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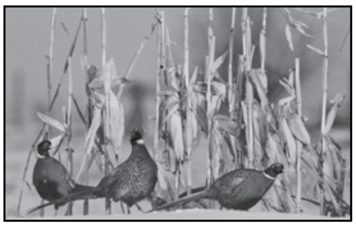

Relations of Ring-necked Pheasant Abundance to Land Cover Patterns in South-central Wisconsin

By **Ronald C. Gatti** and **Daniel R. Schneider**

Abstract

We explored the importance of habitat to the abundance of ring-necked pheasants (*Phasianus colchicus*) in order to assess the underlying assumption of grassland and wetland restoration in the Glacial Habitat Restoration Area (GHRA). The GHRA is a landscape-scale program which began in 1991 and covers 2,262-km^2 (873 mi^2) in an active agricultural landscape of south-central Wisconsin. We counted ring-necked pheasant males from roadside stops and mapped all land cover within 22 pheasant survey units, each 32.5 km^2 (12.6 mi^2) in size and centered on shrub/cattail (*Typha* spp.) winter cover. We modeled the coverage of nine classes of land cover and 13 measures of spatial pattern of habitat to explain pheasant counts in 1999 and 2000, early into the GHRA habitat restoration program. Our objective was to gain insight into pheasant-habitat relationships as a snap-shot in time among sites that might support ongoing habitat restoration efforts across the entire GHRA over time. When only habitat variables were considered, the most parsimonious model included only the coverage of agricultural land within 402 m of winter cover (AGPWC), and the coverage of winter cover in blocks >8.1 ha. When spatial pattern metrics were also considered, the most parsimonious model incorporated the interspersion and juxtaposition of agricultural fields (INJUXAG), the number of disjunct core areas of winter cover >10 m from the edge (NDCAWC), and landscape-level contrast between the structure of patch edges (LTECI). The top five ranked models all included INJUXAG and only included variables of spatial pattern metrics; four of these models also included NDCAWC, three models included LTECI, and three models included the mean shape complexity of agricultural fields (FRACMNAG). Pheasant abundance was positively related to AGPWC, FRACMNAG, the total coverage of agricultural fields, NDCAWC, and INJUXAG, but negatively related to LTECI. We found no evidence that the abundance of secure nest cover and pheasants were positively related, which is the primary assumption behind habitat restoration in the GHRA. The

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broad range of coverage of secure nest cover we studied among survey units (0.5 to 4.0 times the GHRA goal) hints that the habitat restoration program may not restore pheasant populations in southern Wisconsin. Because spatial pattern metrics of habitat were more important than coverage of habitat classes, we suggest that habitat configuration should be considered for pheasant management, although this would benefit from further study. The greater importance of winter cover and winter food over nest cover to pheasant abundance may suggest a different direction for pheasant management in south-central Wisconsin.

Contents

Cover photo courtesy of Roger Hill, Pheasants Forever.

Introduction

The habitat requirements of ring-necked pheasants (*Phasianus colchicus*) have been well-studied across North America, though studies indicate regional differences in what comprises critical habitat (Olsen 1977, Giudice and Ratti 2001). Herbaceous cover of grass and/or forbs has been universally reported to be critical for nesting and brood-rearing (Farris et al. 1977, Riley et al. 1998, Clark et al. 1999), including grasslands provided by the Conservation Reserve Program (Nielson et al. 2008). In the upper Midwest, critical habitat for winter survival varies in form among upland shelter belts of trees and shrubs (Grondahl 1953, Egbert 1968), dense grassland (Gabbert et al. 1999), cattail (*Typha* spp.) wetlands (Trautman 1982, Homan et al. 2000), wooded wetlands, and woodlots during more severe winters (Gatti et al. 1989). The spatial pattern of habitat has also been related to pheasants, with mixed results (Gates and Hale 1975, Clark et al. 1999, Schmitz and Clark 1999, Nielson et al. 2008).

A comprehensive study of ring-necked pheasants in southern Wisconsin (Gates and Hale 1974, Gates and Hale 1975) found that grasslands were critical habitat for nesting. Wetland cover of tamarack (*Larix laricina*), dense shrub, and cattail wetlands were essential for pheasant survival in winter. They also found that provision of winter food was critical for winter survival and spring reproduction. Gates (1970) concluded that pheasant populations could be assessed and managed within units 32.5 km^2 in size, centered on winter cover and extending out 3.2 km from the winter cover. His prescription was to provide 168 ha of the management unit in grassland that does not flood in the spring, 8-12 ha in winter cover wetlands consisting of shrubs and cattails, and 0.4-0.8 ha of standing corn (*Zea mays*). Hydrological disruption has since eliminated most tamarack wetlands in southern Wisconsin (Wisconsin DNR 2014), removing them from restoration planning.

The Glacial Habitat Restoration Area (GHRA) program is an attempt by the Wisconsin Department of Natural Resources (Wisconsin DNR) and conservation partners to increase critical grassland and wetland habitat on a landscape scale for pheasants similar to the Gates (1970) model. The GHRA encompasses 2,262 km^2 (558,902 acres), within which wildlife managers are creating a patchwork of suitable habitat for pheasants and other grassland birds (Crossley et al. 1990, Wisconsin DNR 2013). Management goals are to: 1) restore 4,455 ha of drained wetlands, and 2) establish grassland nest cover so that 15,633 ha of grassland existed within 3.2 km of winter cover wetlands in the GHRA project area (6.9% of the area). By restoring grasslands and wetlands in a pattern that optimally will benefit pheasants and other grassland birds within an active agricultural landscape, the Wisconsin DNR hopes to reverse the decline of pheasants in Wisconsin that has taken place in recent decades (Gatti et al. 1994, R.C. Gatti, Wisconsin DNR, unpublished data). Management implementation in the GHRA began in 1991 but progressed slower than expected. Indices to pheasant abundance varied 10-fold among the pheasant management units in 1999. Although the management plan had not been completed, we hoped that by relating the habitat criteria in 1999 to the pheasant index in each unit, we could gain insight into pheasant-habitat relationships that would provide support to the ongoing habitat restoration efforts across the entire GHRA.

Our research objectives were to: 1) map land cover present in 1999 within pheasant survey units in south-central Wisconsin and 2) use land cover and its spatial pattern among the survey units to explain pheasant abundance at the time.


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Methods

Study Area

Our study took place on 22 pheasant survey units, each 32.5km^2 (12.6 mi^2) in size and centered on shrub/cattail winter cover in and around the GHRA, and overlapping the study area of Gates and Hale (1974). The survey units totaled 712 km^2 in parts of Dodge, Fond du Lac, Columbia, Winnebago, Green Lake, and Jefferson counties in south-central Wisconsin (Figure 1). The area lies within the Southeast Glacial Plains and Central Sand Hills ecological landscapes (Wisconsin DNR 2012, 2014). These regions have gently rolling topography from past glaciations, with soils dominated by silt loams but ranging from sandy to clay (Link 1973). Dominant land use of the area is dairy farming and cash grain cropping with a mix of small woodlots, wetlands, shallow lakes, and residential/urban development (Pohlman et al. 2006). Land cover in the study area in 1990, one year before the start of the GHRA Program, was classified using Landsat satellite data by Polzer (1992). Public lands inside the pheasant survey units included parts of three federal waterfowl production areas totaling 676 ha and state properties totaling 2,127 ha; wildlife was the priority for management on 69% of the state lands. A winter severity index (Gates and Hale 1974) averaged 396 and 289 in the winters of 1998-1999 and 1999-2000, respectively, for our 22 survey units (D.R. Schneider, Wisconsin DNR, unpublished data).

Pheasant Surveys

We counted crowing pheasant males from fixed roadside stops (mean=44 stops/survey unit, range=39-47) between mid-April and mid-May in 1999 and 2000. Established stops were spaced 0.8 km apart and were split between two observers, in separate vehicles, who coordinated counts on the same date and time. We conducted surveys during good weather conditions (wind speed <16 kph, no precipitation), beginning 45 minutes before sunrise and finishing 1-1.5 h after sunrise. At each stop observers listened for three minutes and marked locations of observed or crowing pheasants on aerial photos of the route. Observers triangulated birds from multiple stops. Care was taken to not re-count birds at different stops, yet differentiate between birds in close proximity. We surveyed each route twice during the spring, at least seven days apart, and we used the higher of the two counts as the pheasant index for the unit.

The layout of roadside stops within one survey unit (Puchyan) was complicated by the presence of an extensive marsh that was not dissected by roads. The other 21 units averaged 93% of their area (range=76-99%) within 0.8 km of survey stops, and 99% of their area (range=91-100%) within 1.2 km of survey stops. The Puchyan unit had only 64% and 78% of the unit's area within 0.8 km and 1.2 km of survey stops, respectively. Nearly all pheasants (96.6%) were heard within 0.8 km of survey stops, and 99.8% of pheasants were heard within 1.2 km of survey stops. We divided the Puchyan unit's pheasant counts by 0.86 to extrapolate them up to the size of all other survey units, using the proportion of the unit within 1.2 km of survey stops in a ratio of the Puchyan unit over the minimum of all other units (i.e. 0.86=0.78/0.91).

Land Cover Mapping

We mapped all land cover within each circular survey unit onto orthophotos in June 1999. We classified land cover into 22 classes in the field, which were later pooled into six broad classes for analyses (Table 1). We used ArcGIS version 8.0 for all spatial data entry and management, and version 10.1 for spatial analyses (Environmental Systems Research Institute, Inc., Redlands, CA). Nine cover types were drawn on maps as lines or points and buffered to create polygon shapefiles, which were then "burned" into the land cover polygon shapefiles using GIS overlays. Buffer distances were: 1 m for shrub row, tree row, herbaceous ditch, woody ditch, and creek; 3 m for roads; and 5 m for railroads and lone trees. We assumed that roadside grass existed on both sides of every road, except where woody linear cover, polygon cover of grass, or polygon cover of trees existed; roadside grass was then an additional 2-m width outside the outer edges of buffered road areas. We divided the Puchyan unit's land cover areas by 0.86 to extrapolate them up to the size of all other survey units (32.4 km^2), based on the composition of the area that was mapped.

We defined primary winter cover as a subset of winter cover (Table 1) that was ≥8.1 ha in a block, ignoring their dissection by roads or other linear cover (Figure 2). We calculated eight variables (Table 2) for each unit that involved primary winter cover: area of all primary winter cover (PWC), area of corn within 402 m, area of agricultural fields within 402 m (AGPWC), area of woody cover within 402 m (WDPWC), and area of secure nest cover within 402 m, 804 m, 1.2 km, and 1.6 km. Food from corn and other agricultural fields within 402 m of winter cover are important to the survival of pheasant populations (Gates and Hale 1974). Forest cover is preferred habitat for major pheasant predators (Pils and Martin 1978, Petersen 1979) and therefore believed to be a detriment to pheasant abundance when near primary winter cover; however, this woody cover is used by pheasants to survive winter during periods of deep snow (Gatti et al. 1989). Pheasants prefer to nest close to winter cover and fill the landscape as they move out from primary winter cover in spring to nest (Gates and Hale 1974); we therefore expected that secure nest cover closest to primary winter cover would be the most important for pheasant abundance. We also summarized total linear cover (in summed km) in each survey unit as an index of habitat fragmentation for a predictor variable; we expected total linear cover to be negatively related to pheasant abundance (Schmitz and Clark 1999).

We converted polygon shapefiles of the six aggregated land cover classes (Table 1) into raster format (1×1–m cell size) to calculate their spatial pattern metrics using FRAGSTATS version 4.1 (University of Massachusetts, Amherst, MA). We included the "other cover" class only in total landscape metrics, but did not use it for class-level metrics. We explored the effects of habitat edges on pheasants using various edge depths and edge contrasts within FRAGSTATS. We were interested only in using core area variables (using edge depth) for winter cover and secure nest cover classes. We considered three core area variables for six options of edge depths based on studies of avian nest success in grasslands: 75 m (Pasitschniak-Arts and Messier 1995), 60 m (Burger et al. 1994), 15 m

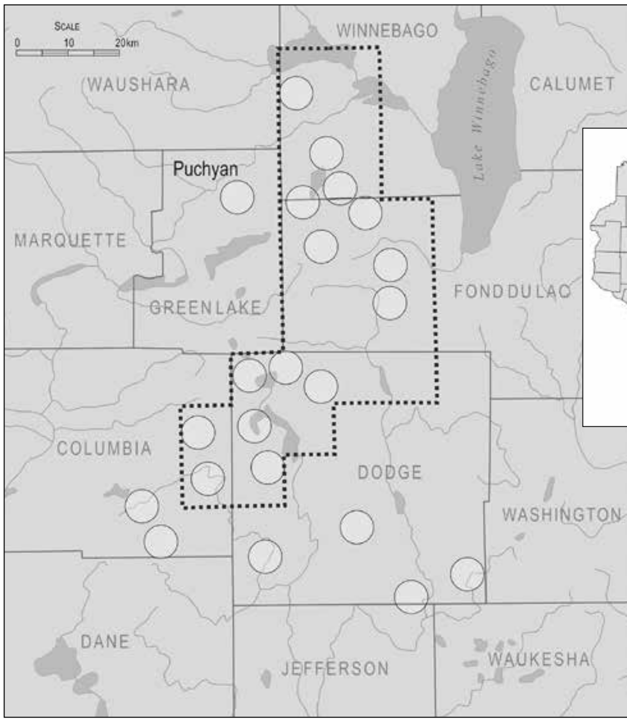

Figure 1. *The Glacial Habitat Restoration Area (GHRA) and pheasant survey units studied within south-central Wisconsin, 1999-2000. The circles are pheasant survey units and the GHRA boundary is outlined in dashed lines.*

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Pheasant survey units centered on shrub/cattail winter cover.

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Food from agricultural fields near winter cover is important for pheasant survival.

Table 1. *Coverage of land cover classes and their aggregations within pheasant survey units in south-central Wisconsin, 1999.*

Land Cover Class[1]	% of All Units Mean	% of All Units Range	Aggregated Class	% of All Units Mean	% of All Units Range
Corn	28.8	16-43	Agriculture	48.7	29-68
Soybeans or Peas	13.6	6-25			
Small Grains	3.6	1-8			
Bare Soil or Crop Stubble	0.5	0-5			
Vegetable or Unknown Crop	0.3	0-1			
Pasture With Trees	1.5	0-7			
Open Pasture	0.5	0-2			
Alfalfa Hay	10.3	4-17	Disturbed Nest Cover	10.9	4-18
Grassy Roadside or Ditch	0.6	0-1			
Open Upland Grass	4.3	1-11	Secure Nest Cover	14.1	4-28
Upland Grass With Shrubs	1.2	0-4			
Wet Meadow	8.3	2-14			
Fallow	0.4	0-2			
Cattails or Other Emergents	5.2	0-13	Winter Cover	9.9	2-18
Shrub Wetland	4.4	1-11			
Upland Shrubs or Young Conifers	0.3	0-2			
Deciduous Forest	9.1	4-28	Woody Cover	9.5	4-29
Conifer Forest	0.2	0-1			
Isolated or Linear Trees or Shrubs	0.3	0-1			
Open Water or Creek	2.4	0-14	Other Cover	7.0	3-20
Residential	3.8	2-6			
Road or Railroad	0.8	0-1			

[1]Classes used to map land cover in the field.

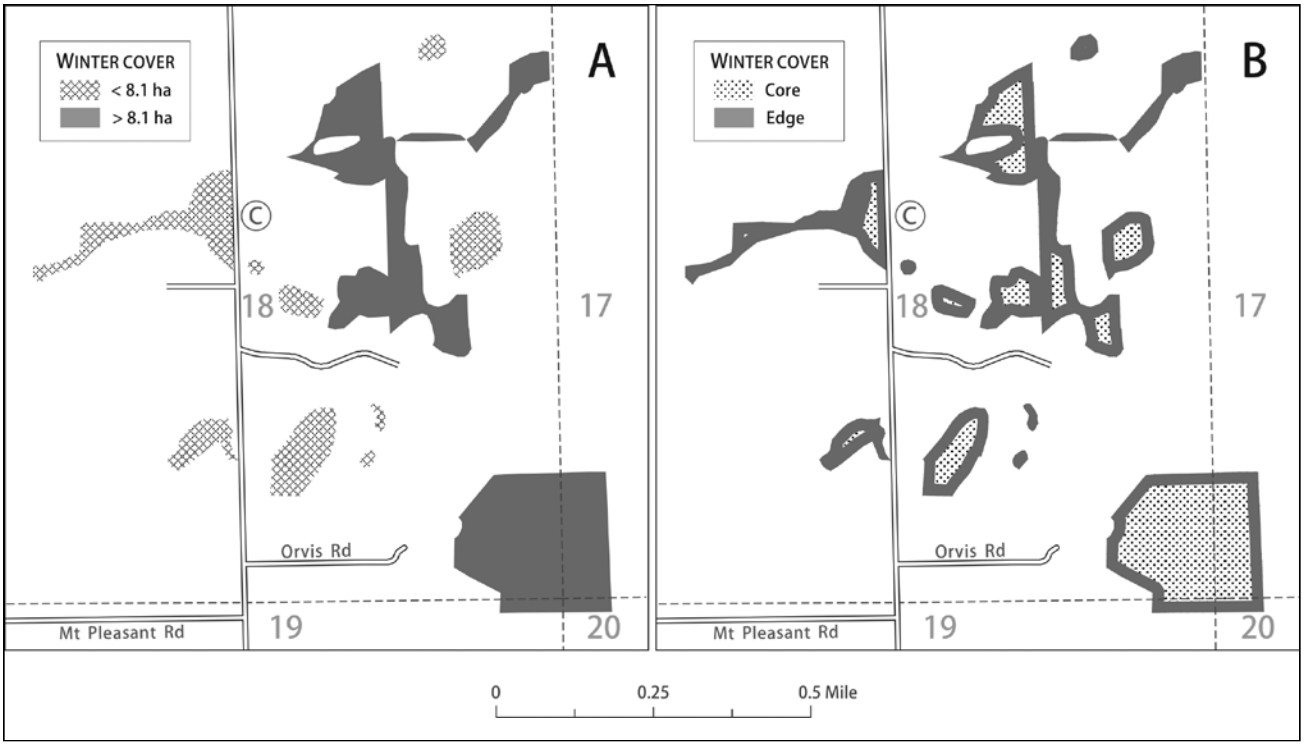

Figure 2. *Examples of winter cover site definitions based on size (A) and edge depth (B) in sections 17-20, Town of Lamartine, Fond du Lac County. Primary winter cover sites are >8.1 ha in size. Core area winter cover sites are >10 m from edge. Edge depths are not shown to scale, but exaggerated for purposes of illustration.*

Table 2. *Acronyms and descriptions for variables of land cover and spatial pattern metrics used in models to predict ring-necked pheasant abundance in pheasant survey units in south-central Wisconsin, 1999-2000.*

Acronym[1]	Description
AGPWC	Area of agricultural fields within 402 m of primary winter cover.
AGRIC	Area of all agricultural fields.
ALF	Area of all alfalfa hay.
DECIDF	Area of all deciduous forests.
LNWOOD	Area of all isolated or linear woody cover.
PWC	Area of all primary winter cover (block of winter cover >8.1 ha).
SECNC	Area of all secure nest cover.
WDPWC	Area of woody cover within 402 m of primary winter cover.
WSHRB	Area of all shrub wetlands.
CAIMNWC	Mean core area index for winter cover (i.e. mean % of winter cover patch areas that are >15 m from the edge).
FRACMNAG	Mean shape complexity for patches of agricultural fields.
FRACMNSC	Mean shape complexity for patches of secure nest cover patches.
FRACMNWC	Mean shape complexity for patches of winter cover.
INJUXAG	Interspersion and juxtaposition of agricultural fields.
INJUXSC	Interspersion and juxtaposition of secure nest cover patches.
INJUXWO	Interspersion and juxtaposition of woody cover patches.
ISOLATDN	Isolation of disturbed nest cover patches.
LPAFRAC	Landscape-level perimeter-area fractal dimension.
NDCAWC	Number of disjunct core areas (i.e. >10 m from edge) of winter cover.
SIDN	Shape index for patches of disturbed nest cover.
SIWO	Shape index for patches of woody cover.
LTECI	Landscape-level total edge contrast index between patches (% of maximum possible structural contrast).

[1] First grouping includes variables of habitat coverage; second grouping includes variables of habitat spatial pattern. Variables used in top models are in bold type.

(R.C. Gatti, Wisconsin DNR, unpublished data), and three edge depths below the resolution of the latter data, 10 m, 5 m, and 1 m. We found no *a priori* basis for setting contrasts between habitat edges from the pheasant literature, so we considered five sets of options for edge contrasts, meaning structural contrast of adjacent edges, ranging from 0.1 to 1.0 between pairings of aggregated land cover class edges. We calculated 40 other spatial pattern parameters of land cover (five classes × eight parameters/class) at the class scale and 10 parameters at the landscape scale that involved edge density, edge contrast, patch size, patch shape, patch density, patch interspersion and juxtaposition, patch isolation, and landscape diversity.

Analyses

We used SAS Enterprise Guide version 4.3 (Statistical Analysis System Institute, Inc., Cary, NC) for all statistical analyses. We calculated Pearson correlation coefficients among initial variables and used them to eliminate variables that were providing redundant information; in these cases of highly correlated pairs ($P<0.001$), we eliminated the variable that was least correlated with the pheasant index. After variable reduction, the remaining parameters were used as predictor variables in regression analyses.

We log-transformed the pheasant index and used it as the response variable in multiple regression (PROC GLMSELECT) with *a priori* models of land cover class area and spatial pattern metrics of land cover. We derived models with assumptions of seven general habitat relationships with pheasant abundance from the literature: three with positive relationships (abundance of secure nest cover, secure winter cover of shrub-cattail wetlands, and agricultural food near secure winter cover), two with negative relationships (abundance of disturbed nest cover, and complexity and fragmentation of critical pheasant habitat across the landscape), and woody cover, whose abundance can have both negative (havens of high predator abundance) and positive (used to survive the most severe winter weather periods) relationships with pheasants. We limited individual models to 1-4 variables to avoid overfitting models, given our sample size (n=22 survey units). The inclusion of many spatial pattern variables led us to double the number of models by various combinations of habitat and spatial metrics of interest. While their inclusion makes biological sense, their combinations have not been adequately evaluated in the pheasant literature to predict abundance. We chose this extension into more descriptive or exploratory evaluation of spatial metrics because this analysis was an interim evaluation of pheasant-habitat relationships whose finding will be re-tested upon completion of the habitat restoration plan in the GHRA. For each model we calculated Akaike's Information Criterion corrected for small sample sizes (AICc) and ranked candidate models according to their AICc (Burnham and Anderson 2010). We then calculated the difference in AICc between each model and the model with the minimum AICc to discover patterns in the importance of pheasant-habitat relationships (Burnham and Anderson 2010). We kept a separate ranking of models with and without the spatial pattern metrics to more easily evaluate the exploratory aspect of the analysis.

Results

Pheasant Abundance and Land Cover

We found considerable differences between pheasant indices of the units in 1999 and 2000, just two months before and 10 months after mapping the land cover, respectively. Pheasant counts increased 12% between the years on average, but were highly variable among units. The change in the pheasant count between years ranged from –60% to +85% among the units; 13 units increased and nine units decreased. This suggests high sampling variance in the pheasant indices because the areas of habitats that are assumed to be critical to pheasant abundance are unlikely to change much in one year. We therefore averaged the 1999 and 2000 pheasant indices and used the log-transformation of this mean for the response variable in all analyses; the un-transformed means ranged 12-fold among the survey units (mean=26.7 pheasants/survey unit; range=6-72).

PHOTOS: JES REES

Agriculture comprised 49% of the area. Fourteen percent was in secure next cover and 10% was in winter cover.

Corn was the most abundant land cover class (29% of the pooled area), followed by soybeans (*Glycine max*) and peas (*Pisum sativum*, 14%), and alfalfa (*Medicago sativa*) hay (10%). Pooled agriculture comprised 49% of the area, while 14% of the area was in secure nest cover and 10% was in winter cover (Table 1). The coverage of secure nest cover ranged 7.6-fold among survey units. Only three of the 22 units were under the 5% secure nest cover goal recommended by Gates (1970), while 10 units had over three times this goal. Similarly, only four units were under the GHRA goal of 6.9% secure nest cover while 11 units had over twice this goal. Over half of the secure nest cover, however, came from the wet meadow class, which has the potential to flood in spring. The coverage of winter cover ranged 8.7-fold among survey units. The coverage of primary winter cover (i.e. winter cover in blocks >8.1 ha) averaged 7.8% in the units and exceeded the goal recommended by Gates (1970) in every unit except one, which consisted of small, isolated wetlands and completely lacked primary winter cover.

Variable Reduction

We selected two of the aggregated land cover classes of interest for modeling because their major component land cover classes were inter-correlated in the same direction: area in pooled agriculture (AGRIC) and secure nest cover (SECNC). The block configuration of PWC was a better index to the benefits of winter cover than its pooled class, and area in "other cover" was not of interest. We also chose area in four of the 22 individual land cover types as model variables. Area in alfalfa hay (ALF) and grassy roadside or ditch were both believed to be sinks for nesting, but from different causes (mowing vs. predation; Gates and Hale 1975, Olsen 1977); though they were not correlated, the latter was highly correlated with the shape index for disturbed nest cover and eliminated. We considered the area in cattail wetlands and the area in shrub wetlands (WSHRB) as separate variables because pheasants use the former as night-roosting in winter and the latter as daytime loafing cover in winter (Gates and Hale 1974), and they were not correlated; however the area in cattail was highly correlated with PWC and eliminated. The area in deciduous forest (DECIDF) and the area in isolated or linear woody cover (LNWOOD) were also entered as separate variables because both are preferred predator habitat, but DECIDF may afford survival advantages during deep snows. We eliminated all but two of the variables (AGPWC and WDPWC) relating habitat proximity to primary winter cover because of high correlation with other variables which were more correlated with the pheasant index.

Core area variables from all six edge depths proved highly correlated with each other, and we eliminated all of the 18 variables except two: the number of disjunct core areas of winter cover >10 m from the edge (NDCAWC) and the mean core area index for winter cover (CAIMNWC), defined as the mean percentage of winter cover patch areas that are >15m from the edge. Variables from all five sets of edge contrasts proved highly correlated with each other, so we chose the set of options whose contrast variables were most highly correlated with pheasant abundance (Table 3). Structural differences between edges (i.e. their contrasts) were highest between secure nest cover and winter cover and secure nest cover and woody cover (0.9), and lowest between woody cover and winter cover (0.1).

Table 3. *Structural contrasts[1] between land cover pairings of patch edges (0 is no contrast, 1 is maximum contrast) in south-central Wisconsin, 1999.*

	Agriculture	Disturbed Nest Cover	Secure Nest Cover	Winter Cover	Woody Cover
Disturbed Nest Cover	0.4	—	—	—	—
Secure Nest Cover	0.8	0.5	—	—	—
Winter Cover	0.6	0.8	0.9	—	—
Woody Cover	0.8	0.7	0.9	0.1	—
Other Cover	0.7	0.8	0.8	0.2	0.2

[1]Input to FRAGSTATS for edge contrast variable calculations.

Table 4. *Spatial pattern variables used to explain pheasant abundance in south-central Wisconsin, 1999-2000.*

Spatial Pattern Variable[1]	Scale	Class	Mean	Minimum	Maximum
FRACMNAG	Class	Agriculture	1.096	1.067	1.148
INJUXAG	Class	Agriculture	85.4	79.1	91.9
SIDN	Class	Disturbed Nest Cover	38.3	28.7	57.3
ISOLATDN	Class	Disturbed Nest Cover	43.7	14.2	72.4
FRACMNSC	Class	Secure Nest Cover	1.232	1.151	1.324
INJUXSC	Class	Secure Nest Cover	91.3	77.1	98.0
FRACMNWC	Class	Winter Cover	1.128	1.093	1.172
NDCAWC	Class	Winter Cover	121	64	240
CAIMNWC	Class	Winter Cover	26.8	17.1	59.1
SIWO	Class	Woody Cover	30.6	20.1	38.0
INJUXWO	Class	Woody Cover	86.8	77.7	96.6
LPAFRAC	Landscape	All	1.278	1.214	1.335
LTECI	Landscape	All	63.9	60.1	69.0

[1]Output from FRAGSTATS; see Table 2 for definition of variables.

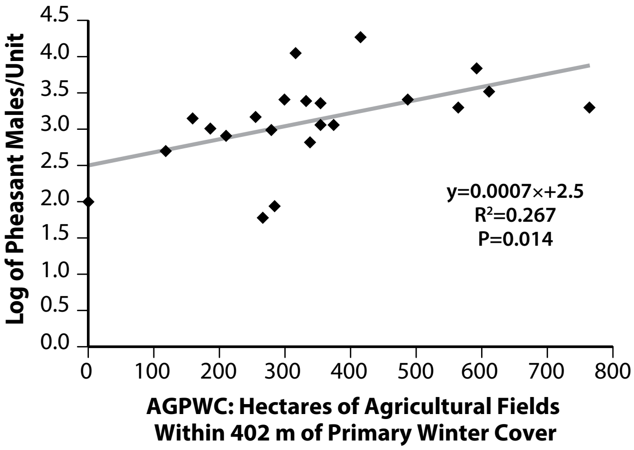

Figure 3. *The relationship between pheasant abundance and coverage of agricultural fields near primary winter cover (AGPWC) in south-central Wisconsin. The highest ranking univariate land cover model.*

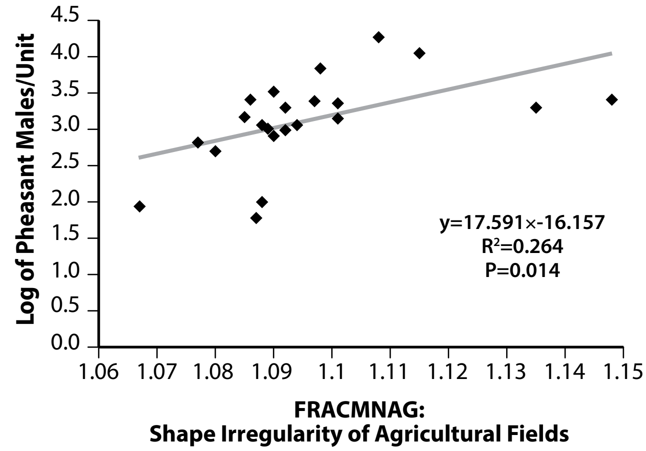

Figure 4. *The relationship between the abundance of pheasants and shape of agricultural fields (FRACMNAG) in south-central Wisconsin. The highest ranking univariate model using spatial pattern metrics.*

Table 5. *Top 30 competing models that only use land cover variables to explain pheasant abundance in 22 pheasant survey units in southeast Wisconsin, 1999-2000.*

Model[1]	P level[2]	AICc [3]	DAICc[4]
AGPWC+PWC	**0.008**	**-1.123**	**0.000**
AGPWC+PWC+ALF	**0.011**	**0.176**	**1.299**
AGPWC	**0.014**	**0.261**	**1.384**
AGPWC+PWC+DECIDF	**0.012**	**0.517**	**1.640**
AGRIC	0.025	1.461	2.584
AGPWC+PWC+SECNC	0.021	1.882	3.005
AGPWC+PWC+WDPWC	0.022	2.078	3.201
AGPWC+ALF	0.034	2.287	3.411
AGPWC+SECNC	0.035	2.341	3.464
AGPWC+PWC+DECIDF+ALF	0.017	2.482	3.606
AGPWC+DECIDF	0.046	2.994	4.117
AGPWC+WDPWC	0.052	3.268	4.391
AGPWC+PWC+SECNC+ALF	0.027	3.948	5.071
ALF	0.100	4.047	5.170
AGPWC+PWC+SECNC+DECIDF	0.030	4.245	5.368
AGRIC+PWC	0.087	4.450	5.573
DECIDF	0.148	4.738	5.862
AGPWC+SECNC+ALF	0.069	5.074	6.197
SECNC	0.235	5.501	6.624
AGPWC+ALF+DECIDF	0.082	5.514	6.637
AGPWC+SECNC+DECIDF	0.084	5.578	6.702
PWC+DECIDF	0.156	5.658	6.781
PWC+ALF	0.148	5.682	6.805
ALF+DECIDF	0.150	5.724	6.847
ALF+PWC+DECIDF	0.089	5.763	6.886
WDPWC	0.332	6.031	7.155
ALF+SECNC	0.192	6.290	7.413
LNWOOD	0.453	6.460	7.583
PWC	0.581	6.750	7.873
SECNC+DECIDF	0.234	6.752	7.876

[1] See text for definition of variables.
[2] Probability >F from general linear model.
[3] Score of the Akaike's Information Criterion corrected for small sample sizes.
[4] Difference between the AICc of the model and the highest ranking model.

Table 6. *Top 30 competing models that use land cover and spatial pattern variables to explain pheasant abundance in 22 pheasant survey units in southeast Wisconsin, 1999-2000.*

Model[1]	P level[2]	AICc[3]	DAICc[4]
INJUXAG+NDCAWC+LTECI	**0.001**	**-5.025**	**0.000**
INJUXAG+NDCAWC+LTECI+FRACMNAG	**0.001**	**-4.482**	**0.543**
INJUXAG+LTECI+FRACMNAG	**0.002**	**-4.130**	**0.894**
INJUXAG+NDCAWC	**0.003**	**-3.165**	**1.859**
INJUXAG+NDCAWC+FRACMNAG	**0.003**	**-3.099**	**1.926**
INJUXAG+NDCAWC+SECNC	0.004	-2.627	2.398
LTECI+FRACMNAG	0.005	-2.190	2.835
INJUXAG+LTECI	0.006	-1.846	3.179
LTECI+AGPWC	0.007	-1.283	3.742
INJUXAG+NDCAWC+LTECI+AGPWC	0.005	-1.224	3.801
AGPWC+PWC *	0.008	-1.123	3.902
INJUXAG+FRACMNAG	0.008	-1.112	3.912
LTECI+FRACMNAG+AGPWC	0.008	-0.706	4.318
NDCAWC+LTECI+FRACMNAG	0.008	-0.600	4.427
LTECI+LPAFRAC	0.010	-0.506	4.518
INJUXAG+LTECI+FRACMNAG+AGPWC	0.006	-0.491	4.534
INJUXAG+LTECI+AGPWC	0.008	-0.470	4.554
NDCAWC+FRACMNAG+AGPWC	0.010	0.029	5.054
NDCAWC+LTECI	0.014	0.174	5.199
AGPWC+PWC+ALF *	0.011	0.176	5.201
INJUXAG+NDCAWC+AGPWC	0.011	0.225	5.250
NDCAWC+SECNC	0.014	0.235	5.260
AGPWC *	0.014	0.261	5.285
FRACMNAG	0.014	0.347	5.372
INJUXAG+NDCAWC+FRACMNAG+AGPWC	0.008	0.389	5.413
FRACMNAG+AGPWC	0.016	0.516	5.540
AGPWC+PWC+DECIDF *	0.012	0.517	5.542
NDCAWC+FRACMNAG	0.016	0.586	5.610
LTECI	0.018	0.746	5.771
LTECI+FRACMNAG+SECNC	0.014	0.919	5.944

[1] See text for definition of variables.
[2] Probability >F from general linear model.
[3] Score of the Akaike's Information Criterion corrected for small sample sizes.
[4] Difference between the AICc of the model and the highest ranking model.
* Model among the top 30 models in Table 5.

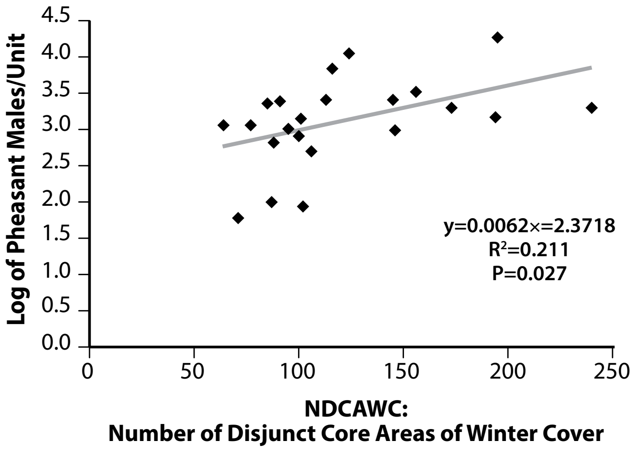

Figure 5. *The relationship between the abundance of pheasants and the number of disjunct core areas of winter cover (NDCAWC) in south-central Wisconsin.*

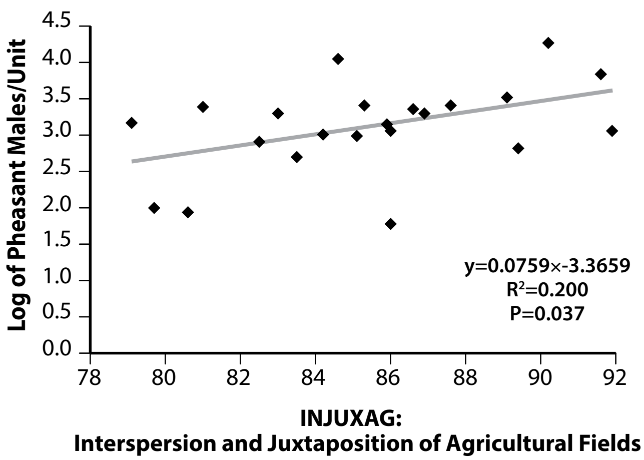

Figure 6. *The relationship between the abundance of pheasants and interspersion and juxtaposition of agricultural fields (INJUXAG) in south-central Wisconsin.*

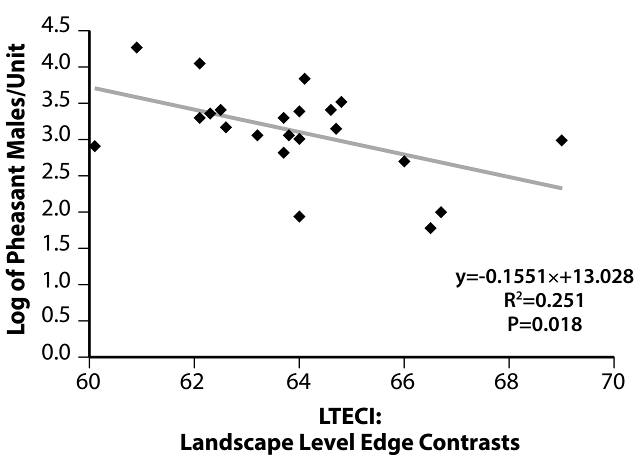

Figure 7. *The relationship between the abundance of pheasants and the total edge contrast among habitat patch edges on the landscape (LTECI) in south-central Wisconsin.*

We eliminated 55 of the initial 68 spatial pattern variables because of correlation among variables. The remaining spatial pattern variables included 11 class-level variables and two landscape-level variables (Table 4). The class-level variables were: the mean shape complexity for patches of agriculture (FRACMNAG), secure nest cover (FRACMNSC), and winter cover (FRACMNWC), the interspersion and juxtaposition of agricultural fields (INJUXAG), secure nest cover (INJUXSC), and woody cover (INJUXWO), NDCAWC, CAIMNWC, the shape index for patches of disturbed nest cover (SIDN) and woody cover (SIWO), and the isolation of disturbed nest cover patches (ISOLATDN). The landscape-level variables were: perimeter-area fractal dimension (LPAFRAC) and the total edge contrast index (LTECI) between patch edges on the landscape, expressed as a percent of maximum possible contrast.

Regression Models

When spatial pattern metrics were not considered, the most parsimonious model incorporated AGPWC and PWC and was ranked 1.30 AICc units ahead of its closest competitor (Table 5). Four models were within two AICc units of the top model, and they all included AGPWC; three of these models also included PWC, while two models also included ALF or DECIDF. Pheasant abundance was positively related ($P=0.014$) to AGPWC (Figure 3), which means pheasant abundance was greater when there was more coverage of agricultural fields within 402 m of cattail or wetland shrub areas, which were >8.1 ha in size. An inverse relationship between pheasant abundance and PWC only showed weakly ($P=0.05$) in the top model; however, this relationship was heavily influenced by two outliers, which were units with the lowest pheasant numbers, yet the highest coverage of primary winter cover. The coverage of ALF or DECIDF were not related ($P>0.13$) to pheasant abundance after their inclusion into models with AGPWC and PWC. Pheasant abundance was also positively related to AGRIC ($P=0.03$), although this was not among the top models.

When spatial pattern metrics were also considered, the most parsimonious model incorporated INJUXAG, NDCAWC, and LTECI, and was ranked 0.54 AICc units ahead of its closest competitor (Table 6). Five models were within two AICc units of the top model, and they all included INJUXAG and only included spatial pattern variables; four of these models also included NDCAWC, three models included LTECI, and three models included FRACMNAG. Pheasant abundance was positively related to FRACMNAG ($P=0.01$, Figure 4), NDCAWC ($P=0.03$, Figure 5), and INJUXAG ($P=0.04$, Figure 6), and negatively related to LTECI ($P=0.02$, Figure 7). In the top model each of the three variables were still related to pheasant abundance after the other two variables were considered, and in the same direction. This suggests that pheasant abundance was higher with more blocks of core winter cover (defined by area >10 m from the edge) and more evenly distributed agricultural fields; pheasant abundance decreased with increasing contrast between structure of edges of habitat patches across the landscape.

Discussion

When spatial pattern of land cover was not considered, the only land cover classes that helped explain pheasant abundance were the total coverage of agricultural fields and the coverage of agricultural fields within 402 m of winter cover areas that were >8.1 ha in size, both in a positive direction. This suggests the importance of winter food for pheasant abundance. Our finding is somewhat surprising in that we had no measure of the amount of corn or other feed grains available (standing) for winter food, but assume that our AGRIC and AGPWC variables were reflecting that. Gates (1970) and Gates and Hale (1974) found in their 1958-1966 south-central Wisconsin study that winter food was in short supply and as important to provide in pheasant management as winter cover. Since that time, southern Wisconsin's deer population has increased 15-fold (R.E. Rolley, Wisconsin DNR, unpublished data). These large deer populations also concentrate in shrub wetlands in winter (Larson et al. 1978) and may have increased competition for adjacent winter food to the point that winter food is even more limiting for pheasant populations.

We found no support for the benefit of more secure nest cover (P>0.23), or the negative impacts of alfalfa, narrow areas of grass nest cover, or any types of woody cover to pheasants. The total coverage of cattails, wetland shrubs, or total winter cover also was not helpful in explaining pheasant abundance among the survey units. The coverage of primary winter cover, while included in most of the top models, had only a weak negative relation to pheasant abundance in the top model; however, two survey units with the lowest pheasant numbers, the highest coverage of primary winter cover, and the farthest north are responsible for the relationship and without them there was no relationship (P>0.20). This suggests that something different might be operating in these two units at the geographic edge of our study area that we were not monitoring (e.g., predation pressure) to produce extremely low levels of pheasant abundance. Nonetheless, the importance of nest cover and winter cover reported in many other studies was not seen in our data. Gates and Hale (1974) concluded that winter cover was the most critical habitat needed for pheasants in Wisconsin and recommended 12 ha/management unit of our dimensions as the ideal amount of winter cover. The amount of winter cover in our units was much greater than this, averaging 322 ha and ranging from 66 to 575 ha; this abundance may be above a threshold where amount of winter cover is no longer limiting pheasants. Likewise, nest cover in our units exceeded their recommended coverage/unit (168 ha=5% of the unit), averaging 458 ha and ranging from 117 to 893 ha/unit. Coverage of secure nest cover at this high end of the scale may also not be limiting or influencing pheasant abundance. Recent studies relating pheasant abundance to grass coverage on the landscape offer conflicting results. A positive relation was found in Minnesota, where grass coverage ranged from 2% to 33% (Haroldson et al. 2006), but in Iowa a positive relation was only present in two of six regions and not statewide, where grassland cover ranged from 3% to 6% (Nusser et al. 2004). Nielson et al. (2008) conducted a multi-state study and found an overall positive relation between pheasant abundance and coverage of herbaceous vegetation provided by the Conservation Reserve Program and agricultural fields, although the relation with herbaceous cover was variable among regions. We agree with Nielson et al. (2008) that regional variation suggests that regionally different models for nest cover may be more appropriate.

Sample et al. (2003) studied the relation between pheasant abundance and land cover in six survey units of similar design from 1984-93 in this same area of south-central Wisconsin. Their best model included positive relationships to coverage of high quality grass, cattails, and shrub wetlands, which is in contrast to our findings. However, their analyses looked at pheasant-habitat relationships across years and survey units, while we only looked among survey units. When their analysis was restricted to differences among units, pheasant abundance was only related to coverage of shrub wetlands (P=0.02 as univariate and P=0.05 in full model) and not cattails or high quality grass (P.W. Rasmussen, Wisconsin DNR, unpublished data). The coverage of shrub wetlands in their study averaged lower

ANDREW BUBOLZ

Woody shrub cover did not appear to significantly benefit pheasants in the study area when >5 % of the landscape.

JES REES

Disjunct core areas with abundant winter cover appear to be important for pheasant survival.

(2.6%) and ranged considerably less (0-4%) among their units than in our study (mean=4.4%, range=1-11%). When we only considered data from our study within these lower ranges of wetland shrub coverage we found the same positive relationship with pheasant abundance (P=0.02, Figure 8). This supports the existence of a threshold of winter cover above which it no longer benefits pheasant abundance (as discussed previously), and suggests the threshold is near 4-5% of the landscape.

When variables involving spatial pattern of land cover were also considered, their importance exceeded all other habitat variables. Only variables of spatial pattern comprised the top five models, an unexpected result. There was a strong positive relationship between pheasant abundance and the number of disjunct core areas of winter cover. This suggests that winter cover is important in a more complicated way than simple winter coverage area. It recognizes the importance of: 1) winter cover patches >8.1 ha in size, 2) core areas of these patches >10 m from the edge, and 3) the number of these areas, all of which are more important than their total area on the landscape. In spite of abundant winter cover in our study area, the importance of disjunct core areas suggests the need for diversity of options for pheasants in winter.

Two variables associated with the spatial pattern of agricultural fields were also positively related to pheasant abundance, the shape and dispersion of agricultural fields, presumably of importance for winter food. Although the benefit of greater dispersion of winter food options seems logical, this is surprising, given the abundance of agricultural fields (49% of the landscape). The benefit of more irregularly shaped fields of winter food suggests an edge effect, but how this works remains unclear. The importance of winter food would come from unharvested corn, which was not provided by management but occurred as a result of limiting harvest conditions. In spite of dry fall weather in south-central Wisconsin in 1999 (42% below normal September-November precipitation, Wisconsin State Climatology Office 2014), over 40,400 ha of planted corn were left unharvested in south-central Wisconsin (Wisconsin Agricultural Statistics Service 2000). But because we did not map standing corn within agricultural fields it is difficult to explain how the importance of its location, shape, and interspersion would interact with pheasant abundance.

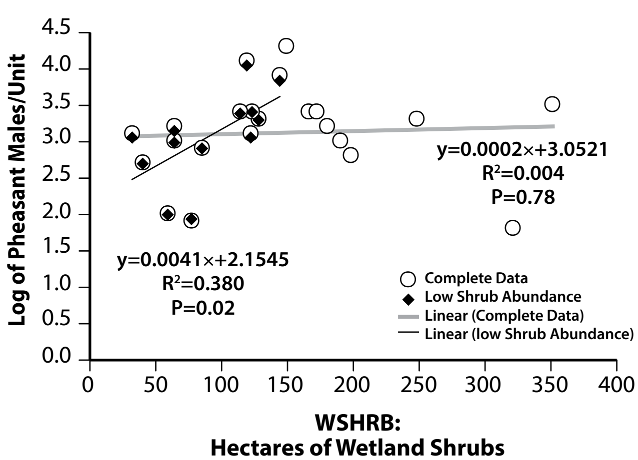

Figure 8. *The relationship between the abundance of pheasants and the coverage of wetland shrubs (WSHRB) in south-central Wisconsin, as shown in a subset of the data (low shrub coverage) and full data.*

The importance of total edge contrast was also among the top models, indicating fewer pheasants when the contrast between structures of edges was greater. The greatest part of total edge contrast came from edges between patches of secure nest cover, disturbed nest cover, and agricultural fields, while winter cover patches contributed the least. The importance of total edge contrast was unexpected. We would expect the mechanism for its importance to be reduced survival as pheasant moved between cover types, particularly ranging from winter cover (Gates and Hale 1974). The low contribution from winter cover patch edges is even more surprising.

There have been several studies reporting the relation of spatial pattern metrics of habitat to pheasant survival. Clark et al. (1999) evaluated 19 spatial pattern metrics but found only three related to pheasant nest success: mean core area (negative), total patch size (positive), and grassland core area standard deviation (positive). Schmitz and Clark (1999) evaluated five spatial pattern metrics, including a 50-m edge depth, but found only edge density related (negatively) to pheasant survival during spring. Nielson et al. (2008) evaluated three spatial pattern metrics and found two to be related to pheasant counts in one of 11 regions each (mean patch size positively and interspersion-juxtaposition of patches negatively). We explored most of these parameters in our study, but selected none of them in our best models.

In general, the overwhelming importance of spatial pattern metrics came from a more exploratory analysis, where there were many inter-correlated predictor variables that underwent variable reduction. While these are thought-provoking findings, they should be considered preliminary; they need further evaluation, which will take place in future years of the GHRA implementation. We found no support that the abundance of secure nest cover and pheasants were positively related, which is the primary assumption behind habitat restoration in the GHRA. The broad range of coverage of secure nest cover we studied among survey units (0.5 to 4.0 times the GHRA goal) hints that the grassland restoration program may not restore pheasant populations in southern Wisconsin. Because spatial pattern metrics of habitat were more important than coverage of habitat classes, we suggest that habitat configuration should be considered for pheasant management. However, because we did not directly map available winter food within agricultural fields it is presumptuous to prescribe distributing irregularly-shaped agricultural fields near winter cover. In our study area, an even distribution of irregularly-shaped agricultural fields provided by private landowners without our direction likely resulted in more available winter food, but further research could determine how this interaction operates or whether direct management of food plots is a simpler alternative. The greater importance of winter cover and winter food over nest cover to pheasant abundance suggests a different direction for pheasant management in Wisconsin, focused on scattering core areas of winter cover and providing winter food adjacent to them.

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