Upland Sandpiper: A Flagship for Jack Pine Barrens Restoration in the Upper Midwest?

R. Gregory Corace III, Jacob L. Korte, Lindsey M. Shartell and Daniel M. Kashian

ABSTRACT

Fire-dependent ecosystems have been altered across much of North America, and their restoration has the potential to affect many wildlife species, including those of regional conservation priority such as the upland sandpiper (UPSA, *Bartramia longicauda*). In the Upper Midwest, fire-dependent jack pine (*Pinus banksiana*) barrens were once common and are now a focus of restoration by state, federal, and non-government agencies and organizations. Given UPSA's association with terrestrial ecosystems such as pastures, hayfields, and barrens, we determined the location of UPSA-occupied areas across multiple states, with special focus on Michigan, to illustrate distributional relationships with specific ecoregions, soils, and land covers while considering what role the species may have as a flagship for barrens restoration. With the exception of Michigan, UPSA-occupied areas in all states studied had greater proportions of agricultural land (National Land Cover Data: pasture/hay and cultivated crops) than other openland cover types. In Michigan, 66% of long-term occupied areas were found in the northern Lower Peninsula, and most often consisted of anthropogenic grasslands providing stable habitat on higher-quality soils. In contrast, short-term occupied areas had a greater proportion of native openlands that were often located on poorer, xeric soils associated with jack pine ecosystems that succeed to closed-canopy forests or shrublands in the absence of fire. Openlands with no UPSA breeding evidence were characterized by intensive agriculture (row crops). Our data suggest that UPSA would be an appropriate flagship species for the restoration of jack pine barrens, as well as the conservation of anthropogenic grasslands.

Keywords: ecoregion, grasslands, hayfields, Kirtland's warbler, Michigan

Restoration Recap

- Jack pine barrens are imperiled, dynamic ecosystem types that have long been a focus of restoration activities in the Upper Midwest.
- Upland sandpiper (UPSA) is an area-sensitive, openland bird species of conservation priority in the Upper Midwest; understanding UPSA use of anthropogenic vs. native openland covers is important for its conservation.
- Unlike other states east of the Mississippi River, UPSA utilize different ecosystem types in Michigan for breeding habitat.

- Existing habitat management for UPSA incorporates frequent disturbances (including prescribed fire) to minimize tree and shrub cover, similar to management for jack pine barren restoration.
- Given the current and historical distribution of UPSA on poor, dry soils where jack pine barrens once dominated and an overlap in management objectives for UPSA habitat and jack pine barren restoration, UPSA appears to be an appropriate flagship species for jack pine barrens restoration in the Upper Midwest.

Humans are increasingly dominating the earth and its ecosystems (Vitousek et al. 1997), contributing to global extinction rates that are 100 to 1,000 times greater than the reported background rate (Pimm et al. 1995). One factor associated with this biodiversity crisis is the simplification of ecosystems and vegetation communities

resulting from shifting land use and changes in underlying ecological processes (Wilcove et al. 1998, Pimm et al. 2006). Fire-dependent, North American grasslands and non-forested terrestrial ecosystems such as prairies, barrens, and early successional stages of some forest types (hereafter, openlands) have experienced severe alterations over the past century due to fire suppression and conversion to non-native land covers (Samson and Knopf 1994). An example of this group of ecosystems is jack pine (*Pinus banksiana*) barrens, which once covered two million ha in northern Michigan, Minnesota, and Wisconsin, US prior

to European settlement (Pregitzer and Saunders 2007). The extent of jack pine barrens in the Upper Midwest, USA has been greatly reduced due to altered fire regimes and land use (Radeloff et al. 1999). Jack pine barrens are characterized by large areas of herbaceous vegetation with scattered, individual trees or small groups of trees (Pregitzer and Saunders 2007). In Michigan, more than 109,000 ha of jack pine barrens existed prior to extensive logging and fire suppression (Comer et al. 1995); today fewer than five high-quality examples totaling only a few hundred hectares remain (Comer 1996). Despite their collection of rare flora and fauna (Comer 1996), importance for some game species, relative uniqueness on the landscape (Radeloff et al. 1999), and long history of restoration activities (Radeloff et al. 2000), jack pine barrens in the Upper Midwest are generally undervalued by many land managers and the public as unproductive badlands, making widespread or effective support for their restoration difficult.

Changes to native openlands have paralleled population declines of many bird species (Askins et al. 2007). Interestingly, the extensive loss of barrens and other native openlands has allowed anthropogenic openlands (e.g., hayfields and pastures) to become increasingly important as surrogate habitat for many grassland bird species, giving them notable conservation value (Corace et al. 2009, Jacobs et al. 2012). The type and intensity of agricultural practices have important effects on avian populations (Fletcher and Koford 2002, Askins et al. 2007, Corace et al. 2009), and thus identifying their relative use of anthropogenic vs. natural openlands is critical for conservation planning. More importantly, linking anthropogenic vs. natural land cover use to habitat selection for species of conservation priority is critical for highlighting the importance of ecosystem restoration and preservation of natural land covers.

Upland sandpiper (UPSA, *Bartramia longicauda*) is a migratory, terrestrial shorebird that breeds in large (> 50 ha) openland patches. UPSA typically breed in areas dominated by short grass, such as native prairies, pastures, and hayfields as well as jack pine barrens (Sample and Mossman 1997). Although U.S. Geological Survey Breeding Bird Survey (BBS) data suggest that UPSA populations in North America are stable overall (Sauer et al. 2014), the breeding distribution and abundance of UPSA have declined in many localities over the past century due to over-hunting and habitat loss (Houston et al. 2011). East of the Mississippi River, population declines have been observed where historical forest cover is recovering following agricultural abandonment or where other land uses have displaced pastures and hayfields. In Michigan, UPSA were once common in the northern Lower Peninsula (Wood 1951), an area that historically had an abundance of jack pine barrens (Comer et al. 1996). UPSA is thus a current conservation priority in many jurisdictions (USFWS 2004). Some studies have addressed UPSA conservation issues in the Great Plains (Helzer and Jelinski 1999, Thogmartin et al. 2006), but few studies have examined the importance of native and anthropogenic ecosystems for UPSA east of the Mississippi River (Vickery et al. 1994, Vickery et al. 2010).

Flagship species include those that help to market the management of a given ecosystem type to a target audience or the larger environmentally-minded community (Veríssimo et al. 2011). For jack pine-dominated ecosystems in Michigan, the endangered Kirtland's warbler (*Setophaga kirtlandii*), which requires large, dense patches of young jack pine forest (Probst 1988), has been a flagship species for jack pine forest conservation for decades. The linkage between Kirtland's warbler and breeding habitat management has been touted in tours for birders and the general public, in secondary education classrooms, and in other outreach efforts (Solomon 1998). These efforts have garnered financial support for the ongoing and intensive jack pine plantation management used in the recovery of Kirtland's warbler (Marshall et al. 2000), but the conservation and restoration of jack pine barrens has been largely overlooked. Flagship species are most useful in drawing attention to the need for preservation and restoration of the ecosystems or landscapes to which they belong (Barua 2010), but those species whose habitat requirements may result from ecosystem-level restoration activities may also be used to prioritize restoration sites (Barua et al. 2011). Studies in this region (Corace et al. 2010) and other evaluations done elsewhere in the Upper Midwest (Sample and Mossman 1997) suggest the conservation and restoration of jack pine barrens have the potential to positively influence many game and non-game bird species of conservation priority, including UPSA. The identification of a suitable flagship species appropriate for jack pine barrens would therefore be heavily influential in garnering support for this increasingly rare ecosystem type (Comer 1996).

Ecosystem restoration occurs at multiple scales and in multiple phases (George and Zack 2001). The planning phase often includes using remotely-sensed data across broad landscapes to provide context for work at finer spatial scales (i.e., stands or patches; George and Zack 2001, Noss et al. 2006). We examined UPSA habitat in Michigan to test the utility of UPSA as a flagship species for jack pine barrens restoration in the Upper Midwest. We hypothesized that because UPSA require large patches of openland, and jack pine barrens are a dynamic ecosystem type whose restoration involves reproducing open conditions (often with fire; Comer 1996), UPSA conservation and management should simultaneously provide significant opportunities for pine barrens restoration. There have been no statewide evaluations of habitats occupied specifically by this species in Michigan, especially with regard to broader landscape features that would affect restoration, and thus we addressed the following questions:

1. How does UPSA distribution across suitable habitat types in Michigan compare with other states east of the Mississippi River?
2. Which Michigan ecoregions, broad soil types, and land covers are associated with breeding habitat occupied for long periods of time, and how do these broad-scale characteristics differ where breeding habitat is occupied only briefly or not at all?
3. Can differences in UPSA occupancy be explained at the scale of individual openland patches (openings), and how does patch size, shape, and distribution for openings occupied for an extended period of time compare to those occupied only briefly or never at all?

Methods

Multi-State UPSA Distribution and Land Cover Assessment

We analyzed distribution patterns of UPSA for these occupied states east of the Mississippi River to provide broader context to our analysis of UPSA habitat in Michigan: Illinois, Indiana, Maine, Massachusetts, New Hampshire, New York, Ohio, Pennsylvania, Vermont, and Wisconsin. All states were primarily forested during pre-settlement times. Despite a broad range of climatic and other environmental gradients, Thogmartin et al. (2006) suggest that climate is not an important covariate in describing UPSA occupancy. We used georeferenced data from state-wide Breeding Bird Atlas (BBA) efforts, along with spatial land cover data, to characterize occupied areas within the breeding distribution of UPSA in these states. BBA surveys occur at a relatively coarse resolution. For instance, in Michigan breeding locations of birds were identified within a grid system of 4.8 km × 4.8 km, producing 2,331 ha Atlas blocks across the state (Brewer et al. 1991). Across a survey period, a level of UPSA breeding confidence was assigned for each Atlas block sampled: "possible" (least certain) was assigned when a male was observed in suitable habitat during the May–July breeding season; "probable" (intermediate certainty) was assigned when a breeding 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).

Only states with available BBA data and ≥ 10 Atlas blocks occupied by UPSA were examined. As stated previously, UPSA breed only in large (> 50 ha) areas (e.g., are area-sensitive) dominated by short grass, including native prairies, pastures, and hayfields as well as jack pine barrens or jack pine forests following severe disturbance (Vickery et al. 1994, Sample and Mossman 1997, Vickery

et al. 2010). We therefore used 2006 National Land Cover Data (NLCD, USGS 2011) that corresponded to land covers used by breeding UPSA in the eastern USA. We determined the mean proportion of the following NLCD classes that approximate or correspond to the above: 1) agricultural land cover (pasture/hay and cultivated crops); 2) anthropogenic grasslands (pasture/hay only); and 3) natural grasslands (grassland/herbaceous) for each state within all Atlas blocks and within those blocks occupied by UPSA. A chi-square goodness-of-fit test was used to determine if the amount of cover within UPSA-occupied blocks differed from what would be expected based on the mean proportion of cover within all blocks statewide.

UPSA Distribution in Michigan

We used Michigan as a case study of UPSA eastern USA distribution because it is the most important state for UPSA occupancy east of the Mississippi River (see below) and because of the availability and comprehensiveness of Michigan Breeding Bird Atlas (MBBA) data. Two independent Atlas projects have been completed in Michigan; 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 utilized:

1. A set of 86 Atlas blocks ("long-term occupied habitat") was selected based on the condition that the level of breeding confidence in a block was probable or confirmed for both MBBA sampling periods. We hypothesized that these blocks contained characteristics of suitable UPSA habitat for the entire period of 1983–2008;
2. A set of 26 Atlas blocks ("short-term occupied habitat") where breeding evidence for a block was probable or confirmed for MBBA I but absent for MBBA II was selected to examine characteristics of UPSA habitat that were seemingly temporary. We hypothesized that these blocks provided habitat for a limited time because they contain dynamic, natural land covers (e.g., fire-dependent jack pine barrens that undergo succession away from openland in the absence of fire rather than static land covers, e.g., low-intensity agriculture). We limited analysis to the Highplains Subsection (VII.2, see below) of the northern Lower Peninsula where jack pine forests or barrens are most common (see descriptions of ecoregions below);
3. A set of 20 Atlas blocks ("SLP") containing no breeding evidence in either MBBA was randomly chosen from the southern Lower Peninsula where UPSA are disproportionately absent despite the extensive coverage of openland (Thogmartin et al. 2006, Corace et al. 2009, Corace 2011). We hypothesized that these blocks would have representative characteristics of openlands that do not attract breeding UPSA;
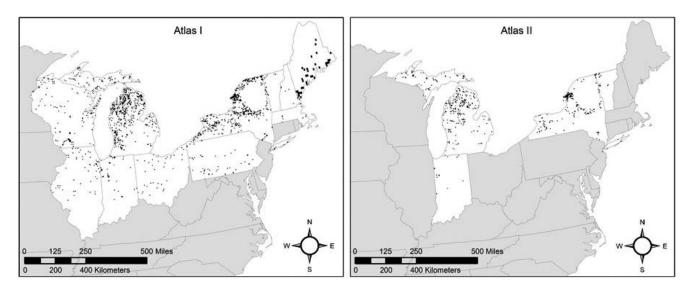
Figure 1. Distribution of upland sandpiper-occupied Atlas blocks in states east of the Mississippi River with ≥ 10 occupied blocks (n = 11 states for Atlas I, n = 4 states for Atlas II, see text). Shading for Atlas I denotes states with < 10 occupied blocks. Shading for Atlas II denotes states with no data or with < 10 occupied blocks.

4. A final set of 86 Atlas blocks ("random") was selected randomly from the entire state, stratified and weighted by ecoregion based on (but excluding) the 86 blocks of the long-term habitat data set. These blocks were selected to test the hypothesis that patterns of occupied Atlas blocks (long-term or short-term) differed from a random sample.

We used the regional landscape ecosystem classification system of Albert (1995) as a framework to examine the distribution of UPSA and its association with ecoregions, soil types, and land covers in Michigan. This system divides the state into a nested hierarchy of broad-scale ecosystem units (ecoregions) based mainly on climate and physiography. The broadest scale of classification divides the state into four sections that differ mainly by climate: Southern Lower Michigan (SLP, Section VI); Northern Lacustrine-Influenced Lower Michigan (NLP, Section VII); Northern Lacustrine-Upper Michigan (EUP, Section VIII); and Northern Continental Michigan (WUP, Section IX). Each of the four sections varies considerably in the total amount of openland that currently exists, with area in openland declining (and forested area increasing) from south to north: 3.6 million ha (70% of the area) in SLP; 1.2 million ha (24%) in NLP; 0.2 million ha (5%) in EUP; and 0.1 million ha (2%) in WUP (Corace 2007). Sections are then subdivided further into subsections and sub-subsection based on physiography and other finer-scale ecological factors that may be used to delineate more refined ecological land units (Albert 1995).

We used ArcMap 10 (ArcGIS Desktop: Release 10, Environmental Systems Research Institute, Redlands, CA) to determine the association of each set of Atlas blocks with ecoregions at the subsection scale. A chi-square test was used 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, we performed overlays of Atlas blocks with major soil types (Farrand and Bell 1982) and with land cover using Integrated Forest Monitoring, Assessment, and Prescription (IFMAP) data (MDNR 2001). [Note: NLCD and IFMAP use different terms for the same openland land covers analyzed in this study.] Associations between Atlas blocks and subsections, soils, or land cover were individually summarized with frequency distributions. We used a two-factor 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, soil or land cover was used as the independent variable, and the interaction term between soil/land cover and data set was used to determine whether the soil/land cover varied amongst the data sets. Proportions were transformed using an arcsine transformation to meet assumptions of normality, but no other departures from assumptions of normality or equal variances were found. Statistical analyses were performed in SPSS at α = 0.05 (SPSS v. 21.0, IBM Corp., Armonk, NY).

Patch-Scale Analysis of UPSA Habitat

We explored patch-scale characteristics 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). The largest two openings in each Atlas block were digitized using 2005 aerial imagery (USDA 2009), with a minimum mapping unit of 16 ha based on past studies of openlands in Michigan (Corace 2007). Patch metrics were calculated in FRAGSTATS (McGarigal et al. 2002) using a cell size of 40 m² to determine patch size (mean patch area), patch

Table 1. Number of upland sandpiper-occupied Atlas blocks in states east of the Mississippi River having ≥ 10 occupied blocks across the state in total.

State	Atlas I	Atlas II	Total State Blocks	Percent Occupied (Atlas I/Atlas II)
Illinois	57	—	1283	4
Indiana	40	13	1215	3/1
Maine	36	—	626	6
Massachusetts	10	9	969	1/1
Michigan	595	297	6120	10/5
New Hampshire	14	—	704	2
New York	476	165	5335	6/3
Ohio	36	—	1086	3
Pennsylvania	54	—	4928	1
Vermont	21	19	544	4/4
Wisconsin	142	—	3840	4

shape (mean edge length or perimeter, edge-to-area ratio, fractal dimension index), patch isolation (nearest neighbor, proximity index), and contagion. Fractal dimension index ranges between one and two, and approaches one for shapes with very simple perimeters (e.g., squares) (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). We used a search radius of 400 m based on an estimate of between-patch dispersal of grassland birds (Sample et al. 2002). All landscape metrics were calculated for all openings together, regardless of land cover. Because they require information about the presence of all openings on the landscape independent of 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.

Results

Multi-State UPSA Distribution and Land Cover Assessment

Eleven states east of the Mississippi River (Illinois, Indiana, Maine, Massachusetts, Michigan, New Hampshire, New York, Ohio, Pennsylvania, Vermont, and Wisconsin) had ≥ 10 Atlas blocks occupied by UPSA from Atlas I BBA data, four of which (Indiana, Michigan, New York, and Vermont) also had ≥ 10 blocks occupied from Atlas II BBA data (Table 1). Michigan and New York had the most occupied Atlas blocks among the 11 states (Figure 1).

With the exception of Michigan, all states had a greater proportion of agricultural land in UPSA-occupied blocks than expected based on all blocks within the state (Figure 2A). The proportion of agricultural lands in occupied blocks was significantly greater than expected for Atlas I data from New Hampshire ($\chi^2 = 6.37$, $p = 0.01$), New York ($\chi^2 = 5.23$, $p = 0.02$), Pennsylvania ($\chi^2 = 7.67$, $p = 0.006$), Vermont ($\chi^2 = 15.00$, $p < 0.001$), and Wisconsin ($\chi^2 = 3.95$,

$p < 0.05$), and Atlas II data for New York ($\chi^2 = 5.73$, $p = 0.02$) and Vermont ($\chi^2 = 7.41$, $p = 0.006$). The proportion of anthropogenic grasslands within occupied blocks was significantly greater than expected for Atlas I data from New Hampshire ($\chi^2 = 4.57$, $p = 0.03$), Vermont ($\chi^2 = 8.10$, $p = 0.004$) and Wisconsin ($\chi^2 = 4.17$, $p = 0.04$), and Atlas II data from New York ($\chi^2 = 4.12$, $p = 0.04$) and Vermont ($\chi^2 = 12.07$, $p < 0.001$; Figure 2B). The proportion of natural grasslands was very low (mean = 0.02 ± 0.01) across all states and within occupied blocks in each. Michigan had a noticeably greater mean proportion of natural grasslands (likely pine barrens or similar) in the statewide sample (0.04 for both Atlas I and II blocks) and within UPSA-occupied blocks (0.08 for Atlas I blocks, 0.10 for Atlas II blocks) than other states (the highest mean proportion for any other state Atlas was 0.02 statewide and 0.04 within UPSA blocks).

UPSA Distribution in Michigan

Two major limitations of MBBA data are that 1) specific locations (e.g., point data) of observed breeding birds—or even the openings that they occupy—are not known, and 2) detection probabilities are unknown (Mackenzie 2006). However, because UPSA breed only in openlands and are known to be area-sensitive (Vickery et al. 1994), we assumed at least one of the two largest openings within any given Atlas block was occupied in that block. We also assumed the probability of detecting UPSA to be equal in all blocks surveyed and across years. As such, the majority of long-term occupied breeding habitat (83%) was found in the Lower Peninsula (Figure 3, Table 2). The overwhelming majority (66%) of long-term occupied Atlas blocks were located in the NLP even when standardized by area, suggesting a disproportionately high value of this ecoregion for UPSA ($\chi^2 = 158.6$, $p < 0.0001$). 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, the five most frequented subsections were located within the NLP. The sixth most frequented subsection was
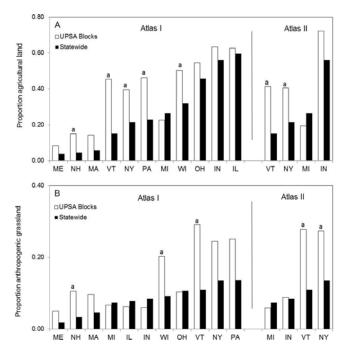
Figure 2. Mean proportion of agricultural land within upland sandpiper-occupied blocks in multiple states and all blocks statewide for each state (A), and mean proportion of anthropogenic grassland within upland sandpiper-occupied blocks and blocks statewide (B). States are ranked in order of increasing proportional dominance of openland overall. Note scale difference. "a" Indicates a significant difference from expected at $\alpha = 0.05$.

Figure 3. Distribution of 86 long-term Michigan Breeding Bird Atlas blocks (shown as black squares) having upland sandpipers during both MBBA sampling periods. Two-digit numbers designate subsections nested within sections as described by Albert 1995 (see text for details).

located along Lake Michigan in the Allegan Subsection (VI.3) of the SLP (Table 2). The distribution of Atlas blocks containing long-term habitat differed significantly from random ($\chi^2 = 265.4$, $p < 0.0001$).

Glacial outwash was a dominant soil type within the Atlas blocks for all data sets except SLP (Figure 4). Atlas blocks in the SLP data set were more often located on finer-textured soils compared to the other three data sets; short-term occupied Atlas blocks were more often found on glacial outwash that tends to support xeric, jack pine ecosystems. About 30% of the area of long-term occupied habitat 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 glacial till, and 14% on ice-contact outwash (Figure 4). The distribution of soil classes within the blocks differed significantly across the four data sets (ANOVA; $F_{42} = 3.30$, $p < 0.001$, Table 3).

The distribution of IFMAP land covers also differed significantly among the four data sets ($F_{39} = 13.18$, $p < 0.001$, Table 3). Atlas blocks with long-term and short-term occupied habitat included deciduous and coniferous forest, forage crops, and herbaceous openlands, but Atlas blocks

within the SLP were dominated mainly by forage crops (33%) and row crops (30%) (Figure 5).

Patch-Scale Analysis of UPSA Habitat

Glacial outwash was still a dominant soil type in the two largest openings within each Atlas block for 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 6). 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%). The distribution of soil classes within these openings differed significantly across the four data sets (ANOVA; $F_{42} = 2.36$, $p < 0.001$), with short-term occupied habitat on more coarse-textured soils and SLP openings on finer-textured soils (Figure 6).

Table 2. Count and percent occurrence of 86 Michigan Breeding Bird Atlas blocks with long-term upland sandpiper occupancy within ecoregion sections and subsections in Michigan, US (Albert 1995). Standardized value is the number of blocks (count) standardized by area of the section or subsection; value is count/area*10000. Southern Lower Michigan (SLP, Section VI); Northern Lacustrine-Influenced Lower Michigan (NLP, Section VII); Northern Lacustrine-Upper Michigan and Wisconsin (EUP, Section VIII); and Northern Continental Michigan, Wisconsin, and Minnesota (WUP, Section IX).

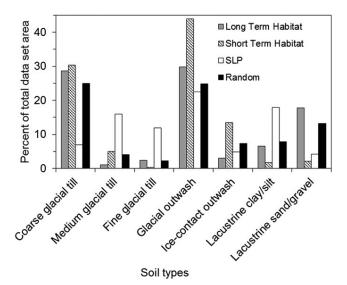| Section	Subsection	Area (km²)	Count	% Occurrence	Standardized
SLP		109745	15	17.0	1.37
	6.1	62821	2	2.0	0.32
	6.3	6882	7	7.1	10.17
	6.4	15192	3	3.1	1.97
	6.5	9564	2	2.0	2.09
	6.6	6190	2	2.0	3.23
NLP		44318	58	65.9	13.09
	7.2	21604	34	34.7	15.74
	7.3	5244	7	7.1	13.35
	7.4	3714	4	4.1	10.77
	7.5	2215	7	7.1	31.60
	7.6	7730	15	15.3	19.40
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
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

Not surprisingly, IFMAP land cover within the openings was limited to non-forested types, including forage crops, herbaceous openland, row crops, and upland shrub (Figure 7). All four data sets contained a significant proportion of forage crops as cover, but short-term occupied habitat was dominated by herbaceous openland and SLP was dominated by row crops (Figure 7). The SLP openings also had far less herbaceous openland compared to the other three data sets (Figure 7). The distribution of cover types within the largest openings of the four data sets differed significantly ($F_{39} = 11.59$, $p < 0.001$).
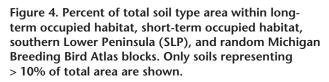
The average size of openings was much larger in SLP (645 ha) compared to the other three data sets, was smallest for short-term occupied habitat (167 ha), and averaged 271 ha for long-term occupied habitat (Table 4). Openings for all four data sets were similar in shape as suggested by similar values for mean edge length, edge-to-area ratio, and fractal dimension index. Openings in SLP had much more edge length (38,482 m), but also a lower edge-to-area ratio (87 m/ha). Long-term occupied habitat openings were a similar distance apart (nearest neighbor index = 826.5) and similarly dispersed (proximity index = 584.1) 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 4).

Discussion

Comprehensive restoration of ecosystem structure is often necessary in managing or restoring habitat for terrestrial wildlife of conservation priority, and thus identifying priority species whose habitat requirements represent key features of ecosystem structure, ecological amplitudes, and ecosystem variability (George and Zack 2001) is a strategic and effective conservation tool for ecological restoration. In this study we show that Michigan represents a geographically important location of UPSA breeding populations east of the Mississippi River. Moreover, we show that USPA-occupied blocks in Michigan differ in land cover composition compared with occupied blocks in most other states that have been analyzed for UPSA habitat in this and other studies (see Vickery et al. 2010). The uniqueness of UPSA habitat in Michigan, the conservation priority status of the

Figure 4. 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% of total area are shown.

Figure 5. 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 total area > 5% are shown.

species in the region, and its association with ecosystems now highly altered or threatened make UPSA a species whose management may be heavily influential in restoring associated ecosystems.

UPSA are particularly appropriate as a flagship species in Michigan because they rely on both agricultural lands and native land covers, making this species important both for the conservation of anthropogenic grasslands (low-intensity managed hayfields-pastures) and restoration of native openland ecosystems (jack pine barrens) within a
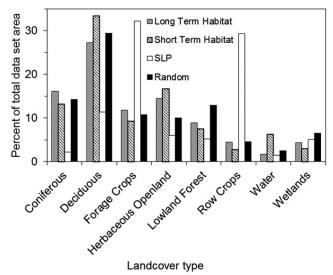
forested matrix. Anthropogenic land covers may provide critical habitat for UPSA in the state because of their persistence and stability (via long-term maintenance by humans) in the face of altered natural disturbance regimes. Two-thirds of long-term occupied UPSA habitat was located in the mostly forested NLP, most often on soils resulting from deposits of outwash, sandy glacial till, or lacustrine sand deposits (75% of long-term habitat). Even the relatively rare long-term occupied habitat found in the SLP is associated with sand deposits near Lake Michigan, rather

Table 3. Results of two-factor ANOVA examining the relationship of data set and soil, and data set and land cover. Significant interaction terms for data set and soil and 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, Southern Lower Peninsula (SLP), and random Atlas blocks) have different distributions of soil types and land cover within them.

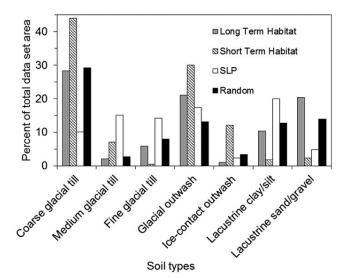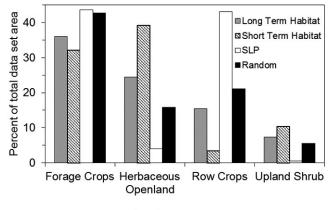| Comparison	SS	df	F	p
Soil in Atlas blocks				
Data Set	0.012	3	0.05	0.98
Soil	34.25	14	32.04	< 0.01
Data set*Soil	10.597	42	3.30	< 0.001
Soil in openings				
Data Set	0.01	3	0.03	0.99
Soil	26.77	14	19.68	< 0.01
Data set*Soil	9.63	42	2.36	< 0.01
Land cover in Atlas blocks				
Data Set	0.02	3	0.32	0.81
Land cover	41.48	13	195.74	< 0.01
Data set*Land cover	8.38	39	13.18	< 0.001
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

Figure 6. 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% total area are shown.

Figure 7. 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 total area > 5% are shown.

than the finer-textured soils generally associated with the SLP and other, more productive sites in the Midwest (see Thogmartin et al. 2006). The association of anthropogenic UPSA habitat with sandy deposits and associated dry sites likely results from lower soil productivity that would favor hayfields and pastures over row crops. These site conditions were also probably related to historical fire regimes that maintained openland-dominated conditions, like jack pine barrens, in an otherwise forested region (Whitney 1987, Comer et al. 1995, Pregitzer and Saunders 2007). Where management to restore openland ecosystem structure is limited, anthropogenic grasslands appear to have served as a critical surrogate for natural UPSA habitat, especially because these land covers are maintained and relatively unchanging, and likely allowed UPSA to persist in Michigan. 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 in some ecoregions in Michigan and in other states east of the Mississippi River (Vickery et al. 2010).

Short-term occupied habitat blocks examined in this study were located primarily in the Highplains Subsection (VII.2) of the NLP, which is dominated by coarse-textured soils (94% of short-term habitat) and was historically very prone to wildfires (Whitney 1987). Conspicuously, many of the oak (*Quercus*) and jack pine barrens of Michigan are located in this ecoregion and were historically maintained in an open condition by wildfires (Comer et al. 1995). The location of short-term occupied habitat in xeric, sandy, fire-prone areas with herbaceous openland is characteristic of the more dynamic, shifting nature of native jack pine barren vegetation compared to the more stable, anthropogenic forage crops (pasture/hay) that characterize a larger proportion of long-term occupied habitat in Michigan and elsewhere in the eastern U.S. With fire suppression, jack pine barrens vegetation succeeds to closed-canopy conditions and becomes unsuitable for UPSA breeding habitat; succession in these land covers may often explain the loss of breeding UPSA from an Atlas block, especially in the Highplains Subsection of the NLP. Conversion of barrens to other land covers—mainly closed-canopy jack pine forest planted for Kirtland's warbler habitat—could also explain the loss of UPSA between Atlas surveys. These

Table 4. 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	826.5	790	789.9	961.3
Proximity index	584.1	339.4	4859.3	450.6
Contagion	68.3	66.6	78.8	66.3

findings complement those of Wood (1951) and lend further evidence to the hypothesis that the fire-prone areas of the Highplains Subsection of NLP were likely a core area of UPSA distribution in Michigan prior to European settlement, with scattered pockets of habitat coinciding with the scattered fire-created openings shown in pre-settlement data (Comer et al. 1995). These ecosystems—with limited tree and shrub cover but not dominated by grasses—are a departure from the classical "grassland" UPSA habitat requirements (Sample and Mossman 1997; Vickery et al. 2010), and are a unique ecosystem in the Upper Midwest for which UPSA would be an appropriate flagship species. Thus, habitat management for UPSA (creation or restoration of openlands) is likely to simultaneously serve as ecological restoration of jack pine barrens and other openlands.

Implications for Management

Our work follows general guidelines for evaluating wildlife habitat restoration from broad scales to finer scales (e.g., George and Zack 2001). Planning on a broad spatial scale allows simultaneous management for multiple objectives and facilitates the integration of conservation and restoration goals (Noss et al. 2006). Moreover, broad-scale planning is critical for its role in developing and implementing restoration strategies at finer spatial scales (Clewell et al. 2005). As stated above, UPSA may function as a useful flagship for the restoration of native ecosystems (pine barrens) in Michigan. For state and federal public lands, restoration of pine barrens would likely occur within the framework of restoration planning, treatments, and evaluation (George and Zack 2001). Our work aids planning as our results indicate the added conservation value of the NLP and the Highplains Subsection relative to other regions in the state with remnant or historic pine barrens (Comer et al. 1995).

The affinity of UPSA for large (> 50 ha) open rather than forested areas indicate that management techniques used for UPSA habitat could simultaneously meet objectives for jack pine barren restoration. For example, in Wisconsin management guidelines for UPSA include large blocks of open habitat where blocks are contiguous or close together (Dechant et al. 2003), often within large conservation areas (> 4050 ha/10,000 ac) with limited housing/commercial development (Wisconsin Department of Natural Resources 2009). Frequent disturbances—often prescribed fire—are also employed to minimize tree and shrub cover at < 10%, typically with simultaneous management of invasive plants (Dechant et al. 2003). Notably, methodologies for jack pine barren restoration include 5–10 year cycles of prescribed burns, timber harvest and removal, mowing, and/or herbicide spraying, usually in large blocks (Radeloff et al. 2000). Given the current and historical distribution of UPSA on low-productivity, xeric soils where jack pine barrens once predominated in the Upper Midwest and the significant overlap in management objectives for UPSA habitat and jack pine barren restoration, UPSA appears to be an appropriate flagship species in the region and would be useful in identifying priority areas for barrens restoration.

Notably in the Upper Midwest, sandy outwash ecosystems in the NLP of Michigan (and recently in south-central Wisconsin) are intensively managed as breeding habitat for the Kirtland's warbler by creating dense forest cover rather than restoring open areas. Because warblers use young jack pine stands for only 5–25 years (Probst 1988), intensive and extensive management for the warbler is critical, requiring large stands of mature jack pine to be clearcut and re-planted. Although these management objectives initially seem at odds with UPSA management, UPSA clearly benefit initially from the land covers created by these extensive clearcuts (likely appearing as grassland/herbaceous in NLCD or herbaceous grassland in IFMAP). Co-management of Kirtland's warbler and UPSA appears achievable with relatively simple adjustments in the current warbler management regime (Corace et al. 2010). Delayed planting following clearcutting, for instance, could extend the duration of use of clearcuts by openland bird species.

Study Caveats and Drawbacks

Despite the usefulness of broad-scale analyses in assessing the potential for a species to be used as a flagship for restoration, we acknowledge several caveats and potential limitations in our study. First, our reliance on BBA data required us to assume that sampling effort and detection rates did not change over the time period of two Atlas sampling periods. This is likely not true. UPSA is a relatively large bird, breeding males are conspicuous early in the breeding season, and birds are likely to be detected similarly within a given ecosystem type over time. Nonetheless, Atlas efforts are based on volunteer sampling effort and therefore detection rates were not evaluated. However, the overall decrease in occupied Atlas blocks across our sampling area does seem to coincide with other data on UPSA population trends east of the Mississippi River (Vickery et al. 2010). Second, our use of BBA data for 1983–2008 to describe the distribution of UPSA in Michigan with a 2006 land cover data set makes our interpretations of the environmental drivers of UPSA distribution in the state somewhat speculative. We note that soil types were also used as ancillary data to confirm the correlation between UPSA occupancy and land cover; soil types are clearly stable over the study period compared to the overlying vegetation. Moreover, soil types are typically very highly correlated with land cover in the NLP, given that the xeric, nutrient poor, acidic sands on which jack pine ecosystems typically develop are rarely suitable even for low-intensity agriculture.

Data resolution of the BBA means that specific locations of UPSA and the specific land covers they occupy are unknown at spatial scales finer than the Atlas block, and thus we cannot say specifically which patch or finer-scaled

"habitat" UPSA may be using in the Atlas blocks. However, the known affinity of UPSA for large openings (Sample and Mossman 1997) greatly limits the available habitat found in each Atlas block, as there were ≤ 2 large openings in 73% of the blocks and ≤ 3 large openings in 86% of the blocks. Moreover, housing/commercial developments are generally rare on these sites, and in many instances, human communities within ecoregions having UPSA in Michigan have declining populations; conversion of openings to these cover types is not likely. Nonetheless, we acknowledge that this study is best suited for restoration planning at the ecoregional and landscape scales and that subsequent analyses and actions should occur before initiating pine barrens restoration at the patch or stand scales.

The implication of UPSA habitat utilization across a range of openland covers emphasizes that conservation planning and land management for UPSA will need to extend beyond the political boundaries of public lands. With UPSA dependence on anthropogenic grasslands, conservation planning in our study area will depend on cooperation among private landowners and public agencies. With additional heavy use by UPSA of jack pine barrens in the NLP (an alternative to the dogma of habitat restriction to native prairies), restorative activities that set back succession of these openlands would not only move ecosystem structure towards that found prior to fire suppression and thus preserve a natural cover type, but would simultaneously benefit UPSA and similar species of conservation priority.

Acknowledgements

References

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification. St. Paul, MN: U.S. Department of Agriculture Forest Service.

Askins, R.A., F. Chavez-Ramirez, B.C. Dale, C.A. Haas, J.R. Herkert, F.L. Knopf and P.D. Vickery. 2007. Conservation of grassland birds in North America: Understanding ecological processes in different regions. *Ornithological Monographs* 64:1–46.

Barua, M. 2010. Mobilizing metaphors: The popular use of keystone, flagship and umbrella species concepts. *Biodiversity and Conservation* 20:1427–1440.

Barua, M., M. Root-Bernstein, R.J. Ladle and P. Jepson. 2011. Defining flagship uses is critical for flagship selection: A critique of the IUCN climate change flagship fleet. *Ambio*, 40: 431–435.

Brewer, R., G.A. McPeek and R.J. Adams, Jr. 1991. *The Atlas of Breeding Birds of Michigan*. East Lansing, MI: Michigan State University Press.

Chartier, A.T., J.J. Baldy and J.M. Brenneman. 2011. *The Second Michigan Breeding Bird Atlas*. Kalamazoo, MI: Kalamazoo Nature Center.

Clewell, A., J. Rieger, and J. Munro. 2005. Guidelines for developing and managing ecological restoraton projects. Society for Ecological Restoration International. www.ser.org/resources/resources-detail-view/guidelines-for-developing-and-managing-ecological-restoration-projects. Accessed August 2015.

Comer, P.J. 1996. Natural community abstract for pine barrens. Michigan Natural Features Inventory, Lansing, MI. 4 pp.

Comer, P.J., D.A. Albert, H.A. Wells, B.L. Hart, J.B. Raab, D.L. Price, D.M. Kashian, R.A. Corner and D.W. Schuen. 1995. Michigan's presettlement vegetation, as interpreted from the General Land Office Surveys 1816–1856. Lansing, MI: Michigan Natural Features Inventory.

Corace, R.G. III. 2007. Using multiple spatial scales to prioritize open land bird conservation in the Midwest. PhD dissertation. Michigan Technological University.

Corace, R.G. III. 2011. Upland sandpiper (*Bartramia longicauda*). Pages 242–244 in A.T. Chartier, J.J. Baldy, J.M. Brenneman (eds), *The Second Michigan Breeding Bird Atlas*. Kalamazoo, MI: Kalamazoo Nature Center.

Corace, R.G. III, D.J. Flashpohler and L.M. Shartell. 2009. Geographical patterns in open land cover and hayfield mowing in the Upper Great Lakes region: Implications for grassland bird conservation. *Landscape Ecology* 24:309–323.

Corace, R.G. III, P.C. Goebel and D.L. McCormick. 2010. Kirtland's warbler habitat management and multi-species bird conservation: Considerations for planning and management across jack pine (*Pinus banksiana* Lamb.) habitat types. *Natural Areas Journal* 30:174–190.

Dechant, J.A., M.F. Dinkins, D.H. Johnson, L.D. Igl, C.M. Goldade, B.D. Parkin and B.R. Euliss. 2003. Effects of management practices on grassland birds: Upland sandpiper. Northern Prairie Wildlife Research Center, Jamestown, ND.

Farrand, W.R. and D.L. Bell. 1982. Quaternary geology of Michigan. Ann Arbor, MI: Dept. of Geological Sciences, University of Michigan.

Fletcher, R.J Jr. and R.R. Koford. 2002. Habitat and landscape associations of breeding birds in native and restored grasslands. *Journal of Wildlife Management* 66:1011–1022.

George, T.L. and S. Zack. 2001. Spatial and temporal considerations for restoring wildlife habitat. *Restoration Ecology* 9:272–279.

Helzer, C.J. and D.E. Jelinski. 1999. The relative importance of patch area and perimeter-area ratio to grassland breeding birds. *Ecological Applications* 9:1448–1458.

Houston, C.S., C.R. Jackson and D.E. Bowen, Jr. 2011. Upland sandpiper (*Bartramia longicauda*). No. 580 in A. Poole (ed), *The Birds of North America Online*. Ithaca, NY: Cornell Lab of Ornithology. DOI: 10.2173/bna.580.

Jacobs, R.B., F.R. Thompson, III, R.R. Koford, F.A. La Sorte, H.D. Woodward and J.A. Fitzgerald. 2012. Habitat and landscape effects on abundance of Missouri's grassland birds. *Journal of Wildlife Management* 76:372–381.

Mackenzie, D.I. 2006. Modeling the probility of resource use: the effect of, and dealing with, detecting a species imperfectly. *Journal of Wildlife Management* 70:367–374.

Marshall, E., F. Homans and R. Haight. 2000. Exploring strategies for improving the cost effectiveness of endangered species management: The Kirtland's warbler as a case study. *Land Economics* 76:462–473.

McGarigal, K., S.A. Cushman, M.C. Neel and E. Ene. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Amherst, MA: University of Massachusetts.

Michigan Department of Natural Resources (MDNR). 2001. IFMAP. Lansing, MI.

Noss, R.F., P. Beier, W.W. Covington, R.E. Grumbine, D.B. Lindenmeyer, J.W. Prather, F. Schmeigelow, T.D. Fisk and D.J. Vosick. 2006. Recommendations for integrating restoration ecology and conservation biology in ponderosa pine forests of the southwestern United States. *Restoration Ecology* 14:4–10.

Pimm, S., P. Raven, A. Peterson, Ç.H. Şekercioğlu and P.R. Ehrlich. 2006. Human impacts on the rates of recent, present, and future bird extinctions. *Proceedings of the National Academy of Sciences of the United States of America* 103:10941–10946.

Pimm, S.L., G.J. Russell, J.L. Gittleman and T.M. Brooks. 1995. The future of biodiversity. *Science* 269:347–350.

Pregitzer, K.S. and S.C. Saunders. 2007. Jack pine barrens of the northern Great Lakes region. Pages 343–361 in R.C. Anderson, J.S. Fralish and J.M. Baskin (eds), *Savannas, Barrens, and Rock Outcrop Plant Communities of North America*. Cambridge, MA: Cambridge University Press.

Probst, J.R. 1988. Kirtland's warbler breeding biology and habitat management. St. Paul, MN: U.S. Department of Agriculture Forest Service General Technical Report NC-122.

Radeloff, V.C., D.J. Mladenoff, H.S. He and M.S. Boyce. 1999. Forest landscape change in the northwestern Wisconsin pine barrens from pre-European settlement to the present. *Canadian Journal of Forest Research* 29:1649–1659.

Radeloff, V.C., D.J. Mladenoff, H.S. He and M.S. Boyce. 2000. A historical perspective and future outlook on landscape scale restoration in the northwest Wisconsin pine barrens. *Restoration Ecology* 8:119–126.

Sample, D.W. and M.J. Mossman. 1997. Managing habitat for grassland birds: A guide for Wisconsin. Madison, WI: Wisconsin Department of Natural Resources.

Sample, D.W., C.A. Ribic and R.B. Renfrew. 2002. Linking landscape management with the conservation of grassland birds in Wisonsin. Pages 359–385 in J.A. Bissonette and I. Storch (eds), *Landscape Ecology and Resources Management: Linking Theory with Practice*. New York, NY: Island Press.

Samson, F. and F. Knopf. 1994. Prairie conservation in North America. *BioScience* 44:418–421.

Sauer, J.R., J.E. Hines, J.E. Fallon, K.L. Pardieck, D.J. Ziolkowski, Jr. and W. Link. 2014. The North American Breeding Bird Survey, Results and Analysis 1966–2013. Version 01.30.2015. USGS Patuxent Wildlife Research Center, Laurel, MD

Solomon, B.D. 1998. Public support for endangered species recovery: An exploration study of the Kirtland's warbler. *Human Dimensions of Wildlife* 3:62–74.

Thogmartin, W.E., M.G. Knutsen and J.R. Sauer. 2006. Predicting regional abundance of rare grassland birds with a hierarchical spatial count model. *Condor* 108:25–46.

U.S. Department of Agriculture (USDA). 2009. National Agriculture Imagery Program (NAIP). Washington, D.C.: United States Department of Agriculture.

U.S. Fish and Wildlife Service (USFWS). 2004. A blueprint for the future of migratory birds: migratory bird program strategic plan 2004–2014. Washington, D.C.: U.S. Fish and Wildlife Service.

United States Geological Survey (USGS). 2011. National Land Cover Database (NLCD) 2006. Multi-resolution land characteristics (MRLC) Consortium.

Veríssimo, D., D. C. MacMillan and R. J. Smith. 2011. Toward a systematic approach for identifying conservation flagships. *Conservation Letters* 4:1–8.

Vickery, P.D., M.L. Hunter, Jr. and S.M. Melvin. 1994. Effects of habitat area on the distribution of grassland birds in Maine. *Conservation Biology* 8:1087–1097.

Vickery, P.D., D.E. Blanco and B. Lopez-Lanus. 2010. Conservation plan for the Upland sandpiper (*Bartramia longicauda*). Manomet, MA: Manomet Center for Conservation Sciences.

Vitousek, P.M., H.A. Mooney, J. Lubchenco and J.M. Melillo. 1997. Human domination of earth's ecosystems. *Science* 277:494–499.

Whitney, G.G. 1987. An ecological history of the Great Lakes forest of Michigan. *Ecology* 75:667–684.

Wilcove, D.S., D. Rothstein, J. Dubow, A. Phillips and E. Losos. 1998. Quantifying threats to imperiled species in the United States. *BioScience* 48:607–615.

Wisconsin Department of Natural Resources. 2009. Upland Sandpiper (*Bartramia longicauda*): Wildlife action plan. dnr.wi.gov/topic/EndangeredResources/Animals.asp? mode=detail&SpecCode=ABNNF06010. Accessed August 2015.

Wood, N.A. 1951. *The Birds of Michigan*. Ann Arbor, MI: University of Michigan Press.

R. Gregory Corace, III. U.S. Fish and Wildlife Service, Seney National Wildlife Refuge. 1674 Refuge Entrance Rd, Seney, MI 49883.

Lindsey M. Shartell. U.S. Fish and Wildlife Service, Seney National Wildlife Refuge. 1674 Refuge Entrance Rd, Seney, MI 49883.

Jacob L. Korte. Wayne State University, Department of Biological Sciences. 5047 Gullen Mall, Detroit, MI 48202 USA.

Daniel M. Kashian (corresponding author), Wayne State University, Department of Biological Sciences. 5047 Gullen Mall, Detroit, MI 48202 USA. dkash@wayne.edu.