2001-2003.

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	0.73	0.54	
P	<0.01	<0.01	

TABLE 3. Re-classification table from the Discriminanat Function analysis for five grassland songbirds at Fort Campbell Army Base, Kentucky and Tennessee, 2001-2003.

	Predicted						
Actual	DICK	EAME	FISP	GRSP	HESP	Total	Correct classification
DICK	29	3	20	5	14	71	41%
EAME	3	23	1	9	9	45	51%
FISP	22	1	35	0	14	72	49%
GRSP	9	15	0	44	2	70	63%
HESP	6	9	6	2	33	56	59%
Total						314	52%