# PROGRESS REPORT

**for**

# COOPERATIVE BOBCAT RESEARCH PROJECT

**Period Covered:**

**1 April – 30 June 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.*

Efforts during this period focused on improving statewide indices of bobcat abundance. For public sightings and hunter surveys, alternative parameters for abundance and effort were considered. For the habitat suitability index developed by Reed (2013), areas of open water were excluded in calculations of mean suitability. Indices constructed with new and previously used parameters were compared by correlation using wildlife management units (WMU) as sample units (similar to Fig. 5 of Litvaitis et al. 2014). Through refinement, we aimed to reduce influence of confounding variables and produce indices that better represented the relative abundance of bobcats. We expected to observe higher correlation coefficients among all indices as a result. JMP 11.0 (SAS Institute, Cary, NC) was used for all statistical analyses.

### *Public Sightings*

The final emailed record of a bobcat observation was logged on 19 April 2014. For each email we extracted the date, township, and WMU of the bobcat observation(s). We also marked records with a "Yes" or "No" to indicate our confidence that the observer witnessed a bobcat rather than something believed to be a bobcat (McKelvey et al. 2008). Reports based on vocalizations and spoor received a "No", as did reports in which the observer described non-bobcat features or expressed uncertainty that the observed animal was a bobcat. As requested by the project webpage, most reports included the township of the observation and a detailed description of the locality within the township. A variety of locality descriptions were observed (e.g., street addresses, geographic coordinates, distances and directions from road intersections). We discovered the amount of positional uncertainty associated with each locality description varied considerably. Consider the following locality descriptions as an example: (1) "I observed a bobcat in the woods, about 5 kilometers northeast of the intersection of Route 125 and Route 4 in the town of Lee", and (2) "the bobcat was next to my chicken coop, or at 43.178309 N 71.873694 W +/- 17 meters, according to my GPS unit". Although both locations can be plotted, the location in first description seems as if it was eyeballed on a map and the actual location of the bobcat could have been a substantial distance from the point exactly 5 kilometers northeast of the referenced street intersection. In contrast, the location of the bobcat in the second description was likely within 17 meters of the provided coordinates, particularly when the chicken coop can be observed using satellite imagery to verify the coordinates. Such issues were relevant when township of occurrence was unknown, and when determining WMU, as WMU and township boundaries do not coincide. Thus, we adopted the methods of Wieczorek et al. (2004) for determining coordinates and positional error estimates from a variety of locality descriptions. If the positional error estimate for a given plotted locality was greater than the distance to the nearest WMU or township boundary, we marked the WMU or township as "unknown" for that record.

For analyses, we restricted public sighting records to observations that occurred between 1 April 2009 and 31 March 2014. After screening to eliminate observations that may not have been of bobcats, 886 were identified to township and 819 to WMU. To avoid multiple records generated by the same bobcat, we only created one record per observer and location per day. During processing, we noticed emails in which observers reported multiple sightings in the same general area of what was likely the same individual. Understandably, a single bobcat taking up residence in a residential neighborhood previously unoccupied by bobcats would generate many inquiries to New Hampshire Fish and Game that often led to public sighting reports sent to the University of New Hampshire. As a result, we elected to evaluate 'the number of months that produced sightings' as a parameter of abundance rather than the raw number of sightings. Because a large percentage of sightings occurred when motorists witnessed bobcats crossing roads, we evaluated total road length as a parameter for effort. We expected to observe an improvement from our previous index, that used human population for effort, because total road length reflects the potential for road crossings as well as the potential for bobcats to encounter human residences, which coincide with the vast majority of bobcat sighting locations.

Both parameters of abundance (Public sightings, Months with reported sightings) had stronger association with total road length than with human population (Fig. 1). Further, months with reported sightings had slightly stronger association with both parameters of effort (Human population, Total road length) than did the raw count of public sightings.

### *Hunter surveys*

The hunter survey index was re-evaluated with the idea that numerous short hunting outings may be more effective at detecting bobcats than a smaller number of lengthier outings. This would be the case if most outings involved a hunter remaining in a restricted area (e.g., a tree stand). If a hunter were situated in a location unused by bobcats, bobcats would not be observed regardless of the duration of the outing. However, if several hunters each visited a different location for a short hunt, the probability of a bobcat observation is higher. We tested the number of hunting outings as a parameter for effort instead of the total number of hunting hours. To reduce the influence of chance encounters with bobcat family groups observed during one outing, we also explored the 'number of hunter outings with bobcat observations' rather than the total number of bobcats observed.

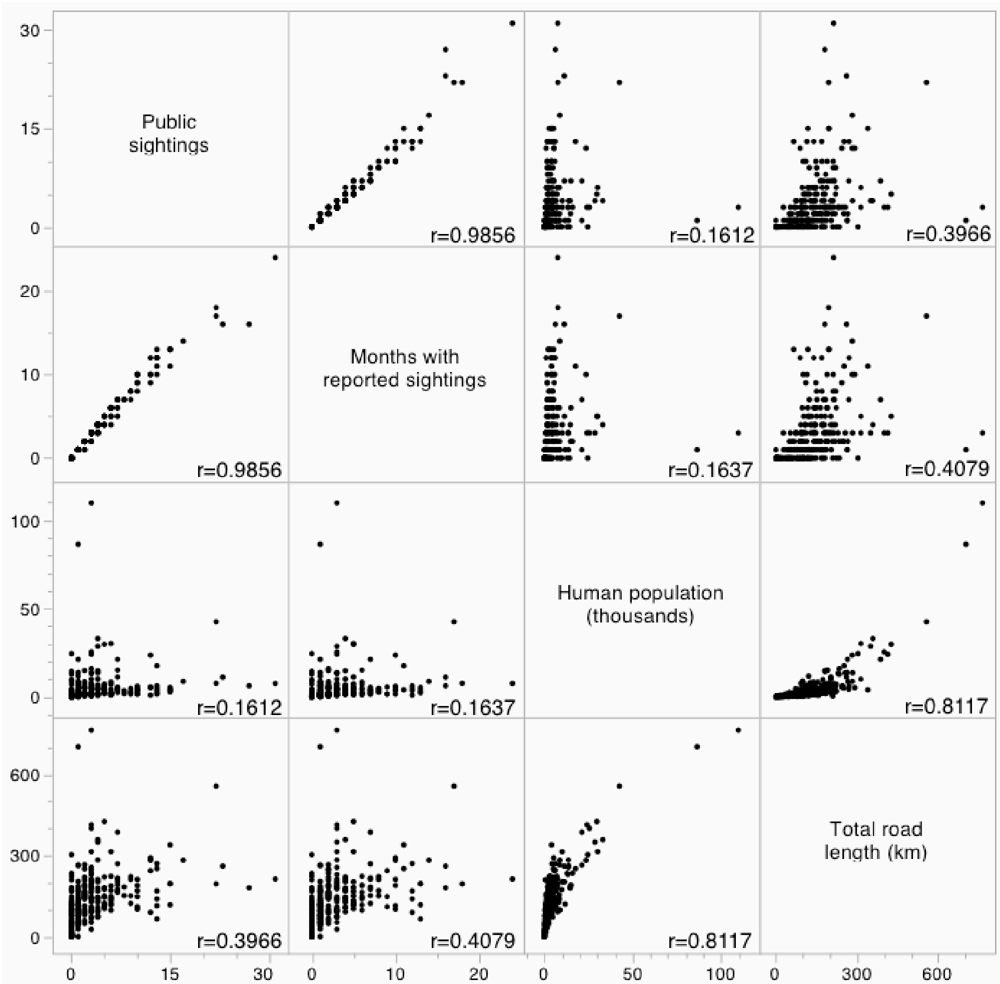


***Figure 1***. *Correlations among alternative parameters of abundance and effort for the public sightings index. Sample units (n=260) consisted of New Hampshire townships, with the town of Pittsburg divided into two units using the A1/A2 WMU boundary. Pearson's correlation coefficients are provided in the lower right corner of each scatterplot. Axes apply to the entire row and column that contain the title of the parameter. Parameters of abundance (Public sightings, Months with public sightings) were summarized from emails describing bobcat observations that occurred between 1 April 2009 and 31 March 2014. Human population data comes from 2011 estimates of population size from the New Hampshire Office of Energy and Planning (2012). Data on road lengths were obtained from the New Hampshire Department of Transportation (Concord, NH).*

Both parameters of abundance (bobcats observed, outings with bobcat observations) had slightly stronger associations with outings than with hours (Fig. 2). Outings with bobcat observations had slightly stronger associations with both parameters for effort (Hours, Outings) than did the total number of bobcats observed. Based on the mean number of bobcats observed across all townships ($\bar{x}$ =2.8), townships in which chance observations of family groups occurred could have been ranked too highly. Using the number of outings with bobcat observations avoids this by assuming that the probability of encountering a lone bobcat is equal to that of encountering a family group, and that both have an equal influence on the index.

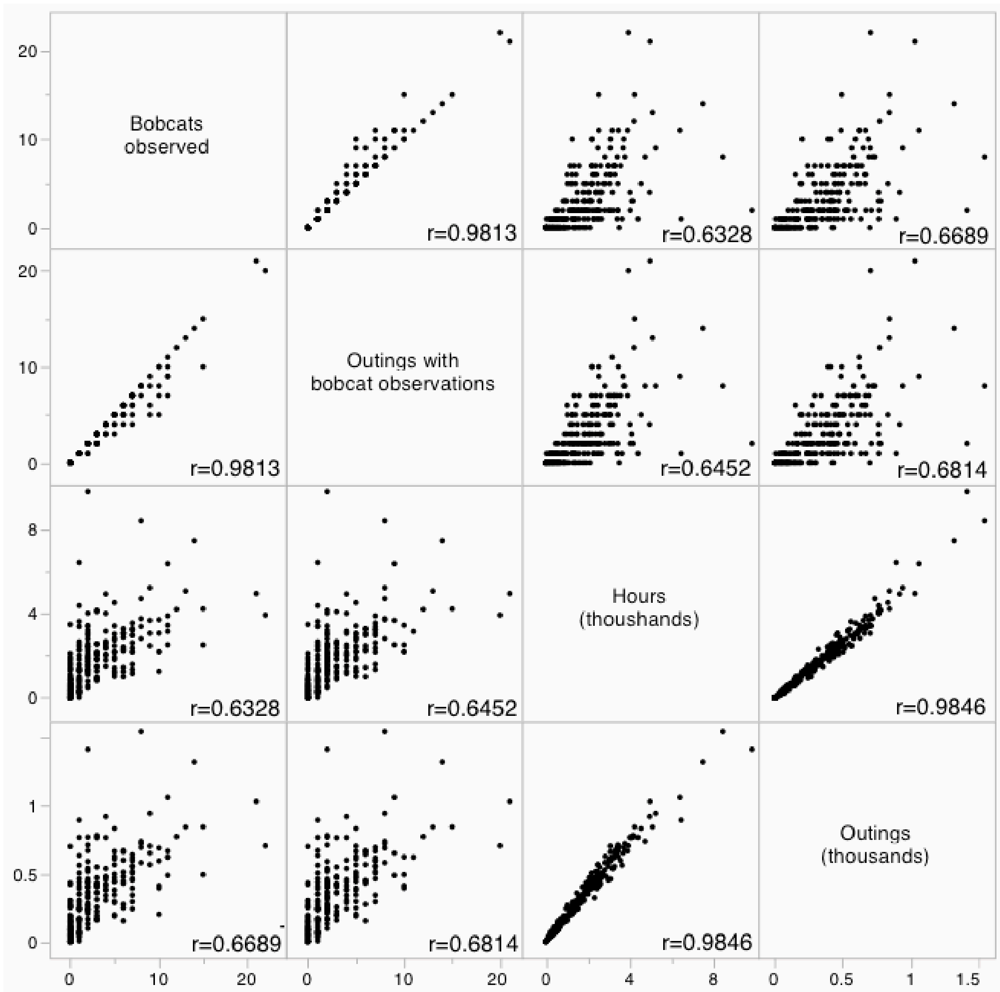


***Figure 2.*** *Correlations among alternative parameters of abundance and effort for the hunter survey index. Sample units (n=260) consisted of New Hampshire townships, with the town of Pittsburg divided into two units using the A1/A2 WMU boundary. Pearson's correlation coefficients are provided in the lower right corner of each scatterplot. Axes apply to the entire row and column that contain the title of the parameter. Parameters of abundance (Bobcats observed, Outings with bobcat observations) and effort (Hours, Outings) were summarized from 82,765 records of hunting outings collected by the New Hampshire Fish and Game Department from 13 Oct 2009 to 8 Dec 2013. Records with contradicting entries in the town and WMU fields were excluded (n =564).*

## *Model of bobcat habitat suitability*

Data from the 2002 New Hampshire Land Cover Assessment (Complex Systems Research Center, Durham, NH) was used to exclude areas of open water from calculations of average habitat suitability index (HSI) value of each WMU and township. Because open water was ranked low by the suitability model, areas of open water negatively influenced HSI means when these were included. We decided to exclude these areas because bobcats do not use open water. Subsequent efforts to refine this index could involve calculating the amount of contiguous land area above an HSI threshold with a high probability of use by bobcats.

### *Comparing indices using alternative parameters*

The appropriateness of a given parameter may depend on the spatial resolution of analysis (i.e., township or WMU). Using 'months with sightings' may be appropriate when comparing townships, but may have compressed the data too much when summarized by WMU. When summarized by WMU, towns with few 'months with sightings' have few sightings, and the number of sightings increases exponentially as 'months with sightings' increases. In regard to hunter surveys, 'bobcats observed' and 'outings with observations' have a much more linear relationship, as a small proportion, n=48 of n=676 hunting outings with bobcat observations, had multiple bobcats observed. With 260 sample units at the township resolution, and 24 sample units at the WMU resolution, we contend that outings with multiple observations have the potential to randomly influence the number of bobcats observed at either resolution. Thus, we suggest that 'outings with observations' is a more appropriate parameter for effort than the raw number of bobcats observed. This is supported by correlations between the hunter survey and public sightings indices at both spatial resolutions, but using the raw number of bobcats observed allowed for stronger agreement with the habitat suitability index (Fig. 3). This could be explained by the suitability index's tendency to rank southern WMU higher than northern WMU. There were more hunting outings with bobcat observations in southern WMU, and observations with multiple bobcats likely had additive effects on the raw number of bobcats observed, thus boosting the hunter survey index in southern WMU.

Public sighitngs index
Hunter survey index
Habitat suitability index
Correlation coefficients based on townships
Correlation coefficients based on WMUs

| | Sightings / human population | Sighitngs / total road length | Months with sightings / human population | Months with sightings / total road length | Bobcats observed / hours | Bobcats observed / outings | Outings with observations / hours | Outings with observations / outings | HSI mean | Land area HSI mean |
|---|---|---|---|---|---|---|---|---|---|---|
| Sightings / human population | | 0.8811 | 0.9766 | 0.8712 | 0.3006 | 0.3143 | 0.3476 | 0.3642 | 0.1868 | 0.2649 |
| Sighitngs / total road length | 0.6287 | | 0.8317 | 0.9697 | 0.2936 | 0.2888 | 0.3240 | 0.3243 | 0.1218 | 0.0724 |
| Months with sightings / human population | 0.8185 | 0.1371 | | 0.8725 | 0.3092 | 0.3317 | 0.3570 | 0.3826 | 0.2371 | 0.3135 |
| Months with sightings / total road length | 0.6369 | 0.7566 | 0.4555 | | 0.3113 | 0.3152 | 0.3438 | 0.3532 | 0.1745 | 0.1234 |
| Bobcats observed / hours | 0.6156 | 0.7190 | 0.3260 | 0.7414 | | 0.9848 | 0.9696 | 0.9626 | 0.0475 | 0.1121 |
| Bobcats observed / outings | 0.5929 | 0.6977 | 0.3073 | 0.7222 | 0.9887 | | 0.9478 | 0.9700 | 0.1156 | 0.1849 |
| Outings with observations / hours | 0.5914 | 0.6998 | 0.3132 | 0.7415 | 0.9900 | 0.9736 | | 0.9856 | 0.0178 | 0.0836 |
| Outings with observations / outings | 0.5673 | 0.6803 | 0.2913 | 0.7233 | 0.9818 | 0.9888 | 0.9878 | | 0.0882 | 0.1572 |
| HSI mean | 0.4115 | 0.6306 | 0.1040 | 0.5891 | 0.6294 | 0.5799 | 0.6216 | 0.5728 | | 0.8378 |
| Land area HSI mean | 0.4272 | 0.6373 | 0.1094 | 0.5858 | 0.6319 | 0.5849 | 0.6218 | 0.5755 | 0.9963 | |

***Figure 3.*** *Matrix of Pearson's correlation coefficients between public sighting indices, hunter survey indices, and habitat suitability indices. Townships (gray) and WMU (green) were used as sample units. Townships that, for any effort parameter, received effort lower than twice the sum of the given effort parameter (across all townships) divided by*

*any of the summed abundance parameters (across all townships) were excluded from analyses. This left n=67 townships. All 24 WMUs were used to calculate correlation coefficients by WMU. Four variations of the public sightings index were constructed by alternating the number of sightings and number of months with sightings as parameters for abundance, and alternating human population and total road length (km) as parameters for effort. Four variations of the hunter survey index were constructed by alternating the number of bobcats observed and 'outings with bobcat observations' as parameters for abundance, and by alternating hunting hours and hunting outings as parameters for effort. Two variations in the habitat suitability index were constructed and consist of the average suitability of all raster cells coincident with each sample unit (HSI mean), and average suitability of all raster cells coincident with all land area within each sample unit (Land area HSI mean). The maximum correlation coefficient for each index comparison has been outlined in red.*

All variations of the hunter survey index had strong agreement with one another (0.9478-0.9900), but considerable disagreement was observed among variations of the public sightings index (0.1371-0.9697). Using total road length produced stronger agreement with hunter survey and habitat suitability indices at the WMU resolution, but human population produced stronger agreement at the township resolution (Fig. 3). It is important to note that townships used in calculations of correlation coefficients were restricted to those n=67 with sufficient effort from all effort parameters. Data is too sparse for thorough statewide analysis of indices at the township resolution. We suggest that road length is a better parameter for effort than human population. At the township resolution, agreement between public sightings and hunter survey indices only varied from 0.29 to 0.38. At the WMU resolution, correlation between public sightings and hunter surveys was approximately 0.7 in all cases when road length was used, but ranged from 0.3 to 0.6 when human population was used.

Agreement between hunter survey indices and other indices did not vary considerably whether hours or outings were used as a parameter for effort. Hours and outings were highly correlated, making it difficult to determine which parameter is more appropriate to use. The difference may not be substantial. Land area HSI mean had a higher correlation coefficient than HSI mean in 13 of 16 comparisons (Fig. 3). Excluding areas of open water from calculations likely yields a more accurate index of relative abundance.

In conclusion, consideration of alternative parameters for abundance and effort has allowed us to construct public sightings, hunter survey, and habitat suitability indices that agree with one another better than initial comparisons made in Fig. 5 of Litvaitis et al. (2014). Agreement between indices supports but does not guarantee the validity of each index. We feel that use of total road length and exclusion of open water are substantial improvements to the public sightings and habitat suitability indices, respectively. We suggest caution with interpretation of analyses at the township resolution because index parameters are based on limited data and index values may not be representative of bobcat abundance of the township for which they are calculated.

### *Comparing camera surveys to the model of bobcat habitat suitability*

A Mann-Whitney test (i.e., Wilcoxon Rank Sum Test in JMP 11.0) was used to compare the camera survey and habitat suitability indices at a fine resolution. Mean habitat suitability index (HSI) values of all land area within a 1 km radius about each camera location that detected bobcat were compared to those that did not. A radius of 1 km was selected as a compromise such that values from the HSI would be representative of the camera's immediate surroundings while allowing for some positional error in coordinates provided by citizen scientists or determined from the locality descriptions they provided. Using the methods of Wieczorek et al. (2004), the maximum positional error among locations where bobcats were detected was 800 m. Because the number of camera stations that detected bobcats limited the statistical power of the Mann-Whitney test, 800 m was the maximum positional error for inclusion of all camera survey records in the test. Mean number of trap nights for surveys that detected bobcats ranged from 7 to 16. All records of surveys that had a mean number of trap nights outside of this range were excluded to constrain the probability of detection at a station based on survey length. Land-area habitat suitability means among locations that detected bobcats were expected to be greater than those among locations that did not. Statistical significance would support use of the HSI to place cameras at localities that have a higher probability of use by bobcats.

The Mann-Whitney test between land-area habitat suitability means of camera station locations with bobcat detections and those without failed to reject the null hypothesis of equivalence ($p=0.97$). However, the land area HSI mean for station locations with detections (0.586) was slightly higher than the land area HSI mean for those without (0.573). Further, the range of HSI means for locations with bobcat detections (0.52 to 0.71) was restricted to higher HSI means, whereas the range for locations without detections included lower HSI means (0.21 to 0.69). Non-significance is attributable to a low sample size of camera locations with bobcat detections ($n=13$). We suggest that placement of trail cameras in localities ranked highly by the HSI could aid in maximize detection probability of bobcats.

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

Genotyping at the 18 planned loci has been completed on all 237 spatially referenced bobcats from New Hampshire, Vermont, and Massachusetts. Analyses of these data revealed the presence of null alleles at 6 loci that have subsequently been removed from the analyses. An additional 4 loci have been added to replace the omitted ones, and we are currently genotyping all bobcat samples at these new loci.

The number of alleles per locus ranged from 5 to 11 ( $\bar{x} = 8.7$). Analyses revealed a genetic structuring within New Hampshire that doesn't exist elsewhere in the region. There were 3 subpopulations in New Hampshire that showed a significant degree of differentiation, often with major roads acting as barriers. Within the state, Interstates 89, 91, 93, and NH 101 seem to be effective barriers to gene flow (Fig. 4). The greatest degree of differentiation occurred in the southwest New Hampshire subpopulation that is bound on all sides by Interstates 89, 91, 93, or MA-2. By contrast, all bobcats sampled from Vermont and Massachusetts represented a 4th subpopulation, suggesting higher gene flow through these states than in New Hampshire. There is also evidence that New Hampshire may be acting as a reservoir for genetic diversity of bobcats in the region. Approximately 50% of loci had alleles that existed only in one of the three New Hampshire subpopulations. None of these "private alleles" existed in Vermont or Massachusetts. Furthermore, there were a small number of bobcats from the Vermont/Massachusetts genetic deme that were found in the highly suitable Lake Winnipesaukee region in New Hampshire. This area is likely very productive for bobcats, and according to the habitat connectivity model developed by Reed (2013), it is linked to Vermont by substantial tracts of suitable habitat. Further analyses need to be done (especially along the NH-ME border) to confirm these metapopulation dynamics.

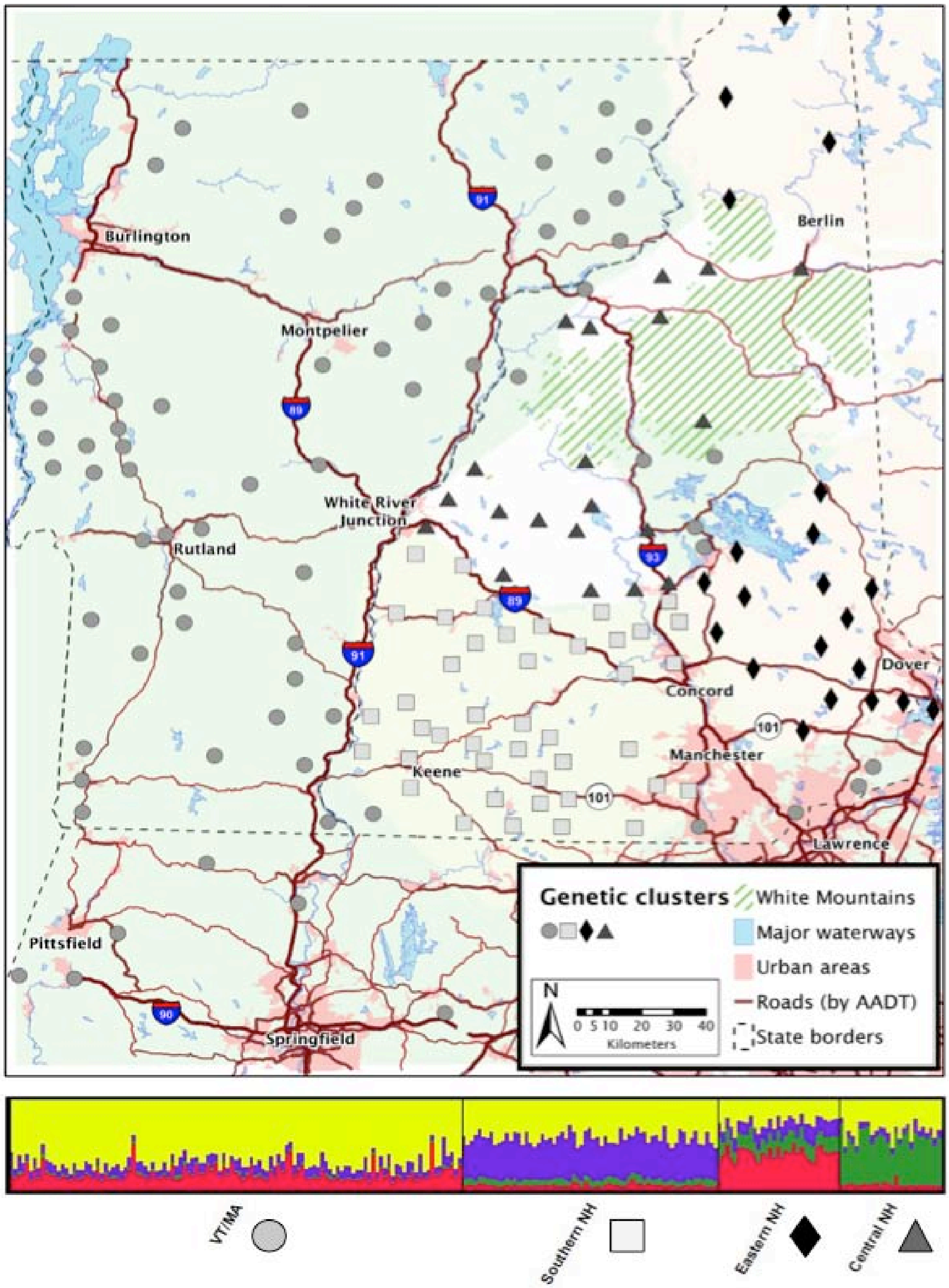


***Figure 4.*** *Map of genetic subpopulations detected by the* R *package* GENELAND*.* STRUCTURE *results confirmed the presence of 4 genetically distinct demes in the region.*

A CITES export permit has been approved and 26 samples from bobcats trapped in southern Quebec are being added to the study. Furthermore, we are reaching out to registered guides and taxidermists in Maine to procure samples from bobcats hunted or trapped in the upcoming season. In light of current findings that indicate a strong genetic boundary effect at the western and southern borders of New Hampshire, these two new sources should prove to be crucial to understanding metapopulation dynamics and landscape effects on bobcat dispersal and connectivity in the region.

## 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.

## LITERATURE CITED

Litvaitis, J. A., T. Mahard, R. Carroll, and M. K. Litvaitis. 2014. Progress report for Cooperative Bobcat Research Project: 1 January - 31 March 2014. Durham.

McKelvey, K., K. Aubry, and M. Schwartz. 2008. Using anecdotal occurrence data for rare or elusive species: the illusion of reality and a call for evidentiary standards. BioScience 58:549–555.

New Hampshire Office of Energy and Planning. 2011 Population estimates of New Hampshire cities and towns. Concord, NH. July 2012. Accessed at https://www.nh.gov/oep/data-center/population-estimates.htm on 6 May 2014.

Reed, G. C. 2013. Bobcats in New Hampshire: Understanding the relationships between habitat suitability, connectivity and abundance in a changing landscape. M.S. Thesis, University of New Hampshire, Durham.

Wieczorek, J., Q. Guo, and R. Hijmans. 2004. The point-radius method for georeferencing locality descriptions and calculating associated uncertainty. International Journal of Geographical Information Sciencewiec 18:745–767.