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A predictive habitat model for bobcat (*Lynx rufus*) in northern New Jersey

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INTRODUCTION

Habitat fragmentation resulting from uncontrolled sprawl development in northern New Jersey is the most serious threat affecting the state's endangered bobcat (*Lynx rufus*) population. Location data from captured specimens and verified sightings show that bobcats are found primarily in Sussex, Warren, Morris and western Passaic counties. Since 1970 these counties have undergone a steady increase in human population density. This trend in population growth is likely to continue throughout most of this region with the exception of the area regulated under the Highlands Water Protection and Planning Act. Since bobcats are highly sensitive to human activity and dependent upon contiguous tracts of undisturbed land for their health and survival, they will be among the first species lost if fragmentation and human encroachment continue at the current pace.

The future of bobcats in New Jersey and in the Skylands Region (Niles et al. 2004) will depend on the state's ability to identify and protect an adequate amount of critical habitat, including connecting corridors, to support a viable population. The use of models to predict the likely distribution of bobcats is a necessary first step in conservation planning and management. A predictive habitat model was developed using location data that was acquired over the past two decades. Comparing habitat characteristics from areas used by bobcats with habitat variables from randomly selected, unused habitat, a predictive habitat model was developed for north Jersey. The result is a distribution map that predicts areas of suitable and unsuitable habitat for bobcat throughout the Skylands Region of northern New Jersey. The model provides biologists with information regarding the habitat variables that likely influence bobcat populations, as well as the amount and spatial arrangement of potentially suitable habitat in New Jersey.

METHODS

Habitat Sampling

Bobcat occurrence information in the state's Biotics database consists of reports of sightings of live specimens, accidental captures by trappers, and locations of animals killed by motor vehicles. The occurrence data used to develop the model consisted only of northern NJ bobcat records with precise point locations (N = 85) that were submitted between 1992 and 2004 (Fig. 1). The study area was defined by constructing a minimum convex polygon around the data points using the Animal Movement Extension (Hooge and Eichenlaub 1997) in ArcView 3.2. The study area included portions of Essex, Hunterdon, Morris, Passaic, Somerset, Sussex, and Warren counties in northern New Jersey. Next, a randomly generated set of 85 points that fall within the study area, but were at least 1000 m away from the nearest bobcat point location, was selected using the Animal Movement Extension (Fig. 1). A 2.82 km radius buffer was then applied to each bobcat point location and each randomly selected point locations. These larger habitat units are thought to be more realistic representations of the habitat that animals actually select, and they tend to stabilize estimates of habitat (Erickson et al. 1998, Rettie and McLoughlin 1999, McLoughlin et al. 2002).

Bobcat home range sizes are highly variable, both regionally and among different sexes, in the same geographic area particularly if suitable habitat components have a patchy distribution (Lovallo 1999). The home range size of males is generally larger than that of females. In New Jersey, the annual home range of a male in 2002 was 121 km^2 with a core of 19 km2. The home range of a female in 2003 was 90 km2 with a core of 11.7 km^2, both as estimated using the kernel home range method. The 25 km^2 buffer (2.82 km radius) that was applied around each bobcat point location is larger than the core area we estimated for a male and female bobcat in the state, and midway between the male and female home range sizes Lovallo (2000) estimated in north central Pennsylvania. It is considered a conservative estimate based on sizes reported for bobcats in the northeastern United States (Lovallo 2000).

Habitat data files were then created for road density, vegetative and soil composition, edge, and topography. The road density (km/km^2) coverage was derived from TIGER Roads 2000 (NJDEP GIS), the vegetation and edge data sets were derived from the 1995/97 Land use/Land cover layer (lulc) (NJDEP GIS), the topography data set was derived from USGS 7.5-minute Digital Elevation Models (DEMs) (NJDEP GIS), and the soil composition data set was derived from SSURGO soil layers (NJDEP/NRCS).

Five vegetation categories were extracted from lulc and 2 soil categories were extracted from the soil layers (Table 1) and converted each into raster datasets with 30 m^2 pixels to ease computation time. Edge variables were developed by identifying areas where forest pixels (30 m^2) were adjacent to open areas, developed areas, or both types of areas and 3 different grids were derived capturing the 3 different edge categories. Slope and aspect were derived from the DEMs that categorized aspect into 8 different categories and slope into 2 different categories, generating one grid for each category (Table 1). Habitat attributes were quantified within each of the buffered bobcat point locations and randomly selected point locations using GIS.

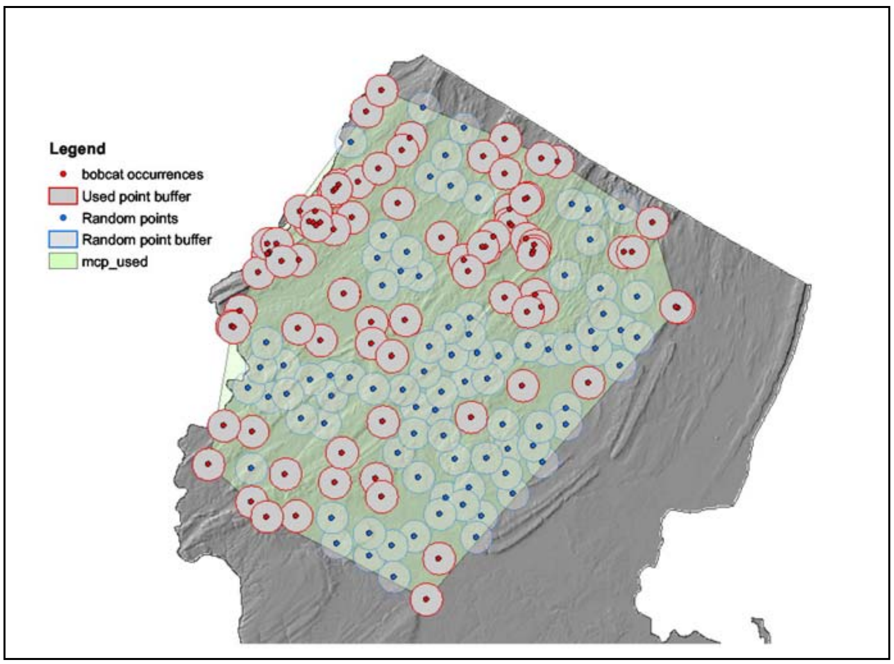

Figure 1. Buffered bobcat point locations (reported between 1992 and 2004) and randomly selected point locations in northern New Jersey.

Table 1. Habitat variables considered for logistic regression analyses.

Habitat Variable	Description
Elevation	Mean elevation
North	Proportion of area with 315 - 45 degree aspects
South	Proportion of area with 135 - 225 degree aspects
East	Proportion of area with 45 - 135 degree aspects
West	Proportion of area with 225 - 315 degree aspects
Northeast	Proportion of area with 0 - 90 degree aspects
Southeast	Proportion of area with 90 – 180 degree aspects
Northwest	Proportion of area with 270 - 360 degree aspects
Southwest	Proportion of area with 180 - 270 degree aspects
0-20slope	Proportion of area with slopes of 0 - 20%
20-40slope	Proportion of area with slopes of 20 - 40%
Agriculture	Proportion of area with agriculture
Urban	Proportion of area with urban
Residential	Proportion of area with residential
Wetlands	Proportion of area with wetlands
Forest	Proportion of area with forest (>50% crown closure)
Edge1	Proportion of area with forest boundary adjacent to developed/open area
Edge2	Proportion of area with forest boundary adjacent to open area
Edge3	Proportion of area with forest boundary adjacent to developed area
Soil1	Proportion of area with a stony surface texture
Soil2	Proportion of area with unweathered bedrock
Road density	Density of roads (km/km^2)

Model Development

The relationships of 22 habitat parameters (Table 1) were explored and all variables that were multicollinear or invariant were eliminated. Point biserial correlations were also calculated for each variable in relation to whether it was associated with a bobcat point location or a randomly selected point location to determine which variables alone were most correlated with presence/absence. Logistic regression models were created using SPSS 10.0 (SPSS Inc., Chicago, Illinois) with the binary response variable of presence or absence and the habitat variables for every combination of the variables.

We selected the best model based on classification success of used and unused locations by comparing the predicted values from the logistic regression models with a probability cut-off value that distinguished suitable from unsuitable habitat. We then used GIS to generate maps of the study area portraying the predicted relative probability of selection for every possible buffer in the study area, based on the final habitat model.

The predicted probability of presence (w(x)) was calculated and classified into eight equal interval categories ranging from 0 to 1.

We tested the model by overlaying satellite collar locations from a male (n = 96, 2002) and a female (n = 253, 2003) that were not used to build the model. We evaluated how well the model correctly classified these used points.

RESULTS

The best model based on classification success correctly classified 75.3% (64/85) used locations and 80% (68/85) of unused locations (Fig. 2). The final model (Table 2) predicts that bobcats select areas with stony soil, and avoid residential areas. Approximately 98% of the satellite collar points fell with probability areas > 0.50 and 80% of the points fell within probability areas > 0.75 (Fig. 3). Percent forested area had the highest correlation with presence/absence in the univariate analyses of any of the variables (r = 0.546) (Fig. 4), but a model with just forest as a variable had a slightly lower classification rate than the final model.

The final model predicts that approximately 32% of the area in northern New Jersey that the model covers has a probability of presence of bobcats > 0.50, or greater than chance alone, with an area totaling approximately 2,128 km^2 (Table 3).

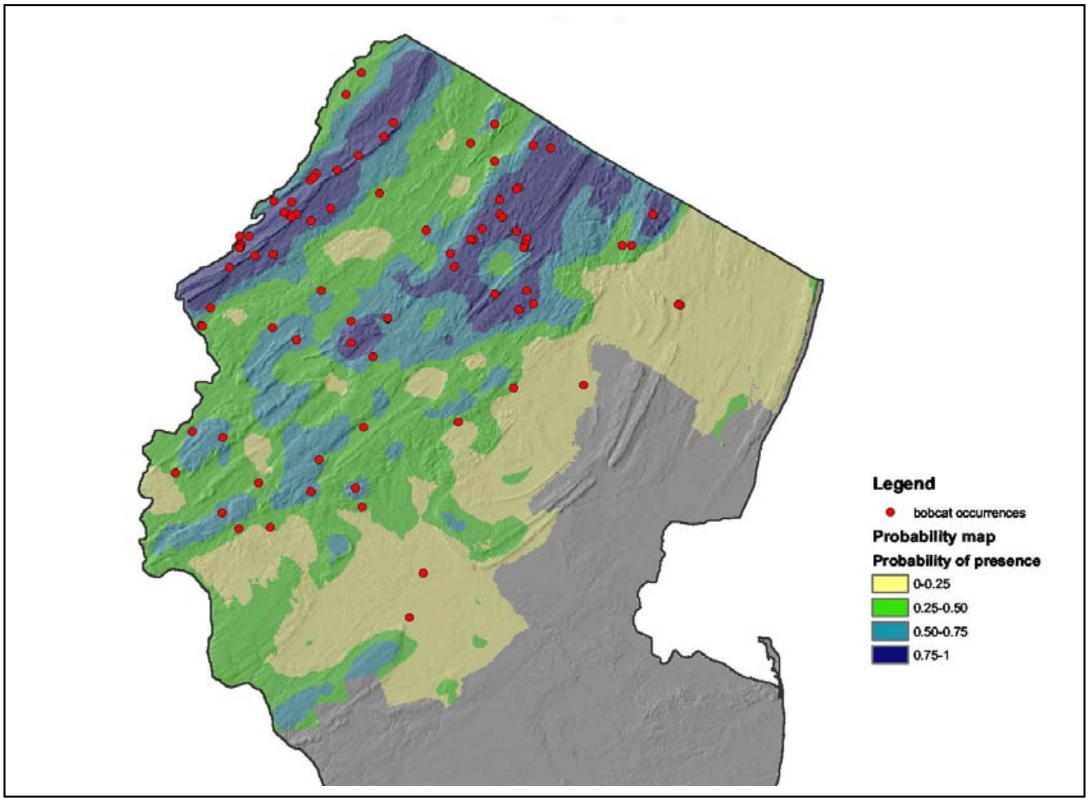

Figure 2. Probability of presence of bobcats in the Skylands Region of northern New Jersey with more suitable habitat areas in blue. Known bobcat occurrences used to build the predictive model are overlaid on top.

Table 2. Final bobcat habitat selection model. Model coefficient (B) and standard error of the coefficient (SE), and probability value (P) are shown for each variable that remained in the model.

Variable	B	SE	P
Residential	-0.064	0.019	0.001
Stony soil	0.046	0.010	0.000
Constant	-0.498	0.483	0.303

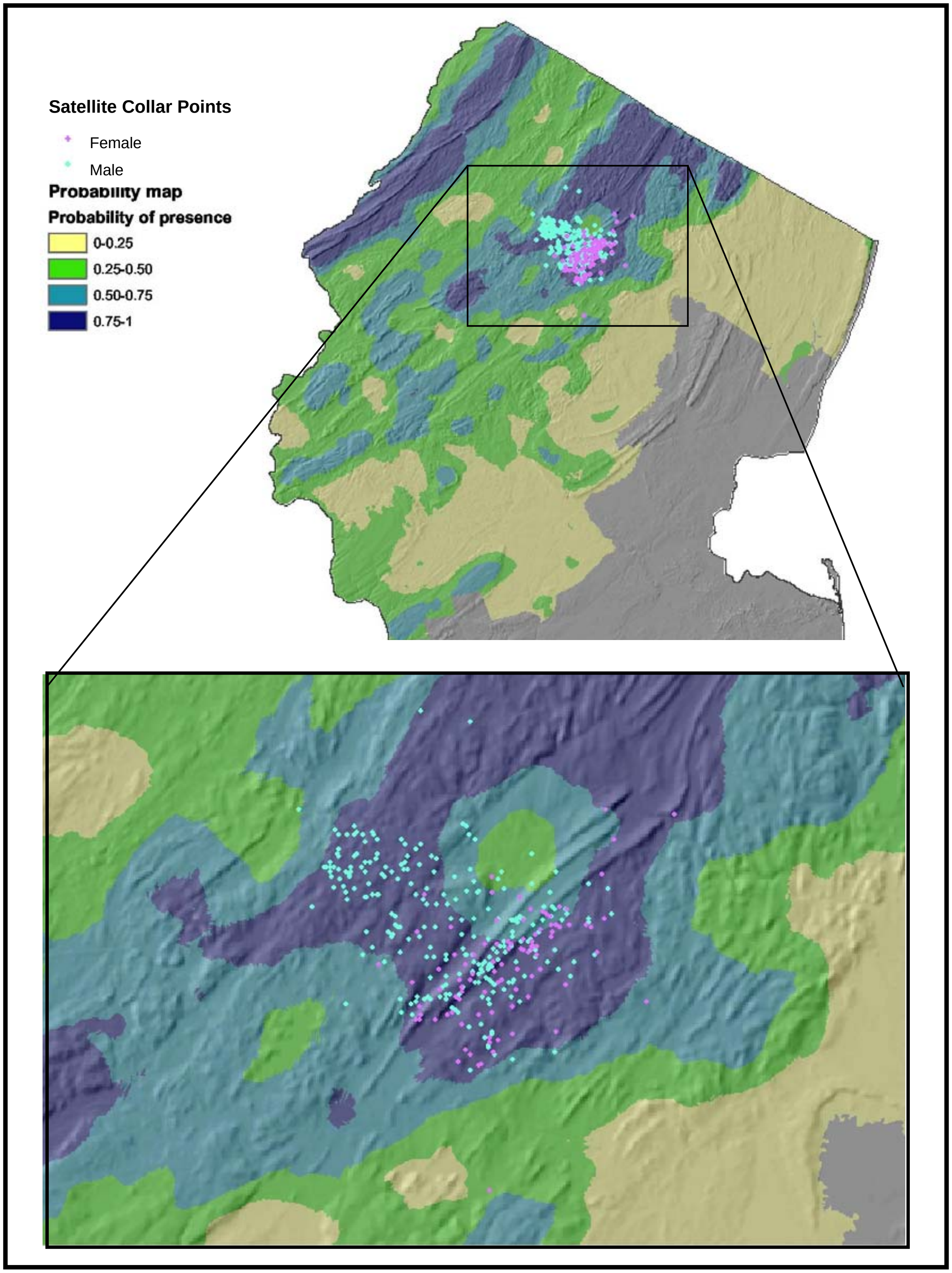

Figure 3. Probability of presence of bobcats in the Skylands Region of northern New Jersey with more suitable habitat areas in blue, and satellite collar points of a male and female bobcat in 2003 and 2002 respectively.

Figure 4. Percent forested area within used and randomly selected locations (mean $\pm$ 95% confidence intervals) in northern New Jersey based on a 2.82 km radius buffer size.

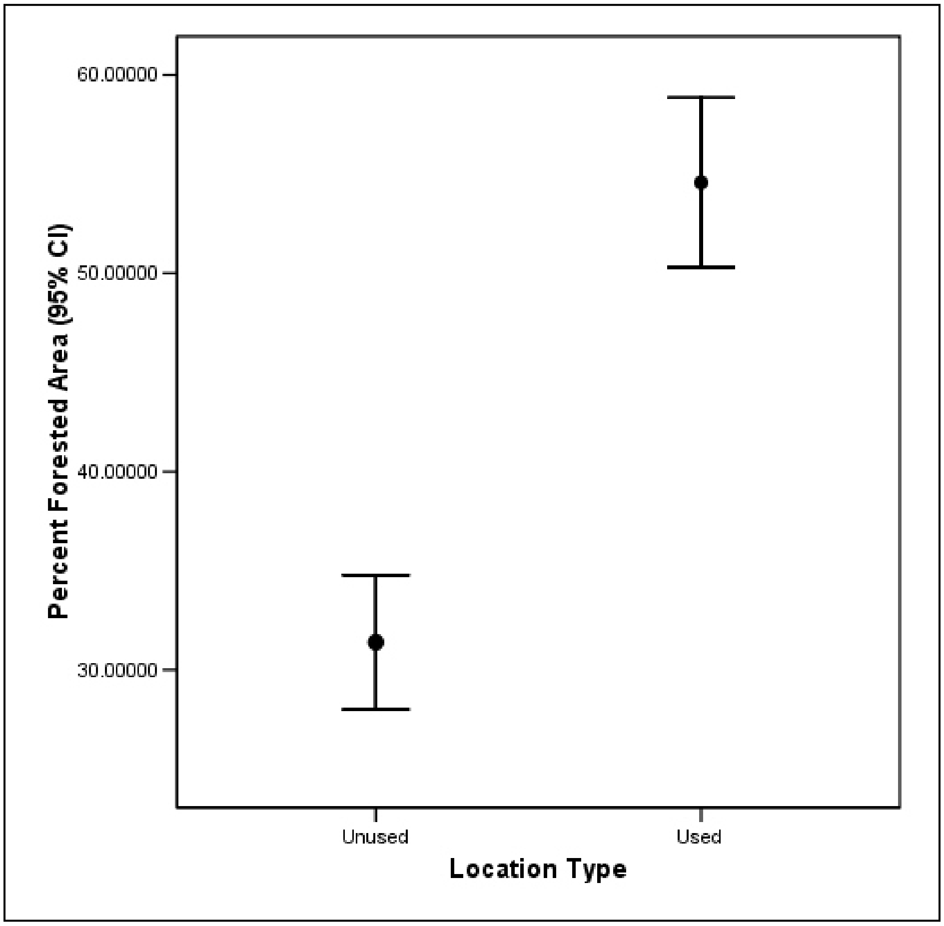

Table 3. Land area (km^2) in the Skylands Region of northern New Jersey, for a predictive habitat model developed for bobcats. Area(%) is the percent of the total study area in northern New Jersey with each probability level of presence.

Probability level	Area (%)
0 - ≤ 0.25	2,310 (34.7)
>0.25 - ≤ 0.50	2,229 (33.4)
>0.50 - ≤ 0.75	1,276 (19.1)
>0.75 – 1.00	852 (12.8)

DISCUSSION

The model fit the data reasonably well, as measured by successful classification of used sites. Areas of high probability are located primarily along ridges and feature a low density of development. Most of the "used" sites were characterized by a high percentage of forested area. This positively influenced the presence of bobcats and supports the argument that human encroachment and fragmentation likely have a detrimental effect on bobcat populations. It is encouraging that the model predicted that nearly one third of the area evaluated in the Skylands Region of northern New Jersey is suitable bobcat habitat. An interesting pattern emerges when evaluating the distribution of suitable habitat in that there are two large, fairly contiguous areas of habitat, along the Kittatinny Ridge and the New Jersey Highlands, separated by the Great Valley. These contiguous areas should be protected and further research conducted to determine if there are well-used travel corridors between the two areas that we should work to protect.

We expect this to be an iterative model and continue to validate and, if necessary, update it with new data as they become available. We will continue to evaluate additional habitat variables to determine their importance for predicting bobcat presence. Though limited, our test using the satellite collar data indicates that the model performs well. However, the collared cats were trapped in areas of known bobcat habitat. A better test of model performance would be to use data resulting from a more systematic survey of northern NJ. It would include areas not currently known to be used by bobcats. The result would help us to determine with how much confidence the current model can be applied and used, and the data gathered could also be used to further refine the model.

There are a number of assumptions associated with the model. We are assuming that all of the suspected unused locations are, in fact, not used by bobcats. We only used points that were at least 5.64km apart to assure there was no overlap between used and unused buffers. Also, models are only as good as the data from which they are built. Most of the sightings data used to build the model were obtained opportunistically and, therefore, all areas where bobcats occur may not be reflected in our dataset. Second, we used both male and female location data when building the model because we cannot distinguish the locations by sex. Our own data as well as that compiled by Lovallo (2000) suggests that male bobcats in the northeastern states have larger home ranges than females. Therefore, it is possible that the buffer size we used, which was midway between the average size of male and female home ranges, was not an accurate reflection of the area used by all of the individuals in the dataset. Third, we did not divide the dataset by season because we would not have had a large enough sample size had we done so. Ideally, we would build seasonal habitat models for both males and females, particularly because males generally travel greater distances during the breeding season than females.

The predictive mapping will be used to target future surveys aimed at building our dataset and obtaining population size and density estimates. Also, the increased understanding we have gained from this habitat model about the distribution of bobcats will enable us to refine and improve the validity of the delineation of bobcat critical habitat in the Landscape Project.

As more data become available we also hope to build seasonal habitat models and apply them in southern New Jersey to determine if one model can accurately predict bobcat habitat across the entire state. Or, it may show that habitat selection is different enough to warrant the development of a separate model for south Jersey. The information can also help predict whether a reintroduction effort in southern New Jersey could be successful. Once we have settled on an accurate, robust model, we will apply it to New York and Pennsylvania to evaluate bobcat distribution regionally. The application of the models to all of New Jersey, as well as New York and Pennsylvania will display the amount of connectivity between suitable patches and inform us of intra and interstate corridors and barriers to movement and dispersal. This information would be helpful in developing a successful conservation strategy. We also will apply it retrospectively to habitat data from 1984 and prospectively to future habitat data being developed by CRSSA. Our retrospective and prospective analyses of past and future suitable habitat distribution for bobcats in New Jersey will give us further insight into the influence of a changing landscape on bobcat habitat, especially habitat fragmentation.

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