PROGRESS REPORT

for

COOPERATIVE BOBCAT RESEARCH PROJECT

Period Covered:

1 April – 30 June 2012

Prepared by

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26 July 2012

SUMMARY BY STUDY OBJECTIVES

OBJECTIVE I -- DEVELOP PROTOCOL TO ESTIMATE CURRENT ABUNDANCE OF BOBCATS AND TRACK POPULATIONS STATEWIDE.

Approach #1: Use of transmitter-equipped bobcats to model suitable habitats and generate density estimate based on area requirements.

Initial second-generation habitat suitability models have been developed using location data from both study areas. Layers used in model development included: National Land Cover Database 2006 (Fry et al. 2011; layers collapsed to open water, light development, heavy development, barren, evergreen forests, deciduous forests, mixed forests, shrub/scrub, agriculture, and wetlands), distance to forest edge (excluding open water/forest edge), distance to roads (both major roads and all roads explored, all roads fit data better), distance to stream (both major and all). Topographic variables included were elevation, slope, aspect, and a vector ruggedness measurement (VRM, Sappington et al. 2007).

Due to the large number of possible combinations of variables and the added computation time of using random effects; a small number of fixed effects models have initially been explored (Table 1). These were mainly built to develop the process and explore the data. Additional and more extensive models will be tested in the future. The top fitting model contains all the variables tested. The subsequent four models contain all variables except one of the least explanatory variables. Models were judged based on Akaike Information Criterion adjusted for small sample size (AICc), which fits the best model, but penalizes additional parameters (Burnham and Anderson 2002). This insures that the most parsimonious, yet still explanatory model is chosen. While it is important to use AICc to find the best fitting model, we are really more concerned with the best predictive model (Boyce et al. 2002). Preliminary testing of the models predictive capabilities has begun with k-fold cross validation, however additional models need to be tested, and therefore that information is not presented here.

Table 1. Initial tests of fixed effects models for all bobcat locations. Locations in the southwest study area were collected in 2009-10, and locations in the southeast study area were collected in 2011. The 'Full Model' contains all variables whereas each subsequent model contains all variables except the one listed.

	K	AICc	Delta AICc	AICc Wt.	Cum. Wt.	LL
Full model	24	24051.18	0.00	0.9	0.9	-12001.56
no elevation	23	24055.64	4.46	0.1	1.0	-12004.79
no VRM	23	24062.28	11.10	0.0	1.0	-12008.11
no slope	23	24075.47	24.29	0.0	1.0	-12014.70
no aspect	16	24119.66	68.47	0.0	1.0	-12043.81

Coefficients for the top fixed effects model highlight some interesting observations about bobcat selection and generally agree with the first generation habitat model and previous work on New Hampshire bobcats (Broman 2012). Bobcats seem to be selecting lower elevations more than available, and areas that have steeper slopes and greater overall ruggedness. All aspect variables are compared to eastern aspect, which bobcats seem to be selecting for the most. The difference between the southern extents and eastern extent was not significant, suggesting a selection for areas of eastern to southwestern extent. Agriculture was used as the comparison for land cover variables and the model suggested that bobcats were selecting barren, shrub/scrub, and wetlands at significantly higher rate than available; and selecting light development, heavy development, and open water significantly less than available. All forest land covers do not seem to be selected for or against at any significance level.

Table 2. *Coefficient scores for best fit fixed effects model which contained all possible variables. All quantitative variables were standardized. For 'aspect' the eastern aspect was the reference category, and for 'land cover' agriculture served as the reference category.*

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	0.078055	0.079013	0.988	0.323212
elevation	-0.046897	0.018448	-2.542	0.011019 *
slope	0.096113	0.018798	5.113	3.17e-07 ***
aspectflat	-1.277702	0.240863	-5.305	1.13e-07 ***
aspectnorth	-0.359465	0.062812	-5.723	1.05e-08 ***
aspectnortheast	-0.270200	0.061000	-4.430	9.44e-06 ***
aspectnorthwest	-0.239807	0.066252	-3.620	0.000295 ***
aspectsouth	-0.114427	0.059744	-1.915	0.055454 .
aspectsoutheast	-0.059013	0.062040	-0.951	0.341495
aspectsouthwest	-0.011136	0.061466	-0.181	0.856237
aspectwest	-0.202808	0.064564	-3.141	0.001683 **
barren	2.046598	0.359595	5.691	1.26e-08 ***
deciduous	-0.006538	0.076710	-0.085	0.932077
evergreen	0.096555	0.076626	1.260	0.207641
heavy_development	-2.023729	0.289617	-6.988	2.80e-12 ***
light_development	-0.306125	0.087682	-3.491	0.000481 ***
mixedwoods	-0.027547	0.073197	-0.376	0.706661
open_water	-0.657647	0.178438	-3.686	0.000228 ***
shrub_scrub	0.449945	0.120477	3.735	0.000188 ***
wetlands	1.167400	0.088301	13.221	< 2e-16 ***
vrm	0.061274	0.017191	3.564	0.000365 ***
dt_rd_all	0.153714	0.018201	8.445	< 2e-16 ***
dt_stream_major	0.062788	0.017080	3.676	0.000237 ***
dt_edge	-0.170534	0.019315	-8.829	< 2e-16 ***

Significance codes: 0 = '***' 0.001 = '**' 0.01 = '*' 0.05 = '.' 0.1 = ' '
Null deviance: 25073 on 18085 degrees of freedom
Residual deviance: 24003 on 18062 degrees of freedom
AIC: 24051
Number of Fisher Scoring iterations: 4

Development of mixed-effects models was performed using the best fixed effect model (Table 3). Random effects for individual bobcat, study area, and individual bobcat nested within study area were tested. The inclusion of random intercepts for individual and study area was tested to account for different rates of selection between individuals and study areas, as well as unequal sample sizes (Gillies et al. 2006, Hebblewhite and Merrill 2008). A hierarchical model where a random coefficient for individual was nested within study area was also tested. Although this model had the highest log likelihood, it was penalized for the large number of parameters.

Table 3. *Mixed effects models were tested using the top fixed effects model. Both 'bobcat' and 'study area' and then 'bobcat' nested within 'study area' were added as random effects.*

	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
bobcat	25	24036.64	0.00	1	1	-11993.29
study_area	25	24053.19	16.54	0	1	-12001.56
bobcat/study_area	195	24350.30	313.65	0	1	-11978.01

The top fixed effects model containing all variables was used to generate a preliminary habitat suitability map for the southern part of New Hampshire, and the map did not contradict bobcat biology. When the map was extrapolated to the entire state, however, the model that included distance to road altered the scale. As a result, it selected areas in the northern portion of the state as the most suitable habitat. Therefore, a model was run with distance to road removed. In addition, the barren land cover class, which showed extremely strong selection, was removed because of the low amount of available (>1%) habitat (DeCesare et al. 2012). Therefore, the resulting suitability map contains the variables land cover, elevation, slope, aspect, VRM, distance to major stream, and distance to forest edge (Figure 1).

An initial review of the map demonstrated that bobcats showed a strong selection against highly developed areas, high elevations, and open water. The southern part of the state seems to have higher suitability compared to the northern part of the state, and the White Mountains seem to be highly unsuitable except within the lower elevations. Due to the bobcats strong selection for both wetlands and scrub/shrub it appears that the middle to southeast corner, as well as the area around Lake Winnipesaukee contains the best habitat in the state, however this will likely change with the inclusion of the distance to roads layer.

Continuing work is being performed to develop an approach to include the potential negative effects of roads without throwing off the scale of the habitat suitability scores for the map. Additionally, other models will be generated and validated to insure the best model is used to compute habitat suitability. Once achieved, estimates of abundance based on amount of suitable habitat will be computed using the information gained from the second group of bobcats.

Approach #2: Development of a method to monitor abundance of bobcat populations based on trail cameras and citizen scientist volunteers.

Cody Merrill, the graduate assistant working on this portion has been replaced by Tyler Mahard. No activity occurred on this portion of the project during this period.

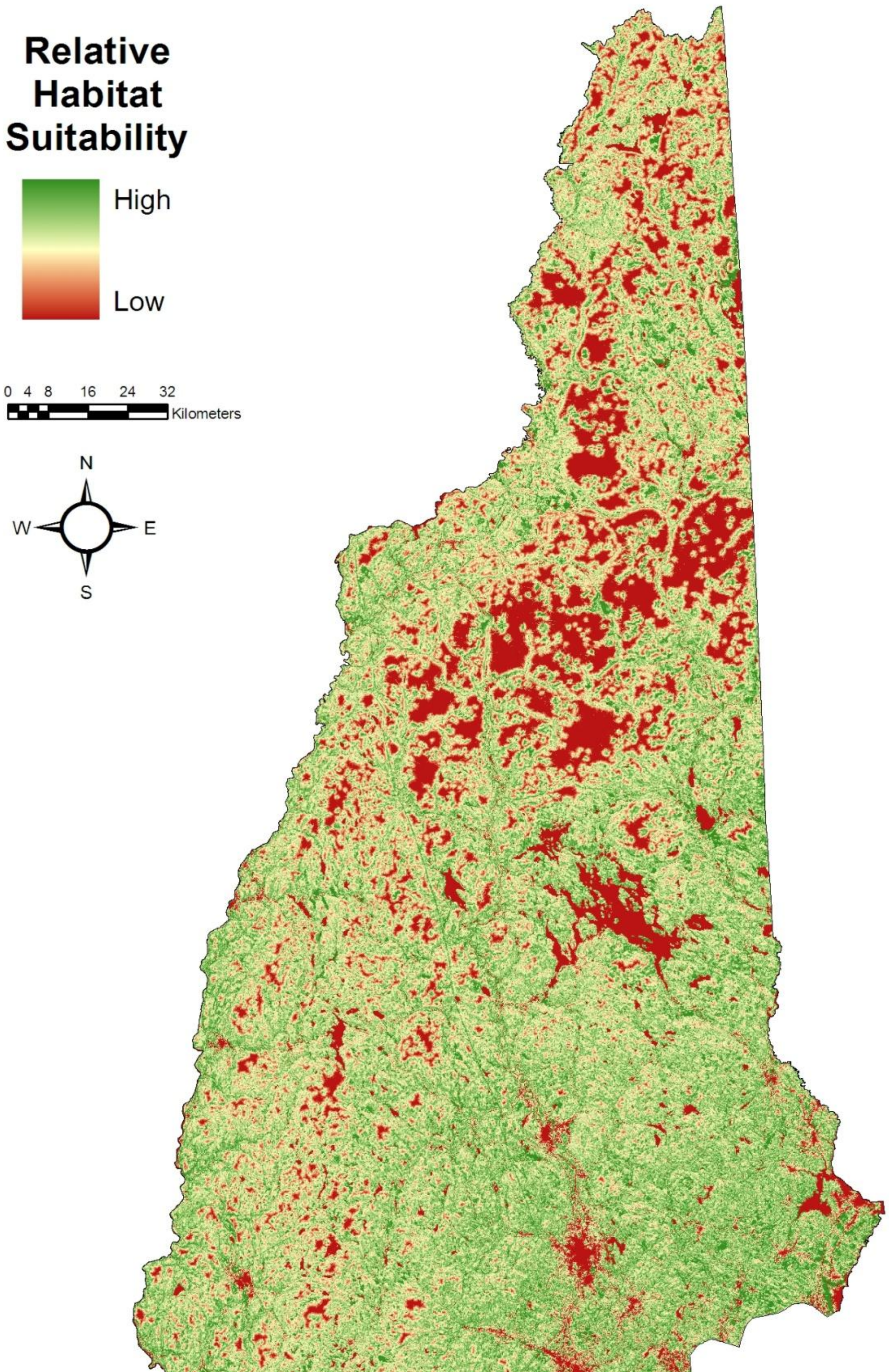

Figure 1. *Habitat suitability map for New Hampshire generated using all variables except 'Distance to Roads'. Locations from both study areas were used to create the model that the habitat suitability model is based on.*

Approach #3: Evaluate the application of population genetics using tissue from road-killed bobcats.

We are now exploring the application population genetics to provide an additional estimate of bobcat abundance within the state. Using 10 microsatellite loci (Menotti-Raymond et al. 1999) identified in the domestic cat *(Felis catus),* it is possible to determine the population genetic structure of New Hampshire bobcats and to estimate their effective population size. DNA has been extracted from 22 live-trapped and 28 carcass specimens. To date, four loci have been optimized for microsatellite analysis and GENSCAN trace files have been obtained for 30 individuals.

OBJECTIVE II -- COMPARE ABUNDANCE OF BOBCATS IN NEW HAMPSHIRE TO POPULATIONS IN ADJACENT STATES.

Additional activity on this objective will occur after a more comprehensive evaluation of the second-generation habitat suitability map has been completed and additional tissue samples are collected from road-killed bobcats.

OBJECTIVE III -- IDENTIFY POTENTIAL WILDLIFE CORRIDORS.

Activity on this portion of the project is also dependent on the second-generation suitability map.

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