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RESEARCH ARTICLE

Geographical patterns in openland cover and hayfield mowing in the Upper Great Lakes region: implications for grassland bird conservation

R. Gregory Corace III · David J. Flaspohler · Lindsey M. Shartell

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Abstract Populations of many grassland bird species such as Grasshopper Sparrow (*Ammodramus savannarum*), Henslow's Sparrow (*A. henslowii*), and Bobolink (*Dolichonyx oryzivorus*) have experienced considerable declines over the last century. To foster multi-species grassland bird conservation in the Upper Great Lakes (UGL) states of Michigan, Minnesota, and Wisconsin, we quantified geographic patterns within three sub-regional zones (e.g., North, Central, and South) of the UGL. Patterns of interest included the distribution and abundance of openland cover type (including managed pasture-hayland), the distribution, phenology, habitat affinity, and long-term population trends of ten grassland bird species, and (in particular) the geographic patterns in hayfield mowing and the temporal changes in hayfield cover. Approximately 10, 38, and 53% of the UGL openland was proportioned in the North, Central, and South zones, respectively. The distribution of hayland also varied by zone: North, 17%; Central, 46%; and South, 37%. In the central portion of the UGL where the greatest area is devoted to hay production, alfalfa—more intensively managed than mixed-grass hay—predominates. Although we found significance differences ($P < 0.05$) in hayfield mowing intensity between zones (with the majority of land under relatively low-intensity mowing found in the North Zone, particularly the Upper Peninsula of Michigan) no strong relationships were found between hayfield mowing patterns, other land cover-land use variables, and bird population trends at finer scales of study. Nonetheless, we suggest that the geographic patterns illustrated here provide useful information for grassland bird conservation planning across the UGL.

Keywords Bobolink · Conservation planning · Grassland birds · Hayfields · Midwest · Michigan · Minnesota · Wisconsin

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Introduction

Many grassland bird species have experienced substantial, long-term population declines throughout much of North America (Bollinger and Gavin 1992; Thompson et al. 1993; Herkert et al. 1996; Herkert 1997). However, considerable geographic variation exists among many ecoregions in population sizes and trends of many grassland bird species (Sauer et al. 2007). Although the causes for such geographic variation are yet unknown, the major reason for the decline in grassland bird populations throughout North America is almost certainly the loss of native grassland habitats (Askins 2000; Askins et al. 2007). No other North American ecosystem has experienced a more consistent and dramatic decline in extent and quality than native prairie (Samson and Knopf 1994; Knopf 1996; Bachand 2001). Grasslands once covered nearly 17% of the continent, but changing land use patterns, especially the concomitant spread of intensive agricultural practices, have greatly reduced the extent of all native grassland types (Warner 1994). Tallgrass prairie alone has declined by 99%, and intact areas that remain are relatively small, isolated, and non-representative (Fletcher and Koford 2002).

Because of the extensive loss of native grassland habitats, other non-forested, upland cover types (hereafter, openlands) found on a range of ownership types (e.g., private lands, public lands, other conservation lands, etc.) have become increasingly important as surrogate habitat for many grassland bird species. For example, in Wisconsin, <1% of the pre-European settlement native grassland remains, yet 105 bird species still regularly or occasionally use openland cover types—like privately owned managed hayfields—during the breeding season for courtship, foraging, nesting, or roosting (Sample and Mossman 1997). Consequently, throughout the Upper Great Lakes (UGL) states of Michigan, Minnesota, and Wisconsin, openland cover types (including the nearly 23,000 km^2 of actively managed hayland, USDA 2000) provide important breeding habitat for many bird species of conservation priority.

Interest in the conservation value of hayfields has prompted a number of studies into the relationships between grassland birds and hayfield habitat at different spatial scales. At relatively broad spatial scales, researchers have documented temporal changes in hayfield cover and structure within agricultural-dominated regions and related these findings to bird population trends (e.g., Bollinger and Gavin 1992; Warner 1994; Herkert et al. 1996; Koford and Best 1996; Herkert 1997; Murphy 2003). At the landscape scale, Ribic and Sample (2001) tested bird-hayfield habitat associations and found landscape composition in an agricultural matrix to be an important predictor of grassland bird habitat quality. Finally, at the field scale, relationships have been identified between a number of habitat variables (e.g., vegetation composition and structure, field age, litter depth) and demographic and community traits such as abundance, density, productivity, and bird diversity in hayfields and other anthropogenic grassland habitats (Vickery et al. 1994; Bollinger 1995; Millenbah et al. 1996; Best et al. 1997; Corace et al. 2005). Other studies at the field scale have documented how relatively high intensity hayfield management practices negatively impact productivity (Bollinger et al. 1990; Perlut et al. 2006).

Because broad-scale conservation planning requires consideration of geographic variation in patterns and processes, the purpose of this study is to provide the first multi-scaled geographic assessment for the UGL that investigates the distribution and abundance of openland cover types, the distribution, phenology, and habitat affinity of ten grassland bird species, and geographic patterns in hayfield mowing and the temporal changes in hayfield cover. These findings are then compared relative to the long-term population trends of grassland bird species in the region. Of special interest in this study is the quantification of geographic patterns in hayfield mowing. Because past research has linked intensive mowing of hayfields with reduced grassland bird productivity by altering the cover of habitat and by directly destroying nests, eggs, and young (Bollinger et al. 1990; Horn and Koford 2000; Broyer 2003; Perlut et al. 2006), a broad-scale assessment that describes geographic patterns in hayfield mowing is likely to have multiple planning uses.

Working within both agricultural-dominated and forest-dominated ecoregions of the UGL, this assessment focuses on three primary scales of interests, namely (1) the UGL regional scale, (2) sub-UGL regional or latitudinal zones (e.g., North, Central, South), and (3) the county scale. In taxonomic order, our selected species (and their four-letter species codes) are: Upland Sandpiper (*Bartramia longicauda*, UPSA), Grasshopper Sparrow (*Ammodramus savannarum*, GRSP), Henslow's Sparrow (*A. henslowii*, HESP), Le Conte's Sparrow (*A. leconteii*, LCSP), Savannah Sparrow (*Passerculus sandwichensis*, SAVS), Vesper Sparrow (*Pooecetes gramineus*, VESP), Dickcissel (*Spiza americana*, DICK), Bobolink (*Dolichonyx oryzivorus*, BOBO), Eastern Meadowlark (*Sturnella magna*, EAME), and Western Meadowlark (*S. neglecta*, WEME). In light of climate change and the shifting distribution patterns of many bird species (Hitch and Leberg 2007), we believe the patterns presented in this study have implications for broad-scale grassland bird conservation planning in the UGL.

Methods

The UGL, as described in the ecological classification system of McNab and Avers (1994), consists of three broad-scale ecoregions or latitudinal zones. These ecoregions closely approximate the three United States Geological Survey Breeding Bird Survey (BBS) "physiographic strata" which are discussed in subsequent analyses and from which population trend data are derived (Fig. 1). For the purpose of this paper, we refer to these three ecoregions and their corresponding three physiographic strata (together) as "zones".

Northern portions of the UGL are included in our North Zone. The North Zone is characterized by gently rolling glacial ground moraine, flat and pitted outwash, and lacustrine plain covered by sand. Elevation varies from 176 to 695 m. Average annual precipitation is 0.65–1.1 m. Snowfall can be considerable due to lake effect, ranging from 1.6 to 8.3 m. Close proximity to the Great Lakes results in a cool lacustrine climate. Mean annual temperature is 2–7°C (McNab and Avers 1994).

The southern portions of Michigan and Wisconsin and the southeastern part of Minnesota are included in our Central Zone. This zone is characterized by till, outwash, and lacustrine formations. Pleistocene glacial drift and loess cover most of this area. Elevation ranges from 175 to 500 m. Average annual precipitation varies from 0.65 to 0.93 m. Mean annual temperature is 4–11°C (McNab and Avers 1994).

The western portion of Minnesota is included in our South Zone. This zone is characterized as a large, level lacustrine plain. Some areas are nearly flat; others have high rounded hills. Pleistocene till and lacustrine sand-silt-clay-peat-muck cover bedrock. Elevation range is 250–350 m. Average annual precipitation ranges from 0.47 to 0.58 m, with 40% occurring during the growing season. Mean annual temperature is 2–7°C (McNab and Avers 1994).

To assess the extent and distribution of all cover types, we tabulated the proportions of each latitudinal zone, each state, and each county in National Land Cover Data (NLCD 1992) openland cover types. Based on previous work (Corace 2007), we considered openland to consist of the following five upland NLCD cover types: shrubland, small grains, pasture, row crops, and grasslands (unmanaged grassland-dominated areas). Other non-forested upland cover types (e.g., orchard-vineyards) were excluded because of their relatively small area. Because NLCD does not split hayfield and pasture and does not differentiate between alfalfa and mixed-grass hayfields, we also used National Agricultural Statistics Service (NASS) data (USDA 1997, 2000) to

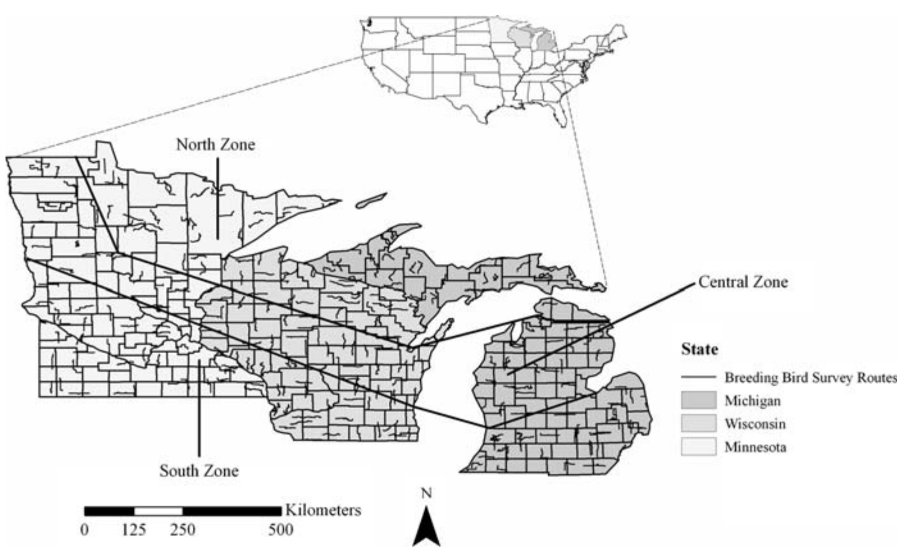

Fig. 1 Upper Great Lakes latitudinal zones that approximate ecoregions of McNab and Avers (1994) and associated Breeding Bird Survey (*BBS*) routes (Sauer et al. 2007)

characterize the composition and distribution of different types of hayfield cover in the UGL.

Because of the roadside, point count methodology used in the BBS, and the conspicuous nature of many grassland birds during the breeding season, the BBS provides an appropriate data set for comparing geographic patterns in population trends (Peterjohn 2003). Consequently, BBS route-level data from 1966 to 2003 (Sauer et al. 2007) were used to compare bird population trends among the North, Central, and South Zones (Fig. 1). BBS routes were assigned to each of the three zones only if >90% of the length of a given route was within a given zone. The total number of possible BBS routes for each zone was 82 for the North Zone, 89 for the Central Zone, and 129 for the South Zone. From these samples, we then deleted any routes with either a trend value of zero (i.e., no documentation of a given species), trend values for a given species based on <10 years of data, and any outliers (i.e., triple digit trend values, etc.). This methodology produced different sample sizes for each zone for each species, and also provided an index of the distribution and abundance of species across the zones (i.e., small trend data sample sizes indicate species that are generally not evenly distributed or are at low abundance in a given zone).

Information regarding grassland bird cover type specificity was compiled through a literature review (e.g., Brewer et al. 1991; Sample and Mossman 1997) and the relative value of hayfields for each species was categorized as "High," "Moderate," or "Low." Bird species arrival times on regional breeding grounds were characterized as "Early" (i.e., March to early April)," "Middle" (i.e., mid-April to early May), or "Late" (i.e., mid-May or later) in the season based on a literature review that consisted of generalized state-level summaries (e.g., Janssen 1987; Barger et al. 1988; Brewer et al. 1991) and more geographically focused work (e.g., Verch 1999). During this review, we tried to account for the lag time between species arrival dates in the South Zone and the North Zone. However, although information regarding arrival times was not geographically uniform in its type or quality (i.e., most sources provided a general range of dates of arrival, not specific dates) the literature review suggested general patterns of relative arrival times that were relatively consistent across latitudinal zones in the region. We chose to use arrival times rather than beginning of breeding as a phonologic metric of interest because (1) our literature review provided more consistent information regarding arrival times and (2) site selection for breeding may be influenced by hayfield composition and structure (Herkert 1997; Murphy 2003) which themselves are affected by hayfield mowing that occurs before breeding begins.

Because no data presently exist that describe UGL hayfield mowing patterns per se, we developed a survey to characterize hayfield mowing intensity for each county in the region. During 2001 and 2002, the following questions were directed at resource professionals who have experience with local hayfield management and who work for the United States Department of Agriculture Natural Resources Conservation Service (NRCS), state extension agencies, and land grant institutions:

1. By what date are the majority (>50%) of hayfields mowed for the first time in a given season (date of first harvest)?;
2. How many times are the majority of fields mowed in a season (number of harvests)?;
3. In fields that are mowed more than once, approximately how many weeks elapse between harvests (weeks between harvests)?

These questions were derived from reported effects of hayfield mowing on grassland birds (Bollinger 1995; Sample and Mossman 1997; Dechant et al. 1999). Date of first mowing was of interest because it would likely alter early breeding season habitat quality and site selection for birds. The number of harvests is important because the more often a field is cut the more likely it is that this activity will directly reduce nesting success. We assumed the number of weeks between cuts was important because it can be related to the minimum period between nest initiation and fledging which is about 25–35 days for most open cup-nesting passerines (Ehrlich et al. 1988).

Responses to our questions were transformed into categorical data. For question 1, results were categorized either as the 1st, 7th, 14th, or 21st of a given month using the following rules: when the respondent stated that most fields were harvested, "around the first of June," a date of 1 June was assigned, when "early June" was given as an answer, a date of 7 June was assigned. "Mid-month," or "late-month," were

Table 1 Values assigned to different levels of each hayfield mowing characteristic and used to calculate an Index of Mowing Intensity (*IMI*) for the Upper Great Lakes region

Mowing characteristic	Response value(s)	Intensity value
Date of first harvest	14–21 May	5
	1–7 June	4
	14–21 June	3
	1–7 July	2
	14 July or later	1
Number of harvests	3–4	3
	2	2
	1	1
Weeks between harvests	1–4	3
	5–8	2
	>8 or 1 harvest	1

assigned dates of 14 and 21 June, respectively. When specific dates were given (e.g., 4th of July) these were rounded to the nearest corresponding categorical value (e.g., 7 July). To handle the variation in responses given to question 2 (above), a mid-range value was assigned when appropriate. If a respondent stated that most fields are harvested "between 3 and 4 times," a value of 3.5 was recorded; the same method was used for question 3. Data were summarized and returned to resource professionals for review and corrections. A geographic information system was used to create maps of these data.

To produce a geographically explicit means of integrating these hayfield mowing parameters, we devised an Index of Mowing Intensity (IMI) in a manner similar to that used for regional conservation planning purposes (Carter et al. 2000) and global

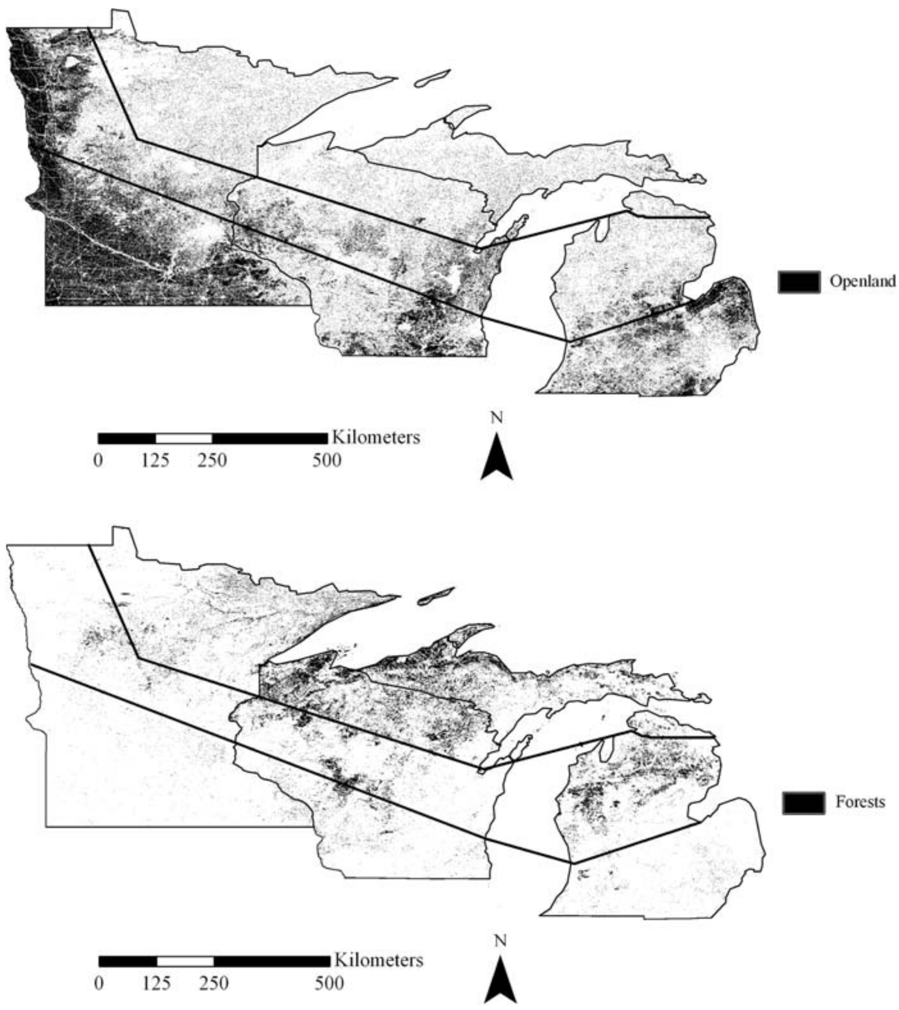

Fig. 2 Area in (*top*) openland cover types and (**b**) forest cover typs by state and sub-regional zones (North, Central, South) in the Upper Great Lakes region (National Land Cover Data 1992)

environmental assessments (Sanderson et al. 2002). Using values for the date of first harvest, number of harvests, and weeks between harvests, we produced an index whereby higher values denote more intensive hayfield mowing practices (Table 1). We then summed values for the three mowing characteristics to produce an overall index for each county. For counties lacking mowing data, we produced an IMI based on the mean IMI from all bordering counties. A mean IMI (with standard deviation) was then calculated for each zone. Because our zone lines (Fig. 1) dissect some counties, border counties were included into the zone in which the greatest proportion of that county's area was found. One-way analysis of variance (ANOVA) followed by Tukey's pairwise comparisons (Zar 1999) were used to test the significance of differences ($\alpha = 0.05$) between the IMI for each zone.

Based upon findings from the above work, we then increased the spatial resolution of our analysis by examining the relationships between population trends (response variable, BBS population trend data for 1966–2003) for a subset of bird species (e.g., Bobolink, Dickcissel, Grasshopper Sparrow, Savannah Sparrow, Eastern Meadowlark, Western Meadowlark) and proportional change in area in county hayfield cover (NASS data for 1966–2000), current proportional county land cover (NLCD), and hayfield mowing characteristics (IMI and individual components) using Pearson correlations for individual variables and step-wise multiple regression (Zar 1999). Bird species included in this subset were selected based on their moderate to high affinity for hayfields, their relatively broad distribution across the UGL, and the availability of BBS population trend data. BBS routes were selected based on three criteria: presence of two or more bird species on a given route, the majority (>90%) of a route residing within one county based on visual inspection, and only one route per county. In instances where more than one route per county were found based on the prior two criteria, we randomly selected which one route to include in the analysis. NLCD input variables included % area of county in: pasture-hayland, row crops, small grains, shrubland, grassland, all forest, residential, and other. During the stepwise procedure, an independent variable had to be significant at $\alpha = 0.10$ to be entered or removed. Models presented were the most parsimonious.

Results

Of the 14,191,100 ha of NLCD openland cover in the UGL, row crops represent the dominant cover type at 64.7% (9,189,200 ha), followed by pasture-hayland at 30.7% (4,354,100 ha), and all other openland cover types combined (4.6%). The percentage of the total regional openland cover increases from the North Zone to the South Zone and concomitantly the area in

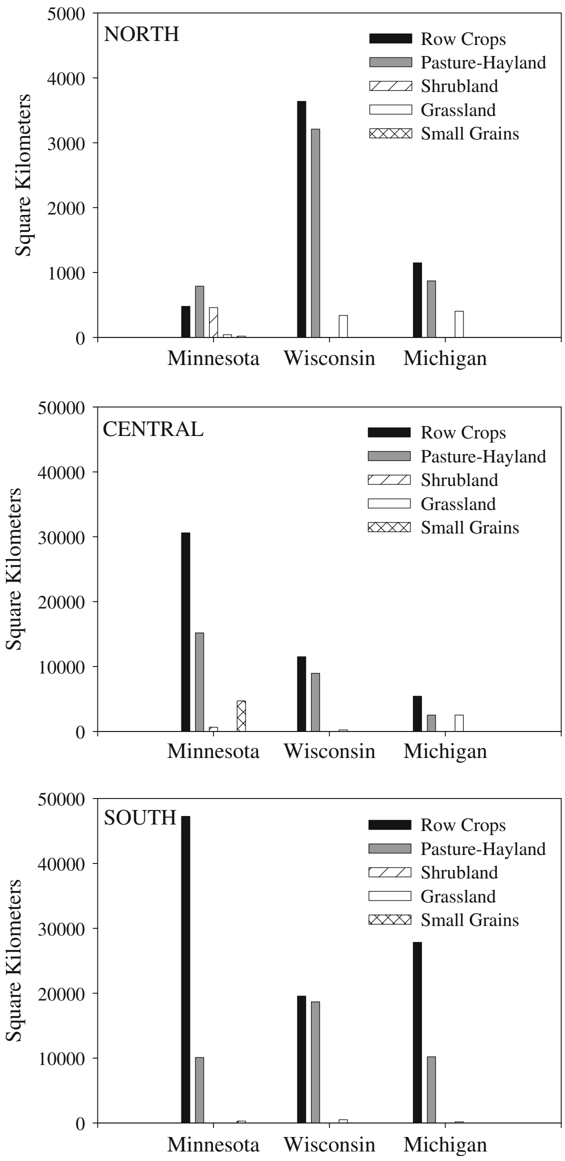

Fig. 3 Area in openland cover types by state and sub-regional zones (North, Central, South) in the Upper Great Lakes region (National Land Cover Data 1992). Note scale differences

Table 2 Breeding cover type affinity and breeding phenology for ten species of ground-nesting grassland birds in the Upper Great Lakes region

Species code	Breeding status by hayfield type[a]		Number other cover types used[b]	Relative value of hayfield	Regional timing of arrival on breeding grounds[c]
	Alfalfa	Mixed-grass			
WEME	Common[c]	Common	5	High	"Early"
					Early March to early May, peak in late March-early
					April[1]
					Early March[2]
					Early March, peak in mid April in Lower Pen.[3]
					April 29[4]
SAVS	Very Common	Very Common	7	Moderate-High	"Middle"
					Early April to late May, peak late April a nd early May[1]
					Late April[2]
					Mid to late April[3]
					April 24[4]
BOBO	Very Common	Very Common	9	Moderate-High	"Late"
					Late April to late May, peak mid May[1]
					Early May[2]
					Late April to early May, peak in Upper Pen.
					middle May[3]
					May 10[4]
UPSA	Infrequent	Infrequent	2	Moderate	"Middle"
					Mid April to late May, peak early May[1]
					Early May[2]
					Mid April[3]
GRSP	Common	Common	8	Moderate	"Middle"
					Mid April to late May, peak early May[1]
					Early May[2]
					Early May[3]
DICK	Common	Common	5	Moderate	"Late"
					Early May to early June, peak late May[1]
					Early May[2]
					Mid to late May[3]
EAME	Common	Common	8	Moderate	"Early"
					Early March to early May, peak early April[1]
					Mid March[2]
					Early March, peak in mid April[3]
					March 31[4]
HESP	Uncommon	Uncommon	3	Low	"Middle"
					Late April to late May[1]
					Early May[2]
					Mid April-mid May[3]

Table 2 continued

Species code	Breeding status by hayfield type[a]		Number other cover types used[b]	Relative value of hayfield	Regional timing of arrival on breeding grounds[c]
	Alfalfa	Mixed-grass			
LCSP	Avoided	Infrequent	3	Low	"Middle" Mid-April to Late May, peak early May[1] Early May[2] Late April to early May[3] May 8[4]
VESP	Infrequent	Infrequent	9	Low	"Middle" Late March to mid-May, peak mid to late April[1] Early May[2] Late March Lower Pen., later further north[3] Mid April[4]

The relative value of hayfields is based on the importance to each species. Species are listed from high affinity to low affinity for hayfields

[a] In the case of all species, affinity for alfalfa fields is based on response to fields older than 1 year and which are comprised of other grasses, but with alfalfa still dominant

[b] Other cover types used include row crop, small grain, fallow field, pasture, idle grass, old field, upland shrub, prairie, savanna, sedge meadow, sedge marsh, shrub swamp, bog, barrens, forest clearcut, young conifer plantation, orchard, park, and golf course (see Sample and Mossman 1997)

[c] Information based on summaries from state and regional sources: [1] Janssen (1987); [2] Barger et al. (1988); [3] Brewer et al. (1991); [4] Verch (1999)

forest cover types declines (Fig. 2). Approximately 9.6, 37.5, and 52.9% of all Upper Great Lakes regional NLCD openland cover is proportioned in the North, Central, and South zones, respectively. Dominant openland cover also varies by zone, with the vast majority of shrubland and grassland in the North Zone and more small grains and row crops (both more intensively managed than shrubland and grassland) in the Central and South zones (Fig. 3).

Throughout the UGL, a substantial change in NASS hayfield area has occurred from 1966 to 2000. On average (±1 SD) the percent area of a county in hayfield cover has declined −3.4% (±4.2%), with the greatest loss of hayfield cover in Brown County, WI (−15.4%) and the greatest gain in hayfield cover in Osceola County, MI (3.8%). Of all 242 counties in the UGL, 201 (83.1%) showed declines in hayfield cover over 1966–2000, whereas only 34 (14.0%) had an increase in hayfield cover. The remaining counties showed no change in the percent area of a given county comprised of hayfield cover.

Currently, the distribution of the total NASS hayland in the region varies by zone: North Zone = 16.8% (389,169 ha), Central Zone = 46.2% (1,053,046 ha), and South Zone = 37.0% (847,015 ha) (Fig. 3). The amount of hayland reported on a county level ranges from 18 to 48,603 ha. This corresponded to counties with <1.0–4.2% of area in NASS hayland in the region. In the central portion of the UGL where the greatest area is devoted to hay production, alfalfa—more intensively managed than mixed grass hay—predominates (Marshall et al. 1998).

Our literature review suggests that hayfields are commonly or very commonly used in the region by six species (Western Meadowlark, Savannah Sparrow, Bobolink, Grasshopper Sparrow, Dickcissel, Eastern Meadowlark) (Table 2). Four species (Upland Sandpiper, Henslow's Sparrow, Le Conte's Sparrow, Vesper Sparrow) use hayfields infrequently or avoid them. Relative to other cover types used by each species, the value of hayfield is "Moderate" to "High" for seven species: Western Meadowlark, Savannah Sparrow, Bobolink, Upland Sandpiper, Grasshopper Sparrow, Dickcissel, and Eastern Meadowlark (Table 2). The majority (8 of 10) of bird species are classified as breeding during either "Middle" or "Late" in a given season. Only Eastern and Western Meadowlarks are considered "Early" breeders (Table 2).

Other than Le Conte's Sparrow and Upland Sandpiper, the other eight grassland bird species were found more commonly in the South Zone, as indexed by the percentage of routes with BBS data (Table 3). Population declines were more pronounced in the North Zone for Eastern Meadowlark (slight), Henslow's Sparrow, Vesper Sparrow, and Western Meadowlark. Besides Western Meadowlark, these species have Moderate to Low habitat affinity for hayfield habitat. Conversely, all four species with more pronounced population declines observed in the South Zone have Moderate to Moderate-High affinity for hayfield habitat: Bobolink, Grasshopper Sparrow, Savannah Sparrow, Upland Sandpiper (Table 4).

Table 3 Sample sizes of Breeding Bird Survey routes (percent of all Breeding Bird Survey established routes) used to determine sub-regional (zonal) population trends for ten species of grassland birds in the Upper Great Lakes region (Sauer et al. 2007)

Species	North Zone	Central Zone	South Zone
Bobolink	34 (41)	64 (72)	64 (50)
Dickcissel	7 (9)	29 (33)	47 (36)
Eastern Meadowlark	39 (48)	68 (76)	75 (58)
Grasshopper Sparrow	16 (20)	50 (56)	58 (45)
Henslow's Sparrow	6 (7)	15 (17)	16 (12)
Le Conte's Sparrow	14 (17)	14 (16)	–
Savannah Sparrow	37 (45)	61 (69)	63 (49)
Upland Sandpiper	16 (20)	39 (44)	28 (22)
Vesper Sparrow	29 (35)	59 (66)	62 (48)
Western Meadowlark	25 (31)	43 (48)	50 (39)

Other than Le Conte's Sparrow which is not found in the South Zone, all zones have all species

We received responses from regional resource professionals representing 213 of the 242 counties (88.0%) in the three states. The response rate for each state was: Michigan, 74 of 83 counties (89.2%); Minnesota, 82 of 87 counties (96.5%); and Wisconsin, 57 of 72 counties (79.2%). Raw data illustrates considerable geographic variation in hayfield mowing practices (Fig. 4).

The map for the Index of Mowing Intensity (IMI) shows significant differences among ($F = 41.1$, $df = 2$, $P < 0.01$) and between ($P < 0.05$) the three latitudinal zones (Figs. 5, 6). The majority of land under relatively low-intensity mowing is found in the North Zone, particularly the Upper Peninsula of Michigan. On average, hayfields in counties of the Central and South Zones are managed more intensively (Fig. 5).

For the entire area covered by the UGL, we were able to match population trend data from 98 BBS routes having >2 of our subset of six grassland bird species with data describing proportional changes in area in county hayfield cover, proportional area in NLCD cover types, and hayfield mowing patterns. For only four species (Boblink, Eastern Meadowlark, Grasshopper Sparrow, Western Meadowlark) were we able to find significant ($P < 0.10$) correlations between population trends and our independent variables (Table 5). The loss of pasture-hayland at the county scale was positively correlated with declining population trends for Eastern Meadowlark and positively correlated with declining trends for Grasshopper Sparrow. All other correlations made involved existing NLCD land cover. However, our overall models poorly explained population trends. Other than Eastern Meadowlark ($R^2 = 12.10$) the

Table 4 Average (±1SD) sub-regional (zonal) population trends for ten species of grassland birds in the Upper Great Lakes region (Sauer et al. 2007)

Species	North Zone	Central Zone	South Zone
Bobolink	−1.11 (9.61)	−2.58 (10.47)	−5.89 (8.92)
Dickcissel	−5.82 (15.14)	−8.99 (14.13)	−4.37 (19.33)
Eastern Meadowlark	−6.76 (14.00)	−6.31 (13.82)	−4.93 (13.27)
Grasshopper Sparrow	0.89 (17.13)	−3.07 (27.59)	−13.42 (17.22)
Henslow's Sparrow	−16.98 (30.01)	−1.90 (18.07)	−4.22 (23.62)
Le Conte's Sparrow	−5.10 (22.19)	−4.56 (13.00)	–
Savannah Sparrow	0.84 (9.36)	−0.80 (8.52)	−3.30 (9.02)
Upland Sandpiper	−1.48 (13.65)	−0.55 (15.24)	−4.41 (19.85)
Vesper Sparrow	−8.04 (8.79)	−4.64 (7.19)	−5.54 (7.61)
Western Meadowlark	−12.47 (13.99)	−7.86 (13.92)	−10.27 (12.46)

Other than Le Conte's Sparrow which is not found in the South Zone, all zones have all species

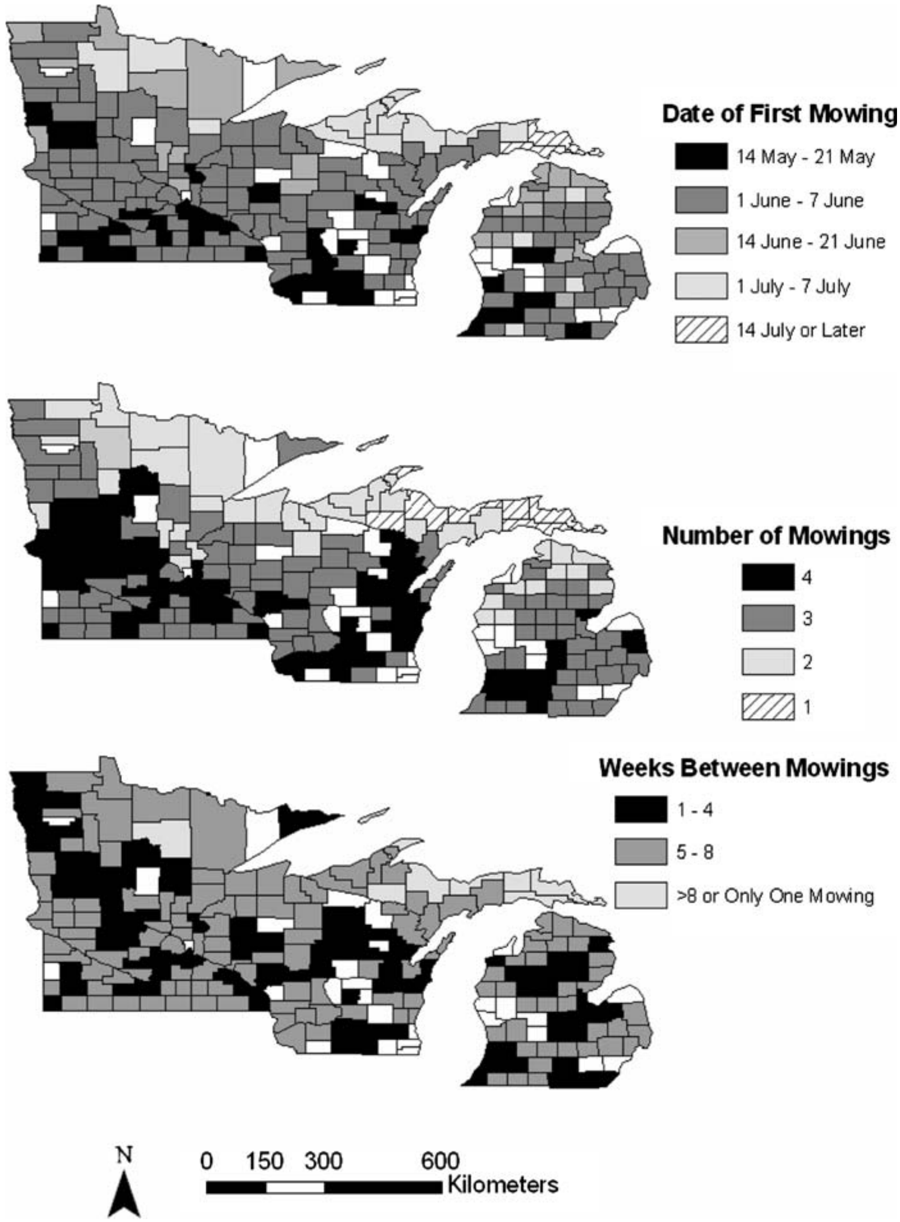

Fig. 4 County-level hayfield mowing characteristics for the Upper Great Lakes region. Counties lacking data are not filled

other three generated models explained <5% of the observed patterns in population trends at the county level (Table 5).

Discussion

Ecological patterns and processes and the impacts of land use often vary among ecoregions and species. Consequently, conservation planning must consider patterns and processes at relatively broad spatial scales (O'Connor et al. 1999; Corace 2007). For instance, information at broad scales provides context to assess the relative importance of any region with respect to extent, availability, and quality of cover types. Such basic information is necessary for multi-species conservation plans—or recovery plans for listed species under the Endangered Species Act—if we are to provide multiple benefits from conservation or restoration activities.

Although previous work by Perlut et al. (2006) has suggested that grassland bird species nesting in

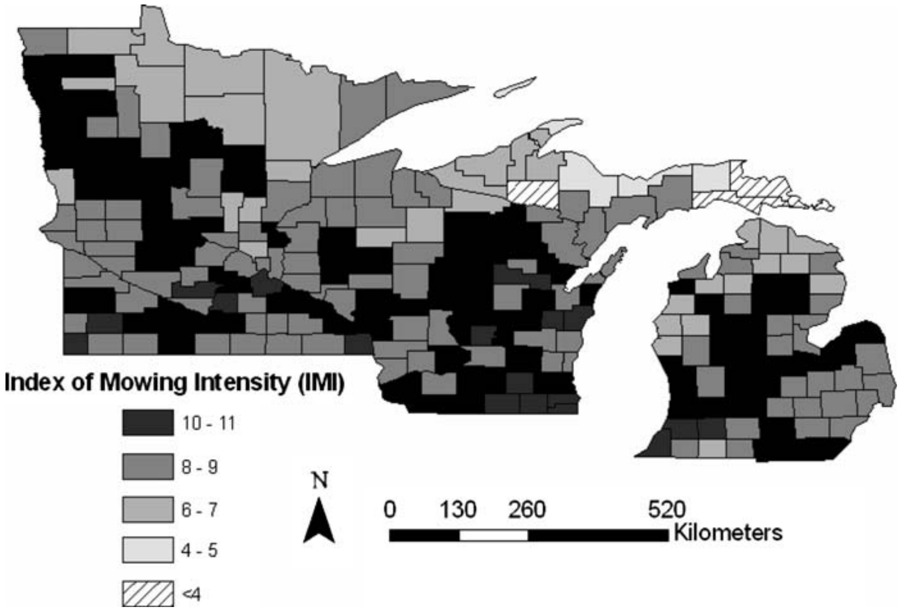

Fig. 5 Index of Mowing Intensity (*IMI*). Larger IMI values (*darker colors*) correspond to hayfields mowed more intensively

hayfields respond differently to management treatments and that early (and repeated) mowing negatively impacts all species studied, we found no strong relationships between hayfield mowing patterns and bird population trends. Instead, at the county-scale, population trends for the subset of species we studied were better explained by patterns in existing cover types. Other possible reasons for population declines in the UGL for the species studied include an increased proportion of area in non-suitable openland cover types (such as row crops) and the loss of farmland to other land uses (Sample and Mossman 1997). In accordance with our finding, Wolter et al. (2006) observed that on average the area in farmland in the three UGL states declined by −10.4% over the period 1982–1992.

In light of the high levels of uncertainty inherent with bird population trend data (Sauer et al. 2007) and the fact that no clear and consistent relationships existed between our findings of hayfield mowing intensity and grassland bird population trends, we nonetheless believe this study has important broad-scale grassland bird conservation planning implications, especially in light of the effect of climate change on bird species distributions (Hitch and Leberg 2007) and the increasing need to conserve farmland habitats (Sample and Mossman 1997). In particular, we believe our finding of significant differences ($P < 0.05$) in hayfield mowing intensity among the three latitudinal zones (with the majority of land under relatively low-intensity mowing was found in the North Zone, particularly the Upper Peninsula of Michigan) is a novel addition to the knowledge base used by bird conservation planners. Our quantification of hayfield mowing patterns indicates that this important ecological process that maintains surrogate grassland habitat exists along a latitudinal gradient of intensity in the UGL. Moreover, we suggest the impacts of this ecological disturbance vary among species due at least to range and habitat affinity differences. For instance, mowing intensity in the Central and South Zones may negatively affect all species except Le Conte's Sparrow and Vesper Sparrow. For these two species, adverse mowing effects appear to be minimized by their relative lack of affinity for hayfields and, in the case of Le Conte's Sparrow, distribution patterns. We also observed management patterns that suggest that the *magnitude* of the impact could vary by species. Regional populations of Grasshopper Sparrow, Savannah Sparrow, Bobolink, Dickcissel, Eastern Meadowlark, and Western Meadowlark have the most potential to be negatively affected by the observed patterns in hayfield mowing as they generally have a moderate to high affinity for hayfield habitat and are found in greatest numbers in the South Zone where hayfield management intensity tends to be greatest. Species-specific responses among

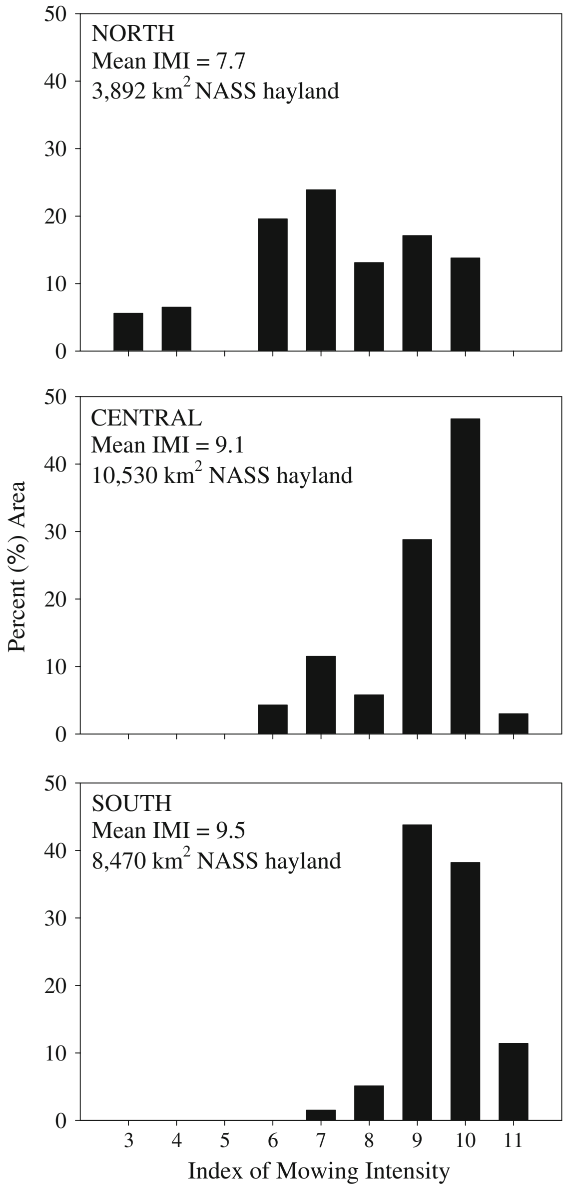

Fig. 6 Percent area (at the county-scale) of each latitudinal zone by Index of Mowing Intensity (*IMI*). Larger IMI values depict more intensively managed hayfields. Amount of National Agricultural Statistics Service (*NASS*) hayland in each zone shown for reference

grassland birds to hayfield management practices have been noted elsewhere in North America (Askins et al. 2007), including the Midwest (Dechant et al. 1999), and Europe (Broyer 2003).

We suggest that the significant difference in hayfield mowing observed among the three latitudinal zones of the UGL is largely driven by climatic differences. In the more continentally influenced portion of the UGL in Minnesota and Wisconsin, larger IMI values may be the result of hayfields maturing at earlier dates and growing more rapidly. Conversely, in more lacustrine-influenced areas of the North Zone (such as the Upper Peninsula of Michigan) proximity to the Great Lakes may reduce hayfield growing season length and thus effects when hayfield are first cut and how often hayfields can be cut. In regards to the observed variation in hayfield management intensity *within* specific zones of the UGL, we suggest variation may be a result of changes in agricultural land use. In areas that were once more agriculturally dominated and are now suburban, the NRCS professionals we interviewed indicated that hayfields are being managed to produce feed for horses, not cattle as they once were. Because hay fed to horses is often nutritionally inferior to hay fed to cattle (Pearson et al. 2006), the remaining hayfields found near more urban areas may be managed less intensively for horse feed. Moreover, because these “hobby farmers” are less likely to be driven by economic factors, the management of hayfields may be less intense.

The patterns of hayfield mowing in the UGL and other recent research (Corace 2007) suggest that relatively less intensively managed agricultural or unmanaged openland landscapes of the North Zone may maintain small, yet self-sustaining (or even source) populations of some grassland bird species if other processes (e.g., scale-dependent landscape effects, predation) are offset by a likely decline in mortality due to haying. By providing a surrogate habitat type that would otherwise not exist in the North Zone, low intensity hayfield mowing may benefit many of the species considered here and others species such as Sharp-tailed Grouse (*Tympanuchus phasianellus*), Northern Harrier (*Circus cyaneus*), and Short-eared Owl (*Asio flammeus*) (Corace 2007). However, we recognize that a number of grassland (or openland) bird species breed at relatively low density in northern portions of the UGL compared to more southern portions of the region that were historically dominated by native grasslands or mesic forests and are now predominately in high-intensity agricultural land use (i.e., eastern Midwest, Central and South Zones). Moreover, the area of pasture-hayfield in the two more southern zones is approximately nine times greater

Table 5 Models generated for county-level relationships between land use and cover type variables, hayfield mowing patterns, and population trends for four grassland bird species of the Upper Great Lakes region

Species code	Pearson correlation (variable, *P* value)	Model (*P* value)	Model R^2
BOBO	−0.18 (% NLCD small grain, $P = 0.09$)	−1.82–107% NLCD grain ($P = 0.09$)	3.06
EAME	−0.23 (% decline NASS hay, $P = 0.05$)	3.57–21.1% NCLD forest ($P = 0.00$)	12.10
	0.26 (% NLCD hayland-pasture, $P = 0.02$)		
	0.21 (% NLCD row crop, $P = 0.07$)		
	0.20 (% NLCD small grain, $P = 0.08$)		
	−0.23 (% NLCD grassland, $P = 0.05$)		
	−0.35 (% NLCD forest, $P = 0.00$)		
GRSP	0.21 (% decline NASS hay, $P = 0.10$)	7.06–55% NLCD hayland-pasture ($P = 0.08$)	4.73
	−0.22 (% NLCD hayland-pasture, $P = 0.08$)		
WEME	0.21 (% NLCD other types, $P = 0.09$)	−11.8 + 12.5% NLCD other types ($P = 0.09$)	4.45

than that of the North Zone, and the variability in large-scale management intensity suggests that management variety at smaller scales (e.g., abandoned hayfields, row crop edges, variable mowing practices, etc.) within such a large area may be a reason that populations in the two southern zones have not declined at an even greater rate. Populations in the North Zone may also be helped by the greater proportions of grasslands and old fields there. For example, the availability of other openland cover types in the North Zone for Vesper Sparrow and Upland Sandpiper may also be related to relatively better population trends in this zone.

Our results highlight the importance of understanding how geographic variation in land cover and land use influence species ranges, landscape preferences, relative cover type affinities, and demographic factors known to impact bird populations. Patterns in agricultural management may be correlated with bird abundances, annual productivity, and population trends (Sample and Mossman 1997; O'Connor et al. 1999; and Askins et al. 2007). Land managers and conservation planners concerned with maintaining productive region-wide populations of grassland birds should evaluate the relative value of landscape-scale openland conservation that includes less intensively managed agricultural areas (Wolff et al. 2001), even with relatively small total area. Not surprisingly, in Europe, farmlands are of the highest conservation priority. In Sweden, Soderstrom and Part (2000) found that most grassland species of higher conservation concern were found in pastures located in forested landscapes and not in agricultural-dominated landscapes, in part due to the negative impacts of intensively managed agriculture.

Our findings also provide another example (Van Horne 1983; Maurer 1986; Vickery et al. 1992) why conservation planners should avoid an over reliance on relative abundance (or density) values. Instead, findings from this study lend support to the call for more creative conservation strategies to favor those species not benefiting from either existing federal or state habitat management practices (McCoy et al. 1999, 2001; Troy et al. 2005). For many grassland bird species in many parts of North America, privately owned surrogate habitats—such as managed hayfields—are critical for regional and sub-regional conservation (Troy et al. 2005; Askins et al. 2007). However, spatial planning that prioritizes the conservation of farmlands must consider the positive and negative effects openland management may have on other bird species and wildlife. In the UGL, the conservation of these habitats and the disturbance regimes required to maintain them represent a novel conservation opportunity (Peterjohn 2003). Habitats resulting from low intensity agricultural land use may, at the minimum, provide temporally important habitat for species of conservation concern (Daily et al. 2001; Troy et al. 2005).

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