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Beaver Habitat Models for Use in Illinois Streams

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ABSTRACT

Although beavers are widely distributed in Illinois, their relative abundance varies among watersheds. We investigated the spatial distribution of beaver (*Castor canadensis*) colonies along the Embarras River in central Illinois, then tested two existing habitat models and developed a new logistic regression model to better assess the habitat requirements of this species. We located and mapped 125 colonies on the river, a mean of 0.40 colonies/km. Colonies tended to be uniformly distributed with a disproportionate number occurring one km apart. Of two habitat models tested, scores developed using the Habitat Suitability Index (HSI) model did not correlate with colony density ($r^2 = 0.111$; $P = 0.588$), but scores developed using a Missouri model did correlate with density ($r^2 = 0.578$; $P = 0.002$). Our logistic regression model ($r^2 = 0.584$, $P = 0.014$) indicated that the presence of beavers was positively correlated with sapling abundance near the river and width of the riparian zone, but negatively correlated with river gradient and road density. Intraspecific competition and changing environment appeared to be the primary forces influencing the spatial distribution of beavers along the river.

Key words: beaver, *Castor canadensis*, habitat models, logistic regression, HSI model

INTRODUCTION

The beaver (*Castor canadensis*) is an ecologically important keystone species capable of altering plant communities and creating vital wetlands through herbivory and water impoundment (Broschart et. al., 1989). Beavers are valued for their fur, but can be costly nuisances when their foraging damages valuable trees and dams cause flooding of roads and crops. Beaver populations have increased dramatically in Illinois during the past 30 years, but they are not distributed uniformly across the state and abundance varies regionally (Hoffmeister, 1989). Previous research showed that aerial surveys can be useful tools for comparing the relative abundance of this species in some watersheds (Woolf et al., 2003). However, these surveys can be problematic in stream habitats (which account for ~84% of all beaver habitat in southern Illinois) because fluctuating water level and tree canopy often obscure bank dens and food caches reducing the detectability of beavers (Woolf et al., 2003).

We investigated whether beaver-habitat models could be useful alternatives for predicting habitat quality and relative abundance of beavers in Illinois' streams. Our objectives were to: (1) map and quantify the distribution of beaver colonies, (2) test the efficacy of two existing models for predicting relative abundance, the Habitat Suitability Index (HSI) model and a Missouri habitat model, and (3) develop a new logistic regression model to predict relative abundance of colonies in Illinois' rivers.

METHODS

Study area

This study was conducted on the Embarras River in east-central Illinois, one of 9 major watersheds in Illinois. The river is typical of many Illinois rivers, is moderate-sized with a low gradient, and drains a large, flat watershed heavily impacted by agriculture. Water levels can fluctuate dramatically in part because the agricultural drainage systems move water quickly from crop fields. Over 50% of the river is classified as "biologically significant", a designation reserved for Illinois' highest quality streams (Wiggers, 1998).

Measuring habitat variables

Locations of all beaver colonies were mapped during November 2001 - February 2002 when bank dens, food caches, and chewed trees were most evident. The entire river was searched thoroughly during this period by canoe and on foot. Most colonies were identifiable based on the presence of dens in close proximity to food caches. When dens were not visible, a colony was defined as a stream segment >300 m in length with fresh sign (Robel et al., 1993). The location of each active colony was recorded in Universal Transverse Mercator (UTM) coordinates using a global positioning system (GPS) and marked on a 7.5-minute United States Geological Survey (USGS) topographic map.

Variables that could influence the quantity and quality of beaver habitat were selected *a priori* based on natural history and previous habitat models. These were measured in 26 2.5-km segments of river selected using a stratified-random scheme. First, the river was divided into upper, middle, and lower divisions, then each division was divided into 25-km sections, and two 2.5-km segments within each section were randomly selected for sampling. The UTM coordinates delineating the beginning and end of each segment were recorded from USGS maps and these were located in the field using GPS. In each segment, the number of colonies (dependent variable) and set of habitat variables (independent variables) were quantified.

Between June and August, we sampled vegetation in each river segment using five 100-m transects located perpendicular to the river at 500-m intervals on alternating banks. Sample points were established along each transect at 10-m intervals and species composition, diameter, and canopy cover of trees were estimated using the point-quarter technique and a densiometer. Shrub cover and height were estimated using the line-intercept method and a height pole (Cox, 2002). We measured channel width, bank height, and composition (silt, sand, or clay) at each transect. Width of the riparian zone, presence of agriculture fields, and number of roads within 200 m of the river, were measured on georectified aerial photographs. Stream gradients were extracted from the Illinois Stream Identification System (ISIS) database developed by the Illinois Department of Natural Resources (IDNR).

Testing habitat models

We first tested the U.S. Fish and Wildlife Service's habitat suitability index (HSI riverine habitat model) for beavers (Allen, 1983). Variables used in the model include: stream gradient, average water fluctuation (m), % canopy closure, % trees in the 2.5-15.2 cm diameter at breast height (dbh) class, % shrub cover, shrub height, and woody species composition within 200 m of the stream. We calculated the HSI score for each of 26 segments using the mean of transect data. Average water fluctuation was estimated based on minimum and maximum flow rates reported by the USEPA at gauging stations in Camargo, Ste. Marie, and Lawrenceville, IL. We used simple linear regression to test the relationship between HSI habitat scores and the number of colonies in each segment to test the efficacy of the HSI model for predicting relative abundance of beavers.

Next, we tested a model developed to quantify habitat suitability in the bottomland forests of Missouri (the Missouri model; Hallett and Erickson, 1980). To our knowledge, this is the only model designed specifically for use in the riverine habitats of the Midwest. However, its validity had not been tested prior to our study. Variables used in the model include: bank texture and slope, tree species composition and dbh, number of important food plants, proximity of crop fields, and presence of permanent water. The model provides the user with the option of removing habitat characteristics not applicable to a site. Because all of the river segments provided permanent water, we deleted the latter variable from the model and adjusted scores accordingly (Hallett and Erickson, 1980). Again, the relationships between habitat scores and the number of colonies in each segment were tested using linear regression.

Finally, we developed a new beaver habitat model using forward logistic regression to determine which of 12 independent habitat variables (Table 1) could be used to predict the presence/absence of beavers in each 2.5-km stream segment. To avoid potential multi-collinearity between variables in the model, we first conducted Spearman correlation analyses and eliminated 3 variables that were highly correlated ($P < 0.05$) with other more easily measured variables. We set the threshold necessary for a variable to enter the model at ≤ 0.15 so as not to exclude any that might be biologically important to beavers. Each of the four variables included in the final model were accompanied by a significant ($P < 0.1$) change in the F-value associated with the overall regression. Spearman correlations and logistic regression analyses were performed using SPSS software (SPSS Inc. Chicago, IL).

RESULTS

Density and spatial distribution of colonies

We located and mapped 125 colonies on the Embarras, a mean of 0.40 colonies/ km (Figure 1). Based on nearest-neighbor distances, colonies tended to be uniformly distributed along the river, with a disproportionate number occurring approximately 1-km apart ($X^2 = 32.6$; $P < 0.01$; Figure 2). The minimum distance between adjacent colonies was 400 m.

Twenty of the 26 (76.9%) river segments contained active beaver colonies; only six segments lacked colonies. Of the segments with colonies, nine had a single colony and 11 contained two colonies. The majority (97.6%) of colonies occupied bank dens; only three occupied lodges and these were all located in the headwaters of the river. Similarly, only two dams were found on the main channel of the river, both in the upper reaches where the river was narrow and flow was low.

Of the habitat characteristics measured, only stream gradient, correlated significantly with colony density ($r = -0.440$, $P = 0.024$). The gradient was lowest in the upper reaches and near the river mouth where densities tended to be high. In contrast, middle sections of the river had the highest gradient and colonies were sparse. Several other habitat parameters approached statistical significance, including percentage of the river with low banks ($r = 0.363$, $P = 0.068$), riparian width ($r = 0.355$, $P = 0.075$), shrub cover ($r = 0.351$, $P = 0.079$), and canopy cover ($r = 0.337$, $P = 0.092$).

Testing existing habitat models

HSI scores ranged from 0.0 to 1.0, with a mean = 0.82 (SD = 0.28), suggesting that the quality of beaver habitat varied considerably along the river, but generally was good. The only segment with unsuitable habitat (HSI = 0.0) had no beavers present and the segments with highest colony densities had optimal habitat according to the model. However, overall HSI scores did not correlate well with the number of colonies ($r^2 = 0.111$, $P = 0.588$). For example, four segments with excellent habitat (HSI > 0.8) had no colonies, whereas six segments with only moderate habitat (HSI ~ 0.5) contained high densities.

Habitat scores derived from the Missouri model correlated significantly with colony density ($r^2 = 0.578$; $P = 0.002$). Scores ranged from 43% to 71% (mean = 59%, SD = 6.7), again suggesting habitat along much of the river was good. Segments with highest scores also had the greatest number of colonies. Segments lacking colonies earned scores ranging from 43% to 60%. Segments with lowest scores lacked a forested riparian zone and provided little winter food after crops were harvested. Variables that most influenced habitat scores on the Embarras River were size class of trees and bank texture. Segments dominated by large, mature trees or with sandy banks unsuitable for dens received low scores.

Logistic regression model

We developed a regression model that retained four independent variables: % riparian trees <15 cm dbh, riparian zone width, stream gradient, and number of roads within 200 m. The resulting standardized regression coefficients (Tree < 15 B = 0.075, RZW B = 0.030, Grad B = -0.760, Roads B = -0.723, and a constant of -0.642) indicated the relative importance of each variable to the model. Probability of a stream segment being occupied by beavers increased with relative abundance of small trees and wide riparian zones and decreased with stream gradient and road density. The resulting model was a significant predictor of the presence/absence of beavers ($r^2 = 0.58$, $P = 0.014$) and successfully predicted their presence/absence in 24 of 26 (92%) stream segments, including all 20 where beavers were present and four of six segments where beavers were apparently absent.

DISCUSSION

Density and spatial distribution of colonies

With a mean of 0.40 colonies/km of stream, the Embarras River provides good quality beaver habitat along most of its length. Robel et al. (1993) found that rivers with good beaver habitat had densities of 0.12 to 1.40 colonies/km in Kansas and Semyonoff (1951 *in* Novak, 1987) found mean densities of 1.5 colonies/km for rivers with good habitat, 0.5 colonies/km in moderate habitat, and 0.1-0.2 colonies/km in poor habitat.

Distribution of colonies varied along the length of the watershed, reflecting changing environments along the river. Colony density was highest in the headwaters characterized by slow moving water, a narrow channel, and a broad floodplain that provided beavers with the opportunity to build lodges, dams, and bank dens. Topography is very flat and prone to flooding; consequently, farmers have removed some low areas from crop production and these ephemeral wetlands provide refuge and habitat during periods of flooding and drought. As flows and channel width increase downriver, beavers build fewer dams and are less capable of altering their local environment to create preferred habitat.

The Embarras watershed, like much of central Illinois, is dominated by corn and soybean fields. Robel et al. (1993) found that beavers in Kansas were as likely to forage on corn and sorghum as preferred trees such as cottonwood and willows. Beavers in our study area fed on corn and soybeans in the fall and corn stalks were evident in many food caches. However, after crop harvests, the landscape changes and the use of woody vegetation by beavers increased. Consequently, during winter, availability, composition, and stem size of woody plants likely influences habitat quality (Boyce, 1981). We found beavers to be most abundant in stream segments where periodic flooding maintained early-successional riparian forests dominated by small diameter trees.

Generally, as bank height and channel volume increased in lower portions of the watershed, the proportion of large trees (>45 cm dbh) increased and woody understory decreased, as did beaver density. Beavers inhabiting the lower portion of the Embarras River have adapted to fluctuating water levels. Trails from the river into cornfields and foraging areas frequently extended up steep banks and den openings were stacked vertically allowing use of different den openings depending on water levels.

Beavers are highly territorial and social interactions should lead to a uniform dispersion in suitable habitat assuming resources are evenly distributed (Davies, 1978). Uniform spacing of colonies along the Embarras River, particularly in the middle and lower portions suggests that territoriality, rather than resource limitation, is an important factor influencing distribution. A greater proportion of colonies occurred approximately one km apart than would be expected by chance. This is consistent with reported home ranges of approximately 0.8 km on streams (Nordstrom, 1972). Busher (1983) reported intercolony distances ranged from 0.84-1.55 km in California streams.

Testing existing habitat models

Habitat models have proven to be useful tools for quantifying habitat quality and relative abundance of beavers in streams and wetlands throughout North America (Slough and

Sadlier, 1977; Allen, 1983; Howard and Larson, 1985; Broschart et al., 1989). We tested Allen's (1983) HSI model because it is widely used for environmental impact assessments throughout the U.S. The model was not developed specifically to predict beaver densities, Robel et al. (1993) noted that HSI scores should be positively correlated with beaver densities if the model is composed of key habitat variables. Robel et al. (1993) and Stromayer (1999) reported poor performance for the HSI model in the midwestern and eastern U.S., respectively. Model limitations in these regions included its failure to incorporate local plant species as high quality foods and narrow definitions of suitable water quality and stream substrates.

The HSI model did not produce useful estimates of beaver density on the Embarras River and probably is not useful for estimating relative abundance of beavers in Illinois' watersheds. Correlations between HSI scores and colony densities were low ($r^2 = 0.111$; $P = 0.588$) in part because the model is based on characteristics more typical of beaver habitat in the northern and western portions of the geographic range, emphasizing winter foods and stream characteristics not typical of Illinois. For example, the model fails to incorporate regional foods such as corn, maple, and ash, and it defines suitable stream characteristics too narrowly, particularly water levels and substrates (Robel et al., 1993; Stromayer, 1999). On the Embarras River, beavers have adapted to fluctuating water levels and steep banks, as long as water depth is sufficient for travel and protection.

In contrast, the Missouri model proved well-suited for predicting the quality of beaver habitat in Illinois. Model variables such as bank characteristics, forest age and composition, important food plants, and distance to cropland are appropriate descriptors of beaver habitat in Illinois. The model captured the importance of tree species, size, and regional food plants (including crops), to beavers in the Embarras River watershed. Our results suggest that the Missouri model could be a useful tool for evaluating the quality of beaver habitat in Illinois and advances in remote sensing and GIS systems will allow future refinement of statewide habitat maps.

Logistic regression model

Our final regression model was a significant predictor of beaver presence, retaining variables that we believe represent important habitat components of Illinois streams. Of 12 habitat characteristics entered into the regression, four were retained in the final model. Two (abundance of small trees and riparian zone width) were positively associated with beaver colonies and two (stream gradient and proximity of roads) were negatively associated.

Habitat models are most useful when they incorporate variables that are easily quantifiable and produce results that can be clearly interpreted (Hurley, 1984; Salwasser, 1984; Garshelis, 2000). Our regression model is useful because variables are habitat features important to beavers and can be derived from existing data sets (watershed surveys and aerial photographs) eliminating the need to measure them in the field.

Riparian trees provide important food for beavers during winter when herbaceous vegetation is dormant and crops have been harvested. Beavers forage on small diameter woody stems during winter and use these to construct dens and dams. We frequently observed willows (*Salix* spp,), maples (*Acer saccharinum*, *A. saccharum*), and green ash

(*Fraxinus pennsylvanicum*) in food caches and dams. Consequently, it is not surprising that availability of small trees and the extent of riparian zone were important factors associated with beaver presence. Mature riparian forests dominated by large trees appear less suitable for beavers, perhaps because felling large trees is labor-intensive, their shade reduces understory growth, and their presence suggests infrequent flooding and scouring, disturbances that favor the early-successional plants used by beavers.

Two variables (stream gradient and road proximity) were negatively associated with beaver colonies. It is not surprising that beavers avoid areas with high gradients. Typically, higher gradients result in a higher flow which makes travel and transportation of food more difficult, and destroys dams, dens, and food caches. We believe that road proximity provides an indirect measurement of human activity along the river. Although beavers often live in close proximity to humans, previous research suggests that roads, railways, and land development near waterways limit habitat quality (Slough and Sadleir, 1977).

In conclusion, our research suggests that the Embarras River provides good quality beaver habitat along much of its extent. Although the HSI model was not a useful predictor of relative abundance of beavers on the river, both the Missouri model and our regression model produced scores that were correlated with beaver abundance. We believe this river is typical of many in Illinois and therefore these habitat models are likely to be useful for evaluating habitat quality and relative abundance of beavers in similar watersheds throughout the state.

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Table 1. Twelve habitat variables tested for use in the final logistic regression model for beaver habitat in the Embarras River Watershed, central Illinois.

Variable	Units	Abbreviation
Canopy cover	%	CC
Riparian trees >45-cm dbh	%	Trees>45
Riparian trees <15-cm dbh	%	Trees<15
Shrub cover	%	SC
Shrub height	m	ShrubHt
Riparian zone width (mean)	m	RZW
Channel width (mean)	m	CW
Stream gradient	%	Grad
Bank height	m	BankHt
Stream sinuosity	%	Sinuous
No. roads within 200 m	--	Roads
No. cropfields within 200 m	--	Crops

Figure 1. Distribution of 125 beaver colonies observed along the Embarras River in eastern Illinois during November 2001 - February 2002. Each dot represents one colony.

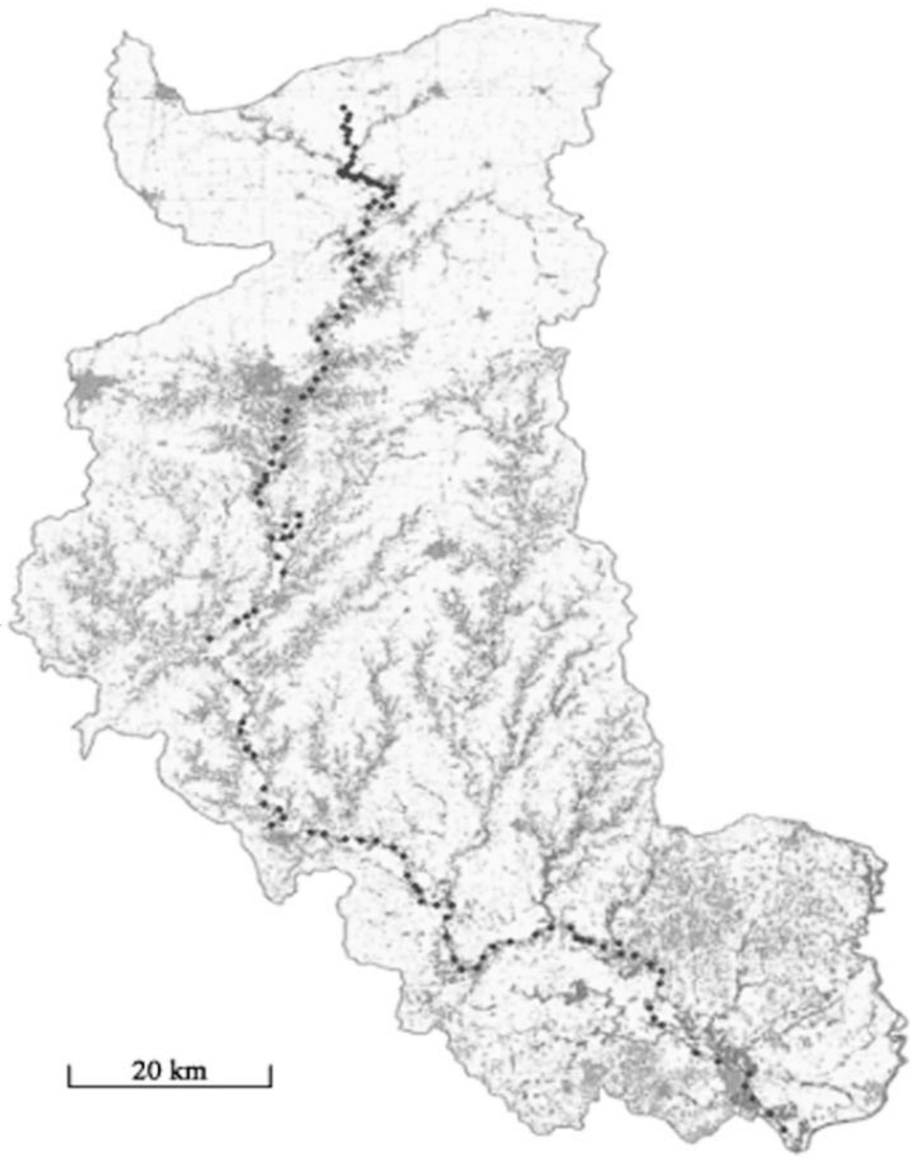

Figure 2. Observed and expected distributions of nearest-neighbor distances between beaver colonies. The expected exponential distribution would occur if colonies were distributed randomly along a river. The dispersion of colonies was more uniform than would be expected by chance ($X^2 = 32.6$; $P < 0.01$).