Transactions of the Illinois State Academy of Science
(1998), Volume 91, 3 and 4, pp.167-178

received 2/25/98
accepted 5/28/98

Landscape Characteristics and Spatial Patterns of Eastern Cottontail Abundance in Illinois

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ABSTRACT

I quantified landscape composition and pattern throughout Illinois from classified satellite imagery and compared them to abundance indexes of the eastern cottontail (*Sylvilagus floridanus*). Rabbits were most abundant in diverse, patchy landscapes that contained moderate amounts of row crops and grassland, and abundant woody edge. These findings were incorporated into a PATREC habitat model to identify and map Illinois landscapes potentially suitable for cottontails. Such landscapes were primarily associated with poorer quality soils and/or areas too hilly for extensive row cropping.

Key Words: Cottontail, habitat, habitat model, Illinois, landscape, rabbit, remote sensing, satellite imagery, *Sylvilagus floridanus*

INTRODUCTION

The cottontail is a habitat generalist that favors disturbed, successional, and transitional vegetative communities (Chapman et al. 1982). Such habitats have become progressively less common in Illinois resulting in substantial declines in rabbit abundance over the past 30-40 years (Kenney 1985, Warner and Onstad 1994). To address these problems at a regional or statewide level, wildlife managers require the ability to inventory, analyze, and interpret habitat at various spatial scales and resolutions (Flather et al. 1992). Classified satellite imagery coupled with powerful computer systems now provide resource managers with the means to assess landscape composition and pattern over large geographic areas (Roseberry and Hao 1996). Questions remain, however, as to whether the distribution and abundance of rabbits are correlated with landscape characteristics and, if so, can these characteristics be discerned from satellite imagery. Habitat preferences of eastern cottontails at the microlevel have been well documented (Swihart and Yahner 1984, Medve 1987, Boyd and Henry 1991, Althoff et al. 1997), but less is known about macrolevel preferences except that diversity and interspersion are important (Uhlig and Anderson 1959). I investigated relationships between cottontail abundance and landscape characteristics through the integrated use of remote sensing, geographic information systems (GIS), and habitat modeling. Specific study objectives were 1) to investigate the relationships between landscape structure (composition and pattern) and

cottontail abundance in Illinois, and 2) to incorporate the findings into a habitat model to inventory Illinois landscapes potentially suitable for rabbits.

STUDY AREA AND METHODS

I examined cottontail–landscape relations at 2 spatial scales. Individual Illinois counties (n = 102) represented large scale study areas (430 - 2,965 km^2). Small-scale study areas (76 - 111 km^2) were 3-km wide buffer zones around 32-km census routes established throughout the state (n = 81).

Population Data

I used hunter harvest density estimates (mean harvest/km^2, 1989-93) as an index of cottontail abundance at the county level. These estimates are obtained annually by the Illinois Department of Natural Resources (IDNR) from post-season questionnaires mailed to a random sample of about 4,700 resident hunting license holders (Anderson et al. 1995). I used harvest density rather than harvest per effort because the former is a function of cottontail abundance and hunter effort; both of which are related to amount of available habitat. In addition, harvest/effort may be biased in counties with little habitat because of small sample sizes, and because effort tends to be concentrated in the limited habitat that does exist (Roseberry and Sudkamp 1998). Census route population data represented mean (1986-89) numbers of cottontails observed by IDNR biologists during roadside counts conducted in March along 81 32-km transects distributed throughout the state.

Landscape Data

Digital land cover data were derived from the Illinois Landcover Database (Illinois Department of Natural Resources 1996*a*). This database contained a land cover classification based on spectral interpretation of 1991-1995 Landsat TM satellite imagery and existing GIS data layers, with overall accuracy estimated at over 85% (Illinois Department of Natural Resources 1996*b*). I combined several of the 23 original land cover/land use classes (Table 1) while retaining the original spatial resolution of 28.5 x 28.5 m (0.08 ha).

Buffer zones within 1.5 km of each IDNR census route were delineated and extracted using the GIS software TNTmips (Map and Image Processing System, MicroImages, Lincoln NE). Landscape composition and pattern for each county and route buffer were quantified with the spatial analysis program FRAGSTATS (McGarigal and Marks 1995). Additional county-level data included a basic soil productivity index (Mausel et al. 1975) and the proportion of area with slope of <8, 8-18, and >18% slope (Runge et al. 1969).

Habitat Model Development and Application

I quantified landscape suitability for cottontails with a pattern recognition (PATREC) model. This approach uses Bayes' theorem of conditional probability (Williams et al. 1978, Morrison et al. 1992) to assess habitat suitability based on probabilities that a particular habitat condition (e.g., suitable, unsuitable) is consistent with a set of observed environmental attributes (e.g., landscape characteristics). Model variables (Table 2) were selected from visual examination of plots of individual landscape metrics vs. county harvest densities . Only variables that were theoretically meaningful, predictive, and

consistent with the resolution and accuracy of the land-cover data were selected. Conditional probabilities and category ranges (Table 2) were based on observed frequencies of the data plots (Fig 1; after Haithcoat and Hallett 1987).

Landscape conditions within each county and route were assessed with a moving window (after Roseberry and Sudkamp 1998). Landscape metrics were generated and PATREC probabilities computed for overlapping 2.6-km^2 circles; probabilities were mapped at a resolution of 85.5 x 85.5 m (0.73 ha). The proportion of each county and route with PATREC probabilities of <0.15, 0.15-0.39, 0.40-0.59, 0.60-0.84, and ≥0.85 was then calculated. A final landscape suitability index (LSI) was derived by systematically combining the probability classes to best fit the regression: log(rabbit density index + 1) = $a + b$(LSI). The resulting index was:

LSI = $(P_{85} + P_{60}) - P_{15}$, with

P_{85} = proportion of area with PATREC value ≥0.85,

P_{60} = proportion of area with PATREC value 0.60 - 0.84, and

P_{15} = proportion of area with PATREC value <0.15

RESULTS

Landscape Structure and Cottontail Abundance

Cottontail abundance in Illinois appeared to be associated with at least 4 landscape variables: proportion of row crops, proportion of grassland, woody edge density, and landscape contagion. County-level harvest densities tended to be highest in counties with 30 - 60% row crops, 15 - 30% grassland, >30m/ha of woody edge, and contagion <65%. (Fig. 1).

Model Validation

I compared model output with county-level harvest densities and census route counts (Fig. 2). The latter comparison represented true model validation; the former did not. Although it was developed exclusively from county-level data, the model performed similarly with both data sets. Virtually all areas with low LSI values had low rabbit populations, whereas areas with high LSI values were about equally likely to have high or low rabbit densities (Table 3 and 4).

Distribution of Potentially Suitable Landscapes

Landscapes potentially suitable for cottontails tended to be located in southcentral and westcentral Illinois, whereas the intensively farmed eastcentral portion of the state was generally devoid of such areas (Fig 3). The relative amount of each county considered unsuitable for rabbits (P_{15}) was positively correlated with soil productivity ($r = 0.85$, $P < 0.001$) and proportion of area with slope <8% ($r = 0.68$, $P < 0.001$). Collectively, these 2 variables accounted for 77% of the variation in distribution of potential rabbit habitat at the county level ($R^2 = 0.77$, $P < 0.001$).

DISCUSSION

Similar to northern bobwhite (*Colinus virginianus*; Roseberry and Sudkamp 1998), cottontails in Illinois were found primarily in heterogeneous, patchy landscapes with moderate amounts of row crops and grassland and abundant woody edge. A notable

characteristic of these landscapes is low contagion. According to Uhlig and Anderson (1959), cottontails thrive in areas where " . . . cropland, grassland and woodland are about equally represented and well distributed." The contagion metric is indicative of such landscapes as it reflects both evenness and interspersion of land-cover types (McGarigal and Marks 1995).

Another characteristic of Illinois landscapes occupied by cottontails is abundant woody edge. Affinity of rabbits for woody vegetation, especially in autumn and winter is well established (Hanson et al. 1969, Swihart and Yahner 1984). Lord (1963) found no relationship between county-level rabbit abundance in Illinois and the proportion of county wooded, although he suggested that some type of relationship between rabbits and wooded areas probably existed. My data confirm Lord's earlier findings and supposition. County-level harvest densities were not correlated with gross amount of woodlands ($P > 0.10$), but were slightly correlated with amount of woody edge ($r = 0.26$, $P < 0.01$).

In addition to low contagion and abundant woody edge, rabbit harvest densities tended to be highest in counties with moderate (30 - 60%) amounts of row crops. This does not necessarily mean, however, that row crops are an essential component of cottontail habitat. Although Klimstra and Corder (1957) found that corn and soybeans were common dietary items of cottontails in southern Illinois, and Mankin (1993) noted seasonal use of crop fields in eastcentral Illinois, Althoff et al. (1997) reported that radio-marked rabbits in Pennsylvania tended to avoid croplands, and intensified row cropping in Illinois has been linked to regional and statewide declines in rabbit abundance (Havera 1973, Vance 1976, Edwards et al. 1981). Rather than constituting an essential habitat component *per se*, it is more likely that row crops are indicative of other landscape characteristics. Illinois counties >60% row-cropped probably afford too little grassy, shrubby, and woody cover, whereas counties <30% row- cropped are likely to be too heavily wooded for rabbits.

In contrast to row crops, grasslands and other herbaceous vegetation are necessary components of rabbit habitat. According to Chapman et al. (1982:111), "The essential ingredients of good cottontail habitat appear to be an abundance of well-distributed escape cover interspersed within a grassland-type community with an abundance of weedy forbs." Why then did the model suggest that intermediate (15 - 30%), rather than predominant, amounts of grassland were preferable? First of all, my study did not identify habitat preference based on use vs availability in the classic sense; rather, it simply compared current abundance to existing landscape conditions. In addition, much of the remaining grassland in Illinois is now generally unsuitable for cottontails. Chapman et al. (1982:104) described the ideal Midwestern grassland situation as: ". . . old, weedy, moderately grazed, unimproved, native grassland pasture containing numerous dense clumps of thorny shrubs and small trees." Present day grasslands tend to be monocultures dominated by tall fescue (*Festuca arundinacea*) and present vastly different conditions then those described above.

Landscape suitability, as measured from satellite imagery, was not a perfect predictor of relative cottontail abundance in Illinois. Although rabbits were rarely, if ever, abundant in unsuitable landscapes, about equal proportions of the apparently suitable landscapes had high and low rabbit densities. The latter situation may reflect a need for proper

habitat conditions at both landscape (macro) and site (micro) level, and the fact that satellite imagery cannot detect the presence or absence of critical site conditions such as brush piles, briar patches, and narrow strip cover (Sudkamp 1997). Low rabbit densities in unsuitable landscapes may reflect a general lack of desirable site conditions as well as their fragmented distribution in space. Small, relatively isolated, local cottontail populations in generally unsuitable landscapes may be threatened by limited immigration and increased susceptibility to predation and hunting (Edwards et al. 1981), and thus be at risk in a metapopulation context (Litvaitis and Villafuerte 1996).

Edwards et al. (1981:769) considered the cottontail's fate in Illinois to be ". . . linked in some direct or indirect fashion to agriculture, the dominant factor in landuse in the state." This observation remains true for several reasons. First of all, as the state's primary land use, farming directly impacts >80% of the Illinois landscape (Warner and Onstad 1994). Secondly, general agricultural systems and individual farming practices affect not only the composition and structure of local vegetative communities (i.e., site conditions), but broad scale spatial patterns as well (i.e., landscape conditions). Both of which influence the distribution and abundance of upland wildlife species in Illinois (Ribic et al. 1998).

Regionally, cottontails are found primarily in those portions of the state where soil fertility and/or terrain restrict row crop agriculture but do not preclude all farming. Even in these areas, unfavorable site conditions may limit rabbit abundance. In the flatter, more fertile portions of Illinois, cottontails exist primarily in relatively isolated, low density populations occupying small, periodically disturbed patches often associated with some type of human habitation or development. Barring major changes in land use, this situation will likely continue into the foreseeable future. The cottontail's moderately adaptive nature, and tolerance for human presence, will allow it to persist as a widely distributed, relatively common component of the Illinois fauna. It will not, however, regain status as an abundant game species. This does not represent a failure of wildlife management, but is simply an inevitable consequence of changing land use. Cottontails can achieve and maintain high levels of abundance only where grass/forb communities are relatively important components of the landscape. Such vegetative types are much less common in Illinois now than in the past (Warner 1994), and are likely to remain so. Most land in Illinois now is either intensively farmed, developed for human habitation, or left relatively undisturbed (Roseberry and Klimstra 1984). There simply are no current land use practices that result in sufficient amounts of successional vegetation to support cottontail populations at high regional or statewide densities. Opportunities for creation of additional grassland habitats at the local level are afforded by the Conservation Reserve Program (CRP) and should be aggressively pursued by IDNR biologists. However, regional or statewide benefits would not be anticipated as only about 2% of Illinois is currently enrolled in this program.

ACKNOWLEDGMENTS

Financial support for this project was provided by the Illinois Department of Natural Resources Division of Wildlife Resources (IDNR-DWR) with funds from the Federal Aid in Wildlife Restoration Program (Project W-106-R). I am grateful to J. C. Cole and L. M. David (IDNR-DWR Upland Wildlife Program) for their support, cooperation, and assistance throughout this project. S. D. Sudkamp and S. Gilbert, Cooperative Wildlife

Research Laboratory, Southern Illinois University at Carbondale (CWRL-SIUC) provided valuable GIS-related assistance. A. Woolf (CWRL-SIUC) constructively reviewed the manuscript.

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Table 1. Remotely-sensed land-cover classes used in this study.

Class	Predominant component
Row crop	Corn, soybeans
Small grains	Winter wheat
Grassland	Pasture, hayfield, CRP[a], early old field
Deciduous woods[b]	Closed canopy deciduous forest
Open canopy woods[b]	Late old fields, surface-mined lands, parks
Coniferous woods[b]	Pine plantations
Bottomland woods[b]	Temporarily or seasonally flooded forest
Orchards–nurseries	Orchards and nurseries
Water	Lakes, rivers, streams
Wetlands	Unforested marsh, swamp, wetlands
Suburbs	Residential, suburban developments
Urban	Urban core, major roadways

[a] Conservation Reserve Program
[b] Used in calculation of woods edge.

Table 2. Landscape suitability PATREC model for cottontail rabbit in Illinois.

Landscape variable	Conditional probabilities	
	Suitable	Unsuitable
Contagion (%)		
<65	0.85	0.50
≥65	0.15	0.50
Row crops (%)		
<30	0.05	0.15
30-65	0.80	0.30
>65	0.15	0.55
Grassland (%)		
<15	0.15	0.40
15-30	0.75	0.50
>30	0.10	0.10
Woods edge (m/ha)		
<30	0.15	0.50
≥30	0.85	0.50

Table 3. Landscape suitability in relation to county-level cottontail harvest density in Illinois, 1989-93[a].

	Harvest Density	
Landscape Suitability	Low[b]	High[c]
Low[d]	47	1
High[e]	28	26

[a] $\chi^2 = 27.7$, $n = 1$, $P < 0.0001$
[b] $<10/km^2$
[c] $>10/km^2$
[d] <0.4
[e] >0.4

Table 4. Landscape suitability in relation to mean counts of cottontails along Illinois Department of Natural Resources census routes, 1989-93[a].

	Mean Count	
Landscape Suitability	Low[b]	High[c]
Low[d]	25	2
High[e]	26	28

[a] $\chi^2 = 15.3$, $n = 1$, $P < 0.0001$
[b] <5
[c] >5
[d] <0.3
[e] >0.3

Figure 1. Relationships between landscape metrics and cottontail harvest densities at the county level, Illinois, 1989–93. Horizontal line separates “high” and “low” population levels; vertical lines indicate population response points.

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Figure 2. Landscape suitability indices versus county-level cottontail harvest densities, 1989–93 (top), and mean counts along census routes, 1986–89 (bottom), Illinois.

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Figure 3. County-level landscape suitability index map for cottontails, Illinois, ca 1993.

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