PROGRESS REPORT

for

COOPERATIVE BOBCAT RESEARCH PROJECT

Period Covered:

1 January – 31 March 2014

Prepared by

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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.

This portion of the project is complete. See Broman (2012) and Reed (2013).

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

Camera survey results and comparison with other indices of abundance – Analysis of the camera survey that relied on volunteers continued during this period. Comparisons with other indices (public sightings, hunter surveys, and habitat suitability model) were refined such that data would be more representative of locations selected by camera survey volunteers (Fig. 1). Camera station locations were plotted in a geographic information system (GIS) and more refined areas were determined by placing a circular buffer around each camera location that was equal in area to the average female home range size of female bobcats in New Hampshire (23.8 km^2, Reed 2013).

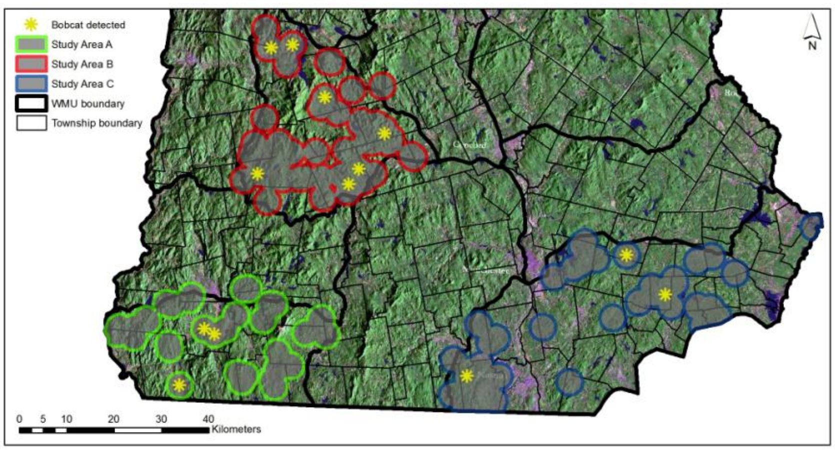

Figure 1. *Study areas and locations of bobcat detections for camera surveys in southern New Hampshire from 30 October through 20 December 2013. Study areas include all of the area within 2.75 km of camera locations. Background imagery derived from Landsat 7 data and National Elevation Dataset, acquired July 1999 – September 2002, U.S. Geological Survey.*

Detection rates from camera surveys (CS) were compared to the relative abundance of bobcats as inferred from incidental public observations (PO), hunter surveys (HS), and Reed's (2013) model of bobcat habitat suitability (HSI) (Table 1). For each study area, PO from 2013 (including mortalities) that occurred in townships containing cameras were summed and divided by the total human population among those townships. Hunter observation rates were calculated in a similar fashion, using hours in the field as a measure of effort. HSI values for each study area were taken as the mean value of all raster cells that coincided with each refined study area (Fig. 1). All indices suggested Study Area C was lowest in abundance, and all but HS indicated Study Area B was highest.

To further investigate agreement, pairwise correlation coefficients were computed by study area among all four indices (Fig. 2). All indices were positively correlated. CS were very strongly correlated with PO, strongly correlated with HS, and weakly correlated with HSI. Interestingly, CS were very strongly correlated with HS rates that were based on 4-year WMU averages (Fig. 2 of

Table 1*. For each study area: number of townships that contained camera stations (Towns), Wildlife Management Unit that the study area was situated about (WMU), number of public sightings and mortalities in 2013 from towns that contained cameras (**PO** Obs), 2011 human population estimate for all towns that contained cameras (HuPop) (New Hampshire Office of Energy and Planning 2012), number of PO per 10,000 people (PO rate), number of bobcat observations by hunters in 2013 from towns that contained cameras (**HS** Obs), total hunter survey hours from 2013 in towns that contained cameras (Hours), bobcat observed per 1,000 hours (HS rate), number of bobcat detection events from CS (Detections), trap night range (from Litvaitis et al. 2013b) (TN range), detections per 1,000 trap nights based on the mean of rates calculated from min and max of TN range (CS rate), and average HSI value of area within 2.75 km of all camera locations.*

			PO			HS			CS			HSI
Study Area	Towns	WMU	Obs	HuPop	PO rate	Obs	Hours	HS rate	Detections	TN range	CS rate	HSI value
A	12	H2S	28	66,897	4.19	16	5,777	2.77	3	442 - 540	0.62	0.579
B	16	I2	28	40,763	6.87	13	5,244	2.48	8	646 - 855	1.09	0.553
C	21	M	33	312,665	1.06	7	8,294	0.84	4	666 - 848	0.53	0.522

Litvaitis et al. 2013b), but the relationship weakened when HS rates were refined to represent towns that contained camera stations. As refined HS and CS rates were based on low numbers of bobcat observations and detections, the degree to which they accurately reflect actual relative abundances of the areas surveyed is questionable. As expected, refining each study area resulted in a stronger correlation between CS and HSI than was found when HSI means were computed from raster values spatially coincident with all grid cells (grid cells – Fig. 3 of Litvaitis et al. 2013a, correlation – Fig. 2 of Litvaitis et al. 2013b). Agreement between HSI and HS also improved substantially (r = 0.29 in Litvaitis et al. 2013b). This could be a result of camera survey volunteers selecting locations similar to, or coinciding with locations selected by hunters. HSI values for the refined study areas are likely more representative of areas that produce HS data, whereas HSI values that span entire WMUs included areas of development and open water.

	PO	HS	CS	HSI
PO	1.00	0.81	0.91	0.58
HS	0.81	1.00	0.51	0.95
CS	0.91	0.51	1.00	0.20
HSI	0.58	0.95	0.20	1.00

Figure 2. *Matrix of correlation coefficients for pairwise comparisons among PO rate, HS rate, CS rate, and mean HSI value (Table 1). Coefficients were calculated using JMP Pro 11.0 (SAS Institute, Cary North Carolina).*

Comparisons of indices statewide – Public observations, hunter surveys, and the habitat suitability model were compared statewide by WMU in a GIS (Fig. 3). Substantial agreement was observed. For each index, mountainous WMU (D2E, E1, E2, and E3) were all ranked low or produced sparse data. Southeastern New Hampshire (WMU M) was associated with heavier development and was ranked lower than surrounding WMU by all indices. Other notable areas of agreement included a medium-high ranking of WMU I1, J1, and J2, and a high ranking of H2N, I2, and K. Standardizing PO by

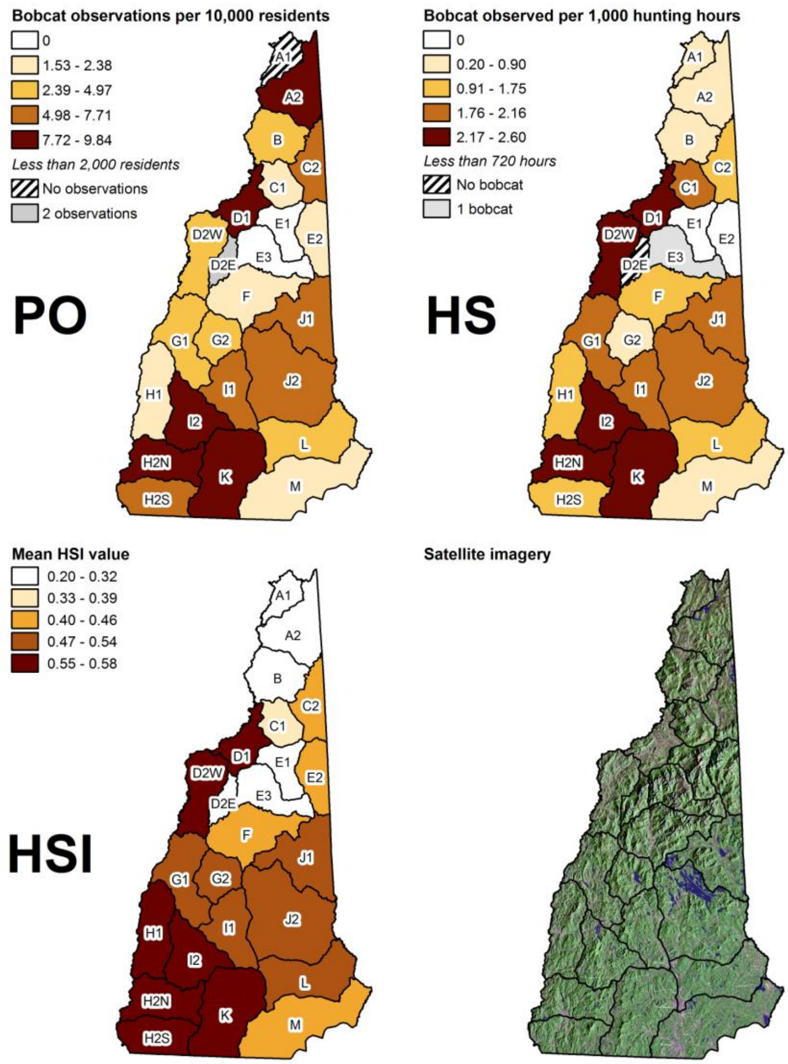

Figure 3 *Bobcat observations per 10,000 residents (PO), bobcat observed per 1,000 hunting hours (HS), mean HSI values (HSI), and satellite imagery for New Hampshire's 24 wildlife management units (WMU) for deer. Color-coded classes are based on quantile distributions. PO rates come from 540 records of bobcat observations sent to UNH from 28 Jun 2005 through 25 Jan 2013 (n = 8 records prior to 2009). PO rates were not calculated for WMU with fewer human residents than the average number of residents per bobcat observation among all WMU (2,049 residents). As township and WMU boundaries did not coincide, human population estimates (New Hampshire Office of Energy and Planning 2012) for each town were used to estimate populations for WMUs by assuming even spatial distribution of human population within each township. HS rates come from 80,146 records of hunting outings that occurred from 13 Oct 2009 through 8 Dec 2013. Records that were ambiguous due to partially-specified WMU (e.g., H2 rather than H2N or H2S), or containing contradicting entries in the town and WMU fields, were excluded (n = 2,653). Partially-specified WMU were fully specified when the reported township was unique to a WMU of the same letter (e.g., WMU=C and Town=Cambridge would have been specified to WMU=C2). HS rates were not calculated for WMU with fewer hunting hours than the average number of hunting hours per bobcat observation among all WMU (723 hours). ArcGIS 10.0 (ESRI, Redlands, CA) was used to calculate average HSI values. This was taken as the average HSI value of all raster cells on a model of bobcat habitat suitability (Fig. 2-7 of Reed 2013) that were spatially coincident with each WMU. HSI was on a scale of 0-1, with 1 being most suitable. Satellite imagery derived from Landsat 7 data and National Elevation Dataset, acquired July 1999 – September 2002, U.S. Geological Survey. Purple indicates areas of human development.*

human population may have ranked northern WMU (e.g., A2) too high. This index may have behaved differently here, as human populations were lower and observations were sparse. In general, the HSI tends to rank WMU in southern New Hampshire higher than PO and HS do, while ranking northern WMU (C1, C2, B, A1, and A2) lower than PO and HS do.

Similar trends were observed using townships as spatial units (Fig. 4), including low abundance in the White Mountains, the southeast, and the north. As a caution, spurious rankings are likely more frequent for PO and HS at this spatial resolution, as rates were based on lower numbers of bobcat observations than those for WMUs. For example, the town of Pittsburgh may have been ranked too high by PO. PO rate for Pittsburgh was based on 2 observations per 871 human residents, and HS and HSI rank the township lower. As an additional caution, the effects of open water may be apparent in the HSI, as townships including portions of Lake Winnipesaukee, Newfound Lake, and Lake Sunapee were ranked lower than surrounding townships. Open water areas may be excluded from HSI means in subsequent analyses. Despite these discrepancies, the indices exhibit similar fine-scale patterns, particularly in the White Mountains and among townships east of Nashua along the MA border and seacoast.

As with camera survey results, agreement among indices was further investigated by correlation. Pairwise correlation coefficients were calculated for PO, HS, and HSI using WMUs as sample units (Fig. 5). Once again, all indices were positively correlated. HS and HSI were strongly correlated, PO and HS were moderately correlated, and HSI and PO were weakly correlated. This is the same order of correlation strength that was observed for these three pairs among camera study areas (Fig. 2). Strong agreement between HS and HSI offers some validation for both indices. Lack of agreement between PO and HS may be a result of these data coming from different regions within each WMU (residential and wilderness areas, respectively). In this case, heterogeneous bobcat density and geographic fluctuation in variables that influence PO and HS rates (e.g., tendency of bobcats to avoid humans, likelihood of observations to be reported) could be responsible for discrepancy between the two indices. Weak correlation between HSI and PO could be influenced by higher rankings of northern WMU by PO (due to low human population) and lower rankings of southern WMU (due to high human population) (Fig. 3). Thus, standardization of PO by human population is questionable. Interestingly, correlation between raw counts of PO by WMU and HSI ($r = 0.45$) was slightly stronger than that using PO per 10,000 residents ($r = 0.29$). This may be investigated more rigorously once a larger dataset of public sightings has been prepared.

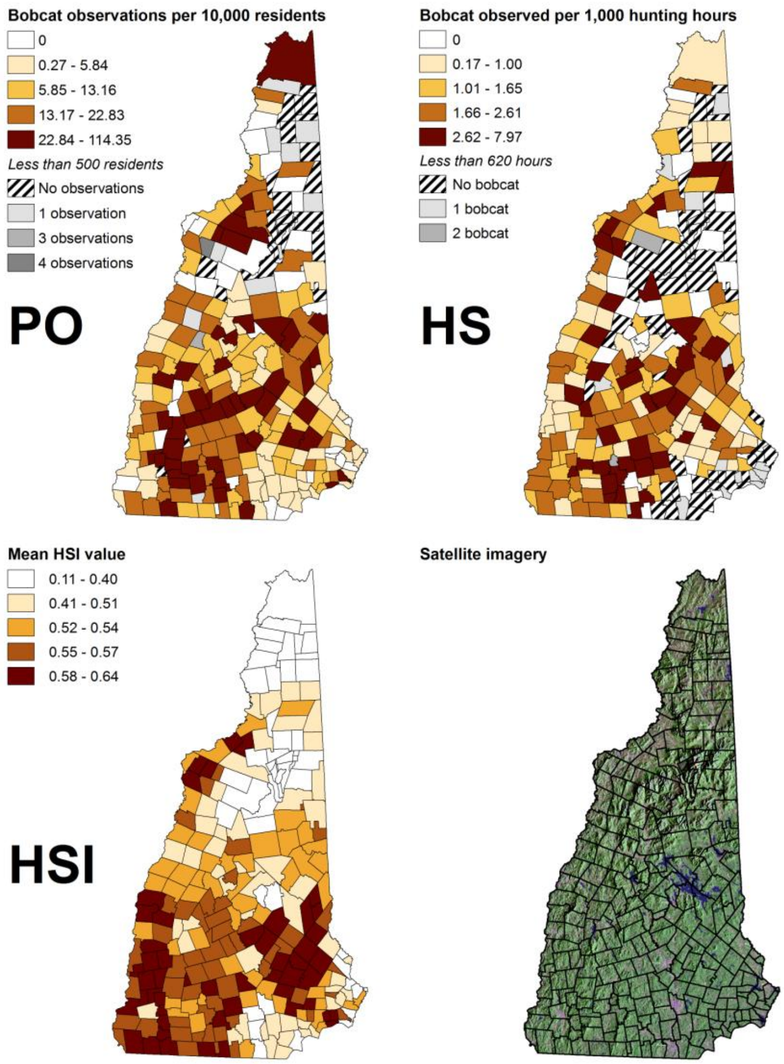

Figure 4 *Bobcat observations per 10,000 residents (PO), bobcat observed per 1,000 hunting hours (HS), mean HSI values (HSI), and satellite imagery for New Hampshire's 259 townships. Color-coded classes are based on quantile distributions. PO rates come from records of bobcat observations reported to UNH (n=897) and documented mortalities reported to NHFG (n=124), collected from 2009 through 2013. PO rates were not calculated for townships with fewer human residents than the average number of residents per bobcat observation among all 196 townships with observation rates >0 (519 residents). Human population estimates for each township were obtained from the New Hampshire Office of Energy and Planning (2012). HS rates were not calculated for townships with fewer hunting hours than the average number of hunting hours per bobcat observation (617 hours) among all 247 townships that generated hunting hours. HS rates come from 82,765 records of hunting outings that occurred from 13 Oct 2009 to 8 Dec 2013. Records with contradicting entries in the town and WMU fields were excluded (n =564). ArcGIS 10.0 (ESRI, Redlands, CA) was used to calculate average HSI values. This was taken as the average HSI value of all raster cells on a model of bobcat habitat suitability (Fig. 2-7 of Reed 2013) that were spatially coincident with each township. HSI was on a scale of 0-1, with 1 being most suitable. Satellite imagery derived from Landsat 7 data and National Elevation Dataset, acquired July 1999 – September 2002, U.S. Geological Survey. Purple indicates areas of human development.*

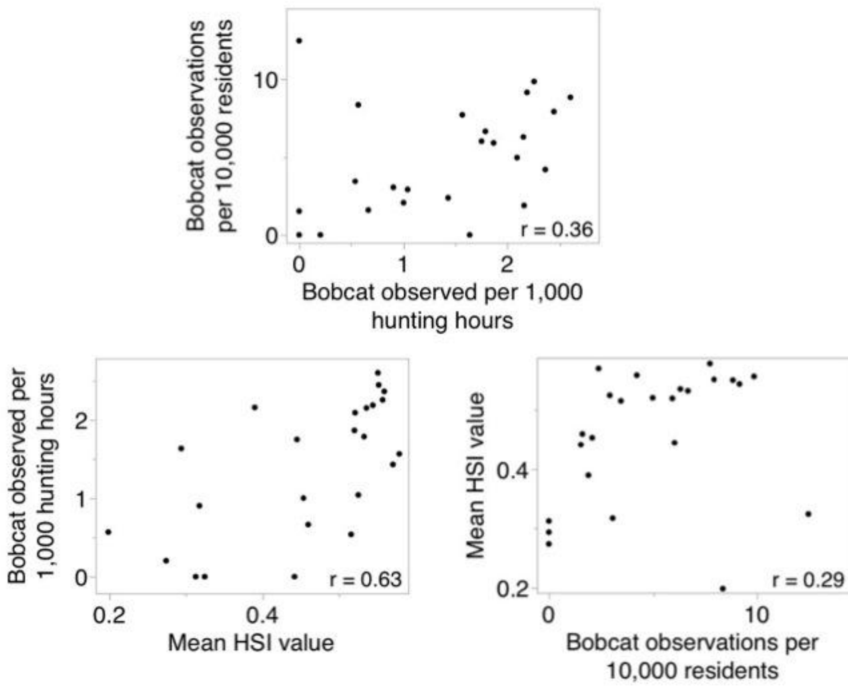

Figure 5. *Correlations between bobcat observations per 10,000 residents (PO), bobcat observed per 1,000 hunting hours, and mean habitat suitability index (HSI) values for all 24 WMU. See Figure 3 for descriptions and histories of the data used. For this analysis, PO and HS rates were calculated for all WMU despite sparse observations, hunting hours, or human residents.*

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

To date, 135 bobcat samples have been collected from New Hampshire. Collection from surrounding areas has largely concluded for the year. 126 widely distributed samples have been collected from Vermont. Ten samples have been collected from western districts in Massachusetts. No samples were collected from Maine this season, but we expect to collect 30-50 during the 2014 hunting/trapping season. Finally, approximately 30 samples have been secured from nearby regions in Quebec. We are currently in the process of applying for the necessary permits from CITES and US Fish and Wildlife Service to retrieve the samples from Canada.

DNA extraction has been completed for all New Hampshire and Massachusetts samples and roughly half of the Vermont samples. 125 New Hampshire and 45 Vermont samples have been genotyped at 18 microsatellite loci. Thus far, analyses have been conducted on all NH samples at 13 loci. As expected, analyses suggest a population-wide deficiency in heterozygotes and a substantial inbreeding coefficient (F_{IS}=0.11), both of which indicate a subdivided population. Geographic distance between home townships was not a significant explanatory factor for genetic distance between individual bobcats (Figure 6). Together, these findings suggest that landscape factors may be the primary drivers of dispersal dynamics in the region and ecological distances may provide the most accurate model of gene flow.

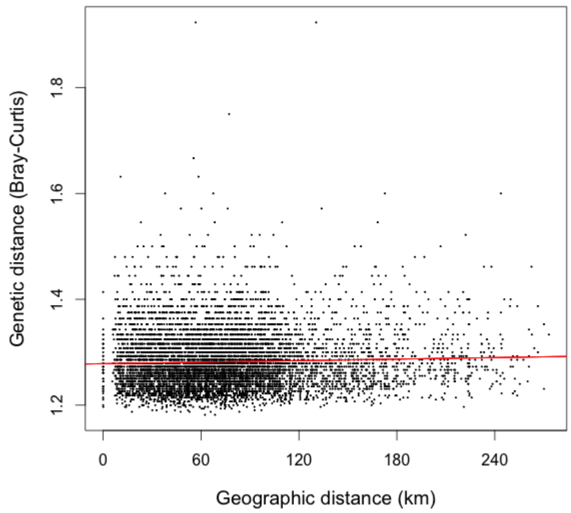

Figure 6. *Geographic distance is not strongly correlated with genetic distance in NH bobcats (Mantel's r = 0.0427, p = 0.118).*

The eigenvalues of a principal component analysis (PCA) are strongly correlated to F_{ST} values in populations and hence are good predictors of population subdivision (McVean 2009). A cluster analysis based on PCA scores of the New Hampshire samples indicates strong genetic clustering (Figure 7). The largest clusters of genetically similar bobcats are in the area north of the White Mountains and the southeastern portion of the state. Areas of stark contrast between dark colors, such as the I-93 corridor or Hwy 125, may represent strong barriers to gene flow.

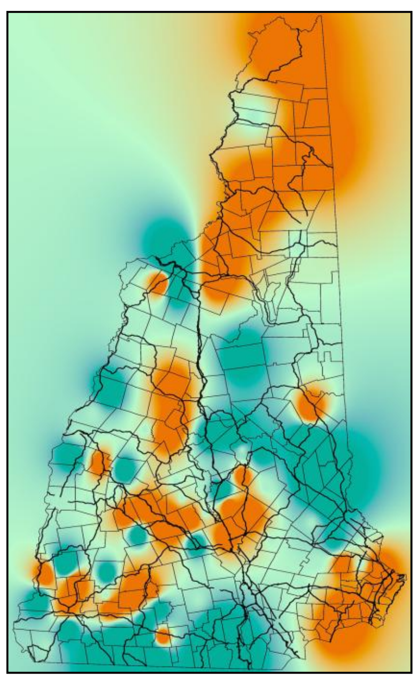

Figure 7. *Geographical interpolation of genetic cluster membership. Darker colors (orange, teal) represent prevailing genetic cluster membership. Lighter colors represent areas of greater genetic mixture. Roads (heavy black lines) and town boundaries are also represented.*

A preliminary estimate of the effective population size of bobcats in NH was calculated using the Linkage Disequilibrium method in the program NeEstimator (Do et al. 2014). Alleles were included only if their frequency in the population was greater than 0.01. The estimated effective population size for NH was 445 individuals with a 95% confidence interval from 259-1333 individuals. Genotyping errors or missing values tend to alter estimates of N_E and increase the size of confidence intervals. A more precise estimate will be possible once the genotype data can be vetted and missing values eliminated.

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

Chapter IV of Reed (2013) addressed this objective.

OBJECTIVE III -- IDENTIFY POTENTIAL WILDLIFE CORRIDORS.

Chapter III of Reed (2013) addressed this objective.

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