LANDSCAPE CHARACTERISTICS OF UPLAND SANDPIPER HABITAT IN MICHIGAN

by

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THESIS

Submitted to the Graduate School

of Wayne State University,

Detroit, Michigan

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

2013

MAJOR: BIOLOGICAL SCIENCES

Approved by:

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Advisor Date

DEDICATION

To my Grandparents

ACKNOWLEDGEMENTS

I have been helped in various ways by many people, but I owe a special thanks to my advisor Dr. Dan Kashian for without whom this thesis would not have been possible. It was Dan who believed in me and invited me to take on this project, and it was he who managed to rein in my focus, occasionally saving me from myself, in order to see it to completion. I am forever indebted to him for his help, patience, and guidance through these many years. Though I have always had an interest in plants and animals, it was Dan that inspired and encouraged me to pursue the study of ecology and seek it as career. His courses are among the best I have ever taken and his ability to weave together absorbing lectures with his good sense of humor and breadth of knowledge is likely unmatched. Dan also needs to be thanked for diverting endless hours of his time to meet with me to discuss and help draft this thesis.

I would also like to thank the other members of my committee, Dr. Greg Corace and Dr. Donna Kashian. Greg could always be counted on to challenge my ideas and ask the hard questions, which certainly improved this work. It is largely due to Greg that I was able to travel across northern Michigan during my field season. Donna deserves thanks for having given me both kind words of encouragement and crucial help in drafting my thesis.

I would like to thank Tony Spencer for his invaluable assistance in the field. Not only is Tony an admirably hard worker, he is also contagiously positive during difficult moments. For example, during one particularly bleak moment I got our field vehicle stuck in about a foot of mud in an area far from any cell phone coverage. Tony helped me dig through wet muck with his bare hands until sundown, enduring ceaseless assaults by mosquitos and deer flies. Somehow Tony managed to turn what could have been a miserable time into a humorous memory that I look fondly back upon. I also owe thanks to Ellen Comes and Meghan Cornwall for their help in the field. Thank you to Angie Lucas of the Grand Traverse Regional Land Conservancy for her help in selecting some of my field sites and getting permission for me to sample on them.

I would like to thank Jordan Sinclair for her moral support especially during the tough times. I also thank her and Dr. Carl Freeman for providing their assistance with statistical analyses.

This work was funded by the U.S. Fish and Wildlife Service Midwest Region Joint Venture Program and Migratory Bird Program, the U.S. Fish and Wildlife Service Midwest Region, Wayne State University Department of Biological Sciences, Seney National Wildlife Refuge, and the Seney Natural History Association. The findings and conclusions in this thesis are mine and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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Introduction

Humans are increasingly dominating the earth and its ecosystems (Vitousek et al. 1997, Foley et al. 2005), contributing to current global rates of extinction that are 100 to 1000 times greater than the reported background rate (May and Lawton 1995, Pimm et al. 1995, McCallum 2007, May 2011). Birds are among the many taxa in decline or under increasing threat because of human impact, with at least 154 documented bird species known to have gone extinct since the year 1500 (Pimm et al. 2006) .

In the United States, urbanization and land use change are often discussed as the greatest threats to ecosystems and biodiversity (Wilcove et al. 1998, Czech et al. 2000). Temperate forest ecosystems are the common focus of investigations of land use change in part because of their role in the carbon cycle (Houghton et al. 1999), the pervasiveness of their fragmentation (Riitters et al. 2002), and their importance to forest bird communities (Boulinier et al. 2001). Prairies and other grassland ecosystems have received relatively little attention in such studies, however, despite their past dominance in North America and a near 100% decline in areal extent since European settlement (Samson and Knopf 1994). Other open land ecosystem types are also in decline or have been highly degraded across North America, including those of the Upper Midwest such as oak (*Quercus*) savannas and related systems (Nuzzo 1986, Leach and Ross 1995, Cohen 2001, 2004, Kost 2004) and pine (*Pinus*) barrens (Comer 1996, Radeloff et al. 1999).

With the decline in native grasslands and other native open land cover types, grassland bird populations have also declined across North America. These changes are most pronounced in the U.S. Midwest, where extensive areas have been converted to intensively managed, row crop agriculture cover types (Herkert 1995, Peterjohn and Sauer 1999). Since European settlement, some regional grassland bird populations have adapted to anthropogenic openings as surrogate habitat, including agricultural land cover types such as hayfields and pastures (Murphy and Moore 2003, Corace et al. 2009a). However, the type and intensity of agricultural practices have important effects on bird communities (Shutler et al. 2000, Murphy and Moore 2003, Corace et al. 2009a), such that identifying their relative use of anthropogenic vs. natural open lands may be critical for informing land-management decisions and conservation and restoration planning for habitat that supports grassland bird species of conservation priority.

Upland sandpiper (*Bartramia longicauda* Bechstein, hereafter UPSA) is a migratory, area-sensitive, terrestrial shore bird that breeds in large, open lands such as prairies, pastures, hayfields, and barrens and savannahs (Buss and Hawkins 1939, Higgins and Kirsch 1975, Brewer et al. 1991, Calme and Haddad 1996). The Great Plains comprise the core breeding area for UPSA in North America, although UPSA are also found east of the Mississippi River in lower densities and were likely present there prior to European settlement in native open land cover types (Coues 1890, Sauer et al. 2011). The distribution of UPSA has likely expanded within states east of the Mississippi with the conversion of forest to pasture and low-intensity managed hayfields (Askins 2000). In the early 1900s UPSA numbers declined sharply across their breeding range, probably due to overhunting and habitat loss (Hornaday 1913, Bailey 1930, Beck 1938, Houston 1999). Although the Migratory Bird Convention Act of 1916 led to limited increases in UPSA numbers (Mitchell 1967, White 1983), UPSA have continued to decline in many states over the last five decades, including Michigan (Sauer et al. 2011). In most areas, these population declines have been attributed to habitat loss due to conversion of low-intensity agricultural fields and pastures into high-intensity row crops such as corn (White 1983). What is less known is how the loss of less--traditional open land ecosystems, such as jack pine (*Pinus* *banksiana* Lamb.) barrens in the Upper Midwest has affected this species. The US Fish and Wildlife Service lists this species as a Bird of Conservation Concern, and the US Forest Service includes UPSA as a Region 9 Regional Forest Sensitive Species (USFS 2003).

Virtually no quantitative data exist that describe historical UPSA distribution, habitat use, or population trends in Michigan. Corace (2011) suggested that UPSA historically inhabited native prairies in the southwest portion of Michigan's Lower Peninsula, as well as jack pine and oak barrens in the northern Lower Peninsula and Upper Peninsula prior to European settlement. Upland sandpipers were abundant in Michigan in the early to mid-1800s (Covert 1881, Cook 1893), but were described by ornithologists as a species "on the verge of extinction" in Michigan by the late 1800s (Taverner 1908, Barrows 1912). Individuals were still uncommon across the state in 1951, with Crawford County – a county that historically had an abundance of area in pine barrens and related ecosystems (Comer 1996) – as a local exception (Wood 1951), and in 1981 were considered uncommon in 13 widely separated counties (Powell 1981). The North American Breeding Bird Survey has reported a steady decline in the population growth of UPSA from 1966 to 2010 in Michigan (Sauer et al. 2011) (but see Corace (2011) for a discussion of the suitability of this monitoring effort for UPSA in Michigan). Presently, remaining jack pine and oak barrens, recent forest clear cuts, and low-intensity agriculture (untilled hayfields and pastures) are thought to have an important role as breeding habitat in the state (Corace 2007, Corace et al. 2009a, Corace 2011). However, there have been no state-wide evaluations of habitats occupied by UPSA in Michigan, nor has any study evaluated the relationship between the restoration of native open land-dominated ecosystems (such as pine barrens) and the conservation of low-intensity anthropogenic cover types in the context of UPSA occupancy and habitat use.

Current conservation efforts and management of UPSA in Michigan rely on data from studies conducted in other areas of the species' range, which are not likely to address the unique ecology of the state or region in general. At the periphery of its geographic range east of the Mississippi, a state-wide analysis of UPSA habitat in Michigan provides an excellent case-study for UPSA habitat along the margins of its range. In addition, few studies have considered multiple spatial scales when characterizing UPSA habitat, even though the distribution patterns of many bird species are influenced by habitat factors at multiple temporal and spatial scales (Urban and Smith 1989, Saab 1999). I therefore addressed the following questions:

(1) Which ecoregions, broad soil types, and land cover types are associated with long-term occupied UPSA breeding habitat in Michigan, and how do these broad-scale characteristics differ where breeding habitat is occupied only briefly or not at all?

(2) Can differences in UPSA occupancy be explained at the scale of individual openings? What is the range of variation in patch size, shape, and distribution for openings occupied for longer periods compared to those occupied only briefly, and those never occupied?

(3) What are the specific characteristics for the range of habitats occupied by UPSA in Michigan, and how do these characteristics differ among habitats?

Study Area

Michigan lies in the temperate region of North America between 50° and 40° N. latitude. Michigan lies entirely within the Great Lakes drainage basin with lakes Michigan, Superior, and Huron affecting the amount and type of precipitation and the temperature. Decreasing temperatures form south to north give a mean annual change from 10° C to 4.4° C. Michigan's climate is characterized by snowy winters, cool to warm summers, and precipitation that is distributed throughout the year (Eichenlaub 1979). Michigan's surface features were strongly influenced by the great ice sheets of the Pleistocene glaciation, ending with the Wisconsinan about 10,000 years ago. The glaciers formed both the Great Lakes and Michigan's landforms, which include glacial moraines, till plains, outwash and lake plains, ice contact terrain, sand dunes, and beach ridges (Farrand and Bell 1982). Michigan's presettlement ecosystem types include coniferous and deciduous forests, coniferous and hardwood swamps, open lands such as prairies and pine barrens, and wetlands such as bogs and marshes (Comer et al. 1995).

Methods

Michigan Breeding Bird Atlas (MBBA) data was used to identify the distribution and general locations of UPSA breeding habitat in Michigan. The MBBA survey occurs systematically at a relatively coarse resolution, with bird breeding locations identified within a grid system of 4.8 km^2 (3 mi^2) Atlas blocks across the state (Brewer et al. 1991). Levels of breeding confidence were assigned for UPSA encountered in an Atlas block: "possible" (least certain) was assigned when a male (singing or not) was observed in suitable habitat during its breeding season; "probable" (intermediate certainty) was assigned when a male-female pair or seven or more males were present in suitable nesting habitat during their breeding season, or when territorial behavior, courtship behavior, copulation, or visiting probable nest sites was observed; or "confirmed" (most certain) was assigned upon the observation of nest building, physiological evidence of breeding, distraction display or injury feigning, used nests or eggshells, immature young, or active nests (Brewer et al. 1991). Two independent Atlas projects have been completed over a 20-year period; MBBA I data were collected from 1983 to 1988

(Brewer et al. 1991), and MBBA II data were collected from 2002 to 2008 (Chartier et al. 2011). For this study, four sets of Atlas blocks from these two projects were selected and important ecological characteristics identified and compared to better understand USPA habitat across the state (Table 1):

(1) A set of 86 Atlas blocks (hereafter termed *long-term occupied habitat*) was selected based on the condition that the level of breeding confidence was at least possible (but could be probable or confirmed as well) for one MBBA sampling period and probable or confirmed for the other MBBA sampling period. These blocks were assumed to contain suitable UPSA habitat for the entire 25-year period of 1983-2008 (Figure 1).

(2) A set of 26 Atlas blocks (*short-term occupied habitat*) where UPSA breeding evidence was probable or confirmed for MBBA I but absent for MBBA II was selected to examine characteristics of UPSA habitat that were temporary and dynamic. I hypothesized that these blocks provided UPSA habitat for a limited time and therefore contain dynamic, natural cover types (e.g., frequently harvested xeric pine forests or barrens) rather than static types (typically low-intensity anthropogenic cover types). I limited my analysis to the Highplains Subsection (VII.2) where such dynamic cover types are most common (see descriptions of ecoregions below).

(3) A third set of 20 Atlas blocks (*SLP*) containing no UPSA breeding evidence in either MBBA was randomly chosen from the southern Lower Peninsula (SLP) where UPSA are disproportionately absent despite the extensive coverage of open land (Corace 2007, Corace et al. 2009a). I hypothesized that these blocks would have representative characteristics of open land cover types that do not attract breeding UPSA.

(4) A final set of 86 Atlas blocks (*random*) was selected randomly from the entire state, stratified by ecoregion and proportionally weighted using the 86 reference blocks from the long-term habitat data set. Blocks included in the long-term occupied habitat data set were not included in the random data set.

Broad-scale analysis of UPSA habitat

I used the Regional Landscape Ecosystem classification system of Albert (1995), which divides Michigan into a nested hierarchy of ecosystem units based on macroclimate, physiography, soil, and vegetation, as a broad-scale framework with which to examine the distribution of UPSA breeding habitat in Michigan. The broadest scale of classification divides Michigan into four ecoregion sections differing mainly by macroclimate: Southern Lower Michigan (Section VI); Northern Lacustrine-Influenced Lower Michigan (Section VII); Northern Lacustrine-Upper Michigan and Wisconsin (Section VIII); and Northern Continental Michigan, Wisconsin, and Minnesota (Section IX). All four sections are composed of lake plains, outwash plains, end moraines, and ground moraines except Section IX, where ground moraine and end moraines are most common. Each of the four ecoregions vary considerably in the total amount of open land: 3,636,342 ha (70% of the section) in section VI; 1,231,606 ha (24%) in Section VII; 235,366 ha (5%) in the Section VIII, and 126,455 ha (2%) in Section IX (Corace 2007). Sections are then subdivided further into subsections and sub-subsections based on finer-scale ecological factors that may be used to delineate more refined ecological land units (Albert 1995).

I used ArcMap 10 (ESRI 2011) to overlay and determine the association of each set of Atlas blocks with ecoregions at the subsection scale. A chi-square test was employed to test for differences from random of the distribution of Atlas blocks containing long-term occupied habitat across sections and subsections, with expected values based on area of each ecoregional unit. In addition, I performed overlays of Atlas blocks with major soil types using the Quaternary Geology of Michigan data set (Farrand and Bell 1982) and with land cover using the Integrated Forest Monitoring, Assessment, and Prescription (IFMAP) system (resolution = 30 m^2, see Table 2 for land cover descriptions). The IFMAP land cover data is created using remote sensing with images from 1997-2001 used for the identification of land cover classes and is derived from the classification of Landsat Thematic Mapper TM imagery (MDNR 2001). Association between Atlas blocks and subsections, soils, and land cover were summarized with frequency distributions. I used a two-factor univariate analysis of variance (ANOVA) to compare distributions of soil and land cover among the four data sets. Proportion of total data set area was used as the dependent variable, and the interaction term between soil or land cover and data set was used as the dependent variable, and the interaction term between soil/land cover and data set was used to determine whether the soil/land cover types vary amongst the data sets. Proportions were arcsine transformed to meet assumptions of normality, but no other departures from assumptions of normality or equal variances were found. Statistical analyses were performed in SPSS using $\alpha = 0.05$ (IBM Corp. Released 2012).

Patch-scale analysis of UPSA habitat

A major limitation of MBBA data is that exact coordinate locations for observed breeding birds – or even the openings that they occupy - are not known, leaving the Atlas block itself as the finest resolution. Because UPSA breed only in open cover types and are known to be area-sensitive (Samson 1980, Vickery et al. 1994, Helzer and Jelinski 1999), I analyzed UPSA habitat at a second spatial scale restricted to the largest openings within the blocks in order to eliminate spurious associations of UPSA to land cover they are unlikely to occupy. I assumed that the occupied area of an Atlas block would be one of the two largest openings, and I therefore explored patch-scale characteristics of the two largest openings within the Atlas blocks to determine differences in size and shape among openings in each of the four data sets (long-term occupied habitat, short-term occupied habitat, SLP, and random).

I digitized the largest two openings on 2005 aerial imagery (USDA 2009) in ArcMap within selected Atlas blocks. I used a minimum mapping unit of 16 ha based on past studies of open lands in Michigan (Corace 2007, Corace et al. 2009a); field experience suggests this opening size would capture most UPSA breeding habitat in Michigan. Openings separated by < 90 m of forested area (i.e., small woodlots) were treated as one polygon, and forested patches with diameter < 100 m within the boundaries of an opening were excised from the polygon. Patch metrics for each data set were calculated in FRAGSTATS (McGarigal et al. 2002) using a cell size of 40 m^2 to calculate metrics of patch size (mean patch area), patch shape (mean edge length or perimeter, edge-to-area ratio, fractal dimension index), patch isolation (nearest neighbor, proximity index), and contagion (Table 3). Fractal dimension index ranges between one and two, and approaches one for shapes with very simple perimeters (e.g., squares) and approaches two for shapes with highly convoluted, perimeters (McGarigal et al. 2002). Proximity index increases as the neighborhood (defined by a given search radius) is increasingly occupied by openings and as those openings become closer and more contiguous (or less fragmented) in distribution. I used a search radius of 400 m based on a general estimate of between-patch dispersal of grassland birds (Sample et al. 2002). All landscape metrics were calculated for all openings together, regardless of cover type. Because they require information about the presence of all openings on the landscape without bias by Atlas blocks, nearest neighbor distance, proximity index, and contagion were calculated from a data set created by extracting all openings > 16 ha from IFMAP within the four data sets.

Field characteristics of UPSA

I examined vegetation structure of 39 open land sites in the Upper Peninsula and northern Lower Peninsula (NLP). Sites were chosen based on known locations of breeding UPSA (Brewer et al. 1991, Corace 2007, Chartier et al. 2011) and included historic pine barrens (Comer 1996), recently burned areas, pine stump fields (sites logged in the late 19th century and still in an early successional state (Cohen 2002, Lytle 2005)), forest clear cuts, and pine plantations. Sampling was completed along three parallel 200-m transects, each established with a random start, with sample points spaced every 10 m along each transect. Vegetation structure in these non-forested areas was characterized using vegetation height; aerial coverage of bare ground, moss and lichens, woody debris, woody plants, grasses, and forbs; and perch density. I also measured litter depth because some studies have shown grassland bird species prefer different amounts of litter (Renfrew and Ribic 2001, Swengel and Swengel 2001). Litter depth was measured with a tape measure at each sample point one meter from the transects. Visual obstruction was estimated using a Robel pole (Robel et al. 1970), whereby the number of non-viewable 5-cm bands on a pole was counted from a standardized distance of four meters from the pole. Vegetation cover of each function group described above was estimated into aerial coverage classes as specified by Winter et al. (2005) with one-meter quadrats at each sampling point (0-2%, 2-4%, 4-8%, 8-16%, 16-32%, 32-64%, and > 64%). Perch density was measured using the point-centered quarter method according to Mitchell (2007) and Warde and Petranka (1981) at four points along each transect.

Data were summarized by type, which included pine stump fields (n=4), recent plantations (n=19), forest clear cuts (n=4), burned sites (n=3), anthropogenic fields (including airfields, pastures, and fallow fields; n=5), and barrens/savannas (n=3). To test for important structural differences in the site types occupied by UPSA in Michigan, significant differences in the mean values of the variables described above were identified with univariate ANOVA at $\alpha = 0.05$ across the six cover types and entered into discriminant analysis to determine whether site types could be differentiated in multivariate space. Vegetation height, litter depth, perch density, coverage of moss/lichen, and coverage of forbs were log-transformed to meet assumptions of normality and equal variances, but no violations of these assumptions were otherwise found. Potential bias in the *a priori* assignment of groups was tested using the jackknife method of discriminant analysis (Williams 1983).

Results

Broad-scale UPSA habitat distribution

Based solely on the occurrence of breeding UPSA during two separate MBBA sampling periods, the long-term occupied habitat data set provides useful insight into the broad-scale distribution of UPSA habitat across ecoregions in Michigan. Although long-term occupied UPSA breeding habitat was found across both the Upper and Lower Peninsulas in Michigan, 73 of the 86 Atlas blocks (83%) were found in the Lower Peninsula (Figure 1). Long-term occupied habitat was also found within all four sections, with most (66%) occurring in the Northern Lower Peninsula (NLP, Section VII), 17% occurring in the Southern Lower Peninsula (SLP, Section VI), and the remaining 17% found in the two Sections of the Upper Peninsula (Table 4). The overwhelming majority of long-term occupied Atlas blocks were located in the NLP (Section VII) even when standardized by area, suggesting a disproportionate value of this ecoregion to UPSA in Michigan (Table 4). Compared to a distribution with expected values based on the area of each section, the distribution of Atlas blocks containing long-term occupied habitat differed significantly from random (X^2 = 158.6, p < 0.0001). At the subsection scale, almost 35% of all long-term Atlas blocks were located within the Highplains Subsection (VII.2) and 15% within the Presque Isle Subsection (VII.6). When standardized by area of the subsections, the five most frequent subsections were located within the NLP, including subsections (in order) VII.5 (Leelanau and Grand Traverse Peninsula), VII.6, VII.2, VII.3 (Newaygo Outwash Plain), and VII.4 (Manistee). The sixth most frequented subsection was located along Lake Michigan in the Allegan subsection (VI.3) of the SLP (Section VI; Table 4; Figure 2). Compared to a distribution with expected values based on the area of each subsection, the distribution of Atlas blocks containing long-term UPSA habitat differed significantly from random (X^2 = 265.4, p < 0.0001).

Glacial outwash of sand and gravel and coarse glacial till was a dominant soil type within the Atlas blocks for all four data sets except for the SLP, where coarse glacial till was less important (Table 5, Figure 3). Atlas blocks in the SLP were generally located more often on finer-textured soil types compared to the other three data sets, and those on short-term occupied habitat blocks were more often found on glacial outwash. About 30% of the area of long-term occupied habitat Atlas blocks was located on glacial outwash, 28% on coarse glacial till, and 17% on lacustrine sand and gravel. For short-term occupied habitat, about 50% was found on glacial outwash, 30% on coarse glacial till, and 14% on ice-contact outwash. For SLP, glacial outwash represented 23% of the area, but smaller proportions of the area were found on medium glacial till (16%), fine glacial till (12%), and lacustrine clay/silt (17%) (Figure 3). The distribution of soil classes within the blocks differed significantly across the four data sets (F_{42} = 3.304, p < 0.001, Table 6).

The distribution of land cover within the Atlas blocks also differed significantly among the four data sets (F_{39} = 13.179, $p < 0.001$, Table 6). Deciduous forest represented a large portion of long-term occupied habitat, short-term occupied habitat, and random Atlas blocks at this larger scale, but also included significant proportions of coniferous forests, forage crops, and herbaceous open lands (Figure 4, Table 7). Atlas blocks for long-term occupied habitat were represented by deciduous forest (27%), coniferous forest (16%), forage crops (11%), and herbaceous open lands (13%). For short-term occupied habitat, the area within the Atlas blocks was represented by deciduous forest (33%), herbaceous open land (16%), and coniferous forest (13%). In contrast, the Atlas blocks within the SLP were dominated mainly by forage crops (33%) and row crops (30%) (Figure 4).

Patch-scale analysis of UPSA habitat

When my analysis was restricted to only the two largest openings within the Atlas blocks, glacial outwash was still a dominant soil type in all four data sets, although a larger proportion of short-term occupied habitat openings were located on coarse-textured outwash, ice-contact outwash, and glacial till compared to the other four data sets (Figure 5, Table 8). Long-term occupied habitat openings were located mainly on coarse glacial till (28% of total opening area), glacial outwash (20%), and lacustrine sand and gravel (19%). Short-term occupied habitat openings were found mainly on coarse glacial till (43%), but also on glacial outwash (30%). Openings in the SLP were located more often on finer-textured soils including lacustrine clay/silt (20%), medium glacial till (15%), and fine glacial till (14%), as well as on glacial outwash (16%). Once again, the distribution of soil classes within these openings differed significantly across the four data sets (F_{42} = 2.360, $p < 0.001$) with short-term occupied habitat on more coarse-textured soils and SLP openings on finer-textured soils (Figure 5).

Not surprisingly, land cover found within the openings included far fewer types than within the entire Atlas blocks, and was limited to non-forested types including forage crops, herbaceous open land, row crops, and upland shrub (Figure 6). All four data sets contained a significant proportion of forage crops as cover, but short-term occupied habitat was dominated by herbaceous open land and SLP was dominated by row crops (Figure 6, Table 9). The SLP openings also had far less herbaceous open land compared to the other three data sets (Figure 6). Long-term and short-term occupied habitat openings were mainly forage crops (35% and 32%, respectively) and herbaceous open lands (24% and 39%); SLP was dominated by forage crops (44%) and row crops (43%), and < 5% herbaceous open land (Figure 6). The distribution of land cover within the largest openings of the four data sets differed significantly ($F_{39} = 11.586$, $p < 0.001$).

The average size of openings was much larger for openings in SLP (645 ha) compared to the other three data sets, was smallest for short-term occupied habitat (167 ha), and averaged 271 ha for long-term occupied habitat (Table 10). Openings for all four data sets were similar in shape as suggested by similar values for mean edge length, edge-to-area ratio, and fractal dimension index. Openings in SLP had much more edge length (38482 m) but also a lower edge-to-area ratio (87 m/ha), probably due to the sheer size of the openings there compared to the other data sets. Long-term occupied habitat openings were much further apart (nearest neighbor index = 2862.6) and dispersed (proximity index = 184.7) compared to short-term occupied habitat (nearest neighbor index = 790, proximity index = 339.4) and SLP (nearest neighbor index = 798.9, proximity index = 4859.3), as evidenced by larger nearest neighbor index and lower proximity index. Openings in long- and short-term occupied habitat exhibited similar values of contagion (68.3 and 66.6 respectively), although both were markedly less aggregated than openings in the SLP (78.8) (Table 10).

Field sampling

Field sampling showed a large range in vegetation cover among field sites, with bare ground ranging 0 - 49% and averaging 16%, moss and lichens ranging 0 - 58% and averaging 11%, woody debris ranging 0 - 17% and averaging the least at 5%, woody plants ranging 0 - 54% and averaging 19%, grass ranging 4 - 76% and averaging the most at 39%, and forbs ranging 0 - 38% and averaging 6%. Vegetation height ranged from 0 - 79 cm and averaged 9.8 cm. The density of perchable objects also varied among sites, ranging 0 - 118 objects per hectare and averaging 25 object per hectare. Litter depth ranged 0.6 - 2.4 cm and averaged 1.2 cm. Nevertheless, only three of the nine variables were significantly different across the six site types: height density (F = 3.88, p = 0.007), coverage of dead wood (F = 2.58, p = 0.05), and coverage of woody plants (F = 8.11, p < 0.001) (Table 11). Height density was greatest in anthropogenic fields (average 23 cm) and burned areas (16 cm), and least in barrens/savannas (3.7 cm) and clear cuts (3.8 cm) (Table 11). Coverage of dead wood was greatest in clear cut areas (6.8%), stump fields (6.5%), and plantations (6%), and was least in anthropogenic fields (0.7%). Coverage of woody plants was greatest in burned areas (43%) and plantations (23%), but least in anthropogenic fields (4.4%) (Table 11).

I included all measured variables in discriminant analysis to examine variation among the site types occupied by UPSA in Michigan. Discriminant analysis resulted in relatively poor separation among the site types in ordinate space (Figure 7). The first canonical variate (CV 1) related most strongly with the height of vegetation and to coverage of forbs; sites scoring high on the first axis generally included those with abundant forbs, while those scoring low (negative) included those with taller vegetation. The second canonical variate (CV 2) was dominated by coverage of woody plants and forbs, as well as vegetation height and coverage of dead wood. Sites scoring high on the second axis included those with more abundant woody plants and/or more forbs, and those scoring low had more dead wood and taller vegetation. The first three canonical variates accounted for 55, 77, and 91% of the cumulative variance (Table 12). The discriminant function had an overall classification accuracy of 74%, and the jackknifed classification rate was 46%, suggesting that the initial classification of site types was relatively unbiased.

Discussion

Management of habitats for species of conservation priority depends strongly on understanding habitat characteristics at multiple scales and across broad geographic areas so as to capture ecological amplitude, relationships between restoration and conservation actions, and how these habitats may be positively or negatively impacted by humans. Specifically, information about habitat frequented by individuals at the edges of a species' geographic distribution, or in disjunct populations, is typically lacking even when such information is important for conservation planning and management. My results suggest that although UPSA rely on a wide range of open land types (except row crops) across Michigan and appear to be relatively non--selective about the types of open land it inhabits, their current distribution provides useful insights into the impacts of land use and land cover change on the persistence of many other grassland bird species. I note, in particular, that anthropogenic cover types within the probable historical range of UPSA in Michigan provide critical habitat because of their persistence and stability in the face of altered natural disturbance regimes that were likely to maintain open land types prior to European settlements.

Analysis of MBBA Atlas blocks

At the broadest scale of analyses UPSA appears to have an affinity for the NLP of Michigan, where two-thirds of long-term occupied habitat Atlas blocks were located even when proportions were standardized by area of the subsections (Table 4). Soils of the Atlas blocks in this region are variable due to its spatial scale, but appear to be generally restricted to sandy deposits of outwash, glacial till, or lacustrine deposits (75% of long-term habitat, and 94% of short-term habitat). It is notable that although relatively uncommon, long-term occupied habitat found in the SLP is associated with sand deposits near Lake Michigan rather than the finer-textured soils associated with the SLP data set. It remains unclear why UPSA habitat is associated with sandy deposits, but I speculate that this relates to the disturbance regimes necessary to maintain open land-dominated conditions in a mostly forested state, such as Michigan. In many of the pine-dominated ecosystems historically found in the state, fire was an important component prior to European settlement (Whitney 1987, Loope and Anderton 1998) with fire occurring frequently enough (and potentially driven by Native Americans) that “barrens” (open land-dominated areas of low soil fertility) were found. I surmise that UPSA became adapted to these fire-dependent systems and now, with fire suppression widespread, require other anthropogenic disturbances and habitats to persist.

My analysis of land cover at the scale of Atlas blocks was probably not insightful for understanding UPSA habitat because it incorporated too wide a range of cover types that are known to be avoided by UPSA, such as deciduous forests. Nevertheless, the abundance of fire-dependent coniferous forest cover types in both the long-term occupied habitat (43%) and short-term occupied habitat (46%) reiterates that the open land that provides UPSA habitat in northern Michigan is found within a heavily forested matrix – a sharp disparity to the landscape found at the core of the species' range in the Great Plains. In contrast, the SLP data set was dominated by agricultural cover types (63% forage and row crops) that while open, went unused by UPSA. This result suggests that while UPSA may nest in many types of open land, the vegetation structure of row crops is not conducive to UPSA breeding habitat (Corace 2007, Corace et al. 2009a). The relative importance of vegetation structure of agricultural landscapes compared to broad dominance of finer-textured soils for UPSA habitat is an interesting and important area of future research.

Analysis of openings likely used as UPSA habitat

At the finer spatial scale of the largest two openings within the Atlas blocks, the importance of land use and land cover change is more apparent. Although specific spatial data for UPSA locations are not available, the area-sensitivity of UPSA allowed me to assume that one of the largest two openings in the block was likely to have contained the UPSA record in the MBBAs. Soil associations with openings were consistent with those found in the broad-scale analysis, with long-term occupied habitat located mainly on coarse-textured glacial till, outwash, and lacustrine deposits (67%), and short-term occupied habitat mainly on coarse-textured glacial till and outwash (73%). As before, unused openings in the SLP were located largely on finer-textured soils of lacustrine origin and medium and fine glacial till (49%). Historically, many of these areas were likely dominated by deciduous forests and the openings are now representative of the association of these soil types and agriculture; these fine soils are highly productive and thus these sites have been converted to high-intensity managed farmland for agricultural use.

Land cover of openings in all the data sets was limited to four relatively broad open cover types, but the varying proportions of these cover types suggests important differences among breeding habitats and their duration of use. Long-term occupied openings were mainly forage crops (such as hayfields and pastures) and, secondarily, herbaceous open lands that includes both natural (barrens and grasslands) and anthropogenic (recent clear cut areas, pine stumpfields) non-agricultural cover types. These findings are similar to those found in the neighboring state of Wisconsin where nesting sites occurred mostly in pastures and grasslands (White 1983), but different from Ohio where the vast majority of breeding habitat is on airfields (Osborne and Townsend 1984). Short-term occupied openings included forage crops, but also included a much higher proportion of herbaceous open lands that were smaller in area and closer together compared to openings of long-term occupancy. While the lack of specific UPSA locations precludes a detailed analysis of land cover preferred by UPSA, I emphasize that the short-term habitat examined in this study was located in the Highplains subsection (VII.2). This region is dominated by coarse-textured soils and was historically very prone to wildfires; many of the oak and pine barrens of Michigan are located in this part of the state and were historically maintained in an open condition by wildfires. Wildfire was also an important process in many of the oak and pine forests prior to European settlement (Albert 1995), and temporarily created openings within these cover types until they regenerated after disturbance.

The location of short-term occupied habitat in dry, sandy, fire-prone areas with herbaceous open land cover suggests a much more dynamic system compared to the more stable, human-maintained forage crops (pastures and hayfields) that characterize a larger proportion of long-term occupied habitat. In the absence of fire because of fire suppression, land cover types quickly succeed to closed-canopy conditions and become unsuitable for USPA breeding habitat;

I suggest that these dynamic cover types explain the loss of breeding UPSA from an Atlas block that included breeding UPSA in the first MBBA. In contrast, hayfields and pastures are more likely to be maintained by humans, or at least succession is much slower there, such that they are more static and remain in a suitable condition for UPSA habitat for a longer period of time. I therefore speculate that the fire-prone areas of the Highplains subsection (and to a lesser extent the southwestern Lower Peninsula) were likely the core area of UPSA distribution in Michigan prior to European settlement. Although fire suppression that accompanied settlement of the area may have reduced the amount of habitat in “natural openings”, subsequent land conversion to stable, anthropogenic openings useable by UPSA on well-drained soils and near the original geographic distribution are likely to have allowed the species to persist in Michigan today. Whereas many species less adaptable to a range of habitat conditions are more negatively impacted by land cover change, UPSA appears to have benefited from it.

The flexibility of UPSA in its utilization of multiple open cover types is not without bounds, as very large open areas in the SLP are largely avoided. In addition to the potential for adverse effects of slower-draining soils, the intensive agricultural conditions and vegetation structure (row crops) in the region are apparently not suitable for breeding UPSA, a result consistent with the findings of previous research in other Midwestern states (Ailes 1980, White 1983). I speculate that in addition to strongly different vegetation structure, pesticide use in row crop cover may reduce foraging opportunities for UPSA compared to less intensively-managed hayfields and pastures. In any case, while land use in the NLP may facilitate the availability of UPSA habitat, that in the SLP may impede it.

Characteristics of UPSA habitat in Michigan

Field sampling across 39 open land sites occupied by UPSA confirmed results obtained at broader scales: that UPSA are flexible in their habitat, and will use a wide variety of open cover types regardless of their origin and, to some extent, their vegetation structure. Multivariate analysis of the sampled sites provided very little separation in ordinate space further suggesting that vegetation structure among the 39 sites was not strongly contrasted. Differences between open cover types were restricted to vegetation height, coverage of woody plants, and the amount of dead wood present. Vegetation height ranged from very low (4 cm) in barrens and recent clear cuts to relatively tall (23 cm) in hayfields and recent burns – a seemingly wide range of vegetation structure apparently to which UPSA are insensitive. Woody plant coverage also differed among sites but was always relatively low; burned areas averaged the highest tree and shrub coverage near 43%, suggesting that open areas need not be completely lacking woody coverage to be suitable for UPSA. In fact, given the likelihood that burned areas in the NLP of Michigan provided the majority of UPSA habitat prior to European settlement, I speculate that presumed UPSA habitat requirements of "openness" in Michigan may be much less so compared to its core habitat in the Great Plains. I did not sample species composition, which would inevitably differ among such a wide range of cover types, but the presence of UPSA at all cover types within this range suggest that UPSA are insensitive to species composition as well. Other studies have also shown that UPSA use a wide variety of cover types despite a wide range in their origin and vegetation composition and structure (Ailes 1980, White 1983). In sum, field data confirm that UPSA in Michigan are most sensitive to vegetation structure rather than composition, and that vegetation structure necessary for suitable UPSA habitat is relatively straightforward and easily obtainable from a management perspective.

Implications for management

My results have several implications for UPSA conservation and management in Michigan and the Upper Great Lakes region. In addition to UPSA on open cover types, sandy outwash ecosystems in the Highplains subsection of northern Lower Michigan also provide the majority of nesting habitat for the Federally-Endangered Kirtland's warbler (*Setophaga kirtlandii* Baird). The specific habitat requirements of Kirtland's warbler populations include large, dense stands of jack pine that were historically created by stand-replacing wildfires, but fire suppression has necessitated the creation of large jack pine plantations for KW habitat since the 1970's. Because warblers use young jack pine as habitat for only 10-16 years before abandoning the stand as it ages and the trees grow too tall (Probst 1988), management for the warbler is critical, requiring that approximately 1,600 ha (4,000 ac) of land are clear cut and planted to jack pine each year to maintain a recommended constant area of 14,500-16,000 ha (36-40,000 ac) of warbler habitat each year (Kirtland's Warbler Recovery Team 1985). Wildfires created patchy stands interspersed by numerous grassy openings that may have also provided UPSA habitat prior to European settlement. Today, UPSA clearly benefit initially from the open cover types created by these extensive clear cuts (in my analysis, likely making up the "herbaceous" open land), but the availability of many areas likely to have been open (barrens or burned areas) prior to European settlement is subsequently lost once canopy closure is achieved by planted jack pine. Co-management of Kirtland's warbler and UPSA appears achievable with relatively simple adjustments in the current warbler management regime (Corace et al. 2009b, Corace et al. 2010), such as – in the presumed continued absence of prescribed burning – delayed planting following clear cutting that could extend the duration of use of clear cut areas by grassland birds including UPSA.

More broadly, the implication of UPSA habitat utilization across a range of open cover types from low-intensity agriculture to areas burned by wildfires emphasizes that conservation planning and land management for UPSA will need to extend beyond the political boundaries of public lands. Management and planning should work to preserve or restore natural disturbance regimes wherever possible in order to mimic the processes that created UPSA habitat on the landscape prior to European settlement. With heavy UPSA dependence on anthropogenic cover types, however, conservation planning for UPSA in Michigan will depend on cooperation among a broad array of conservation partners including private landowners as well as public land managers.

In this study, I identified and characterized several cover types used by UPSA in the Midwest other than pastures, a research need outlined in the *Conservation Plan for the Upland Sandpiper* (Vickery et al. 2010). A better understanding of the importance or quality of these cover types as UPSA breeding grounds is required to understand their population-level benefits for this species. Future research should quantify UPSA density in these cover types and identify habitat characteristics associated with varying UPSA densities. I hypothesize that open land cover types that more closely mimic historic, fire-dependent systems (e.g., recent forest clear cuts, barrens, etc.) would contain a greater density of UPSA than anthropogenic cover types, in part due to the structure afforded these sites and the scale at which they operate, especially within the context of Kirtland's warbler habitat management. Also, it is important to know how UPSA breeding characteristics (such as clutch size, hatching/nesting success, and mortality) differ among these habitat types. Understanding how succession within recently--disturbed open lands affect UPSA and other grassland birds, and in which age classes these openings provide optimal, sub-par, and poor breeding habitat would provide useful information for managing lands for grassland birds. I also recommend that more accurate monitoring efforts be established with a baseline population as a goal to curb declines of UPSA in the Midwest and Michigan.

Conclusions

My analysis suggests that UPSA have a much broader ecological amplitude than is reported in the literature (Houston et al. 2011) and conservation planning (Vickery et al. 2010) and that UPSA relies on a wide range of open land types across Michigan and appear to be highly tolerant of a range of vegetation structures, primarily in the northern Lower Peninsula. UPSA habitat prior to European settlement in this region was likely associated with pine forests and barrens created by wildfires and lost via succession, resulting in a dynamic habitat. Since European settlement and its associated altered disturbance regimes (fire suppression, logging, and plantations), low-intensity agricultural cover types such as hayfields and pastures have been a critical component of current long-term UPSA breeding habitat because they are relatively stable and unchanging. UPSA habitat is lacking in the SLP despite an abundance of large openings that would seem to accommodate UPSA probably due to high-intensity agriculture (row crops) that exists there. Thus human activities have both historically curtailed the amount of UPSA habitat in Michigan via natural ecological processes, yet provided habitat through the creation of stable anthropogenic cover types. This apparent paradox is markedly different than the habitat dynamics of UPSA at the core of its geographic distribution in the Great Plains, and reiterates the importance of understanding the local ecological context of uncommon or threatened species away from the centers of their distribution.

Table 1. Number of blocks, location, criteria, and Michigan Breeding Bird Atlas breeding evidence used for selection of Atlas blocks for the long-term occupied habitat, short-term occupied habitat, SLP, and random data sets.

Data Set	# Blocks	Location	Criteria	MBBA I & II breeding evidence
Long-term habitat	86	State-wide	UPSA breeding grounds for multiple decades	At least possible[a] for one, probable[b] or confirmed[c] for other
Short-term habitat	26	Highplains, subsection VII.2	UPSA breeding grounds for one decade	Probable or confirmed for I, no evidence for II
SLP	20	SLP, section VI	Contains openings never used for breeding	No evidence for I & II
Random	86	State-wide	Stratified-random	Not considered

[a] “possible” (least certain), a male (singing or not) or female in suitable habitat during its breeding season

[b] “probable” (intermediate certainty), a male-female pair or seven or more males in suitable nesting habitat during their breeding season, or territorial behavior, courtship behavior, copulation, or visiting of probable nest sites

[c] “confirmed” (most certain), nest building, physiological evidence of breeding, distraction display or injury feigning, used nests or eggshells, immature young, or active nests

Table 2. Descriptions of the classes of land cover for the Integrated Forest Monitoring, Assessment, and Prescription (IFMAP) spatial data set (MDNR 2001).

Land Cover Type	IFMAP Description
Coniferous Forest	Proportion of coniferous trees exceeds 60% of the canopy
Deciduous Forest	Proportion of deciduous trees exceeds 60% of the canopy
Forage Crops	Vegetation used for fodder production (e.g. alfalfa, hay) and land used for pasture, or non-tilled herbaceous agriculture
Herbaceous Open land	Less than 25% of land area consists of woody cover
Lowland Forest	Land is periodically flooded and/or on hydric soils and the proportion of trees exceeds 60% of the canopy
Row Crops	Vegetation consists of annual crops planted in rows (e.g. corn, soybeans)
Water	Proportion of open water exceeds 75% of land area
Wetlands	Land is periodically flooded and/or on hydric soils and the proportion of trees is less than or equal to 25% of land area
Upland Shrub	The combination of woody shrubs and tree canopy (woody cover) covers more than 25% of the land area

Table 3. Landscape metrics calculated in FRAGSTATS (McGarigal et al. 2002) and used to describe the two largest openings located in the four sets of Michigan Breeding Bird Atlas blocks (long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula, and random).

Metric	Description	Units	Range	Index
Mean patch area	Mean patch size of all patches on a landscape	ha	No limit	Patch size
Mean edge length	Mean of total edge length of individual patches	m	No limit	Patch shape
Edge-to-area ratio	Total edge of all patches per unit area	m/ha	No limit	Patch shape
Fractal dimension index	Fractal dimension of a patch, approaching 1 for simple shapes and 2 for complex	-	1<FDI<2	Patch shape
Mean nearest neighbor distance	Mean of the straight-line distance between a patch and its nearsest neighbor	m	No limit	Patch isolation
Proximity index	Measures proximity of a patch to all other patches within a search radius	-	No limit	Patch isolation
Contagion	Measures aggregation of patches in a landscape	-	0<CONT<100	Patch isolation

Table 4. Count and percent occurrence of 86 Michigan Breeding Bird Atlas blocks with long-term upland sandpiper occupancy within ecoregion sections and subsections in Michigan (Albert 1995). Standardized value is the number of blocks standardized by area of the section or subsection; value is count/area*10000.

Section	Subsection	Area	Count	% Occurrence	Standardized
VI (SLP)		109745	15	(17.0)	1.37
	6.1	62821	2	(2.0)	0.32
	6.3	6882	7	(7.1)	10.17
	6.4	15192	3	(3.1)	1.97
	6.5	9564	2	(2.0)	2.09
	6.6	6190	2	(2.0)	3.23
VII (NLP)		44318	58	(65.9)	13.09
	7.2	21604	34	(34.7)	15.74
	7.3	5244	7	(7.1)	13.35
	7.4	3714	4	(4.1)	10.77
	7.5	2215	7	(7.1)	31.6
	7.6	7730	15	(15.3)	19.4
VIII (EUP)		34159	9	(10.2)	2.63
	8.1	13883	3	(3.1)	2.16
	8.2	8910	2	(2.0)	2.24
	8.3	11366	4	(4.1)	3.52
IX (WUP)		80874	6	(6.8)	0.74
	9.1	5353	1	(1.0)	1.89
	9.2	3061	1	(1.0)	3.27
	9.3	37024	1	(1.0)	0.27
	9.6	6286	3	(3.1)	4.77

Table 5. Mean proportion and standard deviation (stdev) of the area of soil types within long-term occupied habitat, short term occupied habitat, SLP, and random Michigan Breeding Bird Atlas blocks.

	Long-term Habitat		Short-term Habitat		SLP		Random	
Soil	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Coarse glacial till	0.171	0.322	0.060	0.204	0.002	0.005	0.179	0.301
Dune sand	0.017	0.054	0.006	0.028	0.002	0.008	0.020	0.064
End moraines of coarse till	0.119	0.235	0.243	0.366	0.028	0.070	0.069	0.172
End moraines of fine till	0.045	0.165	0.022	0.111	0.045	0.102	0.033	0.128
End moraines of medium till	0.011	0.069	0.050	0.145	0.141	0.259	0.040	0.167
Fine glacial till	0.024	0.101	0.003	0.013	0.075	0.166	0.022	0.117
Glacial outwash sand and gravel	0.297	0.359	0.441	0.362	0.361	0.330	0.244	0.311
Ice-contact outwash sand/gravel	0.029	0.114	0.135	0.260	0.029	0.096	0.074	0.221
Lacustrine clay and silt	0.066	0.214	0.017	0.084	0.218	0.374	0.075	0.229
Lacustrine sand and gravel	0.177	0.320	0.021	0.088	0.010	0.031	0.144	0.279
Medium-textured glacial till	0.030	0.156	0.000	0.000	0.087	0.141	0.055	0.213
Postglacial alluvium	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.115
Peat and muck	0.009	0.061	0.001	0.006	0.000	0.000	0.006	0.056
Glacial till over bedrock	0.000	0.003	0.000	0.000	0.000	0.000	0.001	0.010
Water	0.006	0.032	0.002	0.010	0.002	0.006	0.012	0.040

Table 6. Results of two-factor ANOVA examining the relationship of data set and soil, and data set and land cover. Sum of squares (SS), degrees of freedom (df), F, and p values for the two factors and the interaction effect are given. The interaction between data set and soil and the interaction between data set and land cover are significant for both Michigan Breeding Bird Atlas blocks and openings, meaning that the data sets (long-term occupied habitat, short-term occupied habitat, SLP, and random Atlas blocks) have different distributions of soil types and land cover within them.

Comparison	SS	df	F	p
Soil in Atlas blocks				
Data Set	0.012	3	0.05	0.98
Soil	34.25	14	32.04	0.00
Data set*Soil	10.597	42	3.30	0.00
Soil in openings				
Data Set	0.01	3	0.03	0.99
Soil	26.77	14	19.68	0.00
Data set*Soil	9.63	42	2.36	0.00
Land cover in Atlas blocks				
Data Set	0.02	3	0.32	0.81
Land cover	41.48	13	195.74	0.00
Data set*Land cover	8.38	39	13.18	0.00
Land cover in openings				
Data Set	0.003	3	0.05	0.99
Land cover	37.237	13	169.37	0.00
Data set*Land cover	7.642	39	11.59	0.00

Table 7. Mean proportion and standard deviation (stdev) of the area of land cover within long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula (SLP), and random Michigan Breeding Bird Atlas blocks.

	Long-term Habitat		Short-term Habitat		SLP		Random	
Land Cover	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Bare	0.003	0.005	0.003	0.007	0.003	0.008	0.008	0.045
Coniferous	0.162	0.147	0.199	0.143	0.022	0.020	0.143	0.133
Deciduous	0.272	0.152	0.310	0.158	0.116	0.063	0.293	0.182
Forage Crops	0.117	0.110	0.070	0.085	0.311	0.160	0.107	0.124
Herbaceous	0.145	0.081	0.173	0.103	0.061	0.071	0.100	0.059
Lowland Forest	0.090	0.091	0.091	0.084	0.055	0.034	0.128	0.119
Non-veg Farmland	0.001	0.002	0.000	0.000	0.001	0.002	0.001	0.005
Orchards	0.008	0.026	0.000	0.001	0.004	0.007	0.006	0.028
Parks/Golf Course	0.002	0.007	0.002	0.012	0.002	0.007	0.003	0.008
Row Crops	0.044	0.091	0.007	0.011	0.292	0.160	0.044	0.095
Upland Shrub	0.047	0.038	0.055	0.025	0.008	0.005	0.039	0.039
Urban	0.047	0.070	0.031	0.040	0.056	0.072	0.037	0.062
Water	0.017	0.043	0.013	0.031	0.018	0.032	0.028	0.077
Wetlands	0.045	0.045	0.045	0.053	0.052	0.023	0.065	0.092

Table 8. Mean proportion and standard deviation (stdev) of the area of soil types within long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula (SLP), and random openings within Michigan Breeding Bird Atlas blocks.

	Long-term Habitat		Short-term Habitat		SLP		Random	
Soil	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Coarse glacial till	0.168	0.323	0.075	0.230	0.006	0.028	0.181	0.334
Dune sand	0.012	0.047	0.001	0.004	0.004	0.014	0.004	0.018
End moraines of coarse till	0.119	0.258	0.287	0.418	0.062	0.226	0.087	0.222
End moraines of fine till	0.047	0.179	0.038	0.196	0.073	0.182	0.029	0.136
End moraines of medium till	0.013	0.087	0.084	0.246	0.152	0.298	0.024	0.124
Fine glacial till	0.027	0.117	0.003	0.017	0.118	0.308	0.027	0.130
Glacial outwash sand/gravel	0.302	0.394	0.334	0.411	0.221	0.345	0.249	0.381
Ice-contact outwash sand/gravel	0.025	0.147	0.147	0.305	0.039	0.149	0.070	0.241
Lacustrine clay and silt	0.067	0.223	0.016	0.082	0.196	0.372	0.090	0.271
Lacustrine sand and gravel	0.186	0.346	0.015	0.065	0.037	0.133	0.146	0.322
Medium-textured glacial till	0.026	0.153	0.000	0.000	0.091	0.175	0.061	0.225
Postglacial alluvium	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.055
Peat and muck	0.006	0.043	0.000	0.001	0.000	0.000	0.022	0.144
Glacial till over bedrock	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Water	0.001	0.009	0.000	0.000	0.000	0.000	0.006	0.045

Table 9. Mean proportion and standard deviation (stdev) of the area of land cover within long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula (SLP), and random openings within Michigan Breeding Bird Atlas blocks.

	Long-term Habitat		Short-term Habitat		SLP		Random	
Land Cover	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Bare	0.004	0.006	0.005	0.013	0.001	0.002	0.013	0.092
Coniferous	0.066	0.140	0.055	0.104	0.003	0.002	0.053	0.150
Deciduous	0.052	0.059	0.049	0.063	0.031	0.021	0.052	0.081
Forage Crops	0.308	0.212	0.247	0.235	0.410	0.194	0.346	0.248
Herbaceous	0.321	0.225	0.441	0.258	0.059	0.154	0.268	0.249
Lowland Forest	0.008	0.017	0.007	0.014	0.006	0.009	0.011	0.038
Non-veg Farmland	0.001	0.002	0.000	0.001	0.001	0.002	0.011	0.078
Orchards	0.016	0.051	0.000	0.001	0.005	0.014	0.008	0.042
Parks/Golf Course	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.006
Row Crops	0.086	0.133	0.029	0.048	0.424	0.193	0.097	0.155
Upland Shrub	0.081	0.107	0.118	0.118	0.005	0.004	0.069	0.118
Urban	0.039	0.042	0.033	0.017	0.037	0.033	0.027	0.020
Water	0.000	0.002	0.000	0.000	0.000	0.000	0.002	0.014
Wetlands	0.019	0.046	0.016	0.045	0.016	0.011	0.042	0.152

Table 10. Landscape metrics calculated for the two largest openings within long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula (SLP), and random Michigan Breeding Bird Atlas blocks.

Metric	Long-term Habitat	Short-term Habitat	SLP	Random
Mean patch area (ha)	271	167	645	230
Mean edge length (m)	20981	16574	38482	18917
Edge-to-area ratio	105	118	87	118
Fractal dimension index	1.171	1.178	1.192	1.174
Nearest neighbor index	2862.6	790.0	798.9	2031.6
Proximity index	184.7	339.4	4859.3	180.4
Contagion	68.3	66.6	78.8	66.3

Table 11. Mean values (1 standard deviation in parentheses) for nine vegetation variables sampled at 39 sites of upland sandpiper habitat in the Upper Peninsula and northern Lower Peninsula of Michigan. Variables denoted by "*" were log transformed for analysis but are presented here as original data. AF = anthropogenic fields; FR = burned areas; BS = barren/savannas; CC = clear cut areas; PL = recent plantations; SF = stump field. Height density units are expressed as 5-cm intervals.

Variable	**AF**	**FR**	**BS**	**CC**	**PL**	**SF**	**p**	**F**
N	5	3	3	5	19	4	-	-
*Height Density (5 cm)	4.59 (1.66)	3.10 (1.07)	0.74 (0.56)	0.76 (0.14)	1.91 (0.20)	0.89 (0.51)	0.007	3.884
*Litter Depth (cm)	1.16 (0.15)	1.18 (0.27)	0.80 (0.11)	1.44 (0.30)	0.23 (0.10)	1.15 (0.42)	0.51	0.867
*Perch Density (#/ha)	11.80 (7.84)	13.63 (4.17)	52.00 (33.19)	34.96 (11.05)	22.18 (4.87)	27.73 (8.10)	0.3	1.276
Coverage of Bare Ground (%)	7.85 (2.61)	6.04 (0.95)	14.23 (13.33)	19.49 (8.85)	20.07 (2.99)	8.87 (4.50)	0.28	1.322
*Coverage of Moss and Lichen (%)	4.66 (3.68)	8.37 (0.48)	26.50 (14.08)	9.46 (4.25)	8.16 (3.07)	22.68 (11.98)	0.76	0.523
Coverage of Dead Wood (%)	0.68 (0.60)	1.26 (0.54)	2.22 (0.73)	6.80 (2.90)	5.96 (0.72)	6.47 (3.60)	0.05	2.578
Coverage of Woody Plants (%)	4.35 (2.71)	42.96 (9.40)	7.00 (1.60)	18.06 (3.19)	23.05 (2.23)	13.1 (5.76)	< 0.001	8.108
Coverage of Grasses (%)	56.41 (6.86)	45.23 (8.10)	24.30 (7.24)	33.29 (10.88)	39.51 (3.77)	29.44 (9.24)	0.13	1.877
*Coverage of Forbs (%)	9.81 (3.23)	4.29 (3.27)	15.24 (11.28)	5.20 (1.19)	3.91 (1.49)	8.78 (4.23)	0.15	1.749

Table 12. Standardized canonical discriminant functions of the first three canonical variates using nine independent variables of vegetation structure.

	CV 1	CV 2	CV 3
Eigenvalue	1.806	0.817	0.446
% variance explained	54.6	21.9	14.6
	Canonical discriminant functions		
Height density (m)	-0.992	-0.671	0.261
Litter depth (cm)	0.462	-0.490	-0.495
Perch density (#/ha)	-0.055	0.255	0.919
Coverage of Bare Ground (%)	0.025	0.158	1.294
*Coverage of Moss and Lichen (%)	-0.273	0.107	-0.047
Coverage of Dead Wood (%)	-0.286	-0.775	-0.848
Coverage of Woody Plants (%)	-0.415	1.158	-0.242
Coverage of Grasses (%)	0.397	0.081	1.031
*Coverage of Forbs (%)	0.794	0.548	-0.059

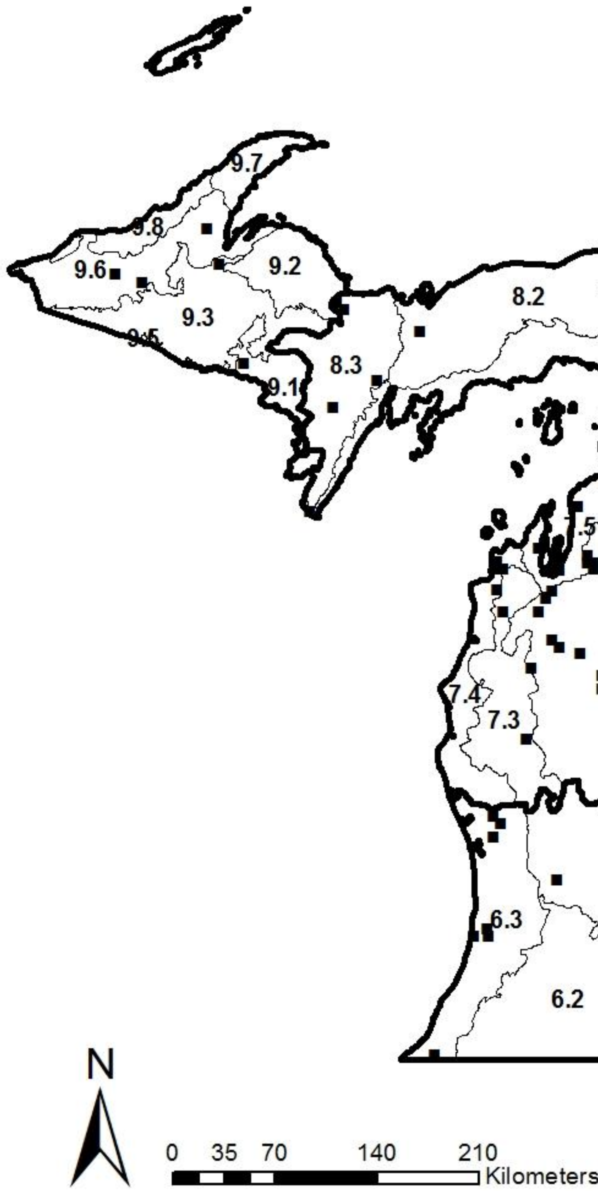

Figure 1. Distribution of Michigan Breeding Bird Atlas blocks (shown as black squares) with upland sandpiper during at least one of the two Atlas sampling periods (1983 to 1988 and 2002 to 2008). Two-digit numbers designate subsections as delineated by Albert (1995).

Figure 2. Density of upland sandpiper long-term occupied Michigan Breeding Bird Atlas blocks within ecoregion subsections as delineated by Albert (1995). Subsections shaded progressively darker with increasing density of long-term occupied habitat.

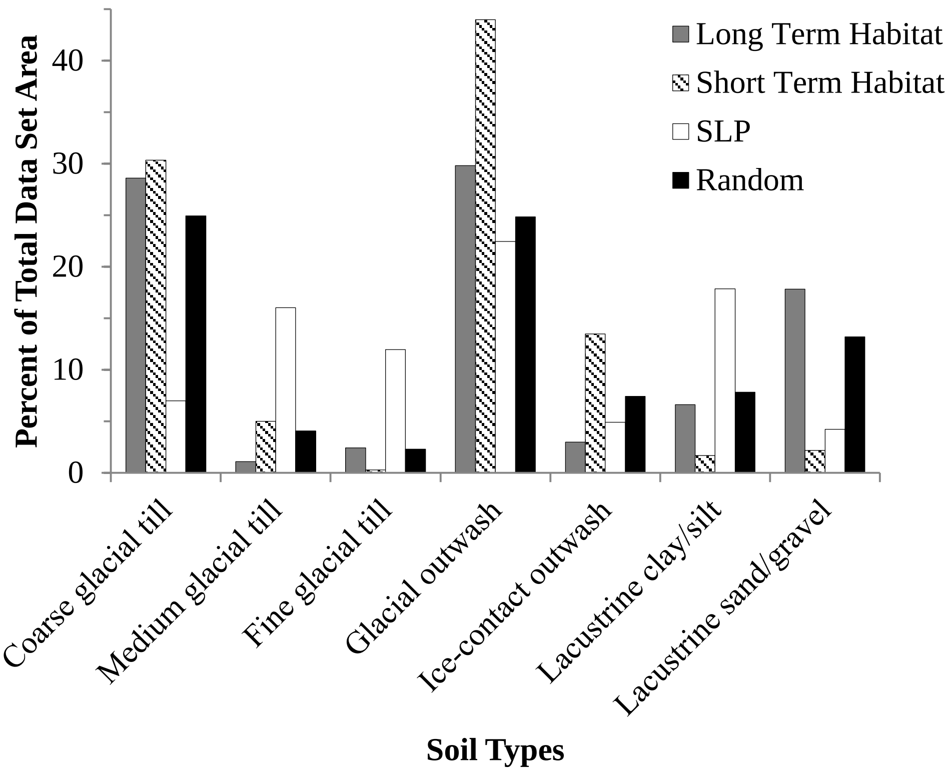

Figure 3. Percent of total soil type area within long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula (SLP), and random Michigan Breeding Bird Atlas blocks. Only soils representing >10% area are shown.

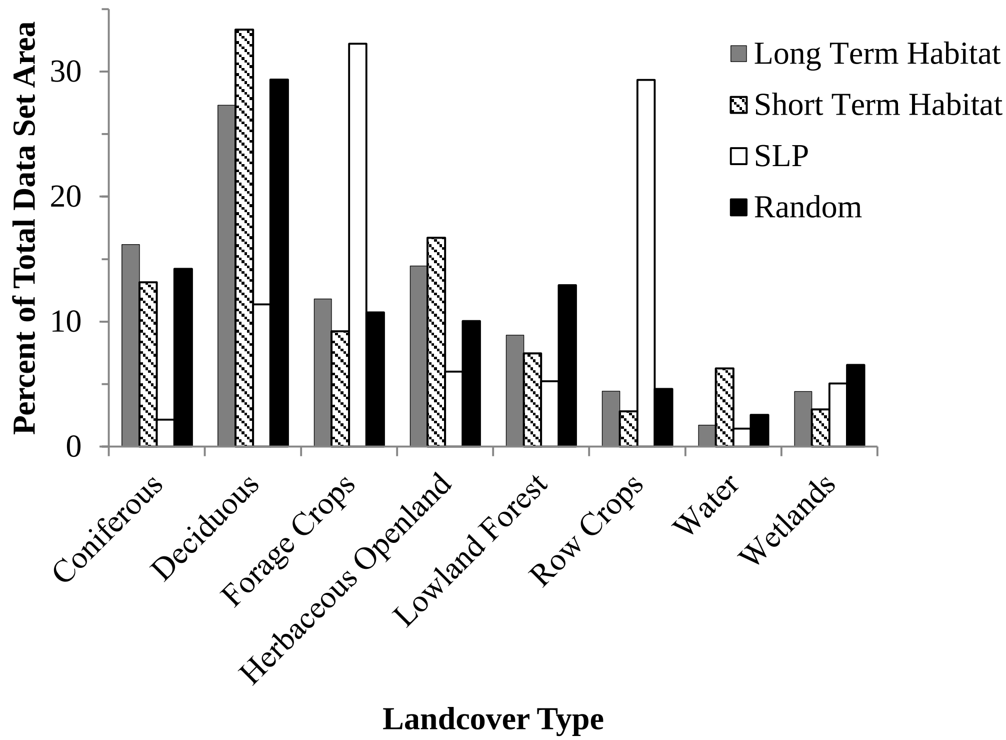

Figure 4. Percent of total land cover area within long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula (SLP), and random Michigan Breeding Bird Atlas blocks. Only land covers with percent area > 5% are shown.

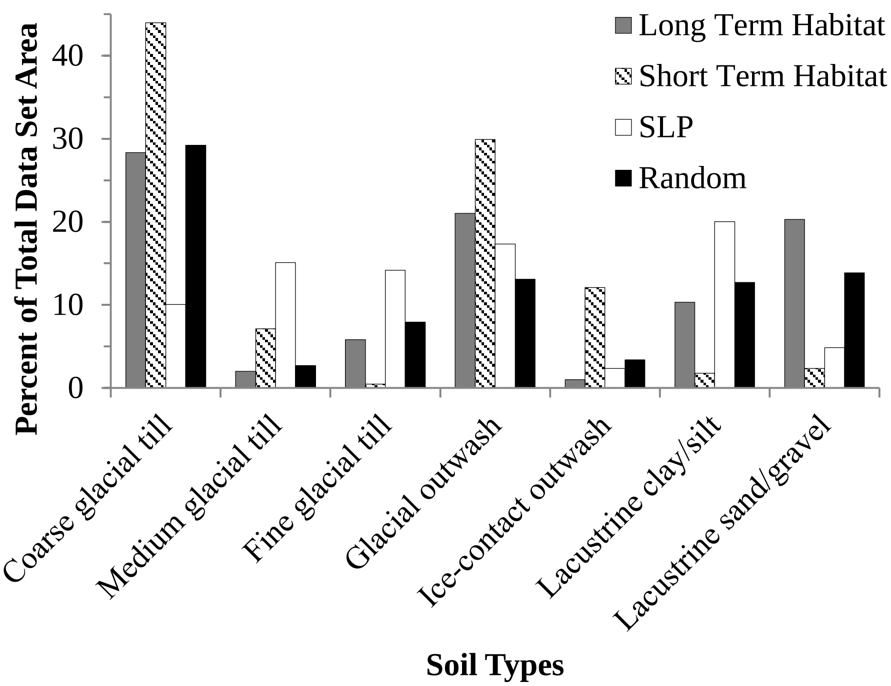

Figure 5. Percent of total soil type area within the largest openings for long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula (SLP), and random Michigan Breeding Bird Atlas blocks. Only soils representing >10% area are shown.

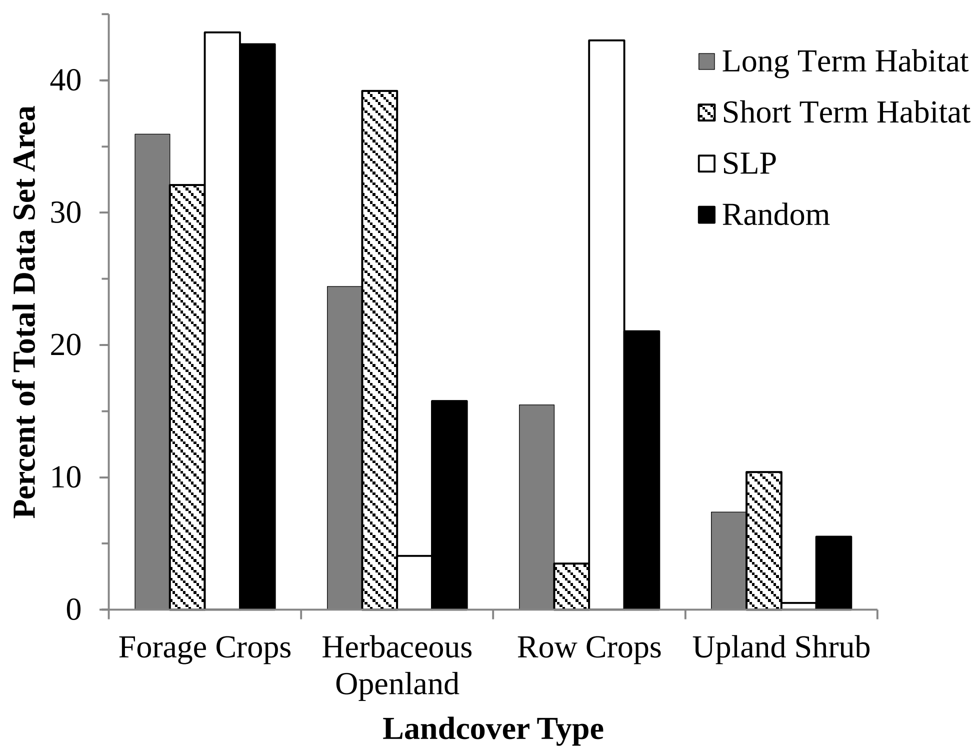

Figure 6. Percent of total land cover area within the largest openings for long-term occupied habitat, short-term occupied habitat, southern Lower Peninsula (SLP), and random Michigan Breeding Bird Atlas blocks. Only land covers with percent area > 5% are shown.

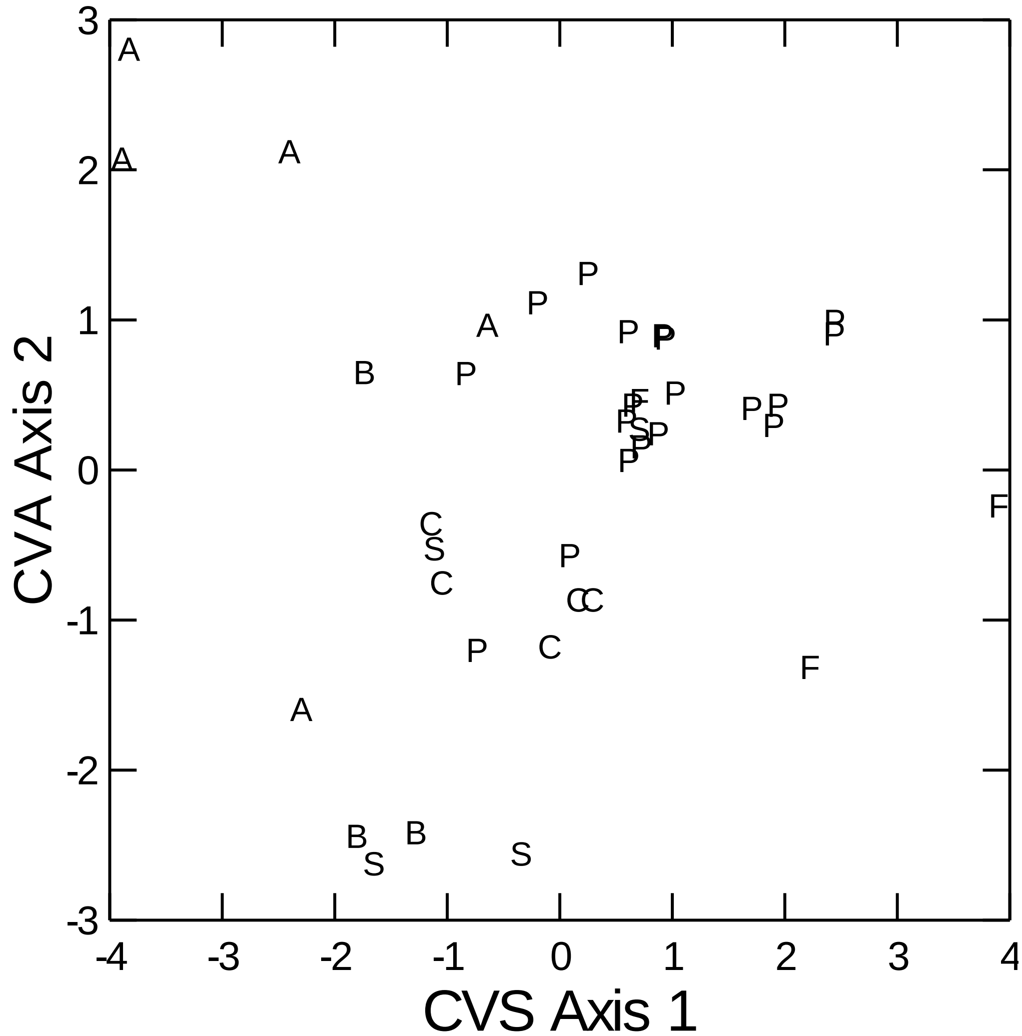

Figure 7. Ordination of 39 open land cover types occupied by upland sandpiper in Michigan along the first two canonical variates of an analysis of six open land cover types. Letters represent stand type: A, anthropogenic fields; F, burned areas; B, barrens/savannas; C, recent clear cuts; P, recent plantations; S, stump field. See Results for interpretation of the ordination.

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ABSTRACT

LANDSCAPE CHARACTERISTICS OF UPLAND SANDPIPER HABITAT IN MICHIGAN

by

JACOB KORTE

January 2013

Advisor: Dr. Dan Kashian

Major: Biology

Degree: Master of Science

Grassland bird populations have declined across North America due to habitat loss but at a disproportionately higher rate in the midwestern United States, where extensive coverage of grasslands and other open land ecosystems have been converted to other land cover types. The upland sandpiper (*Bartramia longicauda* Bechstein, UPSA) is a migratory, area-sensitive, terrestrial shorebird that breeds in grasslands and other open land ecosystem types across their North American range. Although breeding habitats of the Great Plains contain the greatest concentrations of this species, anthropogenic openings such as hayfields and pastures serve as surrogate habitat elsewhere, as do remnant patches of native open land ecosystems that are less understood as UPSA habitats. The upland sandpiper may therefore represent a flagship species for restoration of native open land ecosystems and a novel conservation opportunity within human-maintained open land cover types. A dearth of information about UPSA habitat selection and use in Michigan (a state of decided importance for UPSA habitat east of the Mississippi

River) and elsewhere in the eastern United States forces a reliance on data from studies conducted in other areas of the species' range for conservation and management efforts. I used two Michigan Breeding Bird Atlases (1983 to 1988 and 2002 to 2008) to compare areas where (1) breeding UPSA persisted for both Atlas periods (long-term occupied habitat); (2) breeding UPSA were present only in the first Atlas period (short-term occupied habitat); and (3) areas where UPSA was never located during the two sampling periods. Analyses were conducted at the scale of Atlas blocks (4.8 km^2 blocks defined by the Michigan Breeding Bird Atlas), the largest openings in those Atlas blocks (ranging in size from 17 to 2225 ha), and 39 field sites. At the broadest scale, long-term and short-term occupied UPSA habitat were more commonly located in the northern Lower Peninsula of Michigan (NLP), typically on coarse-textured soils; random Atlas blocks in the southern Lower Peninsula (SLP) where UPSA was not present were more often located on fine-textured soils. These soils are typically associated with row crops and other intensively managed agricultural land covers. At the scale of openings within the Atlas blocks, openings containing long-term occupied habitat tended to be located within agricultural areas dominated by forage crops managed at a relatively low intensity (non-tilled) such as hayland and pasture; short-term occupied habitat tended to be in herbaceous open lands; and non-occupied open lands in the SLP were dominated by row crops. Field sampling in occupied patches in northern Michigan confirmed that UPSA use a wide range of open land cover types as breeding habitat, excluding row crops, even when woody plant coverage approached 50%. The location of short-term occupied habitat in xeric, sandy, fire-dependent ecosystems suggests a much more dynamic system compared to the more stable, human-maintained forage crops (pastures and hayfields) that characterize a larger proportion of long-term occupied habitat. UPSA habitat in Michigan therefore appears to depend more on human-associated cover types, which persist longer and change less than natural cover types in the absence of fire in this region. However, considerable opportunities exist for management of the more dynamic (short-term) habitats as a disproportionate area containing these ecosystem types are under public ownership. As such, conservation planning and management for UPSA in Michigan depends more strongly upon on understanding the long-term stability of cover types forming habitat rather than simply their differences in vegetation structure or composition.

AUTOBIOGRAPHICAL STATEMENT

In 2002, not sure what I was doing, I started my long stint as an undergraduate student at Wayne State University. I began as a music major, changed to a biology major after four semesters, and finally settled on ecology and environmental science a year or two later. My first bit of work in Dr. Dan Kashian's lab was grinding pine cones for a serotiny study. I was fortunate enough to continue to work for Dan as a field tech for two summers in Yellowstone National Park. I have been hooked on field work ever since. My undergraduate research project was a study of color morph proportions of the eastern grey squirrel. I began my Master's research at Wayne State University in 2010 under the advisement of Dan. I plan to pursue some facet of ecology as a career and I look forward to what the future might bring.