Oak Openings Region Biodiversity Model Final Report (Phase II)

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Objective: In Phase II of the project we will be refining the land cover map created in Phase I and developing species distribution models that highlight upland savanna/prairie, floodplain forest, swamp forest, upland deciduous forest and wet prairie.

Introduction

The Oak Openings Region has faced many changes within the past 10 years from anthropogenic activities, natural catastrophes and invasive species. Schetter & Root (2011) created a foundational land cover map, which was used to identify remnant natural communities and identify areas for acquisition, restoration and management. In order to identify the changes which have occurred, we (Root & Martin 2017, Phase I) created an updated land cover map using training data (primarily from Ohio). This updated land cover map performed well for Ohio, however it underperformed for Michigan. In addition, we were also interested in refining the map classification by eliminating Landsat bands that were superfluous or redundant. Our objective was to improve the performance of the land cover classification for Michigan by including additional training data (primarily from Michigan). To compare the land cover map created in June 2017 (Phase I), we followed the same procedures as in Phase I (Figure 1) using three sets (24, 27 and 33) of Landsat 8 bands for our multi-seasonal image and created a new land cover map using the updated training points.

Building on this land cover map, we have also developed habitat models for species that serve as indicator species or that are primarily associated with specific ecosystems within the Oak Openings Region. Habitat models for individual species based on known occurrences are an excellent tool for guiding conservation and management planning (Phillips et al. 2006; Elith et al. 2011) and are very popular for modeling rare or threatened species potential distributions

(Wilting et al. 2010; Clements et al. 2012). These types of models identify the habitat characteristics associated with a specific species and provide insight into areas that are suitable but may not be currently occupied (Moilanen et al. 2005). This type of modeling is typically used to identify species distributions, but has also been successfully used to model landscape features (Hunter et al. 2012; Raney & Leopold 2018). These models provide a way to look at the landscape through the lens of the organisms that occupy them and can highlight areas that are ecologically valuable for one or more species. We have developed a set of habitat models that will focus on the five critical ecosystems and the species that utilize them. Essentially these distribution models map ecologically functional habitat (regardless of the specific land cover designation) and we can assess what features contribute to this functionality. The output of the models also delineates levels of quality that can identify current and potential habitat on the landscape. In addition, by using the same modeling approach across species and ecosystems, we can increase our understanding of biodiversity patterns and better guide management, restoration and conservation.

Methods

Landsat Image Selection

We tested three alternative classifications with varying number of bands to assess which combination led to a more accurate map. For the first band combination, we used 24 Landsat 8 bands removing the 1-Coastal Aerosol, 8-Panchromatic, and 9-Cirrus bands to create a multi-seasonal image. This image most closely resembles the original land cover map (Schetter and Root 2011). The second band combination used 27 bands by removing the 1-Coastal Aerosol and 9-Cirrus bands to a multi-seasonal image. Finally, we used 33 bands to create a multi-seasonal image to compare to the original land cover map completed in June (Root & Martin 2017, Phase I). After comparing each map (image, habitat cover and accuracy), we selected the 27 band image as the best combination with the fewest compromises for the entire region. Note, we are assuming that we are sampling across the full suite of conditions by including data from three different time points within the year. The selection of dates was also constrained by availability of images that were cloud-free.

Training Site Selection

Training sites were identified across the entire Oak Openings Region to provide enough training pixels for a supervised classification. We used 27 bands (9 per image) and this required a minimum of 28 pixels per land cover class (n + 1 pixels required per class, where n is the number of used spectral bands). In April 2017, previous training sites (Schetter and Root 2011) were revalidated for accuracy and additional training sites were selected within Ohio and Michigan. July and August 2017, additional training sites were selected within Ohio and Michigan. Field surveys were done to validate previous training sites and evaluate new additional training sites. For the final classification, we used 132 training sites for 14 classes (average of nine training sites per class). We assumed that these training sets were representative of the land cover class and sufficient to provide a unique signature for each class.

Supervised Image Classification

Using the three multispectral Landsat 8 images, we performed a supervised classification in ArcGIS 10.2 (ESRI, Redlands, CA) (Root & Martin 2017, Phase I). We used spectral bands 2-7 and 10-11 from each of the three selected images for a grand total of 27 bands, each with 30 m pixel resolution. We performed the supervised land cover classification for the 14 land cover classes (i.e., the original land cover classifications from Schetter and Root 2011, minus the agriculture) using the training data.

We then used a cropland “mask” created from the Ohio and Michigan cropland data layer downloaded from the USDA Geospatial Data Gateway through the Farm Service Agency (USDA 2016) (Root & Martin 2017, Phase I). Our final image was clipped to the extended Oak Openings Region (Grigore 2016). The result was a complete map of the region classified into 15 land cover classes, see Figure 1 for general diagram of our approach for the supervised classification.

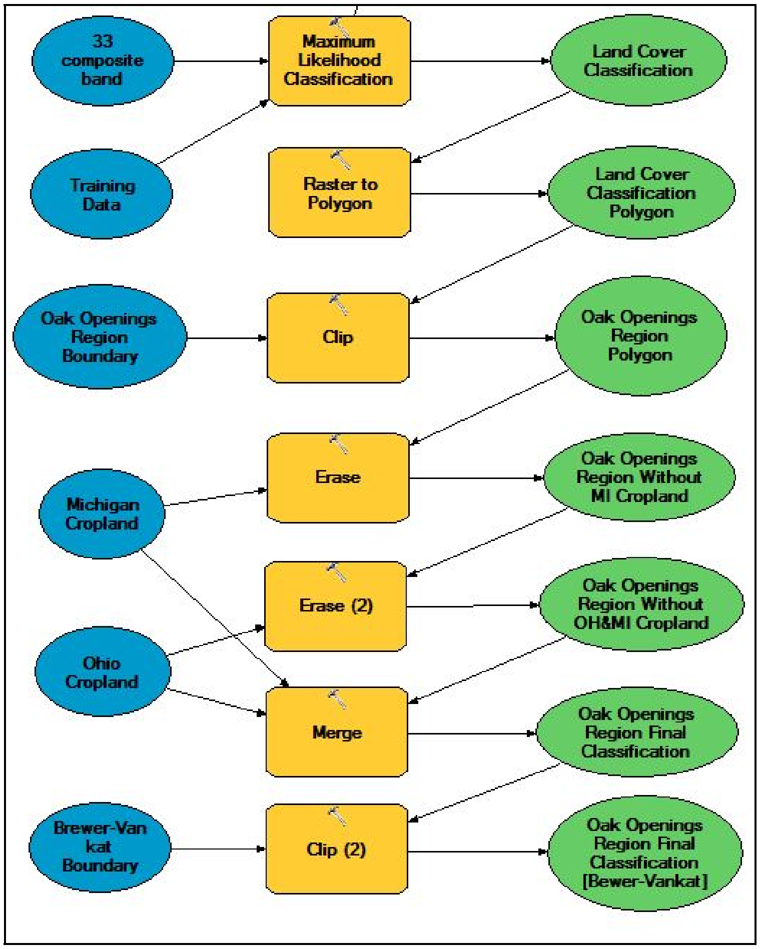


Figure 1. Diagram of model builder in ArcGIS 10.2 illustrating the procedures for the supervised classification.

Accuracy assessment

We used a combination of field surveys and orthophoto surveys to assess the accuracy of the land cover classification. We visually inspected points within major communities of concern (e.g., upland savanna, upland prairie, wet prairie, upland deciduous forest, floodplain forest, and swamp forest) on the ground to identify the land cover class and compare to the designation from the supervised classification. Ground points were delineated through ArcGIS 10.2 and were at least 150 m apart from one another to ensure a reasonable sample distribution. Points were excluded within training sites. To minimize travel time, at each point, we evaluated four adjacent neighboring points.

Land cover verification was also completed using high resolution (0.3 m) color orthophotos acquired in 2017 (USGS 2017). Orthophotos were used for land cover classes that are distinguishable and could be confidently identified (e.g., croplands, dense urban, residential/mixed, perennial ponds, and upland coniferous forest). We analyzed points per land cover class and four additional adjacent neighboring points to identify the land cover class and compare the designation from the supervised classification. We then compiled the results into an error matrix (Table 1) to evaluate the accuracy of the supervised land cover classification.

Table 1. Error matrix for the 15-class Oak Openings Region land cover map. Land cover types are: turf/pasture (TP), wet prairie (WP), residential/mixed (RM), perennial ponds (PP), upland savanna (US), wet shrubland (WS), swamp forest (SF), upland coniferous (UC), upland deciduous forest (UD), floodplain forest (FF), sand barrens (SB), Eurasian meadow (EM), upland prairie (UP), dense urban (DU) and cropland (CR).

		Actual Land Cover (Reference Sites)															
	Class	TP	WP	RM	PP	US	WS	SF	UC	UD	FF	SB	EM	UP	DU	CR	Total
Classified Land Cover (From map)	TP	**1**	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4
	WP	0	**4**	0	3	0	0	0	0	0	0	0	0	0	2	0	9
	RM	1	0	**48**	3	0	0	0	12	1	0	0	0	3	9	0	77
	PP	0	0	0	**41**	0	0	0	0	0	0	0	0	0	0	0	41
	US	0	1	0	0	**21**	0	0	0	19	0	0	0	0	0	0	41
	WS	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0
	SF	0	0	0	0	0	0	**25**	0	4	1	0	0	0	0	0	30
	UC	0	0	0	0	0	0	0	**38**	2	0	0	0	0	0	0	40
	UD	0	0	0	0	1	0	4	0	**46**	0	0	0	0	0	0	51
	FF	0	0	0	0	1	0	0	0	8	**11**	0	0	1	0	2	23
	SB	0	0	2	0	2	0	0	1	1	0	**5**	0	11	0	0	22
	EM	0	0	3	0	0	0	0	0	0	0	0	**0**	2	4	0	9
	UP	1	5	1	4	5	0	0	3	6	0	1	0	**26**	0	0	52
	DU	0	0	0	4	0	0	0	0	0	0	1	0	0	**37**	0	42
	CR	1	0	1	0	0	0	0	0	0	0	0	0	0	4	**53**	59
	Total	4	10	55	55	30	0	29	54	87	12	10	0	43	56	55	**500**

Species Selection

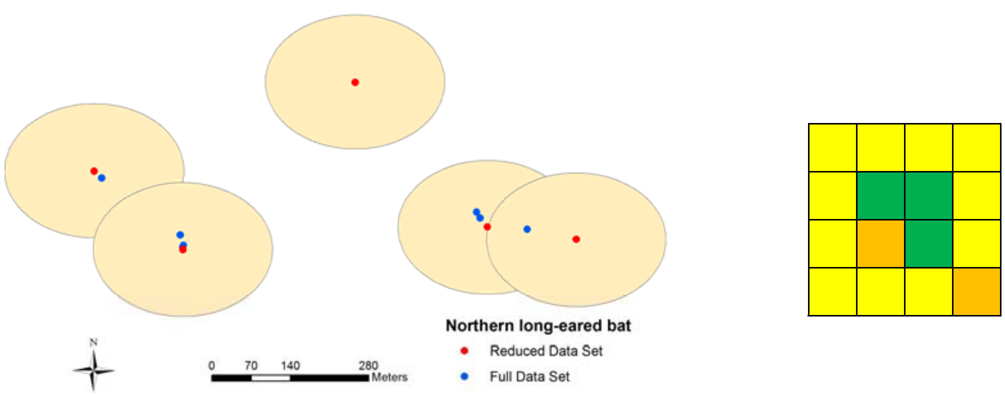
A critical first step for developing the indicator species models was to acquire high quality, recent occurrence data for the species of interest that utilize upland savanna/prairie, floodplain forest, swamp forest, upland deciduous forest and wet prairie. For some species, we have been able to readily obtain these data from local sources (e.g., BGSU faculty, Metroparks of the Toledo Area). However, many researchers are operating under permits and cannot provide the data directly. So we made requests of the Ohio Division of Wildlife (ODOW), HerpMapper, Toledo Zoo, Green Ribbon Initiative, The Nature Conservancy, Ohio State University (Greg Lipps) and Michigan Natural Features Inventory (MNFI) for occurrence data. The final species selection was a compromise dependent on balancing a variety of constraints (e.g., quality of data, availability) with desired attributes (e.g., variety of taxa, species of interest), Table 2.

We have modeled three species for each of the focal ecosystems (i.e., upland savanna/prairie, floodplain forest, swamp forest, upland deciduous forest and wet prairie). These species utilize these habitats preferentially to varying degrees and should highlight habitat that is ecologically functional. By modeling three different species we can better assess the variety of qualities that contribute to functionality and identify lower quality habitat that would be good candidates for restoration.

Species considered for modeling needed to meet the following specific criteria: (1) species must have recent data within the last 10 years to coincide with the land cover classification; (2) be representative of the target ecosystem (in other words, have the majority of occurrence points within the focal ecosystem); (3) have GPS coordinates >120 m apart (equivalent to 4 map pixels) to minimize spatial autocorrelation and bias; and (4) have a minimum of 10 occurrence observations to maximize modeling power. Using the described criteria, we selected 15 different species ranging across taxonomic groups and a variety of life histories (Table 2). Occurrence data was recorded as longitude, latitude in decimal degrees format and all records were converted to GCS_WGC_1984.

While the initial selection of species was based on the pattern of occurrence of the full data set, sub-sampling of the data was random and potentially reduced the percent of points occurring within the focal ecosystem. We reduced spatial autocorrelation by sub-sampling the larger datasets using a buffer of 120 m in radius, Figure 2(a). Kramer et al. (2013) study recommended that spatial filtering of clustered occurrence records is preferably than manipulating background environmental data because filtering reduced omission errors and outweighed negative effects of sampling bias. For the eastern box turtle, we made additional adjustments to reduce the potential bias from the large dataset of tracked individuals using radio telemetry confined to a limited area (Oak Openings Preserve). We reduced the data for each individual using a buffer of 120 m radius. From the reduced dataset, we reapplied the 120 m buffer for all individuals as a whole to reduce the dataset for the final model.

While the initial selection of species was based on the pattern of occurrence of the full data set, sub-sampling of the data was random based on a moving window. As Figure 2a illustrates, the subsampling method essentially treats the individual points as part of an ecological neighborhood (e.g., Addicott et al. 1987; Holland and Yang 2016). Points within the ecological neighborhood are excluded to minimize autocorrelation. However, this reduces the data set and can potentially alter the occurrence pattern since you are now only including part of the data. This is an important distinction to keep in mind when interpreting the output of the model. You would not expect the final MaxEnt model to replicate the occurrence pattern. The more fragmented the landscape is and the smaller the patches, the more likely that other land cover types will influence the model.



(a) Occurrence points (b) Land cover

Figure 2. (a) Subsampling approach for the occurrence data illustrating the inclusion (red) or exclusion of points (blue) based on the 120m radius buffer (circles). (b) Subsampling approach for the proportion of each land cover. An ecological neighborhood illustrating the land use surrounding an occupied cell (30m x 30 m). Swamp forest is shown in green, residential in yellow and upland savanna in orange.

We have developed generalizable models for each species based on the available occurrence data, Table 2, and a set of potential predictor variables for the Oak Openings Region.

Upland savanna/prairie. We modeled three species (1) lark sparrow (*Chondestes grammacus*), (2) red-headed woodpecker (*Melanerpes erythrocephalus*) and (3) wild lupine (*Lupinus perennis*) for upland savanna/prairie that are representatives of the target ecosystem (refer to Table 1). Lark sparrows are a grassland species that is typically found in open areas within prairies and savannas (Hunter et al. 2001). Suitable habitat for this species contains shortgrass, mixed-grass and tallgrass prairie, but also can include parkland, sandhills, barrens, woodland edges, riparian areas and brushy pastures (Dechant et al. 1999). Red-headed woodpeckers spend time within open woodlands, pine and oak savannas, additionally they are cavity nesters (Hunter et al. 2001). Grundel & Pavlovic (2007) found that this species was consistently highly concentrated in savannas or woodlands than open, scrub or forest habitats in the Midwest. Within the Midwest, the red-headed woodpecker may be one of the most representative species for oak savanna (Brawn 2001). Wild lupine is considered an indicator species of oak savanna and is often found at the edge of transition areas into oak woodland (Kappler et al. 2012). Additionally wild lupine serves as a restrictive food source for larval Karner blue butterfly (*Lycaeides melissa samuelis*) which is an oak savanna species within the Great Lakes region of North America (Grundel et al. 1998).

Floodplain forest. We modeled three species (1) giant swallowtail (*Papilio cresphontes*), (2) evening bat (*Nycticeius humeralis*), and (3) eastern box turtle (*Terrapene carolina carolina*) for floodplain forest that are good representatives of the target ecosystem. The giant swallowtail utilizes open woodlands, shrubby wetlands, and forest margins (Daniels 2004). The evening bat is a tree-roosting species that readily uses exfoliating bark, tree cavities, and buildings (Menzel et al. 2000). In Michigan, evening bats will roost in bottomland forest that periodically floods and is dominated with ash (*Fraxinus*) and maple (Acer) trees (Munzer 2008). Eastern box turtles travel a variety of environments and are often viewed as terrestrial forest species that females utilize sand barrens or upland prairies during nesting season. However they will often utilize aquatic habitats (Donaldson & Echternacht 2005) such as floodplain forest. Especially within the Oak Openings Region, they have been shown to select wet forest, upland deciduous forest and upland savanna (Cross 2016).

Swamp forest. We modeled three species (1) Appalachian brown butterfly (*Satyrodes appalachia*), (2) barred owl (*Strix varia*), and (3) wood thrush (*Hylocichla mustelina*) for swamp forest that are representatives of the target ecosystem. Appalachian brown are found in wooded swamps, wet woodlands, stream corridors and forest margins (Daniels 2004; Aschehoug et al. 2015). Barred owls nest in deciduous, pine and mixed forests that are closer to water and forage in oak forest and swamp forests (Livezey 2007). In general, this species utilizes low, wet woods and swampy forests (Bull & Farrand Jr. 1994). Wood thrush are active in upland deciduous forest and woodlands, especially areas with dense second-growth and shrub layers (Hunter et al. 2001), and they breed in mesic forests (interior and edges) (Newell & Kostalos 2007).

Upland deciduous forest. We modeled three species (1) red-backed salamander (*Plethodon cinereus*), (2) northern long-eared bat (*Myotis septentrionalis*), and (3) eastern red bat (*Lasiurus borealis*) for upland deciduous forest that are representatives of the target ecosystem. Red-backed salamanders are widely distributed among upland deciduous forests with population densities reaching up to 0.9-2.2 individuals/m^2 (Pough et al. 1987) and are found preferably under deciduous leaf litter over coniferous forests (Renaldo et al. 2011). Northern long-eared bats primarily roost and forage in upland deciduous forests (Henderson & Broders 2008; Stein & White 2016). The eastern red bat is a solitary, migratory species that commonly roosts in large deciduous trees and gleans insects along forest edges (Mager & Nelson 2001).

Wet prairie. We modeled three species (1) blazing star borer moth (*Papaipema beeriana*), (2) slender willow (*Salix petriolaris*), and (3) spotted turtle (*Clemmys guttata*) for wet prairie that are representatives of the target ecosystem. Blazing star borer moth uses the host plants blazing star or snakeroot and has been found in a variety of plant communities across wet to dry prairies (Cuthrell 1999). Slender willow is considered an obligate wetland species that, within the Oak Openings, spends a majority of its time in wet prairies (Schetter 2012). Spotted turtles use permanent and seasonal pools, upland areas, forested swamps and wet meadows (Joyal et al. 2001). Additionally they are found within emergent and scrub-shrub wetlands (Milam & Melvin 2001).

Table 2: A list of the target ecosystems and associated species including the number of data points used in the final models (after spatial filtering to reduce autocorrelation) and the sources where the data was gathered. Included are references supporting the habitat selection for each species and target ecosystem.

Target Ecosystem	Species	Taxa	Points	Data Source	Habitat Use References
Upland Savanna/ Prairie	Lark sparrow *Chondestes grammacus*	Avian	24	Metroparks; TNC; ODNR; Root (Gustafson 2018)	Herket 1994; Dechant et al. 1999; Kaspari & Joern 1993; Hunter et al. 2001
Upland Savanna/ Prairie	Red-headed woodpecker *Melanerpes erythrocephalus*	Avian	50	TNC; Metroparks; Root (Adams 2014; Gustafson 2018; Jonaitis 2017)	Grundel & Pavlovic 2007; Brawn et al. 2001; Hunter et al. 2001
Upland Savanna/ Prairie	Wild Lupine *Lupinus perennis*	Plant	17	Root (Schetter 2012)	Kappler et al. 2012; Grundel et al. 1998; Pavlovic & Grundel 2009
Upland Deciduous Forest	Red-backed salamander *Plethodon cinereus*	Amphibian	55	Metroparks; Root (Martin 2015)	Renaldo et al. 2011; Pough et al. 1987; DeGraaf & Rudis 1990
Upland Deciduous Forest	Northern long-eared bat *Myotis septentrionalis*	Mammal	25	ODNR; Root (Sewald 2012; Turner 2018)	Henderson & Broders 2008; Broders et al. 2004; Carter & Feldhammer2005; Stein & White 2016
Upland Deciduous Forest	Eastern Red bat *Lasiurus borealis*	Mammal	55	ODNR; Root (Hollen 2017; Nordal 2016; Sewald 2012; Turner 2018)	Hutchinson & Lacki 2000; Mager & Nelson 2001
Floodplain Forest	Giant Swallowtail *Papilio cresphontes*	Invertebrate	10	Metroparks; Kitty Todd	Daniels 2004
Floodplain Forest	Evening bat *Nycticeius humeralis*	Mammal	50	Root (Hollen 2017; Nordal 2016; Sewald 2012; Turner 2018)	Boyles & Aubrey 2006; Menzel et al. 2000; Munzer 2008
Floodplain Forest	Eastern box turtle *Terrapene carolina carolina*	Reptile	50	ODNR; Root (Cross 2016; Gustafson 2018; Jonaitis 2017;	Dodd 2001; Donaldson & Echternacht 2005; Ernst & Lovich 209; Cross 2016

				Martin 2015; Wilson 2012)	
Swamp Forest	Wood thrush *Hylocichla mustelina*	Avian	46	TNC; Metroparks; Root (Adams 2014)	Hunter et al. 2001; Newell & Kostalos 2007; Bull & Farrand Jr. 1994
Swamp Forest	Barred owl *Strix varia*	Avian	10	Raptors Monitoring Program	Livezey 2007; Hunter et al. 2001; Bull & Farrand Jr. 1994
Swamp Forest	Appalachian brown *Satyrodes appalachia*	Invertebrate	10	Metroparks; Kitty Todd	Aschehoug et al. 2015; Daniels 2004
Wet Prairie	Spotted Turtle *Clemmys guttata*	Reptile	14	Root (Harms 2008)	Joyal et al. 2001; Milam & Melvin 2001; Powell et al. 2016
Wet Prairie	Blazing Star Borer Moth *Papaipema beeriana*	Invertebrate	12	Kitty Todd	Cuthrell 1999
Wet Prairie	Slender Willow *Salix petriolaris*	Plant	11	Root (Schetter 2012)	Andreas & Knoop 1992; Schetter 2012

Habitat Modeling

Our goal was to develop generalizable models for each species based on the available occurrence data and the same set of potential predictor variables (e.g., land cover, connectivity, soil) for the Oak Openings Region. These models are readily comparable and can be combined in various ways to examine multiple species or multiple ecosystem patterns. We used nine different environmental explanatory variables for the final model output. Other variables examined but ultimately excluded were: edge density (fragmentation index), contagion (heterogeneity index), Shannon's diversity index (diversity index), largest patch index (alternative fragmentation index), normalized difference vegetation index, distance to roads, and elevation. These rejected variables provided little contribution ($x < 5\%$) towards the final model output.

All environmental layers used in the final model were edited/manipulated within ArcGIS version 10.2.2 and clipped to the Oak Openings Region boundary. Soil data was acquired from the USDA web soil survey (http://websoilsurvey.nrcs.usda.gov) for each county within the Oak Openings Region extending from northwestern Ohio into southeastern Michigan. Soil polygons were categorized into three categorical soil types (e.g., hydric, mesic, and xeric) and then merged together to form one complete polygon layer. Land cover types were derived from updated land cover map (Root & Martin 2017) where land cover types, dense urban and residential/mixed, were combined into a single anthropogenic category.

Categorical data (soil type and land cover type) were converted to continuous data using a 120 m neighborhood moving window in FRAGSTATS (McGarigal & Marks 1995) with the PLAND metric. This created a measurement of percent area occupied by a given land cover type within the 120 m window, illustrated in Figure 2b. In this case the neighborhood consists of cells (including the central occupied cell) that are floodplain forest shown in green but the surrounding neighborhood is dominated by residential (yellow) and has a few cells with savanna (orange). Therefore, these surrounding land use types, e.g., residential, may heavily influence the predictions of the model. This does not mean that the species is preferentially using residential areas, but rather that they occur in ecological neighborhoods that have a large proportion of residential land use. The primary occupied cell may still be floodplain forest but this land use type may not occur in large contiguous blocks. Instead of focusing specifically on the individual cell in which the occurrence point occurs, the subsampling analysis examines the immediate neighborhood adjacent to that occupied cell. Finally, all environmental layers were imported as or converted to a raster format with 30 m x 30 m cell size and then converted to American Standard Code for Information Interchange (ASCII) format. Conversion from raster to ASCII is necessary when running the files in MaxEnt.

We ran species distribution models using a maximum entropy approach implemented in MaxEnt 3.3.3k (Philips et al. 2006) using the default settings with minor changes. For each species and target ecosystem, we ran 10 replicates using bootstrap sampling using a random seed with the occurrence records. In other words, we sampled randomly from the occurrence records with replacement for 10 iterations of the model. During each replicate, the data (i.e., occurrence records) were partitioned into 30% withheld for testing and 70% used as training data. To explore the sensitivity of the model to different amounts of acceptable omission and commission errors, we ran each set of models with four different thresholds. We applied the threshold rule of maximum test sensitivity plus specificity (MSS) for each model, Table 3, which balances the omission (false negatives: a species is present but identified as absent) and commission (false positives; a species is absent but identified as present) error rates. We evaluated other options of exploring restoration potential for each target ecosystem using different fixed omission thresholds of one, five and ten percent omission error rates along with the maximum test sensitivity plus specificity. See Appendix 1 for description of using these alternative versions.

To examine explanatory variable performance, we used the jackknife approach to measure variable contribution alone and in combination with other variables. Overall model performance was assessed using the Area Under the Curve (AUC), where AUC values greater than 0.5 indicate an efficient model and models with AUC values less than 0.5 indicate a poor performance. We used the average model (i.e., average of the 10 replicates) to map the habitat suitability for each species and target ecosystem. The map was reclassified in ArcGIS 10.2.2 from a continuous scale into 10% probability classes (0-100%) to represent the probability of occurrence. We examined the importance of each variable using the percent contribution and permutation importance. Percent contribution was calculated during model development, which includes the changes in the gain. Permutation importance is calculated by changing the variable's and background values during training and then re-evaluating the model. We used percent contribution to determine the top three variables for each model. Our assumptions for the final models are that (1) the species occurrence records used in the analysis are an unbiased representation of the full set of samples; (2) the samples are representative of the suite of environmental conditions for which the species utilizes within the region (this should be predominantly in the focal ecosystem but not exclusively); (3) the final models represent the species functional habitat (e.g., foraging, dispersal, nesting); and (4) the species are reasonable representatives of the target ecosystem (the goal was >50% of the occurrence data within the focal ecosystem). It is important to note that while the initial selection of species was based on the pattern of occurrence of the full data set, sub-sampling of the data was random and potentially reduced the percent of points occurring within the focal ecosystem (see the description about the ecological neighborhood subsampling, Figure 2).

Table 3. Listed are the maximum test sensitivity plus specificity thresholds used to distinguish suitable from unsuitable habitat for each species. Values at or above the threshold were considered suitable.

	Threshold
Upland Savanna/Prairie	0.1859
Lark Sparrow	0.1377
Red-headed Woodpecker	0.2005
Wild Lupine	0.2431
Upland Deciduous Forest	0.1736
Red-backed Salamander	0.1461
Northern Long-eared Bat	0.1648
Eastern Red Bat	0.3058
Floodplain Forest	0.1628
Giant Swallowtail	0.3039
Evening Bat	0.2004
Eastern Box Turtle	0.1199

	Threshold
Swamp Forest	0.2437
Wood Thrush	0.2644
Barred Owl	0.2744
Appalachian Brown	0.2882
Wet Prairie	0.1346
Spotted Turtle	0.1308
Blazing Star Borer Moth	0.3236
Slender Willow	0.2722

We examined each target ecosystem as a whole using occurrence data for three indicator species. We looked at the diversity of species within each target ecosystem by creating a binary map of suitable and unsuitable habitat based on the MSS threshold for each of the three species and then combining the outputs into one final map to represent habitat suitability for multiple species per ecosystem. To create the binary map, we used the maximum test specificity plus specificity (MSS) threshold, shown in Table 3, to distinguish suitable from unsuitable habitat; values at or above the threshold were considered suitable. We also mapped the full set of 15 species for the five focal ecosystems and subsets of the 15.

Results

Landsat Band Comparison

We compared the 24 band, 27 band and 33 band images to each other and found that the 27 band image had the greatest accuracy based on ground truthing. We compared the changes in land cover area and percentage for classification based on all bands (33), fewer bands (27) and even fewer bands (24), shown in Table 4. Removing bands from the image selection did not have any effect on the percent cover for upland coniferous forest, wet prairie, floodplain forest, perennial pond, and wet shrubland. Both sand barren (1.3%) and residential/mixed (1.1%) had the greatest change in land cover from varying the number of bands used in the image. We examined differences in accuracy using the original ground truth points and found that the 27 band image had the greatest accuracy of 61.1%, whereas the 24 band image was 54.5%, and the 33 band image was 60.7%. We compared the 33 band image created in June 2017 with the 33 band image created in September 2017 for upper Michigan and found that the original map (Phase I) image was predominately covered with upland deciduous forest, whereas the new map (Phase II) was predominately covered with upland prairie (Figure 3).

Table 4. Summary of land cover map results for the variations in the number of bands used (24 bands, 27 bands, and 33 bands) using the Brewer and Vankat boundaries.

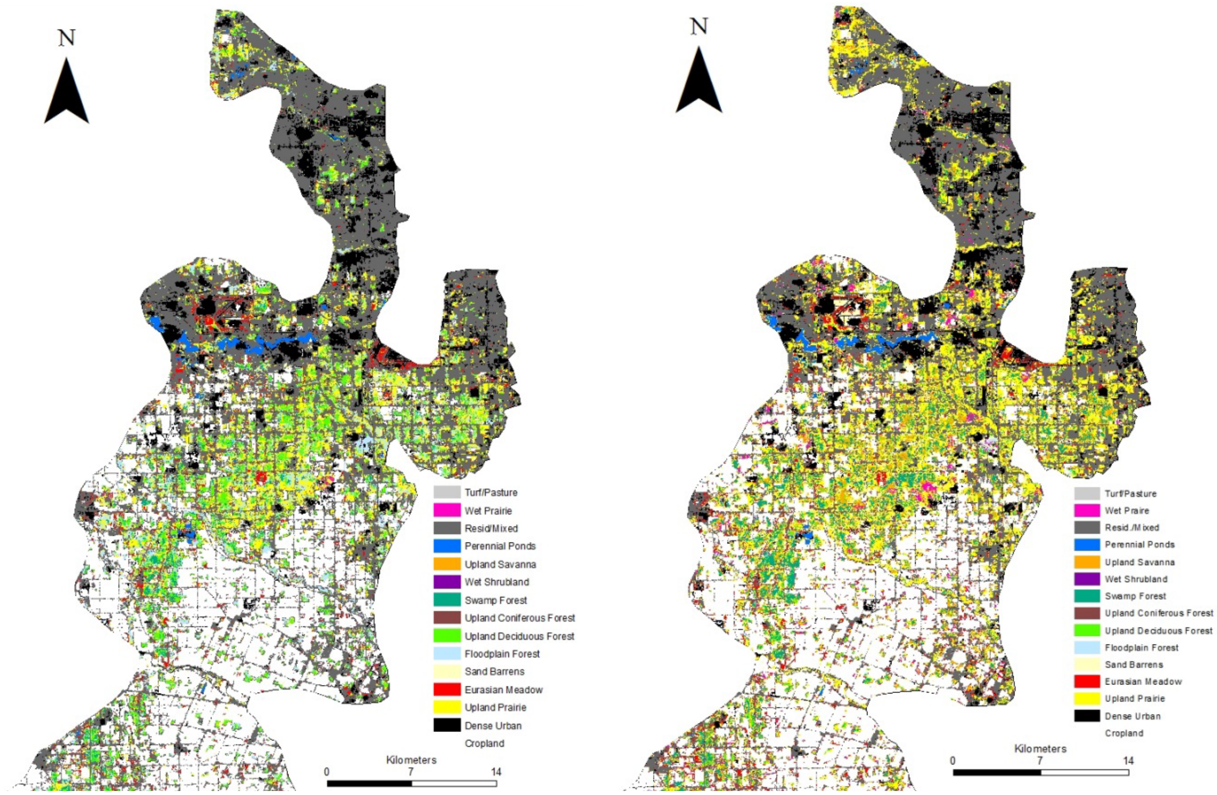
	24 Band		27 Band		33 Band	
	Area (ha)	**% Cover**	**Area (ha)**	**% Cover**	**Area (ha)**	**% Cover**
Natural/Seminatural	15904	33.3	15761	33.0	15409	32.2
Forest and Woodlands	7035	14.7	7044	14.7	7115	14.9
Swamp Forests	3212	6.7	3216	6.7	3297	6.9
Floodplain Forests	1507	3.2	1509	3.2	1536	3.2
Deciduous Forests	1918	4.0	1919	4.0	1876	3.9
Coniferous Forests	398	0.8	400	0.8	406	0.8
Savannas (Upland Savannas)	962	2.0	971	2.0	1070	2.2
Shrublands (Wet Shrublands)	6	0.0	5	0.0	4	0.0
Prairies & Meadows	7662	16.0	7503	15.7	6985	14.6
Wet Prairies	708	1.5	725	1.5	705	1.5
Upland Prairies	3112	6.5	3115	6.5	3134	6.6
Sand Barrens	1999	4.2	1835	3.8	1395	2.9
Eurasian Meadows	1843	3.9	1828	3.8	1751	3.7
Water (Perennial Ponds)	238	0.5	238	0.5	235	0.5
Cultural	31883	66.7	32002	67.0	32400	67.8
Built-up	19687	41.2	19812	41.5	20227	42.3
Dense Urban	1880	3.9	1888	4.0	1880	3.9
Residential/Mixed	17807	37.3	17924	37.5	18347	38.4
Vacant	12196	25.5	12190	25.5	12173	25.5
Turf/Pasture	45	0.1	38	0.1	21	0.0
Croplands	12151	25.4	12151	25.4	12151	25.4
Total Mapped	47787	100	47763	100	47808	100

Map Characteristics

The final extended land cover map of the Oak Openings Region contains 15 land cover classes (Table 5, Figure 4). We found that natural/seminatural land cover classes covered 33.1% of the region, while cultural land cover classes covered 66.9% of the total area. To compare changes in land cover classes over time, we have displayed the original land cover area (ha) and percent area with the updated version clipped to the same extent, and the extended area of the Oak Openings Region (Table 5, Figure 5). We found that natural/seminatural classes increased by 5.8%, whereas cultural classes decreased by 5.8%. Overall, almost all of the land cover classes had large or modest changes over time. For example, forest and woodlands lost 5.4% of the habitat, whereas prairies and meadows gained 10.9% of the habitat. Within individual land cover classes, turf/pasture had the greatest decline (7.6%) in habitat composition, while upland prairies had the greatest gain (5.2%) in habitat composition.

Table 5. Summary of land cover map results for the original land cover map (Schetter & Root), updated land cover map using 27 Landsat bands (Root & Martin Phase II) using the Brewer and Vankat boundary and updated extended region land cover map (Extended Boundary), which includes Michigan.

	Schetter & Root		**Root & Martin**		**Extended Boundary**	
Class	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Natural/Seminatural	12989	27.2	15761	33.0	64246	33.1
Forest and Woodlands	9735	20.4	7044	15.0	14881	7.7
Swamp Forests	1496	3.1	3216	6.7	8807	4.5
Floodplain Forests	4259	8.9	1509	3.2	2151	1.1
Deciduous Forests	3073	6.4	1919	4.0	3502	1.8
Coniferous Forests	907	1.9	400	0.8	421	0.2
Savannas (Upland Savannas)	370	0.8	971	2.0	6027	3.1
Shrublands (Wet Shrublands)	193	0.4	5	0.0	5	0.0
Prairies & Meadows	2438	5.1	7503	16.0	42209	21.8
Wet Prairies	40	0.1	725	1.5	2877	1.5
Upland Prairies	610	1.3	3115	6.5	23092	11.9
Sand Barrens	359	0.8	1835	3.8	8766	4.5
Eurasian Meadows	1429	3.0	1828	3.8	7474	3.9
Water (Perennial Ponds)	253	0.5	238	0.5	1125	0.6
Cultural	34791	72.8	32002	67.0	129740	66.9
Built-up	18749	39.2	19812	41.0	71715	37.0
Dense Urban	1833	3.8	1888	4.0	11472	5.9
Residential/Mixed	16915	35.4	17924	37.5	60243	31.1
Vacant	16042	33.6	12190	26.0	58025	29.9
Turf/Pasture	3141	6.6	38	0.1	60	0.0
Croplands	12901	27.0	12151	25.4	57965	29.9
Total Mapped	47779	100	47763	100	193986	100



(a) Root & Martin 2017 (June) upper Michigan (b) Root & Martin (September) upper Michigan

Figure 3. (a) Land cover map created in June 2017 during Phase I for upper Michigan and (b) updated land cover map created for Phase II in September 2017; both created using 33 Landsat bands.

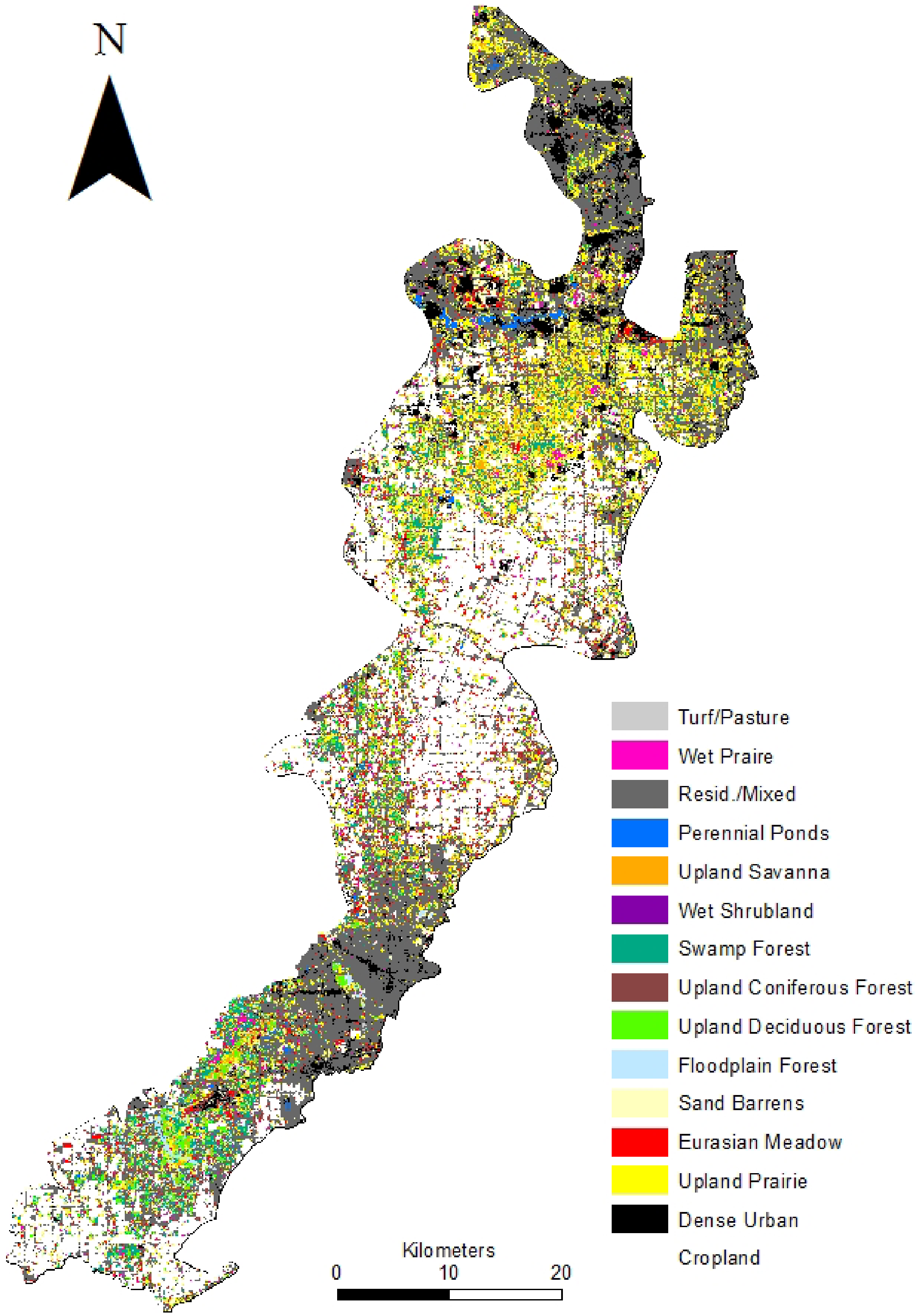
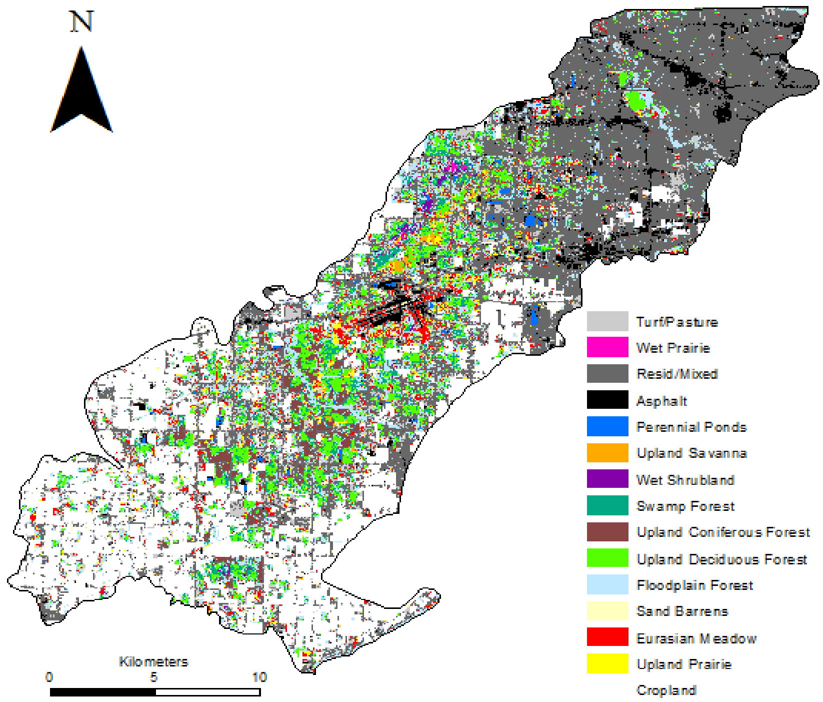
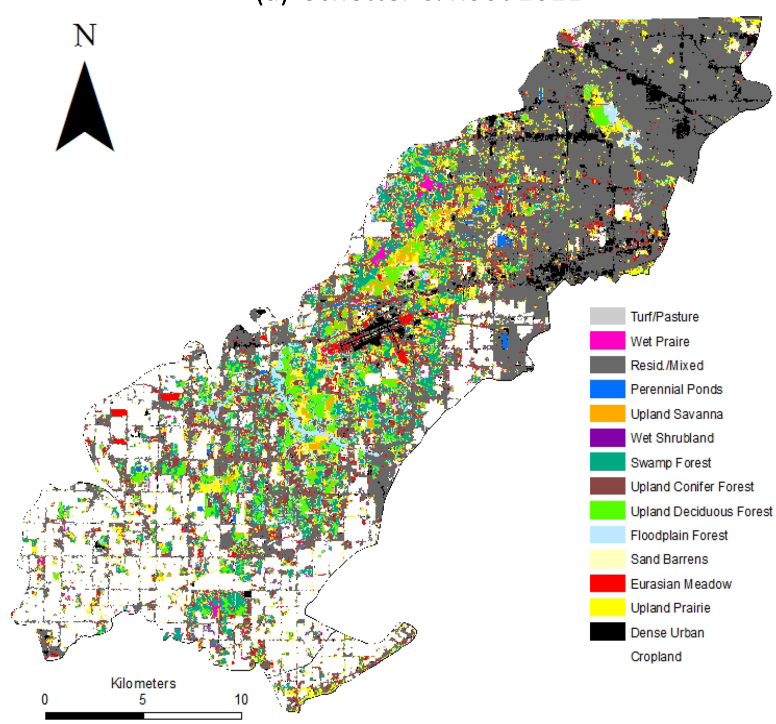


Figure 4. Extended land cover map of the Oak Openings Region of northwestern Ohio, based on supervised classification from Landsat 8 images (Root & Martin 2017).



(a) Schetter & Root 2011



(b) Root & Martin 2017

Figure 5. (a) Original land cover map (Schetter & Root 2011) and (b) updated land cover map (Root & Martin 2017) of the Oak Openings Region of northwestern Ohio using the Brewer and Vankat boundaries.

Map Accuracy Assessment

We evaluated 500 points using ground truthing and orthophotos to validate the updated land cover map. We compiled our results into an error matrix (Table 1) and found that the overall accuracy of the final 15-class map was 71.2%. None of the land cover classes were all correctly predicted by our supervised land cover classification.

Habitat Models

Upland savanna/prairie. We modeled lark sparrow using 7 testing points and 17 presence training points (Figure 6). For the average model (using 10 replicates) the test AUC was 0.9692 ± 0.0197 (SD) representing a strong model performance. We found that soil had the greatest contribution (46.6%), followed by proportion of anthropogenic (15%) and proportion of upland prairie (12.9%) in the ecological neighborhood (Table 6). We examined the response curves and found that species presence increased with drier soils, decreasing proportion of anthropogenic land cover and increased with increasing proportion of upland prairie.

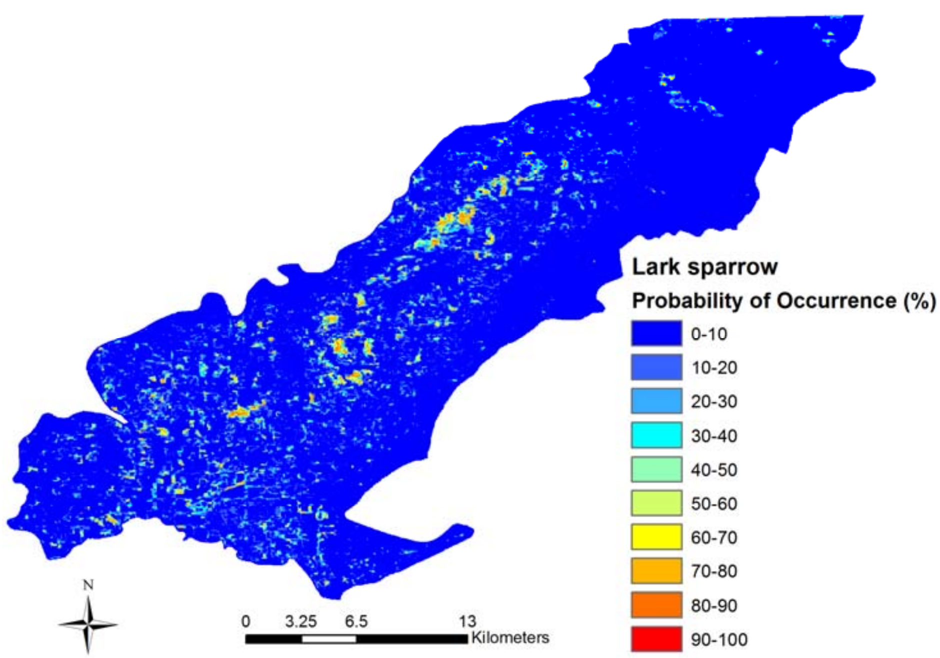


Figure 6: Ten percent probability of occurrence quantiles for the average model for lark sparrow within the Oak Openings Region of northwestern Ohio.

We modeled wild lupine using 5 testing points and 12 presence training points (Figure 7). For the average model (using 10 replicates) the test AUC was 0.9578 ± 0.021 (SD) representing a strong model performance. We found that proportion of upland deciduous forest had the greatest contribution (46.2%), followed by soil (24.6%) and proportion of upland prairie (8.6%) in the ecological neighborhood, Table 6. We examined the response curves and found that species presence increased with increasing proportion of upland deciduous forest, with drier soils and with increasing proportion of upland prairie.

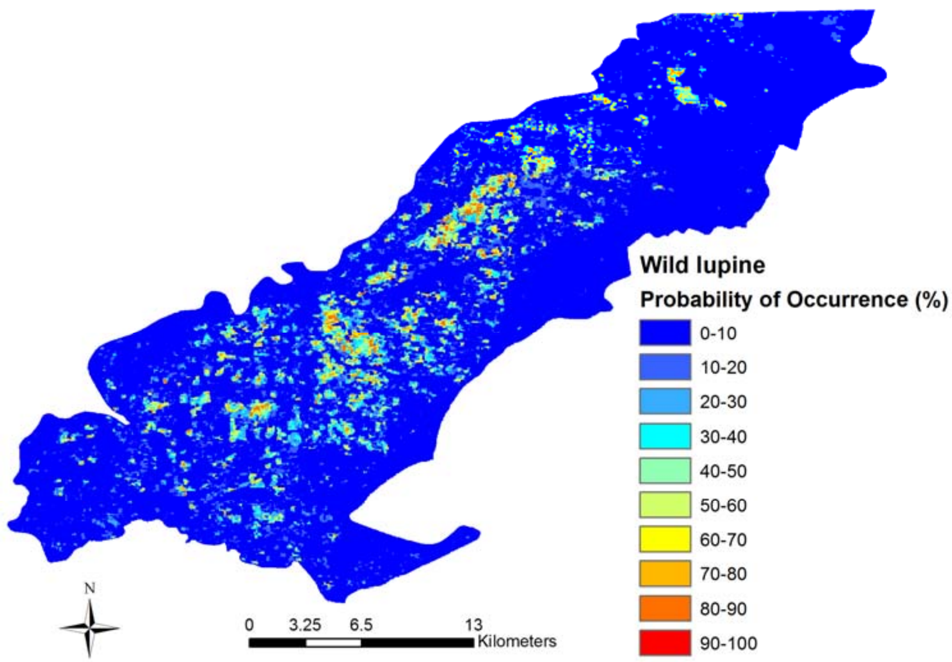


Figure 7: Ten percent probability of occurrence quantiles for the average model for wild lupine within the Oak Openings Region of northwestern Ohio.

We modeled red-headed woodpecker using 15 testing points and 35 presence training points (Figure 8). For the average model (using 10 replicates) the test AUC was 0.9079 ± 0.0291 (SD) representing a strong model performance. We found that soil had the greatest contribution (40.8%), followed by cohesion (connectivity index) (17.2%) and the proportion of floodplain forest (11.6%) in the ecological neighborhood, Table 6. We examined the response curves and found that species presence increased with drier soils, with greater connectivity and increasing proportion of floodplain forest.

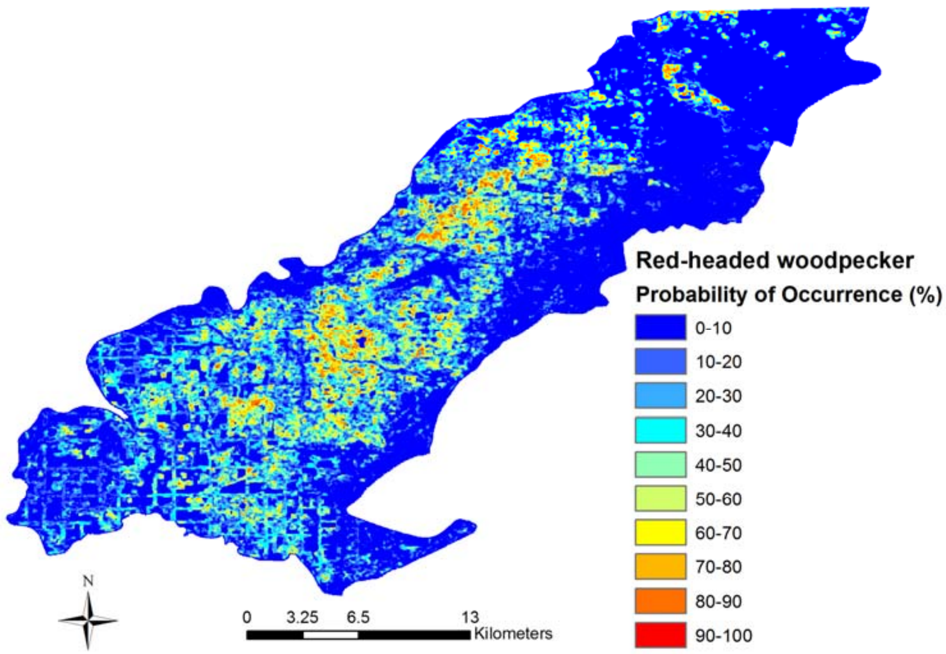


Figure 8: Ten percent probability of occurrence quantiles for the average model for red-headed woodpecker within the Oak Openings Region of northwestern Ohio.

The relative contribution of the explanatory variables differed among the three selected species with proportion of upland savanna having the greatest contribution (6.6%) for the red-headed woodpecker and proportion of upland prairie having the greatest contribution (12.9%) for lark sparrow. We modeled the three species as a whole to represent upland savanna/prairie (Figure 9) for which soil, cohesion (connectivity index) and proportion of anthropogenic contributed the greatest to the model (Table 6). Soil contributed the most to model development as supported by the jackknife measure.

We also illustrate the most suitable habitat in the top 10 (Priority 1) and 20% (Priority 2) in relation to the current protected areas in Figure 10. This map could be used to identify the highest quality areas that are in close proximity to or increase connectivity to current conservation areas. Based on these data there are, conservatively, 49.4 acres in Priority 1 and 502.4 acres in Priority 2 for upland savanna/prairie that are not currently in protected areas in Ohio.

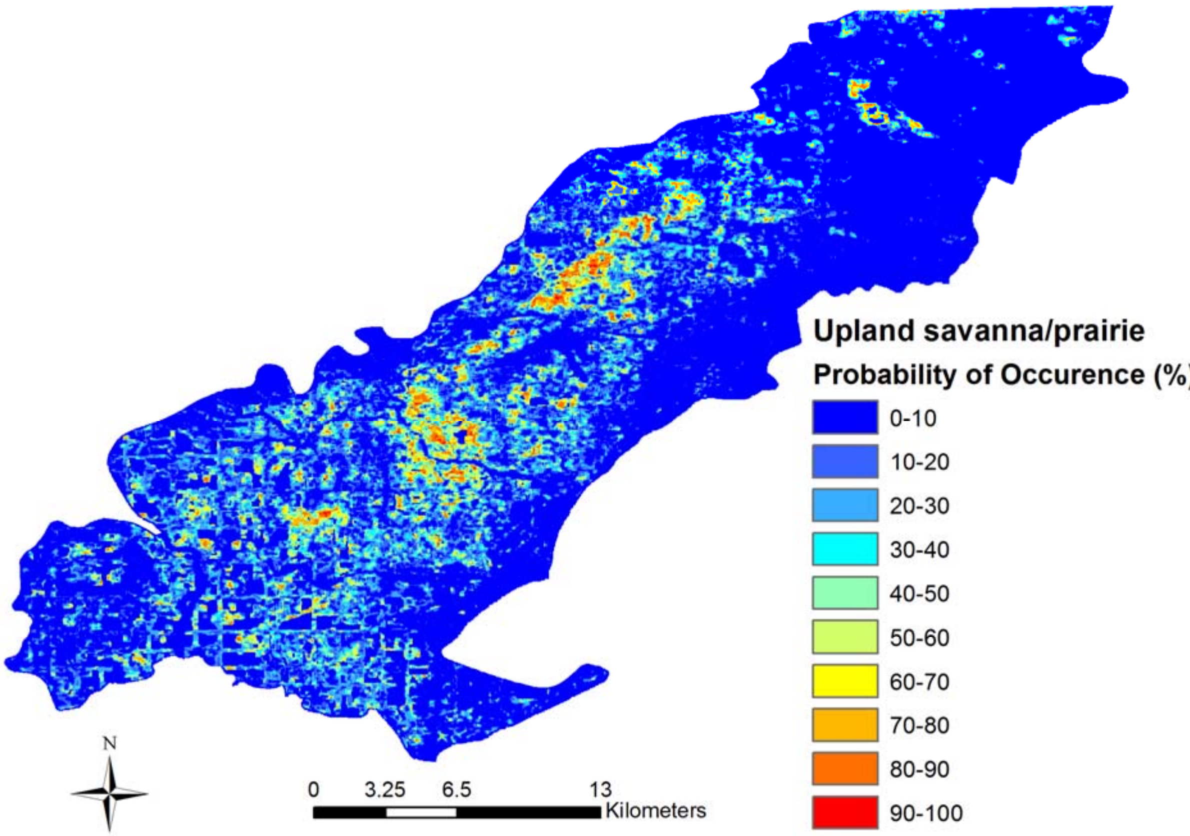


Figure 9: Ten percent probability of occurrence quantiles using the maximum test sensitivity plus specificity (MSS) threshold for upland savanna/prairie within the Oak Openings Region of northwestern Ohio.

Table 6: Percent contribution (% Contrib) and permutation importance (Impt) of the explanatory variables to the average models of each selected upland savanna/prairie species.

	Lark sparrow		Lupine		Red-headed woodpecker		Upland Savanna/Prairie	
Variable	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt
Anthropogenic	15	7.1	6.8	2.3	5.1	9.4	12.2	15.2
Cohesion	7.2	3.1	0.1	9.4	17.2	26.4	16	29.1
Floodplain forest	0.6	0.6	0.5	0.5	11.6	4.1	1.6	1.6
Soil type	46.6	71.7	24.6	25.8	40.8	46.5	44.7	43.2
Swamp forest	9	7.2	1.8	0.3	4	1.2	5.6	4.3
Deciduous forest	0.5	0.2	46.2	15.9	8.1	2	6.7	1.1
Upland prairie	12.9	6.2	8.6	17.6	1.4	1.2	3.6	1.7
Upland savanna	6.5	1.8	3.2	0.2	6.6	2.2	5.7	1.6
Wet prairie	1.6	2.2	8.2	28	5.2	7.1	3.9	2.3

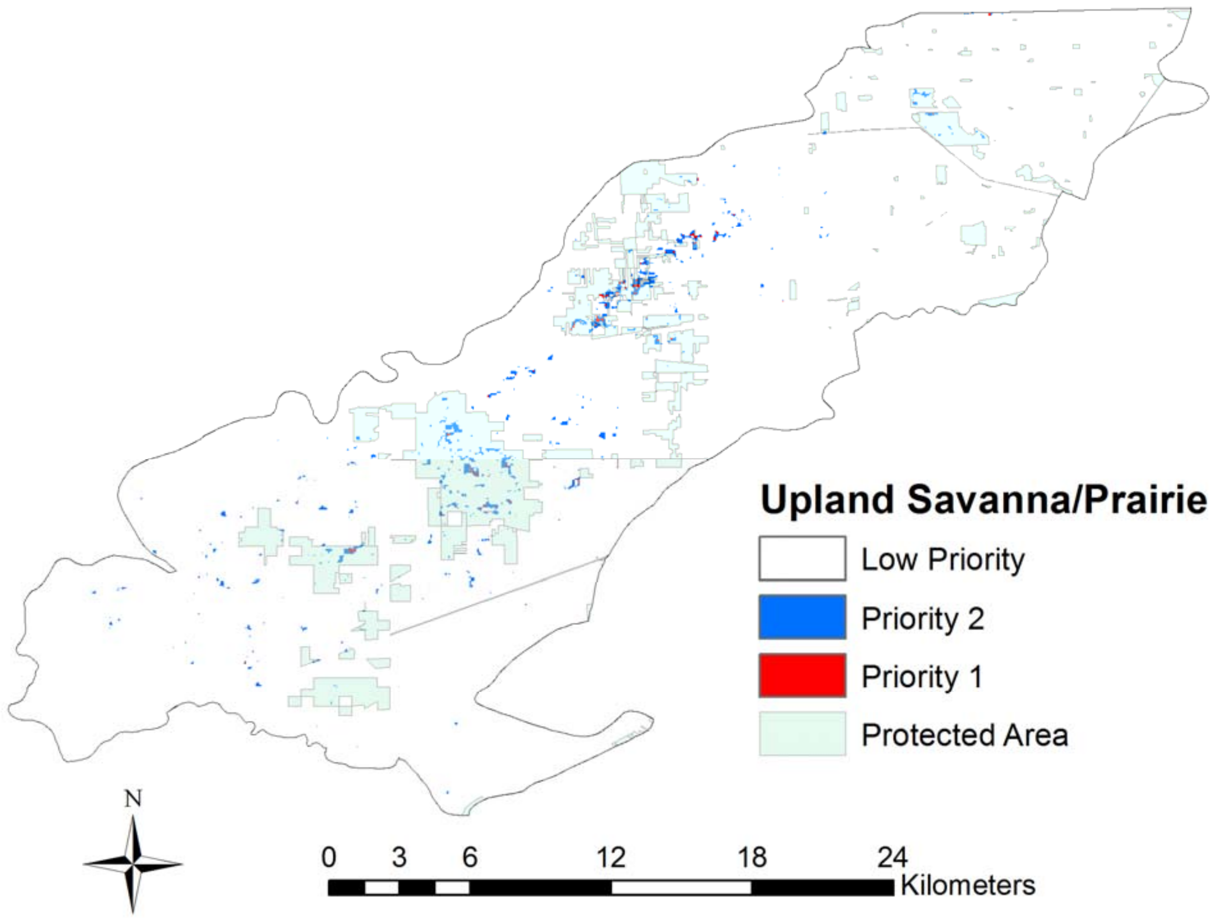


Figure 10. Protected areas and the top 10% (100-90%; Priority 1) and the second 10% (90-80%; Priority 2) of the suitable upland savanna/prairie within the Oak Openings Region of northwestern Ohio.

We modeled the habitat suitability for the three indicator species to identify areas with the greatest upland savanna/prairie quality, indicated by areas with all three species overlapped with one another (Figure 11).

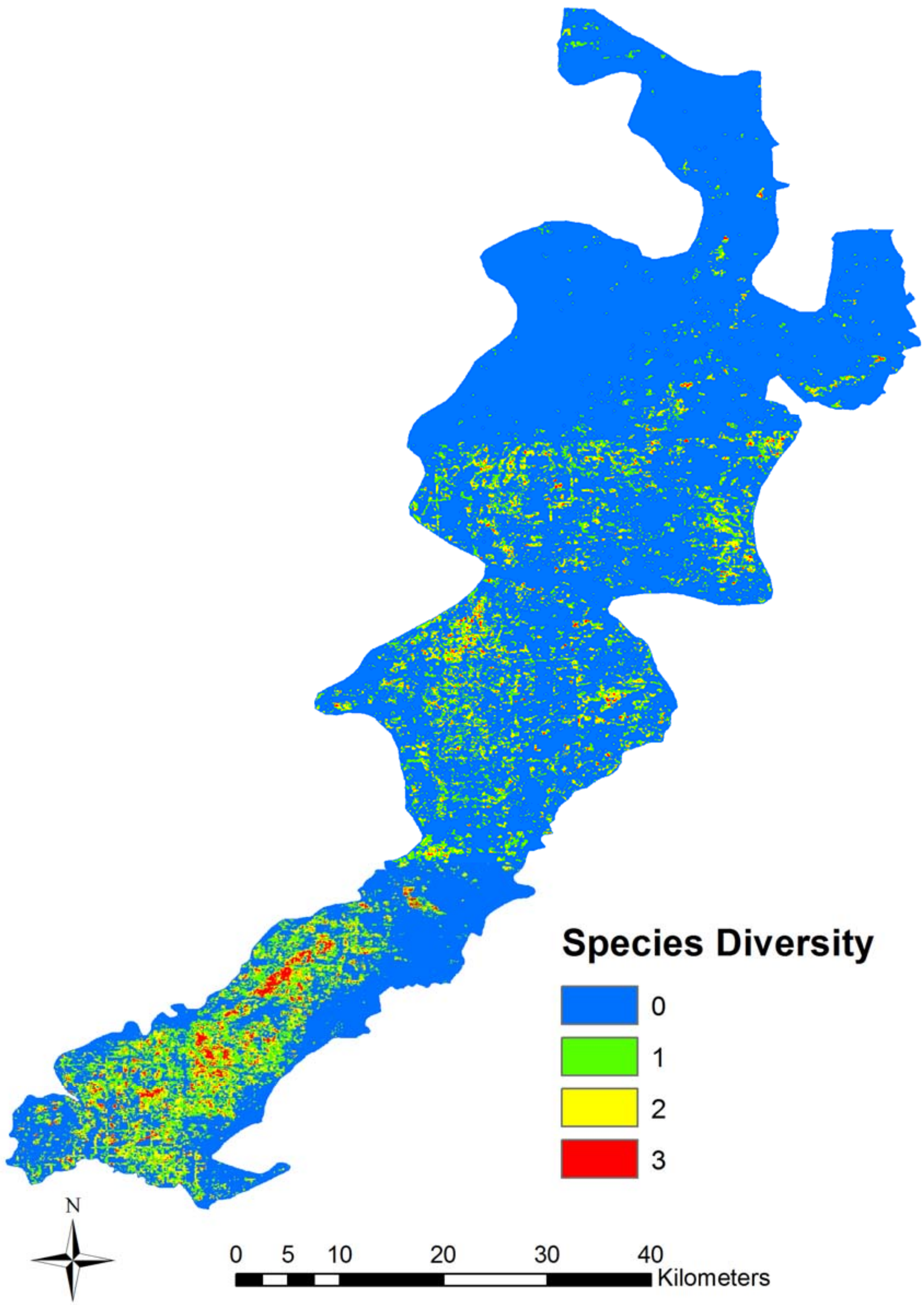


Figure 11: The habitat suitability for three indicator species of upland savanna/prairie within the Oak Openings Region of Ohio and Michigan. Each color shows the number of species that overlap with one another.

Floodplain forest. We modeled giant swallowtail using 3 testing points and 7 presence training points (Figure 12). For the average model (using 10 replicates) the test AUC was 0.8757 ± 0.0668 (SD) representing a strong model performance. We found that proportion of anthropogenic had the greatest contribution (45.8%), followed by proportion of upland savanna (26.9%) and soil type (8.7%) (Table 7). We examined the response curves and found that species presence increased with decreasing proportion of anthropogenic land cover increasing proportion of upland savanna and with drier soils.

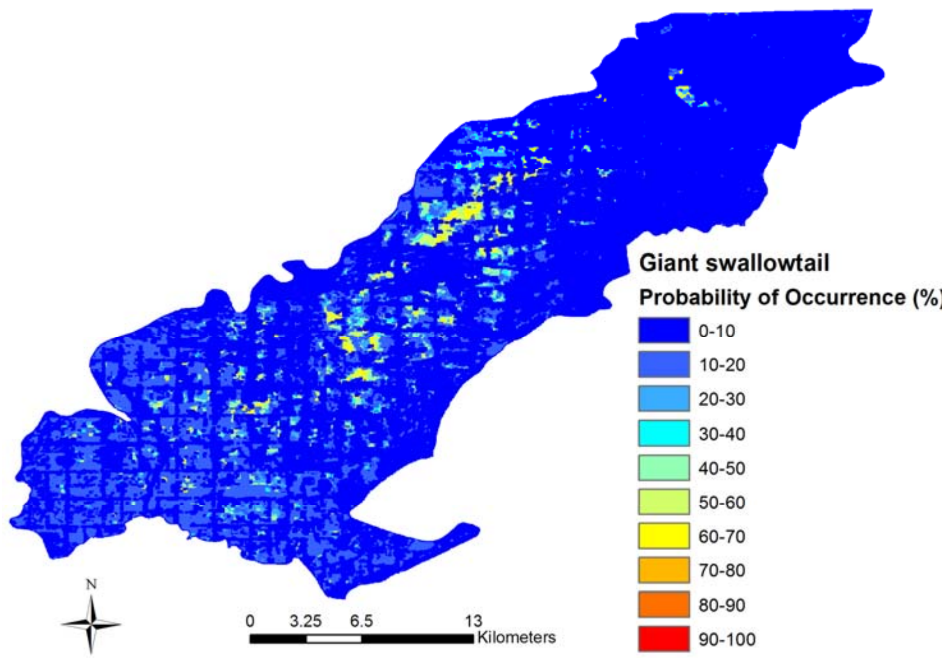


Figure 12: Ten percent probability of occurrence quantiles for the average model for giant swallowtail within the Oak Openings Region of northwestern Ohio.

We modeled evening bat using 15 testing points and 35 presence training points (Figure 13). For the average model (using 10 replicates) the test AUC was 0.9000 ± 0.0278 (SD) representing a strong model performance. We found that soil type had the greatest contribution (32.1%), followed by proportion of floodplain forest (25.3%) and proportion of upland deciduous forest (17.1%), Table 7. We examined the response curves and found that species presence increased with drier soils, with increasing proportion of floodplain forest and increasing proportion of upland deciduous forest land cover in the ecological neighborhood.

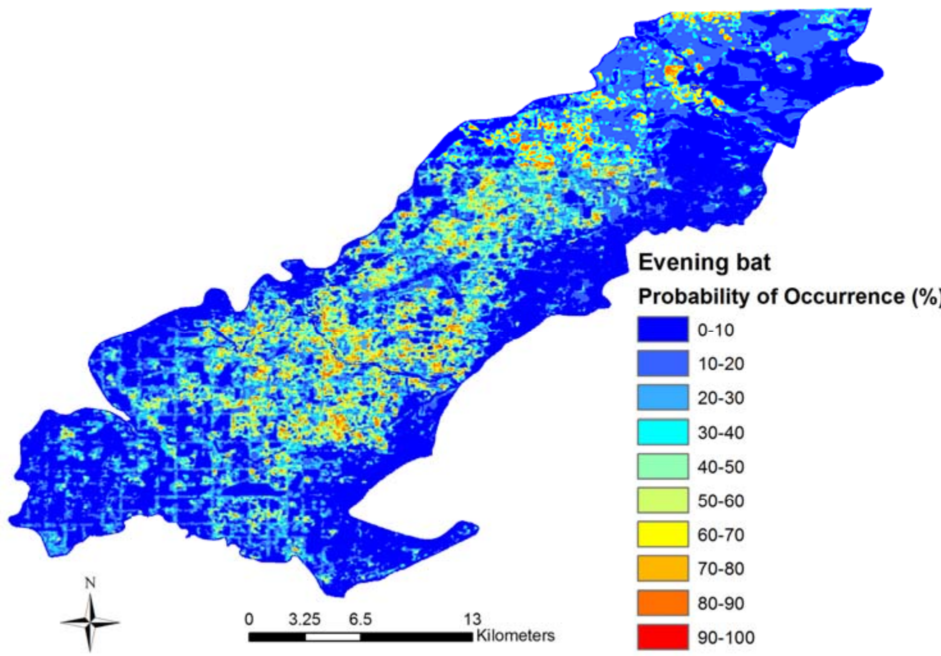


Figure 13: Ten percent probability of occurrence quantiles for the average model for evening bat within the Oak Openings Region of northwestern Ohio.

We modeled eastern box turtle using 15 testing points and 35 presence training points (Figure 14). For the average model (using 10 replicates), the test AUC was 0.9773 ± 0.009 (SD) representing a strong model performance. We found that proportion of floodplain forest had the greatest contribution (32.3%), followed by proportion of upland deciduous forest (%) and proportion of anthropogenic (17.1%), Table 7. We examined the response curves and found that species presence increased with increasing proportion of floodplain and proportion of upland deciduous forest land cover and with decreasing proportion of anthropogenic land cover.

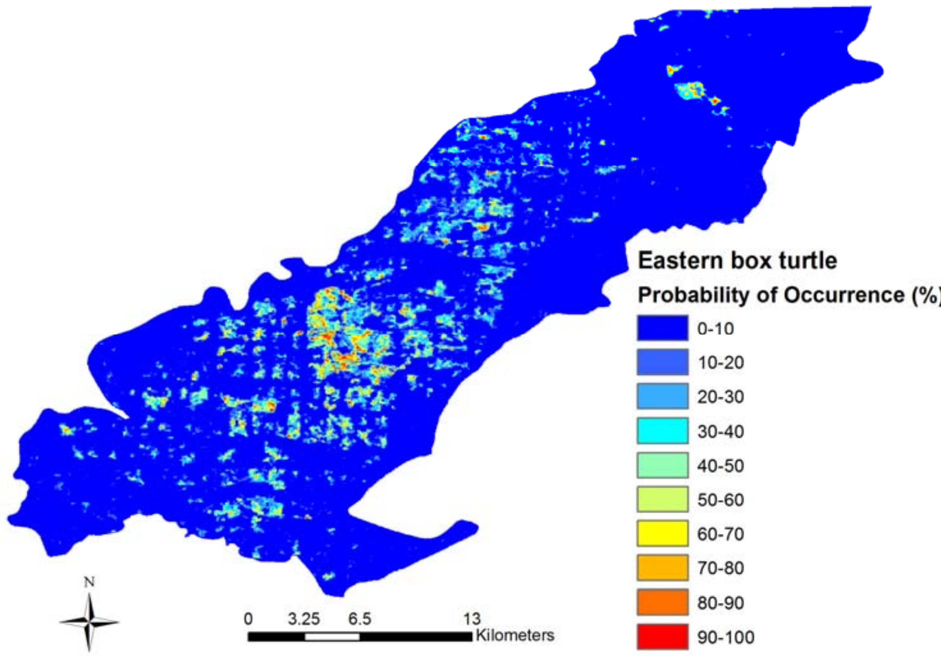


Figure 14: Ten percent probability of occurrence quantiles for the average model for eastern box turtle within the Oak Openings Region of northwestern Ohio.

The relative contribution of the explanatory variables differed among the three selected species with proportion of floodplain forest having the greatest contibution (32.3%) for eastern box turtle. We modeled the three species as a whole to represent floodplain forest (Figure 15) for which soil, proportion of floodplain forest and proportion of upland deciduous forest contributed the greatest to the model (Table 7). Proportion of floodplain forest contributed the most to model development as supported by the jackknife measure.

We also illustrate the most suitable habitat in the top 10 (Priority 1) and 20% (Priority 2) in relation to the current protected areas in Figure 16. This map could be used to identify the highest quality areas that are in close proximity to or increase connectivity to current conservation areas. Based on these data there are, conservatively, 30.0 acres in Priority 1 and 268.2 acres in Priority 2 for floodplain forest that are not currently in protected areas in Ohio.

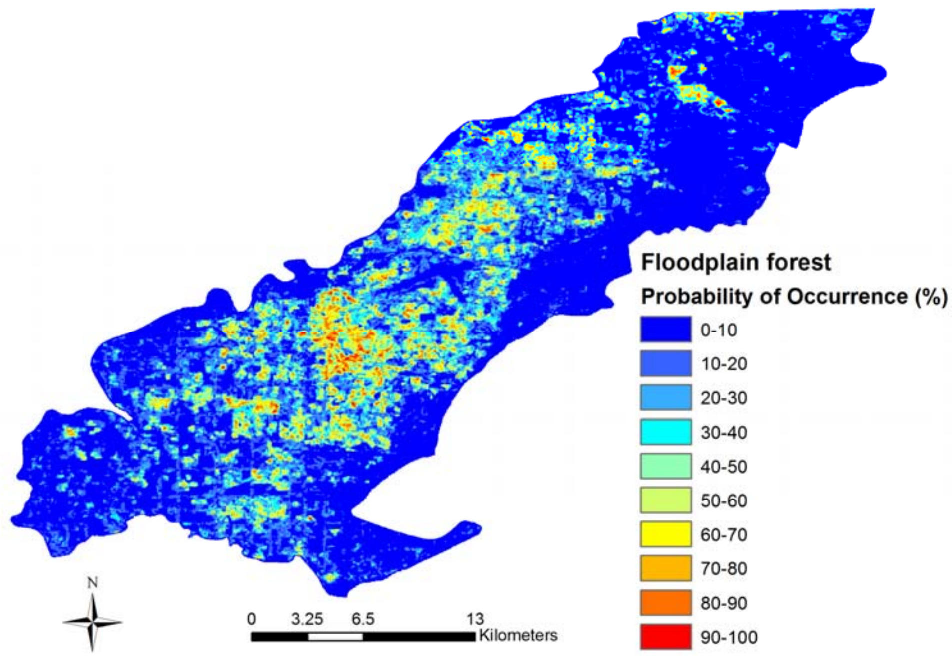


Figure 15: Ten percent probability of occurrence quantiles using the maximum test sensitivity plus specificity (MSS) threshold for floodplain forest within the Oak Openings Region of northwestern Ohio.

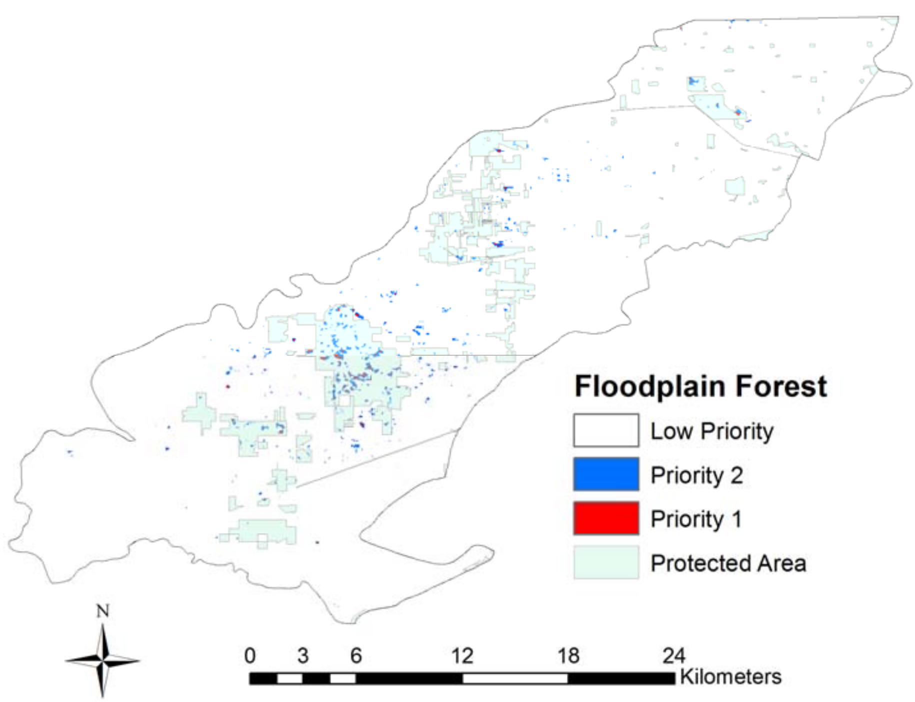


Figure 16. Protected areas and the top 10% (100-90%; Priority 1) and the second 10% (90-80%; Priority 2) of the suitable floodplain forest within the Oak Openings Region of northwestern Ohio.

Table 7: Percent contribution (% Contrib) and permutation importance (Impt) of the explanatory variables to the average models of each selected floodplain forest.

	Giant swallowtail		Evening bat		Eastern box turtle		Floodplain Forest	
Variable	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt
Anthropogenic	45.8	53.3	8.8	13.9	17.1	32.9	5.3	4.8
Cohesion	0.3	6	4.8	8.5	2.7	11.9	5	15.7
Floodplain forest	3.3	0.2	25.3	7.6	32.3	15	26.5	14.3
Soil type	8.7	9.3	32.1	54.6	11.7	17.5	30.3	50.4
Swamp forest	5.6	1.5	3.7	1.9	14.1	7.1	6.1	5.1
Deciduous forest	3.7	1.7	17.1	7.9	18.6	11.4	20	5.4
Upland prairie	2.2	2.8	3.9	4.2	2	1.8	2.7	2.8
Upland savanna	26.9	22.7	3.2	0.9	1.1	0.9	3.2	0.9
Wet prairie	3.4	2.5	1.1	0.5	0.4	1.5	0.9	0.6

We modeled the habitat suitability for the three indicator species to identify areas with the greatest floodplain forest quality, indicated by areas with all three species overlapped with one another (Figure 17).

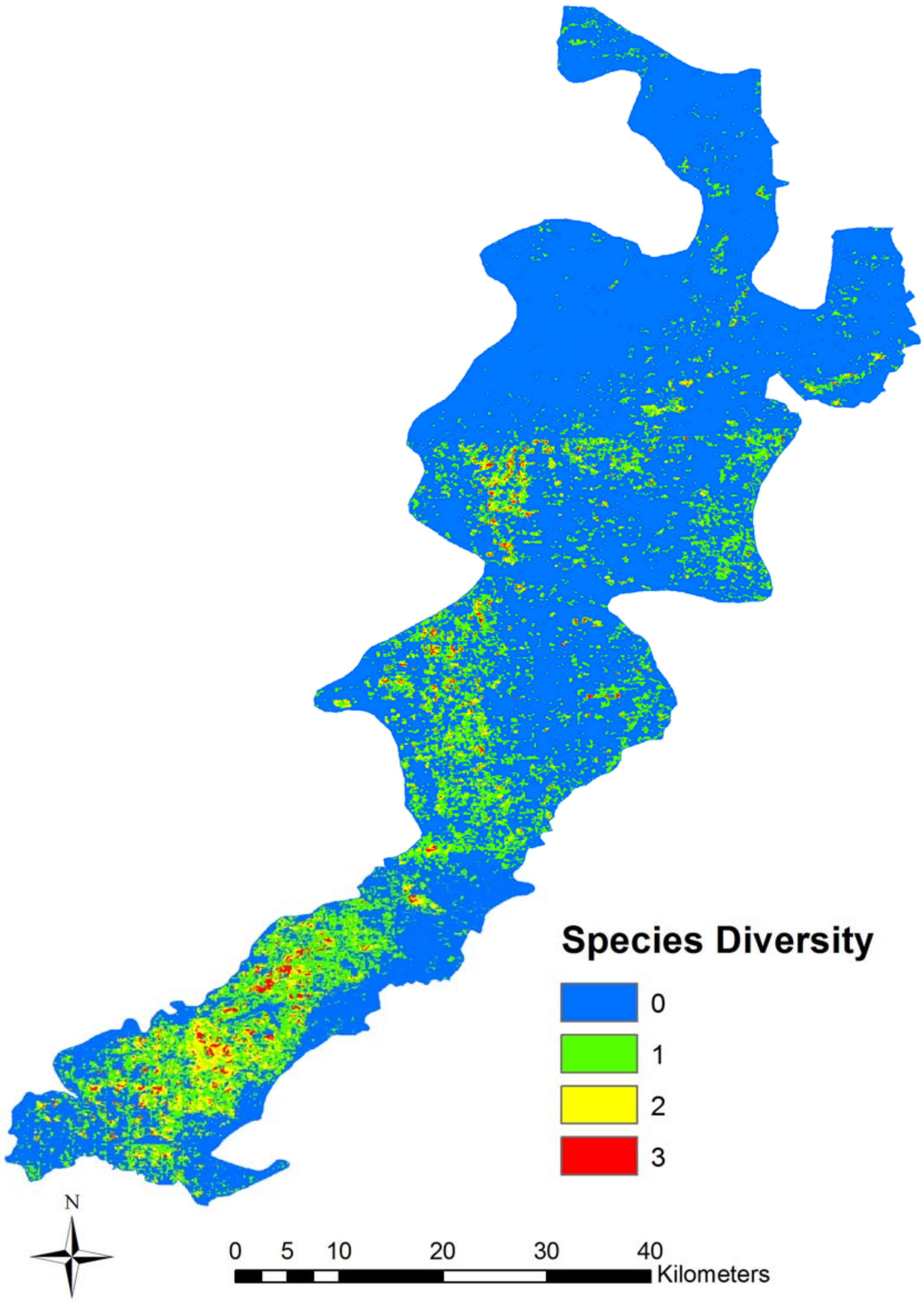


Figure 17: The habitat suitability for three indicator species of floodplain forest within the Oak Openings Region of Ohio and Michigan. Each color shows the number of species that overlap with one another.

Swamp forest. We modeled Appalachian brown using 3 testing points and 7 presence training points (Figure 18). For the average model (using 10 replicates) the test AUC was 0.8675 ± 0.058 (SD) representing a strong model performance. We found that proportion of swamp forest had the greatest contribution (28.7%), followed by soil type (28.6%) and proportion of upland prairie (15.3%) (Table 8). We examined the response curves and found that species presence increased with increasing proportion of swamp forest, drier soils and increasing proportion of upland prairie in the ecological neighborhood.

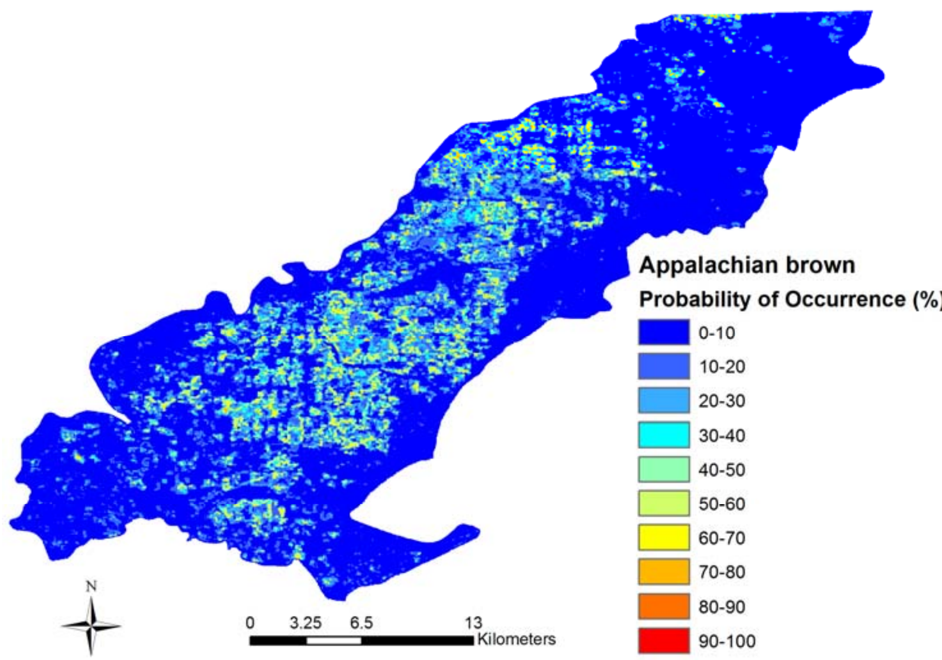


Figure 18: Ten percent probability of occurrence quantiles for the average model for Appalachian brown within the Oak Openings Region of northwestern Ohio.

We modeled barred owl using 3 testing points and 7 presence training points (Figure 19). For the average model (using 10 replicates) the test AUC was 0.8979 ± 0.0667 (SD) representing a strong model performance. We found that proportion of floodplain forest had the greatest contribution (37.4%), followed by proportion of upland deciduous forest (33%) and soil type (16.3%), Table 8. We examined the response curves and found that species presence increased with increasing proportion of floodplain forest and proportion of upland deciduous forest, and drier soils.

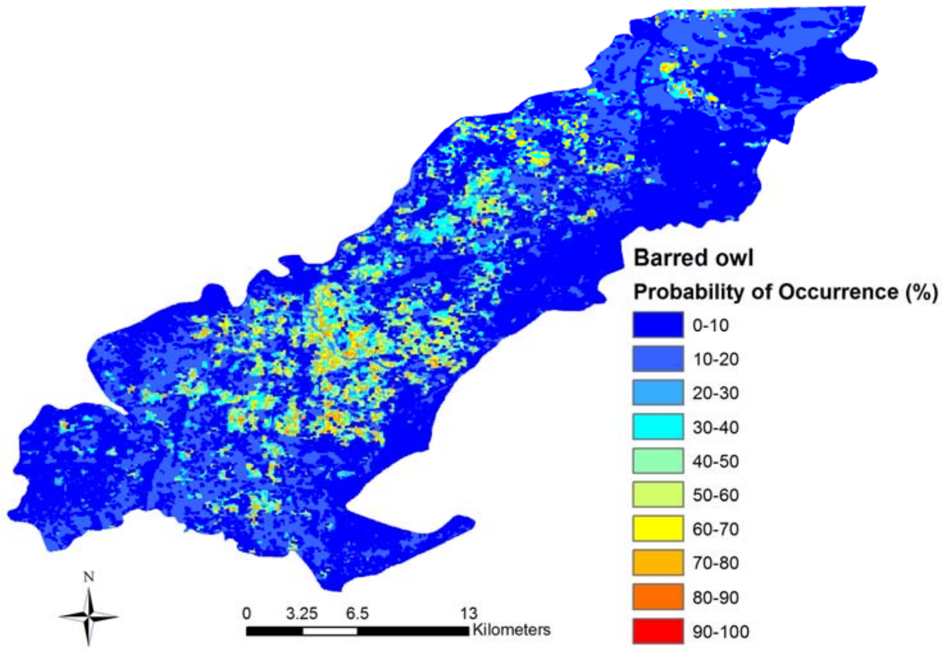


Figure 19: Ten percent probability of occurrence quantiles for the average model for barred owl within the Oak Openings Region of northwestern Ohio.

We modeled wood thrush using 13 testing points and 33 presence training points (Figure 20). For the average model (using 10 replicates) the test AUC was 0.8469 ± 0.0471 (SD) representing a strong model performance. We found that proportion of swamp forest had the greatest contribution (32.4%), followed by cohesion (connectivity index) (18.6%) and proportion of floodplain forest (12.1%) in the ecological neighborhood, Table 8. We examined the response curves and found that species presence increased with increasing proportion of swamp forest, greater connectivity and increasing proportion of floodplain forest.

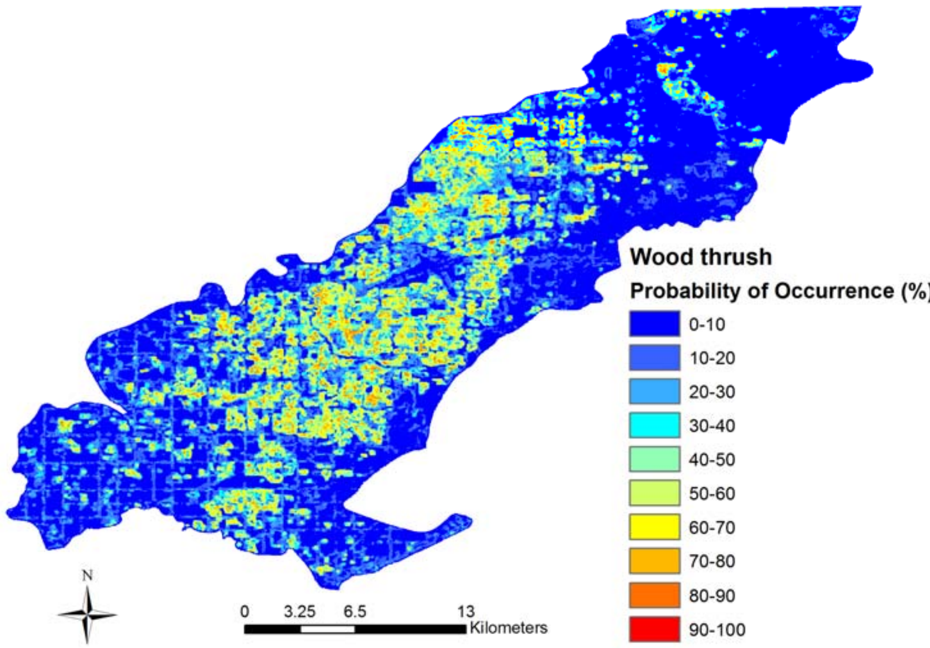


Figure 20: Ten percent probability of occurrence quantiles for the average model for wood thrush within the Oak Openings Region of northwestern Ohio.

The relative contribution of the explanatory variables differed among the three selected species with proportion of swamp forest having the greatest contibution (32.4%) for wood thrush. We modeled the three species as a whole to represent swamp forest (Figure 21) for which proportion of floodplain forest, swamp forest and upland deciduous forest in the ecological neighborhood contributed the greatest to the model (Table 8). Proportion of floodplain forest contributed the most to model development as supported by the jackknife measure.

We also illustrate the most suitable habitat in the top 10 (Priority 1) and 20% (Priority 2) in relation to the current protected areas in Figure 22. This map could be used to identify the highest quality areas that are in close proximity to or increase connectivity to current conservation areas. Based on these data there are, conservatively, 24.7 acres in Priority 1 and 303.8 acres in Priority 2 for swamp forest that are not currently in protected areas in Ohio.

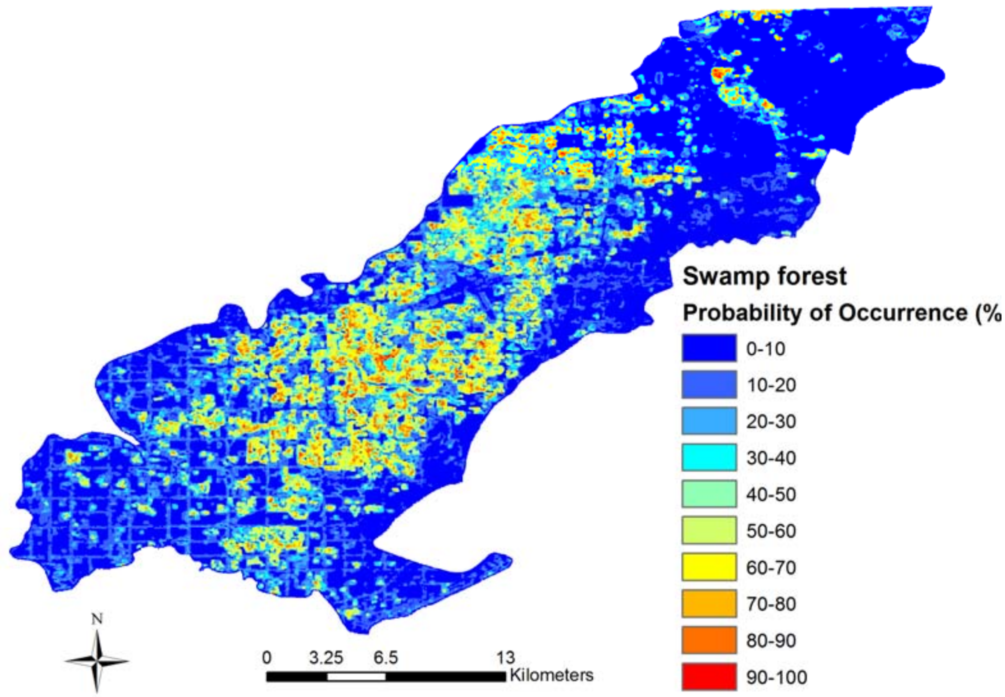


Figure 21: Ten percent probability of occurrence quantiles using the maximum test sensitivity plus specificity (MSS) threshold for swamp forest within the Oak Openings Region of northwestern Ohio.

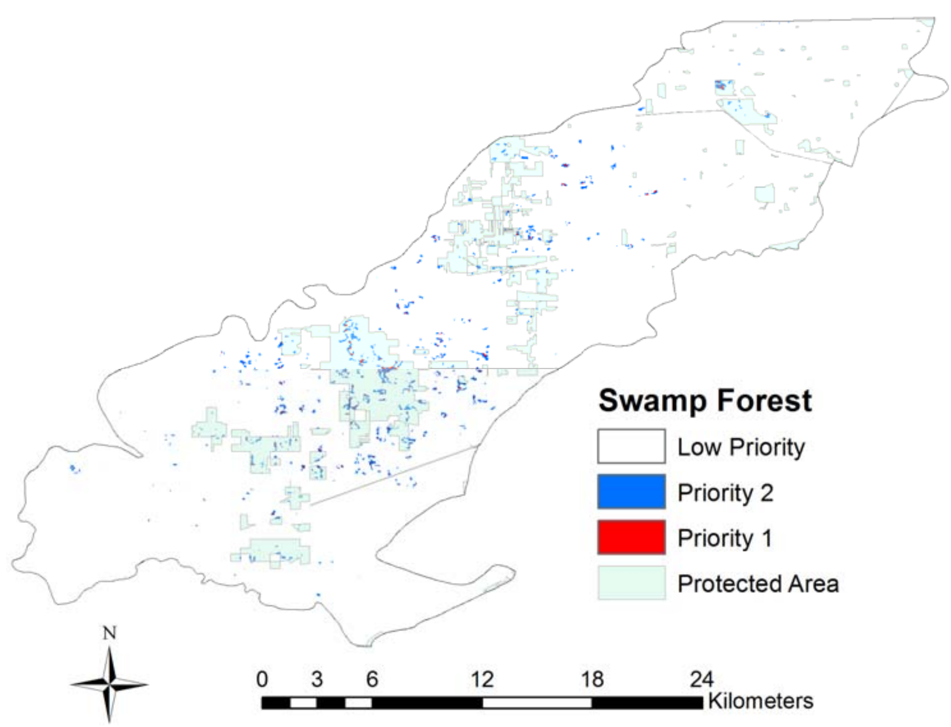


Figure 22. Protected areas and the top 10% (100-90%; Priority 1) and the second 10% (90-80%; Priority 2) of the suitable swamp forest within the Oak Openings Region of northwestern Ohio.

Table 8: Percent contribution (% Contrib) and permutation importance (Impt) of the explanatory variables to the average models of each selected swamp forest.

	Appalachian brown		Barred owl		Wood thrush		Swamp Forest	
Variable	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt
Anthropogenic	1	0.2	0.2	0.1	1.7	4	3.5	12
Cohesion	0.8	14.4	0	0	18.6	41.8	12	17.9
Floodplain forest	11.5	9.4	37.4	20.8	12.1	2.5	26	11.5
Soil type	28.6	34.3	16.3	27.8	9.6	9.7	10	19.4
Swamp forest	28.7	14.1	0.1	0.3	32.4	20.3	18.1	10
Deciduous forest	0	0	33	22.2	10.5	3.4	13.1	6.2
Upland prairie	15.3	18	0.7	0.1	2	2	0.9	1.6
Upland savanna	7.8	2.7	1.5	2	4.8	2.8	7.5	7.2
Wet prairie	6.2	6.9	10.8	26.8	8.6	13.5	8.9	14.1

We modeled the habitat suitability for the three indicator species to identify areas with the greatest swamp forest quality, indicated by areas with all three species overlapped with one another (Figure 23).

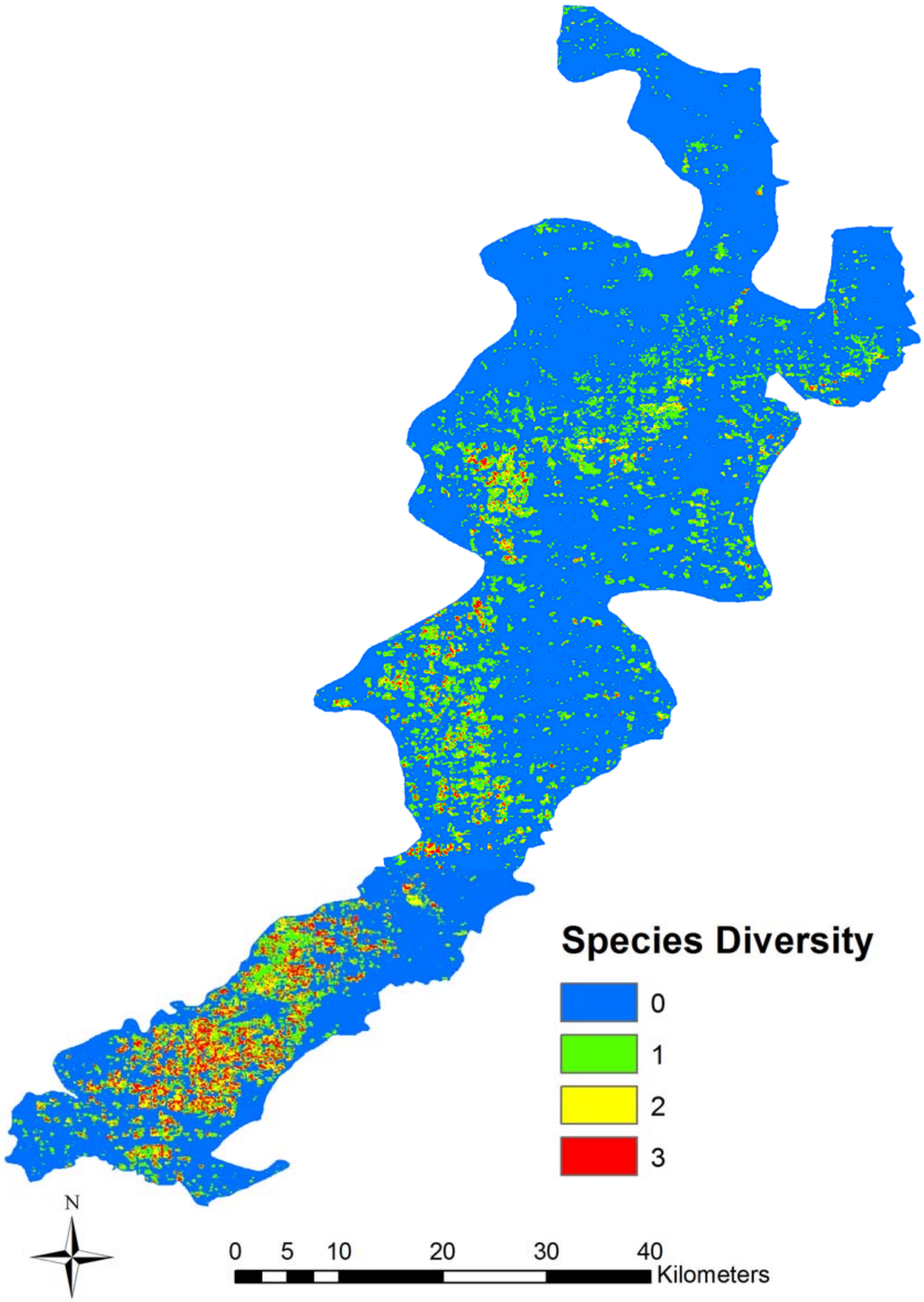


Figure 23: The habitat suitability for three indicator species of swamp forest within the Oak Openings Region of Ohio and Michigan. Each color shows the number of species that overlap with one another.

Upland Deciduous forest. We modeled red-backed salamander using 16 testing points and 39 presence training points (Figure 24). For the average model (using 10 replicates) the test AUC was 0.9749 ± 0.0081 (SD) representing a strong model performance. We found that proportion of upland deciduous forest had the greatest contribution (46.5%), followed by proportion of floodplain forest (18.7%) and soil type (14.6%), Table 9. We examined the response curves and found that species presence increased with increasing proportion of upland deciduous forest and proportion of floodplain forest in the ecological neighborhood and drier soils.

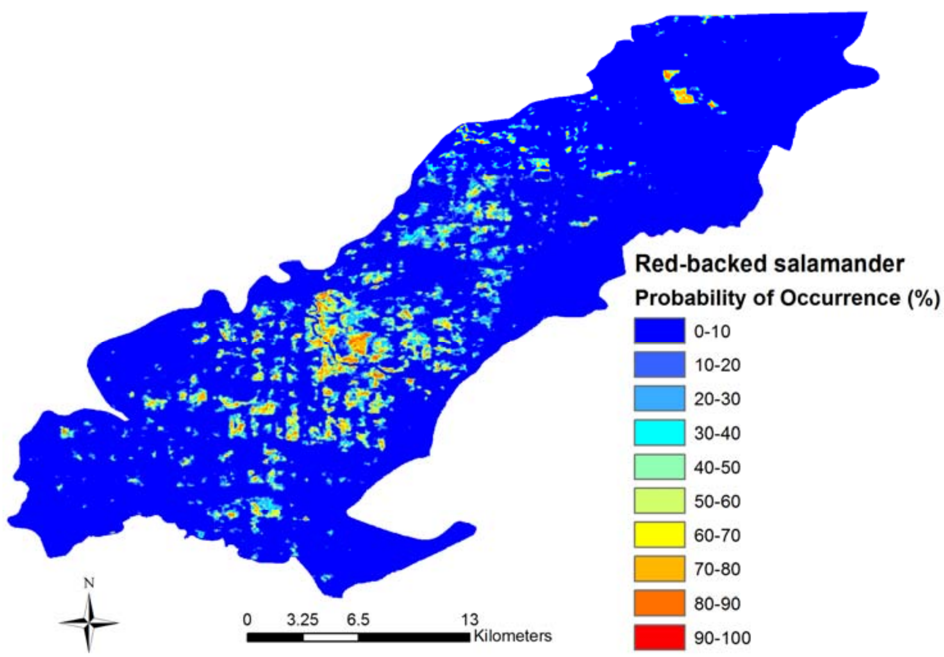


Figure 24: Ten percent probability of occurrence quantiles for the average model for red-backed salamander within the Oak Openings Region of northwestern Ohio.

We modeled northern long-eared bat using 7 testing points and 17 presence training points (Figure 25). For the average model (using 10 replicates) the test AUC was 0.9269 ± 0.0422 (SD) representing a strong model performance. We found that proportion of upland deciduous forest had the greatest contribution (38.6%), followed by proportion of floodplain forest (28.6%) and proportion of swamp forest (7.6%), Table 9. We examined the response curves and found that species presence increased with increasing proportions of deciduous forest and floodplain forest and at high proportions of swamp forest.

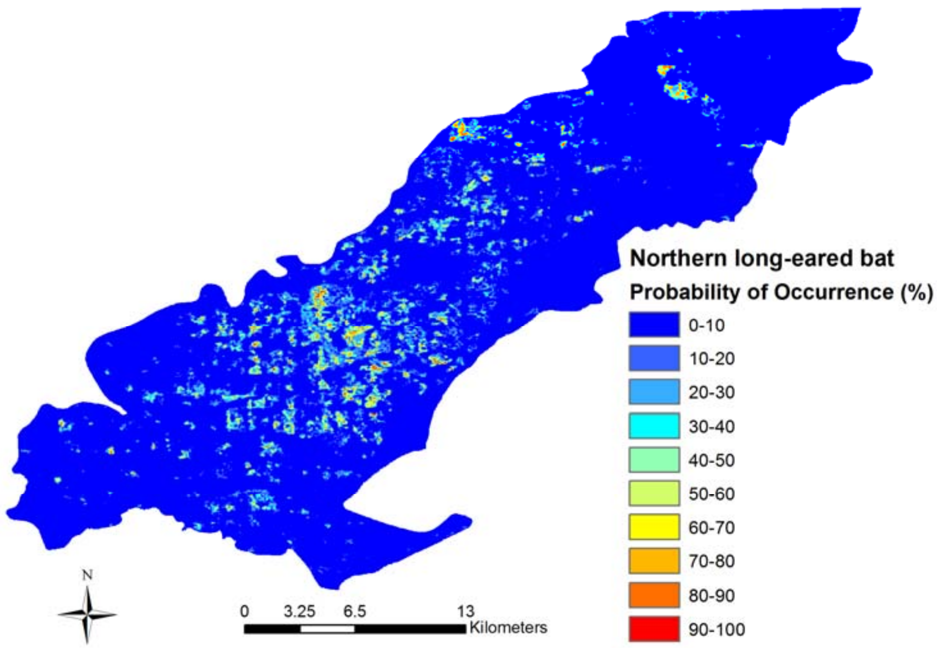


Figure 25: Ten percent probability of occurrence quantiles for the average model for northern long-eared bat within the Oak Openings Region of northwestern Ohio.

We modeled eastern red bat using 16 testing points and 39 presence training points (Figure 26). For the average model (using 10 replicates) the test AUC was 0.876 ± 0.0336 (SD) representing a strong model performance. We found that proportion of floodplain forest had the greatest contribution (27.2%), followed by soil type (25.2%) and cohesion (connectivity index; 24.3%) (Table 9). We examined the response curves and found that species presence increased with increasing proportion of floodplain forest, drier soils, and greater connectivity.

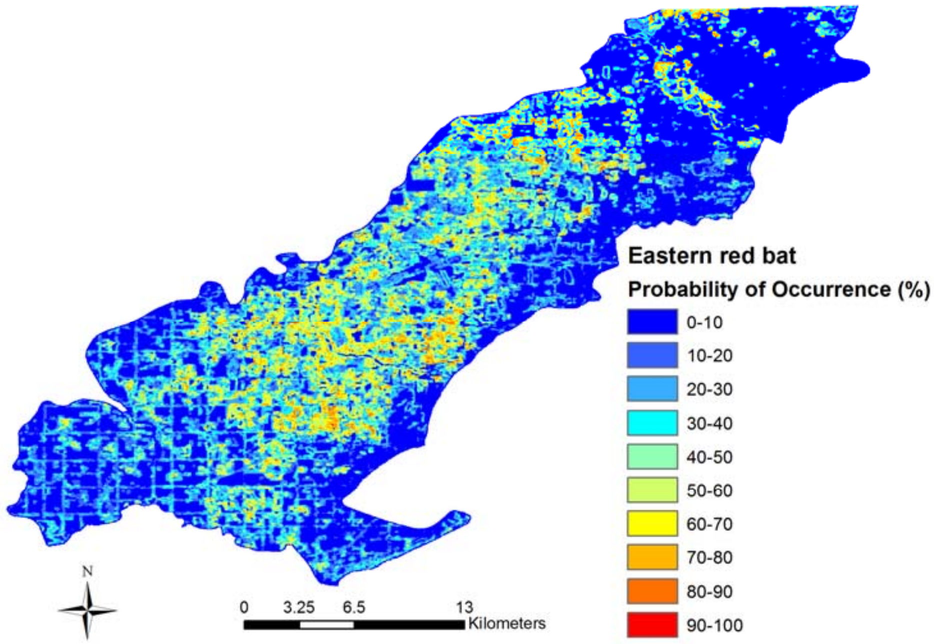


Figure 26: Ten percent probability of occurrence quantiles for the average model for eastern red bat within the Oak Openings Region of northwestern Ohio.

The relative contribution of the explanatory variables differed among the three selected species with proportion of upland deciduous forest having the greatest contibution (46.5%) for red-backed salamander. We modeled the three species as a whole to represent upland deciduous forest (Figure 27) for which proportion of floodplain forest, swamp forest and upland deciduous forest had the greatest contribution to the model (Table 9). Proportion of floodplain forest contributed the most to model development as supported by the jackknife measure.

We also illustrate the most suitable habitat in the top 10 (Priority 1) and 20% (Priority 2) in relation to the current protected areas in Figure 28. This map could be used to identify the highest quality areas that are in close proximity to or increase connectivity to current conservation areas. Based on these data there are, conservatively, 5.11 acres in Priority 1 and 129.9 acres in Priority 2 for upland deciduous forest that are not currently in protected areas in Ohio.

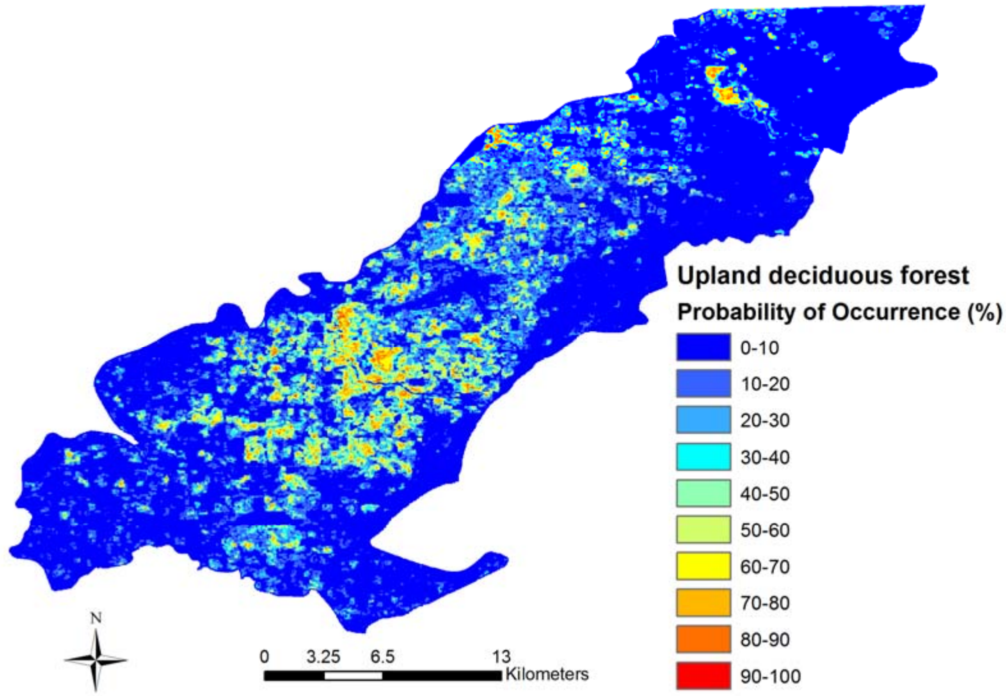


Figure 27: Ten percent probability of occurrence quantiles using the maximum test sensitivity plus specificity (MSS) threshold for upland deciduous forest within the Oak Openings Region of northwestern Ohio.

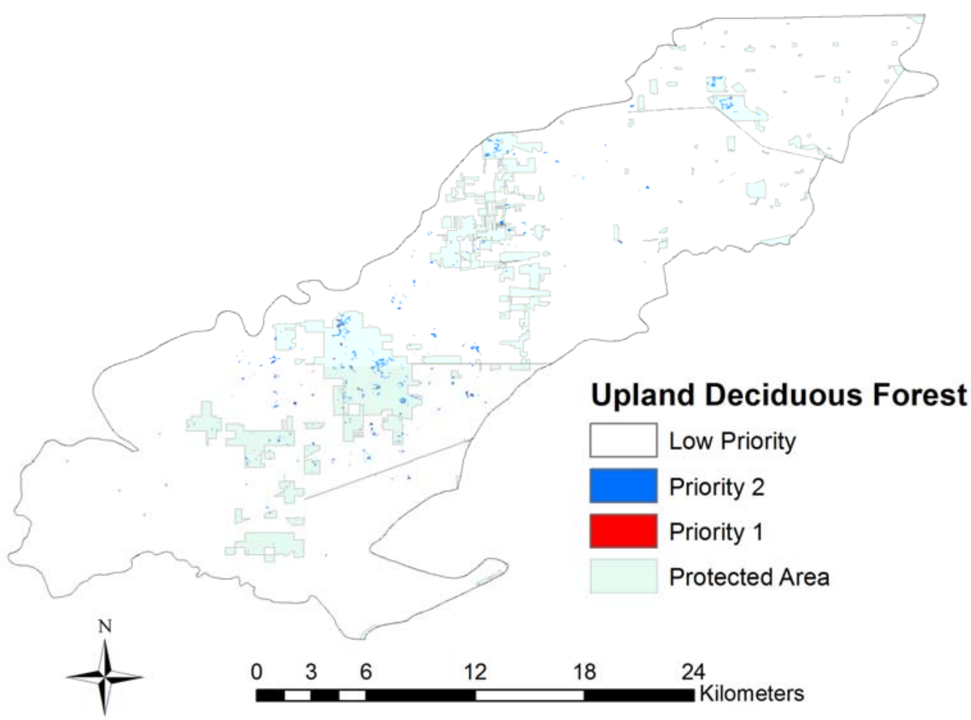


Figure 28. Protected areas and the top 10% (100-90%; Priority 1) and the second 10% (90-80%; Priority 2) of the suitable upland deciduous forest within the Oak Openings Region of northwestern Ohio.

Table 9. Percent contribution (% Contrib) and permutation importance (Impt) of the explanatory variables to the average models of each selected deciduous forest.

	Red-backed salamander		Northern long-eared bat		Eastern red bat		Deciduous Forest	
Variable	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt
Anthropogenic	6.2	23.2	3.2	2	8.8	8	1.8	6.3
Cohesion	0.2	1.5	5.2	18.1	24.3	27	3.8	4.5
Floodplain forest	18.7	7.9	28.6	15	27.2	8.7	24.6	11.7
Soil type	14.6	41	6.4	2.3	25.2	42.4	14.6	28.4
Swamp forest	10.7	5.3	7.6	10.4	1.8	1.4	5.8	6.1
Deciduous forest	46.5	18.2	38.6	33.9	4.9	4.9	40.1	27.7
Upland prairie	0.2	0.3	3.2	2	5.6	5.7	3.1	8
Upland savanna	0.6	0.3	3.4	0	1.4	1.5	3.3	3.6
Wet prairie	2.2	2.3	3.6	16.2	0.7	0.4	2.9	3.5

We modeled the habitat suitability for the three indicator species to identify areas with the greatest upland deciduous forest quality, indicated by areas with all three species overlapped with one another (Figure 29).

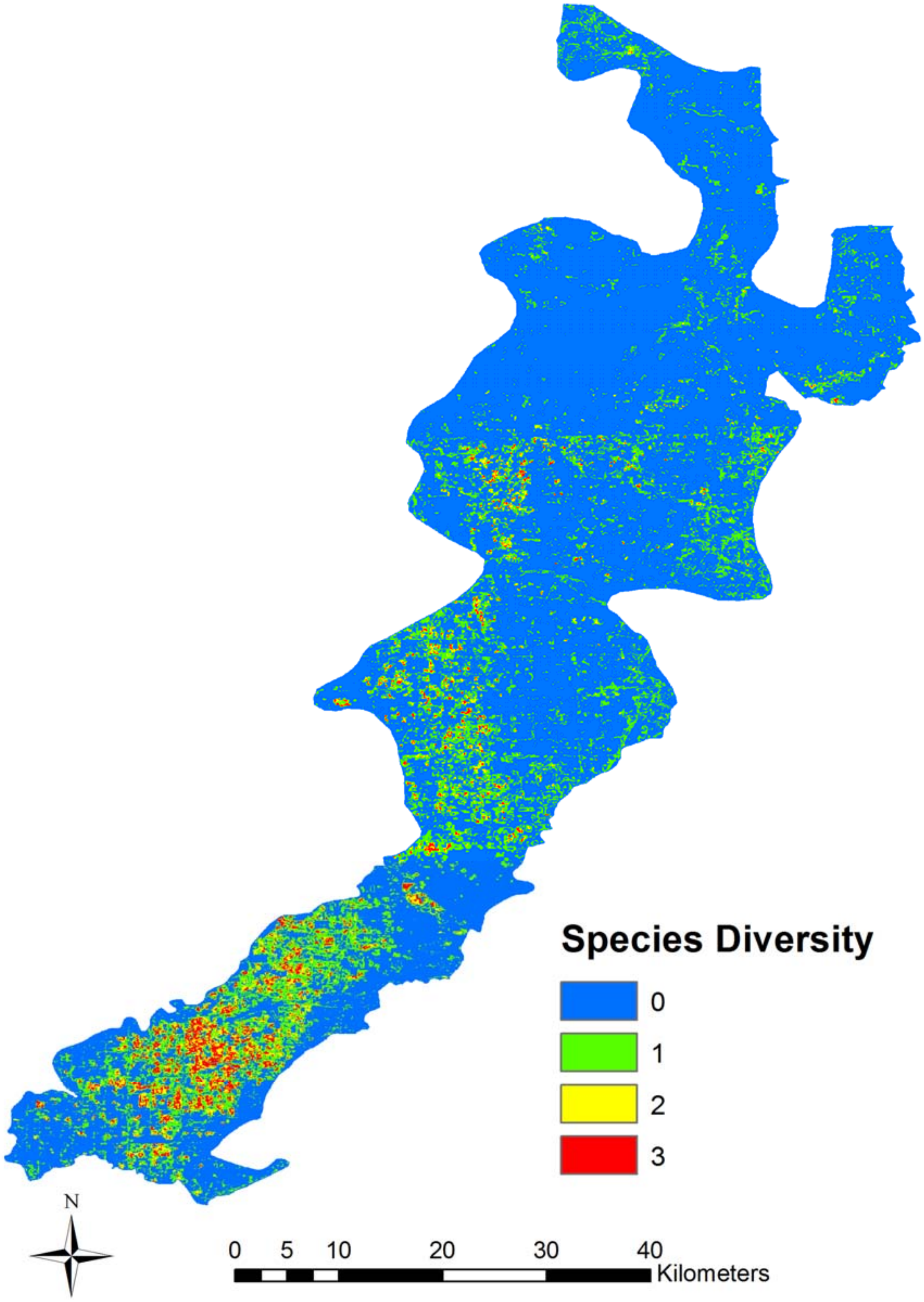


Figure 29: The habitat suitability for three indicator species of upland deciduous forest within the Oak Openings Region of Ohio and Michigan. Each color shows the number of species that overlap with one another.

Wet prairie. We modeled blazing star borer moth using 3 testing points and 8 presence training points (Figure 30). For the average model (using 10 replicates) the test AUC was 0.8147 ± 0.0795 (SD) representing a strong model performance. We found that proportion of upland prairie had the greatest contribution (40.9%), followed by proportion of wet prairie (25.7%) and proportion of anthropogenic (12.5%) (Table 10). We examined the response curves and found that species presence increased with increasing proportion of upland prairie and wet prairie and decreasing proportion of anthropogenic land cover.

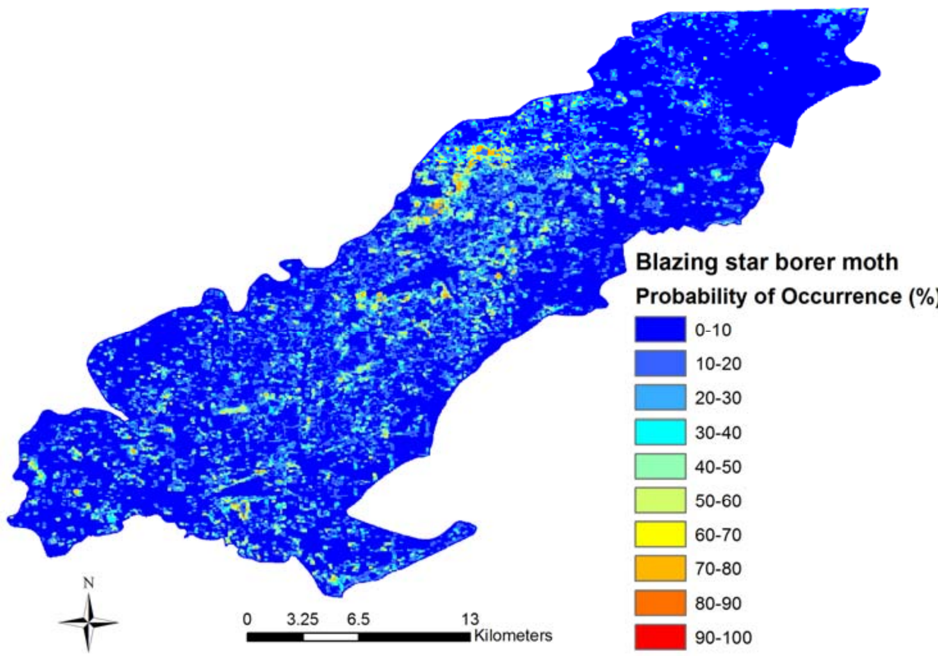


Figure 30: Ten percent probability of occurrence quantiles for the average model for blazing star borer moth within the Oak Openings Region of northwestern Ohio.

We modeled spotted turtle using 4 testing points and 10 presence training points (Figure 31). For the average model (using 10 replicates) the test AUC was 0.9743 ± 0.0173 (SD) representing a strong model performance. We found that proportion of wet prairie had the greatest contribution (48.7%), followed by soil type (14.6%) and proportion of anthropogenic (12%) (Table 10). We examined the response curves and found that species presence increases with decreasing proportion of wet prairie, drier soils and decreasing proportion of anthropogenic.

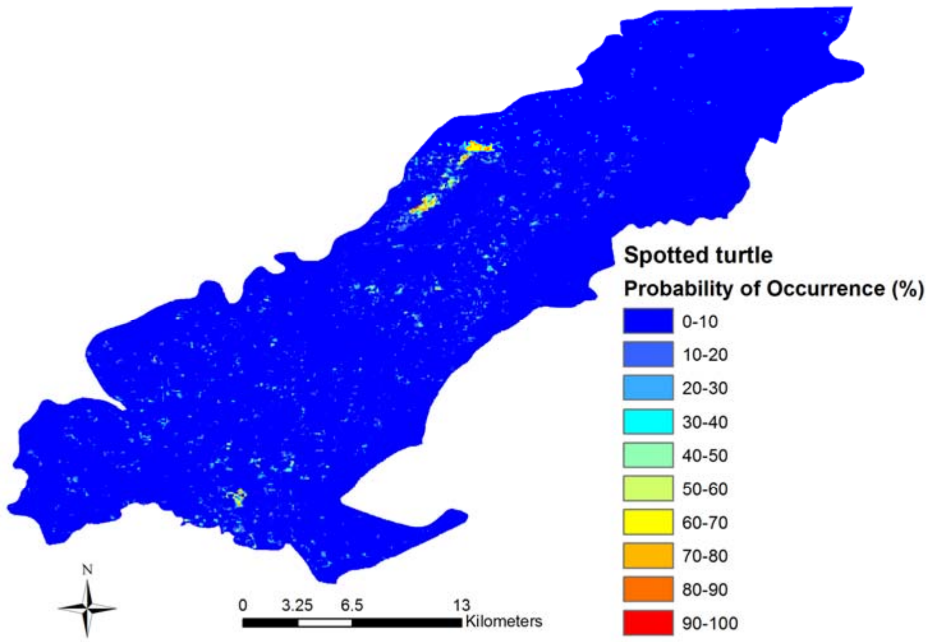


Figure 31: Ten percent probability of occurrence quantiles for the average model for spotted turtle within the Oak Openings Region of northwestern Ohio.

We modeled slender willow using 3 testing points and 8 presence training points (Figure 32). For the average model (using 10 replicates) the test AUC was 0.9583 ± 0.0251 (SD) representing a strong model performance. We found that proportion of wet prairie had the greatest contribution (33.4%), followed by proportion of anthropogenic (29.3%) and soil type (26.8%) (Table 10). We examined the response curves and found that species presence increased with increasing proportion of wet prairie, decreasing proportion of anthropogenic land cover and drier soils.

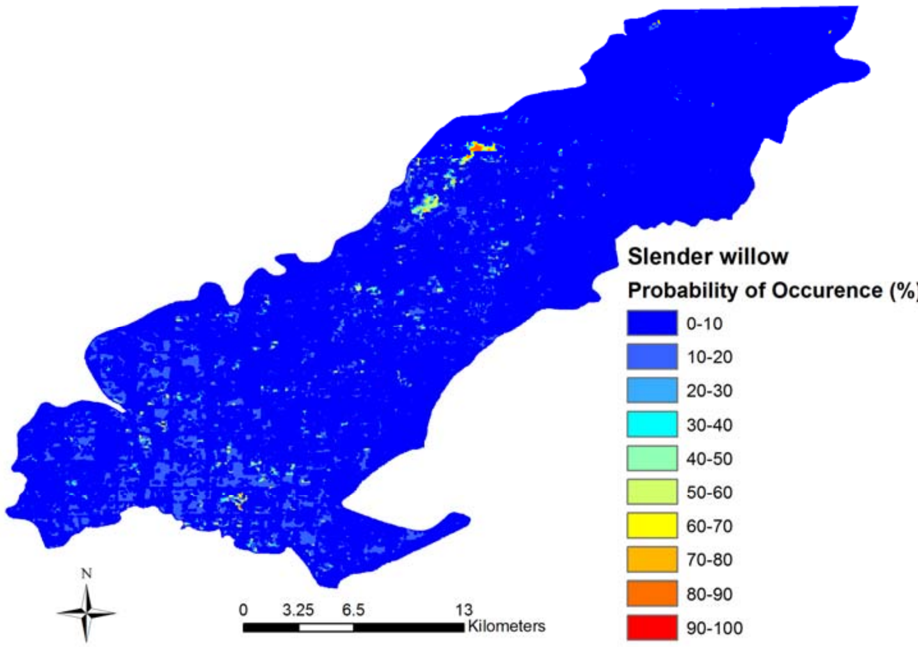


Figure 32: Ten percent probability of occurrence quantiles for the average model for slender willow within the Oak Openings Region of northwestern Ohio.

The relative contribution of the explanatory variables differed among the three selected species with proportion of wet prairie having the greatest contibution (48.7%) for spotted turtle. We modeled the three species as a whole to represent wet prairie (Figure 33) for which proportion of wet prairie, soil type and proportion of anthropogenic had the greatest contribution to the model (Table 10). Proportion of wet prairie contributed the most to model development as supported by the jackknife measure.

We also illustrate the most suitable habitat in the top 10 (Priority 1) and 20% (Priority 2) in relation to the current protected areas in Figure 34. This map could be used to identify the highest quality areas that are in close proximity to or increase connectivity to current conservation areas. Based on these data there are, conservatively, 1.1 acres in Priority 1 and 7.3 acres in Priority 2 for wet prairie that are not currently in protected areas in Ohio.

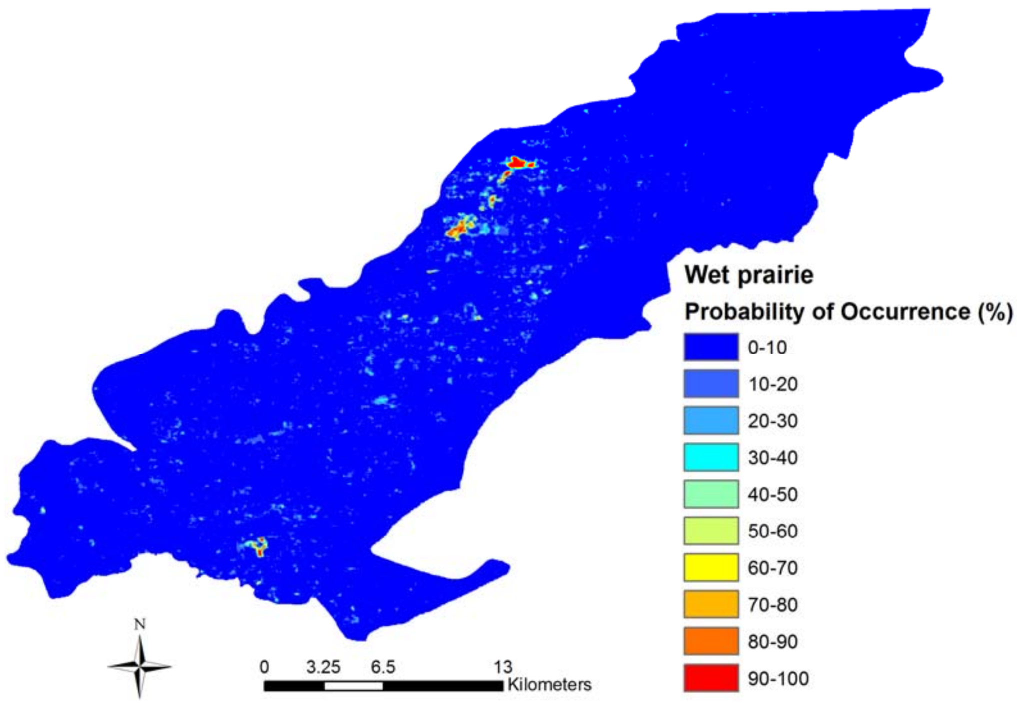


Figure 33: Ten percent probability of occurrence quantiles using the maximum test sensitivity plus specificity (MSS) threshold for wet praire within the Oak Openings Region of northwestern Ohio.

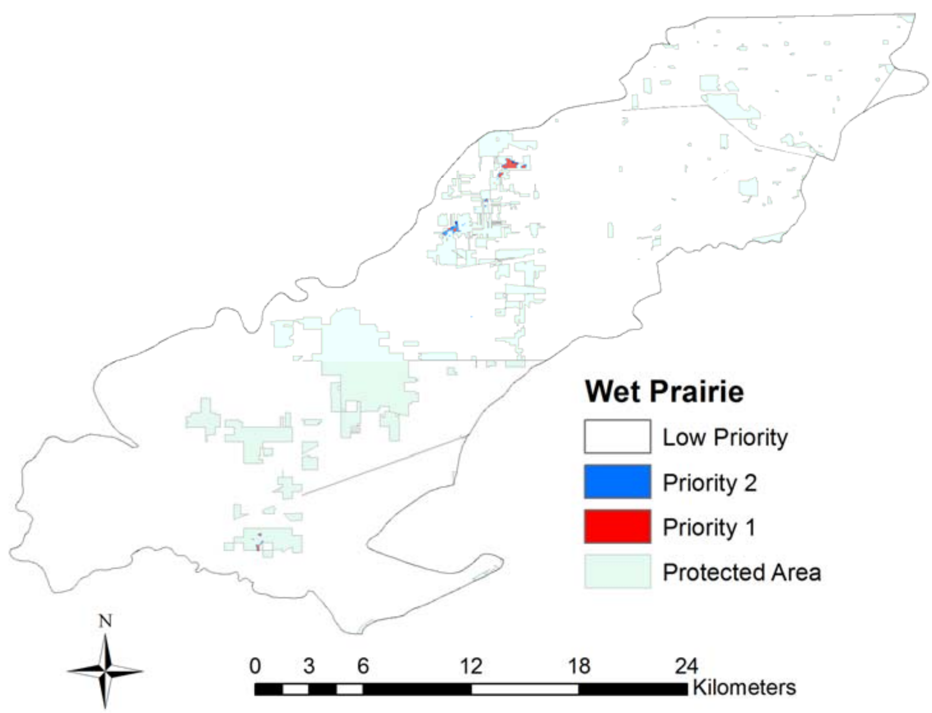


Figure 34. Protected areas and the top 10% (100-90%; Priority 1) and the second 10% (90-80%; Priority 2) of the suitable wet prairie within the Oak Openings Region of northwestern Ohio.

Table 10: Percent contribution (% Contrib) and permutation importance (Impt) of the explanatory variables to the average models of each selected wet prairie.

	Blazing star borer moth		Spotted turtle		Slender willow		Wet Prairie	
Variable	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt	% Contrib	Impt
Anthropogenic	12.5	7.4	12	11.4	29.3	30.1	8.1	23.1
Cohesion	2.2	4.6	1.8	0.5	2.3	0.1	0.9	3.5
Floodplain forest	2.2	0.9	6.2	0.4	3.3	0.1	0.6	3
Soil type	3.8	5.3	14.6	12.2	26.8	40.4	9.1	20.4
Swamp forest	2.7	0.6	9.3	2.5	0.3	0	6.2	1.6
Deciduous forest	5.3	1	5.7	9.6	1.7	0.2	0.4	0.3
Upland prairie	40.9	54.7	0.8	0.1	1.8	0	4.8	11.6
Upland savanna	4.8	6.7	0.8	0.1	1.1	0.1	2.5	2.5
Wet prairie	25.7	18.8	48.7	63.3	33.4	29	67.3	34.1

We modeled the habitat suitability for the three indicator species to identify areas with the greatest wet prairie habitat quality, indicated by areas with all three species overlapped with one another (Figure 35).

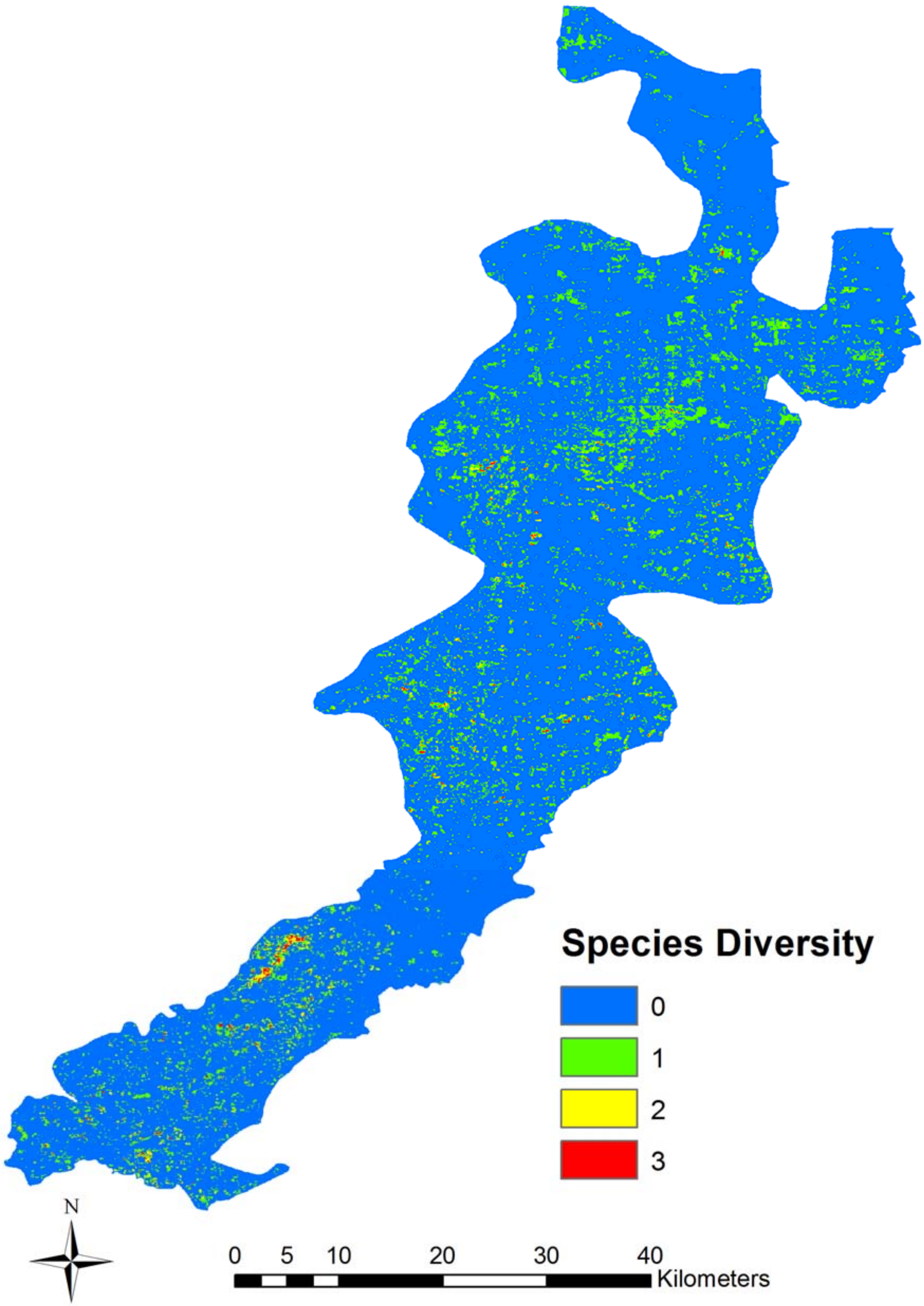


Figure 35: The habitat suitability for three indicator species of wet prairie within the Oak Openings Region of Ohio and Michigan. Each color shows the number of species that overlap with one another.

To further explore the species distribution models, we mapped all of the suitable habitat for all 15 species (Figure 36), and in just Ohio for 0-3 (Figure 37), 3-6 (Figure 38), 6-9 (Figure 39) and 9+ species (Figure 40). We found that there is high species overlap within northwestern Ohio and there are several distinct hotspots within southeastern Michigan (Figure 36). However, there is nowhere in the Oak Openings Region that all 15 species overlap. We found that in general, the fewer species that overlapped with one another occurred outside of protected areas within the Ohio portion of the Oak Openings. As the number of species overlap increases, the more likely they are confined to protected areas (Figures 37-40).

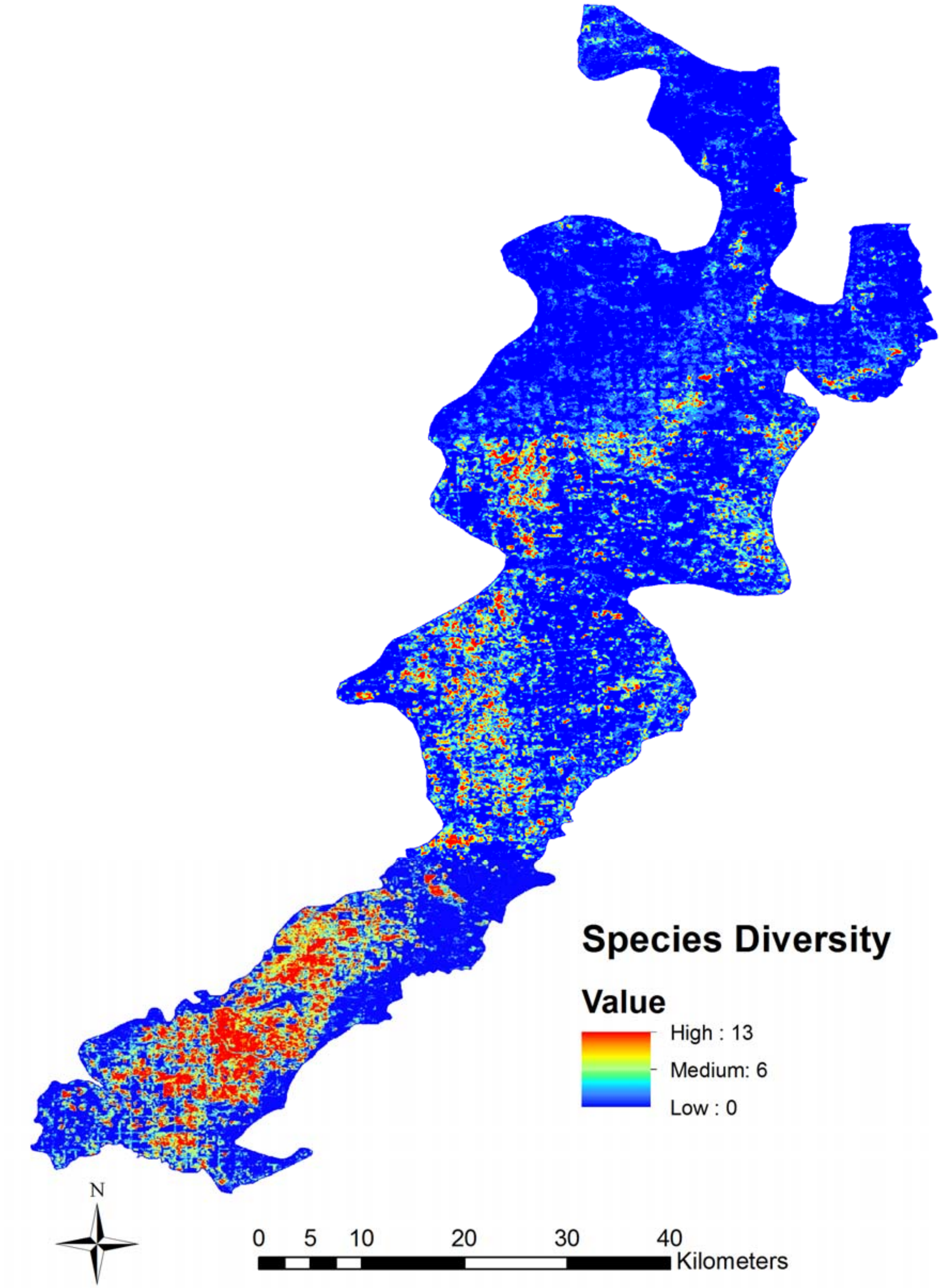


Figure 36. The suitable habitat for all 15 species of the Oak Openings Region of Ohio and Michigan. Each color shows the number of species that overlap.

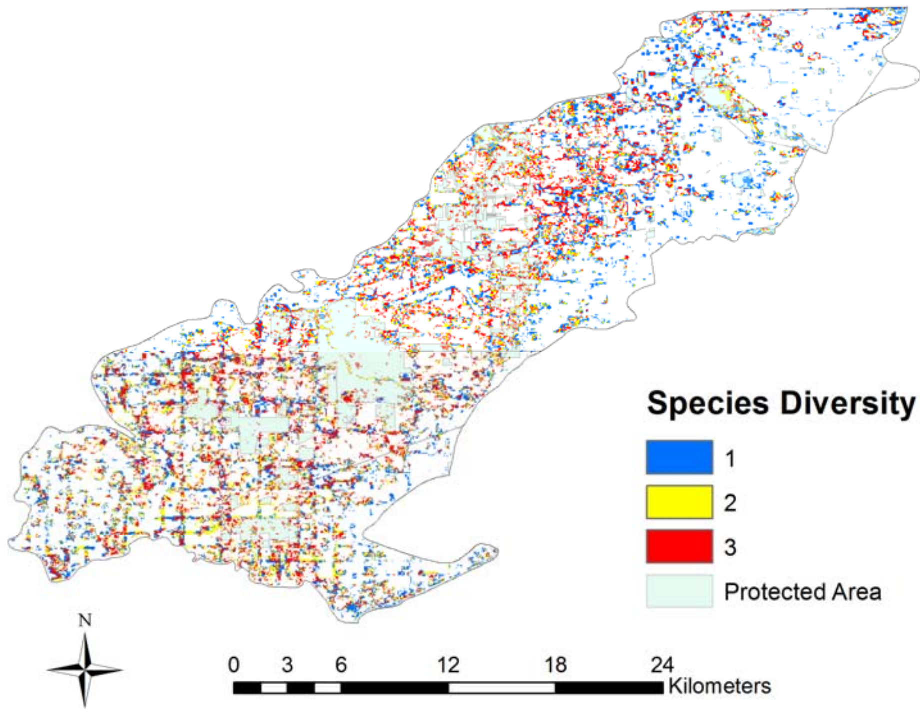


Figure 37. The suitable habitat for 1-3 species (out of 15) the Oak Openings Region of northwestern Ohio with protected areas. Each color shows the number of species that overlap.

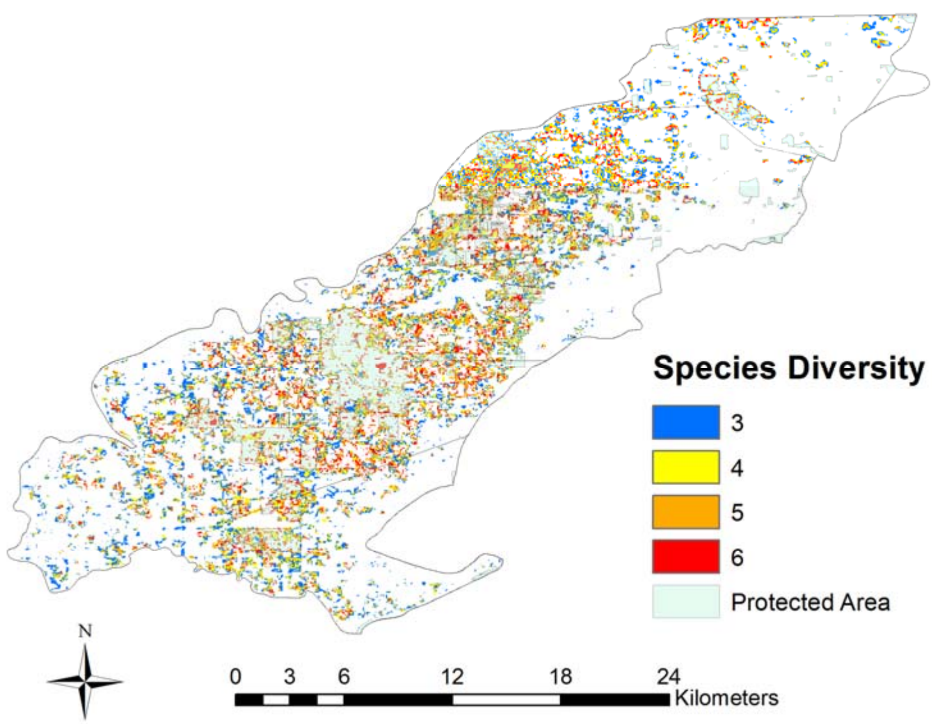


Figure 38. The suitable habitat for 3-6 species (out of 15) the Oak Openings Region of northwestern Ohio with protected areas. Each color shows the number of species that overlap.

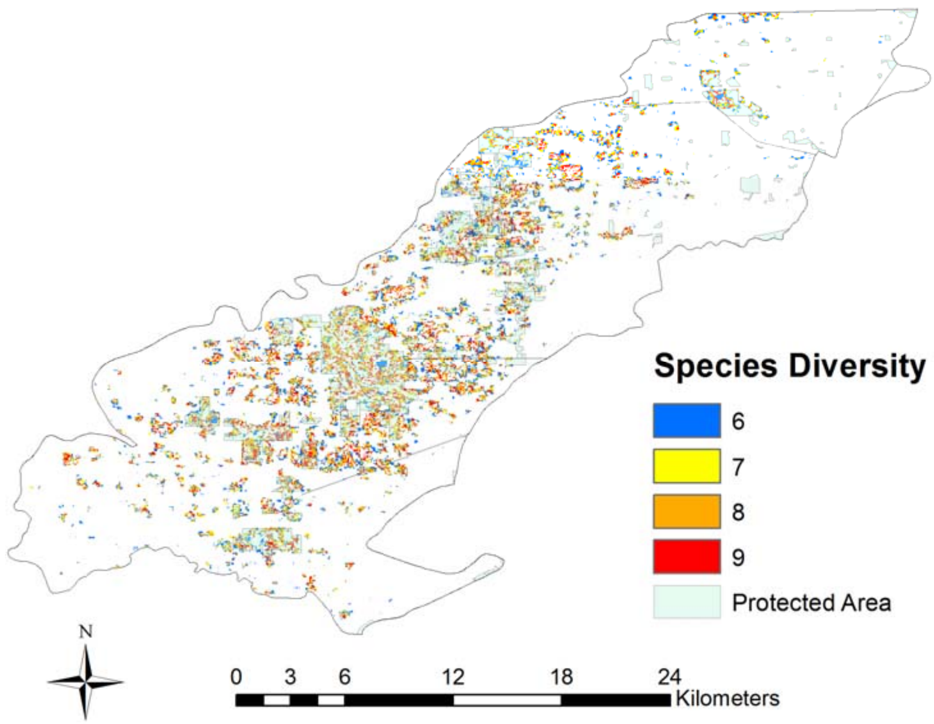


Figure 39. The suitable habitat for 6-9 species (out of 15) the Oak Openings Region of northwestern Ohio with protected areas. Each color shows the number of species that overlap.

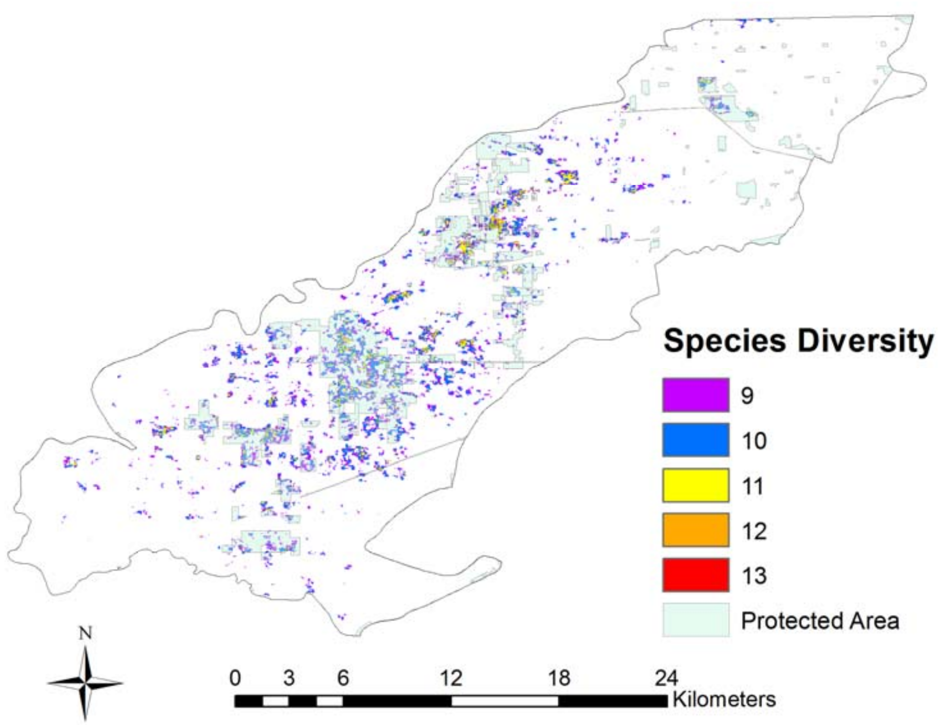


Figure 40. The suitable habitat for 9+ species (out of 15) the Oak Openings Region of northwestern Ohio with protected areas. Each color shows the number of species that overlap.

Discussion

Land Cover Map

We successfully refined the land cover map using additional training data and examined three variations of image classification. When analyzing the three final land cover classifications, we found that in the 33 band image (a direct comparison from our land cover map created in June for Phase I) specifically for upper Michigan, had changed from a predominately upland deciduous forest cover to upland prairie cover. This likely occurred as result of a greater number of training data for upland prairie. Land cover maps are highly influenced by the training data utilized and to improve accuracy more training data would be needed, especially for rare land cover types. We selected the 27 band image for further analysis and found that the training data performed well for Ohio and suggest that it could be helpful to further refine the map using more training data from Michigan for a greater number of land cover types. It is important to note, though, that changes in one area of the map could detrimentally affect the other portions of the map. Although our updated 15-class map had additional training data, the overall accuracy dropped to 71.2% from the previous 73.8%. A small drop was expected with the input of additional validation points; however the accuracy is still an improvement from the 60% accuracy of the original land cover map (Schetter & Root 2011). Although, our accuracy is highly acceptable, we suggest that there is always room for further ground validation to increase land cover types with less representation (e.g., turf/pasture, wet prairie, wet shrubland, floodplain forest, sand barrens, and Eurasian meadow).

The updated land cover map of the Oak Openings Region in northwestern Ohio has demonstrated large changes in land cover composition when compared to the original land cover map. Overall, human-modified land cover classes dropped from 73% to 67%, whereas natural/seminatural areas increased from 27% to 33% over the past ten years. The large increase in natural/seminatural areas is likely a result from the acquisition and restoration of early successional habitat undertaken by the Green Ribbon Initiative. The move to protect and restore early successional habitat has been successful, demonstrated by an increase in habitat cover by 11%, however some caution must be taken. An increase in early successional habitat means other habitat types must decrease. The updated land cover map has revealed declines in vacant (-7.6%) and forest/woodland (-5.4%) land cover. It is important to preserve a variety of natural habitats, including both forest/woodland and prairie/meadows, to maintain the biodiversity of the Oak Openings Region.

Habitat Modeling

The results of our occupancy models for these sets of species highlight some of the areas that are currently occupied or likely to be occupied by these species based on a common set of criteria. A major assumption is that the areas that are currently occupied are the most desirable for that species and would serve as reference points for other potential and/or restorable habitat. If the species is a specialist for a specific type of habitat (e.g., forest dweller), then these models can also provide insight into the location and quality of the overall habitat that would be applicable to other species that utilize these habitats. In addition, by using the same modeling approach across species and ecosystems, we can increase our understanding of biodiversity patterns and better guide management, restoration and conservation. Multiple focal species are very advantageous in conservation planning as they can help identify a variety of habitats and critical characteristics required by most other species (Silvano et al. 2017).

We found that general occurrence data may be scarce or difficult to obtain for certain species. It is more favorable to model threatened or endangered species to gain greater conservation knowledge, however the occurrence data is highly protected or unknown. In addition to traditional survey approaches, new methods such as citizen science or crowd-sourced science (e.g., zooniverse) may help increase the amount of occurrence data available across broad spatial and temporal scales. We were able to obtain a minimum of 10 occurrence observations for each selected species, however for the species with 10 occurrence records only part of the data was used for each replicated to hold back some for testing ($x = 3$). In general the models might be improved by increasing the minimum number of occurrence records to 15-20. However, Maxent has been shown to work extraordinarily well with small sample sizes (Hernandez et al. 2006; Pearson et al. 2007; Kumar & Stohlgren 2009), which is consistent with our study. Although for some species, we worked with small datasets, our models had strong performances (AUC >0.80). This suggests that our models are good representations of the selected species.

Overall, we found that many of the selected species in general are good representatives of their target ecosystem (with the clear exception for swamp and floodplain forest), although some species did not predominantly favor (>50%) the selected ecosystem (e.g., barred owl, giant swallowtail, eastern red bat) once we applied spatial filtering to reduce autocorrelation. It is likely that this is a result of the organisms moving around and using different habitat types than expected. In other words, operating in an ecological neighborhood (e.g., Addicott et al. 1987; Holland and Yang 2016). Therefore species will have complex scale-dependent responses within human modified landscapes because their responses are shaped by resources or interactions from multiple land cover types (Ewers & Didham 2006).

For an example, the bat data was collected using acoustic monitoring and it is highly likely that foraging activity was recorded rather than roosting activity. Eastern red bats are well documented to using upland deciduous forest when roosting (Mager & Nelson 2001; Whitaker 1996), however during foraging it appears that they may be utilizing the floodplain forests for which there are likely more insects to eat as shown by Hutchinson & Lacki's (2000) study where red bats forage over water in mixed mesophytic forests. Similarly, barred owl utilize hydric woodlands and floodplains in the Oak Openings that may provide additional or unique resources for barred owls in comparison to current swamp forests. On the other hand, the distribution models clearly delineate a variety of habitat that these species use and can be readily incorporated in to conservation focused on high quality habitat for species independent of the ecosystem type. How species respond to patch and landscape variables can be quite complex and the influence of variables operating at the local scale may be very relevant for patchy landscapes, in particular (Thornton et al. 2011). Heterogeneity, therefore, does foster a diversity of species and may help bolster the populations of species that are occupying highly fragmented landscapes that may also have a degree of degradation in the natural ecosystems.

While all of the models met the independent criteria (e.g., AUC) for strong models, they did not always match our expectations for a focal ecosystem based on the land cover map. The models for upland savanna/prairie, upland deciduous forest and wet prairie were closest to what would be expected, while the models for floodplain forest and swamp forest were not. There are a number of explanations for this and some ways these models can be improved. One, the spatial filtering and data reduction can reduce spatial autocorrelation but also may unintentionally bias the distribution of the occurrence points utilized for modeling. Alternatively, subsampling could take a stratified approach that preserves more of the underlying pattern rather than using a random moving window, or we could use a smaller window. A smaller subsampling buffer would be particularly useful to look at smaller scale patterns and examine priorities with a finer grain that more closely matches management and conservation actions. Two, some species might be better candidates for mapping on our current land cover classification than others because they may be more specialized in their habitat use, easier to monitor and track, or have more specific interest. Models can be developed with and without different sets of species and the output can be compared to provide a sensitivity analysis or to further refine the specificity desired. Three, larger datasets spread across the region would also improve all aspects of the modeling. While MaxEnt works well with small sample sizes in general (Hernandez et al., 2006) and our models were robust, we only had a final set of 10-15 occurrence points for some of the species.

As expected, we found that each variable contributed differently per species, even among the same target ecosystem. One of the variables that contributed the most among all of the species was soil type, which is a driving force for determining the land cover types. Surprisingly, when soil was important, it appears that most species favor drier soils, even spotted turtles, a wet prairie species. It is likely a result of organisms moving around within their environment. As expected, proportion of anthropogenic land cover has a negative influence on species presence. With many of the protected areas surrounded by anthropogenic features, it would be beneficial to focus on increasing patch size to buffer the impacts of anthropogenic factors. Therefore the surrounding matrix often has large influences on populations and communities often much more than processes within remnant focal patches (Wien 1995) while many species responses are often scale dependent (Turner et al. 2001). Finally, cohesion which is a connectivity index showed that greater connectivity is correlated with species presence. By increasing the connectedness among protected areas will likely facilitate species presence.

These species distribution models also provide an excellent means for prioritizing high quality habitat that is not currently protected. We can identify areas that foster greater diversity of species either within an ecosystem or across the landscape. The approach is very flexible and can be applied in a variety of ways by using different thresholds (e.g., suitable versus unsuitable or top 10%) or different sets of species. Future modeling could examine additional metrics to further refine the habitat selection such as the proximity to other patches or minimum size of a patch.

Conclusions

Overall, the land cover map is an important tool for making large scale spatial and temporal comparisons across the Oak Openings. We have documented notable changes in the natural ecosystems and highlighted gaps in the current protected network. The complementary species distribution models help in refining the view of the landscape towards one of ecological function rather than strict classification. These species models are interesting and demonstrate the value of the Maxent approach. Not only can we identify areas that are currently occupied but those that should be occupied based on similar characteristics. All of the models were rated as good or excellent, which is very promising given the limited scope of some of these datasets. The Maxent approach appears to be especially useful for species that have not been extensively surveyed across the Oak Openings Region. Caution, of course, is warranted in interpreting these maps as they extrapolate based on the sample of occupancy data utilized. To enhance the value of this approach to local conservation and management, we would recommend exploration of smaller subsampling windows to provide a finer grain perspective, further investigating the data sets and other species to increase the power of the species distribution modeling, and additional data analysis that may incorporate additional elements such as patch size.

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Appendix 1: Guide to Using these Models

Key things to remember about models: they are a simplified version of reality; they should be tested and refined as additional data is gathered; and they can be applied to a variety of conservation and management issues. The models developed in this project can be used in a variety of ways, including the four described in this guide. For simplicity, the examples will be limited to the Ohio portion of the Oak Openings Region. This guide is intended to provide a starting point for analysis of these modeling results.

(1) Exploring the land cover

Identifying the types of ecosystems that are on a landscape is a critical first step to conservation and management of any region. The land cover map can be used to identify where specific ecosystems occur or where they previously occurred (by comparing with the previous land cover map). You can also use these maps to examine larger scale patterns. It is important to note, though, that any supervised land cover map should be verified and refined as new data become available and is highly influenced by the training data used in classification.

For example, a quick analysis indicates that the Oak Openings Region of Ohio is dominated by anthropogenic use (67%) but that the amount of natural/seminatural land has increased (27.2 to 33%) since Schetter and Root 2011. The natural/seminatural land is dominated by prairies and meadows (16%) and forest and woodland (15%) but has little remaining savannas (2%) or shrublands (<0.1%). These numbers represent increases in savannas (from 0.8% to 2%) and prairies and meadows (5.1 to 16%). This is heartening and likely reflects the conservation efforts of the Green Ribbon Initiative.

While composition of the landscape matters, it is also important to consider configuration. These data can be further analyzed to estimate the average patch size, level of fragmentation, degree of connectivity, etc. The Oak Openings is clearly a very fragmented landscape. The largest patches occur in the residential/mixed use land cover while the smallest patches are of shrubland (Table A1). Patches of land cover types such as turf/pasture, dense urban, and shrubland are more likely to be in close proximity whereas the natural land cover types are likely to be intermixed with one another in a mosaic (see Interspersion and juxtaposition Index in Table A1). The Interspersion and Juxtaposition Index (IJI) estimates the likelihood that adjacent patches are of the same type and increases as the diversity in neighbors increases.

Table A1. Patch characteristics for the Ohio portion of the Oak Openings region estimated in Fragstats. Listed are the mean patch size in hectares, the interspersion and juxtaposition index (i.e., a measure of tendency of like patches to occur in close proximity), and the connectance index (i.e., a measure of the connectivity among like patches). The area within protected areas of each land cover is shown as % of total and as total hectares. The focal land cover types are highlighted in bold.

	Mean Patch Size (ha)	Interspersion and Juxtaposition Index	Connectance Index	Within Protected Areas (%)
Prairie	**0.4422**	**80.2176**	**0.0064**	**0.0**
Floodplain Forest	**0.4790**	**70.0122**	**0.0152**	**29.2**
Savanna	**0.4007**	**66.8224**	**0.0153**	**3.1**
Swamp Forest	**1.4396**	**71.9156**	**0.0206**	**1.9**
Mixed Use	6.1796	78.5235	0.0240	5.9
Barrens	0.3653	77.1446	0.0061	38.2
Deciduous Forest	**1.1438**	**63.5172**	**0.0201**	**33.9**
Eurasian Meadow	0.3868	53.8509	0.0072	35.7
Wet Prairie	**0.2927**	**76.7130**	**0.0089**	**80.2**
Crops	14.7270	61.8162	0.0551	48.7
Conifers	1.2123	56.2752	0.0718	41.1
Urban	0.9444	28.4323	0.0176	13.3
Ponds	1.2784	54.5380	0.0349	5.6
Wet Shrubland	0.3600	47.8614	0	25.7
Pasture	0.5585	9.5573	0.9219	1.3

Overall, there is very little connectivity among similar patches except for turf/pasture (see Connectance Index in Table A1). The Connectance index estimates the number of connections among patches of similar types. This fragmentation is readily visible when the land cover map is simplified to highlight similar successional stages as in Figure A1. We can also look at heterogeneity by estimating the number of land cover types (out of 15) that occur within a 120 m x 120 m neighborhood across the landscape, Figure A2. More than 26% of the landscape has neighborhoods with at least 4 different land cover types in close proximity.

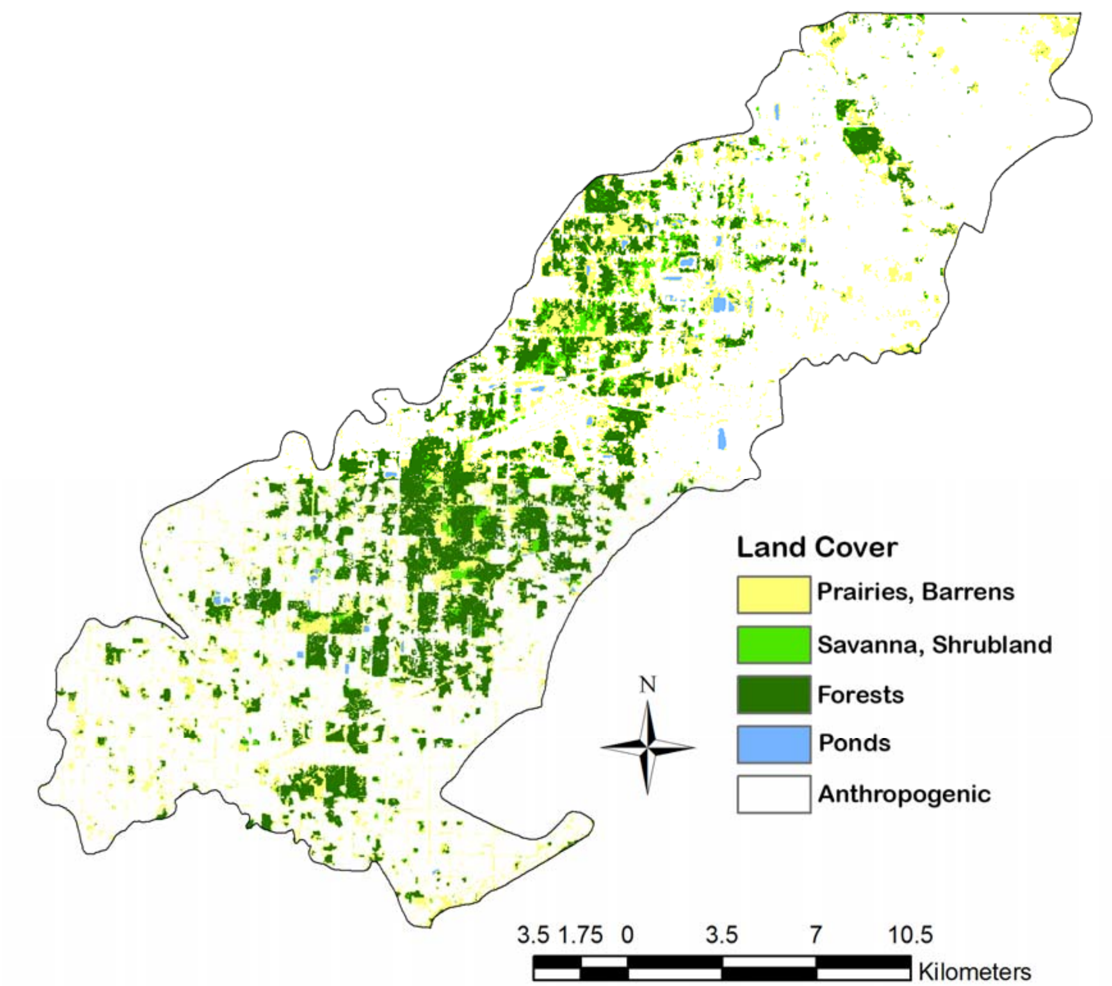

Figure A1. Simplified land cover map for the Ohio portion of the Oak Openings Region. Prairies, barrens includes wet prairie, upland prairie, and sand barrens. Savanna, shrubland includes upland savanna and wet shrubland. Forests include swamp, upland coniferous, upland deciduous and floodplain. Anthropogenic includes turf/pasture, residential/mixed, dense urban, Eurasian meadow and cropland.

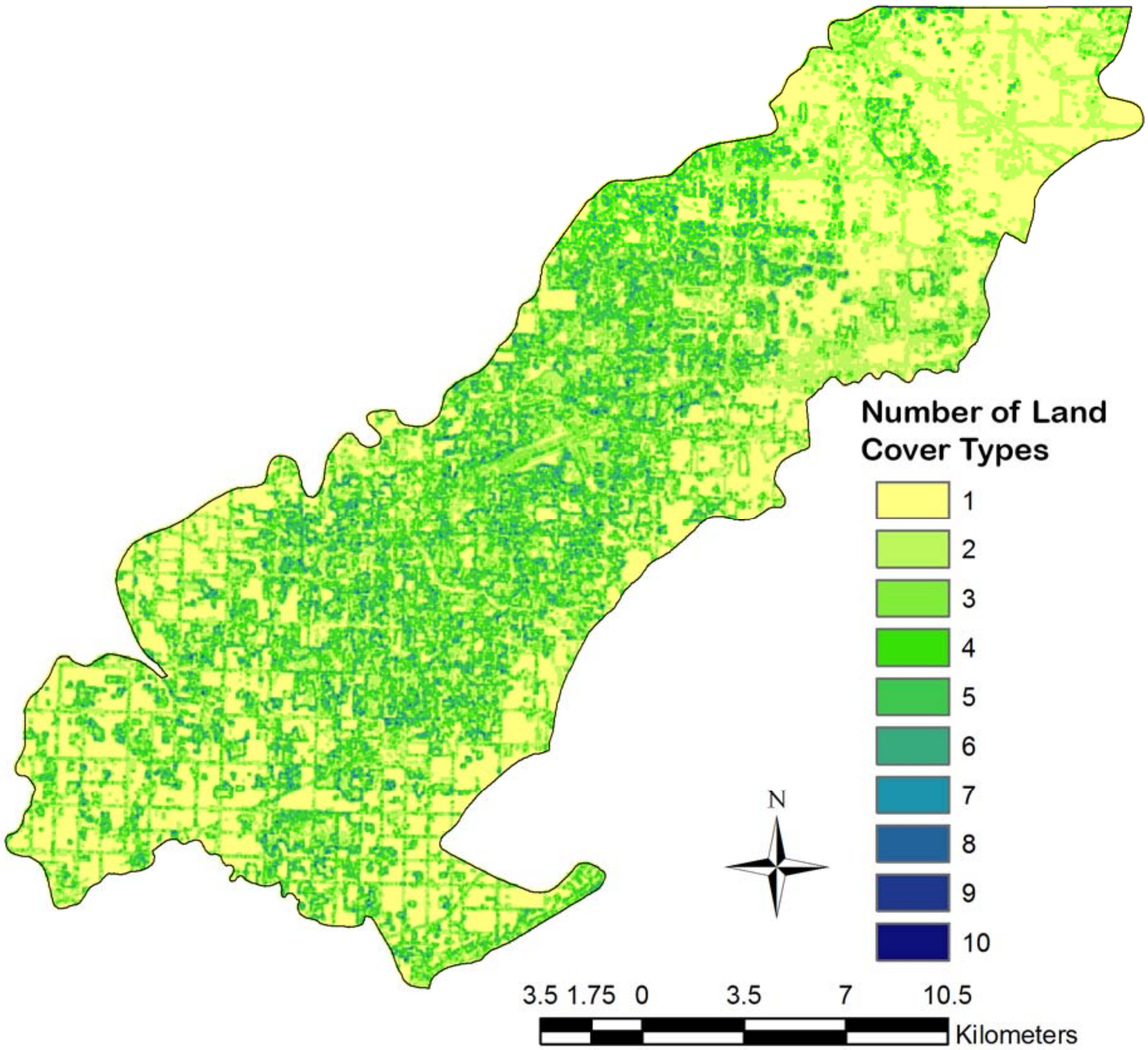

Figure A2. An estimate of the heterogeneity in the Ohio portion of the Oak Openings as the number of different land cover types (out of 15) that are within a neighborhood of 120 m x 120 m. 1 represents a neighborhood of all of the same type of land cover, whereas 10 represents the same size neighborhood with 10 different land cover types.

(2) Examining the five focal ecosystems

In addition to examining the land cover map, we can utilize species distribution models to explore aspects of the current distribution of focal ecosystems (i.e., upland savanna/prairie, upland deciduous forest, floodplain forest, swamp forest and wet prairie). The species distribution models we have developed for this project represent how habitat is used by species specifically within the Oak Openings Region. It is important to note that the literature often suggests a particular species "prefers" one type of habitat (e.g., box turtles are a forest-dependent species). This conclusion should be viewed with caution and there are often differences in the general pattern within a species range based on the availability of ecosystems, accessibility and detectability (e.g., Thornton et al. 2011). These patterns can also differ based on the characteristics of the individuals (e.g., age, size, life history stage) or its fellow inhabitants (e.g., competitors, predators). These species models should not be treated as realistic detailed models of an individual species' habitat preferences. Instead, the models can be used to compare across taxa and ecosystems more generally and for larger scale patterns of occupancy. The habitats highlighted by the models are utilized by the species and represent ecologically functional habitat.

The value of these models is that we can examine currently utilized habitats and the factors that make these functional. Since these models are based on a limited set of survey data, the resulting map predicts where else we might find these species based on these characteristics extrapolated across the landscape. We can demonstrate this by looking at wet prairie. In Figure A3, the land cover map highlighting wet prairie is shown zoomed to the area northwest of Oak Openings Preserve. The area delineated is listed in Table A2.

Table A2. Wet prairie habitat for the Ohio portion of the Oak Openings region as defined by the land cover map, or as habitat suitable for 1, 2 or 3 wet prairie species. Total area in hectares and the percent of the habitat that occurs within protected areas are listed.

	Total Area (ha)	**Protected (%)**
Land Cover Map	721.89	29.2
3 Species Model	322.56	18.2
2 Species Model	789.03	8.6
1 Species Model	3664.17	10.9

In comparison, Figure A4, illustrates what functions as wet prairie from the perspective of the blazing star borer moth, slender willow, and spotted turtle, where the values represent what is suitable habitat for 0, 1, 2 or all 3 of the species. As illustrated, the area that is indicated by the species distribution models is greater and includes areas that may not have been classified as wet prairie. These areas however have attributes (e.g., resources) that are important to the species that occupy wet prairies and provide a more inclusive, functional view of what is needed to support these species. Table A2 lists the amount of habitat that is classified as high quality habitat for 1, 2, or 3 of the wet prairie species. Much of the high quality habitat is not protected; 18.2% of the habitat for the set of 3 falls within current protected areas, while 29.2% of the wet prairie from the land cover is.

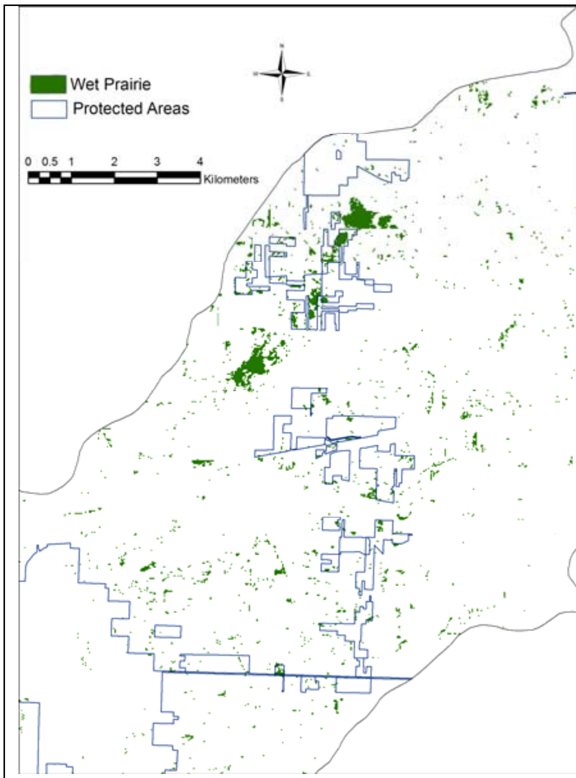

Figure A3. Wet prairie habitat based on the land cover map for a selected portion of the Oak Openings Region with Oak Openings Preserve in the southwest corner of the map. Current protected area boundaries out outlined for reference.

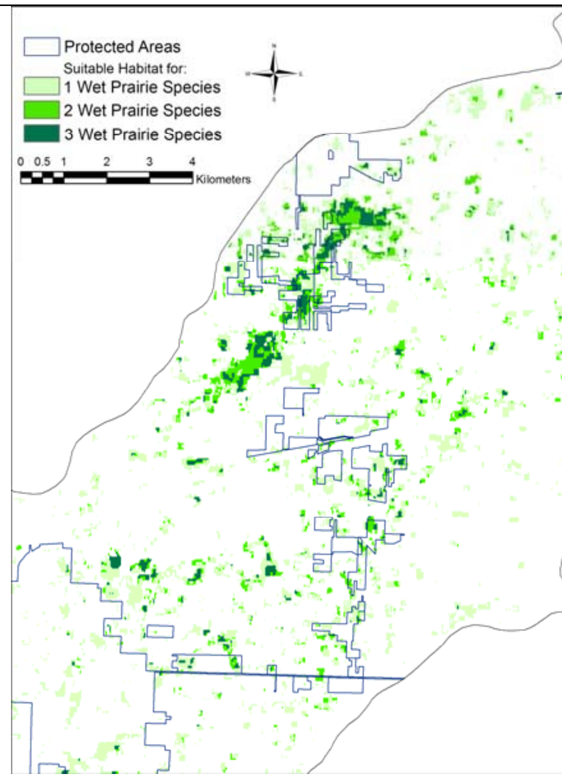

Figure A4. Wet prairie habitat for a selected portion of the Oak Openings Region with Oak Openings Preserve in the southwest corner of the map based on the species distribution models where suitable habitat for 1, 2, or 3 species is shown. Current protected area boundaries out outlined for reference.

(3) Identify gaps in our protected network

One of the strengths of this type of modeling approach is the ability to identify areas that have highly desirable qualities that are not currently within the protected network. This can be done simply based on the land cover map. Table A1 lists the amount of each land cover that is found currently within protected areas (either as a percent of the total or as total hectares). Based on these data, the protection of the focal ecosystem ranges from 19% (wet prairie) to 34.6% (savanna). However, the area actually in protection varies from 50.9 hectares (wet prairie) to 188.4 hectares (prairie).

These data can provide a way to set targets (~25% of each habitat type) or to evaluate the success of restoration projects. We can also look for areas that are of the desired land cover type that are not currently protected for planning acquisition. Based on the low level of connectivity, it might be particularly useful to target desired areas near currently protected patches of the same type. For example, Figure A5 highlights the areas that are in the focal ecosystems that are not currently in protection. Figure A6 zooms in to the area between Kitty Todd Preserve and Oak Openings Metropark to show more detail on the individual focal patches. Alternatively, we can examine the use of these habitats by the species that depend upon them as shown in the Table A2 for the wet prairie species.

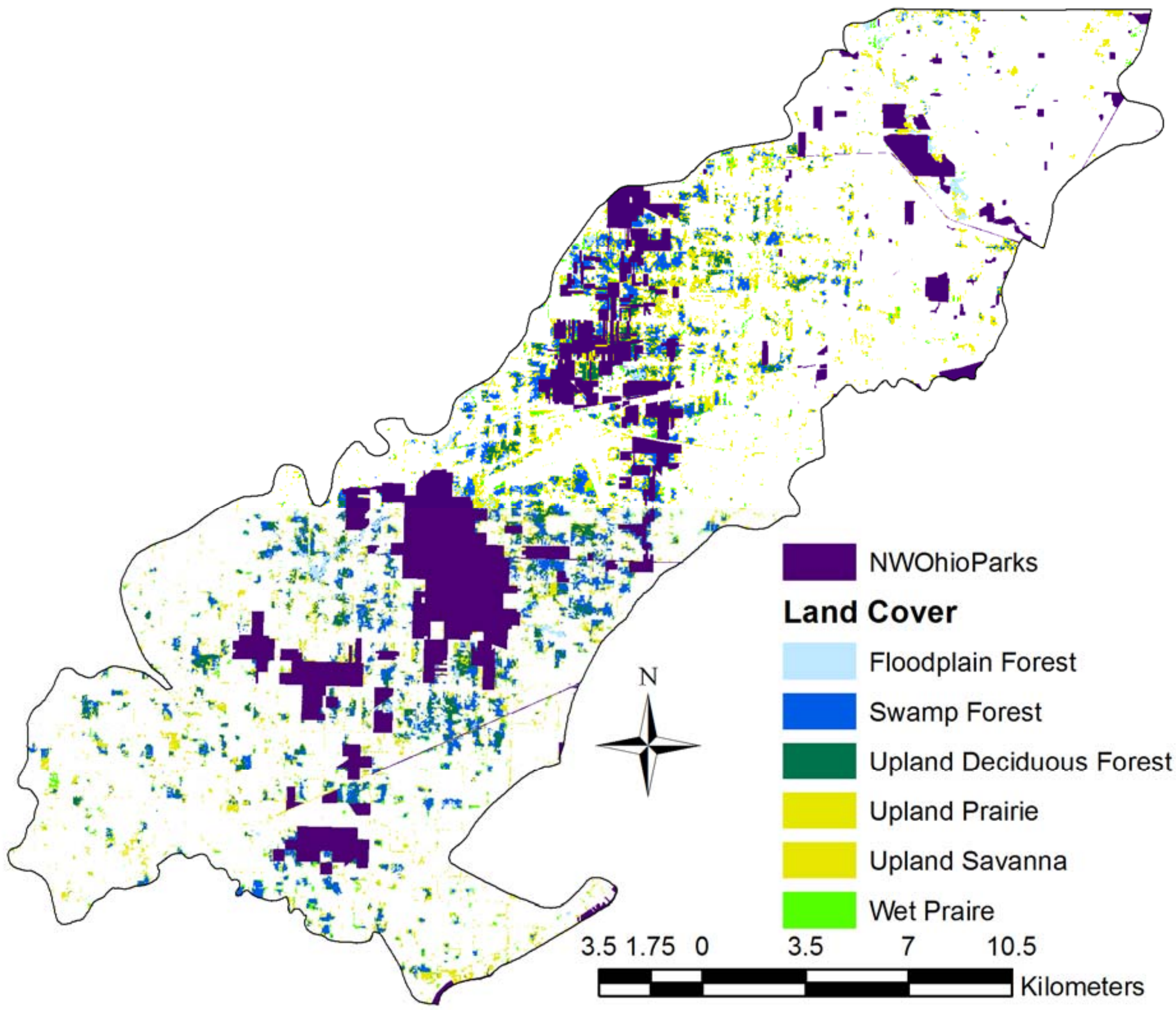

Figure A5. Shown are the focal ecosystems of upland prairie, floodplain forest, upland savanna, swamp forest, deciduous forest and wet prairie. The current protected areas are shown as a mask to highlight the areas that are not currently within those boundaries.

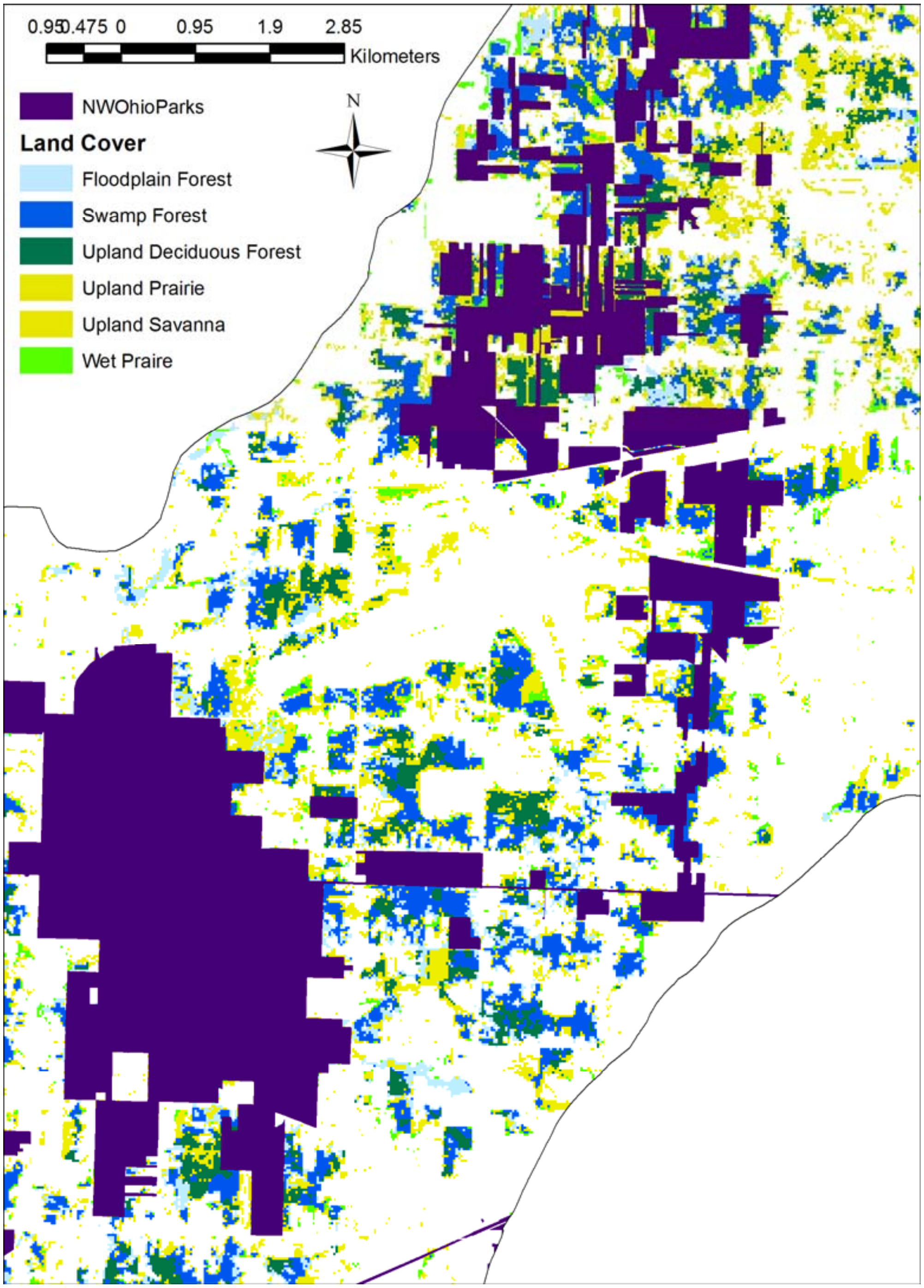

Figure A6. Highlighted are the areas between Kitty Todd Preserve and the Oak Openings Preserve to highlight the unprotected areas of the focal ecosystems of upland prairie, floodplain forest, upland savanna, swamp forest, deciduous forest and wet prairie. The current protected areas are shown as a mask to highlight the areas that are not currently within those boundaries.

(4) Assess restoration potential

We can look at the output of the Maxent models in a number of different ways. By looking at the effect of the species distribution output based on a series of thresholds for percent omission errors or a balance between omission and commission errors (MSS), we can examine the distribution with varying degrees of conservatism. In Figure A7, a comparison of a portion of the maps for each of the 4 thresholds are shown for the set of wet prairie species. The maximum test sensitivity plus specificity (MSS) map maximizes the cases of true negatives while minimizing the false positives. This is considered better, in general, than using other thresholds for most applications (Lie et al. 2005). It is the most conservative of the thresholds and therefore most discriminating. The other 3 thresholds specify the rate of omission errors or the tolerance for excluding suitable habitat. The five and ten percent omission rates could be suitable for evaluating whether the location can be restored to suitable, although based on these data we would recommend only the ten percent. Some of the included habitat will likely be less suitable or lack one or more important features for supporting the species. The one percent is very inclusive and includes much more habitat making it undesirable for discrimination of restoration or conservation targets.

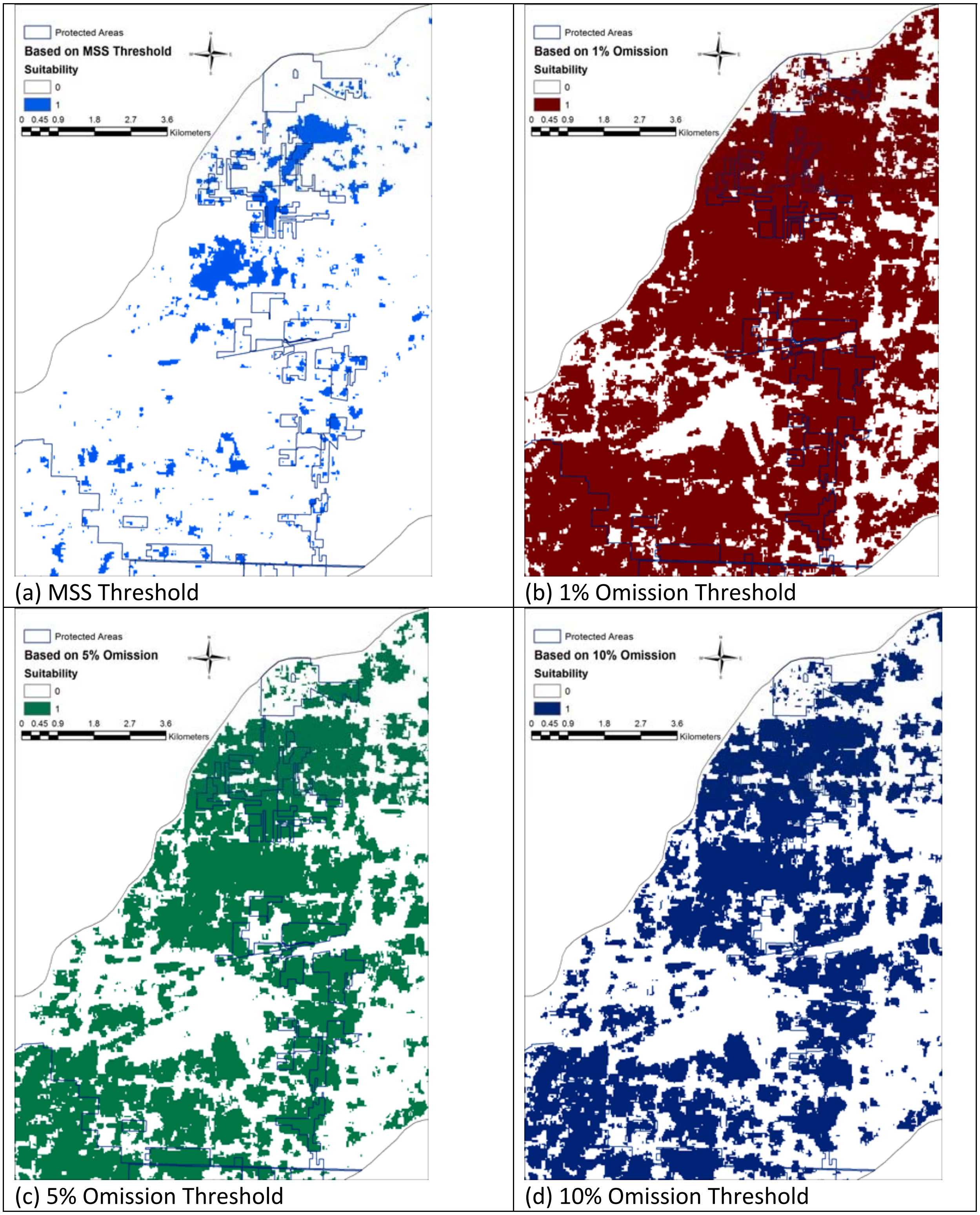

Figure A7. Wet prairie habitat for a selected portion of the Oak Openings Region with Oak Openings Preserve in the southwest corner of the map based on the species distribution models using 4 different error thresholds. Current protected area boundaries out outlined for reference.