EVALUATING LANDSCAPE METRICS FOR DETERMINING OVENBIRD BREEDING HABITAT IN SOUTHERN ONTARIO

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ABSTRACT:

Ovenbird (*Seiurus aurocapillus*) abundance was used to evaluate landscape metrics that would indicate this species' breeding habitat. Abundance values for 22 landscapes, each 10 by 10 kilometers, in southern Ontario were correlated with 19 different landscape metrics and variables. Out of these 19 metrics and variables, 14 had statistically significant Pearson's or Spearman's rank correlation values that were greater than 0.7. Contagion, a metric that measures forest fragmentation, showed the highest absolute correlation (-0.81) with ovenbird abundance, using the Spearman's rank correlation coefficient, whereas the number of dense deciduous forest patches showed the highest Pearson's correlation value (0.83). Total and mean forest core area, variables that would intuitively be very closely related because the ovenbird is a forest-interior species, had significant yet lower values than most other significant metrics and variables calculated in this study. The results suggest that the statistically significant correlations are good indicators for ovenbird breeding habitat.

INTRODUCTION

The ovenbird (*Seiurus aurocapillus*), a neotropical migrant that winters from the southern United States to Venezuela, is fairly common in forested areas of the eastern United States as well as in all Canadian provinces (Cadman, Eagles, and Helleiner 1987). If habitat conditions are suitable, ovenbirds breed in most parts of Ontario (Cadman, Eagles, and Helleiner 1987). Because the ovenbird is a forest-interior species, it needs to have its territory within a forest, which limits its habitat especially in areas with high forest fragmentation (Kricher 1988).

Effects of forest fragmentation on the ovenbird

Forest fragmentation, which has been known to contribute to the decline of certain bird species because their habitats are size dependent (Kricher 1988), is severe in southern Ontario (Friesen, Cadman, and MacKay 1999). As a forest-interior species, the ovenbird is particularly vulnerable to forest fragmentation (Kricher 1988), and the depletion of forested land in southern Ontario reduced the ovenbird population in the past (Cadman, Eagles, and Helleiner 1987). Severely fragmented forests leave very little interior habitat but consist primarily of edge habitat (Temple and Cary 1988), creating unfavorable habitat conditions for the ovenbird although it can occur in lower numbers along forest edges (Kricher 1988). While this project did not focus on the effects of forest fragmentation on the ovenbird but rather on finding appropriate landscape metrics for determining ovenbird breeding habitat in selected areas of southern Ontario, it is important to understand that forest fragmentation greatly influences ovenbird breeding habitat, particularly in the study area of this project.

Ovenbird breeding habitat characteristics

Typical ovenbird breeding habitat is associated with undisturbed deciduous or mixed mature forests (Cadman, Eagles, and Helleiner 1987), although the ovenbird also can occur in largely coniferous boreal forests, as indicated by studies by Bayne and Hobson (2001, 2002), who examined ovenbird pairing success and survival in boreal landscapes in southern Saskatchewan. Flaspohler, Temple, and Rosenfield (2001) also mention that the ovenbird can be found in lowland coniferous forests. Other breeding habitat characteristics include sparse ground cover, dense shrubs, and either closed or open canopy (St-Louis, Fortin, and Desrocher 2004). Ovenbirds both nest and forage on the forest ground (St-Louis, Fortin, and Desrocher 2004, Villard, Merriam, and Maurer 1995), and their nests are well camouflaged on the forest floor and therefore very difficult to find (Cadman, Eagles, and Helleiner 1987).

Forest composition certainly plays an important role for ovenbird breeding habitat, but availability of sufficient forest-core area, which is determined by edge width, is critical as well. Lee and others (2002) found that no ovenbird territories could be located within 50 meters of forest edges in a study around Ottawa, Ontario. Based on ovenbird nesting success, Temple and Cary (1988) divided territories into three categories: Good (farther than 200 meters from forest edge), marginal (between 100 and 200 meters from forest edge, poor (less than 100 meters from forest edge). Flaspohler, Temple, and Rosenfield (2001) used an edge width of 300 meters to compare the effects of edge habitat versus forest-interior habitat on the ovenbird's reproductive ecology. Friesen, Cadman, and MacKay (1999) studied nesting success of migrant songbirds, including the ovenbird, and used 250 meters for the edge width. Forest-interior areas as opposed to areas near edges have higher relative humidity and moisture at the forest floor and more leaf litter, providing better habitat for small invertebrates, the ovenbird's main food source (Burke and Nol 1998). Inside a forest, there is also less risk of nest predation (Flaspohler Temple, and Rosenfield 2001, Burke and Nol 2000, Holmes and Sherry 2001) and less risk of brood parasitism by Brown-headed cowbirds (*Molothrus ater*) (Burke and Nol 2000, Holmes and Sherry 2001).

METHODS

Study Area – Ontario Breeding Bird Atlas (BBA) Data

The study area includes 22 squares, each 10 by 10 kilometers, as described by the Ontario BBA (online). Figure 1 shows the BBA squares that defined the study area. The sizes of the squares seem sufficiently big because Temple and Cary (1988) also used 10 by 10 kilometer squares to relate forest fragmentation to bird population variables.

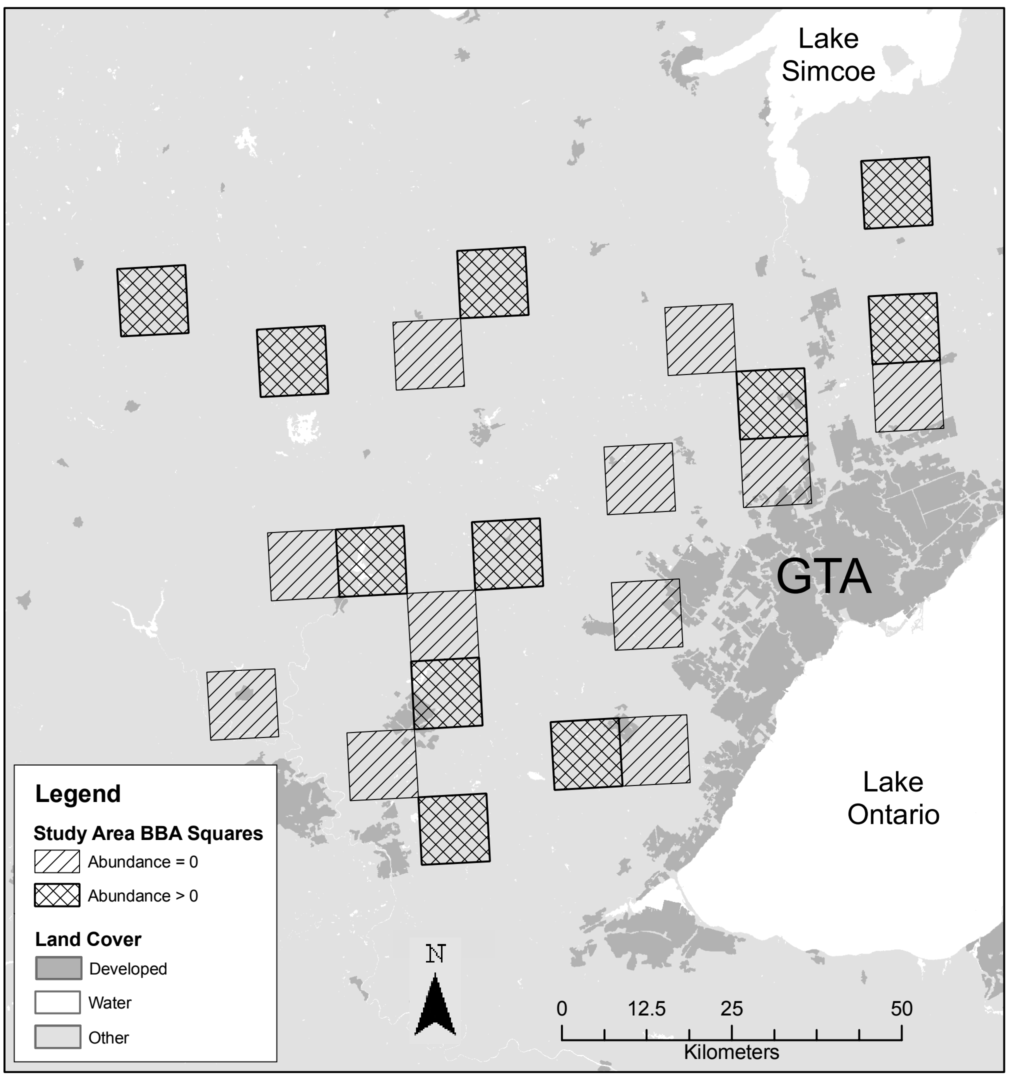

Figure 1: 22 BBA squares, 11 each with abundance values equaling zero and greater than zero, defined the study area. The squares are shown in their context to the Greater Toronto Area (GTA) and water features in southern Ontario.

The squares were chosen based on three parameters: Number of point counts, ovenbird abundance, and hours spent atlassing. Abundance is defined as the average number of birds per point count (Ontario BBA). 11 BBA squares were selected with abundance values greater than zero and 11 more with abundance values that equaled zero for comparison. In order to avoid spatial autocorrelation between squares, they were also picked in a way that no square with abundance values greater than zero touches another; the same was done for squares with zero abundance. Lee and others (2002) used a similar procedure to select squares for their study area. All squares are within the regions of Halton-Peel-Dufferin, Wellington, and York, as defined by the Ontario BBA. The reason to use squares from these regions was that they had similar landscape characteristics and ranges of point counts as opposed to squares from other regions in southern Ontario.

Land Cover Data

The original land cover dataset, in raster format with a grain size of 25 meters, covered the entire province of Ontario and consisted of 28 classes. Reducing this dataset to the spatial extent of the study area already eliminated 13 land cover classes. The remaining 15 classes are shown in Table 1. The pixel counts in table 1 for the classes indicate the distribution of the land cover classes, showing that cropland is the most abundant class, followed by dense deciduous forest, which provides good breeding habitat for ovenbirds.

Table 1: Land cover classes of study area with respective pixel counts.

Land Cover Class	Pixel Count
Pasture and abandoned fields	364,690
Cropland	1,760,780
Mine tailings, quarries, and bedrock outcrops	16,813
Settlement and developed land	57,007
Water	79,506
Inland marsh	5,997
Open fen	512
Deciduous swamp	51,009
Coniferous swamp	48,388
Dense deciduous forest	532,252
Dense coniferous forest	133,638
Coniferous plantation	97
Mixed forest (mainly deciduous)	69,615
Mixed forest (mainly coniferous)	169,072
Sparse deciduous forest	78,056

For further analysis, some of the land cover classes in table 1 were combined in two different ways. First, 12 classes were established by combining pasture and abandoned fields with cropland to yield the class “agriculture/pasture;” mine tailings, quarries, and bedrock outcrops and settlement and developed land were collapsed into “developed,” and inland marsh was combined with open fen into “marsh.” Secondly, 5 classes were created by additionally collapsing all the forest classes into one single class (table 2).

Table 2: Collapsing land cover classes from the original 15 classes to 12 and 5 classes, respectively.

Original Land Cover Classes	Combined to yield 12 classes	Combined to yield 5 classes
Pasture and abandoned fields	Agriculture/Pasture	Agriculture/Pasture
Cropland		
Mine tailings, quarries, and bedrock outcrops	Developed	Developed
Settlement and developed land		
Water	Water	Water
Inland marsh	Marsh	Marsh
Open fen		
Deciduous swamp	Deciduous swamp	Forest
Coniferous swamp	Coniferous swamp	
Dense deciduous forest	Dense deciduous forest	
Dense coniferous forest	Dense coniferous forest	
Coniferous plantation	Coniferous plantation	
Mixed forest (mainly deciduous)	Mixed forest (mainly deciduous)	
Mixed forest (mainly coniferous)	Mixed forest (mainly coniferous)	
Sparse deciduous forest	Sparse deciduous forest	

The reason for combining classes was that some of the landscape metrics that will be explained later are affected by the number of land cover classes in a way that they would produce values that indicate high fragmentation. However, the ovenbird would not see the landscape that fragmented; therefore all landscape metrics that measure fragmentation are based on the land cover classification with 5 classes. The classification with 12 classes was used to correlate areas and numbers of patches of different forest types with ovenbird abundance. When 5 land cover classes instead of 12 are considered, the number of patches is smaller, resulting in a less fragmented landscape, as illustrated in figures 2 and 3.

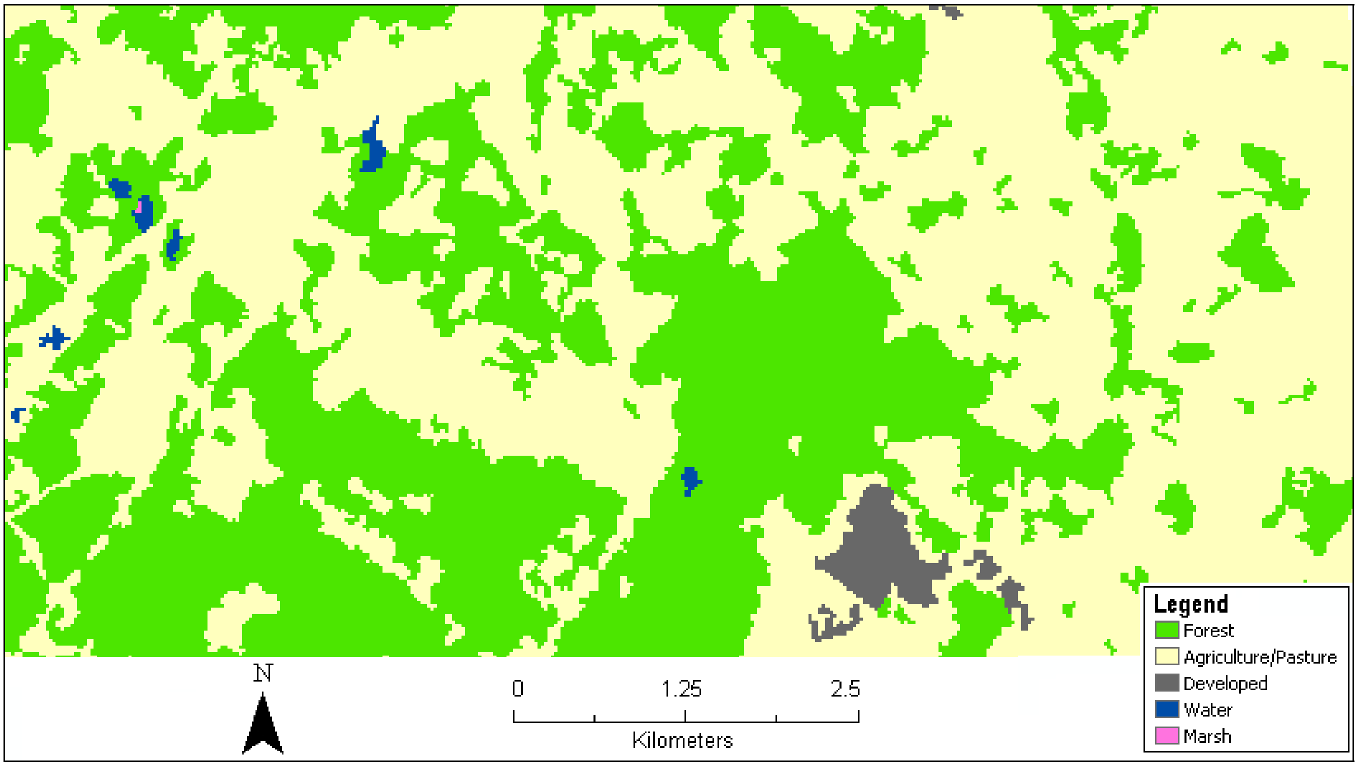

Figure 2: Sample area categorized into 5 land cover classes.

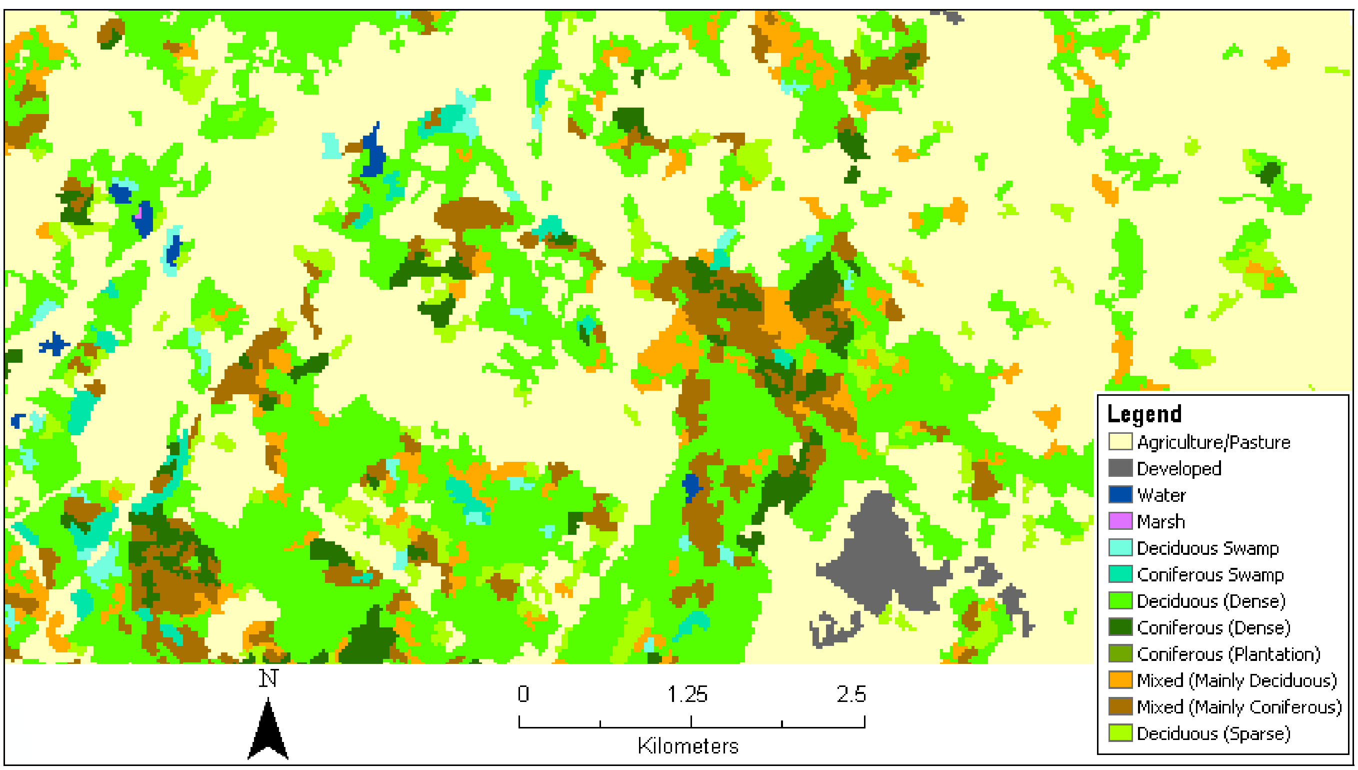

Figure 3: Same sample area as in figure 2 categorized into 12 land cover classes, resulting in a more fragmented landscape.

Landscape Metrics

Based on the literature and on ovenbird breeding characteristics, 19 landscape metrics and variables were calculated and later correlated to ovenbird abundance (table 3).

Table 3: Landscape metrics and variables used with 5 and 12 land cover classes.

Metrics and variables based on landscape with 5 land cover classes	Metrics and variables based on landscape with 12 land cover classes
Contagion	Dense Deciduous Forest (DDF) - Total Area
Landscape Division Index	Dense Deciduous Forest - Number of Patches
Splitting Index	Sparse Deciduous Forest (SDF) - Total Area
Simpson's Diversity Index	Sparse Deciduous Forest - Number of Patches
Forest - Total Area	Mixed Mainly Deciduous (MMD) - Total Area
Forest - Number of Patches	Mixed Mainly Deciduous - Number of Patches
Forest - Largest Patch Index	Mixed Mainly Coniferous (MMC) - Total Area
Forest - Mean Area	Mixed Mainly Coniferous - Number of Patches
Forest - Median Area	
Forest - Total Core Area	
Forest - Mean Core Area	

Flather and Sauer (1996) used contagion, Shannon's diversity index, mean forest area, and several edge metrics, among others to examine abundance patterns of migratory birds, but found only few associations between landscape characteristics and neotropical migrant trends. Donavan and Flather (2002) examined forest fragmentation and its effects on various songbirds, including the ovenbird, and listed the number of forest patches, largest patch index for forest, mean forest patch size, and total and mean forest core areas as influential variables. Friesen, Cadman, and MacKay (1999) used mean forest patch size, edge density, forest core area, number of forest patches, among others to relate risk of nest predation and brood parasitism to nesting success of neotropical migrants.

Additionally to the metrics and variables in the literature described above, landscape division index, splitting index, Simpson's diversity index, and median forest area for BBA squares divided into 5 land cover categories, as well as total area and number of patches for four different forest types for BBA squares divided into 12 land cover categories were calculated. Landscape division index, splitting index, and Simpson's diversity index, all measure landscape fragmentation, as does contagion. Simpson's diversity index was chosen over Shannon's diversity index, which was used in Flather and Sauer (1996), because Simpson's diversity index is less sensitive to rare land cover types and has a more intuitive interpretation than Shannon's diversity index (McGarigal and others 2002), which should ensure that less abundant classes in the study area, such as developed, marsh, and water, do not have a negative influence on calculations. Median forest area was only chosen to see if it yields any better results than mean forest area, and the four different forest type variables based on the landscape with 12 land cover classes were calculated to see there is an indication that the ovenbird prefers one cover type over others.

Metrics and variables for all 22 BBA squares were calculated with the FRAGSTATS software program (McGarigal and others 2002). Based on the literature review about ovenbird breeding habitat, as described in the introduction, it was decided to use an edge width of 250 meters, which corresponds exactly to the value used by Friesen, Cadman, and MacKay (1999) and is close to or within the range of other values that define reasonably good ovenbird habitat. Aside from choosing an edge width, the other critical parameter to decide on was the neighborhood rule. Fauth, Gustafson, and Rabenold (2000) studied modeling habitat for neotropical migrants and chose the 4-neighborhood rule, meaning that patches are defined by vertically or horizontally adjacent pixels of the same land cover class as opposed to the 8-neighborhood rule, which also includes diagonal pixels. The decision of the neighborhood rule must be made with the focal species in mind because it is related to how committed a species is to cross gaps of non-habitat (With 1997). Because "the ovenbird is considered to be sensitive to forest fragmentation" (Flaspohler, Temple, and Rosenfield 2001) and also, as a forest-interior species, considered to be "area-sensitive" (Riley and Mohr 1994), it is assumed that the ovenbird is rather reluctant to leave its typical habitat. Therefore, the 4-neighborhood rule was chosen for this project.

Correlation Analysis

Pearson's correlation coefficient and Spearman's rank correlation were calculated for all 19 landscape metrics and variables to examine if there are any metrics or variables that are highly correlated with ovenbird abundance. Allen and O'Connor (2000) used the same two statistical measures as part of their study to correlate environmental variables and bird abundance. Spearman's rank correlation has the advantage over product-moment correlations of controlling for non-linear distributions (Allen and O'Connor 2000), which was the case for all correlations in this study. Table 4 shows the results of the correlation analysis for all examined metrics and variables.

Table 4: Pearson's and Spearman's rank correlation values for ovenbird abundance versus 19 landscape metrics and variables.

Landscape Metric/Variable	Pearson's correlation values and significance values for landscape metrics versus abundance per BBA square		Spearman's rank correlations and significance values for landscape metrics versus abundance per BBA square	
Based on BBA squares categorized into 5 land cover classes.				
Contagion	Correlation Value	-0.7839053	Correlation Value	-0.8136072
	Sig. (2-tailed)**	0.0000159	Sig. (2-tailed)**	0.0000041
Landscape Division Index	Correlation Value	0.7673619	Correlation Value	0.7942930
	Sig. (2-tailed)**	0.0000308	Sig. (2-tailed)**	0.0000102
Splitting Index	Correlation Value	0.7355508	Correlation Value	0.7942930
	Sig. (2-tailed)**	0.0000959	Sig. (2-tailed)**	0.0000102
Simpson's Diversity Index	Correlation Value	0.7931076	Correlation Value	0.7985180
	Sig. (2-tailed)**	0.0000107	Sig. (2-tailed)**	0.0000084
Forest - Total Area	Correlation Value	0.8222052	Correlation Value	0.7641147
	Sig. (2-tailed)**	0.0000027	Sig. (2-tailed)**	0.0000348
Forest - Number of Patches	Correlation Value	-0.0987627	Correlation Value	0.2252574
	Sig. (2-tailed)	0.6619157	Sig. (2-tailed)**	0.3134985
Forest - Largest Patch Index	Correlation Value	0.7128614	Correlation Value	0.7122080
	Sig. (2-tailed)**	0.0001966	Sig. (2-tailed)**	0.0002005
Forest - Mean Area	Correlation Value	0.8038501	Correlation Value	0.7460077
	Sig. (2-tailed)**	0.0000066	Sig. (2-tailed)**	0.0000672
Forest - Median Area	Correlation Value	-0.3269630	Correlation Value	-0.2610971
	Sig. (2-tailed)**	0.1374777	Sig. (2-tailed)**	0.2405292
Forest - Total Core Area	Correlation Value	0.7464020	Correlation Value	0.6308359
	Sig. (2-tailed)**	0.0000663	Sig. (2-tailed)**	0.0016450
Forest - Mean Core Area	Correlation Value	0.7156235	Correlation Value	0.5812874
	Sig. (2-tailed)**	0.0001808	Sig. (2-tailed)**	0.0045500
Based on BBA squares categorized into 12 land cover classes.				
DDF - Total Area	Correlation Value	0.8130611	Correlation Value	0.7870502
	Sig. (2-tailed)**	0.0000042	Sig. (2-tailed)**	0.0000139
DDF - Number of Patches	Correlation Value	0.8272254	Correlation Value	0.7673492
	Sig. (2-tailed)**	0.0000021	Sig. (2-tailed)**	0.0000308
SDF - Total Area	Correlation Value	0.1157269	Correlation Value	0.3410149
	Sig. (2-tailed)	0.6080554	Sig. (2-tailed)	0.1203957
SDF - Number of Patches	Correlation Value	0.1394688	Correlation Value	0.3790395
	Sig. (2-tailed)	0.5359039	Sig. (2-tailed)	0.0819168
MMD - Total Area	Correlation Value	0.5819823	Correlation Value	0.6753905
	Sig. (2-tailed)**	0.0044904	Sig. (2-tailed)**	0.0005624
MMD - Number of Patches	Correlation Value	0.6801044	Correlation Value	0.7399721
	Sig. (2-tailed)**	0.0004968	Sig. (2-tailed)**	0.0000827
MMC - Total Area	Correlation Value	0.7042984	Correlation Value	0.7315221
	Sig. (2-tailed)**	0.0002535	Sig. (2-tailed)**	0.0001095
MMC - Number of Patches	Correlation Value	0.7349884	Correlation Value	0.7009382
	Sig. (2-tailed)**	0.0000977	Sig. (2-tailed)**	0.0002794

n = 22 (for all landscape metrics)

** Correlation is significant at the 0.01 level (2-tailed)

As shown in table 4, 13 of the 19 landscape metrics and variables calculated have absolute Pearson's correlation values (disregarding minus signs that indicate negative correlations) that are higher than 0.7. Among these 13, four even reach 0.8, indicating fairly strong correlations with ovenbird abundance. The four metrics and variables with correlation values greater than 0.8 are total forest area (0.8222052), mean forest area (0.8038501), total deciduous forest area (0.8130611), and number of deciduous forest patches (0.8272254). The absolute Spearman's rank correlation values produced similar results, as 12 landscape metrics and variables have values greater than 0.7, with contagion (-0.8136072) being the only one that had an absolute value greater than 0.8. All metrics and variables, except total forest core area and mean forest core area, with a Pearson's correlation value of more than 0.7 also had a Spearman's rank correlation greater than 0.7. Conversely, all metrics and variables, except the number of patches for mixed (mostly deciduous) forest, with a Spearman's rank correlation coefficient greater than 0.7 also had a value greater than 0.7 for the Pearson's correlation. This leads to 14 metrics or variables that have a correlation value of 0.7 or greater for either of the two correlation measures; they will be explained in more detail in the results & discussion section.

RESULTS & DISCUSSION

Ovenbird abundance versus landscape fragmentation metrics

As seen in table 4, correlation with ovenbird abundance resulted in absolute Pearson's correlation values well over 0.7 and absolute Spearman's rank correlation coefficients close to and over 0.8. Figure 4 shows the scatterplots for these metrics.

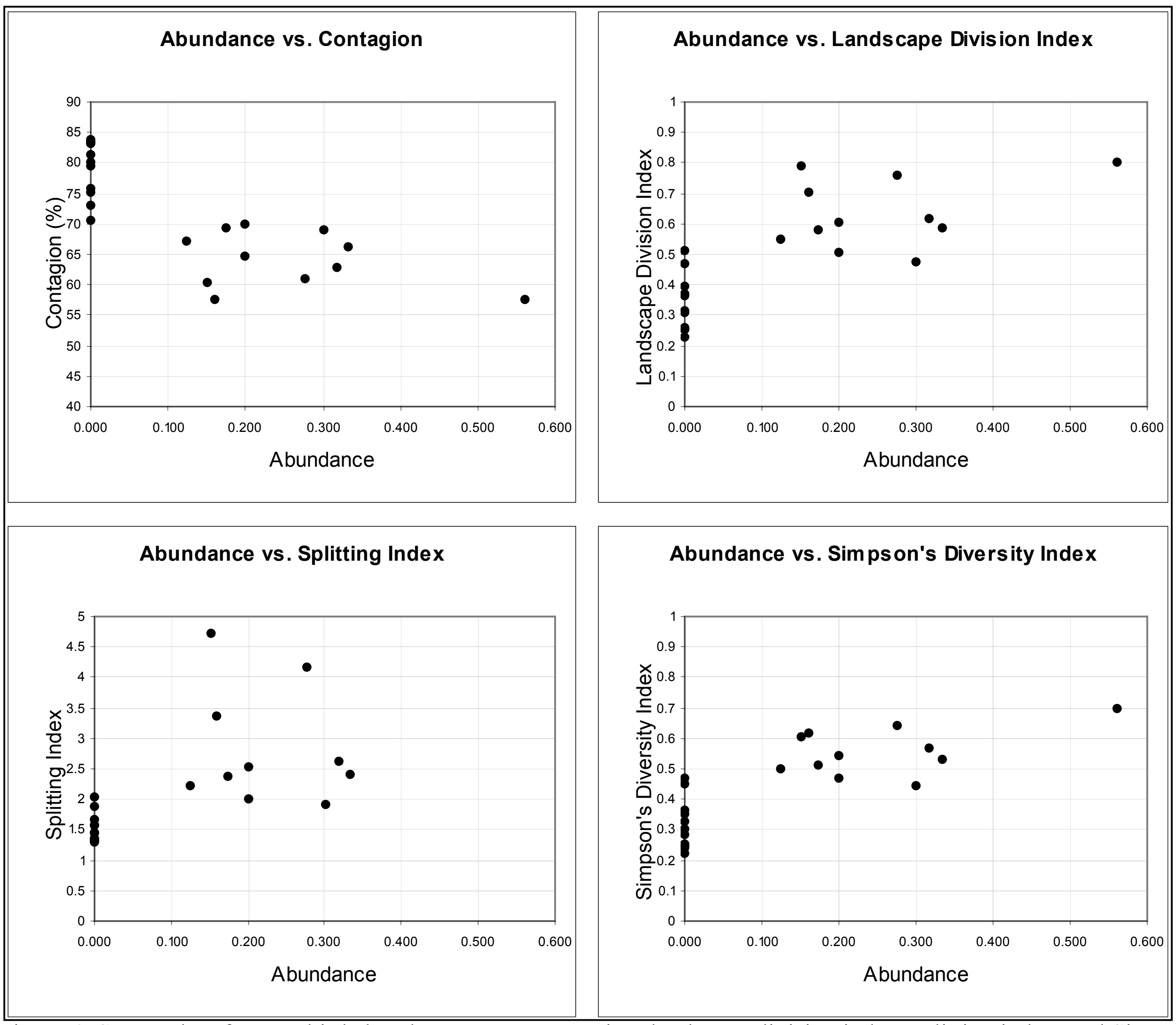

Figure 4: Scatterplots for ovenbird abundance versus contagion, landscape division index, splitting index, and Simpson's diversity index.

All four scatterplots show that it would be difficult to fit a line to these distributions. The line was left out on purpose in the scatterplots for that reason. The issue of missing linearity, which influences the Pearson's correlation measure but not necessarily the Spearman's rank correlation, makes a strong case for rather using the Spearman's rank correlation values than the Pearson's correlation values. This even has a positive effect on the results because the Spearman's rank values for all four landscape fragmentation metrics are higher than the Pearson's values.

By looking at the scatterplots (figure 4), it can be observed that values for contagion are higher for all 11 BBA squares with an ovenbird abundance of zero than for the 11 squares with abundances greater than zero. For the landscape division index, splitting index, and Simpson's diversity index the distinction between abundances of zero and non-zero is not as clear as with contagion, but these three metrics show generally higher values for non-zero abundances than for zero abundance. Therefore, the four measured landscape fragmentation metrics seem to be good indicators for ovenbird abundance, whereby contagion appears to be the best one. The results suggest that ovenbirds tend to be more abundant in less fragmented BBA squares, which corresponds to Kricher's (1988) claim that ovenbirds are particularly vulnerable to forest fragmentation.

Ovenbird abundance versus forest area and forest core area variables

Since the ovenbird is a forest-interior species, it was expected that variables related to forest area and core area would be good indicators of its breeding habitat. It was however surprising that total forest area and mean forest area produced higher correlation values than total and mean forest core area (table 4) because the ovenbird cannot find much or any habitat in a very large fragmented forest patch with little core area, which could be possible by only considering forest area as opposed to core area. A reason for this unexpected result might be that the chosen edge width of 250 meters might have been too high and forest patches that might have sufficient core area with lower edge width values were excluded. Figures 5 and 6 show the scatterplots for the total and mean forest areas and forest core areas, respectively. They show a general trend of higher abundance values in BBA squares with higher total and mean forest and forest core areas. It therefore appears that all four variables related to forest area and forest core area seem to be good indicators of ovenbird abundance.

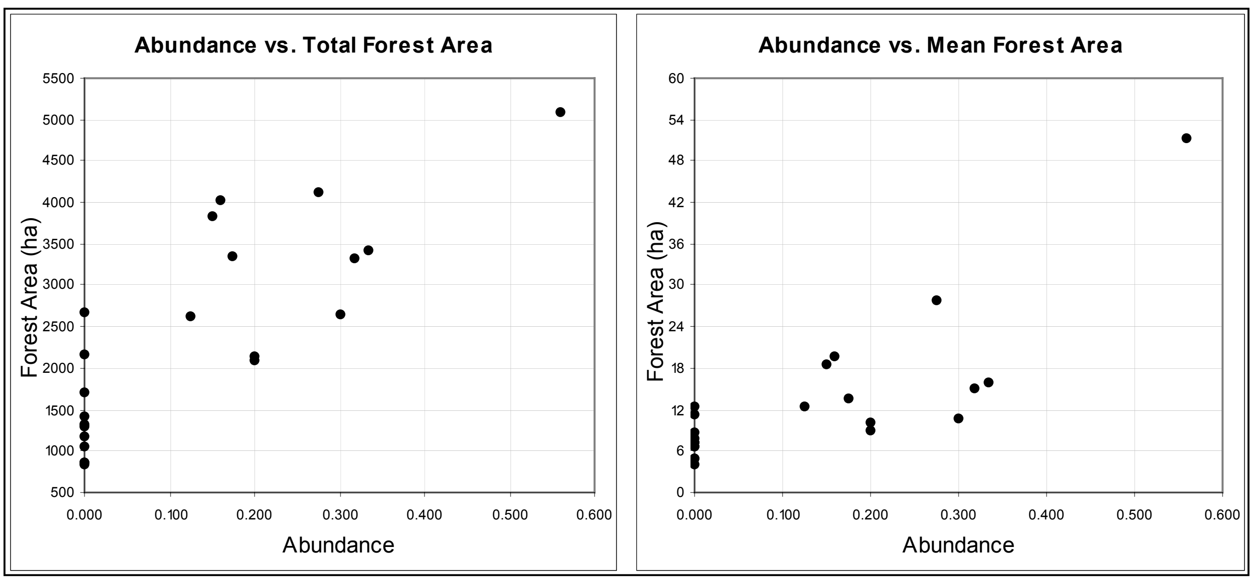

Figure 5: Scatterplots for ovenbird abundance versus total and mean forest areas.

The largest patch index, quantifying the area percentage of the largest patch (McGarigal and others 2002), for forest also had relatively high correlation values. This is in a way surprising that intuitively it should not necessarily be so highly correlated because it can be that there is simply one large forest patch but not any other suitable ones, therefore making the whole landscape or BBA square a relatively bad ovenbird breeding habitat. For this reason, it is suggested that this variable should be interpreted with caution when correlating it with ovenbird abundance. The scatterplot for the largest patch index for forest (figure 7) reveals that only two BBA squares with abundance values greater than zero have lower values than squares with abundance values equaling zero.

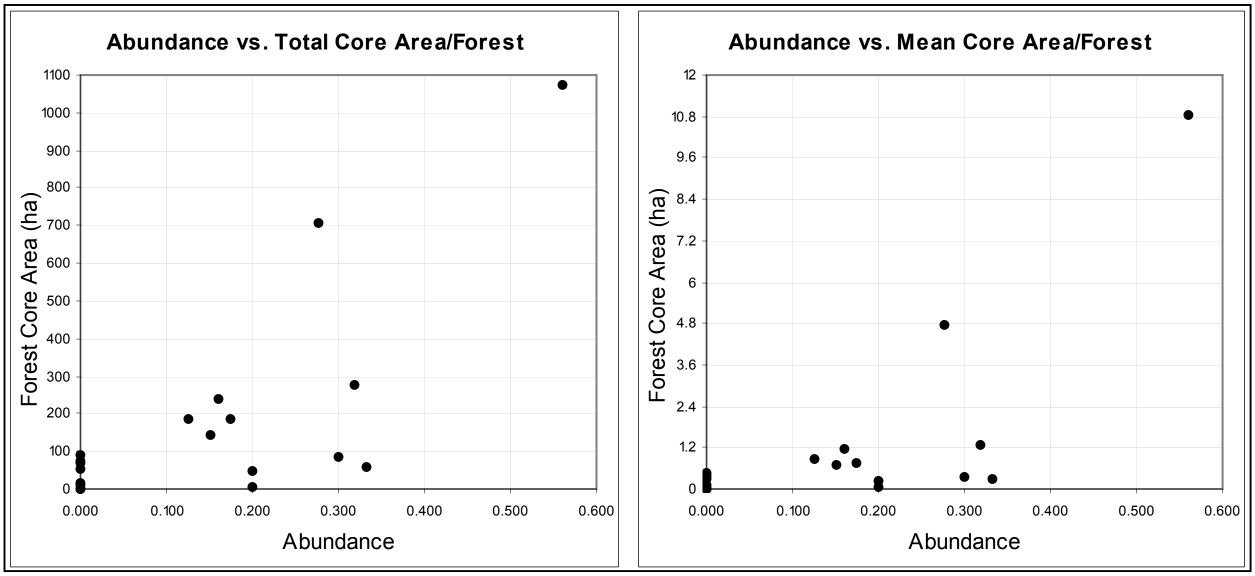

Figure 6: Scatterplots for ovenbird abundance versus total and mean forest core areas.

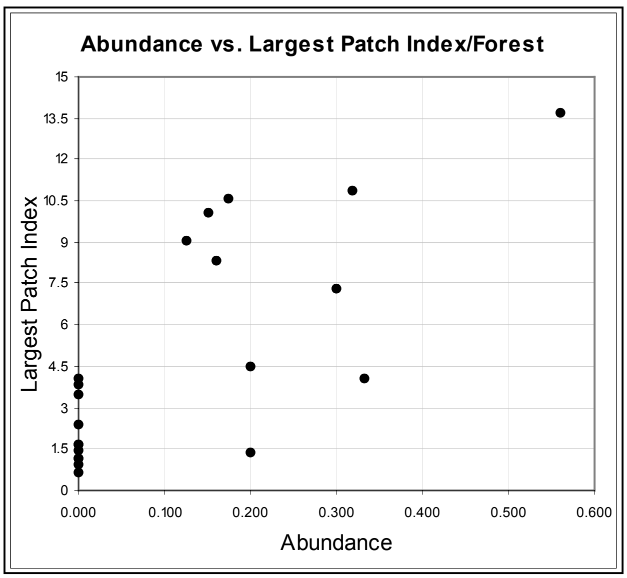

Figure 7: Scatterplot for ovenbird abundance versus largest patch index for forest.

Ovenbird abundance versus specific forest type variables

Total area and number of patches for dense deciduous forest (DDF) show high correlation values (table 4). This was expected because the ovenbird is known to prefer habitat in either deciduous or mixed forest (Cadman, Eagles, and Helleiner 1987). Surprisingly, the total area and number of patches for mixed forest that is mainly coniferous (MMC) show higher correlation values than the same variables for mixed forest that is mainly deciduous (MMD). Only the Spearman's rank correlation for the number of patches with MMD has a higher value than its counterpart with MMC, and it is also the only one of the MMD values that exceeds 0.7 (table 4). Since the ovenbird tends to be rather associated with deciduous forest, based on the literature review, one would rather expect generally higher correlations with variables related to MMD than MMC.

The scatterplots for the specific forest type variables (figure 8) show generally higher values for forest area and number of patches for BBA squares with abundance values greater than zero. Based on the scatterplots and correlation values for DDF total area and number of patches, it appears that these two variables are stronger indicators for ovenbird abundance than any of the mixed forest type variables.

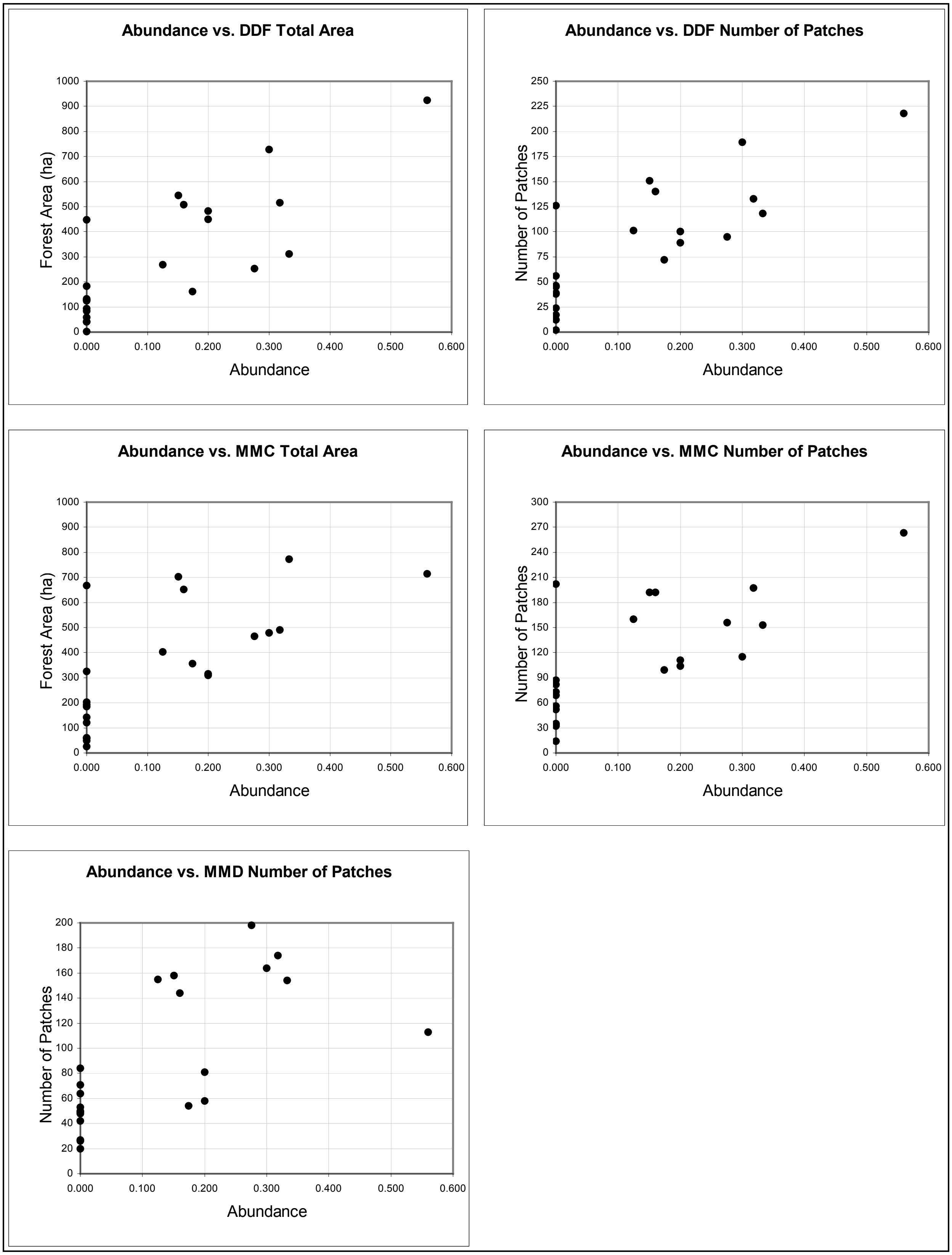

Figure 8: Scatterplots for ovenbird abundance versus total area and number of patches for DDF, total area and number of patches for MMC, and number of patches for MMD.

Data limitations and concluding discussion

Based on the results, 16 of the 19 calculated landscape metrics and variables are significant, and 14 of them show correlation values greater than 0.7 with ovenbird abundance, as measured either with the Pearson's or Spearman's rank correlation or both (table 4). Unexpectedly, the number of forest patches did not yield any good correlations, but when the specific forest types DDF, MMC, and partly MMD were considered, their correlation values were significant for the number of patches (table 4). Aside from number of forest patches, the only other correlations that showed no significance were forest median area, total area of sparse deciduous forest (SDF), and number of patches for SDF (table 4).

However, even the significant correlations need to be interpreted with some caution. As seen in the scatterplots (figures 4 to 8), there are some limitations with the data related to missing linearity, which probably has an influence particularly on the Pearson's correlation values. Another issue that might need to be addressed is the relatively low sample size of 22 BBA squares. For example, Lee and others (2002) selected 34 landscape squares for relating bird species abundance and forest variables and received much better linearity when plotting the logarithm of ovenbird abundance versus the logarithm of forest patch size; however, their scatterplots for the red-eyed vireo and wood thrush looked very non-linear as well. Burke and Nol even used 69 woodlots and produced high linearity and regression values when calculating the relation of ovenbird pairing success and the logarithm of forest core area.

Nevertheless, the results of this project are promising, considering the 14 variables and metrics that yielded significant and strong correlations. Seen as an exploratory project, the results could be verified by using a larger sample size and more in-depth statistical analysis that would validate the correlation results. With these limitations in mind, the methods of this project illustrate that ovenbird abundance show relatively strong correlation with some landscape metrics and variables and can possibly be used to determine ovenbird breeding habitat.

REFERENCES

Allen AP, O'Connor RJ. 2000. Interactive effects of land use and other factors on regional bird distributions. *Journal of Biogeography* 27: 889-900.

Bayne EM, Hobson KA. 2001. Effects of habitat fragmentation on pairing success of ovenbirds: Importance of male age and floater behavior. *The Auk* 118 (2): 380-388.

Bayne EM, Hobson KA. 2002. Apparent survival of male ovenbirds in fragmented and forested boreal landscapes. *Ecology* 83 (5): 1307-1316.

Burke DM, Nol E. 1998. Influence of food abundance, nest-site habitat, and forest fragmentation on breeding ovenbirds. *The Auk* 115 (1): 96-104.

Burke DM, Nol E. 2000. Landscape and fragment size effects on reproductive success of forest-breeding birds in Ontario. *Ecological Applications* 10 (6): 1749-1761.

Cadman MD, Eagles PFJ, Helleiner FM. 1987. Atlas of the breeding birds of Ontario. Waterloo, Ontario. University of Waterloo Press.

Donavan TM, Flather CH. 2002. Relationships among north American songbird trends, habitat fragmentation, and landscape occupancy. *Ecological Applications* 12 (2): 364-374.

Fauth PT, Gustafson EJ, Rabenold KN. 2000. Using landscape metrics to model source habitat for neotropical migrants in the midwestern U.S. *Landscape Ecology* 15: 621-631.

Flaspohler DJ, Temple SA, Rosenfield RN. 2001. Effects of forest edges on ovenbird demography in a managed forest landscape. *Conservation Biology* 15 (1): 173-183.

Flather CH, Sauer JR. 1996. Using landscape ecology to test hypotheses about large-scale abundance patterns in migratory birds. *Ecology* 77 (1): 28-35.

Friesen L, Cadman MD, MacKay RJ. 1999. Nesting success of neotropical migrant songbirds in a highly fragmented landscape. *Conservation Biology* 13 (2): 338-346.

Holmes RT, Sherry TW. 2001. Thirty-year bird population trends in an unfragmented temperate deciduous forest: Importance of habitat change. *The Auk* 118 (3): 589-609.

Kricher JC. 1988. A field guide to ecology of eastern forests, North America. Boston, Massachusetts. Houghton Mifflin Company.

Lee M, Fahrig L, Freemark K, Currie DJ. 2002. Importance of patch scale vs landscape scale on selected forest birds. *OIKOS* 96: 110-118.

McGarigal K., Cushman SA, Neel MC, Ene E. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. <www.umass.edu/landeco/research/fragstats/fragstats.html> Last accessed: 2004 27 Dec.

Ontario Breeding Bird Atlas. World Wide Web. <http://www.birdsontario.org/atlas/map.jsp> Last accessed: 2004 27 Dec.

Riley JL, Mohr P. 1994. The natural heritage of southern Ontario's settled landscapes. Aurora, Ontario. Ontario Ministry of Natural Resources, Southern Region.

St-Louis V, Fortin MJ, Desrochers A. 2004. Spatial association between forest heterogeneity and breeding territory boundaries of two forest songbirds. *Landscape Ecology* 19: 591-601.

Temple SA, Cary JR. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. *Conservation Biology* 2 (4): 340-347.

Villard MA, Merriam G, Maurer BA. 1995. Dynamics in subdivided populations of neotropical migratory birds in a fragmented temperate forest. *Ecology* 76 (1): 27-40.

With KA. 1997. The application of neutral landscape models in conservation biology. *Conservation Biology* 11 (5): 1069-1080.