Middle States Geographer, 2017, 50: 64-73

LAND COVER AND FARMLAND RAPTOR DISTRIBUTION IN PENNSYLVANIA

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ABSTRACT: *Raptors associated with grasslands are a conservation concern in eastern North America. We assessed land use/land cover (LULC) associations of Northern Harrier (Circus cyaneus L.) and Short-eared Owl (Asio flammeus) in Pennsylvania from 2012-2015. Observations of both species were derived from citizen science datasets (eBird and Pennsylvania Farmland Raptor Project). LULC proportions within 1- and 5-km buffer regions were quantified around locations where birds were detected. Sites where higher numbers of Northern Harriers were detected occurred in 1- and 5 km buffer regions with greater percentages of pasture/hay and croplands. The amount of developed land was significantly lower around these high-use sites for Harrier in both buffer sizes as compared to low-use sites. Wintering observations of Northern Harrier also had significantly higher amounts of pasture/hay than did breeding observations within both 1- and 5-km buffers. For Short-eared Owl, there was significantly more grassland and cropland around high-use sites for both 1- and 5-km buffers. A lower amount of developed land around high-use sites was significant for both buffer sizes for Short-eared Owl. Results suggest conservation programs for these two grassland species should focus on clustering grassland cover types and preserve farmland in larger landscapes, while minimizing developed areas in potential conservation areas.*

Keywords: *land cover, raptors, Pennsylvania, grasslands, farmland loss, citizen science*

INTRODUCTION

Natural grasslands in the northeastern U.S. are limited in extent (e.g., only 595 km^2 in Pennsylvania) (Latham and Thorne 2007), therefore many field nesting birds in the eastern United States now rely largely on agricultural grasslands and croplands. Recent research has documented the effects of dwindling grassland habitat on grassland songbirds (e.g., Pabian et al. 2013, Wilson 2010), but less attention has been paid to the impact of habitat loss on farmland or grassland-associated raptors (see Wilson et al. (2010), Amar and Redpath (2005)), which include the Northern Harrier (*Circus cyaneus*), Short-eared Owl (*Asio flammeus*), Barn Owl (*Tyto alba*) and American Kestrel (*Falco sparverius*). All four species have experienced long-term declines in eastern populations (Smallwood et al. 2009, Wilson et al. 2010, Farmer et al. 2008, Herkert et al. 1999).

Northern Harrier is listed as endangered in three northeastern states (NJ, CT, and RI), threatened in four states (PA, NH, MA and NY), and a species of special concern in VT (Smith et al. 2011). In addition, Northern Harrier is one of six species on the National Audubon Society's early warning Blue List of declining species (Smith et al. 2011). Short-eared Owls are endangered in PA, NJ, CT, MA, V, ME and threatened in NY (Owl Research Institute, www.owlresearchinstitute.org, retrieved 31 May 2017, NatureServe explorer (http://explorer.natureserve.org) retrieved 1 April 2018).

In Pennsylvania, cropland has decreased from 3.2 million ha in 1950 to 1.82 million ha in 2012, a decrease of 43% (USDA NASS, retrieved 30 May 2017; Figure 1a). Pasture area in the category "Cropland used only for pasture or grazing" has diminished even more severely, from 413,000 ha in 1974 to 47,752 ha in 2012, a decrease of 88% (USDA NASS, Figure 1b). The category of "permanent pasture and rangeland" fell from 748,668 ha in 1954 to 170,373 ha in 1997, before rebounding to 329,414 ha in 2012 (USDA NASS). The loss of grassland type habitats has had important consequences for grassland birds and likely is the primary reason for the population decline in grassland birds at a national scale (Hill et al. 2014). In addition to loss of habitat, Wilson (2010) summarizes other drivers of farmland bird decline as being (1) a change to fewer, larger farms that are more intensively managed, resulting in greater pesticide use that removes important seed and invertebrate food sources resulting in less mammal and small bird prey; (2) a shift to row crops from pasture; and (3) the more frequent cutting of hay that disrupts ground-nesting farmland raptors raising their young in the hayfields (e.g., Northern Harrier and Short-eared Owl). Despite an

understanding of the main reasons behind the widespread population decline in grassland associated raptors (e.g., Wilson 2010, Hill et al. 2014), there are still questions regarding habitat use by grassland raptors, particularly during the non-breeding season. Because many eastern farmland raptors undergo seasonal movements, knowledge of habitat use during both nesting and wintering periods is important. Northern Harriers prefer extensive open wetlands and upland habitats, and their nests are a platform of grasses on the ground in a thick, dense vegetation in an open field or meadow (Smith et al. 2011). They are most often found nesting in extensive grasslands, reclaimed strip mines, fallow fields and open wetlands or pastures. From the Raptor Population Index (http://rpi-project.org, accessed 31 May 2017) (Brandes et al. 2013), 34 of the 38 raptor count sites from the eastern US and Canada documented declining trends for Harriers from 2006 to 2016, with 15 of the 34 declining trends statistically significant. Although migration count declines could represent decreasing migration tendencies, the long-term and wide-spread pattern of declines supports the data from breeding surveys (e.g. Wilson et al. 2012) that suggest Northern Harriers are declining across the region.

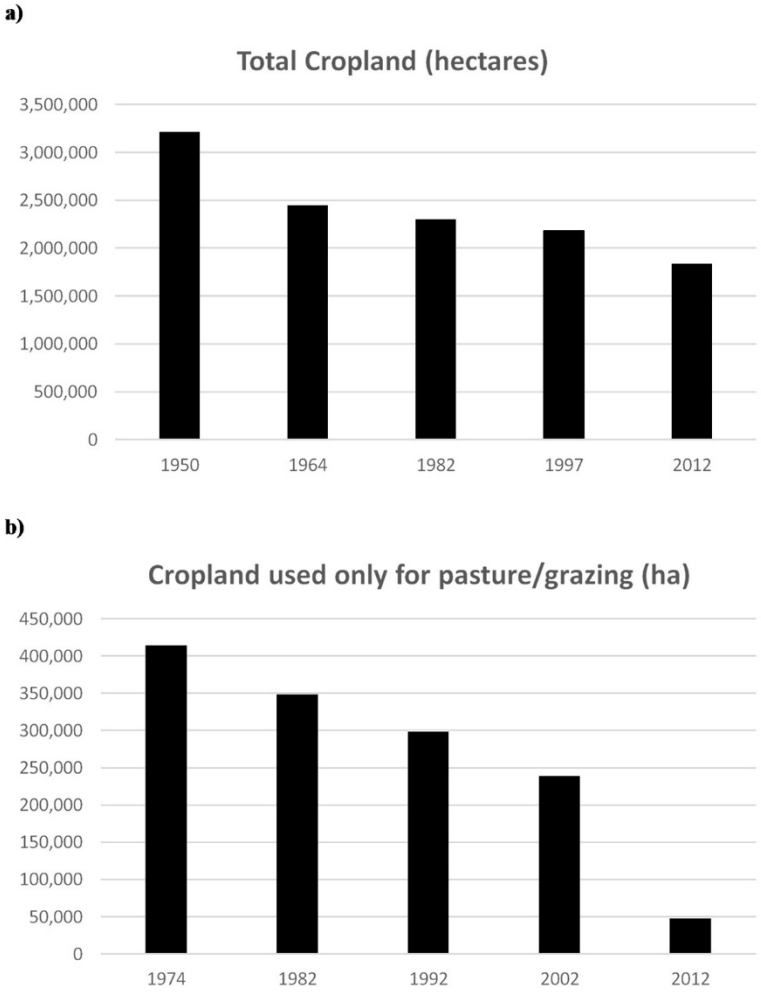

Figure 1. a) Total cropland in Pennsylvania, 1950-2012. b) Cropland used only for pasture/grazing in in Pennsylvania, 1974-2012. Source: Census of Agriculture, US Department of Agriculture, National Agricultural Statistical Service.

For Short-eared Owl, in addition to the previously mentioned threats, reforestation, natural succession, and the loss of field and wetland habitat have led to recent declines (Wiggins et al. 2006). They depend upon large open areas of undisturbed grassland or wetland habitat that extend more than 40 ha where prey is abundant to nest successfully (Wiggins et al. 2006). Both species have been reported to use wide areas for foraging during nesting, hence habitat beyond the immediate field where they roost or nest could be shaping their distribution and survivorship.

Northern Harriers can be colonial in nesting, where food supply is adequate and both species will roost in groups in winter (Wiggins et al. 2006, Smith et al. 2011). Few studies have examined their distribution and the land cover surrounding either nesting or wintering sites.

To better understand how landscape changes may be influencing ground-nesting farmland raptors in Pennsylvania, we examined the relationship between land cover (as a surrogate for habitat) and the presence of two grassland raptors – Northern Harrier and Short-eared Owl during both breeding and wintering periods. We chose these two species because they are both ground-nesting birds that have large ranges and have undergone dramatic declines in the eastern United States (Farmer et al. 2008, Herkert et al. 1999, Del Hoyo et al. 1994, Serrentino 1992, Veit and Peterson 1993).

METHODS

We documented the percentage of land use/land cover (LULC) types within buffers around locations of observed occurrences of these two species across Pennsylvania in both breeding and wintering periods. We compared LULC between high-use sites where more individuals were observed, and low-use sites where fewer birds were observed. Additionally, we examined the influence of local- versus landscape-scale habitat availability on bird distribution by examining LULC around bird observations within buffers of 1- and 5 km.

Raptor Locations

We obtained 942 locations of citizen science sightings of Northern Harrier and Short-eared Owl from the eBird database of the Cornell Lab of Ornithology from December 2012 to August 2014 (Sullivan et al. 2009), and 371 sightings reported from June 2012 through 2015 to the Pennsylvania Farmland Raptor Project of Hawk Mountain Sanctuary (www.hawkmountain.org/farmlandraptors), a citizen science project launched in 2012 to promote better understanding and conservation of farmland raptors across the state. All sightings documented date, time, behavior, number of birds and latitude/longitude of the sighting. Of observers who recorded notes about behavior, most observed the birds in flight, although some birds were seen perching. They are most often seen flying low over fields, and in most cases birds flying low are birds hunting and using the habitat. We recognize that this study does not address active use by individuals but we are assuming the area where the birds were observed was indicative of habitat they use. We recognize that the two citizen science data sources are not systematic surveys and that some areas of the state are more heavily visited by bird-watchers than others. As a result the database does not represent a complete survey of the state for the two species in this study, however, because the Harriers and Short-eared Owl are rare, we recruited bird watchers in each county to look for and report sightings of both species during breeding and winter periods. In addition, the state has an annual winter raptor survey that encourages birdwatchers to survey for wintering birds and share their data with the Farmland Raptor Project (Grove 2017).

We assigned records into breeding (15 March to 15 May) and wintering seasons (15 December to 15 March), based on phenology information for the two species in the region (Smith et al. 2011, Wiggins et al. 2006). All other sightings were considered migratory sightings and were excluded from analysis. The latitude-longitude coordinates of each sighting were entered into ESRI's ArcGIS 10.2 geographic information system (GIS) (ESRI 2014). Duplicate observations within all years and seasons were eliminated from consideration because bird watching activity in some regions was higher than others leading to duplicate sightings being more likely at some locations. Locations were then grouped by the number of birds reported by the observer into categories based on the maximum number of birds at one time for that location, and separately for breeding and wintering observations (Harrier only). We compared LULC in both 1- and 5- km buffers (3.14 km^2 and 78.54 km^2 area, respectively) to assess local vs. landscape effects between:

(1) Those considered "high use" (for Harrier, areas where 4 or more birds were observed) versus "low use" (for harrier, where 3 or fewer birds were observed). This number was chosen as there were only 10 observations where 5 or more birds were observed. We compared percent of various LULC types (see "Land cover data" below) between these groups. For Short-eared Owl, we used 3 or more birds as the cutoff for "high use" and 2 or less for "low use" because there were fewer than 20 observations where 4 or more birds were observed. The rationale for these divisions is that higher numbers of birds observed may indicate in a general sense higher-quality habitat or more prey available in nearby landscapes.

(2) Breeding and wintering sites for Northern Harrier. We compared the same LULC classes above between these two periods to assess if habitat varied by season. There were not enough breeding-season observations in our dataset to do the same for Short-eared Owl.

Land Cover Data

We used 30 m resolution LULC data from the 2011 National Land Cover Dataset (NLCD) produced by the US Geological Survey (Homer et al. 2015). We merged all developed-land classes (developed-open space; low-, medium-, and high-intensity developed) into a sole 'developed' class. We analyzed the grassland/herbaceous, pasture/hay and emergent herbaceous wetlands classes separately, as well as the cultivated cropland class. However, as some small areas within cropland that might be below the resolution limits of the land cover map might still provide areas that support raptor prey or raptors in some way, we also analyzed a combined grassland+cropland category, which might be considered "farmland" land cover and which includes all of the above except for the developed classes.

Data Analyses

Latitude and longitude coordinates from the bird location databases were overlaid onto the LULC data. We quantified LULC proportions for each land cover type within 1-km and 5-km buffers using ESRI's ArcGIS 10.2 and Geospatial Modeling Environment Software (Beyer 2012) to examine both local and landscape-scale processes. Mean LULC proportions in these buffer areas and among groupings were compared using two-sample t-tests and, as this is exploratory research, a significance level of $\alpha = 0.10$.

RESULTS

After excluding records of migrating birds and records where birds were observed at the same site on multiple dates, we examined 598 Northern Harrier sightings across Pennsylvania – 140 during breeding season and 458 during wintering season – and a total of 129 Short-eared Owl sightings in winter. Large amounts of farmland cover types — in other words, non-forested, undeveloped open space of any grassland or cropland cover — occurred around the bird sightings. For Northern Harrier, 59.3% of the area around high-use sites and 46.5 % of the area around low-use sites within 1-km buffers was grassland or cropland. The amount of non-forested, undeveloped open land was even higher for Short-eared Owl, with 72.4% of the area around high-use sites and 59.5% of the area around low-use sites within 1-km being grassland or cropland. With the diverse topography and large population of Pennsylvania adding new LULC types within 5-km of the sighting locations, the percentage of grassland and cropland was lower but still quite substantial — 48.5% and 37.8% for high-use and low-use sites, respectively, for Northern Harrier, and 56.2% and 47.8% for high-use and low-use sites, respectively, for Short-eared Owl (Tables 1 and 2).

Table 1. Mean proportion of land use/cover types (with standard error) surrounding Pennsylvania wintering and breeding locations of Northern Harrier (*Circus cyaneus*), and *P*-values from two-sample, two-tailed t-test.

1 km Buffer, mean (SE)	Grassland+Cropland (%)*	Cropland (%)	Developed (%)
≥ 4 birds (n = 24)	59.3 (5.2)	28.1 (3.8)	9.4 (1.8)
<4 birds (n = 574)	46.5 (1.1)	21.6 (0.8)	16.8 (0.8)
P-value	0.025	NS	<0.001
Breeding sites (n = 140)	37.5 (2.2)	13.4 (1.3)	15.7 (1.6)
Wintering sites (n = 458)	49.9 (1.3)	24.5 (1.0)	16.7 (0.9)
P-value	<0.001	<0.001	NS

5 km Buffer, mean (SE)	Grassland+Cropland (%)*	Cropland (%)	Developed (%)
≥ 4 birds (n = 24)	48.5 (4.4)	25.3 (3.2)	11.9 (2.0)
<4 birds (n = 574)	37.8 (0.9)	17.7 (0.6)	17.1 (0.7)
P-value	0.009	0.011	0.023
Breeding sites (n = 140)	28.5 (1.4)	11.2 (0.9)	17.3 (1.6)
Wintering sites (n = 458)	40.4 (1.0)	19.6 (0.7)	17.4 (0.8)
P-value	<0.001	<0.001	NS

*The grassland+cropland category includes all grassland types: % grassland/herbaceous, pasture/hay and emergent herbaceous wetland as well as cropland.

Table 2. Mean proportion of selected land cover types (with standard error) surrounding locations of Short-eared Owl (*Asio flammeus*) in Pennsylvania, and *P*-values from two-sample, two-tailed t-test.

1 km Buffer, mean (SE)	Grassland+Cropland (%)*	Cropland (%)	Developed (%)
≥ 3 birds (n = 35)	72.4 (3.3)	42.6 (3.1)	10.7 (1.3)
< 3 birds (n = 93)	59.5 (2.9)	32.5 (2.3)	13.6 (1.6)
P-value	0.002	0.019	0.080

5 km Buffer, mean (SE)	Grassland+Cropland (%)*	Cropland (%)	Developed (%)
≥ 3 birds (n = 36)	56.2 (3.1)	33.8 (2.4)	12.6 (1.2)
< 3 birds (n = 93)	47.8 (2.6)	25.1 (1.8)	16.8 (1.9)
P-value	0.061	0.009	0.061

*The grassland+cropland category includes all grassland types: % grassland/herbaceous, pasture/hay and emergent herbaceous wetland as well as cropland.

High-Use vs. Low-Use Sites

Tables 1 and 2 show that all "farmland" land covers – grassland+cropland – was significantly higher around high-use sites for Northern Harrier (P = 0.025 and 0.009, respectively for the 1- and 5-km buffers) and Short-eared Owl (P = 0.002 and 0.061, respectively). Percent cropland was significantly higher around high-use sites for Short-eared Owl at both buffer distances (P = 0.019 and 0.009, 1-km and 5-km buffers respectively), and for Northern Harrier within 5-km buffers (P = 0.011). There was a significantly lower amount of developed land around high-use sites for Northern Harrier at both buffer distances (P = <0.001 and 0.023, 1- and 5-km buffer respectively), and for Short-eared Owl at both buffer distances (P = 0.080 and P = 0.061, respectively). Tables 3 and 4 show the results when separating the different grassland categories. The percentage of pasture/hay was higher at high-use sites for Harrier in the 1-km buffer, but was not significantly different for Short-eared Owl. The percentages of grassland/herbaceous and emergent herbaceous wetland were higher in low-use sites for Harrier but were significant only at 1-km.

Breeding vs. Wintering Sites

Tables 1 and 2 show that there are significantly higher amounts of percent cropland and percent grassland+cropland around wintering sites for both species and at both buffer distances. Breeding sites for Harrier also had slightly less developed land than did wintering sites (0.1% and 0.9% difference at 1- and 5-km buffers, respectively) but the difference was not statistically significant. Tables 3 and 4 show that the percentages of grassland/herbaceous and emergent herbaceous wetland were significantly higher in breeding sites compared to wintering sites for Harrier at both buffer distances. Percent pasture/hay was lower around breeding sites for Harrier (P = 0.008 and <0.001, 1- and 5-km buffer respectively).

Table 3. Mean proportion of grassland cover types (with standard error) surrounding Pennsylvania wintering and breeding locations of Northern Harrier (*Circus cyaneus*), and *P*-values from two-sample, two-tailed t-test.

1 km Buffer, mean (SE)	Grassland/herbaceous (%)	Pasture/hay (%)	Herbaceous wetland (%)
≥ 4 birds (n = 24)	0.48 (0.25)	30.2 (3.3)	0.49 (0.14)
<4 birds (n = 574)	1.34 (0.18)	22.5 (0.65)	1.01 (0.19)
P-value	0.0068	0.020	0.029
Breeding sites (n = 140)	2.76 (0.61)	18.8 (1.5)	2.56 (0.72)
Wintering sites (n = 458)	0.86 (0.12)	24.1 (0.69)	0.50 (0.08)
P-value	0.002	0.008	0.005

5 km Buffer, mean (SE)	Grassland/herbaceous (%)	Pasture/hay (%)	Herbaceous wetland (%)
≥ 4 birds (n = 24)	0.65 (0.16)	22.1 (2.1)	0.34 (0.06)
<4 birds (n = 574)	0.80 (0.07)	18.9 (0.44)	0.43 (0.06)
P-value	NS	NS	NS
Breeding sites (n = 140)	1.35 (0.23)	15.1 (0.91)	0.88 (0.22)
Wintering sites (n = 458)	0.64 (0.06)	19.8 (0.48)	0.33 (0.04)
P-value	0.0032	<0.001	0.005

Table 4. Mean proportion of grassland land cover types (with standard error) surrounding locations of Short-eared Owl (*Asio flammeus*) in Pennsylvania, and *P*-values from two-sample, two-tailed t-test.

1 km Buffer, mean (SE)	Grassland/herbaceous (%)	Pasture/hay (%)	Herbaceous wetland (%)
≥ 3 birds (n = 35)	1.16 (0.6)	28.4 (2.0)	0.20 (0.08)
< 3 birds (n = 93)	1.42 (0.34)	24.5 (1.5)	1.11 (0.72)
P-value	NS	NS	NS

5 km Buffer, mean (SE)	Grassland/herbaceous (%)	Pasture/hay (%)	Herbaceous wetland (%)
≥ 3 birds (n = 36)	1.07 (0.26)	21.0 (1.3)	0.30 (0.05)
< 3 birds (n = 93)	1.09 (0.20)	21.1 (1.2)	0.46 (0.16)
P-value	NS	NS	NS

DISCUSSION AND CONCLUSIONS

Differences among groups were noted in most cases, with the exception of Short-eared Owl for the grassland/herbaceous, pasture/hay and emergent herbaceous wetland classes. Percent cropland around observations distinguished differences between high-use and low-use sites for Short-eared Owl at 1-km and for both species at 5-km. Why percent cropland was able to distinguish between our groupings is unusual, as cropland alone is usually not considered to be directly beneficial to these raptors. Johnson (2000) notes that both cultivated fields and frequently-mowed hayfields are detrimental to certain grassland birds and nests and both are likely to be population sinks. However, Walk and Warner (1999) note that Harriers make extensive use of intervening agricultural lands within grassland for foraging and brood-rearing. In addition, Massey et al. (2009) state that Harriers can shift habitat selection depending upon prey availability and use a variety of prey species from multiple habitats. While farming practices have likely gotten more intensive since Preston's (1990) research, he noted that corn stubble was a cover type that Northern Harriers used more frequently than expected.

Although cultivated cropland is not directly used for nesting, there could be several reasons why this category showed more statistically significant differences between our groupings than the natural grassland or emergent herbaceous wetlands classes. First, the imagery used to derive the LULC map was based on 2011 satellite data whereas the bird observation data were from late 2012 through 2015, perhaps not capturing some possible habitat areas or conservation grasslands established after 2011, or not capturing crop rotations that included grassland after 2011. Second, some pastures, hayfields, or overgrown grassy areas may not have been detected by the 30 m resolution of the imagery – some might be in narrow linear strips, field edges or "waste areas", grassed waterways or small ponds/wetlands. Third, some degree of error/confusion between cropland and grassland/herbaceous, pasture and hay may exist in the image classification process. Fourth, if alfalfa or rye fields occur in cultivated cropland, these crop types may provide some suitable habitat for the raptors in winter. Finally, the raptors could be using the cultivated cropland for foraging but not for nesting in both seasons.

Northern Harrier wintering sites had significantly more pasture/hay than breeding sites within both buffer distances. Wilson et al. (2010) noted that the first decade of the 2000s saw an increase in wintering Northern Harriers in Pennsylvania, and suggested that the increasing amount of conservation grasslands was a likely reason. Another hypothesis might be that due to low prey levels in winter, the raptors need more foraging area, and in summer voles or other prey may be more abundant, with less habitat area needed by the birds. Breeding sites also had more grassland/herbaceous and emergent herbaceous wetlands. However, it is noted that the percentages of these cover types are very small and we hesitate to ascribe conclusive biological meaning to this. A cluster of about a half-dozen sites in the northwestern part of the state having percentages of these classes above 25% may have increased the overall average. This artifact of the citizen science sampling may also explain the occurrence of higher percentages of these classes in low-use areas.

For Pennsylvania as a whole, the following are the statewide percentages of the land cover classes from the USGS National Land Cover Dataset discussed in this paper: cropland – 9.16%, all developed classes – 12.3%, pasture/hay – 13.5%, grassland/herbaceous – 0.69%, emergent herbaceous wetland – 0.23%. As Tables 1 through 4 are examined, we note that the buffer areas where we found high numbers of birds had significantly more of these farmland/open grass/herbaceous cover types than the state as a whole, and places where higher numbers of birds were

observed also had lower percentages of developed land cover than the state as a whole (except for Short-eared Owl in the 5-km buffer, which was roughly the same amount).

For Harriers and Short-eared Owls, there was a significantly lower percentage of developed land around high-use sites at both buffer distances. While Wiggins et al. (2006) state that Short-eared Owl may be particularly sensitive to habitat loss and fragmentation, such as from rural developments, at least one study noted that Short-eared Owls are generally not sensitive to human activity as the nests are difficult to locate (Leasure and Holt 1991). In general, however, most of the literature indicates that human activities around these species locations is important because human activities, depending on the magnitude and frequency of disturbance, can affect the fitness of wildlife populations (Holmes et al. 1993). Massey et al. (2008) examined 128 Harrier nest sites on Nantucket Island, MA and assessed 70 GIS-derived landscape metrics using a classification-tree approach. One of the nodes of the tree was "habitat distant from developed land and roads," and they noted that Harriers nested > 500 m from developed areas. They did not find any strong effects of other landscape metrics at 200-, 500-, or 1-km scales, suggesting that Harrier nest site selection is based on habitat features within a relatively small area around the nest. In our study, we found that high-use sites for Harriers had significantly less developed land within 1-km buffers, but not in the 5-km buffers. Massey et al. (2008) concluded that the avoidance of development by Harriers for nesting habitat may threaten their future on Nantucket as land development continues.

This study shows that LULC can have important consequences on distribution of ground-nesting farmland raptors in both breeding and non-breeding seasons and at landscape-scales. While it is generally known that these species use grasslands and open space, the exact composition around their locations over a state-wide region have not been documented, nor have the differences between breeding and wintering locations been analyzed. In addition, our study has highlighted the importance of proximity to developed land to these raptors. Our study supports the conservation and maintenance of a large, predominantly-open farmland and grassland landscape to support larger numbers of these two ground-nesting farmland raptors. Herkert et al. (1999) noted that Harrier and Short-eared Owl may respond more strongly to total amount of habitat within the landscape, rather than the size of individual habitat tracts, with the species potentially using small blocks of habitat if those blocks are located in proximity to other more extensive grassland areas. Short-eared Owl still had very large amounts of grassland and cropland around their sighting locations, even more than Northern Harrier– 72.4% and 56.2% at high-use sites in 1- and 5-km buffers, respectively.

The limitations of this study include that it may be necessary in analyses in states with similar landscape composition to Pennsylvania to incorporate spatially-explicit data on the locations of conservation grasslands (such as those within the US Department of Agriculture's Conservation Reserve Program, Conservation Reserve Enhancement Program or Wetlands Reserve Program) to detect their influence on farmland raptors, rather than inferring their presence from the grassland or hay/pasture categories of the USGS National Land Cover Dataset. Nevertheless, the significantly higher amount of grassland/herbaceous and grassland+cropland for wintering Northern Harriers found in this study is consistent with previous work showing greater wintering Northern Harrier presence attributed to higher amounts of conservation grasslands in the first decade of the 2000s (Wilson et al. 2010). It would also be useful to separate pasture from hayfields, but this land cover data set combines these areas as one class. Pasture might be more suitable than frequently cut hayfields.

In addition, our study also suggests a sensitivity of Northern Harriers and Short-eared Owls to human influences in that more birds (i.e. high-use sites) were observed in buffer regions with lower amounts of developed land. Among the sources of disturbances that can affect ground-nesting raptors are domestic and feral cats and dogs and human activities (Tate 1992). Nevertheless, development is of concern in rapidly growing southeastern and south-central Pennsylvania, and Theobald et al. (1997) notes the need in conservation and wildlife management to regulate subdivision pattern in addition to density. Clustered development reduces the negative impact to wildlife (Theobald et al. 1997), and clustered farmland and open space preservation provides for these raptor species. Further analysis of Short-eared Owl distribution and habitat use may be warranted as Wiggins et al. (2006) note that its population is difficult to assess for numerous reasons including its nomadic behavior, crepuscular habit, annual fluctuation in numbers and overall low abundance. Telemetry of wintering birds could enhance knowledge of habitat use of both these species, and how it changes between seasons and over decades with changing LULC conditions.

Tracking land use and land cover change in the northeastern U.S. will be important in monitoring these rare species. The latest Breeding Bird Survey analysis (Sauer et al. 2017) shows that the 1966-2015 trend in the Eastern Region for Northern Harrier and Short-eared Owl is significantly declining, and the 2005-2015 trend for both these species in the Eastern Region is still declining, even though the trend in this period is not statistically significant.
In a national-scale study of land cover change and avian diversity in the USA, Rittenhouse et al. (2012) note that loss of grassland and shrub land affected bird species richness and abundance in forested ecoregions, and loss of wetland was associated with population levels in forested ecoregions. Understanding changes in the non-dominant land cover

types and their association with bird diversity was deemed critical thus, understanding the patterns of open farmland within a forested matrix, and in particular understanding natural and conservation grasslands within Pennsylvania farmland areas is essential to management of these farmland raptors. For Harrier and Short-eared Owl conservation, in addition to the careful targeting of future conservation grassland placements in areas with significant grassland (Pabian et al. 2010), it may also be useful to conserve habitat in areas with minimal developed land within key grassland raptor habitat areas, especially within 1-km.

ACKNOWLEDGMENTS

We thank Katie Andrews and Hawk Mountain staff for assisting in compiling observation data. We also thank Pennsylvania birdwatchers, eBird and Cornell Lab of Ornithology for use of their observation data. The Wild Resource Conservation Fund of PA Department of Conservation and Natural Resources provided funding for the first two years of the PA Farmland Raptor Project. David Barber of Hawk Mountain assisted with GIS mapping. This is Hawk Mountain Sanctuary Contribution to Conservation Science Number 298.

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