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Management and Conservation Article

From Wiens to Robel: A Review of Grassland-Bird Habitat Selection

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ABSTRACT Efforts to stabilize or increase grassland bird populations require identification of suitable habitat as a first step. Although the number of studies examining grassland-bird habitat selection has increased substantiall in recent ears, much uncertaint exists regarding local-scale habitat variables that researchers should consider. We reviewed 57 studies and identified important vegetation features correlated with grassland bird abundance, densit , occurrence, and nest and territor selection. Our objectives were to 1) guide future studies of grassland-bird habitat use b providing a reduced set of relevant vegetation characteristics, 2) challenge researchers to criticall think about what variables to consider, and 3) highlight the need to include consistent definitions of terms used to describe grassland bird habitat. We identified 9 variables that were important predictors of habitat use b grassland birds: coverage of bare ground (important in 50% of the instances where it was included), grass (34% of instances), dead vegetation (33% of instances), forbs (31% of instances), and litter (29% of instances), along with an index of vegetation densit (39% of instances) and volume (39% of instances), litter depth (36% of instances), and vegetation height (41% of instances). Onl 25% of studies provided information on effects sizes and measures of variance. Furthermore, definitions of measured habitat variables were not consistent among studies. We provide definitions of the 9 important variables and implore authors to report effect size and measures of variance. Standardization of terms and reporting of meaningful results will facilitate replication of wildlife research and enhance our abilit to recognize general patterns that emerge from observational studies of habitat use.

KEY WORDS Daubenmire, grassland passerines, habitat models, habitat use, litter depth, vegetation densit , vegetation height, vegetation structure.

The widespread decline of grassland birds in North America has been referred to as an unfolding "conservation crisis" (Brennan and Kuvlesk 2005:1). The continent-wide nature of these declines suggests that the causes are not local isolated phenomena and likel involve the loss and degradation of grassland habitat (Vicker et al. 1999b, Vicker and Herkert 2001, Brennan and Kuvlesk 2005). Hence, efforts to stabilize or increase grassland bird populations require identification of remaining habitat as a first step (Vicker and Herkert 2001), followed b habitat management and restoration (Brennan and Kuvlesk 2005). Not surprisingl , the number of studies examining grassland-bird habitat selection has increased substantiall in recent ears.

Two important questions researchers must answer before conducting an t pe of habitat stud are these: 1) what features of the habitat should be measured, and 2) what is the best method for measuring those features. Wiens (1969) contended that a description of bird habitat should provide sufficient detail to differentiate among habitats used b multiple species, et be suitabl flexible and precise to reduce the need to artificiall classif and categorize habitat. Furthermore, researchers should consider those habitat features deemed important to the animals being studied (Wiens 1969). Stemming from these requirements, Wiens (1969) developed a protocol for quantif ing grassland bird habitat based on structural vegetation characteristics such as densit , height, and dispersion. The s stem is both efficient and eas to use in the field, making it one of the preferred methods for quantif ing grassland bird habitat. Man of the structural characteristics included b Wiens (1969) are still perceived to be important for contemporar assessments of grassland-bird habitat use.

Although Wiens' (1969:86) s stem included a set of carefull chosen variables, he suggested that "…it does not seem proper to restrict consideration, a priori, to a few readil -measurable habitat features which ma or ma not have an direct relevance to the activit of birds." Numerous studies conducted since Wiens' (1969) monograph have identified relevant vegetation features influencing habitat use that should aid researchers in defining a priori h potheses regarding grassland-bird habitat selection. This approach would allow development of more robust habitat selection models that could be used to make informed decisions regarding habitat management. Even so, grassland bird researchers still conduct explorator anal ses because the are uncertain of important habitat variables. This is particularl apparent in the grassland-bird Breeding Biolog Research and Monitoring Database (BBird) protocol where >40 vegetation parameters are measured at each nest (Martin et al. 1997). Continued use of explorator anal ses and measurement of all potentiall important vegetation variables suggests that either no pattern regarding grassland-bird habitat relationships has emerged, or that apparent trends are not being recognized, or are being ignored.

We reviewed studies of habitat selection b grassland birds in North America to 1) summarize methods used b researchers for quantif ing grassland bird habitat, and 2) identif patterns of grassland-bird vegetation associations. Our results are intended to 1) guide future studies of grassland-bird habitat use b providing a reduced set of relevant vegetation characteristics for researchers to consider, 2) challenge researchers to criticall think about what variables to consider, and 3) highlight the need to include

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consistent definitions of terms used to describe grassland bird habitat.

METHODS

We gathered peer-reviewed literature via online search engines (Institute for Scientific Information Web of Science, Searchable Ornithological Research Archive, and Google Scholar) that directl tested effects of vegetation characteristics on occurrence, relative abundance, densit , or habitat selection (e.g., nest, territor , or postfledgling habitat) of grassland passerines in North America. We included passerines considered grassland or successional and shrub-breeding species b Sauer et al. (2007) or obligate or facultative grassland species b Vicker et al. (1999b). We did not consider winter habitat because few studies were reported in published literature.

The paucit of information on effect sizes, particularl for statisticall nonsignificant variables, precluded use of a formal statistical meta-anal sis. Instead, we used a vote-counting procedure to determine which vegetation factors were consistent correlates of grassland-bird habitat use (Gurevitch and Hedges 1999). This vote-counting procedure provided a descriptive summation of the importance of individual variables. Our sample size for the vote-counting procedure was the total number of instances a vegetation variable was examined with respect to a bird species response, not the total number of articles. Thus habitat associations of multiple species included in one article each added 1 to the overall sample size. Similarl , if authors developed separate models for a species' response to a vegetation variable over multiple ears or at different sites, each model added 1 to the overall sample size for that vegetation variable. Although models of habitat use that are developed for a single species over multiple ears or sites are not independent, our focus was to identif consistent vegetation features that could reliabl predict bird use across ears and locations.

We used 2 sets of statistical criteria that were most commonl reported when assessing variables for inclusion into our anal ses. For papers reporting statistical h pothesis testing procedures, we judged individual variables to be important if the had P-values <0.05. When an information-theoretic approach (Akaike's Information Criterion [AIC]; Burnham and Anderson 1998) was used, we included variables that appeared in models with $\Delta AIC < 2$. If a variable was included in multiple models with $\Delta AIC < 2$, we onl included it once in our determination of importance. In all anal ses, we calculated the importance of an individual vegetation variable as the number of instances a variable was deemed important (following criteria above) divided b the total number of instances the variable was included as an explanator variable in all studies.

RESULTS

We evaluated 57 studies (Appendix A) spanning 39 ears (1969–2008), which included 31 grassland bird species (Appendix B) found in a variet of grassland t pes (Appendix A). The number of variables measured b researchers averaged 7.6 (SE = 0.6) but ranged from 2 to 23. We included 310 species responses to vegetation structure (i.e., habitat models) in our anal ses (Appendix A). The most common techniques used to assess grassland habitat were Daubenmire frame (Daubenmire 1959), Robel pole (Robel et al. 1970), and Wiens pole (Wiens 1969; Fig. 1). We identified 118 different vegetation variables included in models of grassland-bird habitat use (Appendix C). These variables measured 8 broad characteristics of vegetation structure and composition: densit , height, volume, horizontal canop coverage of biotic or abiotic factors, patchiness (spatial heterogeneit), litter depth, and vegetation communit composition (richness, evenness, or diversit ; Appendix C).

Each of the 8 vegetation categories was composed of individual explanator variables (Appendix C). We examined whether these individual variables were consistent predictors of grassland-bird habitat use. We restricted our anal ses to those variables that had a sample size ≥ 30 (approx. 10% of all species–habitat models). Of 14 variables anal zed, 9 were considered important predictors of grassland-bird habitat use in $\geq 29\%$ of models where the were included (Table 1).

DISCUSSION

Increased awareness of population declines of grassland species has likel contributed to an increased number of studies on grassland-bird habitat selection (Vicker and Herkert 2001). Even so, a lack of information in reported statistical results made it impossible to conduct meta-anal ses using effect sizes. Johnson (2002) advocated the importance of replication in wildlife research and the use of meta-anal tic procedures. These procedures allow researchers to tease apart consistent versus inconsistent effects of explanator variables on the response variable of interest (Johnson 2002). However, effect sizes were presented in onl 25% of the studies that we examined. The lack of basic information such as means and measures of variance in published articles is surprising considering the number of articles highlighting the need to include such information in wildlife research (Anderson et al. 2001, Chamberlain 2008).

Methods

We found substantial overlap in the methods used to assess habitat use b grassland birds. The primar methods (Daubenmire frame, Robel pole, and Wiens method) efficientl and quantitativel describe grassland habitat. These are important considerations given that habitat studies are often subject to time and resource limitations (Herrick et al. 2005). Furthermore, reduction in time conducting habitat measurements ma allow researchers to increase sample sizes.

The vegetation measurement techniques we reviewed were often standardized, but we found inconsistencies in 1) the size of Daubenmire frames (standard size 50 cm × 20 cm; Daubenmire 1959), 2) the distance and height where a visual-obstruction reading was taken for a Robel measurement (4-m distance and 1-m ht provided the best

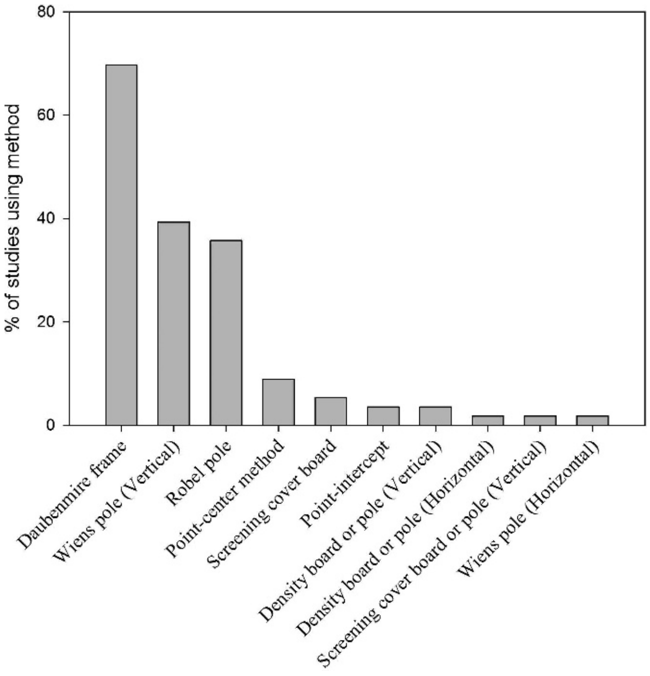

Figure 1. Field techniques used for measuring vegetation structure b grassland bird researchers (n = 57 studies) from articles published between 1969 and 2007.

correlation with vegetation volume; Robel et al. 1970), 3) the shape, diameter, and color of the Robel pole, and 4) the increments on the Wiens and Robel poles (dm increments were used in the original development of these methods; Wiens 1969, Robel et al. 1970). We applaud development of new techniques to measure vegetation (e.g., digital photograph ; Luscier et al. 2006), but continued use of standardized, common techniques will provide common metrics among future studies. We believe that standardized techniques are 1) useful for maintaining consistenc of data sets in long-term studies, 2) allow for easier replication of stud design, and 3) reduce ambiguit among published literature. Along with use of standardized techniques, we also advocate that researchers determine a suitable sampling intensit for their studies.

Table 1. We evaluated vegetation variables using a vote-counting procedure to identif important predictors of grassland-bird habitat use. We considered variables important if the percent of cases in which the variable was deemed important (%) exceeded 25 (n = no. of cases in which the variable was examined).

Vegetation variable	%	N
% bare ground	50	130
% grass[a]	34	143
% dead vegetation	33	30
% forbs	31	139
% litter[b]	29	102
% shrub	23	56
% vegetation cover[c]	23	37
Vegetation densit [d]	39	74
Grass densit [a]	30	30
Forb densit	23	40
Shrub densit	12	51
Vegetation volume	39	126
Litter depth[b]	36	190
Vegetation ht[e]	41	202

[a] Grass cover and densit were used b authors to describe coverage of all grass t pes, without separation into narrower grass categories (e.g., live, dead, native, exotic, etc.).

[b] Litter was based on authors' descriptions of the variable the were measuring. Despite different definitions of litter (see Discussion), if authors reported measuring litter, we included it in this categor .

[c] Vegetation cover was a general term used b authors when pooling all vegetation t pes into one categor . This categor included all t pes of vegetation cover, except bare-ground exposure.

[d] Vegetation densit , as used b authors, included densit of all vegetation t pes. Different plant t pes were not separated in this categor .

[e] Vegetation ht included several definitions (see Discussion), but all were combined into this one categor for our anal sis.

Important Vegetation Factors for Birds

Of 118 individual vegetation variables identified b our review and the 14 variables we used in the vote-counting procedure, 9 appeared to be consistent predictors of grassland-bird habitat use and should be considered in future studies. Bare-ground exposure, vegetation height, and litter depth were 3 of the most consistent predictors of habitat use b grassland birds. Reduced bare-ground exposure and increased vegetation height could both provide concealment and cover from predators or wind for adults and oung birds (Nelson and Martin 1999, Davis 2005, Warren and Anderson 2005). However, moderate levels of bare ground and vegetation height are likel preferable for some species because of the trade-off between concealment, the need for vigilance, and foraging efficienc (Lusk et al. 2003). The biological relevance of litter depth for grassland birds is unclear. We found few explanations of wh litter depth was included in studies of grassland-bird habitat relationships, but Winter (1999) suggested litter (i.e., horizontall l ing dead-plant material) provides a suitable nesting substrate. However, litter (as we define it) also provides a stable soil microclimate, materials for nutrient c cling, a substantial input of organic matter, and food for microorganisms in a health rangeland; thus, it ma also be an index of overall grassland health (Pellant et al. 2000).

Coverages of grass, forbs, litter, and dead vegetation, as well as vegetation densit , were important in 29–39% of the species responses examined. Grassland birds ma respond to grass cover and densit because grass is used as a nesting substrate, and provides concealment (Davis 2005) and abundant pre (Cod 1974). The low percentage of studies (34%) finding that grass cover is important for grassland birds ma seem unusual, but given that measurements at used and unused or random locations were all within grassland habitat, it is not surprising that few differences in grass cover were found. Some forbs ma provide singing and displa perches or a suitable nesting substrate for some species, but the could also be avoided b other species that prefer habitats with high grass:forb ratios (Wiens 1973, Patterson and Best 1996). Horizontal coverage of dead vegetation ma be important because it is the onl source of available cover at the beginning of the breeding season, whereas other factors, such as live grass coverage, onl become important for concealment as the breeding season progresses (Davis 2005). Similar to litter, dead vegetation cover ma also reflect overall grassland health and different grazing intensities in rangelands (Schuman et al. 1999).

We found little evidence for a consistent influence of vegetation communit composition (i.e., evenness, richness, and diversit) or vegetation patchiness on grassland-bird habitat use. However, vegetation communit composition is likel often linked to vegetation structure. Also, the absence of an effect of vegetation patchiness ma result from the small scales at which these parameters are usuall measured (i.e., within the same plot or even within the same territor), whereas studies examining habitat heterogeneit at larger scales have found an important influence on grassland-bird distribution patterns (Fuhlendorf et al. 2006).

We acknowledge that scale ma pla an important role in the variables we found important. For example, the presence of (or distance to) wood vegetation can negativel affect grassland-bird habitat use, but ma be more important at a larger landscape scale than within the small scales we examined (Coppedge et al. 2001). Grassland birds likel select habitat in a hierarchical manner, and so variables at different scales can be incorporated into models of habitat use to potentiall explain variation (Cunningham and Johnson 2006).

MANAGEMENT IMPLICATIONS

We suggest that editors and reviewers implore authors to report effect sizes of both significant and nonsignificant variables in ecological literature to facilitate quantitative reviews, similar to recent policies in medical publications (Gates 2002). Man of the studies we examined included multiple species with multiple explanator variables, making the reporting of this information difficult in a t pical space-limited, 5–6-page article. To alleviate this problem, we recommend inclusion of supplementar data in electronic format appendices as occurs in some electronic ecological journals (e.g., *Ecological Archives* in support of the journals *Ecology*, *Ecological Applications*, and *Ecological Monographs*) and is currentl being implemented b *The Journal of Wildlife Management*.

We recognize that advocating a completel standardized methodolog for quantif ing grassland habitat ma not be prudent given the diversit of habitats, species, stud objectives, and logistics. However, we strongl recommend researchers use standardized terms to describe vegetation, or at the ver least, provide explicit descriptions of these terms. For example, the term "vegetation height" in our review included measures such as maximum vegetation height (Davis 2005), mean vegetation height (Whitmore 1981), and the dm at which the tallest vegetation contacted the Robel or Wiens pole (Martin and Fors th 2003). Litter also had several definitions: mulch (Wiens 1969); unconsolidated plant material (Davis 2005); dead plant material that was oriented 0–45° to the ground (Winter et al. 2005b); unattached dead vegetation (Sutter 1997); and dead vegetation that was standing, but no longer vertical (Madden et al. 2000). Most studies simpl did not define litter or vegetation height.

In light of these discrepancies in variable descriptions, we recommend the following definitions: grass coverage as all graminoids not separated into more detailed categories of grass t pe (e.g., narrow- vs. broad-leaved); litter as the organic debris on the soil surface (i.e., the freshl fallen or slightl decomposed vegetal material on the soil surface [Smith et al. 1995]), and dead vegetation as standing dead vegetation that is attached to the soil; bare ground as an land surface not covered b vegetation, rock, or litter (Smith et al. 1995); forbs as an flowering plants that are not a graminoid (percent ground coverage should be estimated using a Daubenmire frame [Daubenmire 1959]); vegetation densit as the number of stems per unit area measured using the Wiens (1969) method (a single densit measurement of grass and forb vegetation t pes is likel sufficient to predict grassland-bird habitat use); vegetation volume as g/m^2, measured indirectl using the Robel et al. (1970) methodolog ; vegetation height (as often defined in plant ecolog) as the height where approximatel 80% of vegetation is growing below (and measured directl , accuratel , and consistentl using a ruler [Stewart et al. 2001]). Consistent and clearl defined terminolog is required to facilitate communication amongst stakeholders and researchers (Hall et al. 1997). Standardization of terms will facilitate replication of wildlife research and enhance our abilit to make broader generalizations and have greater confidence in general patterns that emerge from observational studies (Madden et al. 2000, Johnson 2002).

The large number of vegetation characteristics that have been measured in past grassland studies suggest uncertaint regarding what should be measured. Furthermore, it was unclear wh authors included certain variables in their anal ses (e.g., litter depth). We could not determine whether variables were related to a priori h potheses, metrics used b land managers, or were simpl replication of past measurements. We are not questioning the choices of these authors to include these variables in their anal ses, but we recommend authors present the ecological reasoning regarding these choices. Such reasoning will facilitate understanding of patterns and processes behind habitat selection of grassland birds (Clark and Shutler 1999). Current anal tical paradigms reinforce the need to determine in advance what variables are likel important and develop a priori h potheses and models (Burnham and Anderson 1998). Reduction of the number of variables examined in observational studies decreases anal tic complexit , as well as the probabilit of finding spurious relationships (Anderson et al. 2000).

Land managers must balance the cost of collecting a large number of samples or measuring a large number of vegetation characteristics (although these are not necessaril mutuall exclusive) with the benefits of developing habitat selection models with relativel high predictive abilit to allow informed decisions. Interestingl , few researchers evaluated whether their habitat selection models adequatel predicted abundance, occurrence, or nest-site selection across time and space, even though the primar focus of the research was to inform management. Inclusion of these

9 habitat variables and standardized terminolog should allow researchers to reduce their number of a priori h potheses and ultimatel provide land managers with useful decision-support tools.

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Appendix A. We reviewed previousl published literature (1969–2007) examining grassland-bird habitat selection. Presented are studies included in the literature review along with the number of vegetation variables examined (variables), the number of species-habitat models (models), the avian response variable(s) studied (response), and the major habitat t pe where the stud took place (grassland t pe).

Study	Variables[a]	Models[b]	Response[c]	Grassland type
Ahlering and Faaborg (2006)	4	1	D	Mixed native
Bajema et al. (2001)	15	1	O	Reclaimed mine
Bakker et al. (2002)	5	18	O	Mixed native
Bollinger (1995)	12	5	A	Planted[d]
Bossenbroek et al. (2005)	4	8	A	Tall, mixed, and short native
Br an and Best (1994)	4	5	NS	Waterwa s
Camp and Best (1994)	5	1	NS	Roadsides
Chapman et al. (2004)	3	1	A	Mixed native
Cunningham (2005)	3	7	O, A	CRP[e]
Davis (2005)	6	5	NS	Mixed native
Davis and Duncan (1999)	17	9	O	Mixed native and planted
Davis et al. (1999)	8	3	O	Mixed native
Delisle and Savidge (1997)	12	8	A	CRP
Dieni and Jones (2003)	13	6	NS	Mixed native
Fletcher and Koford (2002)	5	8	D	Tall native and restored
Fondell and Ball (2004)	6	2	NS	Planted pasture
Fritcher et al. (2004)	4	6	D	Mixed native
Giuliano and Daves (2002)	3	1	A, NS	Planted
Granfors et al. (1996)	5	2	NS	CRP
Grant et al. (2004)	3	14	O	Mixed native
Greer and Anderson (1989)	12	1	NS	Mixed native
Herkert (1994)	8	12	O	Restored native
Herkert and Glass (1999)	2	1	A	Tall native
Jones and Bock (2005)	2	9	NS, F, T	Tall native, planted, and sacaton
Kell et al. (2006)	4	4	A	Short and Chihuahuan desert transition zone
Kershner and Bollinger (1996)	3	1	NS	Airport grasslands
Knick and Rotenberr (1999)	8	5	O	Sagebrush
Koper and Schmiegelow (2006a)	4	11	D, Rich	Mixed native
Koper and Schmiegelow (2006b)	4	10	D, A, Rich	Mixed native
Koper and Schmiegelow (2007)	4	1	NS	Mixed native
Lusk et al. (2003)	8	1	NS	Mixed native
Madden et al. (2000)	9	10	O	Mixed native
Martin and Fors th (2003)	11	4	O, NS	Cropland
Maurer (1996)	8	6	D	Mesquite
McMaster and Davis (2001)	10	10	O, Rich, E	Planted and cropland
Nocera et al. (2007)	5	11	O, A, Rep	Agricultural
Norment et al. (1999)	6	5	A, Rich	Cool- and warm-season, pasture, fallow, forb-dominated, and old field
Patterson and Best (1996)	6	8	D, NS	CRP
Prescott and Murph (1999)	2	2	A, Rich	Planted and cropland
Reed (1986)	6	1	T	Mixed native
Rotenberr and Wiens (1980)	22	16	A	Tall, mixed, and short native
Scott et al. (2002)	10	7	O, A	Reclaimed mine
Sutter (1997)	20	1	NS	Mixed native
Sutter and Brigham (1998)	10	8	A	Planted
Sutter and Ritchison (2005)	12	3	NS	Grazed
Sutter et al. (1995)	5	2	A	Mixed native and planted
Vander Haegen et al. (1999)	14	7	O	Shrub-steppe
Vicker et al. (1999a)	9	12	O	Sand-plain
Warren and Anderson (2005)	10	3	NS	Planted
Whitmore (1981)	11	1	T	Reclaimed mine
Wiens (1969)	18	7	O, NS	Planted
Wilson and Belcher (1989)	10	7	A	Mixed native and planted pastures
Winter (1999)	3	1	D	Mixed native
Winter and Faaborg (1999)	9	4	D	Tall native
Winter et al. (2005a)	8	2	D, NS	Tall native
Winter et al. (2005b)	4	3	D	Tall native
Zimmerman (1988)	7	2	T	Tall native

[a] Includes onl small-scale vegetation variables. Does not include variables such as distances to edges or large-scale evaluations of plant cover t pe (e.g., using Geographic Information S stems or remote sensing). This number onl includes variables that were retained b original authors for statistical anal ses, not all vegetation factors that were measured.

[b] Includes onl those species that fit our criteria of a breeding grassland songbird.

[c] A = abundance, D = densit , O = occurrence (presence or absence), NS = nest-site selection, F = postfledgling habitat selection, T = territor selection, Rich = species richness, E = species evenness, Rep = Reproductive activit .

[d] Planted grassland included ha fields and pastures planted with exotic species.

[e] Land enrolled in the United States Department of Agriculture, Conservation Reserve Program.

Appendix B. We reviewed previousl published literature (1969–2007) examining grassland-bird habitat selection. Presented are the avian species studied in 57 published articles (Appendix A) that we included in our vote-counting anal sis.

Common name	Scientific name	Breeding habitat[a]
Horned lark	Eremophila alpestris	Grassland
Sedge wren	Cistothorus platensis	Grassland
Sage thrasher	Oreoscoptes montanus	Successional or scrub
Sprague's pipit	Anthus spragueii	Grassland
Common ellowthroat	Geothlypis trichas	Successional or scrub
Botteri's sparrow	Aimophila botterii	Grassland
Cassin's sparrow	Aimophila cassinii	Grassland
Cla -colored sparrow	Spizella pallida	Successional or scrub
Brewer's sparrow	Spizella breweri	Successional or scrub
Field sparrow	Spizella pusilla	Successional or scrub
Chestnut-collared longspur	Calcarius ornatus	Grassland
McCown's longspur	Calcarius mccownii	Grassland
Baird's sparrow	Ammodramus bairdii	Grassland
Grasshopper sparrow	Ammodramus savannarum	Grassland
Henslow's sparrow	Ammodramus henslowii	Grassland
Leconte's sparrow	Ammodramus leconteii	Grassland
Nelson's sharp-tailed sparrow	Ammodramus nelsoni subvirgatus	Wetland[b]
Vesper sparrow	Pooecetes gramineus	Grassland
Savannah sparrow	Passerculus sandwichensis	Grassland
Sage sparrow	Amphispiza belli	Successional or scrub
Black-throated sparrow	Amphispiza bilineata	Successional or scrub
White-crowned sparrow	Zonotrichia leucophrys	Successional or scrub
Song sparrow	Melospiza melodia	Successional or scrub
Lark sparrow	Chondestes grammacus	Successional or scrub
Lark bunting	Calamospiza melanocorys	Grassland
Dickcissel	Spiza americana	Grassland
Bobolink	Dolochonyx oryzivorus	Grassland
Western meadowlark	Sturnella neglecta	Grassland
Eastern meadowlark	Sturnella magna	Grassland
Brown-headed cowbird	Molothrus ater	Grassland
American goldfinch	Carduelis tristis	Successional or scrub

[a] Breeding Bird Surve breeding habitat designation (Sauer et al. 2007).
[b] But see Nocera et al. (2007).

Appendix C. We reviewed previousl published literature (1969–2007) examining grassland-bird habitat selection. Presented are the vegetation variables used to predict grassland-bird habitat use in 57 studies (Appendix A) grouped into 8 broad categories.

Abiotic horizontal coverage
- Bare ground
- Dung
- Rock

Biotic horizontal coverage
- Alfalfa (*Medicago* spp.)
- Annual forbs
- Annual grass
- *Artemisia* spp.
- *Atriplex* spp.
- Big sagebrush (*Artemisia tridentata*)
- Bitterbrush (*Purshia tridentata*)
- Black-grama (*Bouteloua eriopoda*)
- Blue-grama (*Bouteloua gracilis*)
- Brome (*Bromus* spp.)
- Broomsedge (*Andropogon virginicus*)
- Cactus
- Clover (*Trifolium* spp.)
- Common arrow (*Achillea millefolium*)
- *Cornus* spp.
- Creeping juniper (*Juniperus horzontalis*)
- Dandelion (*Taraxacum* spp.)
- Dead grass
- Dead vegetation
- False indigo (*Amorpha* spp.)
- Fescue (*Festuca* spp.)
- Forbs
- Grass (all t pes)
- Green rabbit brush (*Ericameria teretifolia*)
- Gre rabbit brush (*Chrysothamnus nauseosus*)
- Herbs
- Japanese brome (*Bromus japonicus*)
- June grass (*Koeleria macrantha*)
- Kentuck blue grass (*Poa pratensis*)
- Leaf spurge (*Euphorbia esula*)
- Lichen
- Litter
- Little bluestem (*Andropogon scoparius*)
- Live grass
- Live vegetation
- Mid-grass
- Moss
- Moss phlox (*Phlox hoodii*)
- Northern wheatgrass (*Elymus lanceolatus*)
- Obtuse sedge (*Carex obtusata*)
- Orchard grass (*Dactylis glomerata*)
- Perennial forbs
- Perennial grass
- Porcupine grass (*Stipa spartea*)
- *Rhus aromatica*
- *Rhus glauca*
- *Rosa* spp.
- Rothrock grama (*Bouteloua rothrockii*)
- Russian thistle (*Salsola kali*)
- Sedge
- Shadscale (*Atriplex confertifolia*)
- Short-grass
- Shrub
- Spruce-top grama (*Bouteloua chondrosioides*)
- Stiff sagebrush (*Artemisia rigida*)
- Stout-stemmed grasses
- Stubble
- Three awns (*Aristida* spp.)
- Three-tip sagebrush (*Artemisia tripartite*)
- Tree
- Vegetation (all t pes)
- Weeds

Appendix C. Continued.

- Western wheatgrass (*Pascopyrum smithii*)
- Wheat (*Triticum* spp.)
- Winterfat (*Krascheninnikovia lanata*)
- Wood
- *Yucca* spp.

Densit
- Broad-leaf grass
- Clumped grasses
- Dead vegetation
- Dwarf shrub
- Exotic grass
- Forb
- Grass (all t pes)
- Horizontal densit (board or pole)
- Litter
- Live vegetation
- Narrow-leaf grass
- Native grass
- Shrub
- Vegetation (all t pes)
- Vertical densit (board or pole)
- Wood vegetation

Litter depth

Patchiness
- CV Robel pole
- CV % grass coverage
- CV % live vegetation coverage
- CV % vegetation coverage
- CV forb ht
- CV litter depth
- CV max. − min. forb or shrub ht
- CV vegetation densit
- CV vegetation ht
- Heterogeneit index (HI) vegetation densit [a]
- HI litter depth
- Point to plant distance HI
- SD of vegetation ht

Richness; evenness; diversit
- Forb richness
- Forb species diversit
- Grass richness
- Grass species diversit
- Herb richness
- Plant richness
- Vegetation (general) diversit
- Vegetation diversit (horizontal plane)
- Vegetation diversit (vertical plane)
- Vegetation evenness

Vegetation ht
- Effective leaf ht
- Forb ht
- Max. grass ht
- Shrub ht
- Vegetation ht

Vegetation volume
- Horizontal screening cover (board or pole)
- Robel pole
- Vertical screening cover (board or pole)

[a] Rotenberr and Wiens (1980).